Zero-emission Bus Fleet: A Review of State Practices, Recent Developments, and Future Directions

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Introduction

- On-road transport the most significant contribution to air pollution and Green House Gas (GHG) emissions
- Only in 2020, worldwide, 16.2% GHG emissions of transportation sector
- Significantly impacts of public transportation on GHG emissions, more prevalent in large cities
- Prediction of urbanization by 68% of the population by 2050
- Decarbonization of the public sector is a significant issue to pay attention to.
- Zero Emission Buses (ZEBs), also known as Electric Buses (E-Buses), part of a strategy

Objectives

- Summary of the impact of ZEBs on people's health, air quality, and noise pollution
- Comparison of maintenance and fuel costs for ZEBs and Conventional buses
- ZEB adoptions across the nation and current challenge
- Available incentives, and funding sources created to advance and promote ZEB

Impact on Public Health and Air Quality

- Vehicle pollution sources cause asthma, lung cancer, premature deaths, dementia, Alzheimer's disease, and high blood pressure.
- In the U.S., the number of annual air pollution deaths could be increased by about 1000 due to a 1 degree K rise in temperature change induced by CO2 increased GHG emissions.

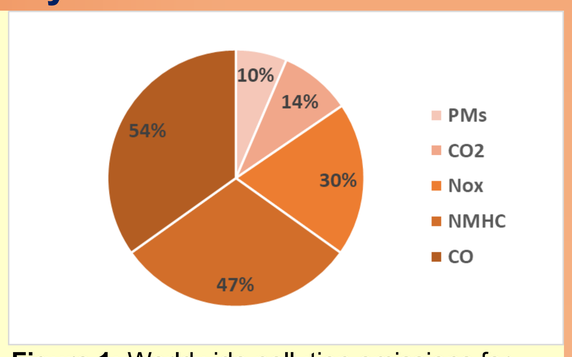

Figure 1: Worldwide pollution emissions for the on-road transport sector

- Increased GHG emissions have increased the probability of extreme weather events like floods, storms, droughts, and even wildfires.
- Based on the study, about 60% reduction in CO2/km by ZEBs compared to diesel buses during their lifetime was reported.
- Per ton CO2 equivalent reduction can save $12,037.
- The annual saving due to carbon reduction of electrification will be about $3,000 per bus
- Transfer of per conventional bus with the ZEB will have an average of $55,000 to 150,000 health savings for residents annually.

Impact on Noise Pollution

- significantly contribution of public transportation to traffic noise, specifically, diesel buses could be a high noise annoyance.
- Based on a comparison of a diesel bus and an electric bus at a constant and low speed of 15km/h, a potential noise reduction of up to 12 dBA was found, and during acceleration, this difference will reach 20 dBA.
- Electric buses not only reduce exterior noise but also decrease interior noise and vibration so that the comfortability of passengers will improve.

Cost of ZEBs

- Whereas upfront costs for ZEBs are higher than conventional buses, expenses are compensated during the lifetime by maintenance and fuel savings.

Table 1: Comparison of maintenance and Fuel costs of BEB and Conventional bus

Evaluation results	Battery Electric Bus	Conventional bus
King County Metro (BEB & Diesel)		
Maintenance cost ($/mile)	0.26	0.46
Maintenance cost ($/bus)	7,229.06	10,717.4
Fuel economy (miles/dge[1])	15.9	5.3
Fuel cost ($/mile)	0.57	0.30
Long Beach Transit (BEB & CNG)		
Maintenance cost ($/mile)	0.44	0.54
Maintenance cost ($/bus)	7,056.76	21,427.37
Fuel economy (miles/dge[1])	20.71	3.49
Fuel cost ($/mile)	0.61	0.43

[1] diesel gallon equivalent

Zero Emission Bus Fleet in the U.S.

- **Battery Electric bus (BEB):** one type of ZEB with no tailpipe emission and are considered zero-emission operations.
- Although electricity generation for battery charging leads to air pollution, the transition to BEBs causes air pollution reduction.
- **Operation of ZEBs in the U.S.:** BEBs's operation is more popular than other types of ZEBs.
- Overall, the use of BEBs has grown 94% from 2020-2021 in the U.S.
- In 2021, the total number of BEBs in the U.S. was reported 3364.
- The major challenges for BEB deployment is its power limitation for acceleration that implementation of hybrid electric bus with supercapacitor (capability of high power density) is recommended.

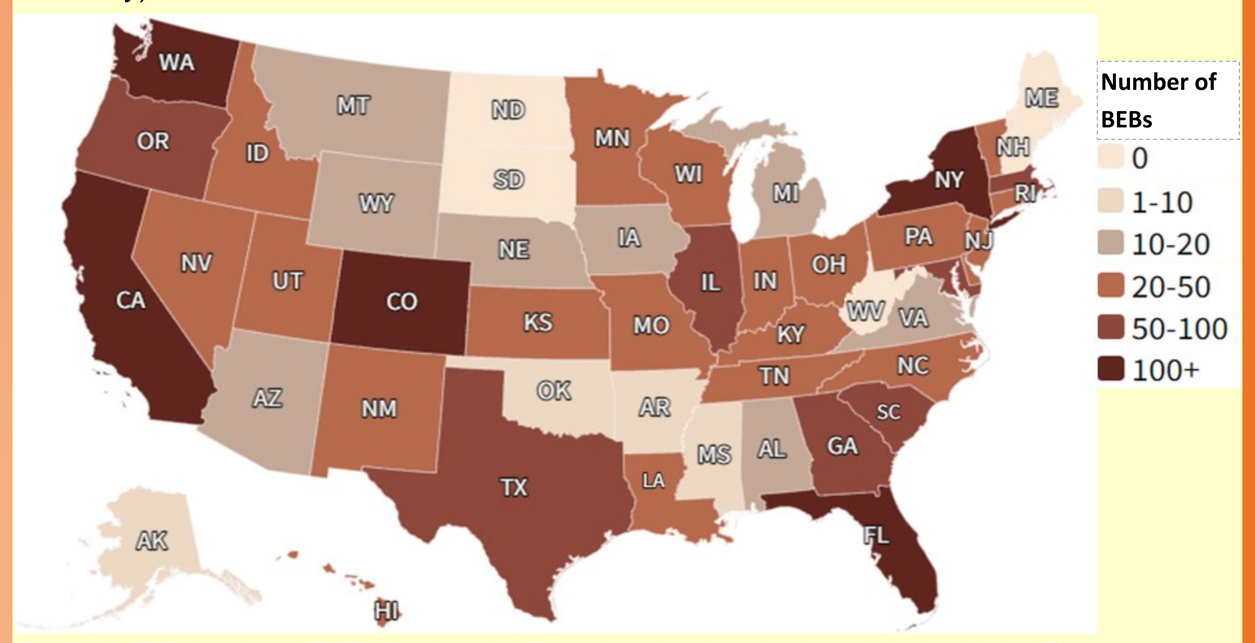

Figure 2: Full size transit BEBs deployed, delivered, ordered, or funded within the United States

Federal, State, and Private Incentives and Funding Sources for Public Bus Electrification in the U.S.

- **Federal:**
  - The most remarkable funding program for transit bus electrification is **The Low-or-No Emissions Grant program** that annually by FTA under the Bipartisan Infrastructure Law is presented.
  - The grant for the fiscal year of 2022 is $1.1 billion, and over five years, $5.5 billion will be allocated.
- **State and Private:**

  Grants, funding for reimbursement, loan, tax credit, rebate or discount for purchase of the vehicle, purchase and installation of infrastructure, electricity expenses, and test or inspection exemption for electric vehicles
  - The major states' incentive for medium and heavy-duty was committed by sign of **Memorandum of understanding (MOU) by 17states**
  - The major private incentive by contribution of 45 states is **National Electric Highway Coalition (NEHC)**
  - A collaboration among electric companies to install electric vehicle fast charging along major routes.

Conclusion

- Implementation of ZEB would significantly impact GHG emissions.
- The saving for health problems related to pollution and healthful future generations were demonstrated.
- The deployment of zero-emission buses (ZEBs) will be beneficial in urban areas under the influence of noise pollution.
- The deployment of supercapacitor with high power as a hybrid fuel can help electric buses improve their efficiency in the revenue service.
- No in-service supercapacitor hybrid electric bus in the country that is recommended.
- Findings provide a single-point resource for agencies, policymakers, practitioners, and researchers to better plan for a fleet transition to ZEBs underway.