

Electric Avenue: Two Case Studies on the Economic Feasibility of the Electrification of Transportation (Solar Charging Stations in CA & University Buses in NC)

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ABSTRACT

The 2007 IPCC report solidified that global climate change is occurring due to the release of greenhouse gases (GHGs) by the anthropogenic activity of burning of fossil fuels. The effects reach beyond the realms of the environment and into health, public policy, national security and the economy. In the U.S., transportation is the largest energy user by end-use sector and I have chosen to focus on the electrification of transportation as one of the more promising approaches to the sector that addresses at the same time multiple facets of the environmental crisis. This is accomplished through the building of bottom-up, spreadsheet-based financial models because economic considerations are the main drivers of the adoption of these kinds of alternative solutions. Two types of solutions are considered: (1) solar charging stations for plug-in hybrid electric vehicles (PHEV) and electric vehicles (EV) in California, and (2) a comparative look at diesel hybrid vs. electric buses for Duke University.

The Financial Feasibility Model (FFM) for solar charging stations in California shows there are many combinations of user-selected inputs that yield profitable investment outcomes. This is applicable for all three scenarios with Scenario 1 achieving the break-even point quicker than Scenario 2 and, in turn, Scenario 3 due to the higher upfront costs of the latter scenarios. The option of financing the project with user-specified loan parameters can yield added Net Present Value (NPV) if the interest rate for borrowing is below the discount rate. The FFM for university buses in North Carolina indicates that switching from traditional diesel buses employed on university campuses such as Duke to alternatives like diesel hybrid or electric buses also makes financial sense. Over the life of the service of the vehicles, a comparative cost-benefit analysis indicates that both technologies come out ahead of diesels with diesel hybrids breaking-even first before electric buses due to the higher upfront cost of the latter.

While air quality, noise pollution, branding, public relations and other intangible assets have clear value, they are not included in both models due to the difficulty of assigning monetary values to such variables. The take away from the project is that both models use conservative parameters to underestimate the benefits for better financial decision-making for the stakeholders, that the results show that there are many avenues towards profitability and that these models are some of the first, if not the first, publicly-accessible of their kind.

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INTRODUCTION

Every generation has its calls to duty. Few times do paradigm shifts occur clearly in front of one's eyes. Simply stated, global climate change is and will continue to affect every corner of our lives and all peoples on this planet. The path forward towards understanding the problem and addressing it with the proper solutions is perhaps the greatest and most complicated task man has ever faced. Its undertow and reach is fundamentally altering the prism through which we see science, economics, business, politics, trade, energy and everything in-between. It is evident that the course that we are on as a collective planet is not one that is sustainable by any definition of that word. With rising carbon dioxide concentrations induced and accelerated by anthropogenic burning of fossil fuels, the way we think about, use and how we apply the driving force behind our societies (energy) must harmonize with the times. The segment that has a great potential in helping address the myriad of problems we face is mobility, or transportation as we call it currently, and specifically the electrification of it. This is what this Master's Project focuses on.

The technology itself is not new. In the 1830s, the first (albeit crude) electric carriage was invented.¹ Electric vehicles enjoyed success at the end of the 19th century but were overtaken by more efficient internal combustion engines (ICEs) with the arrival of cheap oil supplies and the assembly line invented by Henry Ford. Since then, the main forms of electric transportation have been in rail trains, buses and other public transportation. Only recently has this shifted back to a broader spectrum, expanding urban and rail transportation and also private use.² The Obama Administration's focus on underfunded projects like high-speed rail (vis-à-vis the heavily funded

¹ "Electric Car History," 2010.

² "Electric Cars: A Definitive Guide ," 2010.

federal highway infrastructure) is a primary driver of this shift.³ As for personal vehicles, federal funding has also infused low-rate interest loans for manufacturers and enthusiasm into that arena.⁴

Approach: Bottom-Up Financial Models

Two different types of approaches to electrification of transportation have been completed for this project. The first is an evaluation of combining the means to charge public and private electrified vehicles with a cleaner, renewable source of energy (solar) to power them, which henceforth will be referred as the **Solar Charging Financial Feasibility Model (FFM)**. Due to the inherent superiority of the efficiency of electrified engines,⁵ charging plug-in vehicles (PHEVs) or electric vehicles (EVs), even if they are powered by electricity that comes from coal, are still more efficient than traditional gasoline or diesel vehicles.⁶ However, further carbon emission reductions, air quality benefits and other value propositions can be attained with the use of alternative energy, such as solar in this case. Hence, for this FFM, what is being evaluated are the economics of uniting these two separate investments into one in order to capture the benefits that both provide as a more comprehensive solution than each can separately.

The second is an evaluation of switching university bus fleets from the traditional diesels to either diesel hybrid or electric buses, which henceforth will be referred as the **University Bus Financial Feasibility Model (FFM)**. The necessity of this model is based on events happening on the local level, right in the backyard of Duke University, for one. The drive to electrify transportation in the Triangle area is being spearheaded by the non-profit Advanced Energy (AE), an offspring of the local utilities and the North Carolina Utilities Commission, which was

³ CBS News, 2010.

⁴ Hanson, 2010.

⁵ Eberhard, 2006.

⁶ Jones, 2008.

founded in 1980.⁷ Collaborating with Progress Energy and Rocky Mountain Institute's MOVE Smart Garage Initiative 'Project Get Ready,'⁸ AE is moving forward on a transportation electrification plan for the Raleigh area that is set to be implemented in 2010.⁹ As of March 2010, the Raleigh initiative has led to a Clean Cities grant being awarded in the fall of 2009 that will help with EV procurement. More recently, the team is in the midst of developing a permitting process for the installation of charging equipment for electric vehicles, potential locations for charging stations and in-house training for electrical inspectors for this new infrastructure.¹⁰

The intention of this part of the Master's Project was to in essence leapfrog AE with an assessment of how their model of electrification could be applied to future stakeholders like universities. For this, the California model was recalibrated to focus on the North Carolina area and university buses as opposed to personal PHEVs and EVs. Universities would be an integral part of the process for Project Get Ready–Raleigh after the program launches into full swing, expanding the coverage of it into neighboring communities and new stakeholders. Given the clustering of major universities in this general area, they would be important partners to engage moving forward. AE would apply past lessons and address current concerns on a range of issues like permitting, charging rate structure, public charging infrastructure, incentives and customer education to universities. If successful, AE then would expand it to other localities such as Durham and Chapel Hill and the long-term goal is to go statewide. This integral category of stakeholders is the niche that is the focus of this part of the project, as embodied in the University Bus FFM.

⁷ Advanced Energy, 2010.

⁸ Project Get Ready, 2010.

⁹ Advanced Energy, 2010.

¹⁰ NC Get Ready!, 2010.

Purpose of Solar Charging FFM and University Bus FFM

The solar charging station model gives investors in California an economic opportunity to pursue a project that not only has the potential to yield financial returns but also help the state achieve its goals of increasing alternative fuel use¹¹ and meeting its Renewable Portfolio Standard (RPS),^{12,13} one of the most ambitious in the nation.¹⁴ Given California's established leadership on such issues relating to the environment, including stricter emissions standards for vehicles than the rest of the nation,¹⁵ generous support to clean tech companies¹⁶ and other, this is a place where solar charging stations can do its part in an environment receptive to such solutions. See **Figure 1** for details on California's solar potential.

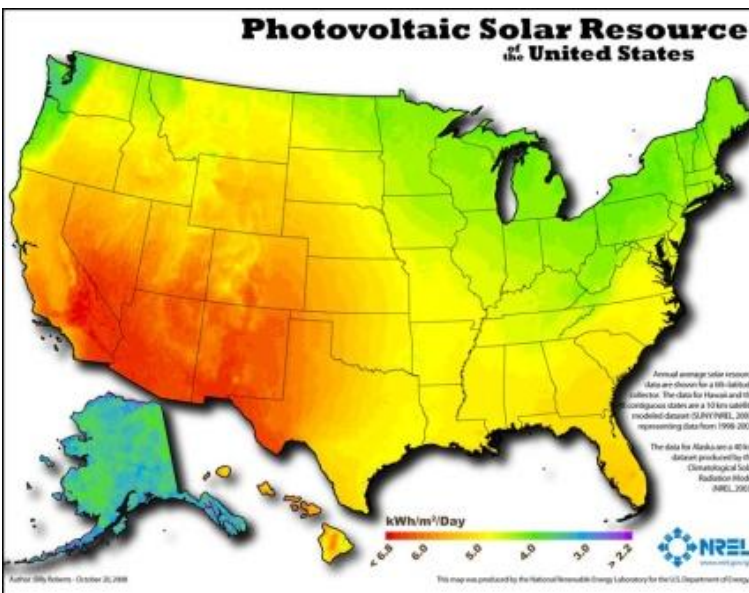


Figure 1: U.S. Solar Potential (NREL)

universities to measure its greenhouse gas emissions and produce a Climate Action Plan to mitigate, and eventually eliminate, these externalities.¹⁷ Duke's Climate Action Plan was passed

¹¹ Olson, 2007.

¹² "California Renewables Portfolio Standard (RPS)," 2010.

¹³ "33% RPS Implementation Analysis," 2010.

