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Using Commercial Electric Vehicles for Vehicle-to-Grid

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Abstract

Commercial Electric Vehicles (EVs) could represent a large share of the electrification of the transportation sector, a step that has been identified as necessary to clean the air, reduce dependence on oil and decrease greenhouse gas emissions. However, making a good business case for commercial EVs is not straightforward. The economic benefits of EVs are especially difficult to materialize when vehicles do not displace enough fuel and do not accrue enough maintenance savings through driving and work site operations. We assessed the economic value of commercial EVs looking at simple payback period and net present value for different vehicle use profiles. We found that EVs make a good business case in class 4 urban driving application when driven more than 60 miles per day. In class 5/6 utility-work site applications on military bases, EVs need to displace at least 6 gallons of diesel per day for the investment to be worthwhile. We then looked at the potential for commercial EVs to be used in Vehicle-to-Grid (V2G) as a way to improve the business case when EVs are placed in low utilization applications. Our results show that V2G for frequency regulation can improve the business case for EVs in urban driving and utility-work site applications. Power charging levels need to be high enough to maximize vehicle battery usage (19.2 kW) and regulation market prices should be greater than $20/MW-h to increase V2G revenue. We conclude that using commercial EVs for V2G can improve the business case and help the adoption of commercial EVs.

Keywords: V2G (vehicle to grid), business model, LCC (Life cycle cost), truck

1 Introduction

Electrification of the US transportation sector is considered an important wedge in reducing air pollution, greenhouse gas emissions and dependence on foreign oil. The introduction of electric vehicles (EVs), while still in the early adoption stage both for personal and commercial use, is on the rise. However, making a good business case for EVs is not straightforward - many current models remain considerably more expensive than their diesel or gasoline counterparts. It is crucial to find the optimal EV usage, displace enough fossil fuels, and capture enough maintenance savings in order to recover the higher initial investment.

In addition to driving, EVs can be used as power sources and provide additional benefits as a result. Earlier studies and reports have shown that EVs equipped with bidirectional chargers can provide power to the electrical grid or to a building while realizing a net profit [1-3]. These studies considered Vehicle-to-Grid (V2G) only for passenger vehicles. In this paper, we examine the potential benefits of using commercial EVs for V2G and how this additional revenue can improve the business case for commercial EVs.

2 Assessing the Economic Value of Commercial EVs

In order to assess the economic value of commercial EVs, we focused on two economic analysis metrics: the *simple payback period* (SPP), which is widely understood and used in the commercial vehicle world, and the *net present value* (NPV) which addresses some of the drawbacks of the simple payback method by looking at life-cycle costs.

2.1 Simple Payback Period

The *simple payback period* (SPP) calculates the number of years an energy efficiency improvement or production system will take to pay for its initial capital cost based on its energy and economic savings. It applies very well for short time periods and/or low discount rates because it ignores the time-value of money and for minor operational and maintenance costs because it usually ignores them as well. Despite these limitations, SPP is one of the most intuitive and useful measures of cost-effectiveness [4].

2.2 Net Present Value

Net present value (NPV) is a measure of the investment's financial worth to the organization, taking into account the preference for receiving cash flow sooner rather than later. An investment is financially worthwhile if its NPV is greater than zero, because the present value of future cash flows is greater than the outlay. In the rare case of an opportunity with a zero NPV, the organization should theoretically be indifferent between making or not making the investment. A positive NPV is the net gain to the organization from making the investment – assuming that the discount rate properly adjusts for the timing of the cash flows.

Besides helping to decide whether an investment is worthwhile, NPV can be used to choose among alternative investments. If an organization has two or more investment opportunities but can only pick one, the financially sound decision is to pick the one with the greatest NPV.

The *discount rate* is an interest rate used to adjust a future cash flow to its present value - its value to the organization today. As the starting point for the discount rate, most organizations use their cost of capital, the rate of return that must be earned in order to pay interest on debt (loans and/or bonds) used to finance investments and, where applicable, to attract equity investors [5].

2.3 E-TTF Business Case Calculator

In early 2011, CALSTART formed the E-Truck Task Force (E-TTF) to speed and support effective commercial EVs production and use [6]. As part of the E-TTF, a calculator was developed to evaluate the business case of commercial EVs. The calculator compares the capital and operational costs of an EV to a conventional diesel truck. It includes a comprehensive list of vehicle and infrastructure inputs and is designed to compute sensitivity analyses on key inputs such as vehicle daily range, fuel prices, battery cost, and incentives. The outputs defining the business case are *SPP* and *NPV*. Figure 1 below shows a screenshot of the calculator.

