

Caltrans Zero-Emission Bus Market Sounding Report

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1. Executive Summary

The purpose of the market sounding presented in this report is to advance ideas and actions that accelerate the zero-emission bus (ZEB) transition for public transit operators across California, with a particular focus on small and rural operators as an area of high need and high opportunity. The report summarizes this effort's approach and findings, with recommendations to further advance potential high-value demonstration projects in support of the California zero-emission transition.

21 companies were interviewed through a market sounding process to assess the feasibility and impact of a range of innovative models and initiatives to support the transit industry's ZEB transition. This process consisted of structured conversations with private companies across four groups within the industry – ZEB original equipment manufacturers (OEMs), battery-electric bus (BEB) fueling infrastructure providers, hydrogen fuel cell electric bus (FCEB) fueling infrastructure investors – as well as informal conversations with transit operators, state agencies, and other stakeholders.

This report summarizes these detailed conversations by sector and offers a series of cross-sector key insights to inform future action, which are briefly summarized below.

Lack of expertise: Transit operators lack the required resources and expertise to plan, procure, deploy, operate and maintain ZEBs and supporting infrastructure. This is both a function of the newness and rapid evolution of the technology (both FCEB and BEB), and the operators' lack of experience with the technology. This lack of resources and expertise is an underlying driver for other observed challenges to the zero-emission transition. At the same time, this dynamic creates a potential role for external private entities, such as investors, to help manage risks and responsibilities of these relatively new technologies on behalf of operators and a recommendation against complex scope elements like on-site hydrogen production.

Needed focus on infrastructure, not vehicles: The most significant challenge and need for statelevel intervention to ensure timely ZEB transitions is related to ZEB infrastructure, not vehicles. This is due to the fact that these projects are not simply about swapping in different equipment, but rather are complex infrastructure projects with all the complications and considerations that these projects entail. There are numerous key considerations for optimizing these infrastructure projects. First, small and uncoordinated infrastructure projects are often inherently challenging and inefficient, a challenge that can be addressed via different "bundling" mechanisms – bringing together multiple projects, products, services, or users – to benefit from economies of scale. However, the concept of sharing infrastructure across multiple users, although initially intuitive, is expected to pose operational, financial, and coordination challenges. As such, shared infrastructure models should be carefully considered before deployment.

Standardization will take time: Standardization is commonly touted as a solution to bring down high equipment costs of extensively customized transit buses. However, this benefit is only likely to be realized in the long term, as it will require both overcoming the inertia of current procurement practices and financial incentives (which lead to price insensitivity in transit capital costs) and developing less labor-intensive manufacturing processes. Statewide purchasing contracts may be one tool for this eventual standardization, although they are not a panacea. In the short term, these contracting tools are primarily generating value by reducing



administrative complexity and procurement costs for transit operators. For infrastructure, projects could be deployed more efficiently with the help of a market-led "cookie cutter" model as the starting point for a project. However, some site-specific planning and engineering work is unavoidable, as ZEB deployments are unlikely to be a commodity that can be deployed "off the shelf" in any reasonable time frame.

The risks and challenges of these rapidly evolving technologies are not easily managed with current mechanisms: ZEBs are still a relatively new technology with novel risks, particularly "interface" risks between the fueling infrastructure and the ZEB, but also between the powertrain and the bus, particularly for BEBs. As vehicles' performance is impacted by weather, terrain, and operator behavior, ZEB OEMs are generally unwilling to guarantee range or performance of their vehicles. This challenge likely requires a suite of solutions, from more sophisticated risk allocation to improved testing to training to optimize vehicle operations.

These key insights informed conclusions about potential scalable, implementable project concepts that can support an efficient and timely ZEB transition for California transit operators. These project concepts incorporated six key themes or "building blocks": bundling to optimize project scope and scale; improved allocation of risks and responsibilities; innovations in procurement, compensation, and contracting; standardization; new approaches to satisfying project needs with improved infrastructure solutions; and state interventions related to resources, coordination, and policy.

This report identifies five project areas based on these building blocks for further research and consideration. Two project areas focus on different ways to re-allocate risks and responsibilities that transit operators are not well-positioned to manage, exploring this possibility both for an individual transit operator via an "as-a-service" model, and for multiple transit operators through a bundled partnership model. A third project area proposes the idea of developing robust market-based fueling infrastructure project specifications as a starting point for operators, aiming to optimize infrastructure deployments and avoid costly mistakes. A fourth project area is centered on the possibility of developing "outside-the-fence" infrastructure for on-route fueling to mitigate range anxiety and improve resilience efficiently, while the final area focuses on filling in gaps in operators' resources and expertise for deployment by ensuring easy access to expert and technical support needed for deployment. The next phase of this effort will focus on developing feasible and specific demonstration concepts to advance these project areas towards realistic implementation.



2. Introduction

The Innovative Clean Transit (ICT) regulation requires all transit operators to purchase 100% zeroemission buses (ZEBs) starting in 2029. As a result, transit operators in California face the task of rapidly decarbonizing their fleet operations in the coming years. This transition is a challenge for many transit operators, who must undertake an ambitious transformation without compromising their primary mission of providing transit services. The challenge is the most acute for small and rural transit operators, who must accomplish these goals with fewer staff, less funding, and without the benefits of scale. As a result, Caltrans and other California state agencies are seeking new ways to support and accelerate progress in this area.

The purpose of the market sounding presented in this report is to advance ideas and actions that accelerate the ZEB transition for public transit operators statewide. The objective is to identify promising demonstration project concepts for deploying ZEBs and refueling infrastructure for both battery-electric buses (BEBs) and hydrogen-powered fuel cell electric buses (FCEBs). While demonstrations are a proven tool across industries to test and validate scalable solutions to address challenges and advance the state of the practice, a demonstration project does require a significant commitment of scarce time and resources. To prepare for an optimal and productive demonstration, market sounding is one tool to help identify market-based, feasible, and impactful project concepts.

A market sounding can present an opportunity for candid and extended dialogue with key players, whether to gather feedback for a specific project or more general market intelligence to inform initiatives or programs. The California Integrated Travel Project (Cal-ITP) previously conducted various market soundings to inform demonstrations and implementation of an innovative statewide approach to helping transit operators procure technologies such as contactless payment systems and real-time vehicle location and information systems. Market soundings are also a common tool employed worldwide for infrastructure-focused public-private partnerships (P3s) to address detailed topics related to project delivery and risk allocation with companies interested in investing in projects. Finally, a market sounding can have the additional benefit of generating market interest in a public procurement or program, which helps to stimulate competition. An intended benefit of this market sounding is that the effort's participants are also potential participants in future partner selection processes for demonstration projects, which will help generate market interest and increase the likelihood of success.

To achieve the objectives of this project, the market sounding process included interviews with companies to assess the feasibility and impact of a range of new partnership, project delivery, and funding/financing models. This market sounding consisted of structured conversations with private companies across four groups within the industry – ZEB original equipment manufacturers (OEMs), BEB fueling infrastructure providers, FCEB fueling infrastructure providers, and infrastructure investors – as well as informal conversations with transit operators, state agencies, and other stakeholders. The effort sought to determine what the market is already doing or planning to do in this sector, and to receive input on what California can do to assist transit operators in making projects more economically viable. The market sounding achieved these objectives by gathering feedback on specific demonstration project concepts that were described to interviewees for their consideration. The discussions also generated important insights about the specific technical, economic, procedural and legal challenges that market players face in providing products and



services to California transit operators and the key business case drivers for different types of companies. This report synthesizes the market sounding's findings and presents a summary of the demonstration concepts that the market found to be most feasible and impactful, and the key considerations, options, and questions for implementation. The information in this report is intended to help California prioritize demonstration project concepts and facilitate collaboration between transit operators, private sector companies, and state agencies.

This project complements a parallel effort within Caltrans to identify and develop new technical assistance and asset management functions through partnerships to further support the ZEB transition. Some of the demonstration ideas raised during the market sounding interviews directly overlap with proposed technical assistance and asset management activities for Caltrans to explore, and such ideas will be initiated primarily through public sector and non-profit collaboration. Other demonstration concepts identified in this report will be catalyzed primarily through market action, with state agencies playing more of a supporting role.



3. Market Sounding Concepts

To optimize the time spent with market participants, preparation for the market sounding included development of a series of potential solutions to key challenges in ZEB deployment for discussion with interviewees. At this stage, the effort identified challenges and opportunities that were common to both BEB and FCEB transitions, with the goal of developing demonstration concepts with broad appeal.

3.1 Identifying challenges, root causes, and opportunities for intervention

Step 1: Identify observed challenges. The process of defining preliminary demonstration concepts to explore with market participants began with developing a clearer understanding of the specific challenges that transit operators face in their ZEB transitions. This challenge identification sought to incorporate findings from desk research, conversations with state agencies, discussions with transit operators, and engagement with other key stakeholders. This approach provided the opportunity to understand and describe the on-the-ground realities and observed challenges for transit operators. This starting point grounded the analysis in the transit operator point of view to ensure potential solutions and eventual demonstration projects would be well-suited to the intended audience – transit operators – and people who depend on the services they provide. The observed challenges to transit ZEB transitions fell into the following broad categories:

- **Costs**, including the level and unpredictability of costs for vehicles, infrastructure, fuel, labor, and "soft" costs related to planning, project development, operations, and maintenance.
- **Uncertainties**, including the availability of key inputs or equipment, access to funding, technology performance, and technology change.
- **Market factors**, including the ability or incentive for companies to provide products and services that meet operators' needs, lead times for delivery, proprietary technology, and interoperability.
- Logistics and coordination, including project siting, operational complexities, procurement, coordination among vendors and project components, and securing funding.

Step 2: Hypothesize root causes. The next step assigned potential root causes to each of the identified observed challenges. A root cause analysis framework recognizes that there can be multiple drivers of an observed phenomenon – for example, high ZEB prices – and provides more clarity as to how a challenge might be addressed. Systematically considering potential root causes identifies more specific challenges that can be linked to actionable solutions. Hypothesized root causes included the following:

- Relatively immature technology compared to internal combustion engine (ICE) vehicles and fueling technologies
- Relatively low transit operator capacity and resources
- High technical complexity of new technologies and equipment
- Uncertainty around future availability and price of electricity and hydrogen fuel
- Limited market power of transit sector and transit operators



- Extensive customization of vehicles and infrastructure projects
- Limited market competition for key products and services
- High indirect costs related to procurement, securing funding, change management (e.g., workforce training for maintenance of vehicles and infrastructure), and contracting
- Regulatory requirements
- Lack of full interoperability between deployment components (e.g., buses, infrastructure, software)
- Lack of dedicated funding sources for deploying and operating infrastructure

Step 3: Identify potential opportunities to address hypothesized root causes. For each hypothesized root cause, a set of potential opportunities to mitigate the observed challenge for transit operators were identified. In order to generate a wide range of opportunities, the research process included examination of solutions deployed in other markets (i.e., outside California and the United States), other sectors (e.g., for Compressed Natural Gas fueling or school bus transition to zero-emission vehicles), as well as potentially novel solutions identified through the detailed root cause analysis. An example of the process progressing from observed challenges to root causes to opportunities is included below.

Figure 1. Root Cause Analysis Framework



Step 4: Prioritize potential opportunities to address hypothesized root causes. Finally, the potential opportunities generated in the previous step were prioritized in order to identify the most promising opportunities for discussion in the market sounding. Six reviewers independently rated each opportunity on a three-point Likert scale based on three factors:

- **Impact:** The extent to which a given opportunity is likely to positively impact transit operators' zero-emission transitions.
- **Feasibility:** The extent to which a given opportunity is possible to implement in a timely, cost-effective manner.
- **Relevance:** The extent to which a given opportunity is well-suited for exploring through a market sounding and potential demonstration project initiated by Caltrans.



Both the average and range of reviewers' scores was examined and discussed in order to gauge reviewers' collective judgment of the promise each opportunity presented. This information was used to assign each opportunity a high, medium, or low-interest categorization.

3.2 Defining discussion concepts

The "root cause" analysis resulted in a list of potential opportunities to address challenges to a successful ZEB transition, prioritized by their likelihood to be feasible, impactful, and relevant to the market.

These discussion concepts were used to prompt open-ended conversations with market participants. The concepts purposely presented a general idea that could be implemented in a variety of different ways rather than guiding interviewees towards a highly specific or preconceived solution. The concepts varied in terms of their level of novelty or innovation and the challenges they are designed to address. The eight discussion concepts presented to interviewees in the market sounding were the following:

State-led fueling infrastructure buildout

Challenges: Upfront costs | Inefficient scale | Indirect costs | Limited expertise

In contrast to today's status quo where transit operators procure, own, operate, and maintain private onsite fueling infrastructure, a **California state agency (or group of agencies) could work with the private sector to procure, coordinate infrastructure delivery, and share key risks** for infrastructure serving transit operators. In this concept, **transit operators would be users of state-provided fueling services, rather than owner-operators** of fueling infrastructure.



Shared infrastructure buildout among multiple users in a region

Challenges: Upfront costs | Inefficient scale | Coordination challenges

In contrast to today's status quo where transit operators procure, own, operate, and maintain private onsite fueling infrastructure, **California could coordinate regional partnerships between transit operators and strategic partners to build shared infrastructure**. In this concept, transit operators could maintain owner-operator status but could share upfront and operational costs with other users for infrastructure built to a more efficient scale.





