Electric School Bus (ESB) Outreach Session

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

ERG

Agenda for today's session

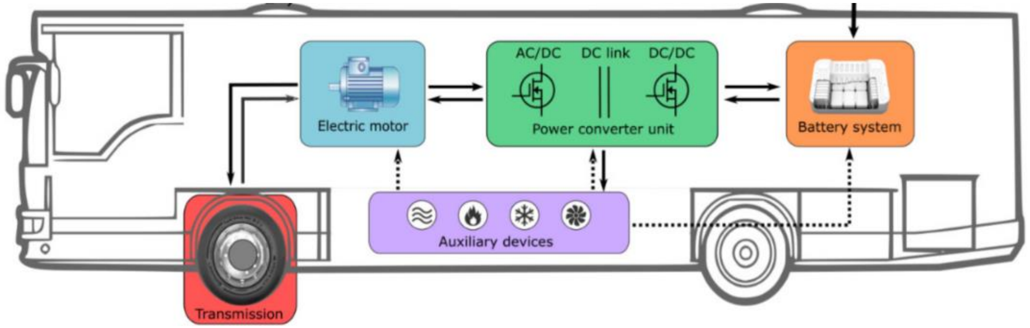
1. Introductions
2. Participant questions
3. Presentation of materials (part 1)
4. Break
5. Presentation of materials (part 2)
6. Questions and answers

Goals of today's session

- Gain a basic understanding of the essentials of electric school bus (ESB) deployment
- Learn more about ESBs and charging infrastructure technologies
- Review sources of funding to support the purchase of ESBs and charging infrastructure
- Answer questions you might have about ESB deployment

Electric vs. internal combustion engine (ICE) school buses

ESB components



What are the key differences between ESBs and ICE buses?

- **Cleaner power source:** ESBs use electricity from the electric grid stored in a battery pack to power a motor, while traditional ICE buses rely on petroleum-based fuels.
- **No tailpipe emissions:** ESBs do not have a tailpipe and do not emit exhaust.
- **Regenerative braking:** When braking, ESBs reverse the electric motor, recapturing and storing energy, thereby extending bus range.
- **Quieter:** Electric motors provide much quieter rides than ICE buses.

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

1. https://doi.org/10.3390/su132112189

What factors impact vehicle range?

- Climate/weather
  - Cold weather can limit vehicle range.
- Topography
  - Particularly steep hills can draw energy from the battery and limit the range of the ESB.
- The number of students and cargo weight
- The frequency of stops and turns

Cold weather impacts on ESBs

- ESBs operate best at temperatures between 55°F–60°F [1]
- When the temperature drops, the battery uses power to maintain battery and cabin temperatures. This reduces vehicle range. [2]
  - A battery-electric transit bus study showed range decreased by 33% when air temperature was 25°F [3]
- There can be a drain on battery life and range associated with cooling the battery and cabin in high temperatures. [4]
  - This loss in battery power is smaller than in cold weather. [5]

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

1. https:/driveelectric.gov/files/esb-cold-weather-help-sheet.pdf
2. https:/driveelectric.gov/files/esb-cold-weather-help-sheet.pdf
3. https:/driveelectric.gov/files/esb-cold-weather-help-sheet.pdf
4. https://electricschoolbusinitiative.org/all-about-range-and-reliability#:~:text=While%20extremely%20high%20ambient%20temperatures,before%20major%20issues%20can%20arise.
5. https:/www.maine.gov/doe/sites/maine.gov.doe/files/2022-06/MaineESBFactSheet.pdf

Cold weather impacts on ESBs

- Reducing the impact of cold weather on vehicle range [1]
  - Include temperature considerations when analyzing ESB route.
  - Park ESBs indoors overnight.
  - Preheat the battery and cabin while still charging the bus (known as pre-conditioning).
  - Insulate the bus.
  - Utilize mid-day charging.
  - Consider auxiliary heaters to maintain vehicle battery and cabin temperature.

