California Energy Commission

Clean Transportation Program

FINAL REPORT

California Zero-Emission Vehicle Highway Blueprint

Prepared for: California Energy Commission

Prepared by: Build Momentum, Inc.

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Hannah Behmaram, Build Momentum, Inc
Nicholas Pieper, Build Momentum, Inc
Primary Author(s)

Build Momentum, Inc.
801 K St., Suite 2800
Sacramento, CA 95814
(916) 444-FUND
https://buildmomentum.io/

Agreement Number: CEC-ARV-21-037

Sara Sanders
Commission Agreement Manager

Mark Wenzel
Branch Manager
LIGHT-DUTY ELECTRIC VEHICLE INFRASTRUCTURE ANALYSIS BRANCH

Hannon Rasool
Director
FUELS AND TRANSPORTATION

Drew Bohan
Executive Director

PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program, formerly known as the Alternative and Renewable Fuel and Vehicle Technology Program. The statute authorizes the California Energy Commission (CEC) to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) reauthorizes the Clean Transportation Program through January 1, 2024, and specifies that the CEC allocate up to $20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

The Clean Transportation Program has an annual budget of about $100 million and provides financial support for projects that:

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and non-road vehicle fleets to alternative technologies or fuel use.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce-training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued GFO-20-601 to accelerate the deployment of medium-duty and heavy-duty zero-emission vehicle infrastructure with a holistic and futuristic view of transportation planning. In response to GFO-20-601, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards April 8, 2021, and the agreement was executed as ARV-21-037 on May 9, 2022.

ABSTRACT

From 1990 to 2020, the vehicle miles traveled by medium and heavy-duty trucks surged by 107 percent. Despite the advancement of fuel economy standards since 2005 mitigating greenhouse gas emission spikes, meeting emissions targets necessitates intensified efforts. The California Energy Commission is at the forefront of these national and state initiatives. The Pilot Company, North America's premier travel center operator servicing over 70,000 trucking fleets, has positioned itself to significantly influence greenhouse gas reduction within transportation. This report focuses on Pilot's blueprint for accelerating zero-emission vehicle adoption by leveraging travel centers for zero-emission vehicle charging and hydrogen refueling. The blueprint, informed by outreach and prior experiences, designs a state-of-the-art travel center tailored for medium and heavy-duty vehicles. The design merges electric charging, hydrogen refueling, and conventional fueling while integrating a resilient microgrid system. This system features a solar photovoltaic array, a battery energy storage system, and natural gas generators, resulting in cost savings and utility reductions. A pivotal part of this proposal is its retrofit site in Hesperia, chosen for its potential to seamlessly embed zero-emission vehicle infrastructure. The proposed layout promises to deliver almost 40 percent cost savings per mile for medium and heavy-duty vehicle users, moving away from conventional diesel. In sum, this blueprint presents a comprehensive, innovative, and sustainable approach for the future of medium and heavy-duty vehicle refueling, paving the way for a widespread transition to zero-emission vehicles.

Keywords: Alternative Fuels, Battery Energy Storage System, Charging, Conceptual Design, Cost-effective, Diesel Fueling Lanes, Direct Current, Distributed Energy Resources, Electricity, Greenfield Applications, Heavy-duty, Hydrogen, Infrastructure, Levelized Cost of Electricity, Microgrid, Natural Gas Generators, Photovoltaic Array, Retrofit, Travel Center, User-experience, Utility Grid Disruption, Zero-emission Vehicle

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TABLE OF CONTENTS

Page

LIST OF FIGURES

EXECUTIVE SUMMARY

Introduction

To help accelerate zero-emission vehicle (ZEV) adoption in California, Pilot—partnering with Arup and Momentum—has completed a conceptual design for a Pilot travel center that caters to medium-duty and heavy-duty (MD/HD) vehicles, incorporating a combination of battery electric charging, hydrogen refueling, and existing fossil fuel sales. This report summarizes the processes of developing the blueprint as well as its outcomes.

Purpose

The aim of this report is to provide a summary of the processes to write the blueprint, present the findings from the final blueprint, and give recommendations to others trying to implement MD/HD ZEV infrastructure. The blueprint addresses the challenges faced when refueling MD/HD vehicles with electricity or alternative fuels like hydrogen and acts as Pilot's first step towards supporting a zero-emission California highway.

Objectives

To address the issues mentioned above, the project team worked to devise a novel and replicable conceptual design for a refueling station at one of Pilot's existing travel centers that addresses real-life cost, technology, and other barriers.

Conclusion

The final blueprint proposed solutions tailored to meet the demands of MD/HD vehicle customers as well as Pilot's financial needs. Final suggestions include two rapid H70 hydrogen refueling lanes, twelve rapid opportunity 2.5 megawatt (MW) charging system charging lanes, thirty 150 kilowatt (kW) overnight direct current fast charging stations, and a microgrid system with distributed energy resources. The comprehensive design optimizes the allocation of site area, ensuring efficient space for charging and refueling infrastructure, vehicle movements, queuing, and parking while maintaining the existing travel center's structures and facilities.

Overall, the blueprint's design for the MD/HD travel center offers a forward-thinking solution that accommodates multiple energy sources while maintaining operational efficiency.

CHAPTER 1: Background

1.1 Problem Statement

Anthropogenic greenhouse gas (GHG) emissions have long been known as the drivers of climate change and the cause of an abundance of health detriments. As the consequences of GHG emissions of the past begin to present themselves with accelerating frequency and intensity, particularly to the most vulnerable communities, the focus to abate and eventually eliminate GHG emissions across all sectors has heightened. In the U.S., the transportation sector is the largest contributor to anthropogenic GHG emissions due to the industry's strong dependence on fossil fuel combustion, supplying 94 percent of the industry's fuel supply. Approximately 26 percent of the transportation sector's GHG emissions are caused by medium and heavy-duty (MD/HD) trucks. From 1990 to 2020, the number of vehicle miles traveled by MD/HD trucks has increased by 107 percent, and while new and progressively advancing vehicle fuel economy requirements since 2005 have curbed the resulting increase of GHG emissions, additional momentous efforts must be made to realize local, state, and federal emissions goals.

