VTrans Zero Emissions Transition Plan

HOUSE TRANSPORTATION COMMITTEE, JANUARY 13, 2022

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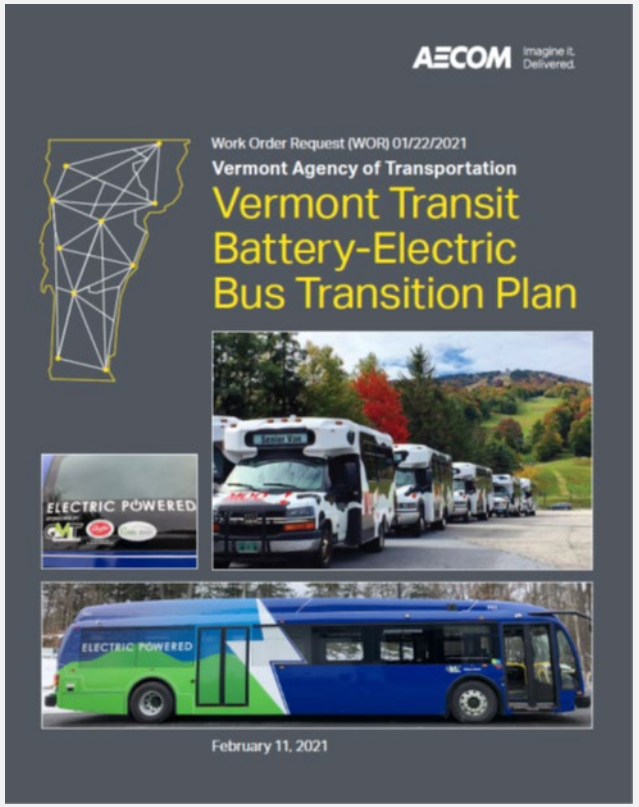
VTRANS ZERO-EMISSION TRANSITION PLAN:

EXECUTIVE SUMMARY

- Purpose and Goals of the Project
- State of the Industry
- Existing Conditions
- Outreach
- Energy
- Route & Block Analysis
- IT, Training, and Maintenance Considerations
- Capital Expenditures
- Funding Programs
- Questions / Next Steps

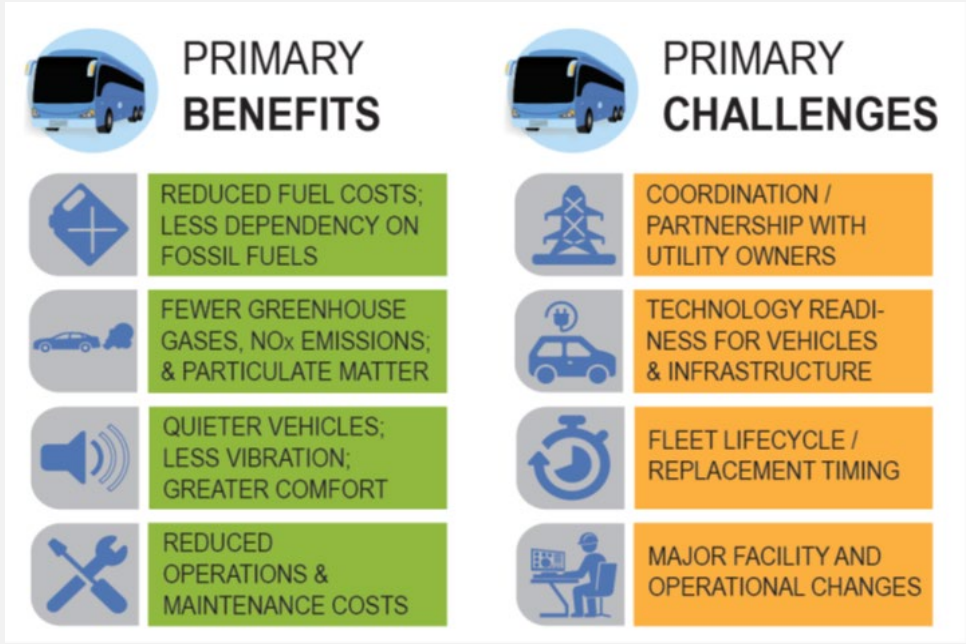
VTRANS ZERO-EMISSION TRANSITION PLAN
PURPOSE AND GOALS OF THE PROJECT

- Vermont's goal is to electrify the state's entire transit fleet by 2050 (CEP) – approximately 400 vehicles
  - How do we get there from here? For context:
    - Seven transit agencies in Vermont
    - Different vehicle types: transit buses, cutaways, vans
    - Challenging operating environments:
      - Mountains, cold weather, many long routes
  - Develop a Transition Plan:
    - Vehicles + charging infrastructure
    - Potential funding sources
    - Service implications:
      - To what extent can existing transit service in Vermont be served by a fully electric fleet, given the range limitations of electric vehicles?
      - What are the operational challenges at the garage level?



VTRANS ZERO-EMISSION TRANSITION PLAN: STATE OF THE INDUSTRY
WHERE IS TRANSIT ELECTRIFICATION BEING DONE IN THE U.S.?

