Transitioning *to Zero Emission technology*

A guide to ensuring a smooth transition towards future-ready public transit

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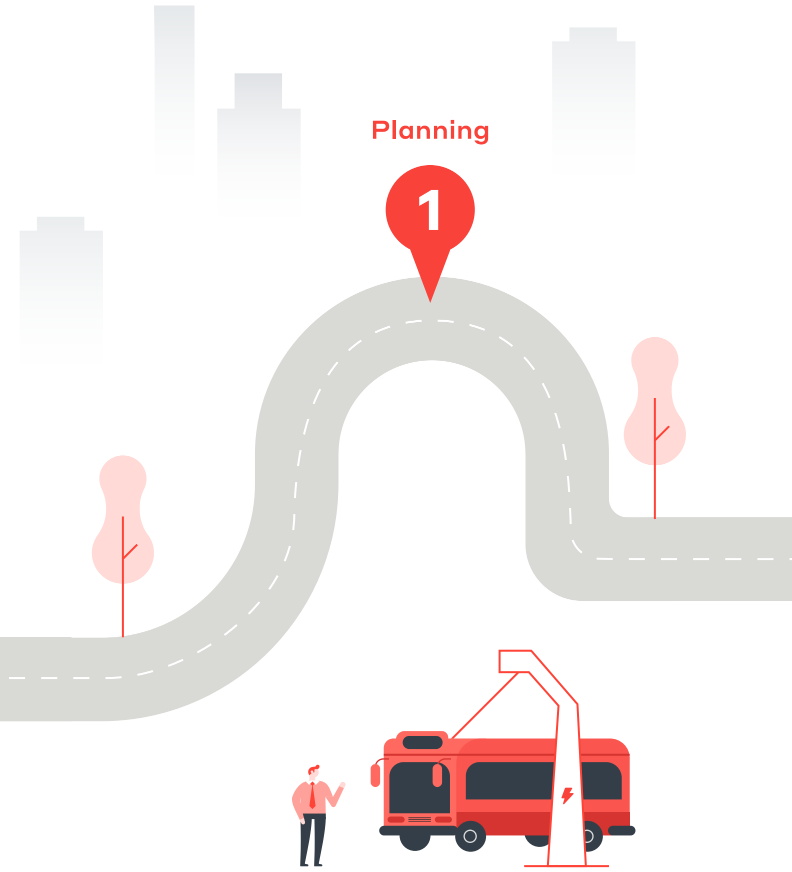
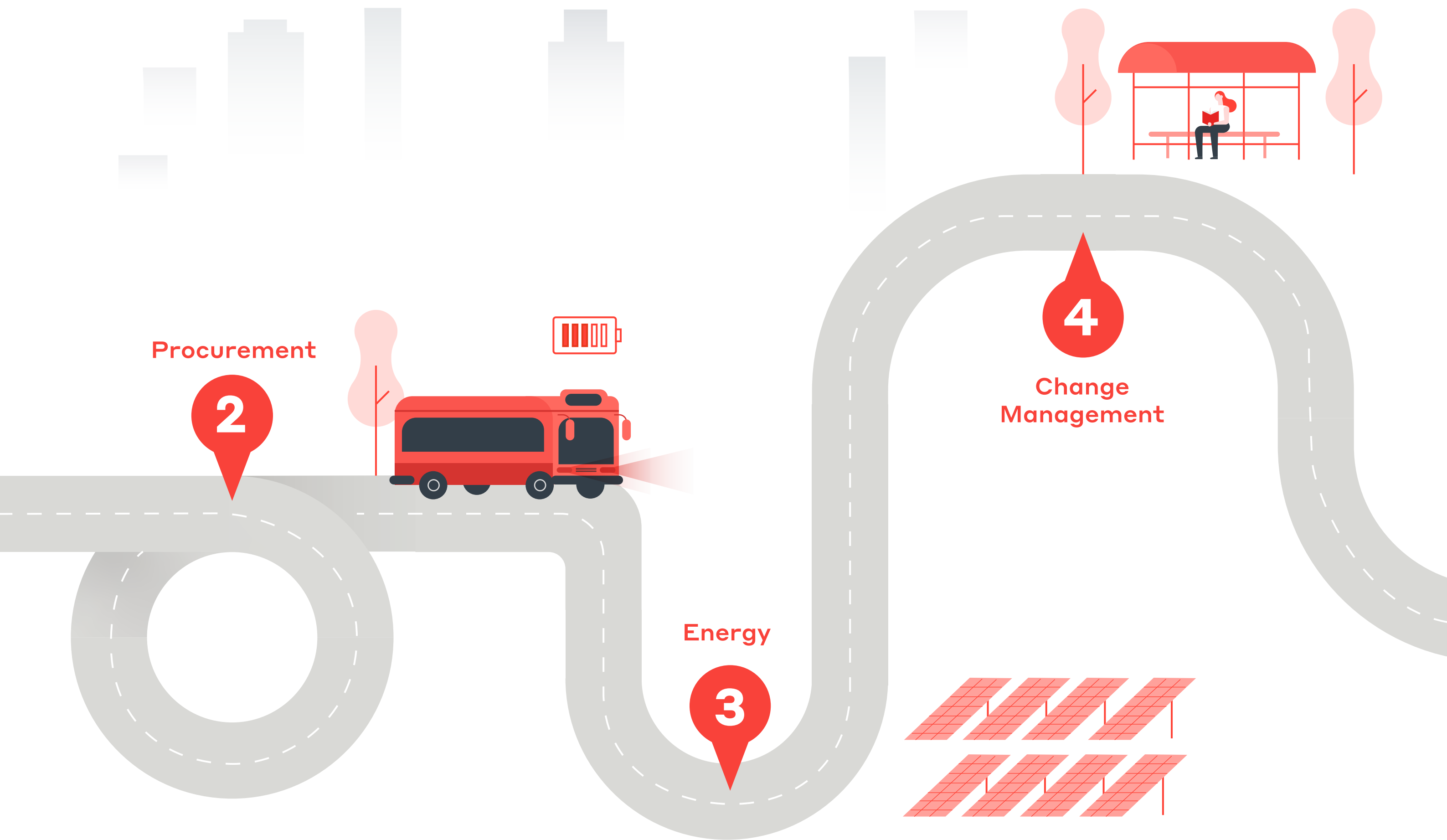
Introduction



In the midst of abundant scientific evidence suggesting that carbon emissions are changing our climate in ways that will damage the environment and create economic distress, public demand for a transition to a zero emission (ZE) world is placing the burden on the shoulders of governments and private businesses around the globe to address this crisis by adjusting their operations.

Public and private transit agencies find themselves on the front lines of this global transition, due largely to their significance and visibility in the everyday lives of people, the extent of government control in many countries, and the industry's legacy of fossil fuel consumption. Accordingly, governments worldwide are focused on the transit industry, embracing a transition to zero emission vehicles (ZEVs) as part of concerted efforts to meet broader climate change mitigation targets. This focus requires coordination and collaboration between numerous stakeholders, including transit agencies, governments, utilities, manufacturers, service providers, and climate activists, with each stakeholder facing a broad range of new challenges in the increasingly cooperative quest to plan, manage, and finance a large-scale transition to ZE technology.

Hundreds of thousands of ZEVs, both battery electric and fuel cell vehicles, are already in service in cities around the world, transporting millions of passengers on a daily basis. Lessons learned from those early adopters go a long way to helping advance the state-of-the-art, which continues to evolve at a rapid pace. The emergence of new and more affordable technologies, refined business models, clearly defined policies and legislation, and flexible financing options together contribute to a set of more comprehensive and implementable options for addressing the many challenges of large-scale ZE technology adoption.



Changing the mechanisms by which public transport is delivered and supported can be challenging given the 24/7 nature of transit operations but transitioning to zero emission can be accomplished with careful planning, a comprehensive approach, and expert advice. While early adopters, including several major metropolitan areas, may have greater resources and capacities to move forward with their transitions ahead of smaller urban and rural markets, the latter will benefit in the long run from greater economies of scale, stabilized pricing, and the availability of tested infrastructure and energy solutions.

Harnessing the collective expertise and experiences of its professionals around the world, WSP has prepared this white paper as a blueprint designed to help prepare transit providers for the many challenges ahead, and to highlight areas where expert guidance can help pave the road to a smooth transition. This paper captures the broad complexities of the ZE transition by focusing on four major elements of ZE technology adoption: comprehensive Planning, a systems approach to Procurement, adapting to new forms of Energy provision, and the organizational challenge of Change Management.