Refueling MD/HD vehicles with electricity or other forms of fuel, such as hydrogen, comes with various challenges, including time to refuel, user experience, and sourcing sufficient electricity. To overcome these challenges the project team explored creating a new conceptual design for a refueling station, that will enable truck drivers and vehicle operators to continue regular travel operations. The organization leading and advancing this effort at the national and state level, and whose regional remit is the focus of this report, is the California Energy Commission (CEC).

1.2 Recipient Background

The Pilot Company is the largest operator of travel centers in North America, serving more than 70,000 trucking fleets in the area. This expanse and influence allow Pilot to be on the forefront of GHG emissions reduction strategies within the transportation sector that have the power to furnish meaningful results.

Pilot Company is investing significantly in growing and enhancing its travel center network this year with plans to add more than 34 locations, including 14 new travel centers and over 20 dealer sites. In partnership with Southern Tire Mart, the two companies are expecting to add 40 new Southern Tire Mart at Pilot service centers to Pilot locations across the country. This is part of Southern Tire Mart at Pilot's expansion plans to provide fleets with over 200 on-premises shop locations within the next few years.

1.3 Project Need and Technical Merit

Pilot's outsized influence on highway-based MD/HD refueling makes it an important player in the zero-emission vehicle (ZEV) transition. Planning for a cohesive network of MD/HD ZEV infrastructure requires a holistic skillset, including:

- **Knowledge of the Trucking Industry**: Pilot's expertise as the nation's largest travel center operator brings decades of experience, research, and understanding of the industry and the companies and individuals that it includes.
- **Understanding of ZEV Trends**: Momentum provided grant and project management for the Blueprint. Momentum's expertise as an innovation strategist and commercialization partner offers unique market insight and perspective, working with global leaders, including Toyota, Volvo, Cummins, Peterbilt, Meritor, Freightliner, Daimler, Tesla, ABB, and Siemens, among others.
- **Multi-Disciplinary Technical Expertise**: Arup, in partnership with Pilot, authored the Blueprint. Arup is a world-renowned transportation planning specialist, trusted by cities and countries to develop and design cutting edge smart mobility solutions and advanced energy infrastructure.

CHAPTER 2: Community and Stakeholder Engagement

The goal of this task was to bring together a broad and diverse stakeholder audience—including employees, customers, technology developers, community leaders, finance partners, agencies, and technical experts—to foster productive and thoughtful dialogue around a new transportation paradigm; identify challenges, risks, obstacles, and opportunities; and create systems and processes to reduce uncertainty.

2.1 Summary of Engagement

The Community and Stakeholder Engagement Plan was crafted to strategize outreach to Pilot's primary stakeholders, focusing on the potential of travel centers as reliable resources for MD/HD ZEV charging and refueling. The primary goal of this engagement was to construct a blueprint for future travel centers, encompassing ZEV services and ensuring resilience against disruptions. The plan prioritized a two-way dialogue, encouraging sharing of insights regarding challenges, opportunities, risks, and concerns. Various stakeholder groups, each with unique perspectives and interests in MD/HD ZEV planning and adoption, were identified. Recognizing the distinct roles and objectives of each stakeholder is crucial for a successful ZEV transition. To facilitate effective engagement, methods like surveys and virtual workshops are employed, with the assurance that individual or company-specific information will remain confidential.

2.2 Lessons Learned

Through the feedback and information gained during engagement, the project team gained the following insight.

1) **Pilot Internal Service & Infrastructure Planning**:

By 2030, there's interest in offering a mix of traditional fossil fuels with electric vehicle (EV) charging and hydrogen dispensing. Goals include adapting current sites to cater to ZEV demands while also contemplating entirely new ZEV-optimized designs. Travel centers typically serve 350-400 fills daily, peaking between 11 am and 3 pm.

2) **Utility and Electrical Concerns (Site Managers and Utilities)**:

Challenges lie in utility upgrade timelines, cost structures, and limited site capacity (180-200 kilovolt-amps). It was determined that large scale ZEV infrastructure could necessitate service studies, new sub-stations, and capacity studies. SoCal Edison's (SCE's) Charge Ready Program has specific requirements that projects need to meet, though potential changes between now and Blueprint implementation were noted in the Blueprint. A phased approach is recommended for brownfield sites, tapping into existing resources initially and planning for broader upgrades in the future.

3) **Hydrogen**:

On-site hydrogen production wasn't viable due to various constraints, making regular liquid hydrogen delivery more attractive. Hydrogen storage differs significantly from fossil fuels; for instance, hydrogen tanks can't be buried. Hydrogen infrastructure needs to be rapid and efficient, with storage and dispensing units closely located. The hydrogen vehicle fuel market is nascent, with uncertainties in infrastructure development. On-site storage and production, alongside mobile refueling, are current solutions. Outreach to hydrogen vendors revealed varied insights, from distribution plans to infrastructure requirements.

4) **Local Regulations and Infrastructure**:

The City of Hesperia lacks explicit guidance for EV charging installation, but updates are in progress. Current public EV charging stations are not designed for MD/HD vehicles, and no public hydrogen refueling stations are available.

5) **Fleet Operators**:

Pilot projects near Victor Valley are strategically placed, given the location's popularity as a trucking corridor. Concerns include the readiness and cost of technology, range anxiety for truckers, and the absence of vocational programs addressing EV charger maintenance. Opportunities involve financial incentives, charging time management, and early engagement with educational institutions.

6) **Community Perspective**:

Community-based organizations stressed the significance of involving the community, particularly since marginalized groups often face the negative impacts of infrastructure projects. Key concerns include displacement, job allocation, environmental repercussions, and potential traffic increases. Workforce development should prioritize union jobs with decent wages. Best practices emphasize local hiring, advanced notifications on hiring requirements, conversion of construction jobs to permanent roles, and the introduction of coordinators to facilitate community job connections.