1. https:/driveelectric.gov/files/esb-cold-weather-help-sheet.pdf

Cold weather impacts on ESBs

- Successful ESB operation in cold weather
  - Three Rivers Community Schools deployed ESBs in Michigan winters as low as -20° Fahrenheit. [1]
  - ESBs in the fleet have outperformed diesel buses:
    - The heavier weight of the ESB makes them less likely to fishtail in snow or ice.
    - ESBs started more reliably and faster than diesel buses.
    - The undercarriage of the ESBs are more resistant to road salt, decreasing rust related maintenance costs.
    - The ESBs have saved the district money on fuel and maintenance costs.

1. https://electricschoolbusinitiative.org/electric-school-bus-series-successfully-operating-cold-weather-three-rivers-michigan-0

Cold weather impacts on ESBs

- Successful ESB operation in cold weather.
  - Similar results have been found in Havre, Montana.[1]
    - Havre Public Schools was able to procure two ESBs for less than the price of one gas bus thanks to the state's Volkswagen settlement funds.
    - The school district has operated their buses in as low as -44° Fahrenheit (-60° Fahrenheit with wind chill).
    - The district has reported that the ESBs are outperforming their gas counterparts.
    - Operation costs have been ½ to ¼ of the costs of operating a gas or diesel bus.

pennsylvania DEPARTMENT OF ENVIRONMENTAL PROTECTION

1. https://www.npr.org/2024/02/01/1228286377/montana-school-district-finds-its-electric-buses-can-handle-sub-zero-weather

Typical cost of ESBs vs. ICE buses

	Price of ESB [1]	Price of ICE Bus [2]
Type A	$195,000 to $381,000	$50,000 to $65,000
Type C	$280,000 to $491,000	$100,000
Type D	$327,000 to $521,000	$100,000

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

1. https://electricschoolbusinitiative.org/all-about-types-electric-school-buses
2. https://www.cnbc.com/2022/12/10/electric-school-buses-give-kids-a-cleaner-but-costlier-ride-.html#:~:text=ESBs%20are%20expensive%3A%20Battery%2Delectric,versus%20about%20%24100%2C000%20for%20diesel.

Example ESB models and performance

Type A

	Bluebird Microbird G5[1]	BYD Type A[2]
Cost	$235,602 -$381,317	$287,000 -$290,000
Battery size	88 kWh	140.76 kWh
Range	100 miles	105 miles

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

1. https://electricschoolbusinitiative.org/all-about-types-electric-school-buses
2. https://electricschoolbusinitiative.org/all-about-types-electric-school-buses

Example ESB models and performance

Type C

	Bluebird Vision [1]	Lion Electric [2]	Thomas Built Buses Saf-T-Liner C2 Jouley [3]
Cost	$308,029 -$491,330	$341,229 -$399,055	$309,571 -$425,347
Battery size	• 124 kWh • 157 kWh	• 126 kWh • 168 kWh	226 kWh
Range	Dependent on battery size • 100 miles • 120 miles	Dependent on battery size • 100 miles • 125 miles	138 miles

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

1. https://electricschoolbusinitiative.org/all-about-types-electric-school-buses
2. https://electricschoolbusinitiative.org/all-about-types-electric-school-buses
3. https://electricschoolbusinitiative.org/all-about-types-electric-school-buses

Example ESB models and performance

Type D

	Bluebird All-American [1]	Lion D [2]
Cost	$327,356 -$521,459	$405,261
Battery size	124 kWh	• 126 kWh • 168 kWh
Range	100 miles	Dependent on battery size • 100 miles • 125 miles

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

1. https://electricschoolbusinitiative.org/all-about-types-electric-school-buses
2. https://electricschoolbusinitiative.org/all-about-types-electric-school-buses

Environmental benefits

- What are the environmental benefits of ESBs?
  - Gasoline and especially diesel engines have significant impacts outside <u>and inside</u> the bus
    - Particulate matter (PM), carbon monoxide and ozone => chronic health conditions
    - Children particularly susceptible (e.g., asthma and bronchitis)
    - Disproportionate impacts on rural and low-income students and communities (health and absenteeism)
  - ESBs have zero tailpipe emissions, improving air quality for students, drivers, and the immediate community

Environmental benefits

- Emission reductions (tons per year)

	CO_2	NO_x	$PM_{2.5}$
Statewide	207,682	648	16
% Reduction	65%	92%	70%

- Accounts for average power plant emissions.
- Assumes full fleet replacement (~27K buses statewide), current power plant mix.
- Smart charging should decrease emissions.
- Reductions will be even greater as grid moves further toward renewables.