Contracting solutions to share risks of technology performance and change

Challenges: Limited expertise to manage technological complexity/uncertainty

Transit operators are struggling with the assessment and management of risks associated with the ZEB transition – specifically, the **risks of technological performance and technological change**. In this context, California may consider the concept **of alternative contracting and/or financing mechanisms that more efficiently allocate these risks** between transit operators, California, and private sector partners.



Coordinate larger, standardized, lower-cost vehicle and/or infrastructure purchase volumes through statewide contracts

Challenges: Upfront costs | Small market | Indirect costs | Limited expertise

While most transit operators conduct independent procurements for small, customized orders of ZEB-related products, California could build on its current strengths in **facilitating larger, more standardized orders via alternative procurement tools such as statewide contracts**. Increasing utilization of these mechanisms could help to lessen the procurement burden for transit operators while encouraging interoperability and leveraging economies of scale.



Establish technical assistance/staff augmentation capabilities

Challenges: Indirect costs | Limited expertise

Small transit operators often lack the personnel, capacity, information and expertise to solve specialized and technical problems in their ZEB transitions. As a key coordinator and source of resources and expertise, California state agencies and key partners could provide access to specialized technical assistance to ease operators' transitions.



Define how transit can use commercial/public fueling infrastructure

Challenges: Upfront costs | Inefficient scale | Indirect costs | Limited expertise

In the future, **transit operators could potentially fully or partially rely on commercially-available heavy duty fueling infrastructure**. Given that transit is a small market segment, this concept would leverage the future larger network of fueling built for other users. Specifically, California could **clearly define transit's requirements for using commercial or retail infrastructure and coordinate and incentivize adoption** where feasible.





Create shared vehicle/parts inventories

Challenges: Small market | Coordination challenges

Rather than maintaining small, independent inventories of vehicles and key parts, **transit operators could pool key inventories regionally to manage challenges in accessing key components in a timely manner**. This concept could leverage **state-level and regional coordination power to build out the asset management and interoperability requirements** necessary for such a shared system.



Provide technical assistance and/or technology to optimize charging and vehicle operation for cost and energy efficiency

Challenges: Upfront costs | Indirect costs | Limited expertise

To maximize efficiency and minimize costs, California could **ensure the provision of smart charging or related technology, driver assist tools, and/or enhanced training that ensure optimal operation of new technologies**. State-level support may include **direct procurement or provision and/or technical assistance** to manage integration and deployment.





3.3 Understanding the landscape of ZEB project delivery

Executing a ZEB deployment entails managing risks that can complicate project delivery. The following table describes key risks common to ZEB deployments and an example in this sector's context.

Risk type	Description	Example
Technology Risk	Risk associated with the development and deployment of new technologies, including a nascent market and the potential for disruptive changes in technology	A new technology purchased today could be quickly replaced with a new and potentially incompatible solution
Interface Risk	Risk associated with uncertainty as to whether system components can effectively interact with other systems, or how effectively project stakeholders can function together	A transit operator's BEB is incompatible with pre-existing charging infrastructure or there is a messy "hand-off" between the infrastructure design and construction teams, creating a project delay
Performance Risk	Risk associated with the uncertainty of operational costs or the ability to meet performance requirements	A newly purchased ZEB cannot meet the intended range and rigor of a route in actual operation, affecting bus service
Utility Coordination Risk	Risk associated with the uncertainty and cost of coordinating with utility providers, including but not limited to interconnection, energy supply capacity, and rate structure	A deployment is significantly delayed due to the length of the local utility's interconnection queue and emergency priorities
Real Estate Risk	Risk associated with the uncertainty or cost of securing a suitable location for a project	Securing appropriate real estate for fueling infrastructure is significantly slower and more expensive than expected
Revenue Risk	Risk associated with the uncertainty around the revenue potential of a project or investment	A transit operator selling fuel "over the fence" brings in less revenue to offset its costs than expected
Counterparty Credit Risk	Risk associated with the uncertainty around the fulfillment of a project partner's obligations due to their internal finances	A bus supplier declares bankruptcy during fulfillment of an order, delaying or terminating the contract; or a transit operator experiences budget cuts and cannot meet its contractual obligations

Table 1. Identification of Key Risks



Another critical dimension of project delivery and structuring is the degree of "bundling" included in the transaction. Different types of bundling can help project sponsors more efficiently allocate risks and responsibilities and leverage economies of scale to improve the economics of a project. The figure below illustrates various types of bundling for ZEB deployments that are discussed in greater detail throughout this report.





4. Market Sounding Participants

4.1 Participant selection and interview process

Market sounding participants included major companies in the zero-emission mobility ecosystem. Companies were sorted by sector and outreach was conducted based on the relevance of their core products and services to the heavy-duty transit ZEB market. Within each sector, at least four companies were included to ensure that a range of business models and opinions were represented and that no statements could easily be linked back to any one company. The market sounding process included 21 formal interviews, in addition to several shorter and more informal conversations with relevant stakeholders. Interviews were conducted under the Chatham House rule, meaning there is no attribution of information in this report to any specific firms or individuals.

Interview participants were experts from a range of roles and disciplines including strategy, sales, product, and policy. The preparation for each interview included reviewing relevant projects or initiatives as well as the company's main product offerings. This allowed prioritization of demonstration concepts for each interview and preparation of company-specific follow-up questions.

Prior to each meeting, a brief agenda and pre-read was shared with the interviewees to stimulate thoughts on the demonstration project concepts. During the meeting, interviewees were presented with these concepts and asked open-ended questions to solicit feedback. The process also included follow-up questions more specifically tailored to each company's views and strategy. This interview structure illuminated key options and considerations for demonstration projects and provided robust information about market dynamics and the technical intricacies of deployment, which further informed this report's conclusions.

The conclusions presented in this report were also supported by public sector interviews performed through a second parallel engagement with Caltrans as well as ongoing, less structured engagement with public-sector stakeholders at the local, regional, and state levels in California. The purpose of this other effort was to specifically identify and develop new technical assistance and asset management functions that Caltrans could implement itself or through partners to advance the ZEB transition. These conversations underscored the planning and project development challenges that many transit operators face, opportunities to improve access to resources, and the potential to lower the lifecycle costs of deploying ZEBs.

4.2 Sectors of focus

Zero-Emission Bus (ZEB) Original Equipment Manufacturers (OEMs)

ZEB OEMs manufacture and deliver the zero-emission vehicles that transit operators need. While many of these firms have in the past or currently produce non-zero-emission transit vehicles, all interviewees have experience with zero-emission transit vehicles in the North American market. Some firms manufacture both battery-electric and fuel cell electric buses, while others specialize in only one technology. In addition, while the most commonly recognized products are full-size transit buses (typically in the ~40 foot range), other market participants fill the need for smaller vehicles including paratransit and cutaway vehicles. In the U.S. context, firms in the transit buse market have limited overlap with other heavy-duty transportation sectors such as school buses



and trucks. Furthermore, due to Buy America legislation, all companies selling to U.S. transit operators conduct significant manufacturing in the United States. Due to this regulatory dynamic, as well as other economic drivers, the key players in the U.S. ZEB market are not necessarily the same as those in international markets.

In order to engage with their customers – transit operators – ZEB OEMs respond to solicitations from individual agencies and participate in statewide contracts, also referred to as leveraged procurement agreements (LPAs), that are available to local agencies. In addition to vehicles, most OEMs sell some associated services such as warranties and basic training; some also allow customers to purchase fueling equipment from third parties on the same contract.

In the context of a ZEB deployment or demonstration project, ZEB OEMs offer not only access to vehicles and services like training, but also key expertise in:

- Technical and operational realities of ZEB deployment and operation;
- A market view on transit vehicle procurement;
- Key insights into the risks and risk management opportunities associated with ZEBs;
- An expert view of "what" should be deployed and "how";
- Insights into the cost drivers and trends of ZEBs;
- Recommendations for ZEB fueling solutions/providers; and more.

Battery Electric Bus (BEB) Charging Infrastructure Companies

BEB charging infrastructure companies manufacture, install/deliver, and sometimes operate and/or maintain the infrastructure that charges BEBs. All firms interviewed have experience manufacturing and selling heavy-duty electric transportation charging infrastructure in the North American market. In addition to transit and other heavy-duty uses, many companies also serve medium- and light-duty customers. While there are some examples of integration across manufacturers of vehicles and infrastructure, the vast majority of BEB charging infrastructure companies do not manufacture vehicles. There is a wide variety of charging technology approaches in the BEB charging market, including plug-in, pantograph, inductive, and even mobile or other innovative solutions. The interviewees represented a range of these technologies, although most placed an emphasis on plug-in charging for transit use cases.

These firms have different business models and expertise and can play a variety of roles in project delivery ranging from that of a vendor selling hardware and software to integrated project design, delivery, and operations. Note, however, that BEB charging companies typically do not play a lead role in the electrical utility upgrades required for a BEB deployment.

In the context of a ZEB deployment or demonstration project, BEB charging infrastructure companies offer not only access to charging infrastructure and services like training, but also key expertise in:

- Technical realities of BEB charging equipment deployment and operation;
- A market view on BEB charger and infrastructure procurement;
- Key insights into the risks and risk management opportunities associated with BEB charging;
- An understanding of key funding sources and incentives for zero-emission transportation;
- An expert view of "what" should be deployed and "how"; and



• Insights into the cost drivers and trends of BEB chargers.

Depending on the business model, technology, and capacity, some may also offer insight into:

- Project design and construction;
- Detailed experience with operating and maintaining charging equipment;
- Insights into charging infrastructure and deployment for non-transit sectors, and more.

Fuel Cell Electric Bus (FCEB) Fueling Infrastructure Companies

Fueling infrastructure providers manufacture, install/deliver, and sometimes operate or maintain the infrastructure that fuels FCEBs. All firms interviewed have experience manufacturing and selling heavy-duty hydrogen fueling infrastructure in the North American market. In addition to transit and other heavy-duty uses, some companies also serve medium- and light-duty vehicle customers. While companies use different technologies, there are fewer distinct typologies of FCEB fueling infrastructure than there are BEB charging infrastructure typologies. One key distinction is between infrastructure that uses liquid vs. gaseous supplied hydrogen; this difference leads to different needs for equipment, power, and more.

These firms have different business models and expertise and can play a variety of roles in project delivery ranging from that of a vendor selling hardware and software to integrated project design, delivery, and operations; unlike BEB charging infrastructure companies, some are also involved in the production (either onsite or off-site) of hydrogen fuel.

In the context of a ZEB deployment or demonstration project, FCEB fueling infrastructure companies offer not only access to fueling infrastructure and services like training, but also key expertise in:

- Technical realities of FCEB fueling equipment deployment and operation;
- A market view on FCEB infrastructure procurement;
- Key insights into the risks and risk management opportunities associated with FCEB fueling;
- An understanding of key funding sources and incentives for zero-emission transportation;
- An expert view of "what" should be deployed and "how"; and
- Insights into the cost drivers and trends of FCEB infrastructure.

Depending on their business model, technology, and capacity, some may also offer insight into:

- Project design and construction;
- Detailed experience with operating and maintaining fueling equipment;
- Insights into fueling infrastructure and deployment for non-transit sectors;
- Insights into fueling infrastructure and deployment for non-hydrogen fuels (e.g., CNG);
- Market expertise in the production, sale, and distribution of hydrogen fuel, and more.

Investors

While many entities can act as "investors", this market sounding focused on equity investors currently involved in the development and financing of transportation and infrastructure projects. The firms interviewed all have experience developing and investing in a variety of clean



transportation, energy, transit, and other collaborative projects with the public sector in North America and worldwide.

In the context of a ZEB deployment, these firms indicated they could take on various roles. They could act as project developers and managers in partnership with project sponsors (i.e., transit operators), arrange or directly provide debt and/or equity financing, and help structure and contract for large-scale projects. These firms bring key expertise in:

- Risk assessment and management;
- Assessing projects' business cases and commercial feasibility;
- Project structuring, development, and management;
- Assessing emerging trends and potential business opportunities across sectors, and more.



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5. Market Sounding Insights by Sector

5.1 ZEB Original Equipment Manufacturers (OEMs)

The market sounding included interviews with four ZEB OEMs, with representation from firms manufacturing BEBs and FCEBs as well as both full-size transit buses and smaller vehicles used by transit operators. The section below summarizes synthesized findings across multiple themes and presents overarching conclusions on how ZEB OEMs view the demonstration project concepts.