7) **Trucking Associations:**

Los Angeles Alliance for a New Economy's (LAANE's) participation highlighted the significance of port trucking and energy & climate justice issues. LAANE is a an organizing and advocacy institution committed to economic, environmental, and racial justice. The association emphasizes the need for a just transition towards more eco-friendly initiatives for working-class drivers and communities, especially near ports like Long Beach. Regulatory measures from 2007 compelled truckers to adopt newer standards, pushing them into financial challenges with predatory loans and rising fuel and maintenance costs. The major challenge for independent operators is the cost and logistics of transitioning to battery electric vehicles (BEVs) and the lack of efficient charging infrastructure.

8) **Financial Community:**

A diverse range of potential financial partners exists, from government agencies to specialized businesses and individual investors. Primary motivations for ZEV investments include return on investment, sustainability missions, and federal and state regulations. Major barriers encompass vehicle availability, cost of entry, electrical system integration, vehicle range, and operational challenges.

9) **Industry Partners (EV Charging):**

Despite the development of megawatt chargers, vehicles currently lack the capability to utilize such a charge, though developments are ongoing. Companies like Heliox, Power Electronics, Eaton, and Greenlane are making strides in developing innovative charging solutions, with varied timelines and objectives.

CHAPTER 3: Operator Needs and Infrastructure Performance Specifications

The goal of this task was to identify and quantify fleet operator and driver needs and critical performance specifications that are important to the recipient's ultimate customers — MD/HD ZEV users.

3.1 Summary of Critical Performance Specification Report

ZEV infrastructure planning methodology is based on typical MD/HD vehicle operation. As per federal legislation, truck drivers cannot exceed 14 hours of driving in any 24-hour period and must take a minimum 30-minute break after the first eight hours of driving. It is assumed that most drivers follow the typical operational profile illustrated to maximize driving time, aligning with a UC Berkeley study on long-haul truck electrification.[1]

Though hydrogen fuel cell trucks can be refueled much like diesel trucks, allowing drivers to maintain whatever operational profile they prefer, battery-electric trucks may have additional limitations on operational flexibility due to longer charging time requirements. With advances in charging station power output, including megawatt charging systems (MCS) which are anticipated to become commercially available in the coming years, layover times can be minimized, and drivers' operations will likely be able to match today's habits, with up to 70 percent charge delivered in as little as 30 minutes.

Based on average daily mileage for long-haul trucks, a mid-day rapid opportunity charging sessions via an MCS, and a second longer potentially overnight charging session on a standard direct current fast charger (DCFC) will be sufficient to meet daily charging demands. The sites should be optimized for charging and refueling demands, based on the following anticipated use patterns including rapid opportunity charging or hydrogen refueling required during short rest stops and slower charging provided during overnight rest stops. Slower overnight charging, referred to as direct current standard charging, can be provided as a lower cost to consumer based on time of use electricity rates and help alleviate congestion on rapid opportunity charging or hydrogen refueling equipment. Prioritizing direct current standard charging for overnight stays will minimize:

- Moving vehicles from opportunity charging lanes to non-energized parking spots.

[1] Tong, Fan, Derek Wolfson, Alan Jenn, Corinne D Scown, Maximilian Auffhammer. 2021. "Energy Consumption and Charging Load Profiles from Long-Haul Truck Electrification in the United States." *Environmental Research: Infrastructure and Sustainability*. IOP Publishing. https://iopscience.iop.org/article/10.1088/2634-4505/ac186a.

- Deployment of additional expensive, energy intensive rapid opportunity MCS.
- Power demand in the evenings, by smoothing demand over longer overnight charging sessions when typical grid demand is low.

However, greater utilization of overnight direct current standard charging will require the deployment of additional DCFCs on site and supporting electrical infrastructure.

Based on the conclusions of the methodology section and stakeholder consultation presented in Task 2, the following performance metrics have been specified to help guide future performance of high-powered MD/HD ZEV infrastructure and outline the conceptual design layouts presented later in this report. This metric for each specification has been iteratively improved throughout the blueprint based on current technology (2023), anticipated market trends, site planning and logistics, and conversations with industry experts. Performance specifications have been identified with a proposed specification unit relevant to potential BEVs or hydrogen fuel cell electric vehicles (FCEV) with corresponding technological certainty ranking.

CHAPTER 4:
Conceptual Travel Design Layout

The goal of this task was to utilize a planned station to advance understanding about how ZEV infrastructure may be deployed at travel centers on day one and what future phased changes are needed to accommodate industry ZEV trends. This task leverages the common elements of travel center service to express insights that can inform a portfolio-based approach to standards-based implementation at scale and subsequent professional design effort as appropriate to undertake investment.

4.1 Preliminary Design Layout

Purpose: Design a travel center for the year 2030 that combines low carbon fuels and existing fossil fuels, with facilities for hydrogen refueling and battery electric charging for light, medium, and heavy-duty vehicles.

Design Proposals:

1) **Brownfield Retrofit**: Transform an existing site to provide fossil fuels, charging, and hydrogen refueling.
2) **Greenfield New Construction**: Construct a new site optimized for low carbon, with charging and hydrogen refueling only.

Design Considerations:

The proposed ZEV infrastructure focuses on an energy mix, with 25 percent allocated to hydrogen fueling and 75 percent to battery electric charging, though adjustments may be necessary as technology evolves. When selecting an appropriate brownfield retrofit site, key factors were considered such as proximity to California's primary trucking corridors like I-5 and I-10, site feasibility requirements, and the impacts of vehicle emissions on local air quality and disadvantaged communities. Areas near major corridors, including cities like Bakersfield and Los Angeles, face significant air quality challenges, with Hesperia, the selected site, having unique concerns about air pollution indicators.

The ZEV infrastructure will accommodate different trucking profiles and vehicles. Hydrogen fuel cell trucks are comparable to diesel in refueling speeds, while battery-electric trucks may face operational flexibility challenges due to longer charging durations. To counteract this, technologies like MCSs can reduce these charging times. Different charging equipment will cater to various vehicle demands, ranging from slow chargers to those that can provide a full charge in under an hour. At the Hesperia Pilot site, the aim is to match the existing fossil fuel infrastructure's service capacity. Despite battery charging being inherently slower than conventional refueling, technological developments, such as ultra-fast charging or battery-swapping stations, may streamline this process. Electrical demand profiles are based on various studies, with peak demand hitting around 19.7 MW at 11 am.