Environmental benefits

- Other benefits
  - Decreased engine noise (esp. diesels)
  - Decreased brake wear and brake dust
  - Reduced waste disposal – no engine oil, coolant, or transmission fluid

Maintenance considerations

- How does ESB fleet maintenance differ from traditional ICE fleets?
  - ICE bus engine: about 2,000 components
  - EV bus motor: <100 components
  - Many maintenance requirements significantly reduced
    - No engine oil or power steering fluid
    - Decreased brake wear
    - Annual maintenance savings typically between $4K and $11K per bus

Maintenance considerations

- ESB maintenance
  - No special EV inspection/maintenance requirements under FMC regulations (49 CFR Part 396)
  - Follow maintenance schedules listed in your ESB service manual
  - Maintenance usually covered by battery/drivetrain warranties (5 yr/100K mi)
  - Trained, certified dealer/manufacturer technicians typically sent on-site for repairs
  - Separate dealer maintenance contracts available
  - Non-EV systems (tires, transmission and brake fluids, etc.) can be handled by in-house technicians

Maintenance considerations

- EVSE Maintenance
  - Follow manufacturer preventative maintenance schedules to maximize system up-time and equipment life
    - Power cable replacement frequency
    - Regular visual inspections for corrosion, nicks, cuts, etc.
    - Listen for unexpected noises from fans, other moving parts
  - If problems are identified contact your dealer/manufacturer for diagnosis and repair
  - *Do not attempt repair of high-voltage systems with untrained in-house staff*

Maintenance considerations

- EVSE Maintenance
  - Basic EVSE warranties run 2-3 years
  - Extended maintenance/service options include
    - Charger manufacturer extended warranties - commonly 5 years w/ up-time % guarantee, low cost, some exclusions
    - Charge management service warranties – on-site diagnosis and repair offered
    - As-a-Service providers – generally all-inclusive service packages, high-cost
    - Reliability as-a-service providers – focus on maintaining system up-time (specific %)

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Cost-effectiveness

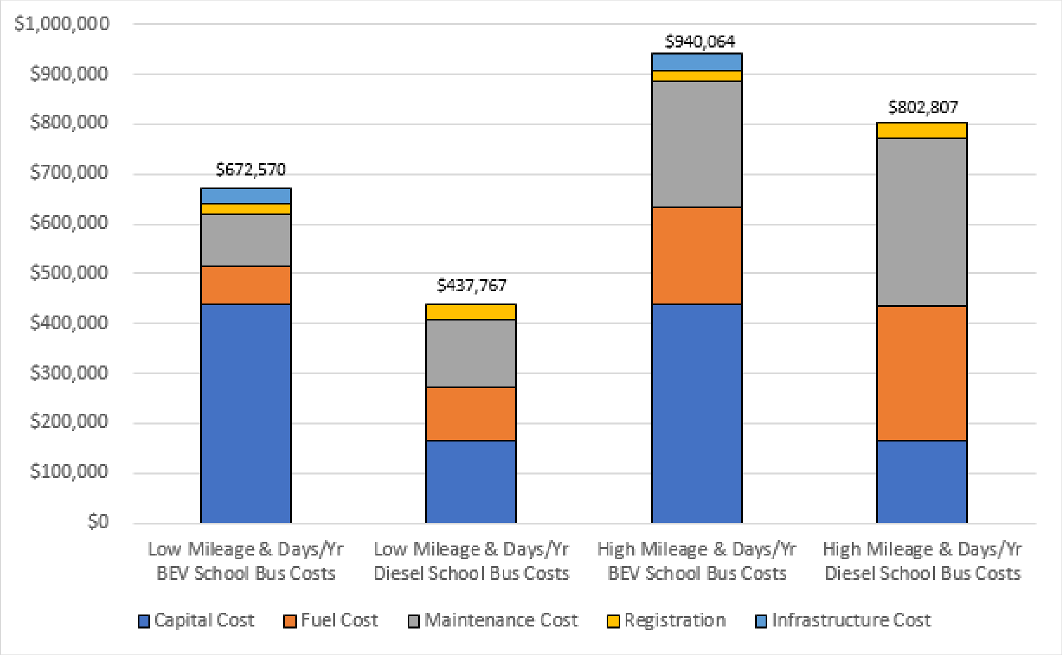
- What are the costs and savings associated with bus electrification?
  - ESB cost factors
    - Up-front - Vehicle and EVSE cost (higher)
    - Operating – Utility charges, maintenance savings (typically lower)
    - Resale/Salvage – Vehicle/battery (uncertain)
    - Subsidies/Incentives – discussed in later slides
  - Potential for payback prior to retirement
  - Total cost of ownership (TCO) preferred metric over $/mi