Planning

Ground zero for successful ZEV technology adoption

While cities in Asia and Europe have deployed zero emission vehicle (ZEV) technology at a large-scale, many other cities, including most North American cities, are just entering the critical early planning stage. Accomplishing large-scale adoption requires visionary planning across all phases and all elements of the technology transition. While the challenges of large-scale ZEV adoption may seem overwhelming on the surface, expert guidance and the leveraging of lessons learned from around the world can foster a holistic approach to the transition. Moreover, the most complex and difficult aspects of a ZEV transition may be the transition itself; i.e., introducing new vehicles and technologies while continuing to operate the legacy fleet and supporting infrastructure. Proper planning can thus ensure that preliminary steps are both rational and scalable, guaranteeing the wide-spread ability to deploy ZEVs at a larger scale further down the road while minimizing disruption of operations and facilities.

From pilot projects through to large-scale deployment, transit providers can benefit from field-proven know-how throughout the critical planning stages of their transition to ensure scalability of all system components. In that journey, it is also important to anticipate and overcome the challenges posed by the operational limitations of some ZEVs, the associated infrastructure modifications, changing cost structures, technology transition, and market factors.

Operational Challenges

The transition to ZE technology requires extensive planning for operational changes to ensure that large-scale adoption can address the full spectrum of each agency's operations. Current limits [1] on the achievable range of many battery electric ZEVs pose challenges in terms of deciding where to deploy ZEVs, how many ZEVs are needed, and whether and how to extend their range through en route charging. Charging requirements [2] for these vehicles pose operational challenges to the fluid operation of fleets, both en route and in the storage depot.

Modelling of ZEV performance on an agency's services can provide critical information needed to plan where and how battery electric ZEVs can be deployed.

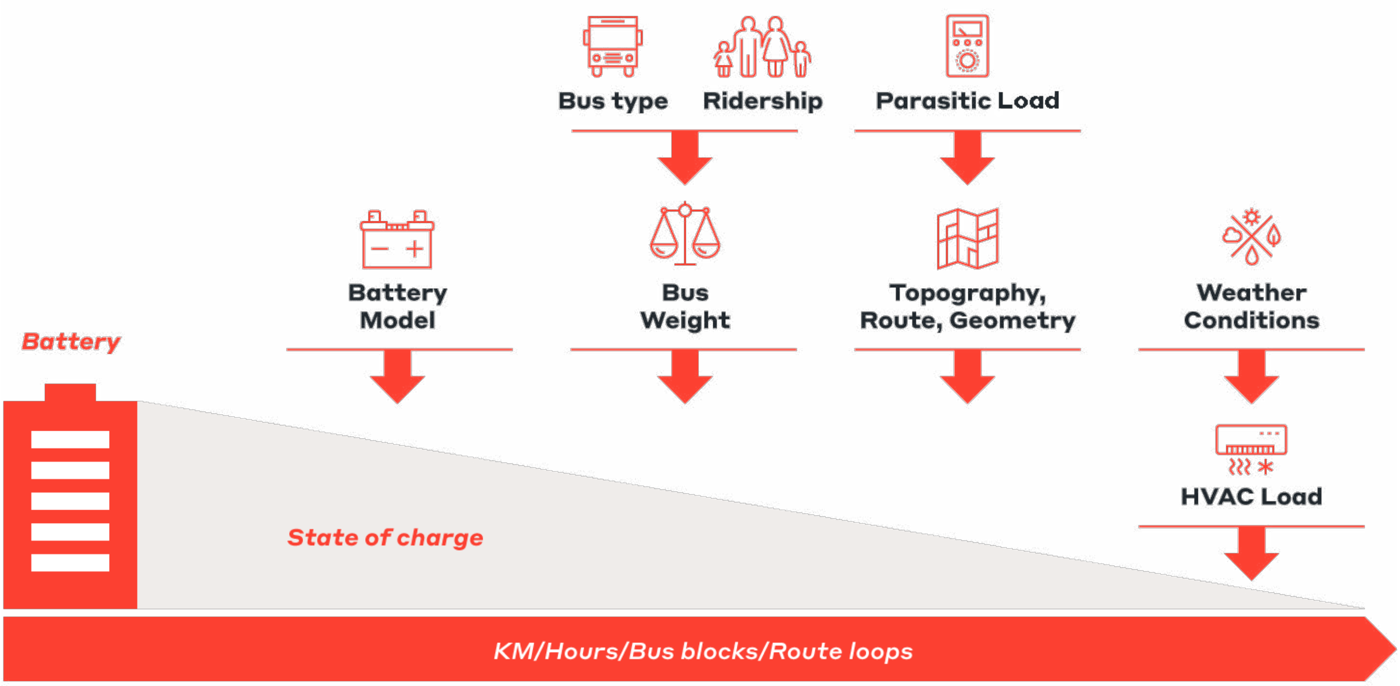
1

The range of battery electric vehicles is limited by battery capacity. Batteries are heavy and less energy dense than conventional fuel sources, and the number of batteries on a vehicle may be limited by vehicle weight restrictions.

To mitigate range limitations, transit operators might consider replacement of conventional buses on a higher ratio than a 1:1 basis, purchasing the additional equipment to split up runs into shorter segments.

2

WSP experts continue to closely monitor progress in the global standardization of plug and charging protocols, noting that standards such as SAE J1772, J3105 continue to emerge as best practices.



Service modelling should consider route topology, stopping patterns, ridership, weather conditions (particularly in cold weather climates), HVAC loads, 3 and numerous other factors affecting energy consumption and ZEV maximum range. Vehicle schedules may need to be adjusted to accommodate reduced range or added time may be needed for en route charging. New operations and maintenance procedures may also be needed at the depot to address new charging procedures, and maintenance staff will require advanced training and new, specialized tools 4 and equipment. Hydrogen fuel cell ZEVs, which have longer range capabilities, may present a viable alternative and/or addition to fleets of battery electric ZEVs. Like batteries, hydrogen fuel cell technologies continue to evolve at a rapid pace. In some cases, fuel cells may be installed on battery electric vehicles as a “Range extender”.

Infrastructure Modifications

Both battery electric and fuel cell ZEVs require new infrastructure for energy provision and to support charging or fueling. An understanding of infrastructure needs is critical to the planning stage of ZE technology adoption, as the electric power capacity needed for charging battery electric vehicles is not commonly available in existing vehicle storage facilities, nor is the hydrogen supply and fueling infrastructure.

3

HVAC loads have a particularly significant impact on vehicle range, as heating and cooling systems can account for a significant share of energy consumption, compromising range in cold and very hot weather climates. Most ZEVs available today cannot achieve a range comparable to conventionally. fueled vehicles.

4

Maintenance of electric vehicles requires specialized tools in order to service the more complex, high-voltage electrical systems not present on conventional fuel buses. These systems include battery packs, inverters, electric motors, and more.

Reliable access to secure, sustainable, and cost-efficient energy generation and distribution systems is key to the widespread ZE transition for urban transport systems. Large-scale electrification inevitably requires new power generation, and sometimes new on-site storage infrastructure. Generation and storage options can be assessed through power system modelling. In the short term, key steps include the identification of existing electrical networks, and planning power grid and generation reinforcements that meet the challenges of the increased power demand. In the long term, a sustainable planning approach will ensure that initial infrastructure will be adaptable to large-scale deployments.

To support an array of charging equipment, the provision of increased electrical service must be supported by on-site substations or transformers. This added equipment, as well as any backup power generation systems or on-site energy storage, can have a significant impact on space requirements at already space-constrained public transit depots. Additionally, power must be subsequently distributed to each vehicle, requiring elaborate electrical conduit and cable runs (6) for charging infrastructure that must be carefully designed to limit negative impacts on transit operations and allow for efficient maintenance and repairs.

(6)

Whether located in trenched exterior bus parking lots, garage floor slabs, or suspended from canopies or roof structures, electrical conduit and cable runs for charging infrastructure need to be designed to limit operational impacts while allowing for effective maintenance, repairs and upgrades.

Hydrogen supply, storage, and fueling for fuel cell ZEVs have their own infrastructure challenges that must be carefully planned for. When planning hydrogen-based ZEV systems, options for the transportation of fuel or, alternatively, on-site hydrogen reformation, as well as storage, must be weighed against space requirements, costs, power requirements, and environmental factors. There may be locations which are naturally pre-disposed to hydrogen deployment due to the proximity of other chemical related industries.