¹⁴ "States with Renewable Portfolio Standards," 2010.

¹⁵ Greenwald, 2010.

¹⁶ Kachan, 2010.

¹⁷ "American College & University Presidents' Climate Commitment," 2010.

in October of 2009 by the Board of Trustees and is available online.¹⁸ There are five main categories which encompass Transportation, Energy, Offsets, Education and Communication. The Transportation section specifically addresses 'greening' the fleet, improving efficiencies and encouraging alternative transit. This is an important category to analyze because transportation accounts for about ¼ of Duke's total carbon dioxide emissions,¹⁹ though it is mostly from private commuting (which the University now takes into account for its own footprint) and air travel. The Energy section could also be relevant if electric buses are a transportation path that the University would pursue since the fuel for the fleets would shift from diesel to electricity and fall under this category.

Intended Audience

The Solar Charging FFM is aimed at both private investors and government officials interested in understanding the financials of such an investment that illustrates whether this is a prudent way for them to fuel PHEVs or EVs that they may be considering purchasing. From the businesses perspective, this tool should be used by such entities as retailers (Walmart, Whole Foods, Costco, REI, etc) and others who either own their own fleets or are looking for ways to retain and capture more customers who might purchase such vehicles. From the governmental perspective, this tool should be used by fleet managers or cities and towns who are looking to transition their fleets beyond traditional service vehicles to meet their own transportation sustainability goals or as a way to utilize their budgets more effectively vis-à-vis their vehicles.

The University Bus FFM is intended to explore issues relating to this topic that may be unique to Duke University and this deliverable will assist immediate and future decision makers like the University administration, the Sustainability Office and the Transportation Director. It

¹⁸ "Duke Climate Action Plan," 2010.

¹⁹ "Greenhouse Gas Inventory 2008 Update," 2010.

will guide them, from the financial perspective, on the path of how to implement such a project in the university context. The research will focus primarily on a benefit-cost analysis of how economically feasible this undertaking may be. While items like quantity and cost of electricity/gasoline and budgetary factors are easier to calculate, monetizing air quality, for instance, will be difficult and will require a look at how agencies and organizations do this, if they even currently do. An analysis of private commuters could be a separate Master's Project that could build upon this and previous ones in order to assist the decision-makers on this other aspect of transportation that the University should address.

The secondary audience includes cities like Durham (which is already moving towards diesel hybrid buses)²⁰ and utilities like Duke Energy and Progress Energy who are paying more attention to the electrification of transportation,^{21,22} smart grid technology²³ and other approaches that they see will be part of the electric utility future soon. Duke Energy itself has committed to electrifying its own fleet in order to meet its corporate GHG emission reductions and saving millions of dollars in the process.²⁴

It is also anticipated that this report could be also most beneficial, in terms of outside interest, to organizations like Advanced Energy, Rocky Mountain Institute, Electric Power Research Institute who have an on-going interest in and research being conducted on the electrification of transportation. Furthermore, other North Carolina universities could employ this model as long as the proper input data for electric rates and diesel fuel purchases is altered to align with their unique regional specifications.

²⁰ Ruch, 2010.

²¹ Advanced Energy, 2010.

²² "Duke Energy and Plug-In Electric Vehicles (PEVs)," 2010.

²³ "Smart Grid: Enabling Affordable, Reliable and Clean Energy," 2010.

²⁴ Addison, 2009.

BACKGROUND

Origins of the FFMs

This financial analysis stems from my 2009 summer Stanback Internship with the environmental non-profit organization Friends of the Earth (FOE)²⁵ in San Francisco, working on their Clean Cars Campaign. The main focus of the internship was to look at how to reduce GHGs from the transportation sector in California and nation-wide by working at the legislative, regulatory and corporate levels to promote sustainable, alternative fuels and ultra-efficient PHEV technologies. That included undertaking an analysis of what policies are necessary to facilitate utility support of mass adoption of plug-in electric vehicles as well as assisting on an initiative to build a network of solar-powered charging infrastructure (i.e. solar fuel/charging stations) for PHEVs and EVs.

Secondary tasks included supporting the Regional Director in putting together comments on working papers and other smart grid initiatives by the California's Public Utilities Commission (CPUC) as well as integrating the goals of the Clean Cars Campaign with these regulatory proceedings. A smart grid appears to be an essential part of integrating such new technologies via a new and more sustainable way of generating, distributing and using electricity in the future. Hence, this experience added a policy and technical dimension to the model building that was instrumental in making them as realistic as possible while taking those considerations into account.

During a meeting with the Mayor of Berkeley Tom Bates and his staff to discuss the potential for the city to adopt solar charging stations as part of their sustainability goals, a stray

²⁵ "Powering Plug-Ins," 2010.

comment by one of the staff members altered the trajectory of my internship. One of the Mayor's aides inquired whether the numbers used in the presentation by my superiors were in Net Present Value or not. It turned out that the preliminary calculations that were contained in the FOE presentation were simple calculations of costs, gas savings and other not adjusted for the time value of money and inflation.

This indicated that not only were the numbers deceptively inaccurate but also that the approach that had to be taken, even for progressive cities like Berkeley, was one focused on the financials and not just on the 'green' aspect of the Campaign. Given that this was coupled by the fact that the state of California was going through a budget crisis, it was clear that the way to pique the interest of municipalities and businesses for this specific idea was not only through an environmental lens. It had to be demonstrated these solar charging stations made sense financially, especially given the finances of the state and the country in 2009 and hence after.

Charging Station Technology Synopsis

Charging stations equipped to charge PHEVs and EVs is a pretty straight-forward technology. It draws energy from either the grid or on-site generation (such as solar or wind energy) that is used to charge the battery packs of such vehicles. There exists a growing number of different types of manufacturers which offer an array of different charging products (see **Figure 2** for an example of a charging station in Cary, NC). Currently, there are three levels of charging that are available (Level I, II and III). Level I chargers are assumed to provide 120 volts



Figure 2: Coulomb Charging Station

at 16 amps for a charger of 1.92 kW and Level II is 240 volts at 32 amps. Level III is 480 volts with varying amperage. The model utilizes Level I charging and Level II charging only. This is similar to plugging into a household outlet for Level I and to the outlet used by washers and dryers for Level II. The higher level of charging, the quicker the battery is replenished.

However, this usually reduces the lifecycle of the battery,²⁶ at least with current technology. Since the battery is a large cost of the PHEVs and EVs, it is an investment that must be protected and this the model neglects Level III charging for this reasoning and since Level I and II will be the most common charging types for the near-future.

Solar Photovoltaic Technology Synopsis

The history of solar photovoltaics is one that is almost two hundred years old.²⁷ The discovery of the photovoltaic effect occurred in 1839 by Edmund Becquerel, a 19 year-old French experimental physicist during experiments with an electrolytic cell comprised of two metal electrodes. An American inventor, Charles Fritts, created the first working solar cell made from selenium wafers in 1883. Application of the technology outside the laboratory occurred during the Space Race that saw the launching of satellites and solar cells as the perfect power source. Today, with the increased focus on alternative energy generation around the world, solar photovoltaic technology is one of the leaders in that realm.

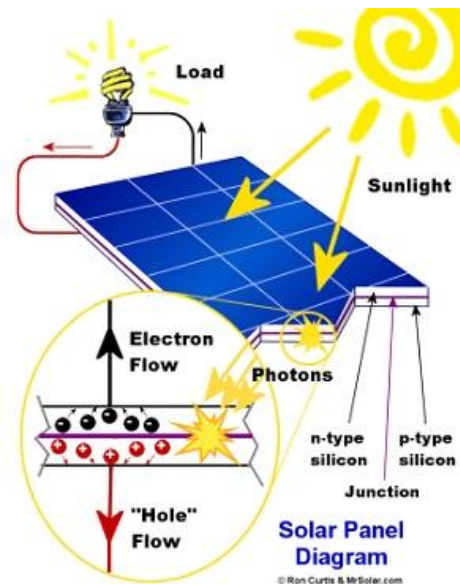


Figure 3: Solar Panel Diagram

²⁶ Anderson, 2009.

²⁷ Bellis, 2010.

Figure 3 illustrates how solar cells work. Individual solar cells are made up of semiconductor materials that are connected together to form modules that could be a few feet in length and width which themselves can be arranged together to form arrays.²⁸ Sunlight, which is just photons, breaks the ties of the electrons in the cells that allow the electrons to move freely. The areas that are left free by the electrons are positively charged and are called ‘holes.’ The semiconductor materials have sections that are positively and negatively charged, creating what is known as a ‘p-n junction’ that has excess of positive holes and electrons, respectively. An internal electrical field is produced that makes the electrons move toward the n side and the holes toward the p side, creating an electrical current. This is known as the photovoltaic effect. See **Figure 4** for how a solar panel is used to generate electricity.