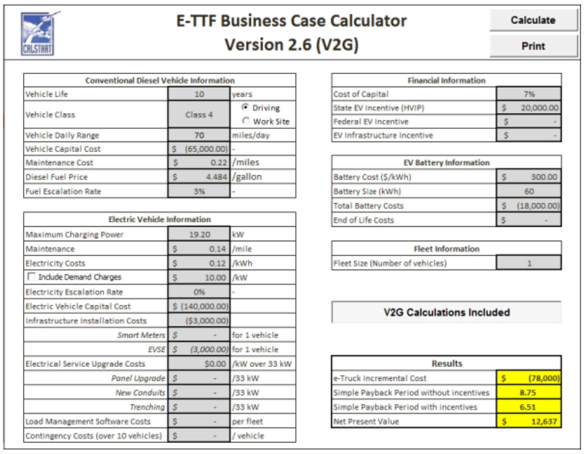

Figure 1: Screenshot of the E-TTF Business Case Calculator

The calculator is described in more detail in a related E-TTF report [6]. In this paper, we used a modified version of the E-TTF Business Case Calculator with added capabilities to calculate V2G costs and benefits. We compare the business case for commercial EVs with and without V2G capability. We first examine the economics of commercial EVs without V2G for two selected applications. Next we examine the value of V2G by investigating the business case of a commercial EV with V2G for those same applications.

3 Economics of Commercial EVs

Commercial EVs are currently being deployed predominantly in urban applications where driving is characterized by low average speed and high number of stops. EVs are expected to perform well under such driving conditions, providing clean and quiet operation while displacing significant amounts of petroleum. In addition, the operation schedules of commercial vehicles are suitable for vehicle electrification. Specifically, fixed driving routes and regular operation times provide a set window for driving as well as for charging.

The upfront costs of commercial EVs remain high, an issue that was identified in a recent survey as one of the main current barriers for electric trucks adoption [6]. Optimal drive cycle or vehicle usage is required to displace enough fuel and accumulate enough maintenance savings in order to recoup the initial upfront costs. We evaluated the business case for selected commercial EVs based on different vehicle usage. The details are discussed below.

3.1 Class 4 / Urban Delivery Vehicle

Our first example is a class 4 truck with a Gross Vehicle Weight Rating (GVWR) ranging from 14,001 to 16,000 lbs. Class 4 trucks are commonly used for urban delivery such as parcel delivery. They are particularly well suited for electric propulsion because of their lower average speed and very high number of stops.
Table 1 below lists the input parameters that were used to analyse the economic value of an electric class 4 urban delivery vehicle replacing an equivalent conventional diesel vehicle.

Table 1: Input parameters for economic analysis of an electric class 4 urban delivery vehicle

Vehicle life	10 years
Fuel economy	Diesel 9 MPG EV 0.7 kWh AC/mile
Vehicle capital cost	Diesel $65,000 EV $140,000
Maintenance cost	Diesel $0.22/mile EV $0.14/mile
Fuel prices	Diesel $4.209 per gallon Electricity $0.12/kWh
Fuel escalation rate	Diesel 3% per year Electricity 0% per year
EVSE capital cost	$3,000
Cost of capital	7%
HVIP Incentive	$20,000

We assumed a 10-year vehicle life. Vehicle capital costs were derived from the findings of the E-Truck Task Force and discussions with CALSTART staff [6]. Diesel and electric fuel economy were derived from discussions with CALSTART staff and information collected from different CALSTART projects. Diesel and EV maintenance costs were derived from a recent Pike Research report [7]. Diesel prices were the weekly California No. 2 diesel retail sales by all sellers as of February 13, 2012 [8]. Electricity prices were the California average commercial retail electricity prices as of November 2011 [9]. Fuel escalation rates for diesel and electricity were derived from a 2011 U.S. Department of Commerce handbook [10]. We also included Electric Vehicle Supply Equipment (EVSE) costs, derived from discussions with CALSTART staff. We chose a cost of capital of 7%, a number which can seem low for a sector generally looking for 2-3 years payback periods. We assumed that companies interested in commercial EVs were demonstrating a certain tolerance to risks and valued the longer term environmental benefits of clean EVs. Lastly, we included appropriate EV incentives currently available in California through the Hybrid Voucher Incentive Program (HVIP).