The infrastructure planning process can include the provision of wider power demand studies, asset condition assessments, facility modernization master planning, and other initiatives that help target cost-effective infrastructure optimization. Location planning, [7] to align ZEV network infrastructure with existing external power sources, will also play a critical role in minimizing extensive off-site power grid improvement costs that may be required by utility providers. Experts can assist in conducting assessments [8] of existing facilities and operating resources, document unique local operating conditions and requirements, and identify real estate or facility constraints.

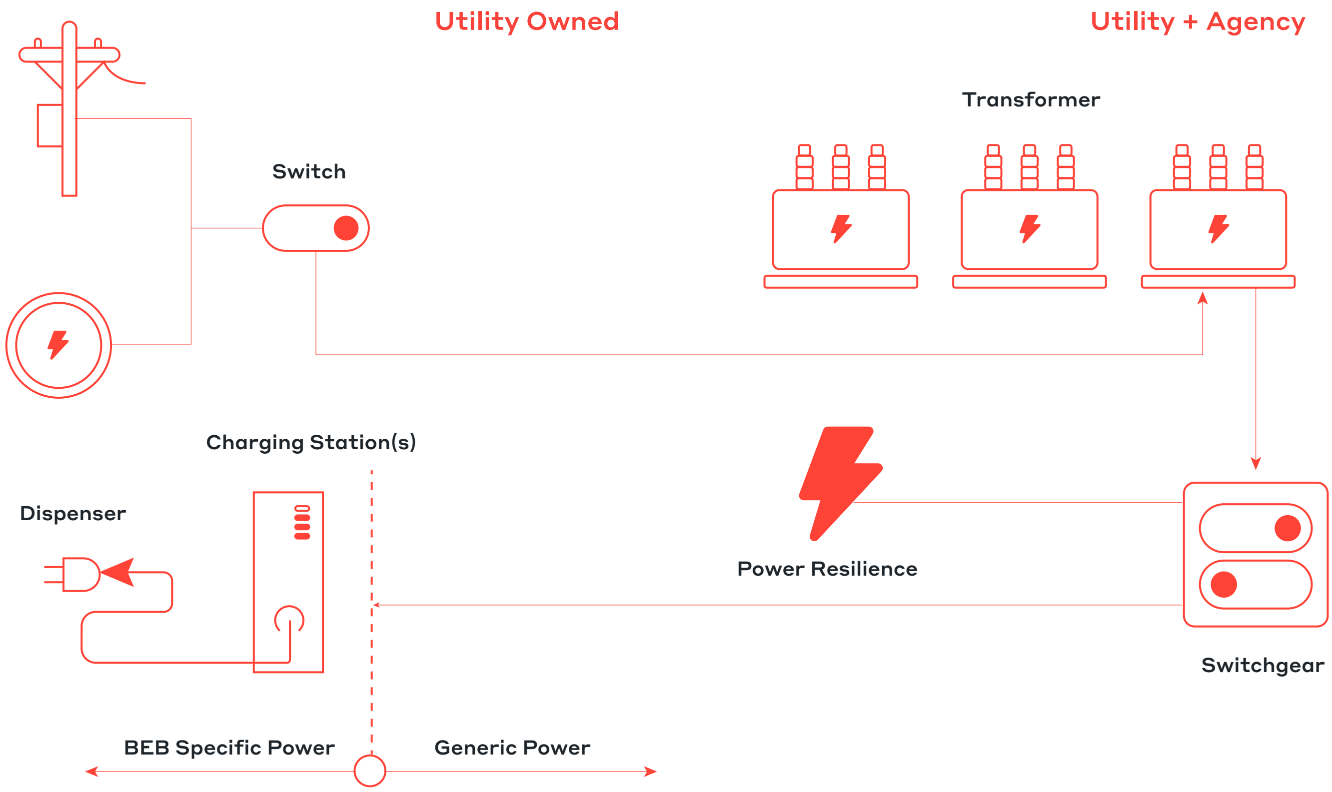
7

A single ZEV depot charger position (charger, installation, electrical infrastructure) can cost as much as a conventional diesel-fueled bus, while off-site power grid improvements can cost millions to bring increased power to a distant site.

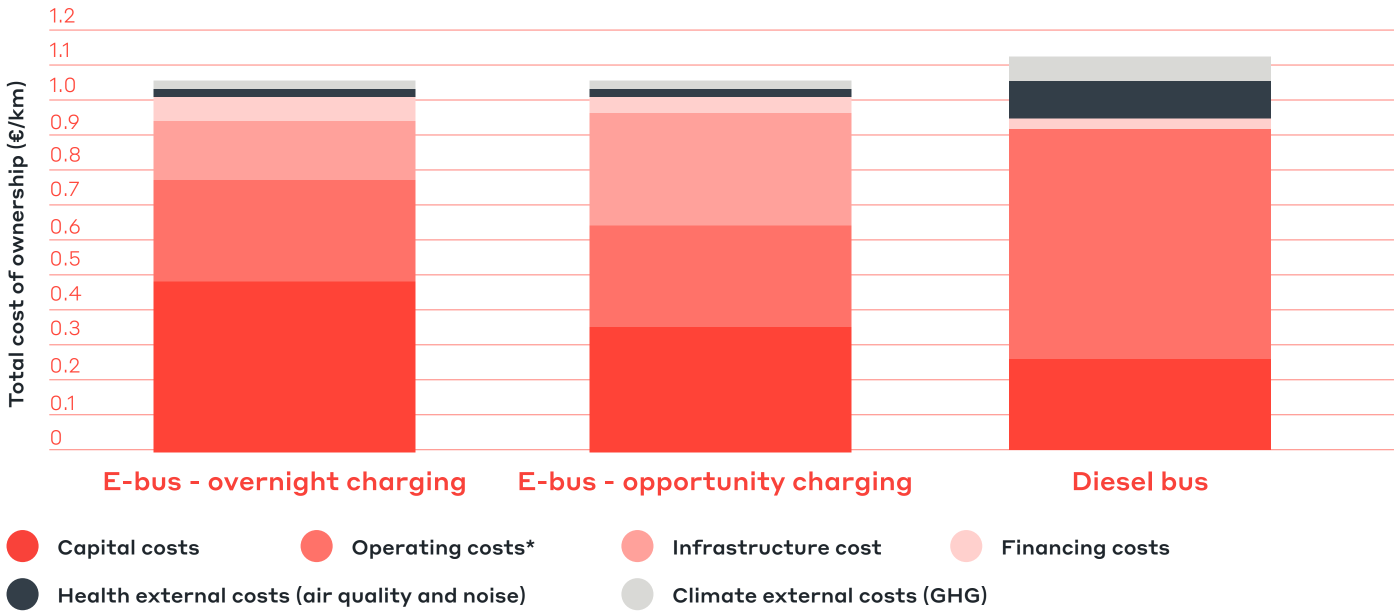
8

Sophisticated modelling tools are available to help transit operators assess the vehicle types, configurations, and charging systems best suited to their operations.

Electrical Infrastructure



8-year TCO calculation, daily distance travelled of 250km, excluding driver costs, in 2018, in Europe (€/km)



*Operating costs of charging infrastructure are included in the "infrastructure cost"

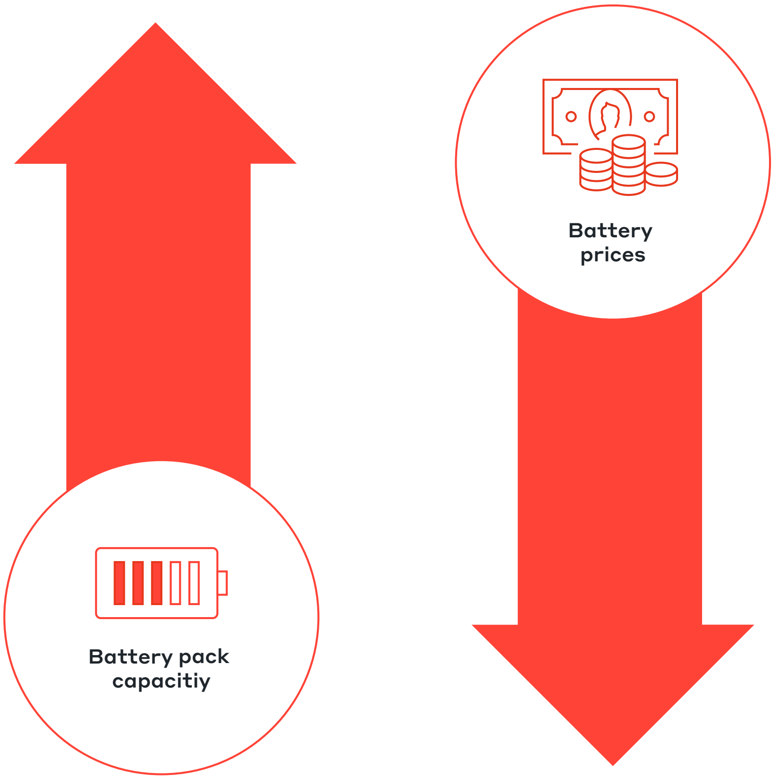
Source: Transport & Environment calculation including inputs from CE Delft

Lifecycle Cost Analysis

Planning that includes a full lifecycle cost analysis can address the changing cost structures associated with the transition to ZEVs and help agencies plan for capital and operating funding requirements. The capital costs associated with ZEV transit system implementation are significantly higher than those associated with conventional fuel systems and include major investments in vehicles, batteries, charging systems, electrical infrastructure, energy provision and energy storage. The acquisition of new tools and equipment required for servicing ZEVs also contributes to significant initial capital costs.