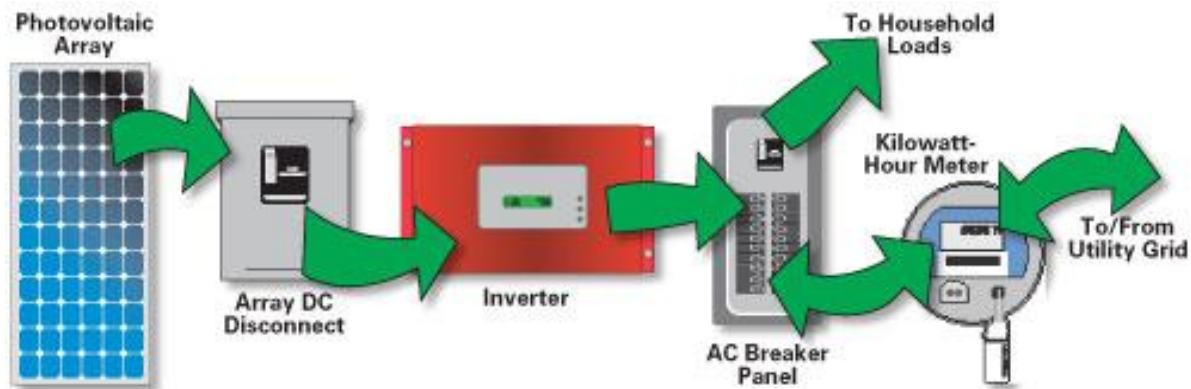


Figure 4: Grid Intertie of a Solar Electric System

²⁸ "PV Physics," 2010.

METHODS

The initial stage of the research was mainly an exercise in data collection from the proper sources of information like the U.S. Department of Energy’s Energy Information Administration (EIA), utility companies, state agencies and phone interviews and email exchanges with the proper actors in the various industries and sectors that are used as inputs into the model. This mainly comprises the data on gasoline and electric price projections as well as GHG pricing schemes, tax information on these relevant investments and technical specifications of batteries and buses. All assumptions for the models are outlined in the next sections and in the appendix for a more detailed understanding of the models as well within the models themselves in comment boxes. Data collection was not an arduous task in itself but resolving the issue of whether it is the best available data, both in terms of accuracy and reputable sources, was done as best as possible, given resource and time constraints.

Due to the scope of the project, the most important data inputs were analyzed more vigorously in order to have better explanatory power for the models so to make the results as accurate as possible. The gathered data is the basis for a bottom-up, Excel-based spreadsheet model that takes the input from the user and calculates the desired output. The end-result is a comprehensive estimate of the viability of the investment given the users unique input, either the Solar Charging FFM or the University Bus FFM.

It should be emphasized that these models are a purely economic look at such an investments. The Solar Charging FFM, unlike the RMI Public Charging Infrastructure tool^{29,30}

²⁹ May, 2010.

³⁰ May, 2009.

(which is a similar financial model but only focuses on the charging stations themselves), does not incorporate potential benefits that are harder to conceptualize, calculate and monetize. Usually termed “intangible benefits” – this includes such things as branding, customer/employee attraction and retention, and goodwill. They do have value but in order to be consistent with the economically conservative nature of the models, an option to calculate such benefits is omitted. A conservative approach is utilized in order to show that such investments are feasible using a metric that will tend to *underestimate* the benefits and *overestimate* the cost potentially in order to be a pragmatic tool for the investment and mitigating risk of cost overruns. This is also directly applicable to the University Bus FFM.

The reader and the user of the model is encouraged to actively analyze the validity of the data and assumptions and substitute their own for their purposes or update them with more recent information. The models should be considered as evolving creatures which need to be refined as new information becomes available to. This will allow the models to forecast more accurate results which will lead to more prudent decision-making for stakeholders, policymakers, academics and industry.

Methodology for Solar Charging FFM

The Solar Charging Financial Feasibility Model (FFM) is designed to be a user-friendly tool that outputs the future cash flows depending on the settings the user-investor inputs into the model via dropdown boxes. The variables alter the model to calculate results tailored to the user’s specifications, depending on their particular risk level, size of investment and other. The model is focused on a single stakeholder, either a business or a governmental body, in order to explore the unique conditions that affect such entities in order to assess the viability of solar charging stations for PHEVs and EVs for them.

This model builds upon the beta version from my summer internship work that focused on modeling the benefit-cost analysis of solar charging stations for PHEVs and EVs for California under various scenarios and user input such as the discount rate, time horizon and form of financing project. This model expands both in scope and breadth but continues to utilize the PG&E service territory as the initial area analyzed and as its proxy for the rest of the state. More accurate results for the state as a whole or for the other service territories in the state can be achieved if the assumptions into the model for the relevant area are substituted.

This FFM takes into account such factors as the accelerated depreciation for the solar panels and equipment and taxes on revenue generated (if any), projections for gas prices, and solar efficiency losses over the years of use and so on. It is dynamic in terms of input and other aspects so as to paint a more accurate picture of what the user can expect the cost of the stations to be in actuality and the return on their investment. For instance, the projections of gasoline prices out to 2035 are done using the standard data, which is supplied by the EIA. The EIA's numbers tend to err on the conservative side³¹ so using their numbers is a proper approach from a policy and business perspective. There has been a conscious effort made to show that using even conservative numbers for the scenarios of the model, it is possible for solar charging stations (and alternative buses for that matter) to make economic sense on many occasions.

In addition, the projected electric rate increases will also be looked at since the 'fuel' of choice to be substituted with will be electricity. Local, state and federal incentives (such as the federal 30% tax credit for renewable energy systems) will also be factored into the upfront cost equation to further tune the accuracy and scope of the analysis. The current model has inputs such as whether revenue is collected from the charging stations, the cost per charge, what time

³¹ Hawley, 2009.

horizon in years is being looked at, the number of days of charging and what type of solar arrangement is being considered. See **Figure 5** for an overall graphical representation of the Solar Charging FFM. For a closer look at selected sections of the model, refer to **Figure 6** (Input and Results) and **Figure 7** (Cumulative NPV). This product is the deliverable for FOE and will be available on their website.