Commercial EVs are currently designed to reach a maximum driving range of 100 miles. In this example, we analysed 3 different cases: an electric class 4 urban delivery vehicle driving 80, 60 and 40 miles per day, 5 days a week and 50 weeks a year, replacing an equivalent conventional diesel vehicle. The results are shown in Figure 2 below.

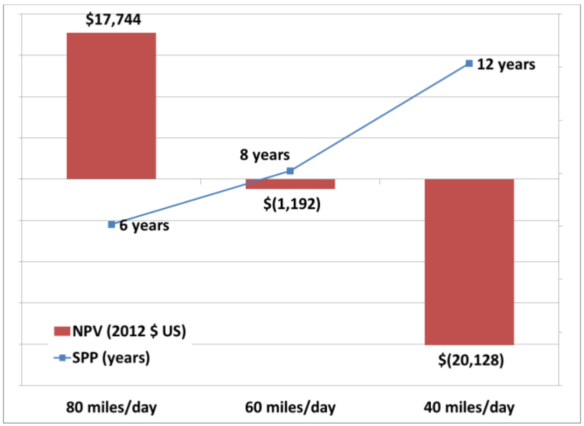

Figure 2: Economic analysis of an electric class 4 urban delivery vehicle replacing a conventional diesel vehicle

Based on the NPV and SPP values for the three cases, we can conclude that electric class 4 vehicles make a good business case when used for urban delivery and driven on average 80 miles per day. In that case, the SPP is about 6 years - the higher upfront cost will be repaid in about 6 years. In addition, the NPV of about $18,000 indicates a benefit when using an EV in that application. As the EV is driven less miles per day, the business case for electric class 4 vehicles worsen. At an average of 60 miles driven per day, the SPP is still under the 10-year vehicle lifetime but the negative NPV indicates the investment's lack of financial worth. Lastly, at an average of 40 miles driven per day, the SPP is over the 10-year vehicle lifetime, indicating that the initial upfront investment will not be recouped by fuel and maintenance savings.

These results clearly show that a high utilization of the EV is needed in order to make a compelling business case in class 4 urban driving applications. By "high" utilization we mean a daily mileage greater than 60-65 miles. At these daily utilization rates, a sufficient amount of diesel fuel is displaced by cheaper electricity to make the investment into higher upfront costs EVs worthwhile. However, at lower daily utilization rates (lower than 60 miles), fuel and maintenance savings will not pay for the higher incremental cost that EVs typically show.

3.2 Class 5/6 / Utility-Work Site Vehicle

Our second example is a class 5/6 utility truck, with a GVWR that ranges from 16,001 to 26,000 lbs. With a utility bucket, these vehicles are designed to drive to different work sites addressing issues with utility lines, using energy to power the lift and the bucket. This is a challenging truck application for electrification, but one that should be evaluated for the utility sector and military bases which have shown interest in plug-in vehicles (hybrid and full electric). For this example, we decided to look at a vehicle used on military bases. Table 2 below lists the input parameters that were used to analyse the economic value of an electric class 5/6 utility-work site vehicle replacing an equivalent conventional diesel vehicle.

Table 2: Input parameters for economic analysis of an electric class 5/6 utility-work site vehicle

Vehicle life	10 years
Fuel economy	Diesel 6 MPG EV 1.2 kWh AC/mile
Vehicle capital cost	Diesel $130,000 EV $200,000
Maintenance cost	Diesel $0.22/mile EV $0.14/mile
Fuel prices	Diesel $4.209 per gallon Electricity $0.12/kWh
Fuel escalation rate	Diesel 3% per year Electricity 0% per year
EVSE capital cost	$3,000
Cost of capital	4%
HVIP Incentive	$20,000

For consistency with the previous example, we assumed a 10-year vehicle life. Vehicle capital costs were derived from the findings of the E-Truck Task Force and discussions with CALSTART staff [6]. Diesel and electric fuel economy were derived from discussions with CALSTART staff and information collected from different CALSTART projects. Diesel and EV maintenance costs were derived from a recent Pike Research report [7]. Diesel prices were the weekly California No. 2 diesel retail sales by all sellers as of February 13, 2012 [8]. Electricity prices were the California average commercial retail electricity prices as of November 2011 [9]. Fuel escalation rates for diesel and electricity were derived from a