In some cases, the higher capital costs may be offset by operating cost savings due to reduced maintenance costs. However, given that the technology is still new and rapidly evolving, agencies have yet to experience the full long-term lifecycle maintenance costs of ZEVs. Furthermore, energy costs for ZEV operations vary widely by region and can significantly impact whether operating costs increase or decrease. With careful planning, utility rate structures can be leveraged for bulk consumption [9] at cheaper rates.

[9] Given the large energy needs of an EV fleet it may not be possible to charge during peak load periods. The role of wind and solar derived electricity may be part of the mix with suitable storage infrastructure.



Operators of ZEVs may also consider alternative cost structures, such as battery leases, which transfer what would be higher initial capital costs to ongoing operating costs using expected savings in operations. Long term battery warranties could also be considered for mitigating significant mid-life battery replacement and disposal costs. As the market matures, it is conceivable that leasing options will evolve (as has been seen in the lighter duty car sector) and similarly the market for life expired batteries (for home energy storage for instance) will also continue to develop.

Technology Transition

After decades of transit systems running on internal combustion engines and fuels, a dramatic shift towards large-scale ZEV systems comes with human considerations as well. As new technologies displace old ones, a variety of stakeholders, including management, drivers, and mechanics, may exhibit cautious reluctance to radical change.

Discussions of transition and phasing strategies are essential to initial planning, ensuring that all stakeholders within a transit agency are considered in the process. Implementing change across multiple phases is the most effective way to involve reluctant or skeptical stakeholders in the process, allowing them to test new technologies, witness proof of reliability, provide feedback, and immerse themselves in the process of change.

This approach should include the planning, development and implementation of pilot projects and trials that address not just the technology options, but also the unique limitations and challenges of each agency's organization and operating conditions. Proper up-front planning will ensure that pilot projects are included in a long-term vision for seamless, phased scalability into large-scale network operations.

Market Factors

Commitment to large-scale investment in ZEV transit systems requires careful study of current, emerging, and forecasted market trends. As the ZEV market continues to expand on a global level, the transit industry is witnessing the onset of more competitive pricing for higher quality products. Market prices [10] for vehicles and battery packs continue to fall, while battery energy density and capacity is increasing, which is only beginning to relax the current range restrictions for battery electric vehicles.

10

Regulatory requirements such as FTA's "Buy America" require U.S. transit agencies to procure vehicles that contain a minimum percentage of domestic content, with final assembly occurring in the United States.

Practical application of hydrogen technologies at scale are also continuing to provide both challenges and opportunities depending upon the geography, topography and duty cycles associated with a given location.

Diligent monitoring of global market trends for current and emerging technologies and pricing, coupled with expert advice, can help ensure that transit providers capitalize on favorable market trends. Market research and analysis can help guide transit agencies through the technology selection process, ensuring technology acquisitions that are most appropriate given the operational, maintenance and environmental requirements of each provider.

Procurement
Transitioning to a Systems Approach

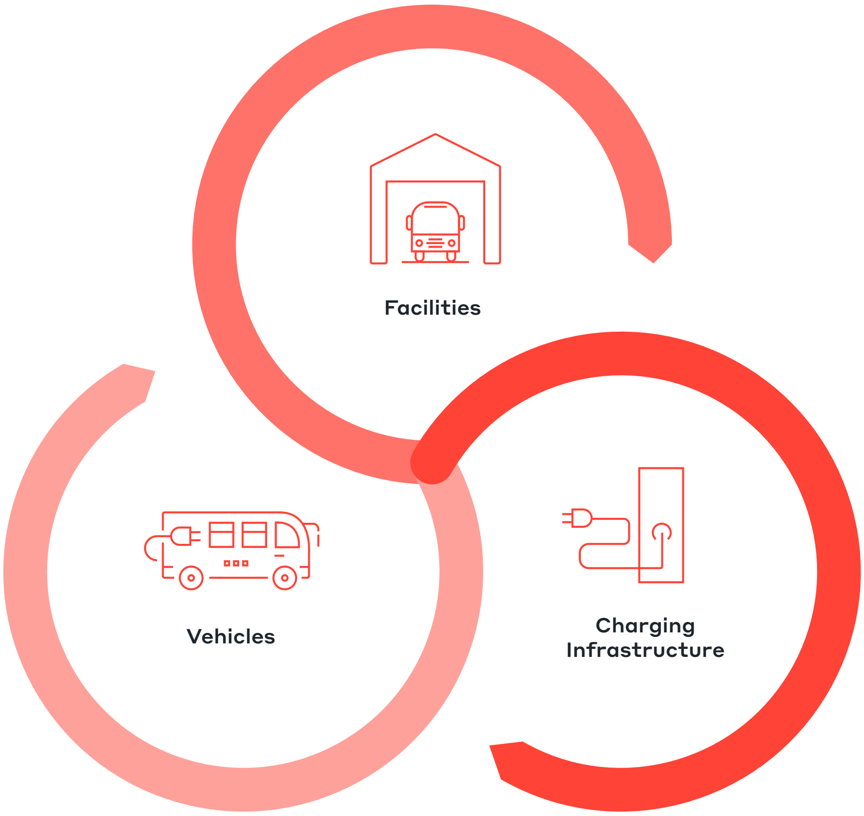
One of the most critical components of ZEV technology adoption lies in the procurement process [1] for vehicles, charging equipment, and electrical infrastructure. Simultaneous procurement and integration of each of these components creates the need for a broad systems-perspective approach to the procurement process, ensuring interoperability between vehicles, charging systems, and power supplies.

Expert analysis of choices made by early ZEV adopters can help other agencies address the unique challenges of ZE systems procurement. Prior to the actual procurement process, the planning process should assess the compatibility between the latest generation zero emission technologies and the agency's own operational requirements. Such assessments can be refined by the procurement and operational experiences of zero emission pilot projects already underway worldwide, leveraging insights gained from both manufacturers and peer transit agencies.

Procurement Challenges

While ZEVs provide the future promise of lower fuel and operating costs than conventional vehicles, the transition will require large upfront capital investments for both vehicles and infrastructure. Unlike conventional fuel vehicle procurements, ZEVs

[1] The evolution of procurement and program delivery methods gives operators and governments several options when undertaking ZE technology transitions.



form part of an integrated system and can pose unique challenges to transit operators. Vehicles and charging or fueling systems must be fully integrated, compatible, and able to communicate. Additionally, ZEVs can function on multiple propulsion systems, battery types, and fueling systems, each with varying range capabilities. Accordingly, procurement of entirely new infrastructure may be required to accommodate new battery charging systems or fueling stations.

The rapidly evolving nature of batteries and charging systems means that ZE procurement strategies inherently carry higher levels of technical and operational risk than conventional procurements. With multiple competing battery electric vehicle charging methods, charger types, and charging standards, not all manufacturers can support all types of chargers and, conversely, not all chargers will support ZEVs from every manufacturer. For initial ZEV pilot projects and fleet acquisitions, ZEV procurement and charging infrastructure projects must be carefully coordinated to ensure that ordered vehicles will be fully compatible with the installed charging equipment. 2 Chargers must match the vehicle's charging configuration and on-board system of plug-in ports, rooftop charging bars, and chassis-mounted power receivers.

2

By identifying and adopting multiple charging standards, such as SAE J1772 or OppCharge, and installing non-proprietary charging technology and management systems at operations and maintenance facilities, fleet owners will increase the number of ZE vehicle and equipment manufacturers they can utilize.