Components of an optimal ZEB purchase and deployment

ZEB OEMs highlighted the challenges of extensive transit bus customization. ZEB OEMs commented on the common types of customization they saw in their business, which all agreed was widespread (and common to all transit buses, not only ZEBs), with one noting that they would characterize the situation as "3,000 published options and 3,000 unpublished options" for vendors and transit operators to navigate. First, it was noted that for the highest-cost component – the propulsion system – there are few options for customization. However, a bus's HVAC system is a high-cost component that is commonly customized to meet operators' manufacturer and brand preferences. Beyond these high-value components, there are numerous smaller components including CAD/AVL (Computer-Aided Dispatch / Automatic Vehicle Location) systems, infotainment systems, seat type and configuration, drivers' seats, paint colors, windows, flooring, driver barriers, wheels, and much more. While these components are not independently costly, customization of component after component can add up; one OEM quoted a price difference between two customers in the range of \$100,000 per bus based solely on customization choices. ZEB OEMs uniformly noted that impacts for OEMs are primarily due to the differences between customers. For example, one OEM mentioned that the difficulty of manufacturing an "astronomical" number of different floorplans for buses is a challenge and cost driver. One OEM explicitly contrasted the situation of the transit bus market with that of the school bus market, where they see a high degree of standardization. All ZEB OEMs emphasized the importance of labor hours and manufacturing complexity as a cost driver for customized transit buses. OEMs indicated that this complexity not only drives costs directly, but also indirectly through an inability to design manufacturing facilities with high levels of automation. While one OEM indicated that roughly 20-30% of labor costs were likely driven by individual customization, it is also possible that the overall direct labor component could be reduced over time with more standardization.

ZEB OEMs think that widespread vehicle customization has multiple drivers, including apparent price insensitivity from operators. While they did recognize that there are some needs that are legitimately different between transit operators, companies view the majority of customizations as driven solely by preference. These include preferences for different manufacturer's products as well as operators' logical desires to match the equipment with the rest of their fleet. This type of intra-fleet consistency likely simplifies maintenance, spare parts, training, and more. Other preferences for drivers' seats, colors, décor, and more may be less driven by operational or budgetary considerations. One OEM mentioned that they feel many of these choices may also be driven by extensive marketing by vendors that convince operators to buy things they don't need. While it may seem inconsistent with a financially-constrained public agency, all ZEB OEMs confirmed that they see very little price sensitivity in their transit operator customers. One driver of



this lack of price sensitivity is a lack of information about the cost implications of customization choices; while this is technically public information, many transit operators do not find out what the cost might be for a similar bus or directly weigh the costs of each choice. In addition, OEMs were aware of the incentives created by funding sources for ZEBs; as many or most capital purchases are grant-funded, operators are not strongly incentivized to look for savings when purchasing vehicles. Due to this price insensitivity and the relative newness of the market, OEMs expressed that they are currently not feeling margin pressure for customized ZEBs like they observe in the internal combustion engine (ICE) market.

One ZEB OEM mentioned the lack of standardization in batteries as another important factor. While other interviewees did not comment on the standardization of batteries, one OEM offered that the lack of a standardized battery pack is likely reducing competition and options for managing battery-related risks. The specific elements of standardization for battery packs were not discussed in detail (e.g., dimensions, capacity, battery chemistry, ability to "plug and play"), and would need to be more precisely defined to allow for action on this challenge. This OEM felt that achieving a standardized battery pack in the short term was highly unlikely, due to competing proprietary chemistries, a lack of a clear "winner" across all applications in terms of technology, and a lack of market pressure as "most customers don't think about battery packs". However, they expressed the view that a standard battery pack that could be switched out for another could be a major gain for operators.

ZEB OEMs' views on standardization varied greatly. There was not unanimous agreement between interviewees on how (or even if) customization should be managed through standardization, although most were open to the idea of reining in excessive customization. As noted previously, most OEMs see customization in small transit bus orders as a key driver of labor costs and manufacturing complexity, particularly in light of current labor shortages in the market. However, OEMs have for the most part shaped their business and manufacturing processes around delivering customized orders, relying significantly less than other vehicle sectors on automation for manufacturing, for example. To this point, one interviewee mentioned that in other non-ZEB subsectors, they see 100 vehicles as a minimum order size to make costly manufacturing worthwhile. However, the fact that most transit vehicle manufacturing processes are adapted to laborintensive processes means that any transition to more standardized manufacturing will be slow and capital-intensive for OEMs. As such, most benefits of more efficient manufacturing would likely not be achieved in the short- or medium-term. Most OEMs were open to the idea of greater standardization. One interviewee in particular asked whether the industry should be looking to the passenger car sector and their experience in establishing set "packages" and limited options to optimize manufacturing. In the words of one interviewee, they "don't want to advocate that it becomes a commodity, but it could be closer." In addition to the more straightforward cost benefits, multiple OEMs mentioned the time efficiencies of streamlined production – a potential lever to mitigate the high lead times and inventory requirements almost all OEMs mentioned. However, the existing business models of some OEMs are much better suited to - even if not optimized for or built around – small orders and extensive customization. This means that the entire market is not united around the idea of standardization, and some firms even feel that customization can be a profit center and source of competitive advantage. This divergence in business models means that some ZEB OEMs would likely support standardization-oriented interventions, while others may be more reluctant.



ZEB OEMs discussed a number of potential mechanisms to implement ZEB standardization. Despite a lack of consensus on the extent to which ZEBs should be standardized, OEMs discussed several options for pursuing standardization. First, at least one OEM discussed the ways in which standard bus specifications provided to transit operators could be helpful, mentioning the APTA White Book specifications as an example. Multiple OEMs mentioned that operators are often over-specifying or mis-specifying their needs in procurement, for example "copy-pasting" ICE bus specifications into their procurements for zero-emission buses, instead of considering specifications specifically for the context of ZEBs. Most OEMs also discussed how statewide contracts and other similar mechanisms could be a tool to reduce customization. They expressed a view that currently, options on these contracts are essentially "unlimited", and that allowing customization only to a point would likely be preferable. While some OEMs mentioned potential industry actions, like consolidating around a smaller number of floor plans, companies did not identify a clear path forward for an industry-led standardization effort at this time. One OEM discussed customization as a collective action problem that requires coordination to overcome; this could be a potential role for California as a coordinator and convener.

Most ZEB OEMs expressed openness to the idea of participating in bundled ZEB deployments. There was no consensus on the use of ZEB contracts that would offer the full range of products and services needed to operate ZEBs throughout their lifecycle. While no OEMs interviewed expressed that they were planning to transition primarily to this business model, most indicated potential interest in participating in a project as a team member or supplier. OEMs recognized several key benefits of bundling for their customers, including the reduction in the number of competitive procurements operators need to run, the assurance that the ZEB OEM supports integration with charging/fueling equipment, and the guarantee that adequate integration testing has been conducted. However, most OEMs did not see a major customer demand for these services, which could indicate a lack of awareness, reluctance to shift away from current practices, or other factors. In terms of the services that would be part of a bundle, most ZEB OEMs mentioned that they would like training (at a minimum, parts and operator training) to be involved. There was no clear consensus on whether ZEB OEMs would prefer for charging/fueling equipment to be bundled with their vehicles or sold separately. One OEM attributed the current popularity of bundled bus and charger sales to a historical happenstance when several OEMs were at one time forced to provide charging equipment with their vehicles because plug-in charging standards were not yet established. This method stuck, and since then, this OEM perceives that customers are looking to ZEB OEMs to also provide fueling equipment. While some ZEB OEMs have incorporated proprietary charging/fueling infrastructure into their business lines, others have taken the route of offering access to and interoperability with a wide variety of fueling/charging infrastructure manufacturers. Regardless of these business model differences, most ZEB OEMs expressed an awareness of the challenges of making the infrastructure components of ZEB deployments fully "turnkey".

Process considerations for successful procurement and contracting

Most ZEB OEMs did not see major opportunities to assume key ZEB performance risks at this stage of technology maturity. OEMs agreed that one of the most commonly cited ZEB performance risks is the risk that vehicles cannot achieve the intended range (i.e., maximum distance driven before refueling/charging). One OEM mentioned that they felt that some OEMs had "promised a lot" in terms of range and performance, and that this dynamic had contributed to operator uncertainty



and dissatisfaction. ZEB OEMs uniformly said that they were not willing or able to guarantee vehicle range, although they understood the importance of this factor to transit operators. In their view, vehicle range is a complex phenomenon driven by a large number of factors, including driver behavior, weather, terrain, and made more unpredictable by the fact that these vehicles do not have an extensive performance history to compare against. Two OEMs specifically mentioned that performance is also determined by the parts, notably batteries, that ZEB OEMs get from their suppliers. Battery range is affected not only by the above factors, but also by how they are discharged and recharged, which can differ by battery chemistry. OEMs see these risks as particularly difficult to manage because the battery market is more volatile and not all suppliers are highly stable. In this context, OEMs do not feel that they would be able to efficiently absorb performance risk for ZEBs.¹

Most ZEB OEMs dismissed the ability to better manage technological change through improved risk allocation and contracting. Most firms felt that it is difficult to manage technological risk specifically, the risk that available technology will change so meaningfully enough that a bus's technology is very outdated or in the worst-case scenario, obsolete – during a single life cycle. One frequently-mentioned option to manage these risks was a very simple one: to simply use a bus until the end of its lifecycle, even if technology has changed or improved, and adjust to newer technology when replacing the bus at the end of its lifecycle. Referencing a previous insight – the lack of standardization in battery packs – the same OEM noted that even if a new battery design or chemistry became available, it wouldn't necessarily be simple to "swap in" the new version. The severity of these risks was tempered by the fact that no OEMs mentioned any obvious or extremely disruptive changes that they see on the horizon (such as a new technology that would make all others obsolete). Although ZEB OEMs acknowledge the risk that ZEB technology is still evolving and that ZEB technology has advanced considerably over the last decade, multiple OEMs noted that the transit sector is unlikely to be the driver behind major technological innovation simply due to the sector's small size (which one OEM noted was 4% of the size of the truck sector). Given that innovations will take a number of years to filter out through manufacturers and through the required testing before they reach operators, they thought it is unlikely that a disruptive change will happen "overnight."

ZEB OEMs were neutral on participating in statewide contracts, and did not see them as a powerful tool to accelerate the ZEB transition. All ZEB OEMs acknowledged the potential benefits of statewide contracts, such as reducing costs and friction for purchasing buses, and providing a potential mechanism to increase standardization. However, several OEMs mentioned potential drawbacks. First, all OEMs were aware of the "competition" between different statewide contracts (particularly those from Washington, Virginia, California Department of General Services (DGS) and CALACT). When considering these very similar contracts, interviewees did not necessarily see the value in being on all relevant contracts if their customers can access them through at least one. In other words, OEMs do not feel highly incentivized to negotiate or make concessions on one statewide contract if they can still access the market through another similar contract. OEMs also mentioned the costs associated with joining some contracts, the pass-

¹ We note that this may be problematic for some forms of performance-based contracting, particularly those involving equity and infrastructure investors. Typically in those arrangements, the equity investors pass performance risk on to the project participants who are responsible for delivering performance, who, in turn often rely on OEM warranties and performance guarantees. Until performance becomes more predictable, such risk transfer may be sub-optimal.



through of certain liabilities in the contract (although no further details were offered), and the perceived bureaucracy or difficulty of negotiating with different organizations as factors they considered when participating in a particular statewide contract. Finally, multiple OEMs emphasized the close relationships they have with their existing customers. These companies felt that they already have strong access to the transit market, have a clear view of demand from their customers, and would want to retain direct access to their customers. One area that most OEMs mentioned for potential improvement in statewide contracts was the level of customization allowed for transit buses, as discussed earlier in this section. One OEM specifically mentioned that the potential cost benefits of higher volumes via statewide contracts was mitigated because of the nearly unlimited options still available on these contracts. Several OEMs also offered relevant insights related to the market structure and competitiveness for OEMs, with some characterizing an effective "duopoly" between the two largest players in the full-size transit bus market. Though some referenced potential changes in this market landscape in the near future, they did not characterize the market as fiercely competitive. Instead, most OEMs currently have a relatively well-established niche with perceived customer loyalty. These competitive dynamics are key to consider in the potential impacts of a statewide contract or other market-oriented intervention. Collectively, these factors do not necessarily mean that statewide contracts cannot be improved or continued to be used effectively, but this sector did not see obvious actions that they would advocate for.

State role and potential interventions

ZEB OEMs view the central ZEB transition challenge as infrastructure, not vehicles. Multiple OEMs felt strongly that California's key focus should be on accelerating and supporting the buildout of charging/fueling infrastructure, not solely on deploying vehicles. At least one OEM said that they would like to see California's state agencies be more proactive in helping with infrastructure deployment, particularly offering more "handholding" in addition to funding. One OEM specifically mentioned the challenge of working with utilities and getting sufficient power for their infrastructure projects as a key hurdle to infrastructure deployment. Some ZEB OEMs mentioned the risks that they saw in transit operators making suboptimal decisions related to infrastructure, particularly in the sizing and phasing of infrastructure investments as operators gradually transition their fleets. Multiple interviewees also mentioned an observed relative abundance of available funding for ZEB transitions at the moment driven by both state and federal policy; some were concerned about what the business case and transition will look like when this funding begins to phase out. As one ZEB OEM stated, "what we don't want is for buses to go out without the ability to charge them"; in this way, this sector has a clear interest in accelerating and facilitating infrastructure investments that will complement their vehicles.

