Zero Emission Bus Jurisdictional Review

Final Report

January 2022

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Executive Summary

With the transportation sector accounting for 25% of Canada's greenhouse gas (GHG) emissions, the adoption of Zero Emission Vehicles (ZEV), such as the Battery Electric Bus (BEB) and the Fuel Cell Electric Buses (FCEB), will play in a critical role in the sector's energy transition and climate change initiatives. In addition to the implied environmental benefits, Zero Emission Buses (ZEBs) can also result in lower operating costs due to the reduced maintenance requirements and efficient energy management. While the adoption of ZEBs has been expanding and accelerating, it continues to be a challenge at the commercial level. This is primarily due to its high initial capital cost and the lack of supporting infrastructure.

To that effect, many federal and state/provincial level governments are stepping in with **subsidies or dedicated funding programs to remove adoption barriers**. Over the last decade, Canadian transit systems have procured over 250 ZEBs through existing programs, primarily through the Public Transit Infrastructure Fund (PTIF). The federal government also recently committed to supporting the procurement of an additional 5,000 ZEBs through the Zero Emission Transit Fund. By contrast, ZEBs currently make up 2% of the United States' (U.S.) bus fleet. This has been enabled through numerous dedicated federal, state and local government funding grants, programs and tax breaks. Recent bill announcements from the federal government, such as the $73B USD Clean Transit for America plan, also demonstrate a continued and sustained effort for ZEB adoption. Other parts of the globe also offer similar funding programs to broadly support ZEB adoption as well as targeted marquee pilot programs. For example, the European Commission (EC) introduced a state aid scheme, the European Clean Bus, which incentivizes countries to invest in ZEBs. While adoption rates still vary, programs such as these has enabled Denmark to lead ZEB adoption in Europe with ZEBs making up 78% of its bus fleet, and Luxembourg and the Netherlands following closely behind at ~67%. It is evident that government support through sustained and dedicated funding programs, that cover the entire vehicle lifecycle, will be required to accelerate the transformation of transit bus fleets.

Funding programs are usually underpinned by **policy and legislative initiatives aimed at meeting emissions targets** through the expansion and acceleration of ZEV adoption. Although the Paris Agreement's targets is setting the broader timelines driving ZEB fleet conversion, it has largely been left to Canadian municipalities and their transit systems to make commitments and set policy on conversion timelines. The Canadian Net-Zero Emissions Accountability Act commits the country to be net-zero emissions by 2050 in order to meet its Paris Agreement commitments. However, there is currently no policy or regulation that dictate transit systems' transition to ZEB fleets by a given date. Meanwhile in other parts of the globe, jurisdictions with strong environmental regulation have set mandates to accelerate ZEB adoption. For example, in the U.S., a number of states have put in place regulations requiring partial fleet conversion by 2030 and full fleet conversion by the 2040-2050 timeline.

Another key driver in the adoption of ZEBs has been the utilization of innovative **business and procurement models** to acquire vehicles and develop the associated supporting infrastructure. While the traditional model is still the main procurement approach amongst transit agencies, many jurisdictions are demonstrating that partnerships between transit agencies, OEMs, utilities and energy companies can help facilitate risk-sharing and reduce costs. Other **innovations** include the **recycling of batteries** through an emerging secondary market, **leasing options** for batteries and/or buses, and the **repowering of existing diesel or CNG powered fleets** into fully electric systems. In addition, non-for-profit organizations and post secondary institutions are also partnering with industry players to perform research, address challenges, and support ZEB deployments through data-driven decision making. These innovative solutions and advancements are driving the evolution of a ZEB ecosystem, that will form the cornerstone of the transportation sector's decarbonization strategy, as jurisdictions strive to achieve emission targets.

2. Market Overview

2.1
Technology/
Commercial Maturity

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Benefits of ZEBs

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Industry Trends

2.1 Technology/Commercial Maturity

Zero emissions buses have a long history on Ontario streets. In 1921, **Windsor** became the first city to trial the new technology through **electric trolley buses**, with Toronto following suit in 1922. Others like Ottawa had their try, but numbers dwindled until the last trolley buses left Toronto's streets in 1993.[1,2]

By the mid 2000s, the first generation of **diesel-hybrid** buses entered service, ushering in the new era of **lower-emissions** transit buses. It wasn't until the second generation of the technology in the mid-2010s that a number of transit systems brought diesel-hybrids into their fleets in high numbers. More recently, **clean-diesel** buses have created yet another option for transit systems to lower the emissions of their fleets.

But it has been **battery-electric** buses that have come to the forefront as the primary choice for transit systems across Canada to enter into the world of ZEBs. Although some view **fuel-cell electric** buses as an alternative and/or complementary solution.

Technology Maturity

Battery-Electric Buses (BEB)

H_2 Hydrogen Fuel Cell Electric Buses (FCEB)

Although BEBs outnumber FCEBs on the road today, both in Canada and abroad, there are advantages to each that suggest they will both make up Canada's future ZEB fleets. BEBs are more widely available and current batteries are well suited to the duty cycles of shorter urban roots. FCEBs offer the ability to use traditional fueling infrastructure while offering longer ranges that align well with longer suburban or inter-urban routes. As both battery and fuel cell technology continues their rapid evolution, its anticipated the cost of each will continue to decline.

BEB suppliers include traditional players such as New Flyer, NovaBus, and VMC as well as a number of new entrants such as, GreenPower, Proterra and BYD who are taking advantage of the increasing opportunities over the last few years. Meanwhile in the FCEB market, leading companies are focusing on strategic collaborations and partnerships with traditional manufacturers to gain a competitive advantage, with many also being BEB suppliers. Key players in the FCEB market include Ballard, Alexander Dennis, New Flyer, Van Hool, Caetanobus SA, EvoBus (Daimler AG), Solaris and Wright Bus. [3,4]

Commercial Maturity

Although the technology's maturity continues to swiftly rise, in Canada the commercial maturity is advancing more slowly. To-date most of Canada's ZEB procurements have been on a smaller scale, particularly compared to what a transit system is otherwise purchasing annually to turn over its fleet. [5] Also, most public sector organizations are more comfortable in traditional forms of procurement, with innovative delivery models and contracting strategies more often seen at the provincial rather than municipal model. That said, as described more in this review, there are interesting opportunities available in new business models, partners and multi-party agreements that can help accelerate conversion to ZEBs.

2.2 Benefits of ZEBs

The many benefits of ZEBs are well documented, but they bear repeating.

Energy Costs

Many transit systems have seen significant cost savings from energy costs of electricity compared to traditional diesel fuel, with reduced exposure to volatility. [6]

Air Pollution

ZEBs eliminate ground level air pollution, reducing the health risks for community residents and eliminate the negative impacts of idling.[6]

Comfort

ZEBs have a smoother ride and less vibration, which benefit both operators and riders, providing a much more comfortable ride. [3]

GHG Emissions

With transportation accounting for 25% of Canada's GHG emissions, ZEBs are a requirements for Canada to meet its 2050 net zero GHG targets. [3,5]

Maintenance

With so many fewer moving parts, manufacturers forecast maintenance savings of ~25% over internal combustion engine vehicles.

Noise

ZEBs reduce noise pollution, both for riders and operators inside the bus or in terminals, but also for the general public along its routes. [3]

2.3 Adoption Challenges

Cost remains the highest barrier, but governments are stepping in to help out.