In order to decrease the risk for technology lock-in effects and create long-term stability for investments, compatibility of multiple systems is of the utmost importance. That being said, varying procurement and ZE technology standards between countries, states, and even cities could further complicate the procurement process.

Procurement Strategies and Business Models

A ZE Fleet Conversion Plan can provide a baseline roadmap for managing the transition. Expert guidance can provide stakeholders with several procurement strategies and business models to consider helping mitigate identified implementation risks and address the specific long-term operating requirements of the system. With the emergence of new business models, including leasing options for vehicles, batteries, and chargers that offer greater flexibility, lower upfront costs, and optimize cash flow, each agency's situation must be uniquely analyzed in order to ensure the best and most sustainable ways of supporting the transition to ZE technology.

Given the rapid evolution of ZE technologies, expert guidance can also help stakeholders negotiate contract provisions [3] to help reduce operating and technology risks, which can include mid-life battery system replacement options, and "Evergreen" refresh programs to secure future ZE technology upgrades. Procurement

[3]

Creating a common method of contracting enables participants to focus, when necessary, on negotiating only those issues for which a departure from the accepted norm is necessary or desirable. This approach saves considerable time and effort and can be applied to cases where the procurement involves "emerging" technology. One example is the current trend employed by several U.S. bus manufacturers who are offering extended battery and propulsion system warranties of up to 12 years.

of infrastructure modifications can be more complex and time-consuming than the procurement of vehicles, but experienced professionals are available to assist stakeholders in balancing multiple contracts for vehicles, chargers, facility improvements, and equipment installation. Additionally, experts can assist in identifying which aspects to combine into single procurements and which to procure separately.

Leveraging expertise in public-private partnerships (P3) [4] can also assist project stakeholders in weighing the risks and rewards of building such considerations into their procurement strategies. This offers numerous potential advantages to transit operators, including faster implementation, mitigation of technology and operating risks, and reduced operating costs. In its fullest form, a P3 approach can include design-build-operate-and-maintain contracts where a consortium of management and financial consultants, designers, vehicle and systems suppliers, and construction contractors undertake the design, development, and delivery of an entire program, including the sharing of some of the commercial risks.

[4] Public-private partnerships are common throughout the world, but are still emerging in the U.S. However, several U.S. companies are in the process of developing and commercializing Public-Private Partnership approaches to building, operating, and maintaining charging system infrastructure.

Energy
Keeping ZE Operations Up and Running

One of the most critical components of large-scale ZE technology adoption lies in the ability to secure sufficient, cost-effective, uninterrupted energy to fuel ZE fleets. Before embarking on the ZEV deployment process, numerous energy generation, transmission, and storage options must be taken into consideration in order to find the right balance to manage costs and ensure network stability and reliability.

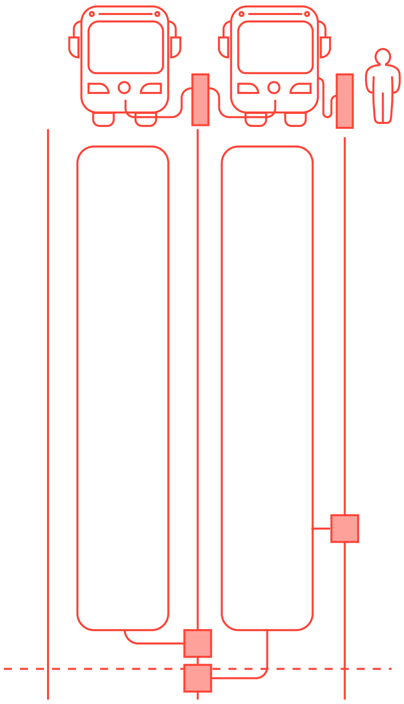
Expertise derived from the documented successes and challenges of ZE deployments around the world can help guide stakeholders through the multiple components of energy provision, from refueling options, to on-site generation, tariff structuring, microgrid development, and preparing for power disruptions.

Propulsion Types

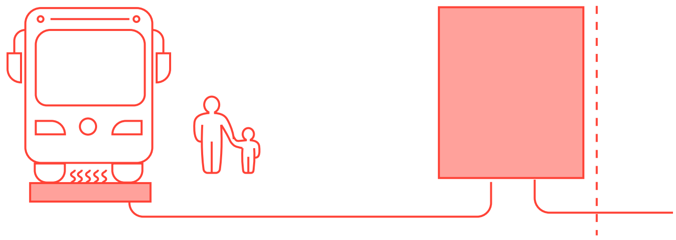
All ZEVs require refueling, whether powered by electrical energy stored in batteries, or compressed hydrogen stored in tanks. Battery electric vehicles require chargers connected to an electrical energy source, receiving power either directly from the grid or from on-site generators and storage systems. In addition to stationary depot charging, en route charging can provide off-site power to vehicles on routes that exceed battery range. In such cases, en route charging can supply the extra power needed to complete longer routes, thus avoiding the need to increase the quantity of vehicles over that needed for conventional fuel operation.

The three electric battery charging technologies currently available are plug-in, conductive and inductive. Plug-in charging can be done with AC or DC power, depending on the vehicle type, and requires that a cord be manually plugged into the vehicle. DC conductive charging is done using an overhead pantograph that automatically connects to charging bars on the roof. DC inductive charging uses in-ground charging pads, is contactless, and has no moving parts, but requires the largest footprint for supporting equipment and is currently the most expensive of the three options. En route charging is typically limited to conductive and inductive systems while depot charging has typically been plug-in, though many agencies are considering conductive options due to faster charging rates and the absence of manually operated cords.

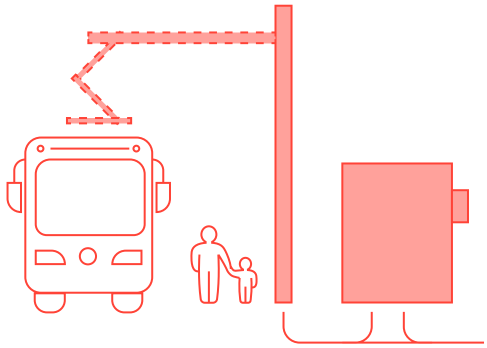
Hydrogen opens up new ways of integrating renewable electricity into the energy system and can play an important role in the transition from fossil to renewable fuels. [1] Hydrogen, together with fuel cells, can reduce environmental impacts and render energy usage more efficient.



Plug-in charging (AC and DC charging, depending on bus OEM)



Induction charging (wireless / contactless connection)



Inverted mast mounted en-route charger

1

Hydrogen can be produced from several types of energy sources but, in the long term, the hope is that renewable energy sources such as sun, wind, and biomass will be used for production.

Additionally, hydrogen can be procured as an existing by-product of other industries. However, hydrogen production is not without challenges.

Hydrogen can be produced from several types of energy sources, with expectations that renewable energy will be used as the primary source for its future production. Hydrogen production by reformation or electrolysis requires electricity. Hydrogen provision may be centralized (hydrogen delivered by truck or pipeline) or decentralized (raw materials delivered to a fueling facility). While centralized hydrogen production can provide high resource efficiency in the production phase, increased distribution costs and energy use can be incurred. Conversely, decentralized production reverses those conditions, with reduced efficiency but lower distribution costs.

Electric Rate/Tariff Structures

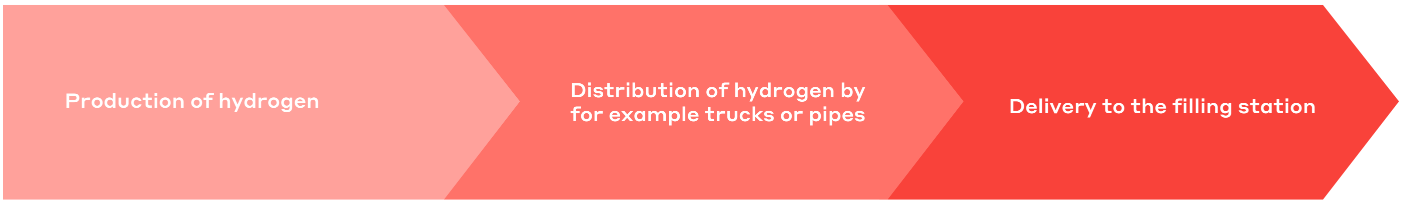
Operating a ZEV transit system is an energy intensive activity and, as such, energy tariffs play a key role in its profitability. Energy tariffs are aimed at balancing consumption through the day/year in order to match consumption with production and achieve a stable energy system. However, designing a tariff is a complicated task, with multiple factors influencing its structure, including regulations, politics, consumer behaviour, and future developments.