- According to Dec 2020 data from CALSTART:
  - 2,790 zero-emission buses (ZEBs) were on the road in the U.S.
  - 24% more deployments in 2020 than in 2019
  - Of the 2,790 ZEBs, only 87 (3%) were hydrogen fuel cell buses, with the rest being battery-powered
  - Of the 80,000 transit buses currently in service in the U.S., only 3.5% are zero-emission
  - APTA reports that 29% of the carbon emitted in the U.S. every year is from transportation
    - If every diesel bus in America were to be replaced with ZEBs, the country would save more than 2 million tons of greenhouse gas emissions annually
  - The trend toward ZEBs is made possible by advances in lithium-ion battery technology as well as standardization among electric bus and charger manufacturers



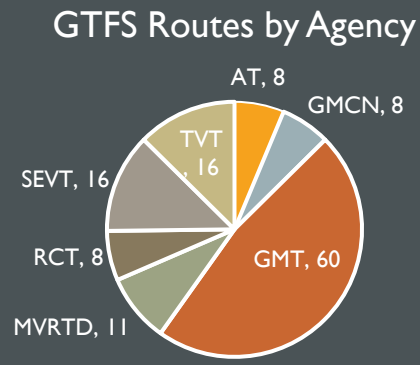
VTRANS ZERO-EMISSION TRANSITION PLAN: STATE OF THE INDUSTRY
CHARGING TYPES

- Charging type for transit agencies in Vermont will more than likely be ground-mounted, corded plug-in chargers, due to lowest capital cost and ease of installation and use

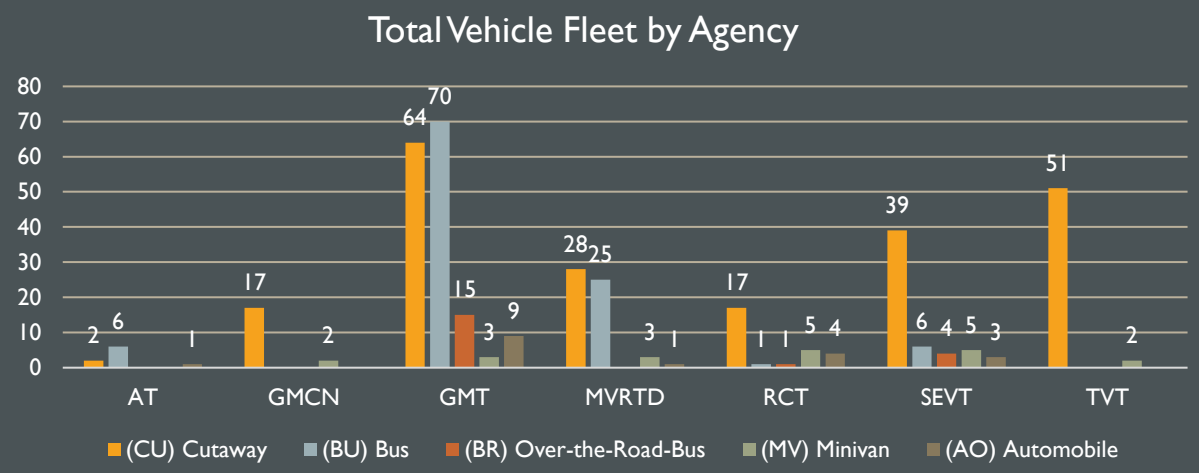
Corded Plug-In	Overhead Conductive Charging	Wireless Inductive Charging
		
• Charge Type: AC or DC • Charge Power: 40 to 120 kW • Charge Time: 1 to 8 hours depending on bus state of charge	• Charge Type: DC • Charge Power: 175 to 500 kW • Charge Time: 5 to 20 minutes for the fastest settings	• Charge Type: AC or DC • Charge Power: 5 to 300 kW • Charge Time: 5 minutes to 8 hours
PROS (+) • Lowest infrastructure cost	PROS (+) • Potential for in-route operations • Smaller capacity batteries possible with in-route charging • No need to plug in and unplug buses	PROS (+) • Smallest infrastructure footprint • Simpler charging mechanism • Consistent power supply • No need to plug in and unplug buses
CONS (--) • Buses charge at depot only • Larger battery capacity required • Larger batteries may reduce passenger capacity on the bus • Must plug in and unplug bus daily • Cords can be damaged and need replacing	CONS (--) • Higher infrastructure costs • Potential peak demand utility costs if in-route charging is used • Largest visual impact	CONS (--) • Higher infrastructure costs • Less efficient energy transfer than conductive charging • Charger receiver on bus requires active cooling during charging • Infant technology • Not offered as standard option by any North American bus manufacturers

VTRANS ZERO-EMISSION TRANSITION PLAN
EXISTING TRANSIT SERVICE AND FACILITIES IN VERMONT

- The seven transit service providers across the state operate 123 GTFS routes, with Green Mountain Transit having the largest number