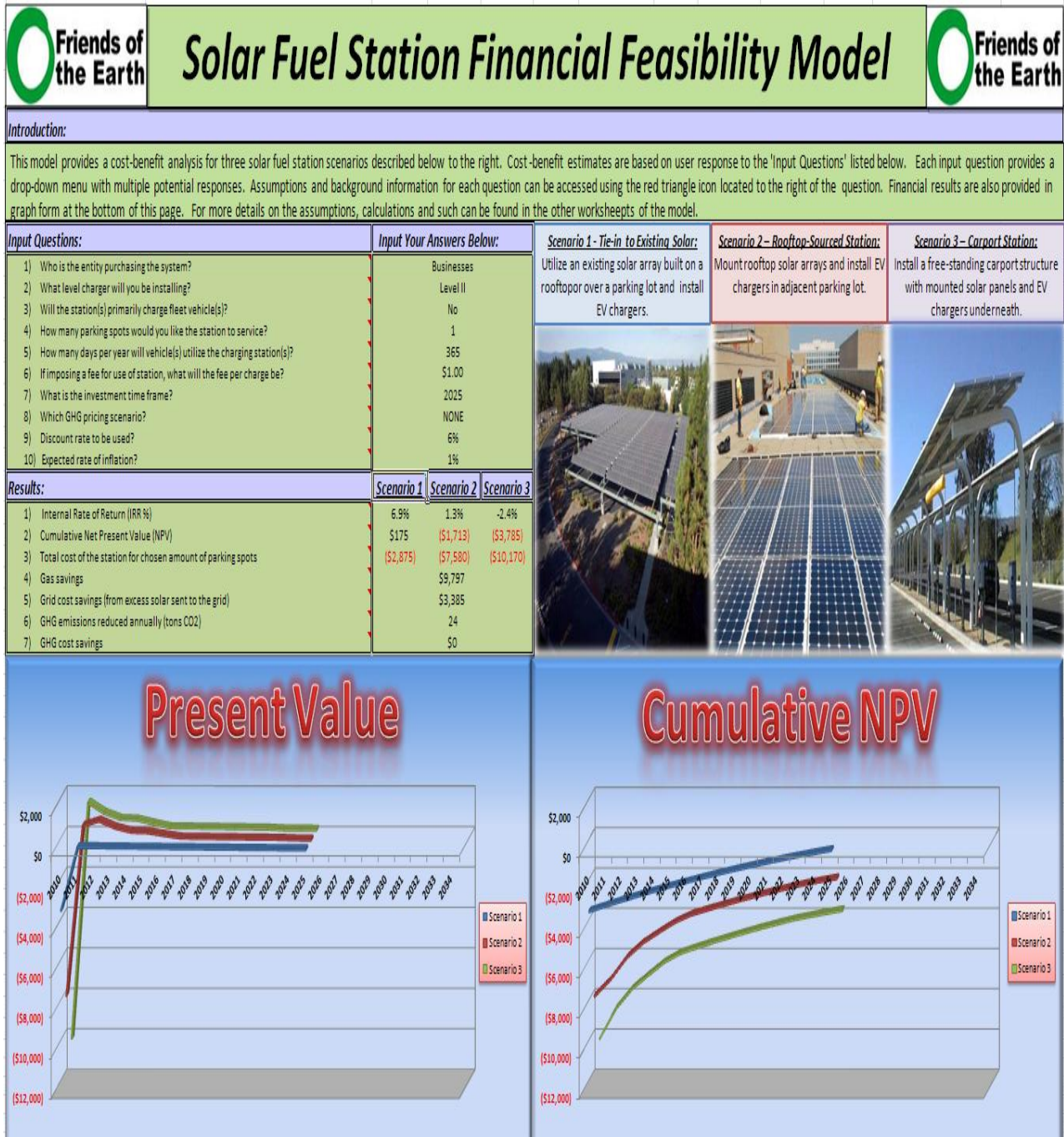


Figure 5: Solar Charging Financial Feasibility Model

Input Questions:	Input Your Answers Below:		
1) Who is the entity purchasing the system?	Businesses		
2) What level charger will you be installing?	Level II		
3) Will the station(s) primarily charge fleet vehicle(s)?	No		
4) How many parking spots would you like the station to service?	1		
5) How many days per year will vehicle(s) utilize the charging station(s)?	365		
6) If imposing a fee for use of station, what will the fee per charge be?	\$1.00		
7) What is the investment time frame?	2025		
8) Which GHG pricing scenario?	NONE		
9) Discount rate to be used?	6%		
10) Expected rate of inflation?	1%		
Results:	Scenario 1	Scenario 2	Scenario 3
1) Internal Rate of Return (IRR %)	6.9%	1.3%	-2.4%
2) Cumulative Net Present Value (NPV)	\$175	(\$1,713)	(\$3,785)
3) Total cost of the station for chosen amount of parking spots	(\$2,875)	(\$7,580)	(\$10,170)
4) Gas savings		\$9,797	
5) Grid cost savings (from excess solar sent to the grid)		\$3,385	
6) GHG emissions reduced annually (tons CO2)		24	
7) GHG cost savings		\$0	

Figure 6: Solar Charging FFM – Input and Results sections

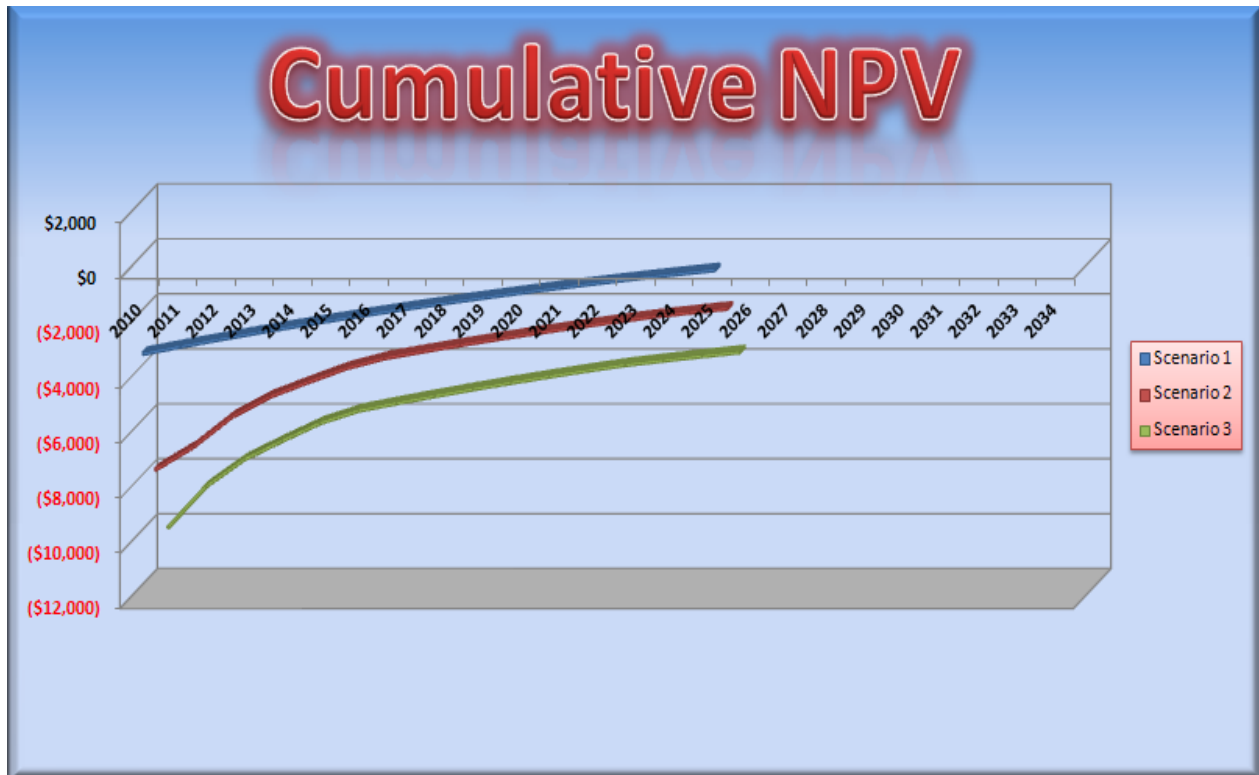


Figure 7: Solar Charging FFM – Cumulative NPV graph

Methodology for University Bus FFM

The University Bus Financial Feasibility Model (FFM) is designed to be a user-friendly tool that outputs the future cash flows depending on the settings the user-investor inputs into the model via dropdown boxes. The variables alter the model to calculate results tailored to the user, depending on their specific risk level, size of investment and other. The model is focused on a single stakeholder, the university, in order to explore the unique conditions that affect such entities in order to access the decision of purchasing new campus buses from a financial perspective.

Since the model is just forecasting the financial portion of the decision to purchase buses for university administrators, a handful of simple inputs by the user are needed to calculate the economic feasibility of such an investment. The user is asked a few simple input questions that will determine the financial viability of the three bus technologies for their needs, using diesel buses a base for comparison for the other two. The user is solicited to answer how many buses they wish to purchase, the time horizon for their operation, the discount rate used by its institution, the inflation rate and the GHG pricing scenario, if any. From this input, the model outputs a handful of financial metrics the user would be interested in. The Internal Rate of Return (IRR) and Net Present Value (NPV) are given along with the cost estimates for the buses, the potential gas savings and GHG-related results. For a brief primer on IRR and NPV, please see the Appendix.

This slice of the purchasing decision is appropriate to analyze due to the fact that it is one of the important, if not most important, in deciding which technology and manufacturer to purchase from. The most important metric, however, is the first one that shows the benefit of switching from diesel buses to the alternatives. This comparative look at cost associated with

diesel, diesel hybrid and electric buses is thus done to decipher the benefits and downsides of each technology. A university campus will need transportation for its student, faculty and working bodies and buses are the common form of transporting large masses of people. The question is how to do it in the manner that is financially sound but also one that leads towards a discussion of looking at such investments beyond traditional metrics and shows that things like noise and air pollution are real costs to the community.

Diesel hybrid and electric buses both have reduced emissions compared to diesel buses because of the higher efficiencies of the former, thus less air pollution per mile occurs. Electric buses do not have any tailpipe emissions which means that for the campus population, negative health consequences are avoided in the environment they operate as they are moved to the point-source site of where the electricity is generated. While it is not possible (at least easily in a standard manner) to attach a monetary damage value of such negative effects as exposure to diesel exhaust per individual, the consequences are still there. One approach could be to pool such damages together. A ‘Social NPV’ metric could be a reasonable step toward that that can then be internalized in a future model as a benefit of using such alternative bus technologies. It would likely be based on an extension of the ‘Value of a Statistical Life’ (VSL) methodology.^{32,33}

However, since the model uses monetized financial input (no air quality nor noise reduction benefits, for instance), benefits and the need associated with campus buses is not fully captured. Hence, it can be expected that traditional financial metrics like IRR and NPV will most likely be negative due to the bias of costs over benefits. It is not the end of the story because they do not capture the comparative advantages of the technologies, which is what the models are after. Due to the fact the University Bus FFM’s positive cash inflow are the savings from using

³² Duvall, 2010.

³³ Kenkel, 2010.

less diesel fuel, all the individual results for the various technologies will be negative due to the high capital costs compared to the cash flows. The aforementioned comparative metric is needed and the Results section provides this as the ‘Financial Savings’ output. This measures the difference between the NPV of the diesel buses with the diesel hybrid and electric buses. If it is positive, this indicates that the NPV for the alternative bus technologies have a smaller negative NPV than the diesels, so given the user input, this outcome dictates that the new technologies provide a better Return on Investment (ROI), even though it is negative. This is a slightly different approach than for the Solar Charging FFM which stresses NPV as the key economic output metric.

See **Figure 8** for an overall graphical representation of the University Bus FFM. For a closer look at selected sections of the model, refer to **Figure 9** and **Figure 10**.

Diesel Hybrid vs. Electric Bus Financial Feasibility Model

Introduction:

This model provides a cost-benefit analysis for alternative bus technologies compared to traditional diesel buses. Diesel buses are the baseline for comparison to Diesel Hybrid and Electric buses. The three scenarios are described below to the right. Cost-benefit estimates are based on user response to the 'Input Questions' listed below. Each input question provides a drop-down menu with multiple potential responses. Financial results are also provided in graph form at the bottom of this page. For more details on the assumptions, calculations and such can be found in the other worksheets of the model.

Input Questions:

- 1) How many buses are you looking to purchase?
- 2) Up to what year would you like to run the financial calculations?
- 3) Discount rate to be used?
- 4) Expected rate of inflation?
- 5) Which GHG pricing scenario?