Cost-effectiveness

Key variables impacting cost-effectiveness

- Total miles travelled (e.g., rural vs. urban routes)
- Fixed costs
  - Battery capacity
  - Charging system level (Level 2 vs DCFC)
  - Charging system infrastructure and installation requirements
- Operating costs
  - Vehicle efficiency (kWh/mi)
  - Electricity charges
  - Demand charges
  - Charge management ("smart charging")
  - Maintenance savings

Cost-effectiveness - example TCO scenarios

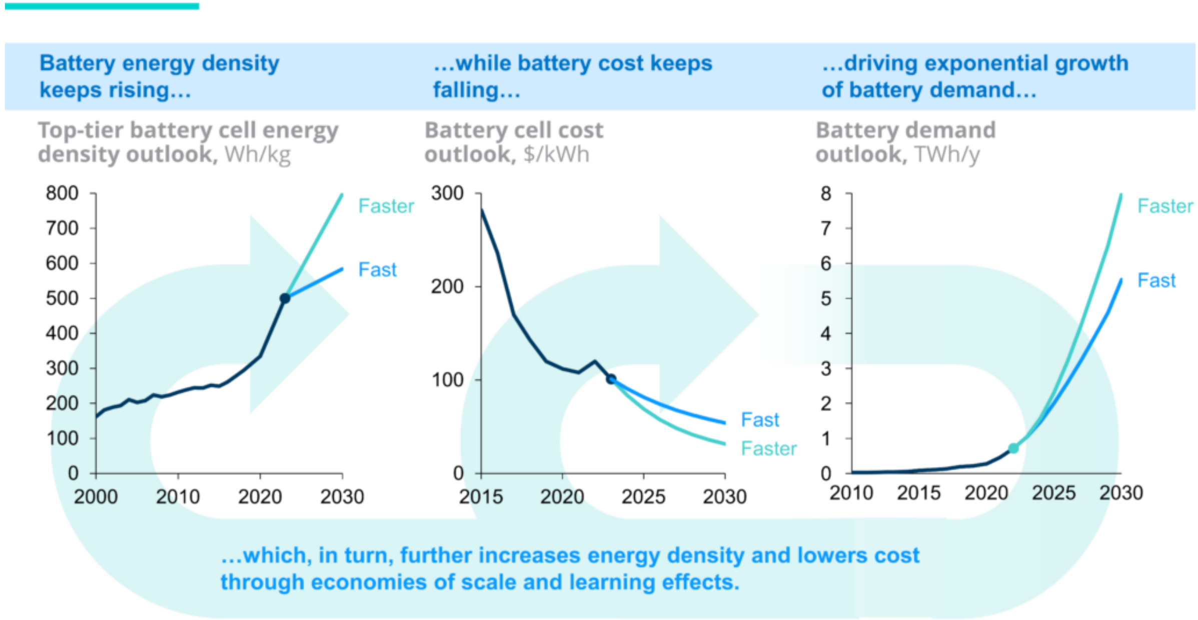


Source – NY State Electric School Bus Roadmap

- Potential TCO reductions over time (e.g., production at scale, battery tech advances, V2G)

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Cost-effectiveness – battery cost over time



Source – RMI The Rise of Batteries in Six Charts and Not Too Many Numbers

- Technological improvements and falling costs situates battery powered vehicles for continued success.
  - More information can be found here: [The Rise of Batteries in Six Charts and Not Too Many Numbers]

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Bus fleet and route analysis

Which buses should be replaced by ESBs?