Infrastructure

BEBs require sometimes costly electrical upgrades and charging infrastructure, adding to the upfront capital investment required. [6]

Facilities

Many transit systems have bus garage facilities where door heights, ceiling heights or lift clearances may not allow for bus maintenance without renovation.

Bus Cost

ZEBs still cost between 25% and 50% more per bus than comparable diesel or diesel-hybrid buses in upfront capital costs. [6]

Range

Although FCEBs can allay many of the range concerns, for many transit systems, current BEB ranges may not meet the needs of all a system's routes. [6]

People

While ZEBs may have reduced maintenance requirements and resources needs, significant workforce training and upskilling will be required to address skill gaps. [3]

2.4 Industry Trends

Adoption is expanding and accelerating. These trends are explored throughout this report.

Active Utilities

Utilities are stepping up to expand their customer based and drive investments that will support broader adoption of electric vehicles. [3]

Falling Costs

Battery, component, solar and equipment costs continue to fall, with some expecting price-parity between diesel and ZEBs by mid-2020s and latest by 2030. [5]

Policy

Most major transit systems are setting full ZEB conversion targets between 2035 and 2040, with some ending non-ZEB purchases by the mid 2020s. [6]

Partnerships

Transit systems are entering into more novel and innovation agreements with vendors and contractors to better share risk and offset capital costs. [6]

Funding

Federal and provincial/state level governments are stepping in with subsidies or dedicated funding programs to remove adoption barriers. [5,6]

3. Funding Programs

Current State:

3.1 **Canada**

3.2 **United States**

3.3 **Globally**

Opportunities

3.4

Although funding programs differ across jurisdictions, one thread connects them all - a recognition that municipalities and their transit systems require support from higher orders of government. That help can come in the form of dedicated funding programs or per-vehicle subsidies that enables the purchase of buses and the systems to support them.

3.1 Current State - Canada

Over the last decade Canadian transit systems have procured over 250 ZEBs, predominantly through existing programs with an emphasis on transit and for green infrastructure.

Federal - Public Transit Infrastructure Fund (PTIF)

The earliest ZEB projects in Canada received partial funding through the federal PTIF program, first introduced in 2016. In addition to major expansion projects and infrastructure state of good repair, cities like Toronto, Edmonton and Ottawa directed the funds to their ZEB fleet. At the TTC, funding for bus state-of-good repair was redirected to ZEB buses and the initial charging infrastructure at three garages. [7]

Federal - Canada Community-Building Fund (CCBF)

Formerly know as the Gas Tax Fund, the CCBF is a permanent source of funding provided twice-yearly to municipalities to support local infrastructure. The $2 billion CAD annual funding can be applied to 18 different project categories, one of which is public transit. Many Canadian transit systems allocation a portion of this funding to support their ongoing capital programs, including bus procurement. [8]

Federal - Zero Emission Transit Fund

In the summer of 2021, the federal government committed to the help purchase **5,000 ZEBs** over the next 5 years through the **$2.75 billion CAD** Zero Emission Transit Fund. Starting in 2021, the fund will be disbursed to both public transit systems and school bus operators to purchase ZEBs and build supporting infrastructure including chargers and facility upgrades, marking the first dedicated federal funding outside of the CIB. [9]

Federal - Canada Infrastructure Bank (CIB) – ZEB Initiative

In 2021, the CIB made ZEBs a central component of its 3-year growth plan, committing **$1.5 billion CAD** to financing conversion of bus fleets to ZEBs. The initiative offers financing through direct loans that cover the incremental cost of ZEBs and their charging infrastructure relative to diesel buses. The repayment of the loans comes solely from the actual savings generated by the lower operating cost of ZEBs, with the CIB sharing cost savings with the transit system at a fixed proportion. The CIB and transit systems will share the risk if the actual cost savings are less than forecasted, with the CIB taking the associated repayment risk. [10]

The intention is to accelerate the adoption of an estimated 4,000 ZEBs across the country. Thus far, it has been announced that **Brampton Transit** and **OC Transpo** will each receive **$400 million CAD** to finance the purchase of 450 ZEBs each by 2027.

Federal / Provincial / Municipal – Investing In Canada Plan

Thus far, Canadian provinces' contributions have largely been centered on matching funds from federal agreements rather than targeted funding for ZEBs specifically. The Investing In Canada plan (2016-2021) includes a focus on both transit and electric vehicle funding. **Cost-sharing** agreements for public transit see the federal government providing **up to 50%** for rehabilitation projects and **up to 40%** for new public transit construction and expansion projects, with provinces required to cost share **at least 33.33%** of municipal projects. [11]

In BC, provincially-run **BC Transit** provides municipal transit services outside of **TransLink's** purview in the Lower Mainland, and has included ZEBs in their core capital program. Québec's *2030 Plan for a Green Economy* dedicated $276M to city and intercity buses.

Similar to provincial funding, municipal ZEB funding has been focused on matching commitments from other levels of government.

3.2 Current State - United States

ZEBs currently make up 2% of the US's transit bus fleets. Much like Canada, the federal government is leading the way in funding and tax breaks, with state and local governments matching a number of programs.

Federal

Battery electric buses made headlines in mid-2021 as a key component of the **$1.2 trillion USD** infrastructure bill. That legislation allocates $7.5 billion (USD) in dedicated electric bus initiatives, although the Center for Transportation and Environment (CTE) estimates it would take between $56 billion and $88 billion (USD) to fully transition the US's transit bus fleet to zero emissions.

In May 2021, Democratic Senators introduced the **$73 billion USD** *Clean Transit for America* plan to replace 70,000 transit buses and 85,000 cutaway/transit vans. [12]

Beyond the bill announcements, a variety of federal departments, administrations and agencies have grants and programs that have been used for ZEB projects, including the following [13]:

Agency	Funding Mechanism
United States Department of Transportation (USDOT)	Rebuilding American Infrastructure with Sustainability and Equity (RAISE) grants, formerly known as BUILD and TIGER
Federal Transportation Administration (FTA)	Bus and Bus Facilities Discretionary Grant; Capital Investment Grants; Low-or No-Emission Vehicle Grant
Federal Highway Administration (FHWA)	Congestion Mitigation and Air Quality Improvement Program
Environmental Protection Agency (EPA)	Environmental Justice Collaborative Program-Solving Cooperative Agreement Program

State Level

At the state level, the funding programs are less consistent. Unsurprisingly, **California** leads the way in terms of dedicated state funding for ZEBs, with multiple entities providing funding mechanisms including the following [14]:

Agency	Funding Mechanism
California Air Resources Board (CARB)	Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP); Carl Moyer Memorial Air Quality Standards Attainment Program
California Transportation Commission (CTC)	Solution for Congested Corridor Programs (SCCP)
California Department of Transportation	Low Carbon Transit Operations Program (LCTOP); Transportation Development Act; Transportation Development Credits

In many states, most electrification programs are additive to the federal funding, but a number have also created dedicated funding streams of their own.

- **Illinois Environmental Protection Agency (IEPA)** transportation electrification grants
- **New York State Department of Environmental Conservation (NYSDEC)** Municipal ZEV Program's per-vehicle grants.
- **Hawaii Green Infrastructure Authority** Green Infrastructure Special Fund, offering loans and a revolving credit line.
- **Massachusetts Department of Energy Resources'** Clean Vehicle Project, offering grants for public and private fleets.

A number of states have instituted one-time programs supporting electrification that have been funded from a **$2.9 billion USD** trust fund stemming from the **Volkswagen Diesel Emissions** settlement. This money was earmarked specifically to invest in green vehicle technology.