Input Answers Below:

- 1
12
6%
1%
NONE

Scenario 1 - Diesel Hybrid Buses



Scenario 2 - Electric Buses



Scenario 3 - Diesel Buses



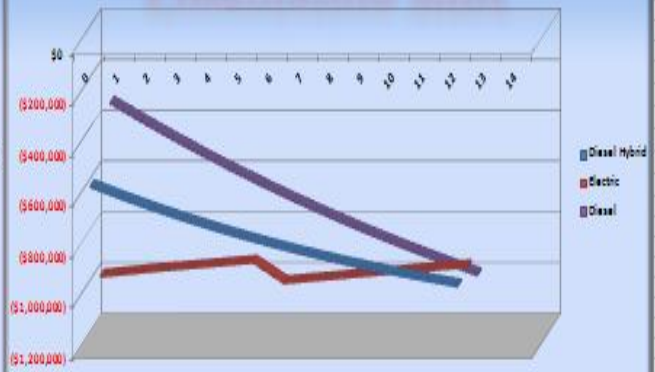
Results:

	Diesel Hybrid	Electric	Diesel
1) Financial Savings from Switching from Diesel to...	\$75,777	\$92,510
2) Cumulative Net Present Value (NPV)	(\$932,059)	(\$915,325)	(\$1,007,036)
3) Internal Rate of Return (IRR %)	IRR undefined	-26.4%	IRR undefined
4) Total cost of buses (and other capital, if applicable)	(\$540,000)	(\$953,000)	(\$330,000)
5) Gas saving	\$151,937	\$270,110
6) GHG emissions reduced annually (tons CO2)	507	547
7) GHG cost saving	\$0	\$0

Present Value



Cumulative NPV



Cost-Benefit Analysis

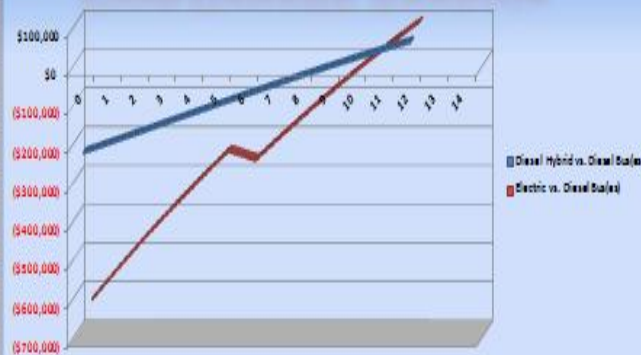


Figure 8: University Bus Financial Feasibility Model

Input Questions:	Input Answers Below:		
1) How many buses are you looking to purchase?	1		
2) Up to what year would you like to see the financial calculations?	12		
3) Discount rate to be used?	6%		
4) Expected rate of inflation?	1%		
5) Which GHG pricing scenario?	NONE		
Results:	<u>Diesel-Hybrid</u>	<u>Electric</u>	<u>Diesel</u>
1) Financial Savings from Switching from Diesel to...	\$75,777	\$92,510	-----
2) Cumulative Net Present Value (NPV)	(\$932,059)	(\$915,325)	(\$1,007,836)
3) Internal Rate of Return (IRR %)	IRR undefined	-26.4%	IRR undefined
4) Total cost of buses (and other capital, if applicable)	(\$540,000)	(\$953,000)	(\$330,000)
5) Gas savings	\$151,937	\$270,110	-----
6) GHG emissions reduced annually (tons CO2)	507	547	-----
7) GHG cost savings	\$0	\$0	-----

Figure 9: University Bus FFM - Input and Results

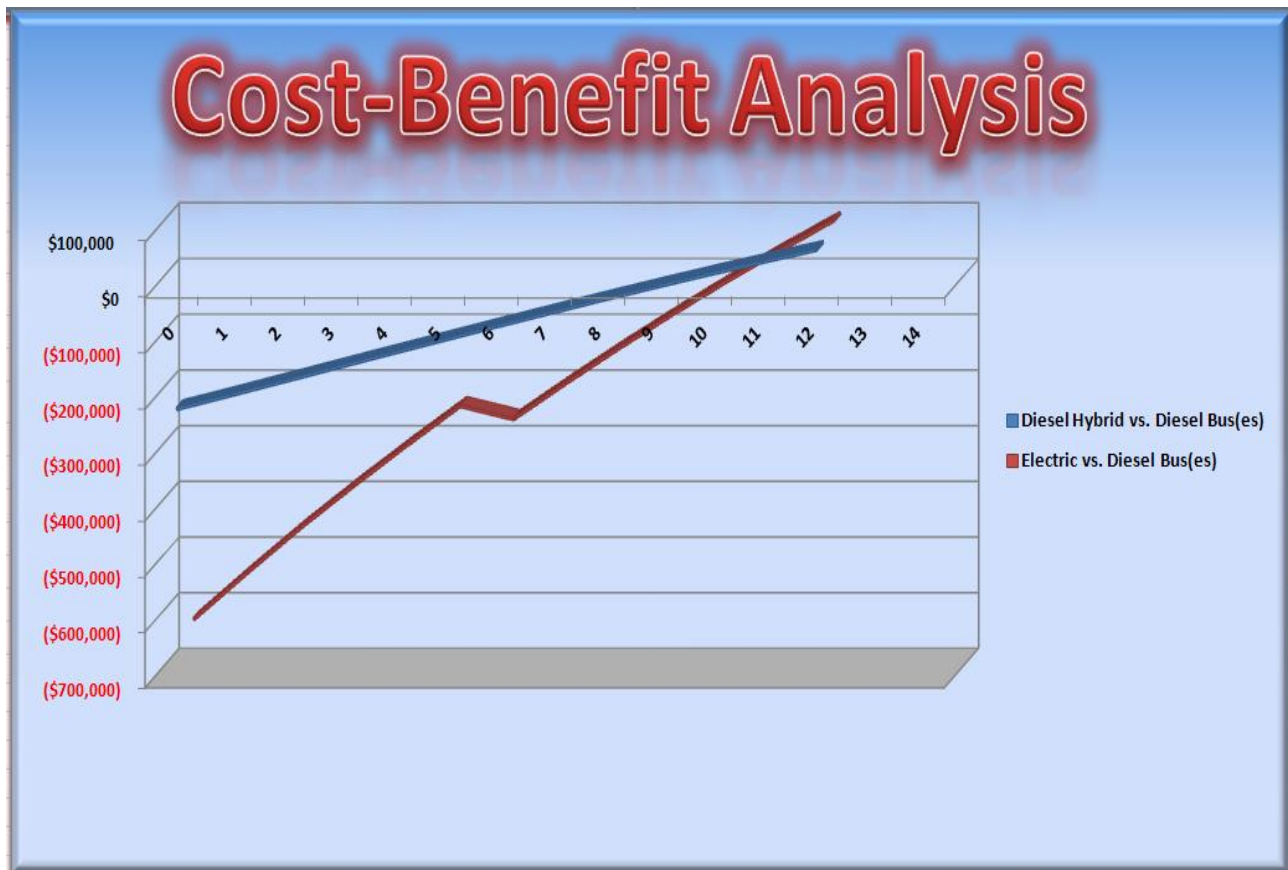


Figure 10: University Bus FFM – Cost-Benefit Analysis graph

FINANCIAL FEASIBILITY MODELS (FFMs)

The model that was constructed originally bottom-up to assess the financial acceptability of solar charging stations for PHEVs and EVs for the PG&E service territory, specifically the Bay Area. It is thus important to understand how it was developed, the assumptions that went into it and how it was modified for the comparative look of diesel-hybrid and electric buses for Duke University. This section will address both variations of the model in an overview of its key parts in order for the user to understand how the results were calculated and, if it needs to be modified or updated as decided by the user, this will facilitate the process. A detailed list of assumptions can be found in the Appendix.

Financial Feasibility Model for Solar Charging Stations for PHEVs and EVs

The model has three major sections: the input (CA Petroleum Prices Projections, CA Electric Price Projections, GHG Emissions Projections & Solar|Charging Station Costs), the processing of the data into financials (NPV|Output Calculations & NPV|Output Calculations (+Loan)), and the output (Financial Feasibility Model). The research and data collection formed the basis of the input of the model that was then used in the other sections to arrive at the results.

CA Petroleum Prices Projections

The main crux of data for this section comes from EIA which is the federal body within the Department of Energy (DOE) that provides “policy-neutral data, forecasts, and analyses to promote sound policy making, efficient markets, and public understanding regarding energy and its interaction with the economy and the environment.”³⁴ Their projections are the basis for analysis for policymakers, academics and researchers as the usual starting point in data

³⁴ "About EIA," 2010.

collection. While it is policy-neutral, the EIA's estimates are widely seen as earning on the side of cautious and are conservative. Since from a financial perspective it is not productive for the client or the agent to base their decisions on overzealous data, this fits well with the nature of the model and contributes to its financial conservatism.

From these estimates, the proper amount of gasoline used is calculated based on what the user input for the number of days of charging and stations chosen. This is translated into what the cost will be and the values then go into the model as cash inflows if the fleet option is selected in the mainframe by the user. If the user specifies that this is for fleet vehicles, then they are the ones capturing the gas cost savings and hence can be part of their NPV. If this is not for fleet vehicles, then the individual owner of the vehicles that are charged capture this benefit which cannot be incorporated into the NPV for the investor and thus not part of the model.