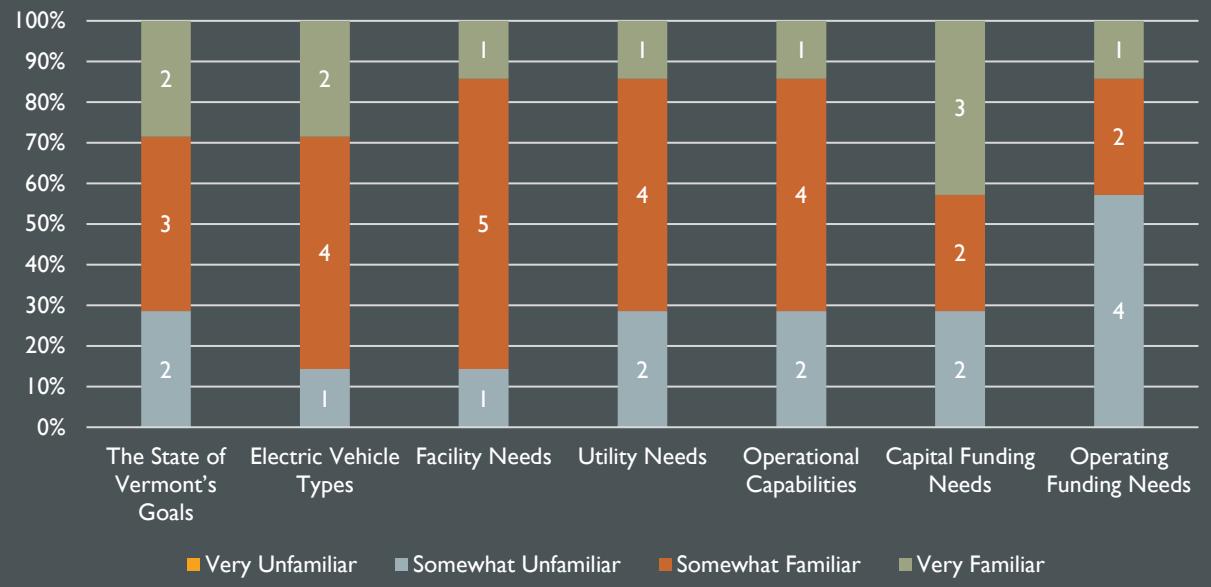
- Statewide, the fleet of transit vehicles is over 400 broken down by agency and vehicle type as shown below:



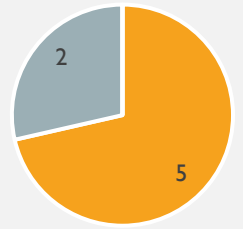
VTRANS ZERO-EMISSION TRANSITION PLAN
OUTREACH – TRANSIT SERVICE PROVIDERS

- Worked with the seven transit service providers across the state to collect technical information and ask questions about readiness and needs
- The transit service providers expressed strong interest in converting to zero-emission vehicles with some hesitation due to technology and wide-scale implementation

On a scale of 1 – 4 (with 1 being very little and 4 being very good understanding), how well do you understand the following:

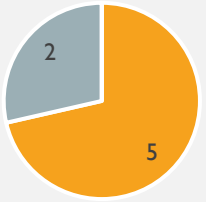


What best describes your level of interest in adding electric vehicles to your fleet?



- Very interested and actively seeking opportunities to add electric vehicles
- Limited pursuit of electric vehicles but somewhat concerned about new technology
- Very concerned about the limitations and cost of new technology but willing to do limited tests
- Waiting to adopt electric vehicles until all technology and operational issues have been resolved

Overall, how do you feel about the State of Vermont's goal to electrify at least 80% of the public transportation fleet by 2050?



- Enthusiastic support and confident it can be achieved
- Supportive but concerned about its feasibility
- Skeptical that it can be achieved and concerned about negative service impacts
- Do not think it is the right direction for Vermont

VTRANS ZERO-EMISSION TRANSITION PLAN
ENERGY CONSIDERATIONS

- Transit agencies and facilities in Vermont are in varying stages of readiness for transit electrification:
  - Upgrades to electrical infrastructure will be needed at up to 5 facilities
  - Space / parking appears to be sufficient at facilities
  - All agencies are capable of EV charging during non-service hours
  - Two areas where agencies should improve: existing plans for transit electrification, and looking ahead toward the installation of solar infrastructure
  - Results of the facility readiness analysis:

	Existing Electrification Plans	Off-Service Charging Opportunity	Sufficient Electrical Infrastructure	Adequate Parking Configuration	Onsite Solar
Advance Transit					
GMCN					
GMT – QCP					
GMT – Berlin					
MVRTD					
RCT					
SEVT – Rockingham					
SEVT – Wilmington					
TVT – Middlebury					
TVT – Bradford					

LEGEND:

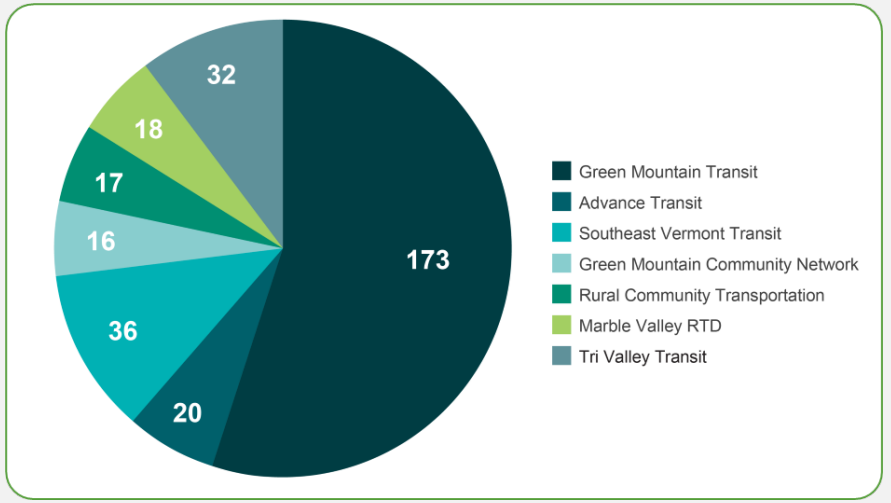
VTRANS ZERO-EMISSION TRANSITION PLAN
ENERGY IMPACTS OF TRANSIT ELECTRIFICATION

- Charging station installations will require space in the parking garage or parking lot for curbs, bollards, and charging units
- Many facilities currently have low-electricity usage, resulting in inexpensive monthly bills. Fleet electrification is expected to greatly increase electricity costs
  - Approx. $1,000 per vehicle / per month… could be offset by savings on fuel costs
- Charging during off-peak times will be critical for reducing monthly bills
  - Each kW during peak times costs roughly $11 more than off-peak times
- To support VTrans agencies in the electrification process, VTrans and Vermont's agencies should continue pursuing partnerships with electric utilities. Potential options include:
    - Incentive programs
    - Make-ready programs
    - Charging electricity rates
    - Technical assistance programs
    - Funding and financing assistance

VTRANS ZERO-EMISSION TRANSITION PLAN
ROUTE & BLOCK ANALYSIS

- The big question: How much of Vermont's existing transit service – as currently scheduled – could be served by a 100% electric vehicle fleet?
  - Assuming a 1:1 replacement of vehicles and a single overnight charge of electric vehicles at the depot
  - What is a "block"?
    - The operating unit that describes what a single vehicle does in a day – how far it travels – and along which route/routes
  - Understanding:
    - Battery-electric vehicles have a shorter operating range than diesel- or gas-powered vehicles
    - Ability to replace an existing vehicle on a block with a battery-electric vehicle
    - Rural areas tend to use smaller cutaway vehicles
    - Many assumptions went into the calculations:
      - Use of auxiliary diesel heaters
      - Overnight depot charging
      - Vehicle sizes, battery capacities, kWh use per mile, etc.

Distribution of scheduled operating blocks among transit agencies in Vermont



VTRANS ZERO-EMISSION TRANSITION PLAN
ROUTE & BLOCK ANALYSIS

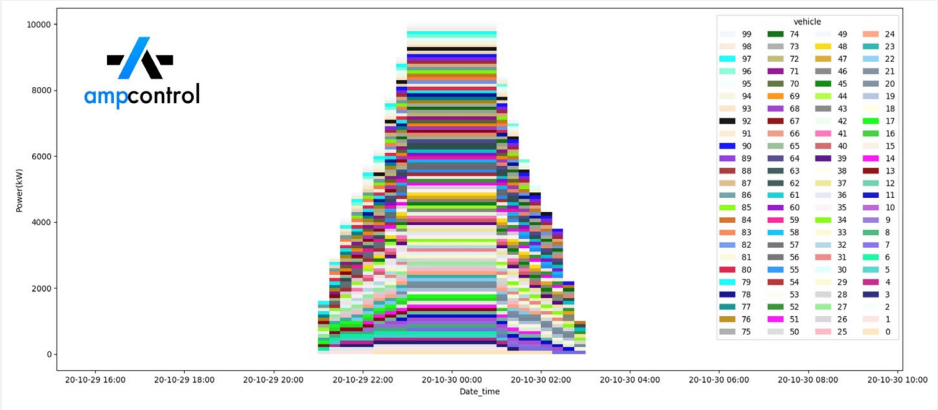
- Preliminary findings *revised estimates as of Dec 2021
  - 86% of current blocks could be operated using a single electric bus on a single overnight charge
  - 54% of current blocks could be operated using an electric cutaway on a single overnight charge
  - More urban blocks than rural blocks can be served by EVs today
    - Transit buses have larger batteries, cover fewer route miles
    - Battery capacities will continue to improve and offer more range

Potential Block Replacement with Electric Vehicles

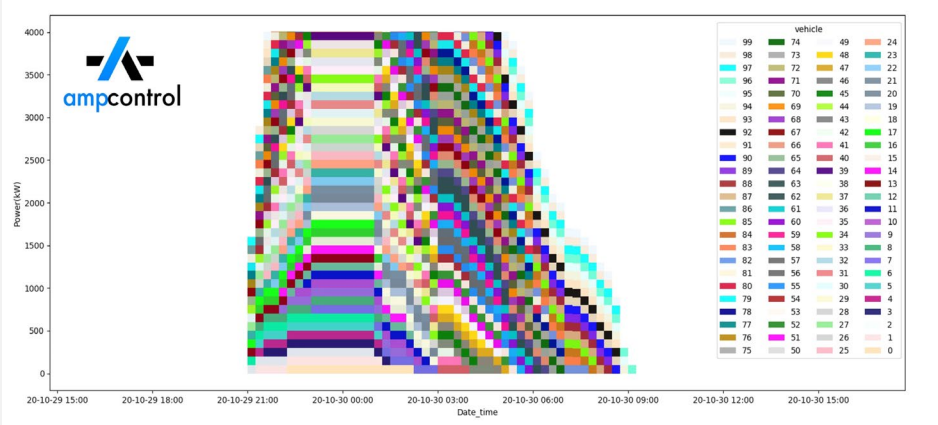
		CAN IT BE SERVED BY ONE ELECTRIC BUS?		CAN IT BE SERVED BY ONE ELECTRIC VAN OR CUTAWAY?	
TRANSIT AGENCY	NUMBER OF BLOCKS	Yes	No	Yes	No
Green Mountain Transit	173	161	12	106	67
Advance Transit	20	12	8	5	15
Southeast Vermont Transit	36	29	7	17	19
Green Mountain Community Network	16	14	2	2	14
Rural Community Transportation	17	12	5	11	6
Marble Valley RTD	18	15	3	5	13
Tri Valley Transit	32	19	13	7	25