Tariff structures imposed by utilities on energy consumption play a crucial role in managing the cost of ZE transit networks, with underlying price structures that can include use, capacity, and energy-based fees. [2] In order to ensure a sustainable business case for both utility companies and transit agencies, efficient, tailor-made tariffs may be required. Energy-based tariffs, for instance, might be negotiated with incentives for off-peak consumption, [3] resulting in lower costs. Current and future challenges, like vehicle-to-grid interaction or the lack of maturity of ZE transport, also need to be addressed in the design of new tariffs.

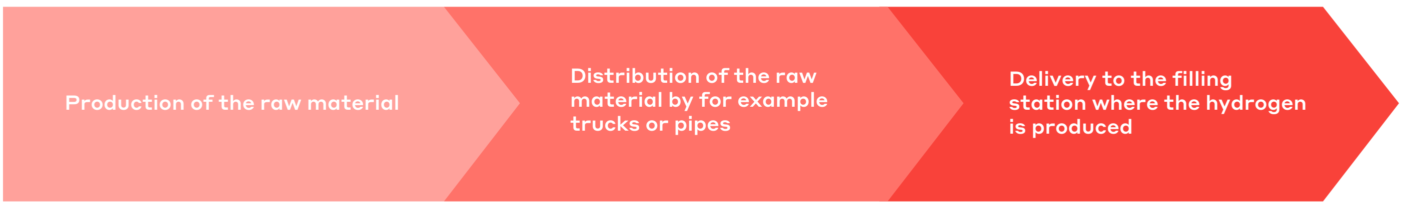
[2] Private customers are often billed through a combination of use and energy-based fees, while high-consumption industries often operate with capacity-based tariffs.

[3] To maintain grid stability, grid companies must supply demanded power while simultaneously working towards decreasing peak demand.

Centralized hydrogen production



Decentralized hydrogen production



Expertise in regulatory matters and experience in breaking down utility pricing structures can help transit network stakeholders to design tariffs and to manage energy consumption demand and behaviour more efficiently.

Charge Management

For larger battery electric fleets, agencies will typically deploy an energy management system 4 to monitor and control the charging process. Smart charging management systems can be applied to all charger types and can enable presetting of maximum power usage limits while providing real-time statistics on the status of charging equipment and practices. Expert guidance in the planning and deployment of charge management systems can help ensure a flexible system that enables scalable implementations over multiple phases of ZE fleet growth.

On-site Power Generation

Complete dependency on power from the grid places transit operations at risk from power outages. While providing double-ended, on-site substations can increase redundancy and resiliency by obtaining redundant feeds from two separate utility circuits, on-site power generation can ensure against large-scale outages.

4

Energy management systems can link together several transit operations systems, including fuel management, yard management, vehicle maintenance tracking software, facility maintenance, and more.

On-site generation can also help mitigate the need for extensive power upgrades and the resulting capital costs of bringing additional power to a depot site. Additionally, any excess in production can be sold back to utility companies to create an additional revenue stream for agencies.

Microgrids

A combination of on-site power generation and in-house energy storage can produce a microgrid capable of charging ZEVs. A variety of sophisticated microgrid blueprints are emerging, allowing energy sources, such as solar power, to generate charging capabilities without connecting to the existing grid.

Experts engaged in research on power generation solutions and emerging technologies can help transit providers determine the right course of action for leveraging the potential of microgrids. Pilot projects in Denmark, the Netherlands, the UK, and the US are being closely monitored, with grid operators investing in battery energy storage projects that could provide additional value in terms of their grid balancing capabilities.

Power Contingency Plans

Power outages caused by extreme weather, natural disasters, or technical failures must also be considered, requiring thorough and robust contingency plans designed to limit service interruptions and ensure ongoing maintenance of operations. Agencies and cities must also reconsider disaster planning and evacuation to accommodate vehicle range, infrastructure, and refueling times characteristic of ZEV technologies.

Experienced professionals can assist stakeholders in designing and implementing region-specific safety and contingency strategies [5] to prepare for such occurrences. Strategies can include redundancy of microgrids and other sources of on-site power generation that address the inherent risks of power outages and help minimize network interruptions.

5

Strategic placement of distributed and redundant infrastructure to support operations during local power outages is among the most effective contingency strategies being deployed to support ZEB refueling.

Change management *Keeping pace with technological evolution*

Around the world, private companies and public agencies alike are incorporating emission reduction into their investment and business strategies, [1] laying foundations for a future targeting new efficiency opportunities, resilient new infrastructure, and the leveraging of sustainable economic development possibilities. Transitioning to a world of zero emission will affect all aspects of the transport industry, and the willingness of transit providers to develop proactive measures and to implement innovative solutions is essential if providers are to keep pace with evolving stakeholder expectations. As part of that process, providers must recognize that managing organizational change [2] is a key component of any strategy to advance zero emission technology adoption.

Transitioning from fossil fuels to ZE technology will inevitably introduce new market players in a variety of sectors and capacities, but transit organizations must ensure that they themselves acquire the technical knowledge and skills that are relevant to understanding, operating, maintaining, and troubleshooting their ZE fleets. This will require appropriate training at all levels of the organization, including management, service planners and schedulers, operations supervisors and dispatchers, drivers and mechanics, and facility operations and maintenance staff.

1

Many companies with business strategies espousing emission reduction targets and conversion to renewable energy are demanding change throughout their supply chains.

2

As organizations effect change, they communicate to stakeholders, including investors, customers, and policymakers, that a future powered by renewable energy is viable.

Service Planning and Scheduling

Until now, service planners and schedulers have focused on optimizing vehicle and driver utilization with little need to consider limitations on vehicle range and fueling requirements. However, with most currently available ZE technologies, vehicle range limitations need to be considered, as well as scheduling times for charging batteries, either en route between trips, or in the depot during night time or midday periods when service is reduced. As ZEVs begin to represent a larger share of an agency's fleet, range limitations could require larger fleets to meet existing service needs. Modelling of the capabilities of the latest ZEVs on an agency's route network may be needed to inform vehicle procurement decisions, and advances in scheduling software are emerging to assist in building schedules that take range limitations and charging requirements into account. Supervisors and dispatchers will also need to be aware of range limitations and charging requirements when assigning ZEVs to the agency's services.

Operations and Maintenance Training

The amount of training that is needed for the transition to ZE fleets will depend on staff familiarity with the technology. Driver training on ZEV regenerative braking and acceleration characteristics is needed in order to achieve expected operational efficiencies, as well as training in en route charging protocols. Additionally, facility staff training must focus on charging and fueling requirements, developing a thorough understanding of depot charging protocols, and proper overnight parking configurations and procedures. While the amount of maintenance training needed will depend on the particular technologies adopted, at a minimum this will require knowledge and skillsets relating to electric traction motors, inverters, batteries, and high voltage, as well as electrical safety training. Proper training can ensure that all required high voltage safety procedures, personal protective equipment (PPE), and specialized tools are in place.

Expert guidance can assist with development of new standardized maintenance procedures, as well as standardized operating procedures and training for battery charging or hydrogen fueling. Additionally, training for emergency responders and utility workers should be provided to ensure that, in the event of an accident, potential high voltage and chemical hazard factors are accounted for.

Consultant expertise can be leveraged during the RFP and contract negotiation processes for vehicle procurement, assisting agencies in establishing requirements for OEM-provided training. Further guidance can be provided during development of comprehensive training programs, including secondary training programs that leverage the newly acquired knowledge and skills of key personnel in order to conduct further training [3] of mechanics and other labour resources internally.

Labour agreements and staffing levels

The skillsets required to manage and maintain a fleet of ZEVs could well be very different from those required for conventional fuel vehicles. Managing the transition to ZEVs will require labour negotiations, as changes associated with ZEV adoption will inevitably alter the scope of work assigned to drivers, mechanics, and facility staff. Working with high voltage equipment, participating in newly required training programs, [4] attaining new certifications, and subsequent new staff classifications will all require adjustments to existing labour agreements. Additionally, as ZE fleets expand, agency staffing levels, in conjunction with changing labour requirements, must be evaluated to ensure appropriate levels of coverage.

3

While OEMs provide related operating and maintenance manuals, additional training can be procured through third-party institutions.

4

Required training should focus on zero emission-specific electrical systems, as other standard electrical features are similar to existing diesel fleet counterparts.