Conceptual Design Layouts Summary:

Intent:

This section considers requirements for different vehicle types, supporting infrastructure, vehicle tracking, microgrid optimization, and site planning.

Brownfield Retrofit Conceptual Design:

The design depicts the gradual phasing out of diesel and its replacement with alternative fuels and charging. Key site components include:

- Retail station, with potential third-party establishments (e.g., Hesperia Pilot site).
- Short-term parking for passenger vehicles with DCFCs for EVs.
- Staff parking with Level 2 charging stations.
- Diesel dispensers (interim).
- Hydrogen dispensers and their storage tanks.
- Pull-through megawatt chargers for quick charging.
- Long-term non-energized and energized parking stalls for trucks.

All sites aim to maintain all components to cater to a diverse customer base. Retrofitting is influenced by the specific size and placement of components at each site. Equipment deployment relies heavily on power availability. Vehicle queuing should be minimal. Rapid charging will take longer, and a reservation system can help in reducing queues. Parking space requirements for ZEV infrastructure might vary. At the Hesperia Pilot site, 54 full-size truck parking spaces (55,000 sq ft area) are sacrificed for the ZEV infrastructure, equating to a 22 percent reduction.

Greenfield Conceptual Design:

The greenfield design keeps the retrofit design components but omits phased diesel fuel dispensing. The greenfield site efficiently uses a 15 percent smaller area (15 acres instead of 18) by combining electrical infrastructure and removing legacy fossil fuel infrastructure. Features include angled light-duty vehicle charging bays for better traffic flow and queuing, and combined charging and hydrogen refueling lanes.

In essence, while the retrofit design focuses on gradually transitioning from diesel to alternative fueling, the greenfield design offers an optimized layout that is devoid of legacy infrastructure. Both designs prioritize efficiency, customer service, and adaptability to the evolving energy landscape.

4.2 Cost Estimate and Economic Evaluation

Integrated Electrical Modeling for Microgrid Design

The modeling aimed to evaluate microgrid design criteria suitable for ZEV infrastructure, factoring in considerations like point of interconnection (POI) sizing, California's utility rate structures, and photovoltaic (PV) canopy modeling. Peak charging loads can significantly influence the necessary utility connection size, emphasizing the need to understand these limits and associated costs. The site planned to utilize California's specific utility rates, with two primary electrical tariff structures:

- 8-D-2: A conventional time of use rate
- EV-9: A specialized rate for EVs, currently exempt from demand charges but anticipated to rise as EV charging becomes more common

An economic analysis indicated that while the EV-9 rate was initially more cost-effective, introducing distributed energy resources (DERs) like PV and battery energy storage system (BESS) made the 8-D-2 rate more favorable. Given these insights, engagement with San Diego Gas & Electric (SDG&E) is recommended to discuss the projected POI range, and future studies should offer a holistic evaluation of the entire charging infrastructure.

Microgrid Resilience, Aggregate Costing, and Charging Analysis

The study undertook an in-depth microgrid modeling to evaluate resilience scenarios and costs, especially during grid outages. Three outage durations were considered: 8 hours, 24 hours, and 48 hours. All scenarios leveraged the site's maximum solar potential of 5.2 MWDC. The study also factored in natural gas generators for extended outages and peak capacities, and BESS determined by energy storage capacity in MWh. Costs were not just limited to the PV and BESS but included infrastructure costs, electric vehicle supply equipment (EVSE), and project overheads. One key note was the impending MCS standard expected in late 2023 or early 2024, with its capital costs estimated to be four times that of the existing 350 kW DCFC. Levelized cost of energy (LCOE) was critical in setting pricing structures for charging services. The 48-hour outage scenario, combining BESS and natural gas, was found to offer the most cost-effective resilience.

Significantly, an eight-hour carbon-free resilience scenario, achieved via a 126MWh BESS system, was identified as cost-efficient. However, its high LCOE and site accommodation challenges render it less preferable. Charging costs for MD/HD vehicles fluctuated based on the resilience model chosen, averaging between $153-226 for batteries of approximately 900 kilowatt hour (kWh) capacity. These estimations don't account for potential costs or benefits, such as maintenance or carbon tax. Comparing traditional diesel fueling for tractor-trailers, which costs about 73 ¢/mile, the anticipated cost for electric charging is significantly lower at 44 ¢/mile, amounting to nearly 40 percent in savings.

CHAPTER 5: Resiliency Planning

The goal of this task was to advance the understanding about how travel centers can be a reliable, resilient resource to the MD/HD industry for MD/HD ZEV charging and refueling even during grid-down events, other potential service disruptions, and emergency scenarios.

5.1 Summary of Resiliency Framework

To ensure a seamless transition to ZEV with maintained service and reliability, it's vital to understand how the ZEV infrastructure can support MD/HD vehicles. The blueprint team investigated resilience scenarios at the service center in Hesperia, California. The methodology leverages data on energy supply reliability from Task 2 and utilizes the technoeconomic DER scenario modeling tool, Xendee version 2023.[2]

The Federal Emergency Management Agency (FEMA) currently operates eight disaster recovery centers in California. Additionally, the State of California's Office of Emergency Services is actively developing disaster response plans. By 2023, service centers have only played a minimal role in these emergency planning processes, but with the growth in ZEV infrastructure, their role may become more prominent. Ensuring consistent and resilient refueling is paramount to Pilot's operations. As of now, Pilot has a system that receives three fuel deliveries daily, but future strategies centered around ZEV are set to incorporate resilience planning.

When discussing EVs, resilience becomes paramount, especially considering potential planned and unplanned grid outages. This issue is especially pronounced in California, which is grappling with extreme weather events that have been intensified due to climate change. Entities like the California investor-owned utilities, such as Southern California Edison, are making efforts to counter these impacts through measures like public safety power shutoffs. DER is one solution that is being considered for energy resilience. This involves on-site generation and storage mechanisms, such as solar PV and battery energy storage systems. These systems have the capacity to hold excess energy, which can then be dispatched during disruptive grid events.