3.3 Current State - Global

Much like Canada and the US, a number of countries have institute federal and state/provincial level funding programs, both offering broad support and targeting marquee pilot programs.

United Kingdom

In 2020, the Department for Transport allocated £170 million in funding to improve services and make bus journeys greener, setting aside £50 million to transform one area into an all-electric bus city. Coventry submitted the winning bid and will receive the fund supported by an additional £75 million of investment from local bus operators to roll out 297 ZEBs, deport charging facilities and associated power upgrades.

More recently, the Department for Transport unveiled a **National Bus Strategy** for England that includes £3 billion of investment aimed at encouraging passengers to transition away from vehicles to buses. The funding will deliver up to 500 ZEBs with the intention of further funding disbursements to be added. [15]

Sweden

Sweden introduced the *Elbusspremien* as a funding program paid for by the Swedish Energy Agency in order to cover the incremental costs of purchasing ZEBs (battery electric, trolley or fuel cell) and plug-in hybrid buses. The funding of SEK 80 million per year through 2023 ($11.75M CAD) is intended to cover 40% of the cost difference on a per-bus basis. Transit systems also have access to the SEK ~1.5 billion ($220M CAD) annual *Klimatklivet* GHG-reduction investments fund. [16]

European Union

The European Commission (EC) introduced a state aid scheme in the form of the *European Clean* Bus whereby funding is provided to countries to incentivize ZEB investment. While adoption varies, Denmark leads ZEB adoption in Europe at 78% of its fleet, with Luxembourg and the Netherlands following at ~67%.

Under the EU's scheme, Germany has been provided with **€650 million** in total funding to be disbursed via subsidies that cover the additional costs for the purchase of electric buses compared to diesel buses.

In Poland, the funding has supported 130 ZEBs in Warsaw by providing **€42 million** towards the €94 million project. This upfront financing support allowed Warsaw to direct funds towards charging infrastructure.

The Île-de-France region that includes Paris has received **€23 million** in grants for ZEBs and the conversion of bus garages to electricity and bio gas.

Since 2017, the **European Investment Bank** has also been providing financing for ZEBs through its *Cleaner Transport Facility*, not unlike the CIB's initiative. Spain has taken advantage of **€200 million** in ZEB funding through a partnership between the EC and EIB. [17, 18]

Hong Kong, China

The Hong Kong Environmental Protection Department developed the **New Energy Transport Fund** to invest in both trial and commercially available solutions powered by alternative energy sources. Hong Kong's MTR has used the program to help fund a double-decker electric bus program. [19]

3.4 Opportunities

	Dedicated & Sustained	Decoupled from Variable Revenue	Operationalization of Costs
Opportunity	— Funding programs that are dedicated to ZEBs and their associated infrastructure. While these programs are primarily focused on capital expenditures, examples such as California's LCTOP cover operational costs as well. — Capital funding that is sustained through a typical vehicle lifecycle, to support transit systems in turning over their entire fleet.	— Decoupling ZEB-related funding from fuel tax based revenue tools. — Program shift has been addressed by multiple jurisdictions in the US and globally.	— Take advantage of the projected operational savings of ZEBs over their ~12 year lifecycle to help offset higher capital costs. — CIB's ZEB loan program allows transit systems to redirect a portion of their savings to pay down a capital loan.
Benefits	— Opportunistic funding programs can force transit systems to make a decision between disrupting an optimized steady-state fleet plan or forgoing available funding. A sustained program removes this risk. — ZEB programs will not compete with other municipal priorities as they do with non-dedicated funding.	— Jurisdictions recognize that fuel tax revenue will continue to decline, driven by increased fuel efficiency in existing vehicles, an increase in HEVs and PHEVs, modal shifts and the continued and accelerating adoption of EVs. — Decoupling protects the long-term viability of the funding stream.	— Transit systems can borrow from the CIB rather than within the debt ceiling of their respective municipalities. — Funding for the loans does not require increased municipal subsidies or increased fare revenue.
Issues / Considerations	— Transit systems need robust long-term integrated fleet plans to understand the vehicle, infrastructure and systems requirements unique to their system in order to properly quantify the long-term funding need.	— Fuel taxes are currently a primary sustained funding mechanism for transit system capital budgets.	— As announced, the program has a finite initial tranche of funding, a significant portion of which has already been allocated to systems including Brampton and Ottawa.

4. Policy & Regulatory Programs

Current State:

Opportunities

4.1	4.2	4.3	4.4
Canada	**United States**	**Globally**	

Although the Paris Agreement's targets set the broader timelines driving ZEB fleet conversion, it has largely been left to municipalities and their transit systems to make commitments and set policy on conversion timelines. In jurisdictions with strong environmental regulation, these entities have set mandates for conversion, accelerating ZEB timelines.

4.1 Current State - Canada

Canada has not seen higher orders of government mandate, through policy or regulation, that dictate transit systems' transition to ZEB fleets by a given date. Although broader emissions commitments imply a need for this transition to be complete by ~2040, it has been left to each system to commit to a timeline within their own policies.

Federal

In June of this year, the federal government passed the *Canadian Net-Zero Emissions Accountability Act*, which commits Canada to be net-zero emissions by 2050 in order to meet its Paris Agreement commitments.

At the federal level, Canada recently announced plans to ban the sale of internal combustion engine (ICE) cars **by 2035**, following the lead of a number of other countries. Beyond these public commitments however, Canada does not have federal policy or regulations that specifically address ZEBs or an expected timeline of their adoption.

Instead, Canada's focus has been on incentivizing adoption, largely through funding programs or the CIB's financing initiative. [20]

Provincial

The provinces have largely taken a similar path to the federal government, without making firm commitments to full ZEB conversion of municipal transit fleets within their borders. Some, have developed plans for a greener future, like Québec's *2030 Plan for a Green Economy*. The plan is predicated on a 37.5% reduction in GHG emissions in 2030 over 1990 levels, and resulted in a specific commitment to having **55% of city buses** and **65% of school buses** electrified by 2030. [21]

BC Transit, responsible for all municipal transit outside of the Lower Mainland, has committed to a fully ZEB fleet by 2040, with a >60% reduction in GHG in 2030 compared to today. [22]

Municipal

Without provincial requirements, it has largely been left to municipalities to make their own commitments to a reduction in GHG emissions. [5]

- **Toronto – TransformTO:** GHG reduction target of 65% by 2030 and net zero by 2050; TTC commitment to a zero emission fleet by 2040 and only ZEB procurements after 2025. [23]
- **Ottawa – OC Transpo:** Commitment to a zero emission fleet by 2036. [24]
- **Mississauga – Climate Change Action Plan:** GHG reduction target of 40% by 2030. [25]
- **Vancouver – Metro Vancouver 2040 Vision:** GHG reduction target of 45% by 2030, and carbon neutral by 2050. [26]
- **Montreal – STM:** Commitment to a zero emission fleet by 2040 and only ZEB procurements after 2025. [5]
- **Edmonton – Change for Climate:** GHG reduction target of 35% by 2035. [27]

4.2 Current State - United States

A number of states have put in place regulations requiring plans or accommodation for ZEBs or electrification infrastructure.

California Air Resource Board (CARB) - Innovative Clean Transport Program (ICT)

The most aggressive regulation in the US on ZEBs comes from the CARB's ICT program, which will **require all public transit agencies in the State of California to transition to ZEBs (battery-electric or fuel cell electric) by 2040**.