Expertise in labour management negotiations can assist management teams in conducting thorough assessments of existing collective agreements in order to clearly determine the impacts of adopting ZE technology. Additional assistance can be provided for developing new internal labour classifications, as well as in the restructuring of labour resource requirements in accordance with fleet expansion and future ZE technology adoption strategies.

Planning for change

Consulting with industry experts in zero emission technology can help transit providers develop a change management process. Strategic advice and thorough assessments of organizational gaps can help transit providers ensure an efficient and effective transition. Expertise in negotiations with external stakeholders can also help facilitate a smooth transition, particularly with respect to utilities who must be part of the conversation. Consultants can assist organizations in orchestrating and implementing internal shifts in corporate culture, policies, and practices, which is a critical step for facilitating the transition for existing management and staff. Having a change management plan in place that incorporates all facets of the transition to ZEVs will streamline the process and overcome many of the potential obstacles to change.

Conclusion

Zero emission transition: Breaking ground on the road to a cleaner, more efficient future

The pace at which change is occurring in the transit industry leaves very little room for procrastination.To keep pace, proactive measures must be taken across the entire landscape, requiring new levels of cooperation, revamped business models, industrial innovation, focused research, experimentation and short- and long-range planning.

Through a future-ready planning approach, transit agencies can address environmental concerns and move towards a bright future of greater operational efficiency and continued benefits to people and communities whose world of mobility depends on public transit. The process of working towards a large-scale ZE transition today will also help prepare agencies internally for the implementation of future innovations further down the road that will continue to drive the leading edge of the transit industry.

As years of investment in research and development of ZEVs and supporting infrastructure continues to bear fruit, more affordable and accessible technologies are entering the market on an increasingly frequent basis. For example, as battery life increases, and battery size and weight decreases, transit agencies are benefitting from increasingly cost-effective options capable of covering the range and scope of their network operations. A smooth transition to zero emission operations also relies heavily on the advancements of external players, and that process will require close collaboration in order to ensure advancement of all facets relating to zero emission operations.

Beyond being a mode of transportation, public transit is a community-building tool that influences investment decisions and fosters economic development and revitalization.

The business case for ZE technology adoption continues to grow with every advancement, and its future opens the door to extensive operational benefits over the longer term, as the cost of purchasing, operating, and maintaining ZEVs eventually decreases. ZE transit systems offer sustainable solutions, including increased energy efficiency, long-term economic benefits, and carbon emission reductions that allow the planet to breathe easier.

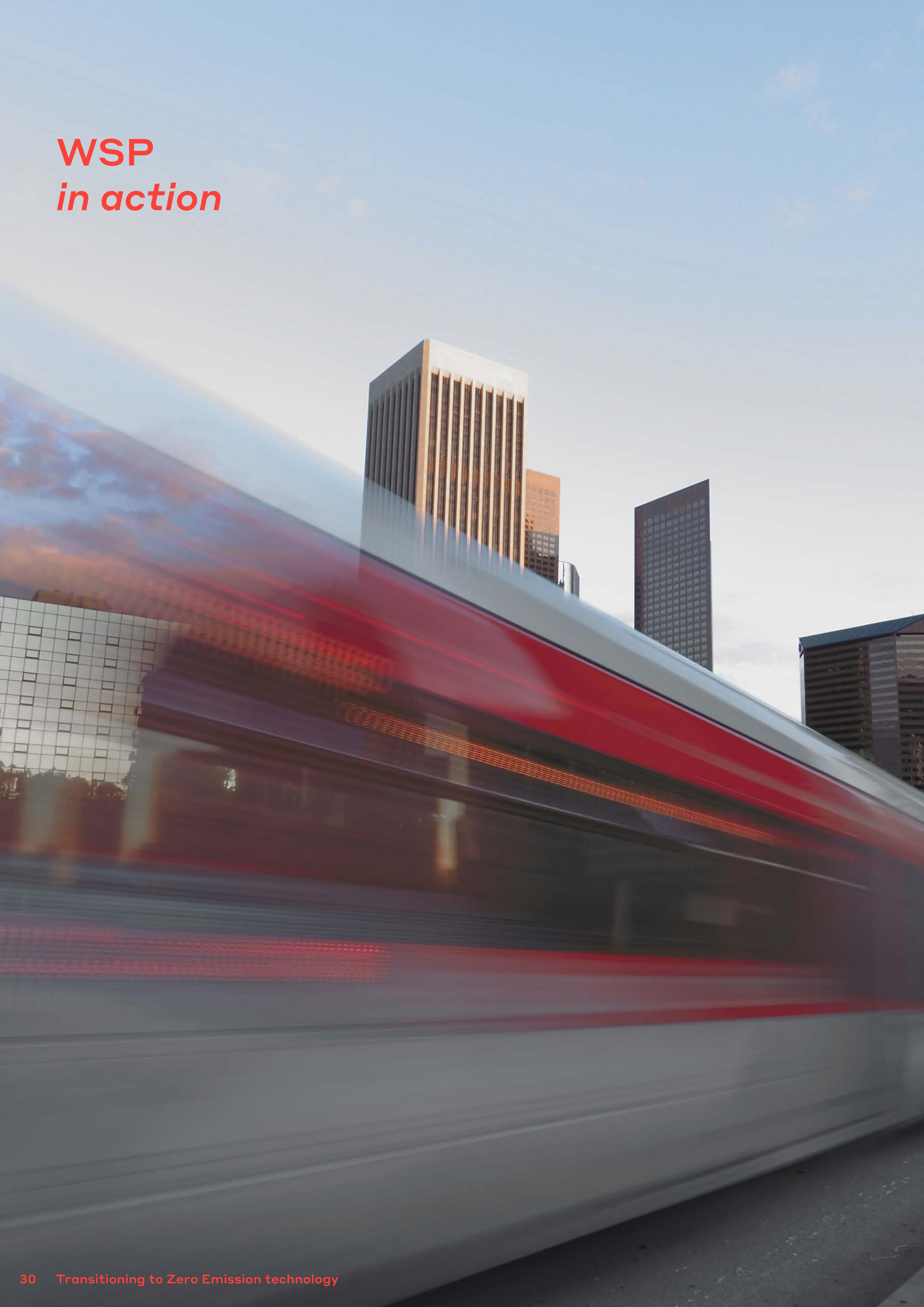
WSP is a global leader in low and zero emission vehicles and has assisted both large and small transit agencies on all continents with optimizing operations and adopting new technologies. Our expertise, accrued over many years, has fostered a holistic approach to transit planning, design, and management, combining depth of experience with the adaptability and responsiveness required to guide government and private sector stakeholders through challenging programs.

WSP experts can guide transit agencies through the full lifecycle of ZE transition, from developing short-term pilots and long-term transition plans, to designing procurement strategies, and recommending steps for large-scale implementation. Our expertise extends to the energy sector, with professionals around the globe involved in research and development of innovative solutions for our clients.

We also possess the experience and know-how to facilitate stakeholder relations, and to facilitate shifts in organizational culture in order to ensure a smooth transition at all levels.

The road to tomorrow begins today, and WSP has the experience and expertise to accompany you along every step of your journey.

WSP
in action



California, USA

LA County Metro ZEB Master Plan

Working on behalf of the Los Angeles Metropolitan Transportation Authority (Metro) and in joint venture with STV, WSP is creating an analysis of Metro's network of 165 bus and bus rapid transit routes and 11 maintenance facilities, making recommendations for the procurement of a new bus fleet, and performing conceptual designs of the modifications at facilities necessary to support the fleet. The master plan provides a year-by-year schedule that will help Metro achieve a 100-percent zero-emission bus (ZEB) fleet by their target of 2030 (10 years before the State's mandate). It includes also recommendations regarding training, safety planning, disaster planning, and cyber security for the bus fleet.

It is the largest such commitment to a ZEB fleet in the U.S., and one of the largest in the world.

As the master plan creates a time table for transition to a fully electric fleet, planners are also evaluating existing routes to determine if they need to be modified to accommodate these vehicles. One of the key challenges with the master plan centers around the battery charging capabilities for each ZEB. To meet current and future needs, the master plan also assesses the feasibility of using existing passenger transfer and layover facilities as en route charging locations.

Advances in smart technology could also help networks like Metro's evolve and adapt into a more efficient and responsive system for commuters. For example, the ability for the vehicles to be monitored for passenger information, real time dynamic monitoring and vehicle-to-vehicle technology are working their way into these buses today; these and other systems will be better integrated to manage energy consumption in the future.