IT Considerations -

- Charge Management
  - What is smart charging? It's using software to:
    - Show the order in which vehicles should be charged, and for how long
    - Optimize operations: buses ready for pull-out
    - Increases fleet utilization
    - Decrease anxiety about vehicle range
    - Manage energy use; can save several MW per night
      - Load balancing (at right)
    - Avoid peak demand charges
    - Monitor power supply into the facility
    - Minimize total cost of ownership

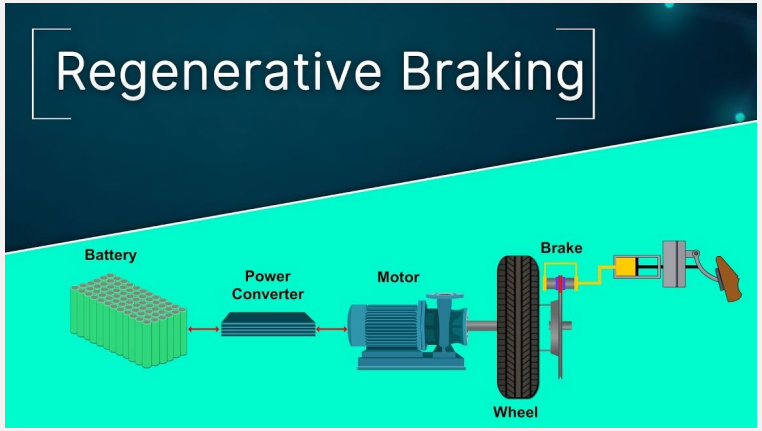


Data visualization of disorganized depot charging (above) and smart charging (below). With a charge management system, vehicle charging is staggered to decrease energy use and costs and ensure that EVs leave the depot with a full state of charge.



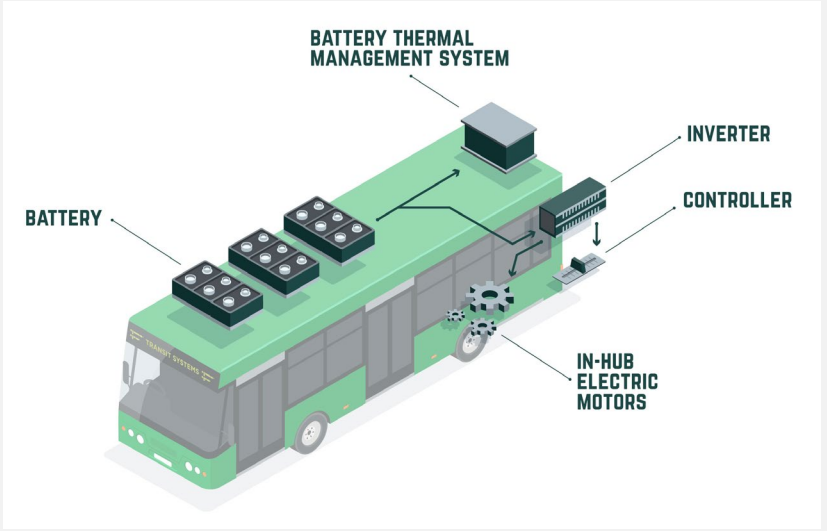
Training of BEB / EV Operators -

- Operating a BEB is different from conventional vehicles
- Incorrect operation of a BEB or EV can result in less vehicle range
  - Sudden stops and starts, use of regenerative braking
- Operators must be well familiar with route alignments, turns, etc.
- Original equipment manufacturers (OEMs) provide on-site training for BEBs
- APTA: “Operation of BEBs requires a change in *mindset*”



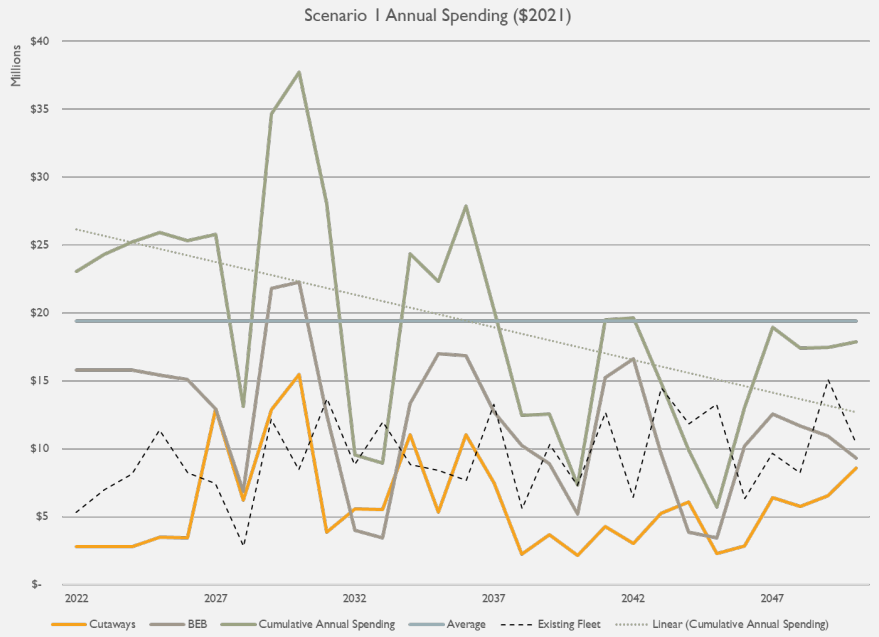
BEB Maintenance -

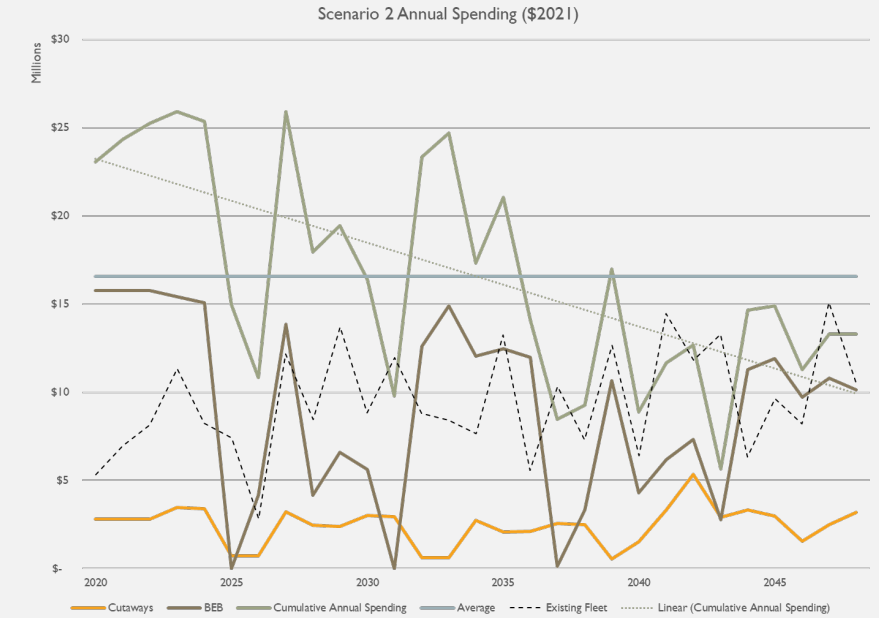
- BEBs and ICE buses are around 75% the same. Hybrids more so. However:
  - Maintenance crews and Emergency Responders need training in the safe handling of high-voltage systems
  - Service and troubleshoot electric propulsion components
  - Work with BEB on-board diagnostics
  - Original equipment manufacturers (OEMs) provide on-site training for BEBs
  - Some BEBs have composite bodies, not metal
- Consideration of specific supply chain issues
- Extended warranties and leasing options



VTRANS ZERO-EMISSION TRANSITION PLAN: CAPITAL EXPENDITURES SCENARIOS AND ASSUMPTIONS

- Goal: analyze the cost to transition the state's fleet to electric vehicles by 2050
- Two scenarios were assessed:
  - Existing fleet
  - Scenario 1: Purchase battery electric vehicles when existing vehicles reach the end of useful life
  - Scenario 2: Purchase battery electric vehicles to meet the state's mandate
    - 10% of statewide fleet by 2025
    - 50% of Green Mountain Transit fleet by 2026
    - 100% of statewide fleet by 2050
- Assumptions included a constant fleet size, vehicle useful lives, costs, how costs decrease over time, costs of equipment, mid-life overhauls, installation, and vehicles
- 30 buses purchased in the first 5 years based on existing contracts
- All costs assessed in 2021 dollars; no discounting or escalation was applied
- Analysis covers 2022-2050 for all agencies in total aside from Green Mountain Transit for Scenario 2
- Analysis considers capital costs only; operating costs are excluded
- Assumes depot chargers are installed when a bus is purchased (1 to 1)





VTRANS ZERO-EMISSION TRANSITION PLAN: CAPITAL EXPENDITURES TAKEAWAYS

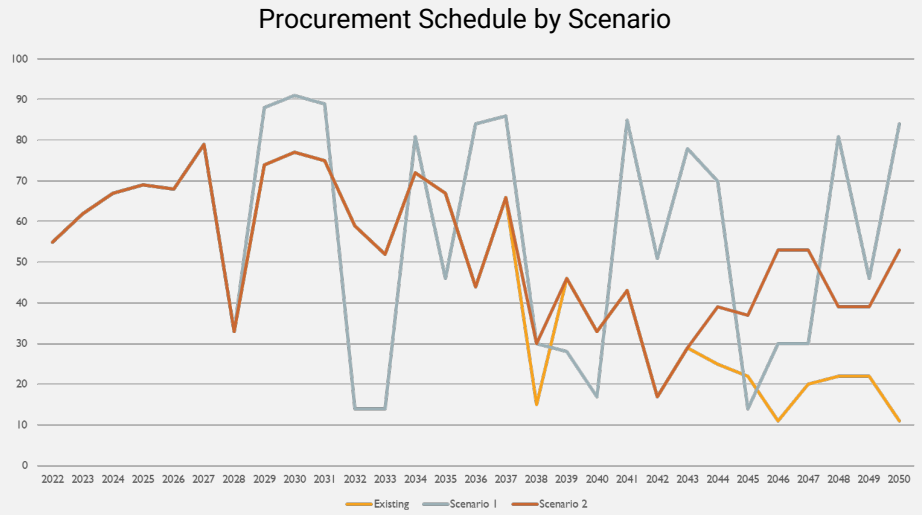
	Fleet Size	Total Cost (2022-2050) $2021M	Delta from Existing Fleet $2021M
Existing Fleet	423	$275.0	
Scenario 1		$562.9	$287.9
Scenario 2		$480.6	$205.6