CA Electric Price Projections

This section deviates from the use of EIA numbers for petroleum projections due to the fact that while the gas prices increase over time in their calculations, electric rates for section that includes California essentially stays stagnant throughout up until 2035. It was decided within the Clean Cars Campaign with the Regional Director that these estimates are conservative even for the EIA model and the decision was made to extrapolate electric rate increases in California from historical data. The analysis was limited to the Pacific Gas & Electric (PG&E) service territory that includes a large part of the state, mostly the middle section, so as to make it more relevant to the governments and businesses that FOE first approached.

Historical tariff data from 2001-2009 for PG&E was analyzed for the E-19 rate which is the demand-metered time-of-use (TOU) service offered to commercial clients.³⁵ This rate is applicable both to business and government entities for our purposes. An annual average increase rate was calculated from the data and was applied to making the projections for the next 25 years from 2010 to 2035. On top of that, the effects of a 33% Renewable Portfolio Standard (RPS) by 2020 was included to measure the impact of such a policy that was enacted via executive fiat by Governor Schwarzenegger recently.³⁶ It should be noted that the additional increases stemming from the policy only incorporate the price increase but do not take into account of the net consumer benefits from the policy that take place from after 2020, as deduced by the CPUC report on the matter.³⁷

From these projections, it was calculated the cost of charging the amount required by the PHEVs/EVs (set at 4 kWhs per vehicle per day per station, the equivalent of about 16.5 miles, or half a daily American's commute). The total amount is defined by how many days of charging and the number of stations the user inputs into the mainframe of the model. Lastly, the amount of excess electricity produced by the solar PV panels is calculated and its monetary value of electricity forgone from buying from the grid or used in lieu on-site goes into the model as a positive cash flow resulting from this investment. This is one of the sources of cash inflow for the Solar Charging FFM.

Greenhouse Gas (GHG) Emissions Projections

The emissions for GHGs were particularly important for FOE due to the fact that funding for such projects for governments would most likely come from federal and state funds that deal

³⁵ "Tariff Book," 2010.

³⁶ Hamilton, 2010.

³⁷ The Center for Resource Solutions Team, 2005.

with air quality and air pollution reduction initiatives. This was one of the likely paths for funding and hence the emphasis on such pollutants in addition to criteria pollutants such as NOx and SOx. Additionally, California is at the forefront of utilizing a GHG reduction mechanism, like cap-and-trade,³⁸ which is expected to go into effect if federal legislation does not pass to supersede it.

In this section, using the emissions rate for gasoline as defined by the US EPA, the amount of GHGs emitted by ICEs and PHEVs/EVs is calculated and then emissions saved from switching. This is one of the outputs in the main part of the model. Further, disparate monetary values are attached to these reductions in order to potentially include these reductions when some carbon dioxide pricing systems is enacted in the U.S. Three scenarios are calculated. The first one is what the pricing would look like if the Waxman-Markey House bill was enacted nationwide. It has constant price increases which I have elected to cap at just above \$30/ton due to the prevailing notion that the price is unlikely to rise much more for the foreseeable future in the timeline of the bill. Beyond this number, the goal of a conservative estimate would be undermined. Further, given that any legislation will most likely have a price floor and ceiling (or a 'price collar') in order to have some built-in mitigation in price volatility. This will make it more politically acceptable to members of Congress whose constituencies are seen as particularly vulnerable to the potential negative effects of the legislation and also give the business community boundaries within which to make their investment choices.

The second scenario is based on what the California Energy Commission (CEC) believes should be the price placed on GHG emissions, or \$16.30/ton. The model takes this number as stagnant for the whole time horizon which makes this a conservative GHG pricing mechanism,

³⁸ "Cap-and-Trade," 2010.

too, since the amount of allowances for emissions would steadily decrease leading to, all else equal, a steady rise in price per ton.

The third scenario is the upper boundary of the pricing of GHGs for the model. The basis for it is the controversial study entitled the “Stern Review on the Economics of Climate Change”, or the Stern Report as it is known, by Nicholas Stern of the London School of Economics for the British government in 2006.³⁹ That study indicated that GHG prices should be set at \$85/ton from the outset. Here too the price is set at the same level throughout the full time horizon.

Solar/Charging Station Costs

This section is what the model uses as input for the cost of the charging stations and the solar system. It is based on cost estimates based on the Coulomb technology for the charging stations and the solar estimates are based on discussion with industry representatives from the Bay Area. The proper state and federal incentives for the stations and panels are taken into account and go a long way in making the financials positive for the investor of this project as does accelerated tax depreciation of the panels. The costs are calculated for the three different types of scenarios as defined in the mainframe of the model. Scenario 1 is a tie-in of charging stations to an existing solar installation, Scenario 2 is a rooftop-sourced station and Scenario 3 is a carport station. This data is then used in the NPV calculating part of the model to provide the user with a proper estimate of the project along with their other inputs.

NPV/Output Calculations / NPV/Output Calculations (+Loan)

This part of the model is the engine. It is the place where the user inputs are translated into workable data in order to calculate whether the project will achieve a positive return or not and to what magnitude. Tersely, here is where the actual financial calculations are processed

³⁹ "Stern Review final report," 2010.

outputting the desired NPV, IRR, graphs and other. The information then is clustered into its respective groupings using excel formulations to tell the model to use the correct corresponding figures based on the input of the user, such as the time horizon, that is selected.

The 'NPV|Output Calculations (+Loan)' is exactly the same as the non-loan one only deviating in having a section in the NPV calculation table include a Financing Expense in the cost section to take into account loan repayment in the given time horizon. The initial capital cost is also different now since the upfront down payment is now only a piece of the previous amount in the non-loan section.

Financial Feasibility Model (Output)

This is where the user inputs his or her data based on their specific scenarios, expectations and type of investment they would like to analyze and where the process data is outputted into the financial metrics used by the model to measure the appropriateness of an investment into solar charging stations. The output is displayed also in graph form for the Present Value of the cash flows and the Cumulative NPVs to better illustrate the potential of the investment as well as indicating at what point the investment breaks even. Additionally, the user is given the option to see what effect taking a loan for the investment has on the financials. Since it is unlikely that if the user wishes to pursue a sizeable solar charging station endeavor he or she will be able to put up the whole capital cost upfront (as is assumed in the first financial calculation), a financing option is given to the user. As a rule of thumb, if the interest rate at which the loan is taken out is lower than the discount rate used, there will be some positive addition to NPV for the project which indicates that financial are, all else equal, much better when the project is financed with a loan rather than all paid up front.

Financial Feasibility Model for Diesel-Hybrid and Electric Buses

The model has three major sections: the input (South Atlantic Gas Prices (EIA), SERC Electric Prices (EIA), SERC GHG Emissions Projections & Buses|Charging Equipment Costs), the processing of the data into financials (NPV|Output Calculations), and the output (Financial Feasibility Model). The research and data collection formed the basis of the input of the model that was then used in the other sections to arrive at the results.

South Atlantic Gas Prices

As before, the data for the prices of the fuel are from the EIA but only now specifically for diesel since that is the fuel that the diesel and diesel hybrid buses use. The annual vehicle miles traveled (VMT) now reflect the average of Duke's fleet of 30 buses that currently are in operation on campus. Given user specifications in the input section of the model, the cost of fueling the current buses is calculated as it is for the diesel hybrids, which forms the basis of a comparative look of the two types of buses and the fuel savings associated with switching from diesel to diesel hybrid. This becomes the one of the two cash inflows for the NPV calculations since this is a cost that is forgone if the vehicle switch is done as opposed to the baseline, status quo scenario. Additionally, the amount of monetary savings for the comparison of diesel to electric buses is measured from this section as are the GHG reductions.

SERC Electric Prices

The electric rate used for this model is from the EIA data, specifically for the SERC region, which includes North Carolina. Attempts to attain numbers specific to the Duke Energy service area (under which Duke University would fall under) were unsuccessful given time limitations. If the data does come available, whether projections or historical figures, the EIA numbers should be replaced with those to give the analysis a bit more accurate reflection of the

situation on a more micro level, tailored to the service area whose grid will be utilized to charge the electric buses. This will also match the approach taken with the Solar Charging FFM for the electric rate projections.

Additionally, the savings associated with the electric buses now here take into account the cost of electricity for fuel. These numbers then are the basis for the GHG emissions reductions associated with these different bus technologies that provide the investor with a sense of the improvement in this category. This is especially a salient topic for universities like Duke⁴⁰ who have committed to sustainability targets and GHG reductions as part of their climate action plans (CAPs).⁴¹ As of April 30, 2010, there are 684 universities that have signed the pledge.⁴² Such reductions can help universities attain their CAPs while providing cleaner air, noise reductions and other benefits while not sacrificing the quality of bus services.

SERC GHG Emissions Projections

In this section, the SERC Virginia/North Carolina electric grid emissions rate is used to calculate the emissions associated with charging the electric buses. As before, the GHGs emitted and reduced are calculated now only for diesel, diesel hybrid and electric buses and comparatively analyzed. Further, the three pricing scenarios are utilized as before but with the GHG savings resulting from the switch from diesel to diesel-hybrid buses and from diesel to electric buses. This information is then used in the NPV calculations as one of the two cash inflows, if the user selects a scenario.