- To maximize the benefits of electrification ESBs should replace the oldest and highest-polluting buses in a diesel fleet.
- The EPA's 2023 Clean School Bus Rebate program mandates that new ESBs replace older diesel buses which must be taken out of service.
  - A fleet with a diesel bus model year 2010 or older must be scrapped. If the fleet does not have such a vehicle:
    - Non-diesel internal combustion engine buses model year 2010 or older must be scrapped.
    - or, diesel or non diesel internal combustion engine buses model year 2011 or newer must be scrapped, sold, or donated.

Bus fleet and route analysis

How far can ESBs go?

- ESB ranges vary: most ESBs have a listed range of at least 120 miles, buses with larger batteries listed up to 210 miles.
  - Feasible routes for ESBs should not target the listed range as cold weather and cabin heating reduce battery range
  - Mid-day charging is a good option for districts who want ESBs to serve multiple routes and are concerned about ESB range.

Bus fleet and route analysis

Which routes should ESBs be placed on?

- Considerations include:
  - Climate/weather
  - Topography
  - Battery state of charge
  - Battery Size
  - Number of routes served
  - The frequency of stops and turns
  - Dwell time between routes

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Charging needs and electrical service upgrades

- What are the charging needs of ESBs?
- ESBs typically have a battery size of 120-250 kWh
- There are 3 kinds of chargers available: Level 1, Level 2, and Level 3 (DCFC)

	Level 1	Level 2	Level 3 (DCFC)
Voltage [1]	120 V AC	208 - 240 V AC	400 V – 1,000 V DC
Typical Power Output [2]	1 kW	7 kW - 19 kW	50 - 350 kW

1. https://www.transportation.gov/rural/ev/toolkit/ev-basics/charging-speeds
2. https://www.transportation.gov/rural/ev/toolkit/ev-basics/charging-speeds

pennsylvania DEPARTMENT OF ENVIRONMENTAL PROTECTION

Charging needs and electrical service upgrades

- When planning to upgrade electrical infrastructure to support ESB charging, early and frequent engagement with your utility provider is key
  - Districts can take advantage of lower rates or make-ready funding (financing to support site or equipment upgrades) from the utility company
- Future Considerations: Vehicle to Grid/V2X
  - Vehicle to grid or V2X refers to the capacity of ESBs to serve as mobile power sources. The vehicles can store energy and release it back through V2X technology. Some of the uses include selling energy back to the grid at peak demand hours and connecting to buildings to provide electricity during power outages.

Charging needs and electrical service upgrades

- How to charge ESBs once the infrastructure is in place.
  - It is a best practice to avoid charging ESBs during peak demand hours (8am-9pm) to avoid higher pricing and demand charges
  - Charging the vehicle up to 80% and minimizing the time charge drops below 20% preserves long-term battery health
  - Districts who deploy charge management software can schedule when charging begins and ends for a bus that has already been plugged into a charger. This allows districts to remotely control when their bus is charging without having to have staff on the premises to physically plug in and unplug the vehicle.
    - This allows for districts to take advantage of cheaper energy rates

Financial incentives

- What funding mechanisms are available to those interested in procuring ESBs/?
- EPA Clean School Bus Program rebates/grants:
  - "With funding from the Bipartisan Infrastructure Law, the EPA's Clean School Bus (CSB) Program provides $5 billion over five years (FY 2022-2026) to replace existing school buses with zero-emission and low-emission models." [1]
  - This program has had multiple rounds of funding. Currently, the 2023 rebate application is open until 4 PM ET on February 14, 2024. This round should provide at least $500 million in total funding

1. https://www.epa.gov/cleanschoolbus

Financial incentives

- EPA Diesel Emissions Reduction Act (DERA) Funding:
  - "The Diesel Emissions Reduction Act (DERA) Program funds grants and rebates that protect human health and improve air quality by reducing harmful emissions from diesel engines." [1]
  - As of 2017, matching funding for eligible DERA projects can be provided through the Pennsylvania Environmental Mitigation Trust Agreement.