The regulation requires a progressive increase in new bus purchases to be zero-emission buses (ZEBs) based on the transit agency's fleet size. A transit agency is considered to have a large fleet size if it operates at least 100 buses in annual maximum service, excluding demand response buses, in an urbanized area with a population of at least 200,000. All others are primarily considered to be small agencies.

Large fleets must have **25%, 50% and 100%** of new bus purchases being ZEB by **2023, 2026 and 2029** respectively. Smaller fleets must have **25% and 100%** of new bus purchases being ZEB by **2026 and 2029** respectively. [28]

Zero-Emission Transit Bus Tax Exemption

In California, ZEBs are exempt from state sales and use taxes when sold to public agencies eligible for Low Emission Truck and Bus Purchase Vouchers. The exemption serves as further financial incentive aimed to reduce the incremental cost of qualified electric, hybrid, or natural gas buses at the time of purchase. [29]

Utility-related Regulations

Utilities are launching programs to incentive the purchase and installation of electric vehicle service equipment (EVSE), both for residential and commercial usage, with some being driven to by their state legislatures. [30]

— **New Jersey:** A 2018 senate bill allows utilities to propose the development and operation of electrical infrastructure as well as financing plans, financial incentives, rate designs and tariffs.

— **Florida:** A 2020 senate bill requires to actively engage in EVSE planning and plug-in electric vehicle (PEV) deployment rather than establish any utility programs.

— **Utah**: A 2020 house bill allows the Public Service Commission to establish an EVSE program with utility-owned infrastructure and associated rate structures, but also requires the state to provide funding.

Zero-Emission Bus Acquisition Requirements / Commitments

States are implementing bus acquisition requirements aimed at transit agencies. [29]

— **15 States:** California, Connecticut, Colorado, Hawaii, Maine, Maryland, Massachusetts, New Jersey, New York, North Carolina, Oregon, Pennsylvania, Rhode Island, Vermont, Washington and the District of Columbia signed on to have 30% of heavy duty vehicle sales (including buses) zero-emissions by 2030 and 100% by 2050.

— **Arizona:** Requirement for local governments in select counties with populations of more than 1.2 million people to develop and implement green vehicle fleet plans >500,000 population local governments required to purchase or convert buses to operate on alternative fuels.

4.3 Current State - Global

Globally, different levels of government have been more active in mandating the purchase of ZEBs. But adoption is still largely been driven by municipal or state/provincial commitments that have been adopted through policy.

United Kingdom

The **National Bus Strategy** promises to deliver 4,000 new British-built electric or hydrogen buses, transition cities and regions across England to emission-free buses and end the sale of new diesel buses. As part of the strategy, the Department for Transport launched the Zero Emission Bus Regional Areas (ZEBRA) scheme which will provide local transport authorities with funding to support the rollout of zero emission buses across England.

Expenditure reform is a key pillar of the strategy because the current bus improvement funding stream (Bus Service Operators Grant) is a fossil fuel subsidy. The strategy requires transit authorities to publish a local Bus Service Improvement Plan detailing actions to transform their local bus fleet to ZEBs in order to qualify for the grant.

In 2016, the Department for Transport and the Office for Low Emission Vehicles announced the **Low Emission Bus Scheme** (LEBS) to support the purchase of ZEBs and charging infrastructure. Bus operators and local councils in England and Wales were provided with £30.4 million to deliver over 300 ZEBs onto roads in England and Wales, followed by £100 million in funding for the purchase of additional ZEBs (£60 million) and support for local authorities to retrofit existing bus fleets (£40 million). [31]

Norway

Norway has been a leader in mandating the adoption of zero-emissions vehicles, both for personal and commercial use. The *Norwegian National Transportation Plan (2018-2029)* required that not only all passenger and light-duty vehicles sold in 2025 be zero-emissions, but that the same requirement apply to the sale of urban buses (or they must use bio-gas). [32]

Germany

Political support has been critical to ZEB adoption in Germany. In 2020, the Hamburg Senate implemented a requirement for transport operators to solely purchase ZEBs, which is further supported by amendments to the energy and electricity tax act by the Federal Government. [33]

European Union

The EU's 2019 *Clean Vehicles Directive* required member countries to transpose it into law by August of 2021. When it comes to ZEBs, the directive set national requirements for ZEB bus procurement, with at least 25% of new purchases needing to be ZEB by 2025, and at least 33% by 2030. [34]

C40 Cities

A number of cities, including within Canada and the US, have signed onto the international C40 Clean Air and Fossil Fuel Free Streets Declarations, which commits to procuring only zero emission buses from 2025 and ensuring a major area of the city is zero emission by 2030. The aim is a dedication to implementing the Paris Agreement at the local level. [35]

4.4 Opportunities

	Procurement Requirement	Per vehicle subsidies	Reduce Regulatory Barriers for Utilities

Opportunity	— Enact regulations requiring ZEB conversion timeline.
	  – E.g. all ZEB procurements after 2025
	— Enact them at the federal or provincial level.
	— Regulation could be applied to sales (vendor) or purchases (transit systems and operators).
	— Differ regulation depending on the size of a transit system.
		— Fund ZEBs and their related infrastructure through per-vehicle subsidies.
		  – E.g. 25% of bus and 75% of infrastructure costs
		— Subsidies could decrease over time as price gap narrows between ZEB and diesel or diesel-hybrid.
		— Systems are required to have long-term fleet plan.
			— Review regulatory guidance on regulated vs. competitive services for local utilities related to neighborhood-level system upgrades to support charging infrastructure (as opposed to the chargers themselves).
			— Develop regulatory guidance related to distributed energy resources (DERs) and the treatment of ZEBs and its supporting infrastructure (local generation & storage).

Benefits	— Ensures conversion on a set timeline. — Supports interim GHG-reduction goals. — Enables accurate forecast of GHG reduction impact. — Mirrors similar federal commitment made for passenger vehicles. — Already self-imposed my many municipalities.	— Eliminates competition between transit systems for scarce pools of dedicated funding programs (federal or provincial). — Better forecasting of costs for funders, as it is predicated on comparable long-term fleet plans.	— Unlocks other means of funding electrical infrastructure upgrades. — DER treatment provides opportunities to offset investments by leveraging infrastructure back into the grid during times of low transit system use.
Issues / Considerations	— Requires stable funding commitment. — Technology availability must align with a system's operating needs.	— Requires commitment to long-term funding. – An average fleet will require 12 years (the typical expected lifespan of a bus) to turnover to ZEBs, assuming steady-state procurement.	— Requires concerted work of utilities and regulators.

5. Business Models & Rate Structures

Current State:

5.1 **Canada**

5.2 **United States**

5.3 **Globally**

Opportunities

5.4

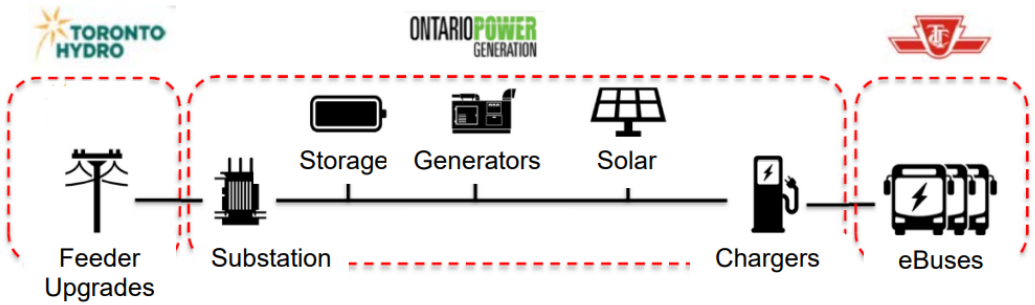
Although business models and rate structures are relatively consistent throughout Canada, other jurisdictions have begun to use creative solutions to accelerate adoption, share risk, and reduce the upfront capital requirements of transit systems.