⁴⁰ “Duke Climate Action Plan,” 2010.

⁴¹ “American College & University Presidents’ Climate Commitment,” 2010.

⁴² “Signatory List by Institution Name,” 2010.

Buses/Charging Equipment Costs

Since the market we are looking at is just the university section, the cost input for the model is simplified than for the Solar Charging FFM. It is the costs of the three types of buses and the additional charging infrastructure costs associated with the electric buses. The diesel bus costs are based on Gillig diesel buses, the diesel hybrid bus costs are based on Gillig Hybrid buses, the like one that were recently purchased by the city of Durham (DATA) for its routes and put into service this winter. The electric bus costs are based on the Proterra EcoDrive buses. The lowest to highest cost of the buses is in the same order as listed above. Diesel, and even diesel hybrids, have one advantage of being out on the road and with that their per unit cost has fallen relative over the years. The same is expected with electric buses when they are also adopted on a larger scale.

NPV/Output Calculations

This section is very much like in the previous model with only a few differences. This model does not have a revenue or excess solar benefit cash inflow stream because the stations are not charging other buses nor is there a solar component associated with this model. For example, there is a maintenance expense associated with the upkeep of the buses which now goes into the cost section of the NPV calculations.

Financial Feasibility Model (Output)

The basic layout of the mainframe of this model is akin to the first model, only simplified. The Cumulative NPV graph reflects these financials and shows that all NPVs are negative. This stems from the assumption that the full cost of the buses is on the shoulders of the university, who, unlike cities and governments, are not eligible for assistance funding like Clean Cities.⁴³ Bearing the full cost of the purchase appears to be a prohibitive barrier for universities in terms

⁴³ "Clean Cities," 2010.

of achieving positive NPV and return on investment. However, a comparative analysis of NPVs is needed. It can be seen that since the buses are an integral part of universities (i.e. there needs to be transportation in and around campus), there is a positive net benefit from switching to both diesel hybrid and electric buses when looked over the full service life of these vehicles. GHG reductions and savings, if there is pricing mechanism for this type of emission, are greater for the electric buses than for diesel hybrids because the former is using a more efficient fuel source.

RESULTS

The results from the two models are dynamic and depend on the input that the user chooses. Hence, an array of results can be calculated while tinkering with such variables as number of stations, days of charging, revenue collection, and type of bus looked at, among other. Some general results can be drawn from the models, however. Both types of investments can be profitable within a reasonable timeframe for the investor and other parameters. This indicates that the investor can pursue such environmentally-better and more socially responsible investments while not necessarily giving up their pursuits of a financial return. This in itself has value for the organization pursuing such ventures which can be central to their business and mission albeit not one that is easily quantifiable in dollar terms. This illustrates that there are pragmatic and results-driven approaches to solving environmental problems that at the same time expand stakeholder reach and involvement in order to facilitate the adoption of next-generation solutions today.

Results for FFM for Solar Charging Stations for PHEVs and EVs

For the Solar Charging FFM, it is observed that using worst-case scenario type of input (ex. no fleets, no revenue collection), and given a long enough time horizon like the upper bound of 25 years, such an investment with the assumptions made for the California PG&E area can very well be not only positive. It can also offer very good returns as compared to other types of investments. Given that the model strives to give a conservative output, the investor should feel comfortable with the results especially since they do not incorporate other intangible benefits such as potential increased through-traffic for businesses, ‘green’ branding, public relations and achievements in corporate sustainability goals.

As a sample case study, let's input into the Solar Charging FFM the parameters as shown in **Figure 11**. Looking at this investment for a business over the total life of the project for five, Level II chargers at a discount rate of 8% and the users being charged \$1 for the use of the charging station, we see that investment makes financial sense in Scenario 1 (**Figure 12**). The Cumulative NPV is \$2,933 (highlighted with a red oval), indicating that the project has recouped its costs and is profitable since it is above \$0, or the break-even mark. Again, the user must note that given the conservative nature of the model, this number is most likely an underestimation and the actual value added is greater. For example, the depreciation of the charging stations themselves is not calculated in the model, a factor that would make the investment more attractive, all else equal.

Input Questions:	Input Your Answers Below:
1) Who is the entity purchasing the system?	Businesses
2) What level charger will you be installing?	Level II
3) Will the station(s) primarily charge fleet vehicle(s)?	No
4) How many parking spots would you like the station to service?	5
5) How many days per year will vehicle(s) utilize the charging station(s)?	365
6) If imposing a fee for use of station, what will the fee per charge be?	\$1.00
7) What is the investment time frame?	2035
8) Which GHG pricing scenario?	NONE
9) Discount rate to be used?	8%
10) Expected rate of inflation?	1%

Figure 11: Solar Charging FFM – Business Case Study (Input)

Results:	Scenario 1	Scenario 2	Scenario 3
1) Internal Rate of Return (IRR %)	10.1%	5.0%	3.0%
2) Cumulative Net Present Value (NPV)	\$2,933	(\$7,328)	(\$14,971)
3) Total cost of the station for chosen amount of parking spots	(\$14,375)	(\$37,902)	(\$50,852)
4) Gas savings		\$93,010	
5) Grid cost savings (from excess solar sent to the grid)		\$30,846	
6) GHG emissions reduced annually (tons CO2)		189	
7) GHG cost savings		\$0	

Figure 12: Solar Charging FFM – Business Case Study (Results)

Results for FFM for Diesel-Hybrid and Electric Buses

For the University Bus FFM, the initial look at the financials is unfavorable. This is in large part due to the high cost of the buses (and infrastructure for electric buses) that is not subsidized by outside funding options like those available for public transportation agencies where, for instance, the federal government may pick up as much as 80% of the cost of buses, mitigating the purchase cost significantly. However, it is imperative not to just look at whether the financials are positive or negative but the difference between the various bus technologies to each other. Given that buses at the Duke University are an integral part of the campus and are considered part of the services that are provided to students, faculty and employees, a pure financial approach is not accurate.

The benefits of transportation people around the campus are obviously great or otherwise service would be cut or even eliminated. Thus, it is reasonable to state that some form of transportation is necessary. What this model should indicate to the user (like Duke) is that compared to the current diesel buses, the other option stack up financially against the current status quo use of diesel buses. In the output section we can see, in general, that both diesel-hybrid and electric buses have lower Cumulative NPV over their lives (ex. 12 years) than do the diesel buses especially the farther out the time horizon is chosen. This indicates that switching to these buses would be a great improvement over the current situation. This is the key element that needs to be extracted from the results and graphs, not just that they are negative. Positive NPV is generated when measured in relation to the status quo, as seen in the Cost-Benefit Analysis graph that does this comparative breakdown.

As a sample case study, let's input into the University Bus FFM the parameters as shown in **Figure 13**. Looking at this investment for Duke over the life of its entire fleet of 30 buses, 12

years of service life and a discount rate of 6%, we see that investment makes financial sense for both alternative technologies of diesel hybrid and electric buses (**Figure 14**). The financial benefit of switching from diesel to diesel hybrid buses would be \$2,273,311 and to electric buses it would be \$6,720,014 (highlighted with red ovals), indicating that the project would have recouped its costs and is profitable. Again, the user must note that given the conservative nature of the model, this number is most likely an underestimation and the actual value added is greater, as stated above in the Solar Charging FFM case study.

Input Questions:	Input Answers Below:
1) How many buses are you looking to purchase?	30
2) Up to what year would you like to see the financial calculations?	12
3) Discount rate to be used?	6%
4) Expected rate of inflation?	1%
5) Which GHG pricing scenario?	NONE

Figure 13: University Bus FFM – 30 Bus Case Study (Input)

Results:	<u>Diesel-Hybrid</u>	<u>Electric</u>	<u>Diesel</u>
1) Financial Savings from Switching from Diesel to...	\$2,273,311	\$6,720,014	-----
2) Cumulative Net Present Value (NPV)	(\$27,961,764)	(\$23,515,062)	(\$30,235,076)
3) Internal Rate of Return (IRR %)	IRR undefined	-22.2%	IRR undefined
4) Total cost of buses (and other capital, if applicable)	(\$16,200,000)	(\$27,303,000)	(\$9,900,000)
5) Gas savings	\$4,558,113	\$8,103,311	-----
6) GHG emissions reduced annually (tons CO2)	15213	16399	-----
7) GHG cost savings	\$0	\$0	-----

Figure 14: University Bus FFM – 30 Bus Case Study (Results)

CONCLUSION

This Master's Project analysis two different solutions to pressing issues relating to different investors and stakeholders in opposites part of the country. While the results are not directly comparable, basic lessons and conclusions can be drawn from the results. The differences also highlight the complexity behind these endeavors that reach into the policy, regulatory, financial and other realms, beyond just the environmental. Understanding each piece is key in facilitating solutions to current and future environmental problems while appreciating the role and perspectives brought into the fold by all the other pieces of the puzzle. For instance, solar charging stations are gaining interest as evidenced by growing media coverage of different types of these stations.⁴⁴

For the Solar Charging FFM, there a few points that help define what makes this investment a success or failure (from a purely conservative financial perspective). **First**, state and federal incentives for renewable energy and charging stations drive the financial viability of the investment. Due to the reduced costs for capital and installation, the investor is able to achieve at least a breakeven point at some point during the time horizon using the conservative metrics of the model even if he or she chooses inputs that are such that they allow only the minimal amount of cash flow streams for the model. **Second**, rising electric rates in California allow the excess solar generated to contribute a large part to the positive cash inflows making the investment achieve profitability quicker absent such increases. The same can be said of the rising gasoline prices that make it progressively costlier to operate vehicles that run on liquid fossil fuels. **Third**, the incorporation of accelerated depreciation of the solar panels also plays a

⁴⁴ Anupam, 2010.

very significant role in making the investment viable. **Fourth**, the method of financing the investment is also important as taking out a loan for part of the project can yield additional NPV benefits. **Fifth**, from a policy and regulatory perspective, California enjoys some of the strongest, if not the strongest, public and political support for alternative energies and environmental damage mitigation legislation. Since this is translated into policy on the local and state level, such support is instrumental in sparking interest and funding for such an emerging market that has the potential to yield many benefits, outside of just environmental or financial. The model appears to be the first (at least public) look at the viability of solar charging stations and will be available on FOE website.