2011 U.S. Department of Commerce handbook [10]. We also included Electric Vehicle Supply Equipment (EVSE) costs, derived from discussions with CALSTART staff. We chose a cost of capital of 4%, in-line with U.S. Department of Commerce guidelines for government agencies [10]. Government agencies are interested in the longer term environmental benefits of clean EVs. In addition, military agencies put a high value on technologies that can displace petroleum use. Lastly, we included appropriate EV incentives currently available in California through the Hybrid Voucher Incentive Program (HVIP).

For this truck application, we use daily fuel consumption as a measure rather than daily mileage. Commercial utility bucket trucks can use up to 12 gallons of diesel per day. In this example, we estimate that the EV replaces a conventional diesel vehicle using an average of 9, 7 or 5 gallons per day, 5 days a week and 50 weeks a year. The results are shown in figure 3 below.

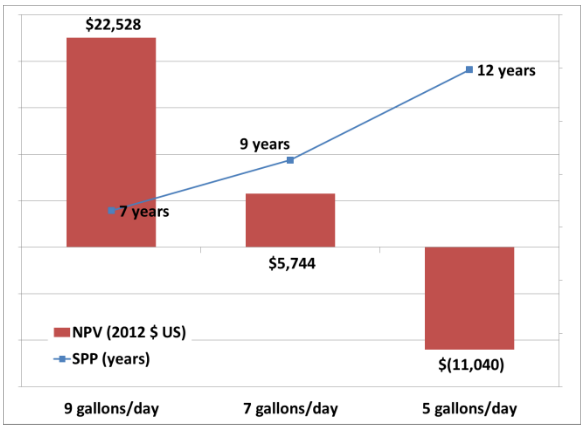

Figure 3: Economic analysis of an electric class 5/6 utility-work site vehicle replacing a conventional diesel vehicle

An electric class 5/6 vehicle makes a good business case when replacing a conventional diesel vehicle that uses an average of 9 gallons of diesel per day. In that case, the SPP is about 7 years, which means that the higher upfront cost will be repaid in about 7 years. In addition, the NPV of about $22,500 indicates a benefit when using an EV in that application. As the EV displaces less diesel fuel per day, the business case for electric class 5/6 vehicles worsens. At an average of 7 gallons per day the SPP gets close to the 10-year vehicle lifetime but the positive NPV indicates the investment still has some financial worth. Lastly, at an average of 5 gallons per day, the SPP is over the 10-year vehicle lifetime, indicating that the initial upfront investment will not be recouped by fuel and maintenance savings.

As in the previous example, these results clearly show that a high utilization of the EV is desirable in order to make a compelling business case in class 5/6 utility - work site applications. By “high” utilization we mean that the EV will displace a daily amount of diesel fuel greater than 6-7 gallons. At these daily utilization rates, a sufficient amount of expensive diesel fuel is displaced by cheaper electricity to make the investment into higher upfront costs EVs worthwhile. However, at lower daily utilization rates (less than 6 gallons) fuel and maintenance savings will not pay for the higher incremental cost that EVs typically show.

4 Can V2G Improve the Economics of Commercial EVs?

We find that many EVs are currently used in applications that may not have the optimal drive cycle or vehicle usage needed to make a compelling business case. At this nascent stage of EV adoption, “range anxiety” remains an issue and influences where vehicles are put in service. In addition, many applications do not need the full battery capacity that is available in current EV configuration. For instance, some parcel delivery routes have very low average speeds and over 100 stops per day. With this type of duty cycle, it is difficult for a vehicle to cover even 40 miles in an 8-10 hour shift.

These applications are ideally suited for V2G in addition to regular vehicle operation. While EVs are parked and plugged in, the vehicle battery can be used as a power sink and source.

In this study, we examine the case when EVs are used for grid balancing services such as frequency regulation. It has been identified as one of the early markets for V2G and several studies and passenger vehicle demonstrations have been conducted applying V2G to frequency regulation [3, 11, 12].

4.1 Market Prices for Frequency Regulation

Independent System Operators (ISO) or Regional Transmission Operators (RTO) manage the markets for ancillary services. In Figure 4 below, we looked at the average 24-hour regulation market clearing prices for PJM, a RTO which covers an area of 214,000 square miles, a population of about 60.1 million and a peak demand of 163,848 megawatts across Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia [13].