Under Scenario 1, internal combustion engines will still need to be purchased to maintain fleet size initially

- By 2032, the fleet has been fully electrified. Bus purchases will need to either decrease due to change in useful life, fleet total will change, or ICE buses will need to be purchased again
  - Assumes ICE buses purchased in 2031 because they are less expensive than BEB and Vermont has reached full fleet

Under Scenario 2, ICE will need to be purchased through much of the analysis period to maintain fleet size

- This results in saving costs, but costing in emissions and not fully switching to electric or using the infrastructure to its fullest
- There will be extra buses purchased in 2022-2026 based on the 30/year assumption; those can go to other agencies than Green Mountain Transit
- Green Mountain Transit reaches 77% electrified fleet by 2026
- Because there is a long stretch of time with no mandate, there is no incentive to continue electrifying between 2027 and 2043
- Must begin purchasing electric again in 2044 to convert entire fleet by 2050



SCENARIO 1

Year	EV Cutaways	EV Buses	ICE Vehicles	*Total Vehicles to Procure*	*Total Cost*
2022	14	16	25	55	$23,068,132
2023	14	16	32	62	$24,328,132
2024	14	16	37	67	$25,228,132
2025	14	16	39	69	$25,918,155
2026	14	16	38	68	$25,336,665
2027	65	14	0	79	$25,799,152
2028	30	3	0	33	$13,085,084
2029	68	20	0	88	$34,665,605
2030	70	21	0	91	$37,725,712
2031	14	10	65	89	$28,051,185
2032	14	0	0	14	$9,546,277
2033	14	0	0	14	$8,940,206
2034	65	16	0	81	$24,352,478
2035	30	16	0	46	$22,302,876
2036	68	16	0	84	$27,849,133
2037	70	16	0	86	$20,164,092
2038	14	16	0	30	$12,475,890
2039	14	14	0	28	$12,557,128
2040	14	3	0	17	$7,298,637
2041	65	20	0	85	$19,478,251
2042	30	21	0	51	$19,641,686
2043	68	10	0	78	$14,845,074
2044	70	0	0	70	$9,910,645
2045	14	0	0	14	$5,698,568
2046	14	16	0	30	$12,995,024
2047	14	16	0	30	$18,931,230
2048	65	16	0	81	$17,397,926
2049	30	16	0	46	$17,475,445
2050	68	16	0	84	$17,869,285

SCENARIO 2

Year	EV Cutaways	EV Buses	ICE Vehicles	*Total Vehicles to Procure*	*Total Cost*
2022	14	16	25	55	$23,068,132
2023	14	16	32	62	$24,328,132
2024	14	16	37	67	$25,228,132
2025	14	16	39	69	$25,918,155
2026	14	16	38	68	$25,336,665
2027	0	0	79	79	$14,960,591
2028	0	0	33	33	$10,834,838
2029	14	11	49	74	$25,896,581
2030	14	0	63	77	$17,959,088
2031	14	3	58	75	$19,440,905
2032	14	2	43	59	$16,380,046
2033	14	0	38	52	$9,777,226
2034	0	16	56	72	$23,322,093
2035	0	16	51	67	$24,693,305
2036	14	16	14	44	$17,324,031
2037	14	16	36	66	$21,033,181
2038	14	16	0	30	$14,083,919
2039	14	0	32	46	$8,469,464
2040	14	0	19	33	$9,266,660
2041	0	11	32	43	$16,975,410
2042	0	0	17	17	$8,893,701
2043	14	3	12	29	$11,675,549
2044	34	5	0	39	$12,663,502
2045	34	3	0	37	$5,670,686
2046	34	19	0	53	$14,641,690
2047	34	19	0	53	$14,886,823
2048	20	19	0	39	$11,285,107
2049	20	19	0	39	$13,309,405
2050	34	19	0	53	$13,316,455

9. Conclusions and Recommendations

Upon completion of the analyses described in the previous sections, the following are conclusions and recommendations for VTrans to use in zero-emission decision-making moving forward:

- There is an increasing awareness of and demand for electric transit vehicles among agencies, but presently there is also limited production capacity among makers of electric buses in particular. The situation is made more complicated by the exclusion of BYD, a Chinese-owned company, from procurements using federal funds. Therefore, VTrans should try to order as many electric buses as possible, before more transit providers in the U.S. develop their own electrification plans.

- VTrans should continue to collaborate with utilities in Vermont on electrical upgrades to bus facilities and on special rates for electric vehicles. This will save the state time and money in the future. Transit agencies are also advised to conduct a more in-depth analysis of infrastructure and space needs at their facilities, including resilience measures such as solar panels and energy storage systems.