King County,
Seattle, WA, USA

Zero Emission Bus Implementation Analysis

Transportation is responsible for half of all carbon emissions in King County. King County Metro is responding to this challenge in a multitude of ways. An important first step in achieving the agency's climate goals has been to dedicate resources and leverage federal funds for electric bus fleet purchases. In April 2016, the King County Council passed Motion 14633, which took these initial steps further by directing King County Metro to develop and transmit a feasibility report that identifies and analyzes strategies for and barriers to achieving a carbon-neutral or zero emission vehicle fleet by 2040. Metro received a USD 3.3 million Low or No Emission Vehicle Deployment Program (LoNo) grant from Federal Transit Administration (FTA) that has helped to fund the purchase of eight additional battery electric vehicles and associated charging infrastructure.

As a subconsultant to Metro's consultant team, WSP provided technical assistance to develop short- and long-term plans for transition to a zero emission fleet. The analysis also informed Metro's next revision to its Long-Range Transit Plan.

Keeping the Future Ready approach in mind, the analysis addressed how current and future technology improvements are likely to affect issues of cost, range, battery life, and types of vehicles available. It also covered all aspects of charging technology and the impact on service characteristics, life cycle cost, and procurement issues, including an analysis of en route and depot charging technologies. Finally, it helped identify and evaluate the significance of technology, policy, market and commercial barriers to deployment of advanced vehicle designs, including advanced propulsion technology.

Lima, Peru

Lima e-Bus Feasibility Study and Pilot

In 2017, WSP was retained by Global Sustainable Electricity Partnership (GSEP) to conduct a feasibility study for introducing electrified urban public transit via battery electric buses (BEBs) in Lima, Peru. The project objective was to study the feasibility of fully incorporating a BEB into a public transit line. WSP analyzed and evaluated the potential for piloting electric buses using its proprietary simulation Battery Optimization and Lifecycle Tool (BOLT). WSP also developed a Total Lifecycle Cost for electric buses comparing the benefits of maintenance and capital costs over the complete lifecycle of the vehicle along with considering socioeconomic and environmental benefits such as emissions and noise reduction.

Furthermore, WSP developed a BEB technical specification which was both performance-based and compliant to local Protransporte vehicle requirements. WSP also provided support with the deployment of a quality assurance inspector to the bus manufacturing facility in China.

To coincide with the launch of the BEB on Route 201 along the Javier Pardo Corridor, WSP developed a pilot strategy to collect data over the 2-year pilot period and feed this data into a Replicability Report to determine the scalability of further BEB adoption. Data collection includes vehicle maintenance records, real time energy consumption, performance monitoring as well as driver and customer feedback.

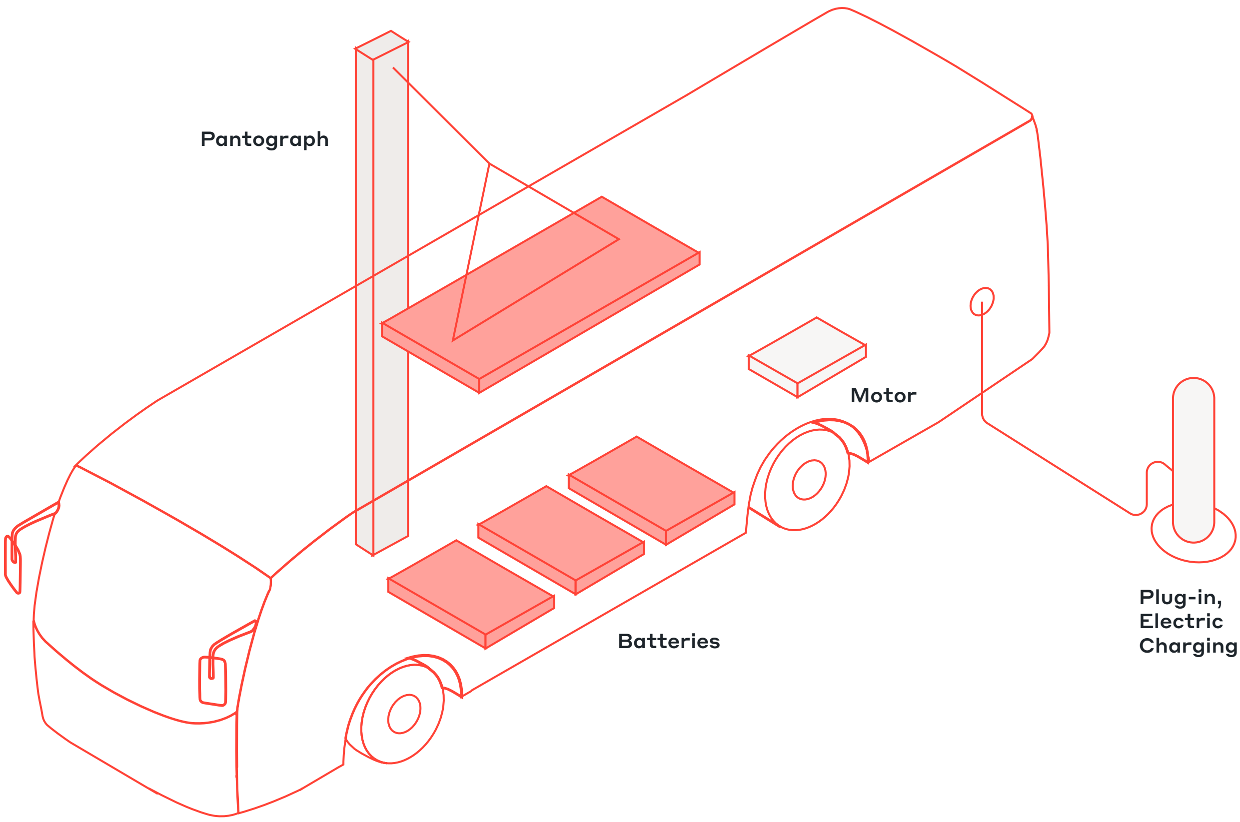
WSP has also performed a site assessment of the Patio where the BEB will be parked and charged in order to bring forth recommendations for improving safety and operational aspects of the pilot. Leading up to the launch, WSP provided a three-day training segment on-site in Lima to local operators and stakeholders of the project. These covered lessons learned from BEB deployments around the globe as well as diving into implications for BEB maintenance, safety, charging infrastructure and impact to operations.

Linköping, Sweden

Electrification of bus transport

In 2018, WSP was mandated by Östgötatrafiken, the public transport agency in Östergötland province, Sweden, to investigate how electrification of bus traffic in the city of Linköping could be achieved, which would serve as a knowledge base for future agency decisions. WSP approached the task in three phases, beginning with a detailed investigation of multiple scenarios for the introduction of electric buses. The second phase focused on how further electrification could be achieved in relation to the aforementioned scenarios, while the final phase studied procurement issues that would need to be addressed ahead of introducing electric buses during the next contract period. Within that framework, WSP conducted literature reviews and interviews with market participants and key stakeholders, and held workshops and meetings with Östgötatrafiken.

WSP's investigation concluded that electrification in Linköping could be achieved without incurring significantly higher costs, and also identified the potential risks of such a transition. WSP also determined that the city's electricity grid would be capable of handling the additional energy demands of electric bus operations. In summary, WSP's report provided an impact analysis of the cost of introduction, environmental impacts, energy usage, and impacts on the electricity grid.



Stockholm, Sweden

Electric transport Stockholm 2030

As part of an initiative to accelerate transition to ZE transport, WSP was commissioned by several industry players, including Vattenfall, Ellevio, Volkswagen, and Scania, to develop an action plan for the electrification of all mobility in the Swedish capital of Stockholm. The ambitious plan covers all types of mobility, including private cars, commercial transport, and heavy equipment.

In collaboration with various stakeholders, the WSP team mapped out future challenges and opportunities related to transition to a fully-electrified transport system, with economic, environmental, and social sustainability factors forming the foundations of the plan's activities and milestones.

Several innovative solutions were proposed for addressing the groundbreaking challenge of electrifying all transportation within a city center as large as Stockholm, including assessments of how logistic centers could be used to transfer goods from conventional vehicles to smaller electric vehicles. The action plan identified necessary legislative and regulatory changes, proposed innovations, and outlined the type of infrastructure that the endeavor would require. Additionally, WSP identified consequences that various sectors, and society itself, will likely encounter in respect to implementation of the recommended steps of the action plan.

Leveraging global expertise in smart cities, sustainability, and much more, WSP professionals from Sweden and around the world collaborated on this project to provide a clear understanding of the complexity of future challenges, and to propose new future-ready ideas for capitalizing on the endless possibilities that current and future technology can provide.

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