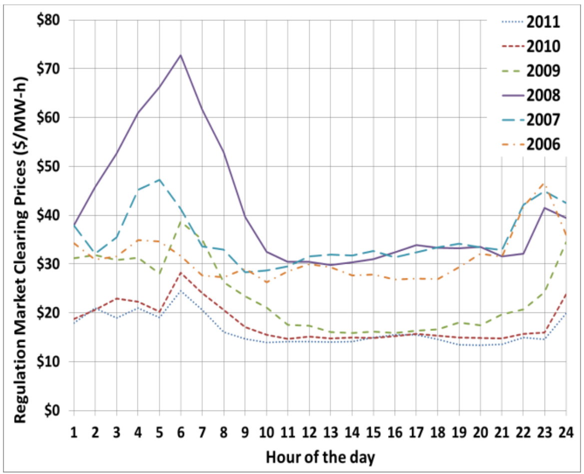

Figure 4: Average Regulation Market Clearing Prices for PJM Interconnection

We see that the regulation market does not follow the same pattern as the energy market where lower night-time demand drives electricity prices down and higher day-time demand drives electricity prices up. Instead, regulation market prices (for the PJM region) rise after 9-10 pm to peak early morning between 5-7am [14]. We find that this particular pattern matches well with commercial EVs charging availability between 6 pm and 6 am.

It is important to note that different regional markets have different regulation prices. In Table 4 below, we listed the average regulation market clearing prices in the PJM region between 2005 and 2011 [14]. In Table 5, we listed the average regulation prices for different regions in the US for 2010 [15].

Table 3: Historical PJM average regulation prices

PJM	Year	Regulation
Average Regulation Market Clearing Prices ($/MW-h)	2005	$49.73
	2006	$31.18
	2007	$35.37
	2008	$41.09
	2009	$23.56
	2010	$18.08
	2011	$16.43

Table 4: Regulation prices for different US energy markets [15]

ISO / RTO	Region	2010 Regulation Prices ($/MW-h)
CAISO	California	$12.30
ERCOT	Texas	$18.08
ISO - NE	New England	$14.47
NYISO	New York	$28.81
PJM	Northeast	$18.08

In this study, we focused on vehicles operated in California where diesel prices are currently higher than anywhere else in the United States and generous incentives are given for purchase of hybrid or electric commercial vehicle through the Hybrid Voucher Incentive Program (HVIP). We looked at regulation prices for the California Independent System Operator (CAISO). CAISO annual hourly average regulation prices are listed in Table 6.

Table 5: Annual Hourly Average CAISO regulation prices

CalISO	Year	Regulation Down	Regulation Up
Annual Hourly Average Price ($/MW)	1999	$20.84	$20.22
	2000	$50.15	$77.28
	2001	$42.33	$66.72
	2002	$13.76	$13.41
	2003	$18.43	$18.08
	2004	$10.95	$17.95
	2005	$16.05	$20.94
	2006	$17.01	$18.94
	2007	$9.97	$16.81
	2008	$15.67	$18.94

CAISO regulation prices range generally from $10 and $20 per MW-h although exceptionally high prices have been observed in 2000 and 2001 during the California energy crisis. Recent studies place CAISO regulation prices at around $12 per MW-h in 2010 [15].

This review of historical and current regulation prices is important as we will base our V2G analysis using different values for regulation prices. Our goal is to identify at which prices additional use for V2G improves significantly the economic value of commercial EVs.

4.2 Class 4 / Urban Delivery Vehicle with Additional Use for V2G

In this example, we come back to the class 4 urban delivery application presented in 3.1. Urban delivery applications, and particularly parcel delivery, seem well suited for additional use for V2G. Parcel delivery vehicles are used on fixed routes and usually leave and return to the same depot at fixed hours. They are generally parked a large part of the night (between 6 pm and 6 am) when most of the businesses they serve are closed.

Table 7 below lists the input parameters that we used to analyse the economic value of an electric class 4 urban delivery vehicle with additional use for V2G replacing an equivalent conventional diesel vehicle.

Table 6: Input parameters for economic analysis of an electric class 4 urban delivery vehicle with additional use for V2G

Daily time plugged in	55% of the day
Battery efficiency	85%
Grid efficiency	93%
Dispatch to contract ratio	10%
Regulation prices	Up $30/MW-h Down $30/MW-h
Power electronics cost	$500
Wireless connection cost	$100
Bidirectional charger cost	$1,500
On-board metering cost	$50

We assumed that the vehicle was out on the road 8 hours per day. We added a 2-hour buffer period when the vehicle is not plugged-in or not being charged. This gives us a share of daily time plugged in of 58% that we rounded down to 55%. Regulation prices were assumed at $30 per MW-h which represents the 7-year average for PJM average regulation market clearing prices. All other inputs were derived from previous studies [1-3].

In this example, we evaluate an electric class 4 vehicle driving an average of 40 miles per day. As we described in 3.1, at this low daily utilization rate, replacing a diesel class 4 vehicle by an EV does not make a good business case. We therefore look at using the EV for V2G to provide frequency regulation in addition to regular daily urban driving use. The impacts of the additional use for V2G on the business case are shown in Figure 5.

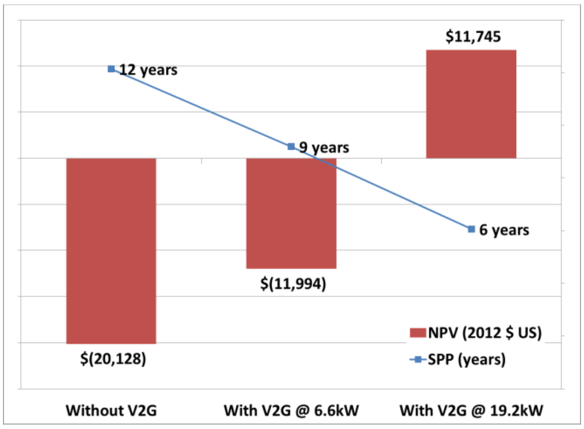

Figure 5: Economic analysis of an electric class 4 urban delivery vehicle driving 40 miles per day with additional use for V2G

We compared the SPP and NPV without V2G and with V2G at two different charging/discharging power levels: 6.6 kW and 19.2 kW. When we include additional use for V2G at a power level of 6.6 kW, the SPP decreases to 9 years and the NPV increases by about $8,000 (in 2012 US Dollars) but remains negative. When we use a power level of 19.2 kW (the upper limit currently used for public Level 2 chargers), the financial worth of the investment improves dramatically with a SPP of 6 years and a NPV of $12,000.

We find that V2G could offset the low utilization of the EV by providing additional use of the vehicle battery when plugged-in. Although lower power levels (6.6 kW) provide some benefits, high power levels (19.2 kW) are preferred to make a business case comparable to the high daily driving cases presented in 3.1.

The example above used market regulation prices of $30 per MW-h. We have seen in 4.1 that current regulation prices vary between $10 and $20 per MW-h. To assess the impact of regulation prices on the business case, we carried out a sensitivity analysis, varying regulation prices from $5 to $35 per MW-h. Figure 6 presents the results for the same vehicle with additional use for V2G at a power level of 19.2 kW.

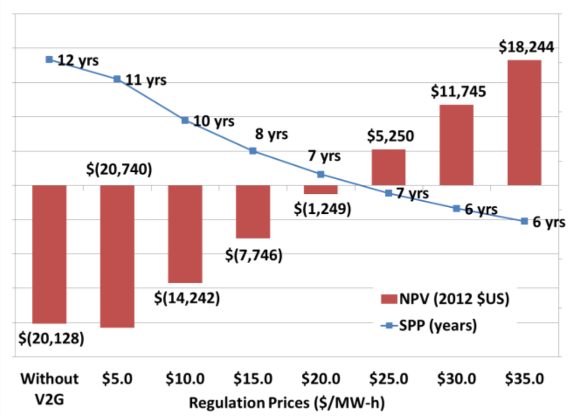

Figure 6: Sensitivity analysis to regulation prices for an electric class 4 urban delivery truck driving 40 miles per day with additional use for V2G

We find that regulations prices would have to be higher than $20 per MW-h in order to make a good business case when replacing an equivalent conventional diesel vehicle.

4.3 Class 5/6 / Utility-Work Site Vehicle with Additional Use for V2G

In this next example, we come back to the class 5/6 utility-work site application presented in 3.2. Military bases are currently interested in deploying EVs but vehicles are usually not used enough to displace significant amounts of petroleum and to make a good business case for EV. However, military bases have been exploring the possibility of using EVs for V2G in order to provide additional revenue and improve the economic value of EVs [16].

Table 8 below lists the input parameters that we used to analyse the economic value of an electric class 5/6 utility-work site vehicle with additional use for V2G replacing an equivalent conventional diesel vehicle.

Table 7: Input parameters for economic analysis of an electric class 5/6 utility-work site vehicle with additional use for V2G

Daily time plugged in	65% of the day
Battery efficiency	85%
Grid efficiency	93%
Dispatch to contract ratio	10%
Power electronics cost	$500
Wireless connection cost	$100
Bidirectional charger cost	$1,500
On-board metering cost	$50

We assumed that the vehicle was out on work sites 6 hours per day. We added a 2-hour buffer period when the vehicle is not plugged-in or not being charged. This gives us a share of daily time plugged in of 67% that we rounded down to 65%. All other inputs were derived from previous studies [1-3].

In this example, we assumed that the EV replaces a conventional diesel vehicle using an average of 5 gallons per day, 5 days a week and 50 weeks a year. To assess the impact of regulation prices on the business case, we carried out a sensitivity analysis, varying regulation prices from $5 to $35 per MW-h. Figure 7 presents the results with additional use for V2G at a power level of 19.2 kW.

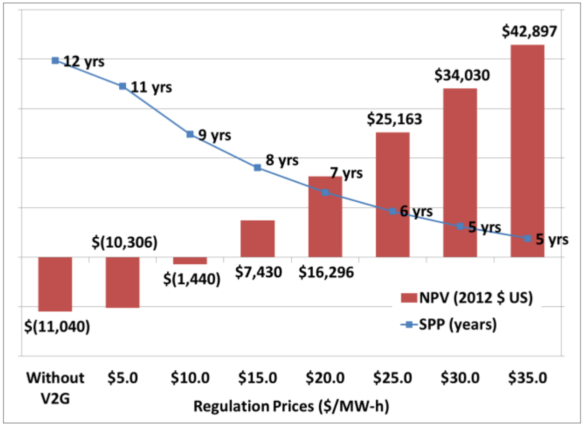

Figure 7: Sensitivity analysis to regulation prices for an electric class 5/6 utility-work site vehicle replacing a conventional diesel vehicle using 5 gallons per day with additional use for V2G

We find that regulations prices would have to be higher than $10 per MW-h in order make a good business case when replacing an equivalent conventional diesel vehicle. These results show that, with current CAISO market regulation prices, EVs on military bases make a good business case if they are used for frequency regulation in addition to their primary use as utility trucks.

5 Conclusions

In this paper, we evaluated the economic value of commercial EVs based on SPP and NPV. We find that high utilization is necessary in order to make a compelling business case for commercial EVs. For instance, a class 4 urban delivery EV needs to be driven more than 60-65 miles per day, 5 day per week and 50 weeks per year to realize a reasonable SPP and a positive NPV. For a class 5/6 utility-work site EV, high utilization means displacing at least 6 gallons of diesel per day, 5 day per week and 50 weeks per year.

However, many urban driving and utility-work site applications are characterized by low utilization operations - low daily mileage and/or low daily fuel consumption. We showed that these cases represent good opportunities for additional use for V2G when the EVs are parked and plugged-in.

Using EVs for V2G, specifically for frequency regulation, increases the EV battery usage and can dramatically improve the business case for commercial EVs. We found that higher charging power levels (in this paper, 19.2 kW instead of 6.6 kW) will maximize V2G benefits. We also identified the minimum regulation prices needed to reach reasonable SPP and positive NPV. For a class 4 urban delivery EV, regulation prices need to be higher than $20/MW-h to reach a positive NPV, indicating that the investment is financially worthwhile. For a class 5/6 utility-work site EV used on military bases, this number needs to be higher than $10/MW-h. At higher regulation prices, additional use for V2G can even bring SPP and NPV back to levels equivalent to EVs with high vehicle usage.

We conclude that using commercial EVs for V2G can improve the business case for EVs in urban driving and utility-work site applications and thus help the adoption of commercial EVs.

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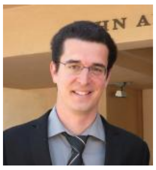

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