1. https://www.epa.gov/dera

Financial incentives

- EPA Clean Heavy Duty Vehicle Programming:
  - "EPA will be distributing this $1 billion in funding for clean heavy-duty vehicles between now and 2031. $400 Million will be going to communities in nonattainment areas." [1]
  - "We will be offering grants and/or rebates to eligible recipients to replace existing heavy-duty vehicles with clean, zero-emission vehicles." [2]

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

1. https://www.epa.gov/inflation-reduction-act/clean-heavy-duty-vehicle-program
2. https://www.epa.gov/inflation-reduction-act/clean-heavy-duty-vehicle-program

Financial incentives

- State/local funding avenues:
  - Many state and local governments provide funding opportunities for ESBs or their associated charging equipment.
  - It is also worth checking with your local utility to see if they can provide make-ready funding or lower rates for your electrification project.

Financial incentives

- State of Pennsylvania funding:
  - PA Alternative Fuels Incentive Grants Program [1]
    - This program provides $5 million of yearly funding to advance the use of vehicles using alternative fuels and prioritizes zero-emission transportation projects.
    - Funding can be used for vehicle replacement, infrastructure, necessary training, deployment activities, and vehicle retrofits.
  - Driving PA Forward Grant and Rebate Program [2]
    - This program contains various subprograms that would be able to provide funding for ESBs and their associated infrastructure. These include:
      - On-road Rebate Program;
      - PA State Clean Diesel Grant Program (DERA);

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

1. https://www.dep.pa.gov/Citizens/GrantsLoansRebates/Alternative-Fuels-Incentive-Grant/Pages/default.aspx
2. https://storymaps.arcgis.com/stories/6f5db16b8399488a8ef2567e1affa1e2