Vehicle-to-grid integration (V2G) is another avenue that is being explored. This allows for power to be transferred both from the grid to electric vehicles and vice versa. The idea is to harness the stored energy in ZEV batteries and discharge this energy when required. However, this V2G technology mandates bidirectional charging, a feature that is currently only available in select vehicles and chargers. Even so, the potential benefits of V2G are numerous, such as providing power during grid outages, managing on-site loads, and even earning compensation for reducing peak energy demands.

[2] https://xendee.com/

The topic of hydrogen is also covered in the blueprint. The reliable provision of hydrogen has been a significant barrier to its wider adoption. To counter this, the CEC has mandated that new grants include provisions for a backup supply agreement. Furthermore, the CEC's Clean Transportation Program is making strides in funding renewable hydrogen production. There is also a recommendation to ensure on-site storage for up to 10,000 kilograms (kg), or three days' worth of hydrogen demand, particularly as infrastructure for renewable hydrogen production is being developed.

Lastly, the blueprint explores utility system disruption scenarios. Traditional centers have heavily depended on a robust fossil fuel infrastructure and haven't implemented electric grid resilience. With the emergence of ZEV technology, a comprehensive resilience strategy is no longer a luxury but a necessity. The risk is that ZEVs could become stranded due to a lack of infrastructure, leading to public skepticism. Therefore, the project team’s analysis of various utility disruption scenarios becomes especially pertinent, with durations ranging from 8 hours to 48 hours and causes stemming from traffic accidents, high temperatures, severe weather events, natural disasters, and more.

CHAPTER 6: Maintaining Flexibility for Future Technological Improvements

The goal of this task was to segment phased portions of the overall MD/HD ZEV infrastructure buildout and develop a prioritization methodology for advanced MD/HD ZEV infrastructure while maintaining flexibility for future technological improvements and reducing the risk that early investment is abandoned.

6.1 Flexible Infrastructure Planning Summary

Goals and Mandates: The blueprint is in line with the California Air Resources Board's (CARB) Advanced Clean Fleet Regulations which aim for a gradual transition to ZEVs.

Adaptability and Future-Proofing: The design process should incorporate flexibility to adjust to emerging technologies and evolving requirements. Some proposed technologies, not yet commercially available for MD/HD vehicles, are expected to be in the near-term product pipeline.

Infrastructure Planning Software: The project team explored the use of various software tools available for ZEV infrastructure planning such as EVI-Pro[3], HOMER Pro[4], Xendee[5], and StreetLight's Interactive EV Charging Dashboard.[6]

Data Requirements for Robust Planning: Several datasets are needed, including charging demand curves, charging standards, future ZEV technologies, existing site conditions, charging rate structures, and local utility details.

Infrastructure Phasing Approach: The blueprint proposes a four-phase approach for EVSE and hydrogen dispensing tied to the projected ZEV adoption under CARB regulations. The plan emphasizes the need for initial pilot phases, where limited investments are made for ZEV infrastructure, allowing time for data collection, testing, and understanding customer behaviors. More significant infrastructure upgrades and expansions are proposed for later phases as ZEV demand increases.

Financial Considerations: There is an emphasis on the significant capital expenditure during phase three, suggesting that stakeholders need to assess the feasibility and timing of these investments against projected ZEV adoption rates.

In summary, as California works towards the adoption of ZEVs, there is an acute need for a flexible, scalable, and data-driven approach to infrastructure planning. This involves a blend of forward-thinking design, strategic phasing, the utilization of modern

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3 https://afdc.energy.gov/evi-pro-lite
4 https://www.homerenergy.com/products/pro/index.html
5 https://xendee.com/
6 https://www.streetlightdata.com/refine-ev-charging-infrastructure-plan/#dashboard

software tools, and careful financial planning to ensure successful and sustainable outcomes.

ZEV Infrastructure Stakeholder Cooperation Report Summary

Installing a robust ZEV infrastructure for MD/HD vehicles requires a concerted effort from various stakeholders. The deployment's success hinges on collaborative efforts to address technical, financial, regulatory, and community-related challenges. This collaboration aims to fast-track the adoption of ZEVs and develop a sustainable transportation infrastructure.

Breakdown of Stakeholder Actions:

1) **Internal Stakeholders (e.g., Pilot)**: Conduct feasibility studies, identify charger locations, budget, collaborate with external stakeholders, and oversee the construction process.
2) **Hydrogen Providers**: Engage in the early stages to guarantee future demand fulfillment. Evaluate infrastructure compatibility with hydrogen vehicles and ensure that facilities cater to hydrogen-powered vehicle needs.
3) **Local Jurisdictions**: Develop policies and guidelines to streamline ZEV installations. Ensure compliance with local building codes and regulations.
4) **Policy Makers and Regulatory Agencies**: Offer incentives like financial benefits or tax credits for ZEV infrastructure. Promote collaboration between public and private entities for ZEV infrastructure.
5) **Community-Based Organizations**: Conduct public outreach, advocate for equitable infrastructure in underserved regions, and involve the community in planning processes.
6) **Financial Partners**: Offer grants, loans, or other financing options. Assess financial viability and potential return on investment for projects.
7) **Industry Partners**: Collaborate at all project phases, share technical knowledge, and ensure vehicle-charger compatibility.
8) **Truckers' Associations and Trucking Companies**: Advocate for infrastructure that supports MD/HD vehicles. Collaborate with infrastructure projects to meet trucking company needs and provide input on charger locations.
9) **Electrical Utilities**: Assess grid capacity and requirements for installations. Upgrade power distribution systems, provide incentives for off-peak charging, and ensure grid reliability.

In conclusion, every stakeholder has a unique yet interconnected role in the development of flexible ZEV infrastructure. A coordinated approach ensures faster ZEV adoption and creates a solid foundation for sustainable transportation.

CHAPTER 7: Evaluating Community Impacts

The goal of this task was to evaluate how the transition to ZEVs will impact California communities, in terms of job provision, equity, and reduced emissions. This will include considering how the benefits associated with the transition can be enhanced.

7.1 Summary of Workforce Education and Training Resources

The rapid evolution of the ZEV industry is poised to bring about significant changes in the job landscape of California. As the industry expands, there's an increasing need to understand and address the implications on the community, especially in terms of employment opportunities and workforce training.

ZEV Infrastructure Maintenance Needs:

A well-maintained infrastructure is pivotal in building trust among consumers. The creation of MD/HD charging infrastructure could result in approximately 9,090 job-years in areas ranging from planning and design to operations and maintenance. There's a significant emphasis on apprenticeships, training programs, and workforce development to bolster electric charging and hydrogen fueling capabilities.

MD/HD Vehicle Maintenance:

Though there's limited data on long-term maintenance of MD/HD ZEV fleets, studies indicate that ZEVs can lead to up to 25 percent reduction in annual maintenance costs when compared to traditional internal combustion engine vehicles.

Charging Infrastructure:

The charging specifications for MD/HD vehicles include both rapid opportunity charging and slower overnight charging. The high power DCFC systems, tailored for MD/HD vehicles, need regular upkeep due to their active cooling processes during charging.

Hydrogen Fueling Infrastructure:

This domain requires specialized knowledge in maintaining high-voltage systems, handling cryogenic liquids, and ensuring safety. The maintenance of hydrogen fueling stations is multifaceted, involving equipment checks, software updates, and more. There is room for improvement as the 2021 station availability rate in California was a mere 31 percent.

ZEV Maintenance Overview:

Traditional vehicles rely on services like oil changes, whereas BEVs typically require less maintenance. However, they have specific needs, especially around coolant system changes. Hydrogen FCEVs have their unique maintenance requirements centered on the fuel cell stack, coolant system changes, and hydrogen storage systems.

Recommendations:

California is on the brink of a significant shift in the transportation sector, with the rise of zero-emission vehicle (ZEV) technology. This evolution demands immediate investment in workforce training, apprenticeships, and capacity development, especially since ZEV advancements will increase the demand for specialized services like charging and hydrogen refueling infrastructure maintenance. As conventional fossil fuel-related jobs decline, new roles will emerge, particularly for skilled technicians specializing in EVSE and hydrogen storage. By 2042, the workforce will undergo a notable demographic transition, emphasizing the importance of targeting educational efforts at the Gen Z population. Institutions like Long Beach City College have identified knowledge gaps in ZEV technology, battery safety, and equipment maintenance, signaling a need for collaborative efforts between educational institutions, original equipment manufacturers, labor unions, and workforce development entities.

Furthermore, while the rollout of MD/HD infrastructure is vital, a glaring gap exists in the trained workforce to support it. As the state grapples with this transition, it becomes essential for retail MD/HD fueling stations to reevaluate their maintenance services, ensuring that their teams are well-trained. Despite advancements in the state, there remains an educational disparity between charging infrastructure and hydrogen technology, with charging infrastructure taking the lead. Sustained funding, from both state and federal levels, is imperative to drive workforce development in the ZEV domain. A unified approach, involving various stakeholders, is paramount for California to capitalize on this transportation revolution.

7.2 Summary of GHG Emissions Reductions Goals

The ambitious and necessary goal to curb GHG emissions in California has seen concerted efforts from various jurisdictions within the state. San Bernardino County, for instance, outlined plans by the San Bernardino Associated Governments in 2014 aiming to curtail community GHG emissions by 15 percent below 2008 levels by 2020.[7] Similarly, the City of Rialto has established a more long-term target, aspiring for a 40 percent reduction from its 2016 GHG emission levels by 2030.[8] Statewide initiatives are equally compelling. Senate Bill 375 mandates an 8 percent reduction in per capita GHG emissions from passenger and light-duty vehicles by 2020, increasing to a 13 percent reduction by 2035 compared to 2005 levels.[9] Notably, for cities like Rialto, on-road

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[7] ICF. 2021. *San Bernardino County Regional Greenhouse Gas Reduction Plan, Public Draft*. Prepared for San Bernardino Council of Governments, San Bernardino, California.
[8] Estrada, Bryan, Darshan Shivaiah, RK Engineering Group, Inc. 2020. *Foothill & Larch Air Quality and Greenhouse Gas Impact Study, City of Rialto, California*. Prepared for Keystone DCS, Inc.
[9] CA SB 375; https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200720080SB375.

transportation remains the most significant contributor to GHG emissions, emphasizing the sector's centrality in any reduction strategy.[10]

Given the escalating effects of climate change combined with the established regulatory environment at the county, state, and national levels, there's an unmistakable urgency for large-scale transformative actions targeting GHG emissions reduction. Transportation emerges as the sector with the most significant GHG emissions footprint, emphasizing the critical need for cleaner transportation mechanisms. Supporting the transition of MD/HD fleets from fossil fuels to zero emission technology presents a robust strategy that not only directly mitigates the effects of the region's highest emitters but also fortifies the broader emission and air quality goals at city, county, state, and national levels.

The move to ZEVs promises a substantial decrease in criteria air pollutants, which originate primarily from fossil fuel combustion. Such a transition aligns with San Bernardino County's aspiration to minimize NOx and reactive organic gas emissions, adhering to state and national standards by 2037. Moreover, pivoting MD/HD fleets to ZEVs considerably trims the CO2e emissions from on-road transportation, amplifying Rialto's ambition to slash on-road transportation CO2e emissions by 32.4 percent by 2030. Furthermore, such an initiative supports the State of California's commitment to achieving a 40 percent drop in GHG emissions by 2030, aligning with the broader goals of AB 1279. AB 1279 requires California to achieve "net zero greenhouse gas emissions" as soon as possible, but no later than 2045, and to achieve and maintain net negative GHG emissions thereafter.

7.3 Summary of Qualitative Benefits to DACs

Disadvantaged communities (DACs) face disproportionate health, economic, and environmental justice burdens from on-road transportation pollutions. Excluded from political power and decision-making processes, these communities have become the sites of highways, warehouses, and other industries with harmful environmental impacts. These historic injustices make equity and environmental justice a primary focus in the ZEV transition in California. Pilot's adoption of ZEV travel centers to spur MD/HD vehicle adoption in California brings benefits to disadvantaged communities in three main ways:

- Reducing air pollution, which allows for improved health and social outcomes
- Limiting dependence on and extraction of fossil fuels, which causes detrimental impacts to health and climate
- Increasing local opportunities for the clean energy economy

[10] Estrada, Bryan, Darshan Shivaiah, RK Engineering Group, Inc. 2020. *Foothill & Larch Air Quality and Greenhouse Gas Impact Study, City of Rialto, California*. Prepared for Keystone DCS, Inc.

Furthermore, pairing these impacts with increased decision-making for local communities and targeted investments in workforce and infrastructure development will guarantee a fair distribution of such benefits and support the development of an equitable clean energy economy.

Hesperia case study:

The blueprint team conducted a case study of the region to further inform community benefits and impacts. Hesperia, California is a city located in San Bernadino County alongside I-15, one of the major truck corridors in California. Its population is around 100,000 people. Though only one census track within it is considered "disadvantaged," the tracts that make up the city perform poorly when it comes to certain indicators. Hesperia faces large amounts of traffic. According to CalEnviroScreen 4.0[11], the city tracts fall into the 90th percentile or above in California for ozone pollution, the 95th percentile or above for cardiovascular disease, and 70th percentile or above for asthma. Though only a few tracts experience higher than average diesel pollution, Hesperia's ozone pollution and existing health disparities make improvements in air quality vital to the community. Worsened air quality could result in higher sick days, missed school days, and worsening of symptoms leading to increased hospitalizations and mortality. Turning Hesperia's existing Pilot Travel Center into a ZEV-enabled transit center for ZEV MD/HD vehicles could help alleviate strain on existing health disparities as well as bring new jobs, workforce training, and opportunities to participate in the clean energy economy.

[11] https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-40

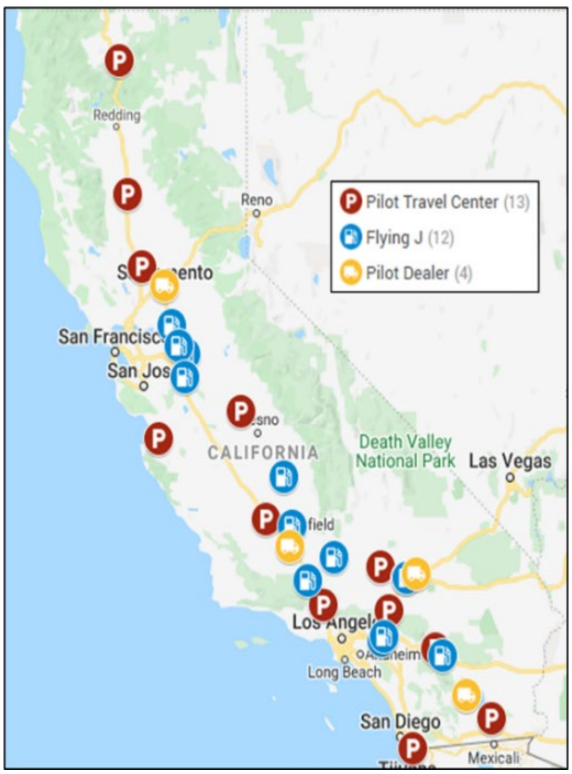
CHAPTER 8: Blueprint

The goal of this task is to formalize the information gathered under Tasks 2 through 7, into a formal blueprint that can be used internally by the project team and shared with key stakeholders.

8.1 Purpose and Context for Blueprint

The purpose of the blueprint was to compile the information gained in Tasks 2 through 7 to develop a feasible, readily deployable roadmap to support MD/HD transition to ZEVs. Pilot's blueprint will send a clear market signal that a cohesive and reliable network of MD/HD ZEV infrastructure can be accessible to all.

Figure 1: Pilot's 30 California Stations



Source: Pilot Flying J

Arup has completed a conceptual design for a future travel center that caters to MD/HD vehicles, incorporating a combination of battery electric charging, hydrogen refueling, and existing fossil fuel sales. This design encompasses both retrofit and greenfield applications, allowing for the integration of future ZEV infrastructure while ensuring compliance with all applicable codes and safety standards. The retrofit site chosen in

Hesperia was strategically selected to leverage the existing layout, enabling the seamless integration of ZEV infrastructure while preserving the functionality of the current site operations.

The proposed solution is tailored to meet the demands of MD/HD vehicle customers, matching the existing site infrastructure utility of eight dedicated diesel fueling lanes. It includes two rapid H70 hydrogen refueling lanes, twelve rapid opportunity 2.5 MW MCS charging lanes, and thirty 150 kW overnight DCFC stations. This comprehensive design optimizes the allocation of site area, ensuring efficient space for charging and refueling infrastructure, vehicle movements, queuing, and parking while maintaining the existing travel center's structures and facilities.

To further enhance the sustainability and resilience of the travel center, the design incorporates a microgrid system with distributed energy resources. This microgrid utilizes a solar PV array, a BESS, and natural gas generators. This configuration minimizes the LCOE, reduces the required electrical utility POI size, and provides a reliable power supply in case of a utility grid disruption.

In addition to the environmental and cost advantages, the recommended system presents substantial savings when compared to traditional fossil fuels. For an average tractor trailer, the cost per mile for third-party "refueling" is 73 cents when fueled by diesel and diesel exhaust fluid in an internal combustion engine. In contrast, a rapid MCS session of a battery electric tractor trailer incurs only 44 cents per mile, representing almost 40 percent savings.

Overall, Arup's conceptual design for the MD/HD travel center offers a forward-thinking solution that accommodates multiple energy sources while maintaining operational efficiency. The incorporation of ZEV infrastructure, renewable energy generation, and a resilient microgrid system showcases the potential for sustainable and cost-effective alternatives in the transition to ZEVs.

8.3 Lessons Learned and Next Steps

Challenges

Many of the blueprint's challenges centered around the changing market. What will be financially feasible over the next few decades is difficult to predict. Since the market is uncertain, it was difficult to balance BEV and FCEV technologies. Ultimately, the project team assumed 25 percent FCEV and 75 percent BEV for this blueprint based on research and latest trends in the market and technological adoption. The discussion of hydrogen and its storage difficulties was also part of this conversation.

Successes

Overall, the blueprint accomplished exactly what it set out to do, and Pilot can replicate the suggestions as they become feasible. The blueprint maps out the most cost-effective and realistic way Pilot may move toward travel center EV infrastructure adoption. Stakeholder engagement was also particularly successful with many different organizations, internal, and external stakeholders participating in meaningful conversations with the project team.

Next Steps

Pilot's next steps will be to explore future sources of funding and financing to potentially adopt the blueprint, and to continue to research market and technological changes as they come. Pilot will also socialize the blueprint with stakeholders, potential partners, etc.

GLOSSARY

BATTERY ELECTRIC VEHICLE (BEV)—Also known as an “All-electric” vehicle (AEV), BEVs utilize energy that is stored in rechargeable battery packs. BEVs sustain their power through the batteries and therefore must be plugged into an external electricity source in order to recharge.

BATTERY ENERGY STORAGE SYSTEM (BESS) – A storage system comprised of devices that enable energy from renewables, like solar and wind, to be stored and then released when the power is needed most.[12]

CALIFORNIA ENERGY COMMISSION (CEC)—The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The Energy Commission's five major areas of responsibilities are:

1. Forecasting future statewide energy needs
2. Licensing power plants sufficient to meet those needs
3. Promoting energy conservation and efficiency measures
4. Developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels
5. Planning for and directing state response to energy emergencies.

DIRECT CURRENT (DC)—A charge of electricity that flows in one direction and is the type of power that comes from a battery.

DIRECT CURRENT FAST CHARGER (DCFC) – Fast chargers that convert AC power to DC within the charging station and deliver DC power directly to the battery, allowing them to charge faster.[13]

DISTRIBUTED ENERGY RESOURCES (DER) — Small-scale power generation technologies (typically in the range of 3 to 10,000 kilowatts) located close to where electricity is used (for example, a home or business) to provide an alternative to or an enhancement of the traditional electric power system.

ELECTRICAL UTILITY POINT OF INTERCONNECT (POI) — The location where the microgrid or other electricity generation source connects to the main power grid. This is where electricity can be drawn from or sent back to the main grid.[14]

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[12] https://www.nationalgrid.com/stories/energy-explained/what-is-battery-storage

[13] https://www.chargepoint.com/blog/when-and-how-use-dc-fast-charging#:~:text=DC%20fast%20chargers%20convert%20AC,Find%20a%20Fast%20Charge

[14] https://www.lawinsider.com/dictionary/point-of-interconnection-poi

ELECTRIC VEHICLE (EV) – A broad category that includes all vehicles that are fully powered by electricity or an electric motor.

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE) – Infrastructure designed to supply power to EVs. EVSE can charge a wide variety of EVs including BEVs and PHEVs.

FUEL CELL ELECTRIC VEHICLE (FCEV) – A zero-emission vehicle that runs on compressed hydrogen fed into a fuel cell "stack" that produces electricity to power the vehicle.

GREENHOUSE GAS (GHG) – Any gas that absorbs infra-red radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), halogenated fluorocarbons (HCFCs), ozone (O3), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs).

H70 HYDROGEN REFUELING — A standard for hydrogen refueling stations which deliver hydrogen at a pressure of 70 MPa (10,000 psi), commonly used for passenger vehicles.[15]

LEVELIZED COST OF ENERGY (LCOE) – A cost of generating energy for a particular system.[16]

LIGHT DUTY VEHICLE (LDV) – Any motor vehicle with a gross vehicle weight of 6,000 pounds or less.

MEGAWATT CHARGING SYSTEM (MCS) – A charging connecter to provide efficient and high-power charging to large BEVs.[17]

MEDIUM DUTY/HEAVY DUTY (MD/HD) – Vehicle type that have a gross vehicle weight rating of more than 10,000 pounds and includes vans, buses, and trucks.[18]

MICROGRID — a combination of localized electricity generation sources, energy storage devices, and multiple loads that acts as a small electric grid with respect to the main electric grid. The microgrid can operate interconnected or isolated from the main electric grid.

NATURAL GAS GENERATORS — Devices that produce electricity by burning natural gas as fuel.[19]

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[15] https://www.energy.gov/energysaver/how-hydrogen-filling-station-works#:~:text=The%20H70%20designation%20indicates%20a,par%20with%20gasoline%2Dpowered%20vehicles

[16] https://www.nrel.gov/analysis/tech-lcoe-documentation.html

[17] https://www.charin.global/technology/mcs/

[18] https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics/medium-and-heavy

[19] https://woodstockpower.com/blog/how-does-a-natural-gas-generator-work/

NORTH AMERICAN CHARGING STANDARD (NACS) – Tesla's charging connector and charge port.[20]

ORIGINAL EQUIPMENT MANUFACTURER (OEM) – Makes equipment or components that are then marketed by its client, another manufacturer, or a reseller, usually under that reseller's own name.

SOLAR PHOTOVOLTAIC (PV) ARRAY — A system of solar panels designed to convert sunlight into electricity using the photovoltaic effect.[21]

VEHICLE TO GRID (V2G) – A technology that enables energy to be pushed back to the power grid from the battery of an EV.[22]

ZERO-EMISSION VEHICLE (ZEV) – Vehicles which produce no emissions from the on-board source of power (e.g., an electric vehicle).

150 kilowatt (kW) OVERNIGHT DIRECT CURRENT FAST CHARGING STATIONS — Charging stations that can deliver up to 150 kW of direct current power to electric vehicles, suitable for fast-charging, especially if vehicles are left overnight.[23]

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[20] https://www.tesla.com/blog/opening-north-american-charging-standard
[21] https://www.sunrun.com/go-solar-center/solar-terms/definition/solar-array
[22] https://www.virta.global/vehicle-to-grid-v2g
[23] https://chargehub.com/en/electric-car-charging-guide.html