5.1 Current State - Canada

ZEB adoption has brought Canadian transit systems and their utility partners closer together than they have been before.

Toronto Transit Commission – Green Bus Program

In April 2021, the TTC brought forward for approval a tripartite Framework for Agreement enabling the TTC, Ontario Power Generation (OPG) and Toronto Hydro-Electric Supply Ltd. (Toronto Hydro, or THESL) to enter an enter into a non-binding memorandum of understanding (MOU) for ZEB electrical infrastructure. Under this new business model, Toronto Hydro is responsible for upgrading the electrical supply to TTC properties and OPG co-invests, designs, builds, owns and operates the electrification infrastructure on TTC property, as shown below. [36]



This agreement will focus the first $79 million CAD required to install the first 300 (of 1,140) chargers the TTC will ultimately require.

BC Hydro

Two optional Fleet Electrification Rates are available for customers who qualify for a General Service Rate – businesses, government agencies or other organizations – and who own or lease and operate electric fleet vehicles or vessels. [37]

Demand Transition Rate: Available for eligible customers who cannot charge their fleet overnight at the depot and require in-route charging during fleet operating hours. Customers must have an annual maximum demand of at least 150 kW and service must be provided by separate meters. To reduce the impact of high demand charges due to short-duration, high-load charging during the EV fleet ramp up period, the Demand Transition Rate does not have a Demand Charge for the first six years from April 1, 2020 to March 31, 2026. Over the subsequent six years, from April 1, 2026 to March 31, 2032, as customers continue to grow their electric fleet, an escalating Demand Charge will be phased in.

Overnight Rate: The rate has a flat rate Energy Charge. The Demand Charge only applies to maximum demand set between the hours of 6 a.m. and 10 p.m. daily per billing period. There is no Demand Charge between the hours of 10 p.m. and 6 a.m.

Local Distribution Companies

In 2020, the Ontario Electricity Distributors Association (EDA), who represents Local Distribution Companies (LDCs), released its position paper *Power of Local Hydro* advocating that LDCs should, among other things [38]:

— be enabled and encouraged to support the electrified transportation through infrastructure developments;
— have the ability to rate-base strategic investments in electrification technologies, such as EV and transit-oriented charging stations

5.2 Current State - United States

Similar to the Canadian experience, US utilities have increasingly been partnering with transit systems, but bus OEMs have also joined the fray.

King County Metro (Seattle, WA)

King County Metro entered into an MOU with Seattle City Light to receive technical support, concept design documents, and charge management and commissioning support. The partnership has been working on a rate pilot specific to charging based on Time-Of-Use (TOU) with the intent to minimize TOU avoidance and enable efficient load management. King County Metro has also partnered with Puget Sound Energy (PSE) for the installation of the first on-route charger. [39]

Foothill Transit (Greater Los Angeles, CA)

Southern California Edison (SCE) initiated the Charge Ready Transport (CRT) Program to provide low-to no-cost electrical system upgrades to support the installation of charging infrastructure. Through the program SCE will design, permit, construct, and install the infrastructure connection from the bus yard to the grid. In 2018, Foothill Transit reached an agreement with SCE to install a bank of charging stations to power 14 ZEBs and provide rebates for the purchase of charging stations.

SCE has worked to implement rate structures to incentivize customers, including transit agencies, to transition their fleets to EVs. In 2019, SCE implemented commercial EV rate schedules that exclude demand charges for 5 years with the intention of slowly phasing them back in the subsequent 5 years. [40]

Regional Transportation District – RTD (Denver, CO)

Denver's RTD replaced its fleet of compressed natural gas buses with 36 BEBs in 2017. The roll out was challenging because Xcel Energy's (local utility provider) rate structure generated demand charges amounting to ~80% of RTD's annual bus electricity bill, resulting in the BEB fleet costing nearly 60% more to operate than the previous fleet. Colorado Legislature passed a bill requiring Colorado's electric utilizes to support transportation electrification, which led Xcel Energy to introduce a new rate structure for commercial electric vehicle fleets. The new rate expects to cut RTD's annual costs by 25-30%.

Denver's RTD is now participating in Xcel Energy's EV Supply Infrastructure Program for its upcoming fleet of 17 ZEBs, which aims to provide organizations the opportunity to add charging infrastructure at no cost. [41]

Proterra Energy Service

Proterra Energy provides a comprehensive y solution to deliver a complete energy ecosystem with the intention of lowering upfront cost and reducing risk. Proterra's service offering includes design, build, finance, operations, maintenance, and energy optimization. More specifically, Proterra Energy can [42]:

- Retain ownership of the charging infrastructure and batteries
- Provide infrastructure upgrades that can be paid for over time
- Provide charging infrastructure financing options whereby customers can invest upfront or "pay-as-you-go"
- Provide charging and energy optimization services to minimize demand and TOU charges

5.3 Current State - Global

Europe leads North America in ZEB adoptions, which has permitted time for a variety of new and interesting business models to develop.

Zenobe Partnership Program

Zenobe Energy, the UK's leading independent owner and operator of battery storage, launched up to £120 million of funding to partner with local councils and/or bus and fleet operators to accelerate the rollout of commercial electric vehicle fleets. Zenobe can provide a range of services including upfront financing for batteries in the depot, charging infrastructure, batteries on the vehicles, as well as the vehicles themselves.

The partnership is intended to provide local councils and/or bus and fleet operators with an end-to-end solution in exchange for a *pence-per-mile* service fee or a fixed monthly charge. More specifically, Zenobe will own and operate batteries in the depot, smart charging infrastructure and the batteries on the vehicles. [43]

PSIebus Partnership

Berlin leads Germany in ZEB adoption, driven by Berliner Verkehrsbetriebe's (BVG) plan to convert their entire fleet to ZEBs by 2030.

BVG employs innovative fleet and operational strategy initiatives by partnering with manufacturers for depot and charging management systems.

PSI Transcom GmbH was commissioned to utilize their PSIebus system to dispatch, monitor, and control the ZEBs. The integrated PSI charging management system controls the energy demand of the depot and monitors and controls the individual charging devices, with the goal of avoiding expensive peak loads. This partnership enabled BVG to optimize the use of its ZEBs and charging infrastructure. [44, 45]

Volvo Buses Turnkey

Although Volvo Buses' North American presence is limited to their Canadian-based subsidiary NovaBus, Volvo is a ZEB leader within Europe. Similar to Proterra's Energy offering, Volvo offers its Turnkey solution as an all-inclusive e-mobility offering. The model is predicated on giving a transit system a specified availability of fully operational buses with a pricing structure set on a per-kilometer basis. Volvo offers leasing and financing options depending on whether the operator wants to own the vehicles.

The resulting offering can include all of vehicles, maintenance, connectivity, zone management, infrastructure and implementation, as well as project management and training as required. At this moment, Volvo doesn't offer this solution to non-European markets, but it's a model that has the potential to be successful in North America depending on transit systems' appetite for alternative contracting models. [46]

Daimler Buses eMobility

Daimler Buses represents another major European ZEB player that doesn't have a North American presence in the transit bus market (although subsidiary Thomas Built is strong in the school bus market). In Europe, they offer a suite of eMobility services similar to Volvo.

Their consulting group can determine the best routes for electrification while their eBasic or ePremium and BusDepot Management service contract offerings allow Daimler to take part in a variety of public-private-partnership type delivery models.

Offerings like this lay the groundwork for future business models that may see some OEM players transition to mobility providers, particularly with the adoption of autonomous technologies. [47]

5.4 Opportunities

	Partnerships with Utilities	Partnerships with Bus OEMs	Develop Public-Private Partnership model
Opportunity	— Responsibilities/Ownership – Transit system: buses & batteries, O&M – Utilities: charging & electrical infrastructure — Leverage the expertise of utilities, whether they are local distributors or producers. — Institute electricity rate specifically for EV charging.	— Responsibilities/Ownership – Transit system: bus, O&M – OEM: batteries, charging & electrical infrastructure — Leverage expertise of bus manufacturer in developing an optimal solution for their vehicle and batteries.	— The combination of infrastructure requirements, an environmental driver and a steady stream of revenue (from an availability-type charge per bus) makes transit fleet electrification, at scale, a potentially attractive public-private opportunity.
Benefits	— Most transit systems do not want to own, operate and maintain additional electrical infrastructure. — Utilities are better positioned with expertise and the ability to take advantage of economies of scale. — EV-specific rates can diminish the impact of time-of-use (TOU) charges during peak demand on-route charging.	— OEMs can offer a turn-key integrated solution that includes planning, design, infrastructure, vehicles and batteries. — Can be structured with varied balance of up-front investment and pay-as-you-go with OEM's own financing.	— Organizations, like CUTRIC, have already kickstarted these discussions in the market. — Potential to tap into institutional investor market — May be more attractive to investors for transit systems that have contract bus O&M as well.
Issues / Considerations	— Requires stable funding commitment. — Technology availability must align with a system's operating needs. — EV-specific rates require alignment between government, regulators, utilities and transit systems.	— Potentially limits a homogenous bus fleet from a single OEM. — Integrated solutions not offered by all OEMs.	— Varying familiarity and experience among transit systems in alternative delivery models. — Must be structured to be both beneficial to the transit system and commercially viable.

6. Procurement Models

Current State:

6.1
Canada

6.2
United States

6.3
Globally

Opportunities

6.4

The majority of electric bus projects are still acquired through traditional procurement, with the transit system paying for the cost of the buses and batteries upfront. Experiences in Europe and elsewhere highlight that as the market matures, there will be a growing opportunity to deploy innovative procurement models.

6.1 Current State in Canada

The majority of ZEB procurements in Canada have used traditional models for small-scale trials, with more models being explored for scaling up.

Toronto Transit Commission – Green Bus Program

As a part of the TTC's development of its Green Bus program, it analyzed a variety of contract bundling strategies including:

the traditional design-bid-build (#1); design-build (#2); a design-build-finance-operate-maintain of the infrastructure (#3); and a design-build-finance-operate-maintain of infrastructure and vehicles (#4), as well as the ultimately selected TTC-OPG-THESL Framework (#5).

The benefits of each are shown below, with the result being a bespoke agreement where each party is responsible for the scope with which it has the most expertise and best ability to manage the risks. Despite a lack of experience in this new form of agreement, the TTC recognized the opportunity to think differently. This should help to de-risk and ensure the success of implementation. [36]

	1 Design-Bid-Build (DBB)	2 Design-Build (DB)	3 Contract Bundle 1	4 Contract Bundle 2	5 TTC-OPG-THESL Framework for Agreement
Benefits	▪ Well understood approach ▪ Most control ▪ TTC can source buses competitively, separate from infrastructure	▪ Transfer of most DB risk ▪ Potential DB efficiencies and cost savings ▪ TTC can source buses competitively	▪ Transfer of most DB and O&M risk ▪ Potential to optimize lifecycle cost ▪ Greater lifecycle cost and schedule certainty ▪ TTC can source buses competitively	▪ Transfer of most DB, O&M, and vehicle performance risk ▪ Potential to optimize lifecycle cost ▪ Greater lifecycle cost and schedule certainty	▪ Co-investment and OPG ownership reduces overall risk ▪ Greatest potential to optimize lifecycle cost ▪ TTC can source buses competitively ▪ Opportunity for gov. rate financing
Risks	▪ TTC retains delivery and performance risk ▪ High integration risk ▪ Not likely to optimize lifecycle costs	▪ TTC retains performance risk regardless of O&M delivery model ▪ Not likely to optimize lifecycle costs	▪ Less direct control ▪ Higher long-term maintenance costs ▪ Private sector rate financing ▪ Interface risk between bus and infrastructure	▪ May loose ability to source vehicles competitively	▪ Regulatory developments may offer greater opportunity ▪ Some interface risk between bus and infrastructure

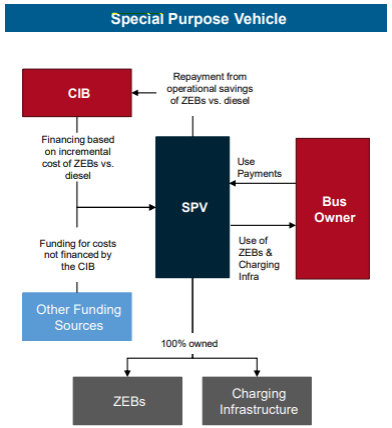
BC Transit FCEB Procurement

BC Transit's FCEB procurement trial during the 2010 Winter Olympics brought to light several lessons learned that have been used for more extensive ZEB procurements moving forward. The tight and rigid delivery date driven by the Olympics resulted in a product that was not fully developed and required improvements after deployment.

Following the end of the 4-year trial, BC Transit recognized a need to invest an additional $20 million to continue operating the FCEB fleet, and ultimately decided it was cheaper to replace the fleet altogether. While 20 FCEBs were successfully delivered in time for the Olympics, the rushed delivery schedule and lack of a central integrator led to the inability of BC Transit to sustain the vehicles and the ultimate sale of the FCEBs. [48]

CIB - Zero-Emission Bus Initiative

The CIB's *Zero-Emission Buses Initiative* can serve traditional procurements, but has also been tailored for a public-private-partnership (PPP) type model as shown at right. CIB's direct lending can be used for a traditional procurement where the 'Bus Owner' receives financing from the CIB and maintains ownership of the ZEBs and charging infrastructure. A PPP model can use a 'Special Purpose Vehicle' that receives financing from the CIB and maintains ownership of the ZEBs and charging infrastructure. The 'Bus Owner' then provides 'use payments' to the SPV in exchange for usage of the ZEBs and charging infrastructure. [49]



6.2 Current State - United States

The United States procurement environment is very similar to Canada's, but with a slower adoption of PPPs generally and a higher uptake in leasing.

Cooperative Purchasing

The Stark Area Regional Transit Authority (SARTA) in Canton, Ohio only has a bus fleet of ~50 buses. As it looked to affordably acquire ZEBs, its assessment of procurement options suggested that many smaller transit systems were keen on the idea of cooperative purchasing. They cited **Sourcewell**, a Minnesota government entity that performs joint procurements on behalf of its members, as a way to bring multiple agencies together. As of 2020 however, the Federal Transportation Authority does not allow grant funding to go to cooperative purchases.

Instead, transit systems in California, Georgia and Virginia can rely on State-wide contracts (similar to Metrolinx's joint procurements) for BEBs, with California also offering FCEBs. [50]

Procurement Evaluation Preferences

Some states are implementing procurement evaluation preferences to support the adoption of ZEBs and other alternative fuel vehicles (AFVs). The **Connecticut Department of Administrative Services** has permission to give a price preference of up to 10% for the purchase of AFVs or for the purchase of conventional vehicles. [29, 48]

Bus & Battery Leasing

Proterra, in partnership with Japanese firm Mitsui Co. Ltd., introduced battery leasing as an option in 2019. Proterra noted that battery leasing brings down the capital investment for a ZEB to be on-par with a traditional diesel bus, with the battery lease cost (and electricity charge) being less that the typical spending on diesel fuel.

The 2015 FAST Act made battery leasing possible, setting regulations that allow it to be leased separately from the vehicle itself. The transit systems of MetroLINK (Quad Cities, IL) and Park City Transit (Park City, UT) are two jurisdictions that have signed on. Proterra's leasing is only available in North America. [51]

BYD similarly partnered with clean-energy financing firm Generate Capital for leasing of the whole bus. [52]

States have taken notice of the leasing options, with California's *Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project* (HVIP) and New York's Truck Voucher Incentive Program both allowing battery leasing. [29, 50]

Ride On (Greater Washington D.C.)

Ride On is the transit system for Montgomery County, MD, northwest of Washington D.C. Ride On entered into a PPP arrangement in 2021 with energy-as-a-service (EaaS) provider AlphaStruxure, to develop a microgrid and electric bus charging infrastructure at one of its bus garages.

AlphaStruxure is a joint venture of Schneider Electric and the investor Carlyle Global Infrastructure Opportunity Fund. The DBFOOM (design-build-finance-own-operate-maintain) arrangement will allow the Ride On to procure 44 electric buses and allow them to avoid utility demand charges and time-of-use tariffs. [53]

6.3 Current State - Global

With ZEB adoption at different stages of maturity around the world, procurement models are different, depending on the local conditions. In Europe, the presence of the EU has allowed joint procurement to prosper across national boundaries. As cities have rapidly expanded their bus networks in South America, they have moved to a P3 model, the most recent of which now specify ZEBs.

Joint Initiative for Hydrogen Vehicles across Europe (JIVE)

The JIVE is a project consortium comprised of 22 partners from seven countries aimed to deploy 139 ZEBs and associated charging infrastructure across five countries throughout Ireland, Germany, and the UK. The consortium's objective is to leverage large-scale deployment and unlock economies of scale such that ZEBs are commercially viable without additional subsidies. The initiative is co-funded by a £32 million grant from the Fuel Cells and Hydrogen Joint Undertaking under the European Union Horizon 2020 framework program for research and innovation.

An expansion of the project (JIVE II) was initiated in 2018 seeking to deploy an additional 152 ZEBs and associated charging infrastructure across 14 cities throughout France, Germany, Iceland, Norway, Sweden, the Netherlands, and the UK. It is co-funded by an additional £25 million grant. [54]

Romania

Alliances between cities proved effective in Romania's efforts to electrify their city fleets. Cluj-Napoca, Timisoara, Arad, and Oradea entered into an alliance to meet a threshold for EU funding for economic development. The alliance also enabled autonomy and information sharing which was critical in the development of urban mobility plans. Cluj-Napoca also acquired an additional 11 ZEBs through the Swiss-Romanian Cooperation Programme. [55]

The Procurement Partnership Limited (TPPL)

Launched in 2004, TPPL offers a range of procurement solutions and services (to the public sector) across various industries to maximize the efficiency of its member organizations, drive value for money, and meet compliance regulations. In 2021, TPPL launched a new Minibus, Bus and Coach purchasing Framework Agreement in partnership with Bath & North East Somerset Council (BNES) to provide UK public bodies with a compliant route to 27 leading bus suppliers for the next 4 years. Some of the key benefits of this framework include financial support for buying customers upon delivery of a full hydrogen fuel cell vehicle, access to key suppliers at the forefront of hydrogen powertrain technology. [56]

TransMilenio (Bogota, Colombia)

TransMilenio is Bogota's public transit agency and owns the largest bus rapid transit system in the world. As they rapidly expanded their services over the last 20+ years, TransMilenio has adopted the P3 model for ~15 year operating agreements to operate and maintain various components of their system.

In 2021, TransMilenio awarded a € 874 million euros ($1.3B CAD) to France-based Transdev for the 15-year operations, maintenance and supply of 406 electric buses (from BYD), which are anticipated to carry 36 million passengers annually. The project also includes the construction of South America's largest electric bus depot. [57]

6.4 Opportunities

	Leasing	Innovative Procurement Models	Joint Procurement
Opportunity	— Purchase buses, at a comparable cost to diesel or hybrid buses, but lease the batteries. — Leasing the bus/battery, either as a capital or operational lease.	— Incorporating co-ownership, financing, maintenance and/or operations into agreements to better share risk and improve affordability. — Moving into public-private partnership models such as DB, DBF, DBFM, DBFOM. — Being creative by implementing hybrid agreements that fit best in	— Joint purchases by two or more transit systems. — Can apply to buses, charging infrastructure, system design, energy management systems and/or generation or storage infrastructure. — Joint procurement could be for more than one OEM product, to prevent overreliance on a single solution.
Benefits	— Reduces upfront costs. — Repair and maintenance costs remain with the lessor. — Successful track record in the US and globally, including through bus OEMs like Proterra. — Protects against some technology obsolescence.	— Ability to leverage different partners for their specialist expertise. — Optimal management of risk by the party best suited to manage it. — Can remove or reduce technology risk for transit system. — Ability to tap into other sources of private or investor financing.	— Economies of scale can lessen initial and per-vehicle investment. — Forces harmonization of specifications, which can benefit interoperability of adjoining transit systems.
Issues / Considerations	— Depending on the nature of the lease, could reduce the amount of maintenance performed by transit system staff on the fleet.	— Many transit systems are not familiar or comfortable with innovative procurement models. — Innovative procurement requires different commercial management practices and a change in focus to service outputs rather than technical inputs.	— Requires harmonized bus and charging specifications between transit systems.

7. Innovative Programs / Initiatives

7.1 **Battery Recycling**

7.2 **Bus Conversion**

7.3 **Research & Development**

Although the adoption of ZEBs is bringing significant benefits and opportunities, there are also challenges that need to be addressed. Technology companies, OEMs, non-profits and post-secondary institutions are all lending their support to capitalize on the opportunities and address the challenges.

7.1 Battery Recycling

As highlighted earlier, batteries represent one of the main drivers of the cost premium between traditional diesel buses and BEBs. The concept of battery leasing has, at least in part, been made possible by the fact that industry has recognized the secondary market for these batteries. The drive to ZEBs are also driven by a broader desire to be environmentally conscious, beyond just GHG reduction, meaning the end-of-life recyclability of the batteries is considered and effective.

New Flyer Industries & Li-Cycle

Winnipeg-based New Flyer Industries partnered with Mississauga-based lithium-ion battery recycler Li-Cycle to successfully recycle 45 end-of-life electric bus batteries as part of the first battery salvage pilot in the heavy-duty vehicle sector. With demand for battery recycling growing, this partnership demonstrates a strong case for electric OEMs trying to prove the value of the battery after-life. New Flyer warranties its batteries for 6 years, with an extension available to 12. [58]

Volvo Buses & BatteryLoop

Sweden-based Volvo Buses (parent to Canada's NovaBus) partnered with BatteryLoop, a subsidiary of Swedish recycler Stena Recycling, in a global arrangement that covers all batteries in all Volvo buses worldwide. The business plan is for batteries to spend their first lifecycle in a Volvo bus, their second lifecycle as BatteryLoop stationary energy storage, before finally being recycled by Stena.

Test cases were previously run in Sweden using the batteries to store solar energy for use in high-density residential complexes. [59]

CALSTART

Currently, U.S. federal law does not mandate EV battery recycling or compel battery producers or EV manufacturers to "take back" batteries at the end of their useful life. Instead, federal laws generally streamline requirements for handlers, transporters and destination facilities that dispose of or recycle battery packs.

Without a federal mandate, states have begun exploring EV battery recycling or reuse laws. California, for example, created in 2018 a Lithium-Ion Battery Recycling Advisory Group to provide policy recommendations to the legislature, which are expected in April 2022. [60]

Aceleron

UK-based clean technology company Aceleron uses new technology to create what it claims are the world's most sustainable lithium battery packs. The co-founder Cumming said that, "Creating batteries that are easier to disassemble will encourage reuse and support a circular ecosystem. It will also create additional storage capacity as batteries could be repurposed to help store electricity at EV charging points." [61]

7.2 Bus Conversion

While the discussion so far has been focused on the purchase of new ZEBs, the conversion of existing fleets powered by diesel and/or CNG into fully electric systems, is seen as a viable interim solution. Bus conversion allows for repowering and retrofitting during planned overhaul or refurbishment, which provides a natural complement to municipal service schedules and budgets, compared to the longer timelines and higher cost of normal fleet replacement. The delayed need to procure new ZEBs, can allow Cities to better plan and also reap the rewards of future ZEB cost reductions. Relative to new procurements, this transitional solution enables the realization of environmental benefits and GHG reduction targets sooner, while reducing ZEB operational and capital costs in the short to medium term.

MTB Transit Solutions

Ontario-based MTB Transit Solutions, a large bus repair company, is launching a bus conversion service through its ZEV Clean Power initiative. Its first pilot conversion, on a Winnipeg-made New Flyer diesel formerly used in Hamilton, Ont., is now underway.

According to MTB, in addition to reduced capital costs, transit agencies will save $40,000 to $50,000 per year in maintenance and fuel costs by going electric. [62, 63]

Linkker

Finland-based Linkker recently launched LinkDrive, a retrofit kit for industrial scale diesel to electric bus fleet conversions, to allow for a faster transition to emission free public transport. The possibility to do the conversion in local workshops also minimizes down time. The main sub systems of the conversion kit are traction system, battery system, power distribution unit, vehicle control system, charging connectivity system and driver's work place upgrade. Suitable fleets for conversion are 5-7 year old vehicles that offer sufficient space for traction batteries in the rear and on the roof.

Linkker recently delivered its first LinkDrive conversion kit in Singapore. [64]

Complete Coach Works (CCW)

California-based Complete Coach Works (CCW), provides a Zero-Emission Propulsion system (ZEPs) by taking existing low-floor transit buses and remanufacturing them into like-new vehicles containing an all-electric drivetrain. ZEPs deployed so far have covered more than 4 million miles of revenue service

in early 2021, the company delivered its latest ZEPs by fulfilling a contract to Capital Area Transit (CAT). The agreement calls for the rehabilitation of two 60' articulated New Flyer buses which included a repowering of the engines to Cummins Recon ISL. [65]

E-troFit

e-troFit, a subsidiary of a Munich-based tech company in-tech, launched its first retrofit series model solution for city buses in 2020. The e-troFit solution has won the German Mobility Prize, which is awarded by the German Federal Ministry of Transport and Digital Infrastructure.

While the e-trFit kit is only currently available for the Mercedes Citaro, kits for other city bus manufacturers are being planned. [66]

7.3 Research & Development

A number of jurisdictions have seen both non-profit research organizations and post-secondary institutions step up to help advance ZEB research. That includes spurring the market, providing technical expertise to transit systems and helping make good, data based decisions on ZEB deployment.

CUTRIC

The Canadian Urban Transit Research & Innovation Consortium (CUTRIC) is an Ontario-based non-profit that was founded in 2014 with the support of the Canadian Urban Transit Association (CUTA). In the time since, it has focused on launching technology and commercialization projects to advance projects like ZEBs other zero-carbon mobility solutions across Canada. CUTRIC has also developed accessible simulation tools to help transit systems plan their ZEB rollouts. [67]

Milan

Milan's transit operator (ATM) launched a plan to transition the city's entire public transport network to electric by 2030, and entered into an innovative collaboration to ensure effective implementation. ATM partnered with the Municipality of Milan and the Polytechnic University of Milan to ensure the transition away from diesel buses is efficient. The collaboration considered the city's public transport requirements and conducted analysis to design charging infrastructure and routes accordingly. [68]

Germany

BVG has joined forces with the Technical University of Berlin and the Reiner Lemoine Institute to form a research constellation for the "E-MetroBus" project. As part of the project, the TU Berlin is developing, for example, an e-bus guidance system with better range prediction, investigating the energy-efficient use of heating and air-conditioning systems and the environmental balance of the buses. In addition, the TU Berlin is helping to develop an operating and incident concept. The Reiner Lemoine Institute is conducting research in various scenarios on how a local, grid-serving supply of the charging stations at the bus stops and in the depot can be implemented. It has also developed an app with which passengers can calculate the CO2 footprint of their journey and find further information on the topic of e-buses and sustainable mobility. [69]

NREL

The American National Renewable Energy Laboratory's (NREL) aim is to advance the science and engineering of energy efficiency, sustainable transportation, and renewable power technologies and to provide the knowledge to integrate and optimize energy systems.

When it comes to ZEBs, NREL's focus has been on partnering with institutions and industry on initiatives like using machine learning for route optimization (with Google Maps), improving Li-on battery and hydrogen fuel cell technology and advancing next-generation commercial vehicle charging systems. [70]

8. Conclusion

Our jurisdictional review suggests there are multiple opportunities to be replicated from other jurisdictions, both in Canada and abroad, to support transit systems in the accelerated adoption of ZEBs and the systems and infrastructure that support them.

- Funding Programs that are dedicated and sustaining, are decoupled from variable revenues and help operationalize capital costs.
- Policies and regulatory programs that have a procurement requirement, supported by per vehicle subsidies, and remove regulatory barriers for utilities.
- Business models and rate structures that involve partnerships with utilities, with OEMs and the broader use of public-private partnership delivery models.
- Procurement models that involve leasing, joint procurements and the broader use of innovative contract models.
- Engagement with industry and research entities to tackle challenges.

Integrated Insights

Presented below are a number of key themes and recommendations from the Jurisdictional review as well as the potential timeline for implementation and widespread adoption.

Short Term | Medium Term | Long Term

- Funding Programs that are dedicated and sustaining, are decoupled from variable revenues and help operationalize capital costs
- Policies and regulatory programs that have a procurement requirement, supported by per vehicle subsidies, and remove regulatory barriers for utilities
- Business models and rate structures that involve partnerships with utilities, with OEMs and the broader use of public-private partnership delivery models
- Procurement models that involve leasing, joint procurements and the broader use of innovative contract models
- Engagement with industry and research entities to tackle challenges

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