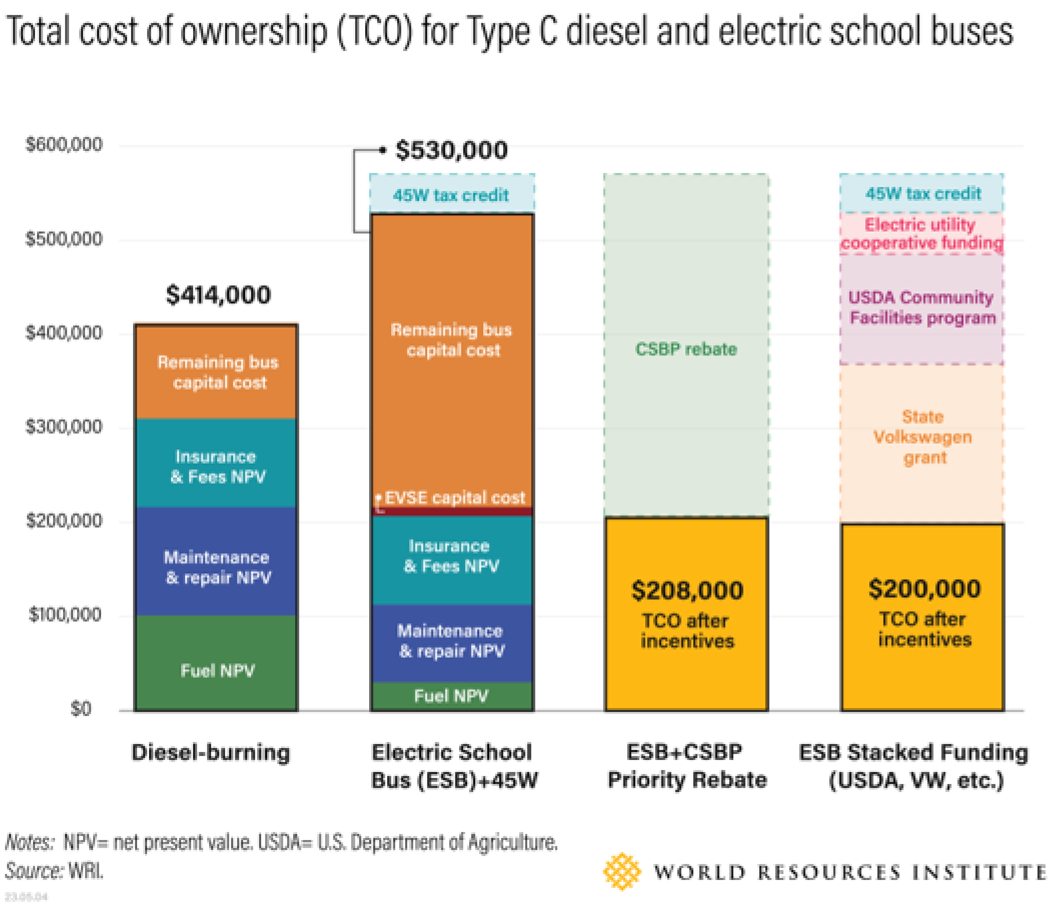
Financial incentives

- Some notable make-ready funding programs in Pennsylvania :
  - The Duquesne Light Company offers a Fleet Charging Program in which they design, build, and maintain the appropriate infrastructure to support ESBs from the power grid to the charging station. [1]
  - The PECO Energy Company offers a Public Benefit Charging Program which includes up to 50% of Make-Ready work or $60,000 max funding per project. In addition, they can offer funding for chargers on a per-port basis. [2]

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

1. https://www.duquesnelight.com/docs/default-source/default-document-library/fleet_programguide_final.pdf
2. http://peco.com/ev

Impact of financial incentives - example



1. https://electricschoolbusinitiative.org/all-about-total-cost-ownership-tco-electric-school-buses

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Safety

- What are important safety considerations for ESBs?
- Vehicle fires are a risk when operating any vehicle.
  - Through extensive battery testing and built in safety measures, fires are significantly less likely to occur in an ESB than an internal combustion engine bus.
  - The placement of the battery in the vehicle helps to make rollovers (a common cause of fires) less likely.

Safety

- It is still important to coordinate with first responders, vehicle operators, and maintenance staff to provide trainings on the safest ways to work with ESBs and the best practices in case of an emergency.
- Emergency Response Guides can be found online alongside other helpful resources on websites such as the National Fire Prevention Association. [1]

1. https://www.nfpa.org/EV

References

- BTCPower: DC Fast Charger Installation and Maintenance Manual – (see example – p. 21)
- Environmental Defense Fund: Electric School Bus Fact Sheet – Focusing on environmental benefits of ESBs.
- EPA: Clean School Bus Program – EPA's most recent Report to Congress on its Clean School Bus Program.
- Rocky Mountain Institute: More EVs, Fewer Emissions – Discusses the emissions benefit potential of smart charging.
- World Resources Institute: Why Electric School Buses – Download and customize a 'pitch deck' to share information on the benefits of school bus electrification.
- Department of Energy Alternative Fuels Data Center: ESB Education – A video series focused on everything ESBs including cost factors and vehicle requirements.
- Electrification Coalition: DRVE Tool – Allows users to input fleet data to help optimize EV deployment.
- What you need to know about EV Charger Maintenance: A Comprehensive Guide to Essential Upkeep – Guidance for proper charging system maintenance

References

- CALSTART: Electric School Buses Market Study – An analysis of the current ESB market.
- World Resources Institute Electric School Bus Initiative: Funding Clearinghouse – An overview of available ESB funding opportunities.
- World Resources Institute Electric School Bus Initiative: All About Types of Electric School Buses – A market report and a guide to the available ESBs on the market.
- World Resources Institute Electric School Bus Initiative: The Electric School Bus Series: Successfully Operating in Cold Weather in Three Rivers, Michigan – Information on the successful deployment of ESBs in Three Rivers, Michigan.
- Joint Office of Energy and Transportation: Cold Weather Impacts on Electric School Buses – Information on ESB performance in cold weather.
- RMI: The Rise of Batteries in Six Charts and Not Too Many Numbers – Information on battery performance and cost.
- National Public Radio: Montana school district finds its electric buses can handle sub zero weather – Case study of a school district in Montana succeeding with their ESBs.

Thank you for attending

Please fill out our bus operator survey
https://erg.qualtrics.com/jfe/form/SV_1TSWbJ9oxxD0EBM

Jonathan Ells: Jonathan.Ells@erg.com

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION