Supplementary Materials: On the Front Lines of a Sustainable Transportation Fleet: Applications of Vehicle-to-Grid Technology for Transit and School Buses

Tolga Ercan, Mehdi Noori, Yang Zhao and Omer Tatari

S1. Background Information

S1.1. Background Information of Life Cycle Assessment and Alternative Fuel Applications

Frey *et al.*'s [1] article compared the life cycle assessment (LCA) results for diesel and hydrogen fuel cell transit buses. Hess [2] evaluated the environmental emissions of alternative fuel transit buses. Using process-LCA tool GABI and fuel cycle models, Ally and Pryor [3] likewise compared diesel, natural gas, and fuel cell bus options. Chester and Horvath's [4] research is particularly crucial for literature since it defines and quantifies all of the public transportation modes' LCA analysis results, but although it is an important study in terms of methods and data, the study itself is beyond the scope of this research which will assume that the infrastructure of BE and diesel buses will be the same except for the charging infrastructure of each bus type, as will be further explained in later sections. Ou *et al.* [5] investigated alternative fuel use level scenarios for future years under various scenarios related to the adoption of alternative fuels for transit buses. Moreover, their study was followed by another crucial research study that served as an extension to the first study, evaluating different policy recommendations for reducing GHG emissions and fossil fuel consumption in China by using alternative fuels for transit buses [6]. Cooney *et al.* [7] advanced literature with a study using a hybrid-LCA approach to evaluate the environmental emission impacts of BE and diesel transit buses, taking the different state-based electricity grid mixes into account. García Sánchez *et al.* [8] published a similar study comparing the GHG emissions and energy consumption rates of BE, hybrid, and diesel buses for Spain's current and future electricity generation mixes. Lajunen [9] presented crucial research for the lifetime energy consumption rates and cost-benefit analysis results of BE and hybrid transit buses. More recently, Xu *et al.* [10] investigated the environmental emission performance of various alternative fuel options for transit buses in different U.S. cities under different operational conditions. Finally, Ercan and Tatari [11] studied diesel, hybrid, BE, biodiesel, Compressed Natural Gas (CNG), and Liquefied Natural Gas (LNG) fuel options of transit buses in terms of their lifetime environmental emissions and water withdrawal impacts. Ercan and Tatari's study also considered the electricity grid mixes of the different North American Electric Reliability Corporation (NERC) regions for analysis of emissions and water withdrawal impacts, and also presents the significant differences of using BE buses in different regions much like Cooney *et al.*'s study did.

S1.2. Background Information of Vehicle-to-Grid Technology

Electricity is a unique commodity, which has to be generated and consumed at the same time. However, apart from the predictable peak hour electricity demand (which is commonly estimated based on historical data), the random turning on/off of millions of appliances in any given period of time would also affect the balance of the system; any additional power demand from these fluctuations is currently provided by ramping up/down gas turbine generators [12]. In addition, the frequency of the electric grid is supposed to be maintained as close to 60 Hz as possible, which requires a fast responding mechanism. Electricity storage means have proven to be more efficient for this purpose from both an environmental perspective and an economic perspective [12,13]. However, current electric systems lack usable storage methods other than a few hydropower storage stations and/or stationary battery sets. Kempton *et al.* studied the feasibility and potential benefits of electricity ancillary services provided by electric vehicles and found that "the vehicle-to-grid (V2G) system as a grid storage means, stores the excessive electricity and release it back to the grid when the demand is high, and allows the electric system operator to precisely control the timing of the electricity flow" [14]. Hence, the V2G provider can store the "cheap" electricity during non-peak hours and then sell back the stored electricity at a higher price as needed during peak hours.

Kempton and Tomic [15] performed a study researching the actual availability of EV power, in which they also compared V2G ancillary service revenues as well as the costs incurred due to battery degradation. In addition, the integration of V2G technologies and highly fluctuated renewable energy sources has also been studied [16]. The power capacity provided by a single EV is merely a "noise" to the grid, so aggregators are needed for the real-life adoption of V2G technologies. Furthermore, Kempton and Tomic [12] have also discussed possible business models for the incorporation of V2G and fluctuated renewable energy.

The main drives for the implementation of EVs in tandem with the V2G system in a fleet are the wide range of economic and environmental benefits, and so Noel and McCormack [17] studied the potential revenue of the V2G system for school buses. The State of Charge (SOC) variation in vehicle batteries during responses to Pennsylvania-New Jersey-Maryland (PJM) interconnection regulation requests have tested by Kempton *et al.*'s study. The random signal patterns of the regulation requests are recorded, and the shallow charge/discharge of the battery is also revealed [14].

In addition to the above mentioned studies with respect to the potential benefits of V2G systems, an energy-system model has been used to project the future changes of both energy and transportation systems, as well as the possible emission savings from implementing a V2G system [18]. Kudoh *et al.* [19] studied Vehicle to Home (V2H) systems, which are a parallel concept of V2G technologies, from a LCA perspective, and the result of this study shows significant emission savings.

S1.3. Background Information of Air Pollution Externalities

In addition to GHG emissions' harmful impacts on the environment and on public health, other seriously harmful emissions emitted from vehicles include emissions of CO, SO_2, NO_x, PM_{10}, and $PM_{2.5}$. All of these pollutants, including GHG, have damage impacts on public health at different levels, and furthermore, their harmful affects are quantified with the consideration of each emission type's impact on human health and the setting (e.g., urban or rural) in which the emissions occur. In 2006, Muller and Mendelsohn developed the Air Pollution Emission Experiments and Policy (APEEP) analysis model to quantify these air emissions' human health impacts [20,21]. The harmful effects covered in the APEEP model include mortality, morbidity, crop loss, timber loss, *etc.*, as well as impacts on human health caused by the aforementioned air emissions. Likewise, Michalek *et al.* [22] enhanced this analysis model and presented air emission externalities for vehicle manufacturing, fuel production, electricity generation, and tailpipe emissions, quantifying emission externalities based on the assumption that, excluding tailpipe emissions, all other activities occur most likely in rural areas. Michalek *et al.*'s results have since guided several studies for life-cycle analyses of buses in literature. Gouge *et al.* [23] utilized these analysis methods to present an optimal transit bus operation for reducing environmental impacts. Ercan *et al.* [24] also presented an optimal bus fleet in terms of life cycle cost, CO_2 emissions, and air emission externalities with different alternative fuel choices for transit buses under different driving conditions. Finally, Noel and McCormack [17] also presented diesel and BE school bus results for air emission externalities.

S2. Methods and Materials

S2.1. Life Cycle Assessment Method

The LCA approach was first developed in the early 1990s, and is defined by the International Standards Organization (ISO) as a method that considers all of the stages of forming a product or process (*i.e.*, life-cycle phases) on a cumulative and quantitative basis [25]. This widely utilized powerful assessment tool considers all of the impacts connected to a given product or process over the course of its entire life cycle, starting with the raw material extraction phase, followed by the production phase, use/operation phase, transportation phase, and finally the end-of-life phase [26].

Downstream emissions are gathered from the emission data for diesel transit and school buses from Environmental Protection Agency's (EPA) widely utilized MOVES tool [27]. It is important to highlight that MOVES provides on-site emission data for model years 2010 and 2015, and that the emissions (in grams per mile) from these model years are adjusted using deterioration factors based on vehicle age. In other words, the emissions reported for the model year of 2015 will not remain at the same rate for the lifetime of vehicle. For instance, PM_{10} emissions reach up to 151% of the reported emissions for a diesel school bus in 5 years for the model year 2010, whereas the corresponding CO emissions reduce to average 94% of reported emissions (please see Tables S7 and S8 for each year's g/mile emissions). Moreover, the MOVES tool only reports tailpipe emissions for some conventional air pollutants: CO, NO_x, PM_{10}, $PM_{2.5}$, and VOCs. Therefore, on-site activity related GHG emissions are gathered from another source, also in units of grams per mile. M.J. Bradley's report on transit buses presented the tailpipe GHG emissions for different driving cycles with different engines, whereas electric buses have no downstream impacts [28].

Upstream impacts involve many different activities, as opposed to downstream impacts, which can be calculated using a simple quantification of tailpipe and TBW emissions. For example, an analysis of emissions pertaining to diesel production must consider the impacts of crude oil extraction, petroleum refinery production, and transportation activities. As part of a WTW analysis, the results of a separate Well-to-Pump (WTP) analysis are gathered from the tool GREET 2015 [29]. The WTW analysis can then be concluded with the summation of downstream and WTP emissions for each bus and fuel type.

Like those of diesel production, the total emissions from electricity generation also consist of emissions from many different activities. Furthermore, there are many types of power generation plants in the U.S. for electricity generation, and all of these power plant types have different emissions rates per kWh of electricity generated. The costs and environmental emission impacts of consumed electricity vary significantly throughout the U.S. due to each region's variations in terms of electricity generation source mixes. In other words, generalized nationwide electricity generation related impacts would not present sufficient information on the efficiency of operating electric vehicles. Besides, due to power trade between states in order to supply demand, electricity consumption (grid) mix differs in the same state than electricity generation mix. The impacts of this difference for electric vehicle use is studied in literature for the U.S. and Italy [7,11,30–32].

S2.2. Regional Selection of Analysis

The electricity markets in the states is divided into two parts: regulated markets and deregulated markets. Regulated markets (for example Florida, Colorado, Idaho, and Kentucky) feature vertically-integrated utilities that own or control the entire flow of electricity from generation to meter. Deregulated markets (the five ISO/RTO regions studied in this paper) (regional transmission organizations (RTO)) feature grid operators that administer wholesale markets to ensure reliability on the grid and prevent blackouts. Only in these ISO/RTO regions can the flow of electricity controlled or coordinated by the grid operators, and in the regulated states, data such as regulation service price is not available. In other words, since fleet/vehicle owners will not be able bid/sale electricity back to the grid so regulated market regions of the U.S. are selected for analysis. Following Figure S1 presents the regions that suitable for V2G service analysis on the U.S. map.

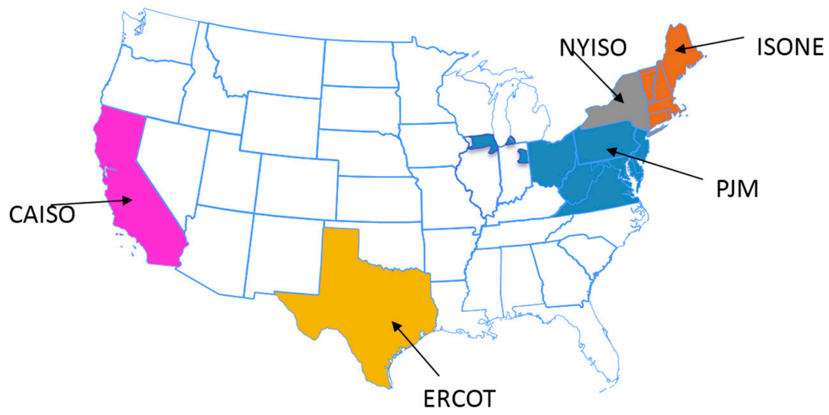

Figure S1. International standards organization/regional transmission organizations ISO/RTO regions for the scope of this study.

S3. Data Collection

S3.1. Transit and School Bus Specifications

The analysis and data collection steps used in this research are performed for 40′ long diesel and BE transit buses and for Type C diesel and BE school buses. These are most commonly used bus types for transit and school bus fleets and they are identical for their gross vehicle weights (GVW: 33,000–40,000 lb for 40′ transit bus and GVW is required to be greater than 25,000 lb for Type C school buses where it is found mostly 33,000 lb [33,34]). However, transit buses are designed as low floor for ADA regulations with less seating availability and front door is front of tire, where type C school buses are designed to have maximum seating availability and front door is located behind tire.

Initial cost values are also important to calculate another cash flow parameter: the resale value. This study utilizes the assumptions from the Argonne National Laboratory's Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) tool for the depreciation effects of lifetime usage [35]. Based on these assumptions, a vehicle loses 23% of its value after the first year, and then 15% for subsequent years.

The maintenance costs of each bus type ($C_{B\text{-main}}$), excluding battery replacement, are also gathered from AFLEET tool data. In addition, Noel and McCormack's [17] study is used to present a maintenance-related range for BE buses. It is commonly accepted in literature that BE buses require less maintenance than internal combustion engine powertrains, but the precise maintenance cost reduction is not clear, as noted by the range presented in Table 3 (please see the manuscript). Furthermore, diesel transit and school buses are assumed to have the same per-mile maintenance cost rate of 1.00 $/mile [36].

The fuel consumption rates of transit and school diesel buses have been tested in many different aspects, and the resulting data is available from multiple sources. In particular, the fuel economy of transit diesel buses varies significantly as shown in Ercan and Tatari's study, due to different driving cycle conditions such as those corresponding to Manhattan (low average speed with frequent stops), the Central Business District (a theoretically designed drive cycle with equally distributed stops), and the Orange County Transit Authority (high average speed with less frequent stops) Based on these driving cycles and Ercan and Tatari's [11] study information, the fuel economy of diesel transit buses is assumed to vary between 2.82 to 4.14 MPDGE (miles per diesel gallon equivalent). In contrast, the fuel consumption of diesel school buses does not indicate any significant variety according to Noel and McCormack's study and the NREL's report, so the diesel school bus fuel economy is assumed to be 7 MPDGE [17,37]. Similar to their electricity price projections, the Energy Information Administration's (EIA) Annual Energy Outlook 2015 presents low, medium, and high oil price projections for the U.S. in different regions [38], and so the diesel prices per gallon for the study regions are assumed based on these oil price projections (Study period regional diesel price projections are presented in Table S6).

Charging facility cost is another important requirement for BE vehicle operations, and requires more consideration from fleet owners. Even though school buses are assumed to be charged after each driving cycle (depot charging), transit buses can also have different charging options such as on-route charging with overhead or wireless technologies, battery swapping, opportunity charging, overnight depot charging, *etc.*, each of which could be more widely studied in order to optimize revenues and operation efficiency. There are three levels of chargers that are mostly used for EV charging: level 1 charger is simply a special cord that connect the EV and the traditional plug seat, level 2 charger is usually a charging station which has a higher voltage and level 3 charger is specialized for fast charging [39]. Since the charging strategy is beyond the scope of this study, it is assumed that transit buses are operated with opportunity charging, which allow buses to quickly charge at their depot stops and then charge overnight after hours. Hence, it is assumed that charging facilities should have Level 3 charging for convenient service.

S3.2. Vehicle-to-Grid System Specifications

The V2G system, as defined in this study, is a service that can supply electricity to the grid from the energy stored in a vehicle's battery. As such, this service is only available when the vehicle is plugged into its charger. As discussed in manuscript's Section 1, transit buses are expected to operate all day long to gather revenue for the transit authorities that employ them, while school buses are mostly used two times a day for picking up and dropping off students, which could take a total of five to six hours per day and available during school holidays.

Table S1. Regional electricity generation mix projections from 2014 to 2027. (Energy Information Administration provides electricity generation mixes as FERC regions where this study use ISO regions. The states that are considered in FERC regions are not consistent with ISO regions, therefore below table only present approximate location of ISO regions in FERC regions [38].)

ISO/RTO Region	Region	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
ERCOT	**Texas Regional Entity**														
	Coal	37%	38%	35%	35%	35%	35%	34%	34%	33%	33%	33%	32%	32%	32%
	Residual oil	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Natural Gas	41%	40%	43%	43%	44%	44%	45%	45%	46%	47%	47%	48%	48%	49%
	Nuclear	12%	12%	12%	12%	12%	12%	11%	11%	11%	11%	11%	11%	11%	11%
	Biomass	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Renewables 2/	10%	10%	10%	10%	10%	9%	9%	9%	9%	9%	9%	9%	9%	9%
	Distributed Generation	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
ISONE & NY-ISO	**Northeast Power Coordinating Council/Northeast**	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Coal	3%	3%	0%	2%	3%	4%	4%	4%	4%	4%	4%	4%	4%	7%
	Petroleum	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Natural Gas	52%	53%	53%	53%	53%	52%	52%	51%	50%	50%	49%	49%	48%	46%
	Nuclear	31%	27%	27%	26%	26%	26%	26%	26%	26%	27%	27%	27%	27%	27%
	Pumped Storage/Other 1/	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
	Renewables 2/	12%	15%	18%	17%	17%	17%	17%	18%	18%	18%	18%	18%	19%	19%
	Distributed Generation	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Northeast Power Coordinating Council/NYC-Westchester	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Coal	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Petroleum	2%	2%	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
	Natural Gas	61%	60%	60%	53%	55%	56%	56%	56%	57%	58%	59%	60%	59%	58%
	Nuclear	36%	36%	37%	44%	43%	41%	41%	42%	41%	40%	39%	38%	39%	40%
	Pumped Storage/Other 1/	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
	Renewables 2/	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
	Distributed Generation	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Northeast Power Coordinating Council/Long Island	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Coal	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Petroleum	5%	5%	5%	4%	4%	2%	2%	2%	2%	2%	1%	1%	1%	1%
	Natural Gas	82%	81%	81%	83%	83%	79%	77%	78%	80%	82%	83%	83%	82%	82%
	Nuclear	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Pumped Storage/Other 1/	2%	2%	2%	2%	2%	3%	3%	3%	3%	2%	2%	2%	2%	2%

	Renewables 2/	11%	12%	12%	11%	11%	17%	18%	17%	16%	14%	14%	14%	14%	15%
	Distributed Generation	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Northeast Power Coordinating Council/Upstate New York	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Coal	7%	8%	8%	8%	8%	9%	9%	12%	14%	14%	14%	14%	14%	15%
	Petroleum	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Natural Gas	28%	29%	26%	28%	28%	29%	28%	25%	22%	20%	20%	19%	19%	18%
	Nuclear	28%	25%	26%	25%	24%	24%	24%	24%	25%	25%	25%	25%	25%	26%
	Pumped Storage/Other 1/	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Renewables 2/	37%	38%	40%	39%	38%	38%	38%	38%	40%	40%	40%	40%	40%	41%
	Distributed Generation	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
CAISO	**Western Electricity Coordinating Council/California**	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Coal	6%	6%	6%	6%	6%	6%	6%	6%	5%	5%	5%	5%	5%	5%
	Petroleum	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Natural Gas	51%	52%	50%	50%	51%	51%	51%	52%	53%	53%	53%	53%	53%	53%
	Nuclear	9%	9%	9%	9%	8%	8%	8%	8%	7%	7%	7%	7%	7%	7%
	Pumped Storage/Other 1/	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Renewables 2/	34%	33%	35%	36%	35%	35%	35%	35%	35%	34%	35%	35%	35%	35%
	Distributed Generation	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
PJM	**Reliability First Corporation/East**	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Coal	30%	30%	28%	27%	28%	28%	29%	30%	30%	30%	30%	31%	31%	31%
	Petroleum	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Natural Gas	26%	25%	28%	29%	29%	29%	29%	28%	27%	27%	26%	26%	25%	23%
	Nuclear	40%	41%	40%	38%	38%	37%	37%	37%	38%	37%	38%	38%	38%	39%
	Pumped Storage/Other 1/	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Renewables 2/	4%	4%	4%	5%	5%	5%	5%	5%	5%	5%	5%	6%	6%	6%
	Distributed Generation	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Reliability First Corporation/Michigan	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Coal	60%	59%	42%	39%	40%	40%	40%	39%	39%	39%	40%	41%	40%	40%
	Petroleum	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Natural Gas	21%	20%	35%	36%	36%	36%	36%	36%	37%	37%	36%	36%	36%	37%
	Nuclear	14%	14%	14%	15%	15%	15%	15%	15%	15%	15%	14%	14%	14%	14%
	Pumped Storage/Other 1/	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Renewables 2/	5%	8%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	9%	9%
	Distributed Generation	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Reliability First Corporation/West	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Coal	65%	62%	61%	62%	63%	64%	63%	63%	63%	62%	62%	61%	60%	59%
Petroleum	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Natural Gas	7%	9%	10%	10%	10%	10%	11%	11%	12%	13%	13%	13%	15%	16%
Nuclear	24%	24%	24%	23%	22%	21%	21%	21%	20%	20%	20%	20%	19%	19%
Pumped Storage/Other 1/	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Renewables 2/	4%	4%	4%	4%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Distributed Generation	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table S2. Combustion (inefficient) power plant emissions for regulation services in study regions (emissions/kWh) [29]. (It should be noted that Table S3 presents the average regional electricity generation emissions for per kWh where this table only presents the electricity generation related emissions from traditional power plants.)

Regional Emissions		**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
PJM	GHG (CO_2 eq. g/kWh)	1513.81	1513.81	1513.81	1513.81	1513.81	1513.81	1513.81	1513.81	1513.81	1513.81	1513.81	1513.81	1513.81
	CO (g/kWh)	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
	NO_x (g/kWh)	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.40	1.40	1.40	1.40
	PM_{10} (g/kWh)	0.39	0.38	0.37	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
	VOC (g/kWh)	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
ISO-NE	GHG (CO_2 eq. g/kWh)	1558.29	1558.29	1558.29	1558.29	1558.29	1558.29	1558.29	1558.29	1558.29	1558.29	1558.29	1558.29	1558.29
	CO (g/kWh)	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
	NO_x (g/kWh)	1.50	1.51	1.51	1.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
	PM_{10} (g/kWh)	0.27	0.28	0.27	0.28	0.28	0.28	0.28	0.28	0.29	0.29	0.29	0.29	0.29
	VOC (g/kWh)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
NYISO	GHG (CO_2 eq. g/kWh)	1217.41	1217.41	1217.41	1217.41	1217.41	1217.41	1217.41	1217.41	1217.41	1217.41	1217.41	1217.41	1217.41
	CO (g/kWh)	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	NO_x (g/kWh)	1.51	1.51	1.51	1.50	1.50	1.52	1.52	1.52	1.51	1.51	1.51	1.51	1.51
	PM_{10} (g/kWh)	0.27	0.28	0.28	0.27	0.27	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
	VOC (g/kWh)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
ERCOT	GHG (CO_2 eq. g/kWh)	1515.28	1515.28	1515.28	1515.28	1515.28	1515.28	1515.28	1515.28	1515.28	1515.28	1515.28	1515.28	1515.28
	CO (g/kWh)	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
	NO_x (g/kWh)	1.45	1.45	1.45	1.45	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46
	PM_{10} (g/kWh)	0.36	0.36	0.35	0.35	0.35	0.35	0.35	0.34	0.34	0.34	0.34	0.34	0.34
	VOC (g/kWh)	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
CAISO	GHG (CO_2 eq. g/kWh)	1330.97	1330.97	1330.97	1330.97	1330.97	1330.97	1330.97	1330.97	1330.97	1330.97	1330.97	1330.97	1330.97
	CO (g/kWh)	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
	NO_x (g/kWh)	1.47	1.47	1.46	1.46	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47

PM_{10} (g/kWh)	0.28	0.29	0.29	0.29	0.29	0.29	0.29	0.28	0.28	0.28	0.28	0.28	0.28
VOC (g/kWh)	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11

Table S3. Electricity price (C_{elect}) and emission projections for study period based on EVRO tool's results (Reference: [40]) (It should be also noted that, for the electricity prices, it is assumed the commercial electricity rate is equal to levelized cost of electricity reported by following projections. Electricity prices and power generation related emissions are presented for each study regions.)

Regional price and emissions		**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
PJM		0.1057	0.1053	0.1051	0.1065	0.1034	0.1027	0.1022	0.1018	0.1012	0.1008	0.1003	0.0998	0.0994
	Electricity price ($/kWh)	0.1152	0.1151	0.1154	0.1165	0.1119	0.1112	0.1107	0.1102	0.1095	0.1091	0.1086	0.1080	0.1075
		0.1303	0.1300	0.1316	0.1319	0.1266	0.1259	0.1254	0.1248	0.1242	0.1237	0.1231	0.1224	0.1218
	GHG (CO2 eq. g/kWh)	1134.99	1,116.56	1122.03	1128.33	1130.42	1129.10	1129.10	1129.78	1127.21	1128.64	1129.24	1127.56	1127.29
	CO (g/kWh)	0.61	0.59	0.60	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
	NO_x (g/kWh)	1.05	1.02	1.03	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
	PM_{10} (g/kWh)	0.24	0.22	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
	VOC (g/kWh)	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
	$PM_{2.5}$ (g/kWh)	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	SO_x (g/kWh)	1.05	0.99	1.01	1.03	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.01
ISO-NE		0.0904	0.0909	0.0878	0.0914	0.0885	0.0887	0.0888	0.0890	0.0891	0.0893	0.0894	0.0895	0.0900
	Electricity price ($/kWh)	0.1026	0.1039	0.1035	0.1036	0.0982	0.0983	0.0984	0.0985	0.0985	0.0985	0.0986	0.0986	0.0990
		0.1201	0.1221	0.1240	0.1212	0.1146	0.1146	0.1146	0.1145	0.1144	0.1143	0.1141	0.1139	0.1142
	GHG (CO2 eq. g/kWh)	918.87	892.37	902.64	913.39	916.89	915.58	914.05	911.87	909.46	908.70	908.58	905.70	917.74
	CO (g/kWh)	0.40	0.37	0.38	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.40
	NO_x (g/kWh)	0.70	0.67	0.68	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.70
	PM_{10} (g/kWh)	0.10	0.09	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.12
	VOC (g/kWh)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
	$PM_{2.5}$ (g/kWh)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	SO_x (g/kWh)	0.08	0.02	0.04	0.07	0.08	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.15
NYISO		0.0881	0.0893	0.0869	0.0903	0.0876	0.0878	0.0883	0.0886	0.0888	0.0891	0.0893	0.0895	0.0896
	Electricity price ($/kWh)	0.1011	0.1028	0.1028	0.1027	0.0977	0.0978	0.0982	0.0984	0.0985	0.0987	0.0988	0.0989	0.0989
		0.1195	0.1213	0.1234	0.1204	0.1147	0.1147	0.1149	0.1150	0.1149	0.1149	0.1148	0.1148	0.1147
	GHG (CO2 eq. g/kWh)	609.40	600.51	591.88	596.82	585.57	583.39	589.64	593.35	595.59	598.50	599.79	597.11	594.16
	CO (g/kWh)	0.40	0.40	0.39	0.39	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
	NO_x (g/kWh)	0.46	0.46	0.45	0.45	0.44	0.44	0.45	0.45	0.45	0.45	0.45	0.45	0.45
	PM_{10} (g/kWh)	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	VOC (g/kWh)	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
	$PM_{2.5}$ (g/kWh)	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	SO_x (g/kWh)	0.12	0.11	0.10	0.10	0.08	0.08	0.11	0.12	0.12	0.12	0.12	0.12	0.12

		0.0995	0.0978	0.0966	0.1002	0.0994	0.0992	0.0991	0.0989	0.0987	0.0986	0.0986	0.0985	0.0985
	Electricity price ($/kWh)	0.1118	0.1103	0.1110	0.1126	0.1096	0.1094	0.1092	0.1089	0.1087	0.1086	0.1085	0.1084	0.1083
		0.1301	0.1279	0.1311	0.1305	0.1269	0.1265	0.1262	0.1258	0.1255	0.1253	0.1251	0.1249	0.1247
	GHG (CO2 eq. g/kWh)	1155.92	1141.79	1143.35	1142.89	1142.28	1141.14	1139.97	1138.64	1137.31	1136.32	1135.55	1134.63	1133.70
ERCOT	CO (g/kWh)	0.64	0.62	0.62	0.62	0.62	0.62	0.61	0.61	0.61	0.61	0.61	0.61	0.61
	NO_x (g/kWh)	0.85	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.82	0.82	0.82	0.82	0.82
	PM_{10} (g/kWh)	0.21	0.20	0.20	0.20	0.20	0.19	0.19	0.19	0.19	0.19	0.18	0.18	0.18
	VOC (g/kWh)	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
	$PM_{2.5}$ (g/kWh)	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	SO_x (g/kWh)	0.85	0.79	0.79	0.79	0.78	0.77	0.76	0.75	0.74	0.73	0.73	0.72	0.71
		0.0870	0.0881	0.0845	0.0877	0.0867	0.0869	0.0872	0.0875	0.0877	0.0879	0.0882	0.0885	0.0887
	Electricity price ($/kWh)	0.1033	0.1054	0.1044	0.1040	0.0993	0.0993	0.0993	0.0994	0.0995	0.0995	0.0996	0.0997	0.0997
		0.1278	0.1314	0.1318	0.1283	0.1217	0.1213	0.1209	0.1206	0.1203	0.1201	0.1198	0.1195	0.1193
	GHG (CO2 eq. g/kWh)	713.30	704.25	702.97	705.14	704.07	704.91	706.61	708.39	709.61	707.03	706.52	707.26	706.07
CAISO	CO (g/kWh)	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
	NO_x (g/kWh)	0.74	0.74	0.73	0.74	0.73	0.73	0.74	0.74	0.74	0.74	0.73	0.74	0.73
	PM_{10} (g/kWh)	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.11	0.10	0.10
	VOC (g/kWh)	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
	$PM_{2.5}$ (g/kWh)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	SO_x (g/kWh)	0.15	0.15	0.14	0.14	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.11

Table S4. Air externality cost rates by emission source and types. (All of the cost values presents 2015 dollars (Reference: [21,22]).)

Air externality type			Low	Median	High
Power generation related health damage cost per megawatt hour electricity [$/MWh]	Downstream Emissions	GHG	$8.75	$26.26	$87.54
		NOx	$1.50	$1.50	$1.50
		PM10	$0.08	$0.08	$0.08
		PM2.5	$1.31	$1.31	$1.31
		SO2	$16.94	$16.94	$16.94
	Upstream Emissions	GHG	$0.47	$1.41	$4.71
		CO	$0.00	$0.00	$0.00
		NOx	$0.08	$0.08	$0.08
		PM10	$0.73	$0.73	$0.73
		PM2.5	$0.71	$0.71	$0.71
		SO2	$0.11	$0.11	$0.11
Tailpipe emissions related health damage cost [$/ton]	Downstream	GHG	$15	$46	$153
		CO	$326	$968	$2595
		NOx	$1268	$3765	$10,090
		PM10	$859	$12,726	$28,210
		VOC	$398	$7824	$17,607

Air externality type			Low	Median	High
		PM2.5	$4075	$82,897	$187,115
		SO2	$2375	$27,882	$44,653
Diesel production related emissions' health damage cost [$/ton]	Upstream	GHG	$15	$46	$153
		CO	$49	$708	$4183
		NOx	$1039	$2192	$729
		PM10	$603	$7,336	$43,255
		VOC	$298	$4,520	$23,891
		PM2.5	$3068	$47,918	$257,691
		SO2	$1917	$19,690	$158,234

Table S5. Ranges for capacity price (C_{cap}) in each study region. (These price information are gathered from each regions' websites [41–45].)

Region	Minimum ($/MWh)	Maximum ($/MWh)
PJM	16.43	49.73
ISO-NE	9.3	30.22
NYISO	11.8	59.5
ERCOT	11.04	38.07
CAISO	10.6	41.06

Table S6. Regional diesel price projections for study regions based on Energy Information Administration's Energy Outlook forecast for 2040 (Reference: [46]).

ISO/RTO	Region	Oil Price	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
PJM	(Middle + South Atlantic+ East North Central)/3	High	4.85	5.09	5.30	5.48	5.65	5.86	6.07	6.29	6.57	6.86	7.16	7.46
		Reference	3.15	3.18	3.21	3.28	3.35	3.43	3.53	3.62	3.71	3.80	3.90	4.00
		Low	2.62	2.68	2.76	2.87	2.98	3.08	3.18	3.26	3.35	3.47	3.57	3.67
CAISO	Pacific	High	4.81	5.05	5.26	5.44	5.61	5.81	6.02	6.23	6.52	6.81	7.10	7.40
		Reference	3.06	3.07	3.08	3.12	3.17	3.22	3.30	3.36	3.43	3.49	3.56	3.63
		Low	2.58	2.64	2.72	2.83	2.94	3.03	3.13	3.22	3.31	3.42	3.52	3.62
ERCOT	West South Central	High	4.77	5.01	5.21	5.39	5.56	5.76	5.97	6.18	6.47	6.75	7.04	7.35
		Reference	3.02	3.03	3.04	3.08	3.13	3.18	3.27	3.33	3.39	3.46	3.52	3.59
		Low	2.53	2.60	2.68	2.78	2.90	3.00	3.10	3.18	3.26	3.38	3.48	3.57
ISONE	New England	High	5.00	5.24	5.46	5.64	5.81	6.02	6.23	6.45	6.74	7.03	7.33	7.64
		Reference	3.26	3.25	3.26	3.31	3.35	3.41	3.49	3.55	3.61	3.68	3.75	3.82
		Low	2.77	2.84	2.92	3.03	3.15	3.25	3.35	3.44	3.53	3.65	3.75	3.85
NYISO	Middle Atlantic	High	4.94	5.17	5.39	5.57	5.74	5.94	6.16	6.37	6.66	6.95	7.25	7.55
		Reference	3.16	3.19	3.20	3.24	3.29	3.34	3.42	3.48	3.55	3.61	3.68	3.75
		Low	2.70	2.77	2.85	2.96	3.08	3.17	3.27	3.36	3.45	3.57	3.67	3.77

Table S7. Diesel-Transit Bus Tailpipe Emission Rates for Each Year [gram/mile]. (This table could be generated with the consideration of deterioration rate for each year of vehicle use. MOVES tool provides this information, however, for this study, AFLEET tools' background information is used [27,35].)

Emission type	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
GHG	Uniform (1257–2836)												
CO	0.9386	0.9780	0.9997	1.0435	1.0700	1.1122	1.1458	1.1815	1.2150	1.2481	1.2811	1.3155	1.3508
NOx	1.1131	1.2771	1.2795	1.4440	1.4470	1.5714	1.5752	1.5792	1.5829	1.5866	1.5903	1.5942	1.5981
PM10 Total	0.0672	0.0703	0.0703	0.0736	0.0736	0.0759	0.0759	0.0759	0.0759	0.0759	0.0759	0.0759	0.0759
VOC	0.0826	0.0852	0.0857	0.0884	0.0890	0.0912	0.0919	0.0927	0.0934	0.0941	0.0949	0.0956	0.0964
PM2.5 Total	0.0308	0.0338	0.0338	0.0370	0.0370	0.0392	0.0392	0.0392	0.0392	0.0392	0.0392	0.0392	0.0392

Table S8. Diesel-School Bus Tailpipe Emission Rates for Each Year [gram/mile]. (Similar to Table S7, diesel-school bus emission changes over the lifetime is gathered from AFLEET.)

Emission type	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
GHG	Uniform (1257–1714)												
CO	2.8830	2.8775	2.8722	2.8723	2.8773	2.8872	2.9082	2.9332	2.9498	2.9585	2.9667	2.9727	2.9809
NOx	1.2401	1.2642	1.2635	1.2635	1.2641	1.2653	1.2678	1.2708	1.2728	1.2738	1.2748	1.2755	1.2765
PM10 Total	0.0971	0.0975	0.0975	0.0975	0.0975	0.0975	0.0975	0.0975	0.0975	0.0975	0.0975	0.0975	0.0975
VOC	0.1134	0.1137	0.1136	0.1136	0.1137	0.1139	0.1144	0.1149	0.1152	0.1154	0.1155	0.1157	0.1158
PM2.5 Total	0.0381	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385

S.4. Additional Results

In addition to the results that are presented in manuscript following results are presented in this document in order to limit wording and space of manuscript. There is interesting findings is following table that should be highlighted; NYISO regions' V2G revenue payments lead to provide profit for BE school bus operator as oppose to all costs throughout the lifetime for operating school bus such as purchase, maintenance, fuel, charging station, V2G equipment, and battery replacement/degradation costs.

Table S9. Life cycle cost analysis results for each bus types in five ISO regions.

Bus type	Cost/Revenue items	PJM	ISO-NE	NYISO	ERCOT	CAISO
School Bus—BE	Purchase Price	$230,000	$230,000	$230,000	$230,000	$230,000
	Lifetime Fuel Cost (Electricity)	$23,715	$21,626	$21,404	$23,790	$21,915
	Maintenance Cost	$66,821	$66,586	$66,739	$67,185	$66,814
	Charging Station Purchase Cost	$23,446	$23,446	$23,446	$23,446	$23,446
	Charging Station Maintenance Cost	$8,971	$9,004	$9,014	$9,000	$8,971
	Battery Replacement Cost (due to operation)	$29,716	$30,200	$30,183	$29,898	$29,819
	V2G Capacity Payment Revenue	−$292,347	−$174,783	−$314,618	−$216,253	−$229,498
	V2G Energy Payment Revenue (Exchanged Electricity)	−$61,510	−$55,204	−$55,082	−$60,471	−$56,329
	V2G Cost (V2G equipment + Battery degradation)	$85,385	$77,901	$77,803	$84,181	$79,285
	Resale Value	−$32,658	−$32,658	−$32,658	−$32,658	−$32,658
	Government Incentives (if applicable)	$0	$0	−$60,000	$0	−$84,876
	Net Value	**$81,540**	**$196,116**	**−$3,770**	**$158,117**	**$56,888**
School Bus—Diesel	Purchase Price	$110,000	$110,000	$110,000	$110,000	$110,000
	Lifetime Fuel Cost (Diesel)	$84,651	$86,573	$85,092	$81,753	$82,494
	Maintenance Cost	$140,470	$140,508	$140,473	$140,502	$140,461
	Charging Station Purchase Cost	$0	$0	$0	$0	$0
	Charging Station Maintenance Cost	$0	$0	$0	$0	$0
	Battery Replacement Cost (due to operation)	$0	$0	$0	$0	$0
	V2G Capacity Payment Revenue	$0	$0	$0	$0	$0
	V2G Energy Payment Revenue (Exchanged Electricity)	$0	$0	$0	$0	$0
	V2G Cost (V2G equipment + Battery degradation)	$0	$0	$0	$0	$0
	Resale Value	−$17,199	−$17,199	−$17,199	−$17,199	−$17,199
	Government Incentives (if applicable)	$0	$0	$0	$0	$0
	Net Value	**$317,921**	**$319,882**	**$318,366**	**$315,056**	**$315,756**
Transit Bus—BE	Purchase Price	$800,000	$800,000	$800,000	$800,000	$800,000
	Lifetime Fuel Cost (Electricity)	$94,994	$85,631	$85,376	$93,762	$87,181
	Maintenance Cost	$311,909	$311,976	$311,864	$311,854	$311,892
	Charging Station Purchase Cost	$23,587	$23,587	$23,587	$23,587	$23,587
	Charging Station Maintenance Cost	$8996	$8988	$9000	$8990	$8979
	Battery Replacement Cost (due to operation)	$75,226	$74,979	$75,213	$75,641	$76,073
	V2G Capacity Payment Revenue	−$122,610	−$73,295	−$131,950	−$90,706	−$96,261
	V2G Energy Payment Revenue (Exchanged Electricity)	−$61,881	−$55,386	−$55,004	−$60,546	−$56,469
	V2G Cost (V2G equipment + Battery degradation)	$85,838	$78,105	$77,636	$84,228	$79,423
	Resale Value	−$106,123	−$106,123	−$106,123	−$106,123	−$106,123
	Government Incentives (if applicable)	$0	$0	−$60,000	$0	−$106,146

Bus type	Cost/Revenue items	PJM	ISO-NE	NYISO	ERCOT	CAISO
	Net Value	**$1,109,936**	**$1,148,462**	**$1,029,599**	**$1,140,687**	**$1,022,135**
Transit Bus—Diesel	Purchase Price	$340,000	$340,000	$340,000	$340,000	$340,000
	Lifetime Fuel Cost (Diesel)	$513,809	$525,622	$516,279	$495,502	$500,113
	Maintenance Cost	$415,878	$415,968	$415,818	$415,806	$415,856
	Charging Station Purchase Cost	$0	$0	$0	$0	$0
	Charging Station Maintenance Cost	$0	$0	$0	$0	$0
	Battery Replacement Cost (due to operation)	$0	$0	$0	$0	$0
	V2G Capacity Payment Revenue	$0	$0	$0	$0	$0
	V2G Energy Payment Revenue (Exchanged Electricity)	$0	$0	$0	$0	$0
	V2G Cost (V2G equipment + Battery degradation)	$0	$0	$0	$0	$0
	Resale Value	−$43,810	−$43,810	−$43,810	−$43,810	−$43,810
	Government Incentives (if applicable)	$0	$0	$0	$0	$0
	Net Value	**$1,225,877**	**$1,237,780**	**$1,228,287**	**$1,207,497**	**$1,212,158**

References

1. Frey, H.C.; Rouphail, N.M.; Zhai, H.; Farias, T.L.; Gonçalves, G.A. Comparing real-world fuel consumption for diesel- and hydrogen-fueled transit buses and implication for emissions. *Transp. Res. D Transp. Environ.* **2007**, *12*, 281–291.
2. Hess, D. What is a clean bus? Object conflicts in the greening of urban transit. *Sustain. Sci. Pract. Policy* **2007**, *3*, 45–58.
3. Ally, J.; Pryor, T. Life-cycle assessment of diesel, natural gas and hydrogen fuel cell bus transportation systems. *J. Power Sources* **2007**, *170*, 401–411.
4. Chester, M.V.; Horvath, A. Environmental assessment of passenger transportation should include infrastructure and supply chains. *Environ. Res. Lett.* **2009**, *4*, 024008, doi:10.1088/1748-9326/4/2/024008.
5. Ou, X.; Zhang, X.; Chang, S. Scenario analysis on alternative fuel/vehicle for China's future road transport: Life-cycle energy demand and GHG emissions. *Energy Policy* **2010**, *38*, 3943–3956.
6. Ou, X.; Zhang, X.; Chang, S. Alternative fuel buses currently in use in China: Life-cycle fossil energy use, GHG emissions and policy recommendations. *Energy Policy* **2010**, *38*, 406–418.
7. Cooney, G.; Hawkins, T.R.; Marriott, J. Life Cycle Assessment of Diesel and Electric Public Transportation Buses. *J. Ind. Ecol.* **2013**, *17*, 689–699.
8. Sánchez, J.A.G.; Martínez, J.M.L.; Martín, J.L.; Holgado, M.N.F.; Morales, H.A. Impact of Spanish electricity mix, over the period 2008–2030, on the Life Cycle energy consumption and GHG emissions of Electric, Hybrid Diesel-Electric, Fuel Cell Hybrid and Diesel Bus of the Madrid Transportation System. *Energy Convers. Manag.* **2013**, *74*, 332–343.
9. Lajunen, A. Energy consumption and cost-benefit analysis of hybrid and electric city buses. *Transp. Res. C Emerg. Technol.* **2014**, *38*, 1–15.
10. Xu, Y.; Gbologah, F.E.; Lee, D.Y.; Liu, H.; Rodgers, M.O.; Guensler, R.L. Assessment of alternative fuel and powertrain transit bus options using real-world operations data: Life-cycle fuel and emissions modeling. *Appl. Energy* **2015**, *154*, 143–159.
11. Ercan, T.; Tatari, O. A hybrid life cycle assessment of public transportation buses with alternative fuel options. *Int. J. Life Cycle Assess.* **2015**, *20*, 1213–1231.
12. Kempton, W.; Tomić, J. Vehicle-to-grid power implementation: From stabilizing the grid to supporting large-scale renewable energy. *J Power Sources* 2005, 144, 280–294.
13. Lin, J.; Damato, G.; Hand, P. *Energy Storage—A Cheaper, Faster, & Cleaner Alternative to Conventional Frequency Regulation*; California Energy Storage Alliance: Berkeley, CA, USA, 2011.
14. Kempton, W.; Tomic, J.; Letendre, S.; Brooks, A.; Lipman, T. Vehicle-to-Grid Power: Battery, Hybrid, and Fuel Cell Vehicles as Resources for Distributed Electric Power in California. Institute of Transportation Studies, UC DAVIS: Davis, CA, USA, 2001.
15. Kempton, W.; Tomić, J. Vehicle-to-grid power fundamentals: Calculating capacity and net revenue. *J. Power Sources* **2005**, *144*, 268–279.
16. Lund, H.; Kempton, W. Integration of renewable energy into the transport and electricity sectors through V2G. *Energy Policy* 2008, 36, 3578–3587.
17. Noel, L.; McCormack, R. A cost benefit analysis of a V2G-capable electric school bus compared to a traditional diesel school bus. *Appl. Energy* **2014**, *126*, 246–255.
18. Turton, H.; Moura, F. Vehicle-to-grid systems for sustainable development: An integrated energy analysis. *Technol. Forecast. Soc. Chang.* **2008**, *75*, 1091–1108.
19. Kudoh, Y.; Motose, R.; Tahara, K.; Genchi, Y. A potential CO_2 reduction of vehicle to home system from life cycle perspective. In Proceedings of the IEEE Electric Vehicle Symposium and Exhibition (EVS27), Barcelona, Spain, 17–20 November 2013; pp. 1–10.
20. Muller, N.Z.; Mendelsohn, R. *The Air Pollution Emission Experiments and Policy Analysis Model (APEEP) Technical Appendix*; Yale University: New Haven, CT, USA, 2006; Volume 1.
21. Muller, N.Z.; Mendelsohn, R. Measuring the damages of air pollution in the United States. *J. Environ. Econ. Manag.* **2007**, *54*, 1–14.
22. Michalek, J.J.; Chester, M.; Jaramillo, P.; Samaras, C.; Shiau, C.S.N.; Lave, L.B. Valuation of plug-in vehicle life-cycle air emissions and oil displacement benefits. *Proc. Natl. Acad. Sci. USA* **2011**, *108*, 16554–16558.
23. Gouge, B.; Dowlatabadi, H.; Ries, F.J. Minimizing the health and climate impacts of emissions from heavy-duty public transportation bus fleets through operational optimization. *Environ. Sci. Technol.* **2013**, *47*, 3734–3742.

24. Ercan, T.; Zhao, Y.; Tatari, O.; Pazour, J.A. Optimization of transit bus fleet's life cycle assessment impacts with alternative fuel options. *Energy* **2015**, *93*, 323–334.
25. ISO (International Standards Organization). ISO 14040 International Standard. In Environmental Management—Life Cycle Assessment—Principles and Framework. ISO 14040 2006. http://www.iso.org/iso/catalogue_detail?csnumber=37456 (accessed on 1 October 2015).
26. Finnveden, G.; Hauschild, M.Z.; Ekvall, T.; Guinée, J.; Heijungs, R.; Hellweg, S. Koehler, A.; Pennington, D.; Suh, S. Recent developments in Life Cycle Assessment. *J. Environ. Manage.* **2009**, *91*, 1–21.
27. *Motor Vehicle Emission Simulator (MOVES)*; EPA: Washington, DC, USA, 2010.
28. Bradley, M.J.; Associates, L.L.C. Comparison of Modern CNG, Diesel and Diesel Hybrid-Electric Transit Buses: Efficiency & Environmental Performance. MJ Bradley & Associates: Concord, MA, USA, 2013.
29. *The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model*; Argonne National Laboratory: Lemont, IL, USA, 2015.
30. Onat, N.C.; Kucukvar, M.; Tatari, O. Conventional, hybrid, plug-in hybrid or electric vehicles? State-based comparative carbon and energy footprint analysis in the United States. *Appl. Energy* 2015, 150, 36–49.
31. Donateo, T.; Ingrosso, F.; Licci, F.; Laforgia, D. A method to estimate the environmental impact of an electric city car during six months of testing in an Italian city. *J. Power Sources* **2014**, *270*, 487–498.
32. Donateo, T.; Licci, F.; D'Elia, A.; Colangelo, G.; Laforgia, D.; Ciancarelli, F. Evaluation of emissions of CO_2 and air pollutants from electric vehicles in Italian cities. *Appl. Energy* 2015, 157, 675–687.
33. *Standard Bus Procurement Guidelines Low Floor Diesel—For 35/40 Foot Heavy-Duty Diesel-Powered Transit Bus*; American Public Transportation Association: Washington, DC, USA, 2000.
34. Department of Public Safety—State of Minnesota. Definitions of School Bus Vehicles. 1999; 571. Available online: https://dps.mn.gov/divisions/msp/forms-reports/Documents/SBTypesPhotos.pdf (accessed on 1 January 2016).
35. Burnham, A. Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool 2013; Argonne National Laboratory: Lemont, IL, USA, 2013.
36. Kay M, Clark M, Duffy C, Laube M, Lian FS. *Bus Lifecycle Cost Model for Federal Land Management Agencies: User's Guide*; U.S. Department of Transportation Research and Innovative Technology Administration John A. Volpe National Transportation Systems Center: Cambridge, MA, USA, 2011.
37. Barnitt, R.; Gonder, J. *Drive Cycle Analysis, Measurement of Emissions and Fuel Consumption of a PHEV School Bus Preprint;* National Renewable Energy Laboratory (NREL): Golden, CO, USA, 2011.
38. U.S. Department of Energy—Energy Information Administration. *Annual Energy Outlook 2015 with Projections to 2040*; U.S. Energy Information Administration: Washington, DC, USA, 2015.
39. Chang, D.; Erstad, D.; Lin, E.; Rice, A.F.; Goh, C.T.; Angel, A. Financial Viability of Non-Residential Electric Vehicle Charging Stations. Luskin Center for Innovation: Los Angeles, CA, USA, 2012.
40. Noori, M.; Gardner, S.; Tatari, O. Electric vehicle cost, emissions, and water footprint in the United States: Development of a regional optimization model. *Energy* **2015**, *89*, 610–625.
41. California ISO. California-ISO Market Processes 2015. Available online: https://www.caiso.com/market/Pages/MarketProcesses.aspx (accessed on 1 October 2015).
42. ERCOT. ERCOT Market Prices 2015. Available online: http://www.ercot.com/mktinfo/prices (accessed on 1 October 2015).
43. ISO-New England. Forward Capacity Market 2015. Available online: http://www.iso-ne.com/markets-operations/markets/forward-capacity-market (accessed on 20 May 2010).
44. New York ISO. The New York Installed Capacity (ICAP) Data & Information 2015. Available online: http://www.nyiso.com/public/markets_operations/market_data/icap/index.jsp (accessed on 1 October 2015).
45. PJM. Capacity Market (RPM) 2015. Available online: http://www.pjm.com/markets-and-operations/rpm.aspx (accessed on 1 October 2015).
46. *Annual Energy Outlook 2013 with Projection to 2040*; U.S. Energy Information Administration: Washington, DC, USA, 2013.