9. Conclusions and Recommendations - Continued

- VTrans should explore the potential for conversion kits in addition to, or as an alternative to, new electric vehicle purchases. Similarly, VTrans should look into the benefits of leasing electric vehicles and batteries as opposed to purchasing them outright.

- Because battery technology is rapidly improving, vehicle range and service that would be difficult to fulfill today with electric vehicles may *not* be out of the question in another five or ten years. Therefore, the results of the route and block analysis are merely an indication of what is possible in 2021, but not in the future. VTrans should consider building out the electric bus fleet of Green Mountain Transit – the only urban agency in the state – as it waits for smaller vehicle ranges to improve enough to serve longer routes of rural agencies.

- Related to the above: more manufacturers are developing light- and medium-duty electric vehicles such as vans and cutaways. Even a few years ago, it was difficult to deploy smaller electric transit vehicles; however, Vermont's rural transit providers may not have to wait much longer if current trends hold.

9. Conclusions and Recommendations - Continued

- While not strictly “zero-emission”, VTrans is advised to use auxiliary diesel heaters on its electric vehicles, as doing so will greatly assist in maximizing electric vehicle range during colder months.

- VTrans should consider hydrogen fuel cell vehicles and wireless inductive chargers, two technologies that exist, but are uncommon today due to logistical concerns that may be solved in the coming years.

- Around 86 percent of currently scheduled blocks can be served by an equivalent electric bus, and 54 percent can be served by an electric van or cutaway – both on a single overnight charge. In those cases where existing transit service in the state *cannot* be fulfilled by a 1-to-1 replacement of an existing conventional vehicle with an electric vehicle, VTrans and the state’s agencies may consider:

9. Conclusions and Recommendations – Continued

- Expanding fleet sizes so that two electric buses can, in some cases, do the work of one conventional bus;

    a. Installing in-route overhead conductive chargers in strategic locations around the state, to allow electric buses to continue operation during the service day via opportunity charging; or

    b. Permitting vehicles assigned to long blocks to return to the depot for midday charging.

    - Note that these options are expensive but may be a preferable alternative to changing schedules and reducing service until battery technology improves to the extent that these measures are not required.

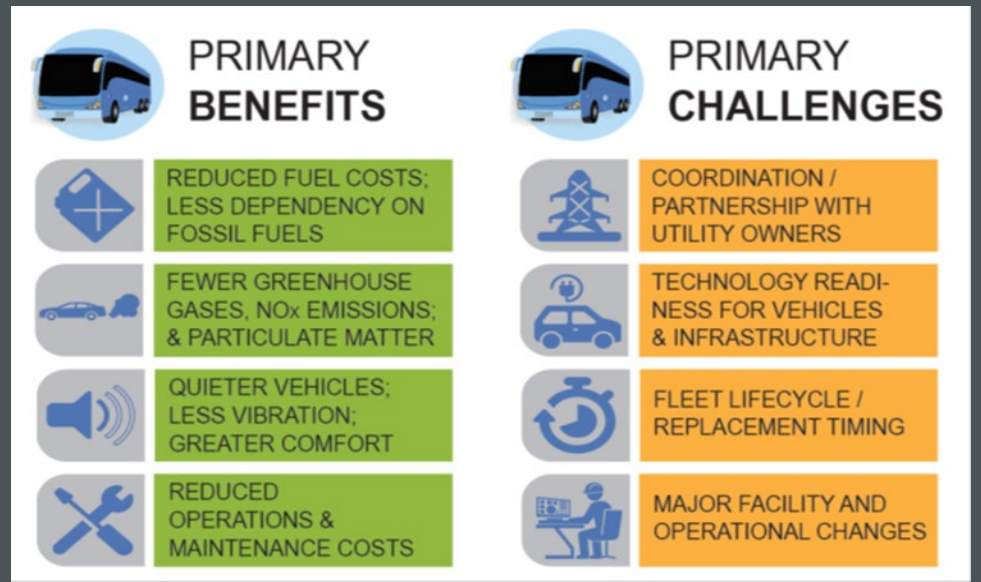
9. Conclusions and Recommendations – Continued

VTrans is also advised to:

- Use telematics systems for performance monitoring of its electric vehicles and chargers, and to develop key performance indicators in advance of deployments;
- Explore whether a charge management system would be beneficial for transit providers;
- Investigate working with “charging as a service” companies to facilitate the implementation and charging of electric vehicles; and
- Work with manufacturers to provide as much training as possible for operators, maintenance crews, and first responders, as electric vehicle fleets have different requirements than those of conventional fleets.
- VTrans has already had success in leveraging federal funds for electric bus procurements and is encouraged to continue applying for as much funding as possible to defray the capital cost of transit electrification.

VTRANS ZERO-EMISSION TRANSITION PLAN: NEXT STEPS

- Administration and Legislature presentations
  - Review Recommendations
    - Prepare for upcoming Low and No Emissions Bus and Bus Facility Grant program
    - Provide funding for GMT Fleet Transition Plan
    - Quarterly reviews of existing e-bus procurements, issues, and projects.
    - Begin implementation with the understanding of the associated challenges and benefits



QUESTIONS / DISCUSSION