Most ZEB OEMs acknowledged needs for improvement in ZEB-related training. Some OEMs described the extent to which the training landscape is currently a patchwork of training offered by ZEB OEMs, component OEMs, and other stakeholders. Not all ZEB OEMs have their own training departments, but one OEM stated that each has their own training program, which may not always align with operators' needs. One firm observed a variation between different Caltrans regions in terms of the level of knowledge and accessibility to operators; while some regional representatives are excellent, others were perceived to be hard to reach and offering less support. Key opportunities for training improvements across OEMs include improved driver training to operate buses more efficiently and how to charge BEBs most efficiently and avoid batter



degradation. Various interviewees emphasized the potential state role in ensuring that transit operators are equipped to assess vendors' claims and form realistic expectations for performance.

ZEB OEMs saw room for improvement on the structure of funding for ZEB transitions. One key area of agreement between interviewees was the recommendation that California should reduce barriers that prevent small transit operators from accessing grants by moving away from competitive grant programs towards formula funding. This is particularly relevant for funding for consulting, planning, and other technical or professional assistance that operators may not have in-house. Consistent with the insights offered above about the importance of infrastructure, multiple OEMs mentioned a need for greater infrastructure funding (which, according to one firm, could include optimizing use of California's unused land to accelerate development of infrastructure in strategic locations). However, one company mentioned the concern that funding can pull in new market entrants if there are relatively low barriers to entry, particularly for software-related products for charging and fueling infrastructure, which can lead to "churn" in the market (i.e., frequent changes in which vendors are active in selling to transit operators).

Sector Conclusions

ZEB OEMs were generally open to a variety of potential options to accelerate transit's ZEB transition. These companies expressed some flexibility in terms of investigating a more optimal bundle for ZEB deployment components, openness to mechanisms like statewide contracts, and potential interest in participating in a team for bundled ("turnkey") ZEB contracts. Notably, ZEB OEMs acknowledged that reducing customization in buses could result in long-term savings, but that current manufacturing processes are not designed to realize those benefits. In addition, these companies recognize the challenge of better managing technology and performance-related risks. While these interviews did not clearly indicate an obvious choice for promising demonstration projects or concepts directly centered around ZEB OEMs, this sector expressed some openness to participating in new ways of doing business that will help their customers. In addition, the insights summarized in this section may prove useful to public sector stakeholders in other policy and programmatic decisions, such as the structure of statewide contracts in California.

The key areas of consensus for this sector that could act as "building blocks" for a market-informed demonstration concept are included below:







5.2 BEB Fueling Infrastructure Providers

The market sounding included interviews with six different BEB fueling infrastructure developers, manufacturers, and solution providers. These conversations illuminated the market perspective on how transit operators might optimize their BEB fueling infrastructure deployments, the pros and cons of different structures for procurement and contracting, the services that BEB fueling infrastructure providers are interested in offering, and the ideal role for California in accelerating the ZEB transition.

Features of an optimal BEB fueling infrastructure deployment

BEB fueling infrastructure providers did not see a major need for further standardization of their products. While interviewees supported open standards, open architecture, and interoperability, some companies felt that a push to create a "standard" specification for BEB fueling equipment would hasten commoditization of their product, making it harder for companies to create and maintain a competitive advantage. Companies also felt that interoperability was not a significant barrier for transit operators, with most using either the Combined Charging System (CCS) connector to charge vehicles, which is used for direct current fast charging (DCFC) in the light duty electric vehicle (EV) space, or the SAE J3105 standard for pantograph charging systems. In addition, the recent adoption of SAE J3400 (NACS) may settle the charging connector standards over time into one technology. The open-source Open Charge Point Protocol (OCPP), which is software that communicates between the charger and the charging manager and is used predominantly in the light duty EV space, is also leveraged in the heavy-duty sector to help transit operators manage their BEB fueling assets across a network and across different vendors and models.



Companies felt that requests for technology customization were not a significant overall cost driver for BEB fueling infrastructure. In addition, companies expressed reservations about the ability to standardize station design, engineering, and installation, which are typically more significant costs than the purchase of BEB charger hardware and software. Interviewees expressed that trying to force a certain BEB fueling infrastructure station design on a transit operator may result in operational inefficiencies. Operators have very different constraints regarding physical footprint, power availability, and charging schedules; these and other considerations must be factored into the BEB fueling infrastructure project. Companies supported a more collaborative and systematic approach to reviewing transit operators' BEB fueling infrastructure design plans early on to better manage key risks and identify potential optimizations.

BEB fueling infrastructure providers saw limited applications for infrastructure sharing across multiple users. The general consensus among interviewees was that transit operators would not want any shared charging arrangement that had the potential to compromise daily operations. This means that most operators would be unlikely to agree to a partnership with a non-transit user of BEB fueling infrastructure on their own yard. However, some transit operators are maintaining optionality by moving away from pantograph charging (a technology which precludes the ability to share infrastructure with all but a very small subset of other users). Most companies did not recommend that transit operators include "over-the-fence" commercial retail sales of charging services in their deployments, in part since BEB charging typically requires co-locating chargers with parking space. They said "over-the-fence" sales would be more feasible, although still challenging, for hydrogen fuel. For both technologies, interviewees expressed the view that demand for "over-the-fence" fueling is highly uncertain and cannot currently meaningfully contribute to the business case.

Interviewees identified a number of specific challenges with shared infrastructure. First, in these companies' experience, most other fleets would prefer to build or control their own charging facilities and likely would not want to share equipment with another fleet except potentially as a temporary bridge solution. Furthermore, most other fleets are likely to have similar operational schedules as transit, discharging batteries during the day and charging them at night. This means that most potential fleet partners would "compete" with transit for access to charging, rather than efficiently using the facilities when transit demand is low. Geographic location is also critical for successfully sharing infrastructure between multiple fleets – for example, sharing with a freight operator would require charging facilities to be efficiently located near key freight corridors and delivery routes. When comparing the relative feasibility of sharing infrastructure with different users, companies saw the most potential for transit sharing with school buses and refuse trucks, followed by other municipal or public fleets. They were more skeptical of class 8 or other freight vehicles, and highly skeptical of sharing with the general public for light duty EV charging. Companies also mentioned that having multiple users on a charging site may result in a more expensive service level agreement (SLA) due to greater risk of accidents and other O&M issues, which may partially offset the benefit of sharing fixed costs of the infrastructure.

BEB fueling infrastructure providers believe that transit may be able to use commercial fueling facilities in some instances. Instead of inviting other commercial users to charge at their sites, transit operators could potentially take advantage of commercial BEB fueling infrastructure. Again, location is the critical factor since commercial fueling will tend to be within a mile or two of major highways. Transit operators may not have such a location near their current operations



and the operational tradeoff of driving longer distances to fuel at a commercial charging site is unlikely to be worthwhile. However, since transit is an early adopter of ZEBs, they may be able to influence where some commercial stations are located by acting as a strategic "anchor customer". Some BEB fueling infrastructure developers are creating business models that allow for any charging customer to purchase dedicated access to chargers on a commercial site with multiple users. One company estimated that such a fueling solution could lower the lifecycle costs for a transit operator between 40-80% when compared with the traditional model of an operator designing, building, and owning all BEB fueling components on its own site. Furthermore, because of the commercial benefits of certain demand, a transit operator is likely to get more attractive pricing for (dedicated) access to commercial fueling if it agrees to exclusivity or a minimum usage guarantee.

BEB fueling infrastructure providers brought up "opportunity charging" as a potentially promising demonstration project. Opportunity charging (also known as "on-route charging") allows transit operators to fuel ZEBs "opportunistically" away from the depot, and are often placed at the endpoint of routes. Some interviewees believed that opportunity charging could be more conducive to infrastructure sharing arrangements, in part because it would help avoid some of the challenges cited regarding shared access to an operator's depot. Transit operators could make use of opportunity charging at the endpoint of longer routes to provide the batteries a boost for the return trip. This use case is most prevalent because stopping mid-route, even for just a few minutes, is operationally inefficient and creates a poor user experience for the passenger. Opportunity charging can enable BEBs to meet longer duty cycles where otherwise FCEBs or ICE vehicles could be the only technologies capable of reliably completing the route and return trip. Companies generally saw opportunity charging as underutilized in the transit space. They also commented on the potential for transit operators to share opportunity chargers with other fleets, such as freight and delivery vehicles or rideshare drivers, to increase utilization of the infrastructure and thereby improve the business case for the project.

Structuring a BEB fueling infrastructure contract and procurement process

BEB fueling infrastructure providers felt that current procurement processes do not adequately fit the technology. Generally, companies felt that transit operators have procured ZEBs and associated infrastructure in the same way as they have always procured other vehicles, missing opportunities to address the unique characteristics of the asset class. For example, low-bid procurement processes are not well-suited to a vendor selection process for BEB fueling infrastructure where unique deployment considerations cannot be directly compared. Instead, companies encouraged transit operators to move to "best value" procurements that allow for a more nuanced comparison. For example, one interviewee noted the fact that some proposed direct-current fast charging (DCFC) solutions may require costly upgrades to utility transmission and distribution infrastructure, whereas others may include components that prevent such upgrades from being necessary. In some procurements, these factors were considered in the evaluation criteria. BEB fueling vendors also supported the idea of more collaborative procurement processes, such as Project Development Agreements (PDAs), to enable flexibility around the "bespoke" elements of infrastructure design. Companies see an educational opportunity for California to potentially play a role in assisting transit operators with their procurement decisions to reach better outcomes.



BEB fueling infrastructure providers offer a spectrum of bundled services with BEB equipment. Most BEB fueling infrastructure providers are flexible in terms of the services they can offer to a transit customer. All interviewees mentioned they offer basic services around startup, commissioning, and training in connection with provisioning of BEB fueling equipment. However, many companies prefer to keep installation – which they view as highly site- and project-specific – unbundled from the core scope. Companies also prefer that most operations and maintenance activities be kept separate from equipment provisioning, although the bundling of some maintenance services with equipment is common. For software, such as charge management software, the level of bundling is highly dependent on the BEB fueling company's business model. Although there was consensus that charge management and other software solutions can be impactful in enhancing efficiency and reducing costs, interviewees had notable differences of opinion in terms of the ideal level of hardware/software integration. Some companies prefer to market and sell an integrated hardware/software solution, whereas others prefer to make software an add-on option and produce hardware compatible with multiple software solutions. Firms without integrated solutions make an argument that bundled solutions promote vendor lock-in, whereas those with integrated solutions point to potential benefits such as guaranteed interoperability and performance as a counterargument. Companies agreed that transit operators often under-specify their needs with regards to software, including the need for ongoing service and software updates, which can significantly impact operations if not managed properly. Interviewees also generally preferred for BEBs and fueling infrastructure to be purchased separately, although active measures need to be taken to ensure interoperability, such as the requirement for interoperability testing. For some BEB fueling infrastructure companies, strategic partnerships with ZEB OEMs have been beneficial whereas others cite poor experiences selling equipment through vehicle manufacturers. Companies noted that vehicles and infrastructure are often on different manufacturing and delivery timelines, with infrastructure taking significantly longer to commission, which also complicates the implementation of a bundled procurement.

BEB fueling infrastructure providers like the idea of bundled transactions across multiple stations. Generally, interviewees looked favorably on the idea of multiple transit operators' stations being bundled into one transaction, although there was a range of opinions about the "sweet spot" regarding the number and makeup of agencies in the bundle and the ideal capital investment amount. Although multiple companies advocated for more coordination between agencies purchasing as a group, there were also concerns about the additional governance complexities of managing such a deployment. Some agencies cited 10-25 agencies and ~150 charge points as an attractive deal size, and also liked the idea of including some medium or larger agencies in the group along with small and rural agencies. One company mentioned that a smaller group could develop the procurement and let others piggyback off the contract.

BEB fueling infrastructure providers were neutral on the use of statewide contracts. Although interviewees mentioned that they would carefully consider participating in any statewide procurements for BEB fueling infrastructure, they cited several challenges and arguments why the positive impacts of statewide contracts are limited for this technology. The main benefit of a statewide contract is avoiding the resource-intensive nature of individual operator procurements, although vendors say that the red tape, paperwork, and inflexible nature of the terms and conditions can make statewide procurements equally unattractive. For example, most companies cited negative views and/or experience with the Government Services Administration (GSA) technology purchasing schedules, which is in some ways similar to the hypothetical state



purchasing schedule that was discussed in the interviews. In addition, companies expressed that maintaining updated product lists and committed pricing and lead times for technology can be challenging due to external supply factors. Furthermore, vendors' ability to provide volume discounts for larger orders is minimized by the lack of any minimum volume commitment or guarantee on these contracts. Companies claimed that the wraparound support that many transit operators need in order to deploy a project successfully is not easily solicited as a standard statewide contract. Relatively simple services like design and installation are hard to standardize in a scope of work, and alternative contracting approaches such as "Charging as a Service" (CaaS) are even more complicated to procure.

BEB fueling infrastructure providers expressed some openness to performance-based contracting. Companies acknowledged that fueling infrastructure performance and uptime is critically important for transit operators. Even just one charging port going out of service for an extended period of time could significantly reduce a fleet's capacity and impact an operator's service. As such, savvy transit operators understandably look for vendors to stand behind the performance of their products through service level agreements (SLAs), or through maintenance packages that include key performance indicators (KPIs) with financial penalties for failure to meet a certain level of service. BEB fueling infrastructure providers say that SLAs that guarantee response times for non-performing equipment are growing in popularity. As one example, an interviewee offered that many agencies that did not secure SLAs for initial pilots are now asking for them as they scale up. Still, such performance-based contracting elements are not standardized and are not always easily affordable or accessible for operators.

Services that BEB fueling infrastructure providers are interested in delivering

Some BEB fueling infrastructure providers are interested in offering "Charging-as-a-Service" (CaaS) models. In a CaaS model, a single company would be responsible for design, engineering, construction, operations, and maintenance of a BEB fueling facility. Unlike traditional project delivery, which is the status quo today, BEB fueling infrastructure providers have a strong incentive to ensure that operations are efficient and lifecycle costs are managed optimally. Some providers offer CaaS as an option today, whereas some others are not interested in owning, operating, and maintaining the BEB fueling equipment that they sell. Some interviewees expressed that they would potentially offer turnkey CaaS contracts but would not want to take on real estate risk or responsibility for the siting of the BEB fueling infrastructure. For transit operators, the ability to transfer performance and interface risk more fully to a single company may be an attractive proposition given the relative nascency of the technology and the potential for reliability issues. Companies estimate that the approximate cost, or "premium" that a transit operator would pay for this turnkey contract with more robust risk transfer is anywhere from 10-25% above the traditional model in which the transit operator retains more risk. Contract length for a CaaS deal is important in order to allow providers to be able to amortize the cost of building a facility; one interviewee suggested that such a contract would have to be significantly longer than five years.

BEB fueling infrastructure providers foresee moderate technology changes on the horizon and can play a limited role helping transit operators manage technological risk. Interviewees shared their doubts about any hugely disruptive technology change affecting this market in the next decade and generally felt that most transit routes can be managed with today's technology. Accordingly, most firms said that they are able to absorb some of the technology risk for a single lifecycle of a



unit of BEB fueling equipment (~10 years). However, they are not willing or able to take on that risk over a longer period of time, as improvements and changes in the technology over multiple decades could lead to substantially different pricing. Firms felt that agencies need to understand that technology replacement will likely need to be factored in, but these changes are not priceable today. Companies opined that the industry is unlikely to see changes in major components such as connectors (CCS or NACS) and that battery size and vehicles are likely to change faster than charging equipment. Although the megawatt charging standard is currently in development, it remains to be seen whether this will be applicable to the public transit context. Software may be evolving faster than hardware, so it will be important for transit operators to ensure that their procurement and contracting allows them to adapt to these changes. For example, one company highlighted that last year the SAE J3105 standard for pantograph charging released an update to allow for sequential charging of multiple vehicles, but this is not compliant with the OCPP reporting requirements, which may mean that operators still need one charger per bus instead of realizing cost savings with sequential charging. Against this backdrop, BEB fueling infrastructure providers are actively looking to come up with more modular systems that allow components to be swapped in and out easily, which would provide some "futureproofing" protection against stranded assets resulting from major technology change.

Opportunities for state support in BEB fueling infrastructure deployment

BEB fueling infrastructure providers highlighted several constructive roles for California state agencies to play in order to advance deployment:

- Coordination of P3-style transaction: While interviewees provided mixed reactions to this idea, they generally suggested that California could play a role as a facilitator and convenor of transit operators to make a P3-style deal possible. This could involve helping to make technical and procurement expertise available, aggregating funding sources, or providing other technical assistance or policy support. One interviewee mentioned that a financing product based on operating expenditure savings or another innovative financing method, could help create a payment stream for the project. Some companies said that ultimately transit operations, whereas other companies said that they also didn't think transit operators should be operating charging stations themselves.
- Optimizing BEB fueling deployments: Simply put, firms stated that transit operators need more support in determining what to build. Procurement of chargers, one interviewee said, is often being driven by vendors and not always based on the best interests of the transit customer. They noted a drive towards bigger, faster chargers but that this may not always be the optimal choice for transit operators in terms of cost or the ability to secure enough (affordable) access to power for the site. Due to a lack of experience, small transit operators without expertise in ZEB fueling or budgets for extensive planning often need to do an RFP for design and consulting services to determine what to build. California could help such agencies by making high-quality planning expertise more readily accessible early on in the process. California could also assist with best practices around helping operators navigate key tradeoffs between upfront cost and ongoing performance and scoping projects to allow for gradual deployment and growth over time.



- Supporting utility coordination: BEB fueling infrastructure providers see provision of electricity for charging as a major challenge for the ZEB transition. There is a broad concern among market participants that California's ambitious zero-emission goals across sectors could lead to stakeholder competition for a shrinking pie of limited electrons without adequate long-term planning. Companies feel that utilities could and should do more to support BEB fueling infrastructure projects. Interviewees perceived a poor track record of utility involvement in BEB fueling deployments and stated that new coordination models are needed.
- Coordinating short- and long-term transit planning: Interviewees mentioned that California could help transit operators do more learning from their peers and less testing of technology on their own. Particularly the small and rural operators need substantial help understanding the nuances of ZEB, and particularly BEB, fueling operations. In addition, companies hear from operators that they are uncertain about the funding landscape, how to project future operating costs (including the cost of fuel/electricity), and what financing options might be available to them. BEB fueling providers feel that California's technology neutrality is a challenge since it allows transit operators to "waffle" and wait for more information about the hydrogen market which they view as currently uncompetitive in terms of the underlying economics but supported by federal and state policy before making investment decisions. One company suggested that California needs to do more, in general, to get all the relevant public actors together to get stakeholders to "play nice" and start acting in a more concerted manner to advance the zero-emission transition statewide.
- Providing more funding flexibility and credit support: Although this problem is not unique to ZEBs, vendors and transit operators alike wish for more flexibility tied to federal and state transit funding sources, particularly to mix and match capital and operating dollars. Companies said that many grant programs tie BEB fueling infrastructure to buses, but that breaking this connection would increase operators' flexibility to best serve their needs. In addition, operators often have a hard time using grant funds to purchase SLAs, since they do not necessarily like to capitalize the cost of the SLA and include it in the equipment purchase price. One company said that operators should be allowed to purchase BEB fueling services with the same sources of funding used today to purchase diesel fuel, even if the method of obtaining the fuel is entirely different. Generally, companies say that operators should be sufficiently well-funded to implement strategies that make sense long term for operators, rather than being backed into suboptimal solutions out of necessity. Some companies suggested that for some projects involving financed components, California could play a role to lower the operator's credit risk and thereby reduce the total cost of financing for the project.

Sector conclusions

BEB fueling infrastructure providers saw the potential for innovative business models to accelerate ZEB deployments but point to several structural barriers that may still stand in the way in terms of funding, policy, transit operator expertise and other issues. While BEB fueling infrastructure providers were skeptical of the practicality of transit operators sharing their infrastructure with other users – particularly for light-duty retail charging – there are some applications that were seen as



less risky and operationally possible, such as sharing with other public fleets (school buses, refuse trucks, municipal vehicles, etc.). They also saw a potential for shared opportunity (on-route) charging which they recognized as being currently underutilized. BEB fueling infrastructure providers looked favorably upon the idea of procurements in which multiple transit operators would bundle their stations together into one transaction. Companies in this sector saw various opportunities to modernize procurement and contracting to better align with the characteristics of the sector and help transit operators optimize lifecycle costs and achieve better value for money. They did not think that transit operators are necessarily best positioned to be operating BEB fueling facilities at this point, and that more should be done to educate transit operators on how optimize procurements, including the cost impacts of key project scoping choices. Although some firms were open to participating in CaaS/P3-style delivery models, they did not necessarily want to lead a P3 consortium.

The key areas of consensus for this sector that could act as "building blocks" for a marketinformed demonstration concept are included below:

Figure 4. "Building Blocks" Suggested by BEB Fueling Providers





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5.3 FCEB Fueling Infrastructure Providers

The market sounding included interviews with four different FCEB fueling infrastructure developers, manufacturers, and solution providers. The section below summarizes the main findings from the interviews and presents conclusions on how FCEB fueling infrastructure providers view potential demonstration project concepts.

Features of an optimal FCEB fueling infrastructure deployment

FCEB fueling infrastructure providers generally supported a greater degree of standardization. Multiple FCEB infrastructure providers shared that a primary cost driver of developing hydrogen refueling stations is the unique and bespoke nature of each project as they are currently procured. As such, they see significant opportunities to enhance cost savings and efficiency through pre-fabrication and standardization. Firms generally agreed that to make these projects more cost-effective, equipment should be pre-fabricated as much as possible to minimize on-site work. One company estimated that this pre-fabrication alone could generate cost savings in the 10-20% range. This same company claimed that approximately 80% of a station design can be standardized, even for different sizes of stations, with the other 20% remaining site-specific based on footprint, permitting needs, and other factors.

Some interviewees believed that a standard specification could be developed for a liquid hydrogen refueling station that meets all basic operational requirements, and some are actively working on developing such a standard specification. The FCEB infrastructure providers said that a more standardized design for refueling stations would not just create capital savings, but also operating savings due to the ability to create efficiencies and economies of scale. These economies of scale would be related to spare parts, as well as labor associated with training service technicians on fewer, more repeatable processes. One provider claimed that, in order for this standardization to happen, transit operators (and their consultants) would need to start asking for standard specifications and not over-specifying design details. Despite maturation of the industry that has led to experts coalescing further around certain scope and design choices (e.g., liquid rather than gaseous hydrogen solutions), there is still a long road ahead to meaningful standardization in this space. In addition to the practical challenges of standardization, not all interviewees agreed about the commercial feasibility of standardization for their business models. For FCEB fueling infrastructure providers who produce and deploy proprietary technology as a core part of their solution, standardization (e.g., "right-sizing" the size of infrastructure for operational needs, requesting standard fueling speeds, coalescing around liquid rather than gaseous hydrogen, etc.) and interoperability (particularly between different hydrogen delivery tankers and on-site liquid hydrogen storage) pose a challenge to their ability to operate as they do now. The different business models prevalent in the sector will be an important factor in individual private entities' interest in participating in a demonstration project or intervention that incorporates standardization and interoperability.

FCEB fueling infrastructure providers were mixed on the idea of infrastructure sharing at a transit operator depot. Some providers conveyed cautious optimism about the idea of "over-the-fence" commercial sales but emphasized that the key consideration for the business case of any particular project is location. This is because location will determine the potential future demand and refueling use case for any non-transits user that could share the infrastructure (e.g., light-duty vehicles, refuse and freight trucks, etc.). One company said that a station that could viably serve



different types of users adjacent to a transit station would be an "ideal project" and could allow transit operators to offset costs and achieve better pricing on fuel deliveries through greater scale. Similarly, another company mentioned that retail demand could potentially "smooth out lumpy transit demand" to help transit operators more efficiently scale infrastructure as they convert their fleets to FCEBs over time. An additional benefit of shared infrastructure, one provider said, is that adding additional infrastructure to accommodate light duty vehicles may only add a marginal amount of additional capital expenditure to a FCEB refueling station. Some of the issues related to shared infrastructure that interviewees raised, apart from location, were the operational complexities around storing and dispensing hydrogen fuel at different pressures (transit buses fuel at 350 bar, whereas light duty vehicles and many medium and heavy duty vehicles fuel at 700 bar), creating the appropriate physical separation between different types of users at the site, and other logistical challenges that could add costs and delays to a project.

FCEB fueling infrastructure providers saw strong potential for transit operators to use commercial or retail fueling stations under the right conditions. When evaluating the potential for transit operators to use commercial or retail fueling stations, location is still key, companies said, since most transit operators want to minimize "deadhead" miles (i.e., non-revenue operations) as much as possible. Interviewees once again noted the operational complexities associated with mixing transit with other fleets, which include fueling protocols, fueling pressure, fueling interface, and ingress/egress into the station. However, companies suggested that the concept of transit operators using commercial or retail fueling stations was more feasible for hydrogen refueling than battery recharging. If transit operators can make the location work, their participation has strong potential to improve the economics of a station by providing consistent refueling demand. Some companies believe that existing truck stops are natural locations for commercial or retail fueling stations. However, given the space constraints at existing truck stops, many stations may need to be greenfield projects although it is important to note that space constraints, especially in urban centers, will make this strategy difficult in many areas. Some companies said that they are cautiously taking the strategy of building multimodal commercial stations with a "build it and they will come" approach, as they cannot predict how demand will evolve but are generally optimistic about the future of these stations.

FCEB fueling infrastructure providers strongly cautioned against onsite production of hydrogen. The firms agreed that transit operators, particularly small and mid-sized operators, do not have sufficient knowledge to run a hydrogen production facility well and typically do not have an efficient scale for onsite production. Multiple FCEB fueling infrastructure providers said that it is completely reasonable and economical for transit operators to source fuel from hydrogen produced at larger facilities, even if those facilities are located across state lines. Producing affordable hydrogen fuel that is "green" enough to meet California's standard for hydrogen renewable energy content (33%) requires access to low-cost renewable energy, they said, and hydrogen fuel suppliers are often able to efficiently truck liquid hydrogen fuel long distances at a lower total cost than producing the hydrogen in California closer to the end user. This model resembles the current distribution model for diesel fuel, which has proven very effective and reliable. However, it is important to note that the distribution of hydrogen production facilities is currently quite limited, and the cost of long-distance transportation may still be an important factor for transit operators, particularly those in remote or hard-to-access locations.

Structuring a FCEB fueling infrastructure contract and procurement process



FCEB fueling infrastructure providers felt that transit operators' current procurement approach is too rigid for this technology. Interviewees expressed a perception that transit operators' lack of ability to collaborate with vendors during procurement is leading to operators "building the wrong thing", and that transit operators should consider more collaborative procurement strategies. Multiple firms suggested that transit operators tend to assume hydrogen refueling infrastructure can be procured in a manner similar to other assets they buy by just tweaking small components of the RFPs they already use, rather than sufficiently considering more substantial changes to the way procurement rules and requirements should apply for new technology. Some firms felt strongly that transit operators should focus more on output-based performance specifications and let the FCEB fueling infrastructure providers use pre-certified and pre-tested products out of their factories, rather than creating bespoke designs and design-bid-build processes with "faulty" specifications. Some firms also mentioned procurement terms and conditions that are problematic for vendors to accept. One such example is "termination for convenience" provisions that are flowed down from required FTA clauses that must be included in contracts for operators using federal funding, which most operators rely on.

FCEB fueling infrastructure providers had mixed responses to the concept of bundling fueling equipment with related services and fuel supply. Companies mentioned that the status quo in the transit market is that the design/build of stations, operations/maintenance, and fuel supply are structured as three separate contracts. In relation to the first of these categories, interviewees expressed mixed opinions driven by their business model and what they see as their competitive advantage in the market. Some companies would prefer for design and build services to be integrated with the sale of their products, whereas others don't want to "waste time" building stations, instead focusing on their core business of selling technology and equipment.

For operations and maintenance contracting, most FCEB fueling infrastructure providers expressed strong support for bundling some level of operations and maintenance services with fueling equipment. This preference was driven by the perception that most smaller transit operators lack the experience and resources to optimally operate and maintain the companies' equipment, and that the providers could do so more efficiently and effectively themselves. However, some interviewees stated that as the market matures, transit operators' capacity could grow and operators would then be better positioned to take on responsibility for these activities. Critically, for a subset of infrastructure providers, selling a bundled package of equipment plus services is not only a preference, but a requirement. The reason behind this requirement is, once again, protection of these firms' proprietary technology, since they are not prepared to share the necessary competitively sensitive information about their technology that would be required to operate and maintain it.

Regarding the bundling of hydrogen fuel with fueling equipment, fewer interviewees expressed strong opinions. While the same companies that require customers to utilize the firm's services due to proprietary technology may require customers to purchase hydrogen fuel through them, others are more open to unbundled fuel contracts as a means to ensure healthy competition.

FCEB fueling infrastructure providers supported project bundling (i.e., including multiple transit operators' projects in one transaction) as a useful way to create scale. Companies focused on the fact that scale makes an important difference in terms of their ability to dedicate staff resources and to be able to supply and service remote regions. Some interviewees acknowledged



FCEB fueling infrastructure providers saw benefits and drawbacks to using statewide contracts. The main benefit that firms identified was that statewide contracts are a vehicle to contract more efficiently and achieve greater scale, even if their companies need to jump through bureaucratic hoops to do it. However, they cited a concern about the challenges of standardizing site-specific design and installation activities in a statewide contract structure. One firm mentioned that this was particularly important for retrofitting existing facilities compared to building greenfield stations. Another firm mentioned that optimizing the distance between fuel storage and dispensing matters, so the statewide contract should account for a non-standard layout of the site due to the differences between transit properties and related space constraints.

FCEB fueling infrastructure providers suggested that transit operators move towards longer-term take-or-pay fuel contracts. Firms mentioned that transit operators currently tend to prefer short-term (i.e., 3-5 years or less) fixed-price contracts for fuel without indexation or any volume commitment, which is leading to higher quoted prices for fuel supply. At the current stage of market development, with low offtake, longer-term contracts that include volume commitments (e.g., through a take-or-pay mechanism) are very attractive to FCEB fueling infrastructure providers/fuel suppliers and potentially create meaningful operating savings for transit operators, companies said. Some interviewees mentioned that for stations built with proprietary technology that can be exclusively supplied by that same company, there is a naturally built-in "long-term supply contract" if the user wants to continue using the station.

Services that FCEB fueling infrastructure providers are interested in delivering

Some FCEB fueling infrastructure providers were eager to offer "fueling-as-a-service" contracts. While some firms say they are ready to offer such a contracting structure today, they haven't seen significant interest in this model as of yet from transit operators. These firms said that they would also be able to offer some financing services as part of a turnkey contract (effectively allowing transit operators to pay for up-front capital expenses over time), which would be recovered as part of the per-kilogram price for hydrogen fuel. However, firms also noted that the relatively more complex nature of these agreements does create a cost in terms of the added time and resources needed for contracting and negotiation, even though some FCEB infrastructure providers are already familiar with this contracting structure. It is also important to note potential uncertainty about whether transit operators will be able to use existing (grant) funding sources to pay for fueling-as-a-service as opposed to more traditional capital projects to own and operate a fueling station.

FCEB fueling infrastructure providers expressed different preferences on asset ownership. Whereas some companies have a business model built around proprietary technology that relies on maintaining private ownership of the infrastructure, other firms stated that they do not have a desire to own the assets themselves because of the impact on their balance sheet.

Opportunities for state support in FCEB fueling infrastructure deployment

Some FCEB fueling infrastructure providers believed that California should tread carefully in facilitating P3-style transactions. While companies suggested that a P3-style delivery model may


create a useful pathway for transit operators to obtain this infrastructure, there was concern about California "getting in the middle" of these transactions.

FCEB fueling infrastructure providers thought that California state agencies can help educate transit operators to optimize deployments. Firms cited various reasons that transit operators may develop suboptimal projects. These challenges included a lack of education, an inability to collaborate with vendors, local politics, and misdirected advice from consultants. Some specific issues that interviewees cited included operators specifying non-standard fueling speeds, making suboptimal decisions regarding onsite production, developing suboptimal scale-up plans, overdoing resiliency and redundancy thereby increasing costs more than necessary, and generally not scoping the project optimally in terms of the number of pumps needed, the size of tanks, and other crucial design choices. One interviewee estimated that such decisions can increase project costs in the range of 20%, and California could do more to provide education or resources that would help operators avoid these additional costs.

FCEB fueling infrastructure providers want California to improve suitability and flexibility of funding programs for their products and services. The most commonly cited example in interviews was "color of money" issues restricting the use of capital funding sources for operations since transit operators are most constrained in their operating budget. Relatedly, many firms said that operators should be able to use capital funding sources to pay for fuel. A specific suggestion to address this issue cited by one firm was that California (or federal agencies) could allow some infrastructure capital grant funding dollars to be used for fueling cards to allow operators to fuel at commercial stations. Another company suggested that California should do more to reform the Low Carbon Fuel Standard (LCFS) program to make it helpful for both operators and vendors as a funding source for hydrogen refueling stations, including making credits more easily transferrable. They also suggested instituting an auto-adjustment mechanism for LCFS to protect against credit price volatility and avoid a lengthy rulemaking process when adjustments are inevitably needed. Finally, multiple companies advocated for a new operating subsidy for hydrogen fuel to bridge the gap in this transition from traditional fuels, which are currently significantly less expensive than hydrogen.

Sector conclusions

FCEB fueling infrastructure providers described the transit market for hydrogen refueling infrastructure as promising but still nascent, with many challenges for small operators in particular. These companies were optimistic about the potential for innovative partnerships between transit and non-transit users if siting and co-location challenges could be solved. They were also bullish on the ability of commercial hydrogen refueling stations to eventually be able to serve transit operators, even if this is not a likely scenario in the next five years. Interviewees generally saw a clear need and benefit for a market-informed standard for a basic station specification as a starting point to reduce costs. However, they acknowledged that this process may not be quick and that varying business models and competing value propositions within the sector pose a real barrier. While FCEB fueling infrastructure providers were open to fueling-as-a-service models, they didn't believe that transit operators currently see the benefits, and some were wary of California's role in facilitating these partnerships.



The key areas of consensus for this sector that could act as "building blocks" for a market-informed demonstration concept are included below:

Figure 5. "Building Blocks" Suggested by FCEB Fueling Providers





5.4 Investors

The market sounding included interviews with three major infrastructure investment firms. While the investor discussions began with the demonstration project concepts, two principal areas of discussion arose that applied to demonstration concepts. These were (1) correctly defining the optimal structure of a ZEB deployment project under different conditions and for different use cases, and (2) considerations for how to run a successful project development process, from procurement through contracting to implementation. In addition, the investors provided significant insight into the roles they anticipate playing in this sector and how they viewed commercial risks. The section below summarizes findings and presents overarching conclusions on how infrastructure investors viewed the demonstration project concepts.

Components of an optimal ZEB deployment project

All investors emphasized the crucial importance of reaching a commercially viable project scale, which can be accomplished by bundling small individual projects. For equity investors, a key consideration is whether the project scale and "equity ticket" (i.e., the equity investment on which the investor earns its financial return) are of a sufficient scale. According to interviewees, investors' minimum equity investment ranged from \$10-\$30M to be interested in a project, although one expressed that for strategic projects in certain sectors they have gone down to as low as a \$5M equity investment. However, these equity requirements do not equate to total project size or capital investment; once grants and leverage (debt) are taken into account, the needed project size to achieve a \$10M equity investment, for example, could be around \$100M+. One common way to achieve this scale – apart from pursuing projects with very large project sponsors – is to create a bundle of smaller projects which can be structured and contracted as a package. In this context, bundling might entail constructing ZEB fueling or charging infrastructure on multiple independent sites for multiple small or mid-sized transit operators. Investors recognized that some geographies or transit operators are likely to be more attractive investment opportunities, based on their creditworthiness and ability to work collaboratively with investors in a long-term relationship. However, the packaging of more and less attractive components is a familiar structure for most investors, who will examine the business case of a project overall. Investors did not express any reservations about delivering projects in multiple geographies, apart from considerations about operational efficiency. An additional downside mentioned by one investor to a large, bundled project is the need for appropriate expectations about delivery timelines, particularly with current lead times for key equipment (particularly vehicles and chips).

Investors expressed strong interest in lifecycle bundling for ZEB infrastructure projects. Investors expressed interest in ZEB deployment projects and other "fleet-oriented opportunities" with highly predictable demand in the green mobility sector, with at least one investor citing ZEBs as a near-term strategic focus for their firm. Interviewed investors uniformly expressed a preference for goods and services associated with ZEB infrastructure to be bundled throughout the project lifecycle, as visualized in Figure 2. However, investors were sensitive to the fact that not all transit operators would be interested in contracting out responsibility for certain tasks, such as elements of operations. In general, investors seemed relatively comfortable with assigning the operational responsibilities associated with scheduling and driving buses to external contractors but felt that contracting out bus and infrastructure maintenance would impact their ability to provide optimal value. This view reflects these interviewees' typical business models - i.e., long-term investment in



infrastructure projects with large capital requirements. At the same time, participants emphasized the potential benefits of lifecycle bundling to transit operators; specifically, improved management and allocation of project risks. The key project risks that investors commented on their ability to manage included the following:

- Interface risks: Investors stated a consistent belief that a bundled model would improve the management of interface risks, which exist during both the construction and operations phases of a deployment. Interface risks occur in the interactions between stakeholders, such as the risk of miscommunication or a messy "hand-off" between the partner designing a project and the partner constructing it. In this context, project interfaces are numerous, including between the planner, designer, builder/installer, operator, and maintainer. For example, the company installing a ZEB charger might misinterpret the planner's intent for the positioning of the charger, leading to delays in commissioning. In addition, compatibility issues between the software on ZEBs and charging infrastructure is another interface risk that must be managed in these deployments.
- **Performance risks**: Investors expressed confidence in their ability to manage performance risks and to develop mutually agreeable contractual provisions that transfer performance risk, given the central role that performance-based contracting plays in their core business model. In this case, managing performance risks might involve contractually committing to providing a certain level of service or availability to a transit operator, with penalties for non-compliance. One investor provided insights from an ongoing deployment outside the U.S. where they have successfully used key performance indicators (KPIs) related to fleet availability and the fleet's ability to travel on one battery charge for a certain distance. Despite the fact that performance is dependent on actual deployment conditions, they found that transferring this risk to the private sector was successful.
- Technology risks: Investors understood the importance of addressing technological risks in ZEB deployments, particularly for more "leading edge" technologies. In general, most investors are not looking for opportunities to pioneer the first implementation of a particular product. As one investor stated, they have often strived to be one or two steps behind the "bleeding edge" of technology. Investors generally perceived the technology risks of hydrogen to be higher than electric buses, largely based on the extent to which technologies had been extensively deployed and evaluated. In contrast to interface and performance risks, which investors were generally comfortable managing over a project's lifecycle, investors tended to endorse risk-sharing when it came to incorporating new technology. While they felt that some portion of these risks can be managed through technical expertise, knowledge, and optimized management, much of the risk is outside any individual organization's control. For example, if a significantly improved technology becomes available shortly after a project is completed, rendering the new project relatively inefficient near the beginning of its lifecycle, most investors feel the risk of changing or upgrading technologies should be shared (or, as some mentioned, transferred away from the private sector with a guaranteed minimum return on their investments). Some mentioned specific contractual



risk-sharing mechanisms that have been used in other contexts, while most focused on the general strategies of limiting bundled contracts to a single lifecycle. Investors would look to pass through as much of this risk as possible to "upstream" technology vendors who they say are better positioned with of-the-moment knowledge about their own industries and products. Investors also focused on the idea that the party responsible for project performance throughout its lifecycle should have the maximum appropriate flexibility to make decisions that let them effectively manage and adapt to change.

- **Real estate risk:** The investors interviewed were not interested in assuming the risk for siting projects, acquiring, or managing real estate for ZEB projects. However, they did feel that other entities such as real estate developers focused on acquiring, managing, and profiting from real property may have an interest in this responsibility. One investor made the comparison to the National Electric Vehicle Infrastructure (NEVI) program, where some states are requiring that developers buy real estate on identified corridors and take the risk of NEPA approval in order to participate; this company did not feel that it was wise to "make [ZEB fueling infrastructure deployment] a real estate issue".
- Utility coordination risk: Investors indicated that they could provide value in the area of utility coordination. One investor mentioned specific strategies that they saw promise in, such as allowing the private sector to lead capital investment for utility upgrades i.e., having a private entity more directly engaged with the buildout of electrical infrastructure and capacity, potentially shortening the wait time associated with a utility's queue for capital projects in order to expedite development. However, investors generally expressed a view that the barriers to successful coordination were not related to a lack of resources or a need to spend money to resolve the problem. Instead, they see a larger, systemic challenge to ZEB deployment due to utility-related constraints (both generation and distribution).

Investors expressed relatively neutral views on the concept of bundling fueling infrastructure and vehicles in a commercially viable project. For the most part, investors viewed the concept of bundling buses and infrastructure as a positive, both in terms of increasing the project size (and therefore, the required equity investment – a key positive factor for investors) and reducing interface risks between the parties responsible for the vehicles and the infrastructure that maintains and fuels them. However, investors did not necessarily view this type of bundling as a "must-have". While some cited successful project models that bundled buses and infrastructure – particularly outside of the U.S. context – others expressed the view that investor-arranged financing for ZEBs would be unlikely to be price-competitive or more efficient than financing arranged by other parties (such as ZEB OEMs). While other types of component bundling such as fuel and software were not discussed in detail, some investors did mention project precedents involving energy-related services (e.g., onsite solar and storage) in a positive light.

All investors noted the importance of a robust governance model for projects with multiple sponsors and stakeholders. While investors were optimistic about the idea of bundling multiple smaller projects in order to reach a commercially viable project scale, the elements of governance and coordination during the entire process will be critical to the feasibility of the project. In fact, the primary concern about bundling multiple projects across transit operators was the complexity involved with managing multiple partners with varying expectations, processes



and governance in one transaction. The large number of transit operators in California, each with their own governing board, is well known. Typically, investors are accustomed to bundled projects for only one public sector counterparty. Investors were particularly concerned with ensuring adequate and dependable commitments from project partners to avoid disruptive changes in project teams, negotiating partners, and project scope. Specifically, investors wanted to avoid a situation where transit operators might give a general expression of interest without any commitment and the project team would invest in further developing the project only to have a key participant withdraw suddenly. Furthermore, during later stages of project preparation, deployment, and operations, investors felt strongly that minimizing their exposure to the complex coordination of multiple stakeholders would reduce project risks and costs. Examples of these coordination challenges included balancing different stakeholders' requirements for key performance indicators; whether all project sponsors would have individual termination rights; monitoring and managing any changes in creditworthiness from multiple project sponsors; managing and adjudicating change order requests from multiple parties; and managing multiple counterparts during procurement and negotiation. One investor provided a positive example in the structure of a project in a major North American city in which one central counterpart successfully took effective responsibility for the behavior of smaller transit operators. This guarantee of responsibility (for example, that users will not over-use or damage infrastructure) gave significant comfort to the private partner in this case.

Investors were aware of both potential benefits and practical challenges to developing multi-user zero-emission fueling and charging infrastructure. For most investors, the concept of including users beyond transit operators (e.g., commercial and municipal fleets) in a potential project was viewed as another route to achieving the commercially viable project size and "equity ticket" they are seeking. In practical terms, they noted that additional users might underwrite or provide funding for a portion of the infrastructure's fixed cost, bringing down costs for any individual user and improving the project's business case. For example, one investor mentioned the possibility of a commercial long-haul partner that could underwrite a portion of the infrastructure on a large artery. From an operational point of view, they also saw the potential of other users to smooth otherwise "lumpy" demand or further optimize the use of the infrastructure. For example, including users that would typically fuel or charge during the day when a transit bus fleet was on-route might lead to a more efficient utilization of infrastructure. Despite these opportunities, investors emphasized the substantial practical challenges of managing this type of shared infrastructure. Specific challenges included the need for reciprocal obligations with users (e.g., agreements not to damage or over-use infrastructure and compensation requirements if these events occur), more complex and expensive insurance requirements, potential changes to transit operations or yard design to allow access for outside users, security concerns associated with transit fleets, and the need for a wider variety of performance obligations. While investors did not see this as an insurmountable challenge, most expressed meaningful caution about the complexity the decision to bundle across users would introduce.

Process considerations for successful procurement, contracting, and deployment

Investors saw a crucial role for state and regional entities to coordinate across transit operators. This identified need for coordination is particularly salient for small operators, who cannot reach effective economies of scale on their own. Investors encouraged examining models that move

away from small agencies doing all of the complex activities of planning and deployment in



isolation. Potential coordination activities mentioned by investors include both short- and longterm ZEB transition planning on a multi-agency or regional level, coordination of routing and operations to relieve some of the capacity constraints of small agencies, and coordination related to funding and incentives. As one investor stated, transit operators might make different decisions if they had the flexibility to optimize a joint investment within a region, asking "how do you incentivize agencies to work together?".

Investors stressed the importance of a strong public-sector team and process for project development. In order for investors to feel comfortable becoming involved in a ZEB infrastructure deployment project—particularly if it involved delivering services for multiple transit operators—a strong public-sector team and process was key. These prerequisites included experienced legal advisors, a clear procurement strategy, good governance among multiple stakeholders and counterparties with clear decision-making authority. In addition, the public sector team should ideally have adequate expertise with land use, public funding programs and incentives, and technical elements of projects, or a "swiss army knife" understanding, in the words of one investor. All of these elements, based on investors' past experience, lead to more collaborative, efficient, and expeditious project development and deployment. One investor gave the example of a past project that faced significant challenges in generating market interest and took significantly longer to close due to suboptimal choices about effective legal counsel, a lack of marketoriented procurement processes, and inefficient project scoping. For some investors, this concern with the project counterparty's expertise and governance and institutional structure was based in a concern that transit operators may not fully understand the risks and process of implementation for a ZEB infrastructure project. In general, investors expressed support for a state-level counterparty or advisor that would enhance their interest in investing in a project like this. Depending on the resources or expertise available, one investor also mentioned the possibility of bringing on one or more private sector partners (such as a master developer) to sit on the public "side of the table" and act in their interest (similar to a "owner's engineer" role commonly employed in construction or energy development projects in other sectors). They expressed a strong view that equity investors and developers would be better suited for this task as opposed to a contractor or OEM.

Investors have a clear preference for more collaborative and flexible procurement processes. In a theme common to most other sectors included in this market sounding, investors preferred a procurement and contracting process that allows more extensive public-private collaboration and market feedback. There was a clear preference for a "project development agreement" (PDA) process, as compared to a "hard bid" process. In the "hard bid" process, the project sponsor defines its project specifications in detail and describes the solution it would like to purchase from the private market. Bidders are then asked to submit fully committed proposals that specify how they would provide this solution, and at what cost. Interaction between the procuring agency and bidders is limited during the procurement, typically to written questions and answers and sometimes a handful of structured one-on-one meetings. While this process is typically used to maximize the competitive tension between bidders in order to push towards lower prices, investors emphasized that the public sector's relative inexperience with ZEB procurements would likely lead to suboptimal project and procurement document definition when pursuing a "hard bid" approach.

In contrast, a PDA process allows a project sponsor to procure a partner to work with in defining and developing the project jointly (e.g., developing more detailed specifications, determining a



realistic project budget, etc.). This process allows significantly more private sector input into a project before the scope and requirements are fully "baked". In their view, this allows greater scope for introduction of innovative ideas, optimization of the project scope based on current best practices, and the ability to focus resources on project development rather than the legal and transaction costs of the bidding process. Particularly for newer and more innovative projects (as opposed to, for example, routine and familiar activities like building a diesel bus maintenance facility), investors saw major benefits to both them and the public sector from being able to collaborate and use their expertise to inform project definition.²

Investors communicated a desire for California to invite greater private sector participation in program design and other areas where they offer value. In addition to greater private sector participation in the procurement process, investors saw opportunities to increase their participation in the transit sector's ZEB transition. Some investors felt that California currently keeps private entities – including companies like theirs – at an arm's length, rather than fully leveraging all available expertise and experience, exemplified by the current status of public-private partnership legislation in California. One investor mentioned that they would strongly encourage California state agencies to find ways to invite the private sector more into data-gathering and decision-making processes to help the public sector think through potential solutions, also acknowledging that there are limitations to this involvement to avoid being precluded from participating in future procurements.

Investors' role and commercial considerations

Investors have a clear preference for steady, contracted compensation for a project. Private partners or investors in a fueling infrastructure project can be compensated in multiple ways that reflect different levels and types of risk. All investors interviewed expressed a strong preference for a contracted revenues model, where a private partner's full compensation comes in the form of a fixed, ongoing payment stream (e.g., flat annual payment over a long period, at least partially adjusted for inflation). For these investors, a common reference point for this commercial model when working with the public sector is an "availability payment" (AP), or a defined payment for making an asset or services "available" over a long period of time. This model requires investors or project developers to meet defined performance standards, taking on the risk to ensure that an asset meets all specified public needs and is in good working order. If these standards are not met, compensation would be reduced accordingly. Investors recognized the potential challenges involved in shifting expenditures from a "capital" to "operations" category in transit operators' budgets. Investors acknowledged the complexity of these types of relationships, particularly as it involves separating the capital and operating components of contracts for the purposes of grant eligibility, budgeting, raising capital, and credit rating impact. However, they also noted that these are not new issues to the broader infrastructure sector and are manageable.

² We do note that, in our experience, most infrastructure investors have a clear preference for these collaborative processes both for the reasons listed above, but also for some reasons that may not be as attractive to transit operators. In particular, the use of a collaborative approach reduces competitive tension in the process, as a preferred partner is selected early, before design is far advanced. Notwithstanding the comments received during the market sounding, which did not include interviewees that would be able to provide a counterbalancing view, in some situations, this can reduce the level of innovative solutions offered and the level of cost competitiveness. In addition, transit operators will need to carefully monitor and analyze if the solutions being offered add value for the additional costs they are incurring.



Investors' interest in BEB versus FCEB-related projects varied. In the context of their preferred contracted revenue compensation structure, wherein they would theoretically assume many performance and technology-related risks, investors emphasized that the maturity and level of commoditization of fuel and technology is key. While not entirely uniform, some investors were uncertain about whether this model can be successful for hydrogen fueling infrastructure at this point. Given its more extensive deployment track record and arguably more mature technology, investors appeared to prefer investing in BEB infrastructure, although they emphasized that this view is likely to change over time. One investor noted that it is "easier to sell an electric bus than hydrogen" due to the conventional nature of charging and the ready availability of electricity as compared to hydrogen. Notably, at least one investor did express specific interest in investing in FCEB infrastructure deployments, demonstrating the range of current opinions on this topic. Regardless, this investor was still carefully considering the high costs of hydrogen storage, potential "molecule anxiety" related to fuel availability, and demand uncertainty.

Most investors were not interested in taking on meaningful revenue risk for ZEB infrastructure. In contrast to the contracted revenues model explained previously, investors can also be compensated via the right to generate and claim future revenues from a project (e.g., the toll revenues from a toll road). In the case of ZEB infrastructure, this model would likely take the form of a private partner being compensated for its services through charging for fuel based on actual use. This is similar to how commercial gas stations currently operate. Investors uniformly expressed skepticism about the fit of this commercial model within their businesses at this time. The "revenue risk" associated with the transit operator's demand and the rapidly evolving alternative fueling space was not an attractive investment opportunity for interviewed investors. This included revenue risk that might be associated with additional commercial users in addition to a transit operator. At present, investors would only want to take revenue risk as an "upside" above a guaranteed minimum return. The investors noted that while there are certainly companies investing in commercial charging infrastructure around the country, those are different business models that depend on very careful site selection, which often does not correlate to the locations of transit operator charging depots.

All investors saw the financial strength and creditworthiness of their counterparty in a project as of utmost importance. In the context of a partnership with contracted revenues, all investors emphasized the criticality of the financial stability and creditworthiness of a potential public partner. Given that the source of security for an investor in this case is a contract with a promise to pay a certain amount over time, one of an investor's main objectives is to ensure that this promise is credible and they will be repaid as expected. While they were interested in structuring these partnerships creatively, investors did express some reservations that transit operators alone or in combination would be able to provide sufficient assurances of financial strength to make these projects marketable opportunities. These concerns related to a wide variety of factors, including available financial resources, ability to make long-term commitments that give partners appropriate recourse, the existence and strength of a significant financial or borrowing track record, and the structure and governance of the transit operator. Investors suggested interventions that might serve to mitigate this "counterparty credit risk", including the potential for credit assurances or support from larger state-level entities for specific transit operators, which could unlock otherwise challenging projects. One investor specifically raised this idea of credit enhancement or "backstopping" as a possible role for Caltrans. Alternatively, all investors discussed the potential amalgamation of transit operators through a Joint Powers Authority (JPA)



or other similar mechanisms, which all agreed would hinge on the specific quality of the underlying credits and any additional JPA-level features.

Sector Conclusions

Overall, although investment opportunities in ZEB infrastructure projects are seen as relatively new and less mature, investors expressed strong interest in future participation. Key considerations from the private investment sector that may inform future demonstration concepts include the applicability of lifecycle bundling for ZEB infrastructure projects as a way to manage performance risks and engage external expertise; the importance of assembling a project of sufficient scale (i.e., a required equity investment of \$10M+); the importance of market- and expert-informed project scoping, structuring, and procurement; the governance and creditworthiness credentials of a project sponsor or counterparty; and the relatively greater interest in projects that focus on delivering high-quality services for transit operators in exchange for contracted payments as opposed to building out a comprehensive retail-based infrastructure system. Investors strongly encouraged state agencies to consider more open and collaborative models that include private-sector actors in decision-making, flexing California's ability to help transit operators coordinate, leveraging state resources to augment project development expertise, and considering ways that California can provide credit support or enhancements to "unlock" financeable opportunities in projects involving small and rural transit operators.

The key areas of consensus for this sector that could act as "building blocks" for a market-informed demonstration concept are included below:









6. Conclusions

6.1 Key insights from the market sounding process

- 1. Transit operators lack required resources and expertise: Very few small transit operators have the necessary expertise to plan, procure, deploy, operate or maintain ZEBs and supporting infrastructure, especially given rapid and ongoing technology change in the sector. This is a major concern for operators and private sector partners. Operators need wraparound support for successful deployment, but this kind of support is not always easily accessible, as it can be expensive and many funding sources are competitive and costly to apply for.
- 2. California should focus on ZEB fueling infrastructure: There is a strong consensus that the biggest challenge and need for state-level intervention to ensure timely ZEB deployment is related to ZEB infrastructure, not vehicles. To successfully deploy ZEB infrastructure, stakeholders will need to shift from seeing the ZEB transition as a plug-and-play "swap" of one type of equipment for another. Instead, deployments should be considered as infrastructure projects, with all of the risks and challenges that this entails, from utility coordination to design and permitting. Stakeholders must clearly understand the implications of completing hundreds of such projects throughout California over the coming years.
- 3. Small transit ZEB deployment projects have inherent inefficiencies that may be addressed with creative bundling and coordination: Small projects and equipment orders can be inefficient for both transit operators and private sector equipment and service providers. To the extent that each small project must access significant resources and expertise, conduct sophisticated procurement and contracting processes, and start with a "reinvent the wheel" approach for a small, customized project, projects are likely to face higher costs and longer deployment timelines. There is a clear role for bundling mechanisms to overcome this challenge and achieve economies of scale, although bundling across multiple stakeholders, types of products and services, or users is not without challenges.
- 4. Shared infrastructure solutions are not a silver bullet, but they should be thoroughly explored in certain circumstances: Although the concept of shared infrastructure seems intuitive for example, it seems far more efficient for small infrastructure users to share common infrastructure rather than many entities independently building their own, this type of user bundling has real operational, financial, and coordination challenges. These challenges, and the risks they present to transit operators, should be taken seriously. However, this does not mean that shared infrastructure solutions should not be considered in appropriate circumstances, particularly for depot-based hydrogen fueling (as opposed to battery charging) or for opportunity/on-route charging/fueling.
- 5. A ZEB infrastructure project can start with an efficient "cookie cutter" model, but some customization is unavoidable: Efficiency could be enhanced for many transit ZEB infrastructure projects particularly for FCEB deployments by starting from a reasonable "cookie cutter" model, rather than a blank page. Developing one or more standard best-practice models as a starting point with significant leadership from industry and technical experts could be a compelling way to expedite and improve project development. However, site-specific planning and engineering work is extremely difficult or impossible to standardize. As discussed above, efficiency enhancements must be considered within the



frame of an infrastructure project, with all of its complexities and challenges, rather than viewed as an "off the shelf" purchase.

- 6. Infrastructure investors could be a new type of partner in ZEB deployments to take on challenging risks and responsibilities: Infrastructure investors are not typically involved in small-scale transit infrastructure or bus fleet deployments in the United States. However, these companies would be interested in engaging in ZEB infrastructure deployment projects if they were bundled in a transaction with sufficient scale and high-quality coordination and governance. This type of partner offers an interesting possibility of efficiently transferring risks and responsibilities associated with a ZEB transition away from transit operators who are not well-equipped to or interested in managing them. It is not yet clear what these risk management mechanisms will be, and their development will be crucial to securing the involvement of these investors.
- 7. Standardizing ZEBs is likely to be a long-term investment that requires intentional intervention: Standardization is commonly touted as a solution to bring down high equipment costs of extensively customized transit buses. However, this potential solution is only likely to be realized in the long term for two core reasons. First, transit bus manufacturing is currently optimized for a labor-intensive, non-automated process, which will be slow and costly to change. Second, since transit operators have strong preferences and are not highly price sensitive for capital investments (which often involve substantial grant funding), incentives are not currently aligned behind standardizing to achieve ZEB cost efficiencies. However, laying the groundwork for long-term change may be a worthwhile investment.
- 8. ZEBs are still a relatively new technology requiring intentional risk management: Both transit operators and private companies recognize novel operational and performance risks for ZEBs due to the nascency of the technology in the transit sector. Transit operators are struggling to understand and manage these risks, but ZEB OEMs are also unwilling to guarantee range or performance of their vehicles due to factors out of these companies' control, including weather and terrain, actions by operators and battery and fuel cell manufacturers, as well as a lack of long-term performance data. This challenge likely requires a suite of solutions, from more sophisticated risk allocation to improved testing to training to optimize vehicle operations.
- 9. Statewide purchasing contracts are not a panacea: Statewide contracts for purchasing ZEBs and related products and services can be optimized, but they are not an ideal tool for solving many of the challenges with ZEB and infrastructure deployment. Statewide contracts do generate value by reducing administrative complexity and procurement costs, as well as potentially providing a mechanism for optimizing contract terms. However, structural challenges such as implicit "competition" between different states' similar contracts, extensive customization, and a lack of incentives to reduce prices are preventing maximum savings from coordinated purchasing. An innovative statewide contract that addressed these structural challenges could make this tool even more impactful.
- 10. Onsite hydrogen production is not recommended: Onsite hydrogen production is very challenging and not recommended for transit operators, despite real concerns about hydrogen access and long-distance transportation costs. However, on-site electricity production (i.e., microgrid project components) may reasonably be considered on a case-by-case basis.



6.2 Potential demonstration project areas

The market sounding interviews provided rich, cross-sector insights into market participants' views about what could and should be done to support and accelerate the ZEB transition for transit operators in California. In order to move towards the objective of scalable, implementable project concepts that can support and accelerate a successful transition, it was necessary to both compare insights across sectors and to look holistically at how stakeholder-specific insights and suggestions could be combined to create a cohesive concept.

As presented at the end of each sector-specific sub-section in Section 5, the market sounding identified the actions supported by each sector that could form the "building blocks" for more comprehensive solutions. Each "building block" is intended to represent a potential action to influence a ZEB deployment's success. This framework recognizes that there is a wide variety of potential levers that could be pulled by different stakeholders to influence ZEB deployment success, such as:

- **Bundling:** Changing the scale and/or scope of an otherwise small project
- **Risk transfer:** Re-allocating project responsibilities and risks
- **Procurement, compensation, and contracting:** Changing the approach to partner selection, project development processes and key agreement terms
- **Standardization:** Increasing the consistency and commonality between equipment and key deployment components
- Infrastructure solutions: Introducing new approaches to satisfying project needs
- State interventions: Changing the structure and allocation of available resources or policy and requirements.

These "building blocks" are re-assembled in the section below into potential demonstration areas, informed by market suggestions and validation. While these suggested areas are preliminary and high-level, they provide guidance for those wanting to direct future efforts towards promising areas with potential for aiding the ZEB transition. We note that some concepts may be better suited to BEBs, and some may better fit FCEBs, but there are a number of themes that are common to both. As the demonstration projects are refined in the next phase of work, we will customize the scope of any demonstrations for the appropriate technology and stakeholders.





Rationale & Theory of Change:

A well-structured state-sponsored lifecycle partnership could address a broad set of root cause challenges for transit operators and accelerate deployment of ZEBs at scale. Conversations with market players validated the potential feasibility and impact for this type of partnership. The purpose of this project concept is twofold: a) demonstrate that this partnership structure can serve to effectively share the burden of risks and responsibilities that transit operators feel unequipped to manage with the private sector and b) demonstrate that this type of project is replicable for other groups of operators (in California and across the United States). If successful, this could be a viable new path for compliance with ICT targets and capturing lessons learned from the project development process to improve the scoping, contracting and procurement process for future projects.



- What components and lifecycle stages should be part of the "bundle"?
- What project governance and financial/counterparty structures would be feasible?
- Is it possible, or necessary, to test a "minimum viable product" (MVP) version of this model quickly and effectively?
- What partners would be interested in participating?





The collaborative development and execution of an "as-a-service" contract for deployment of fueling infrastructure would mitigate concerns about individual transit operators' expertise in ZEB technology and ability to manage risks. This market sounding confirmed interest in this contracting model from a wide variety of market participants. The purpose of this project is similar to the demonstration project area outlined above: a) demonstrate that this partnership structure can serve to effectively transfer risks and responsibilities that transit operators feel unequipped to manage and b) demonstrate the scalability and replicability of this model for other transit operators.

- What components and lifecycle stages should be part of the "bundle"?
- What pricing could be achieved for this model?
- What partners would be interested in participating?





The coordination of various market players to develop common tueling intrastructure specifications would improve financial and operational outcomes for ZEB deployments. The market was clear in its concerns regarding some transit operator choices in specifying requirements in fueling infrastructure procurements and in its belief that a greater degree of standardization and collaboration would be beneficial at least as a starting point for new deployments. The purpose of this project area is to demonstrate that a practical set of base specifications can be developed and incorporated into procurements, which will help accelerate project delivery, reduce costs, and help operators avoid common pitfalls.

- How many different "profiles" for specifications would be needed, and which should be included in a demonstration?
- How should standard specifications be rolled out/implemented via a procurement mechanism, as technical assistance, or via the private sector?
- What partners would be interested in participating?
- How can agencies reconcile the desire for common design with the use of proprietary technologies?





suggested that this area has potential but has not been sufficiently explored, and that state or regional entities could play a more significant role during early-stage planning to originate projects. The purpose of this project is to demonstrate that opportunity fueling infrastructure prioritizing transit could be successfully operated and integrated into transit operations.



- What commercial model would be feasible for this type of infrastructure (retail model vs. state-contracted)?
- What users would be feasible to bundle?
- How should feasible locations that prioritize transit be selected?
- What partners would be interested in participating?





technical capacity of transit operator staff, addressing a key obstacle to the speed and quality of status quo ZEB deployment. This suggested project area was frequently raised by market sounding participants as potential "low-hanging fruit" and a key driver for producing more favorable outcomes in ZEB procurements. The purpose of this project is to demonstrate the effectiveness of various strategies for delivering information, expertise, and resources to transit operators.

- What model(s) would be most effective in delivering this support in a scalable way?
- To what extent can the needed resources be accessed from the public vs. private sectors?
- What partners would be interested in participating?
- What mechanisms would ensure that "master developers" or advisors act in agencies' best interest, not their own?



6.3 Next steps

The next phase of this effort will focus on applying the feedback and insights gathered during the market sounding to develop feasible and specific potential demonstration projects that can be advanced towards realistic implementation. A key first step in this process will be further engagement with stakeholders and market sounding participants to identify potential participants in a future demonstration project. These interested parties will be an integral part of the demonstration project development process, informing project scope and specifics as well as raising questions, barriers, and new ideas. In addition to this recruitment and stakeholder engagement, the project will involve further targeted research, outreach to subject matter experts and implementers, and relevant analysis.

Future work is expected to pick up where the conclusions of this market sounding report end, using the demonstration project areas in Section 6.2 as a starting point. However, potential demonstration projects still have potential for evolution. In addition, the next steps of this project will continue to return to the detailed feedback in the market sounding that addresses both "how" interventions should be structured, not just "what" should be implemented. Next steps will also consider how "building blocks" that are currently not incorporated into a demonstration project area could be opportunities either for an addition to a demonstration or as a smaller, standalone concept.