For the University Bus FFM, it was expected that diesel hybrids were going to be the preferred alternative due to the fact that it is not a new technology that has been adopted across the country for many years now and whose cost is much more comparable to traditional diesel buses than to electric buses. The latter are only an emerging technology with the high cost its biggest drawback to adoption. Costs are expected to be reduced once more production occurs but this can become the classical chicken-or-the-egg game. However, it was not expected that all the financials for the technologies would be negative. Considering there are few cash flow streams for this model as opposed to the Solar Charging FFM, the potential for recoupment of the investment outright was not viable from the beginning, using traditional economic metrics. The seeming lack of policy incentives for the reduction of cost for entities like universities is a major reason for this result.

Positive or negative NPVs do not tell the whole story. What are important are not the absolute results of the model but the relative ones between the different bus technologies. Diesel hybrid buses do break even and generated value added for the investor, doing so before electric

buses accomplish the same result. Also, given a timeframe on the longer side of what the user can select, electric buses can be financially preferable to diesel hybrids.

Thus, we see that both diesel hybrid and electric buses make financial sense relative to the regular diesel buses that zip around campus today. Considering that the average life of the 30 main Duke buses is 12 years and retirement of many is imminent, if not passed due, this model provides a solid foundation for the decision makers at Duke to pursue either technology more in-depth as the transition to newer buses will take place in the next few years, regardless. It is a perfect opportunity to make a decision that makes sense environmentally and financially, both important realms which are important to Duke University as well as for image and branding purposes.

The results conform to some basic conclusions (diesels save fuel expenses) that have been reached in similar projects in cities, states and federal authorities. However, it was expected that since this will be perhaps the first analysis of the electrification of transportation specific to the university sector, some results will deviate due to the unique nature of institutions being observed and its different institutional structures, incentives and objectives, as should be the case. It was expected that the economic viability of such a campus-wide project will heavily depend on the cost projections of such variables as fossil fuels for transportation, local electricity, electrified vehicles (and thus batteries indirectly), carbon emissions, among others. If the incentives lean in the favor of such alternative transportation methods, the financial metrics and payback periods are expected to be at least palpable for decision-makers and at best very competitive with alternative forms of potential investments over the same time horizon.

These results are anticipated to give credence to the electrification of transportation that AE and Raleigh are working on, as well as other cities. Analyzing and reporting on the

incremental steps needed to be taken for success will alleviate a lot, if not most, of the work that would be needed to enact such a project vis-à-vis the community and groups leading the effort from the outside. This also appears to be the first publicly available model available for universities like Duke to make this decision for their transportation needs. For use with non-North Carolina universities, some of the assumptions would need to be redone. This mainly includes matching the appropriate fuel prices projections for petroleum and electricity generation along with any incentives that could bring down the cost of the buses with states with more generous support than North Carolina.

All in all, this Master's Project has shown that solutions to the pressing issues of the day are not necessarily tradeoffs between environmental improvements and economic opportunities that yield positive economic returns. Electrification of transportation is only one approach that will need to be utilized, further studied and improved in order to increase its potency and saliency as a solution. In many ways, we are lucky to live in a non-ideal world – one that has many inefficiencies and unexplored technological territories that can be used in order to improve our current global climate crisis that is already affecting local areas.

While many issues like toxicity and availability of rare earth metals in batteries and lifecycle emissions from the production of new vehicles are important and need to be addressed, this type of analysis clearly indicates that when the world is looked through a lens of forethought and the internalization of externalities, the way to address global climate change is nuanced and one that will reach into all aspects of our lives, perhaps like nothing before. The greatest problem is also the greatest opportunity. The path forward is the one that will go beyond the old thinking of past decades and even centuries while reinventing what it means to do business as usual in today's world in order to reach a sustainable tomorrow.

APPENDIX

Overview of Financial Concepts (Net Present Value, NPV & Internal Rate of Return, IRR)

In order to understand the Financial Feasibility Models, it is imperative to understand what is meant by the two main metrics that is used in this analysis – Net Present Value (NPV) and Internal Rate of Return (IRR). These are two of the more common and standard financial methodologies used in assessing whether an investment is worth pursuing. Comprehending these concepts will allow the user to understand the results in a proper way that will allow the investor (the university in this case but applicable to such entities like municipal transportation departments) make the decision whether this is an endeavor that is worth pursuing for them.

The first concept that must be understood is NPV. NPV is the net difference between the present value of future cash inflows (i.e. revenue) that a project will yield and the cash outflows (i.e. initial investment/capital). The cash inflows and outflows are discounted back to their present value. The discount rate is the rate of return one could earn on an investment with akin risk. It is a standard method of appraising mutually exclusive projects and can dictate how a firm's capital budgeting may be directed. If the net difference is positive, the investment/project is profitable and most likely should be pursued, all else equal. This is, of course, if another investment/project yields a higher return. If the net difference is negative, the investment/project is not profitable and should not be pursued, all else equal. We shall see in the results section that this is not as simple as it seems because, in the right situation, a project that gives you negative results may be a more optimal situation to be in and hence should be pursued. Refer to the results section for further detail.

The IRR is the discount rate at which NPV equals zero. Same metric of comparison is done as for NPV to judge whether a project may be accepted or should be rejected. In general, a positive IRR means that the project generates positive cash flows and a negative means that it generates negative cash flows.

In mathematical terms, the NPV can be illustrated as such:

$$\text{NPV} = \sum_{t=0}^n \frac{C_t}{(1+r)^t}$$

...and IRR:

$$\text{NPV} = \sum_{t=0}^N \frac{C_t}{(1+r)^t} = 0$$

The first figure means that NPV is just the summation, from time = 0 to the n number of periods chosen of future cash flows (C_t) discounted ($(1+r)^t$) back to back to its present value using the discount rate (r) to the time of the cash flow. The second figure says the same as the first only set to zero to indicate a breakeven point of NPV at what discount rate that occurs.

Assumptions for Financial Feasibility Model (Solar Charging Stations)

⇒ General Assumptions:

- No maintenance costs. Charging stations are expected to have a lifetime of 25 years although newer and better technology is expected to replace the current one.
- The model's output results are linear, meaning that purchasing 1 charging station and 10 charging stations does not take into account any bulk purchasing that would reduce the per unit cost for the investor. It is unlikely that such an arrangement would not be made, indicating that this aspect of the model is conservative, overestimating the capital cost as quantity input increases which would allow the user-investor to get a discount on the purchase, like a personal economies of scale.

⇒ Gas Price Projections:

- Gasoline price projections are taken from the EIA's Annual Energy Outlook 2010 (<http://www.eia.doe.gov/oiaf/aeo/>).
- For this model, forecasts that are used are for the Pacific Region (http://www.eia.doe.gov/oiaf/aeo/supplement/suptab_19.xls), under which California falls under.
- The EIA uses 2008 real and nominal dollars per mmBTU. This was converted into dollars per gallon by dividing the EIA numbers using the formula that 1 gallon = 125,000 BTU.
- The amount of vehicle miles traveled (VMT) was set at a stagnant level of 6,000 starting in 2011, the first year of operation of the investment, and going through the timeframe of the model (25 years) (<http://www.epa.gov/OMS/climate/420f05004.htm>). This is half the average amount of miles a typical American car travels in one year, as assumed by the EPA's Office of Transportation and Air Quality (OTAQ).
- This translated into about 16.5 VMT per day, also a stagnant number assumption.
- The miles per gallon (MPG) assumptions are based on the Obama Administration's new vehicle fuels standards (<http://www.nytimes.com/2009/05/19/business/19emissions.html>) and held constant starting in 2020 at the approximate level the EIA expects fuel efficiency to be in 2035. This over estimates the fuel efficiency improvements vis-à-vis the EIA up until that point, reducing more GHG emissions, giving the model a conservative tilt.
- From these assumptions the total cost of gasoline is calculated and used in the model to calculate the NPV.

⇒ Electric Price Projections:

- Electric price projections are taken from the Supplemental Tables (http://www.eia.doe.gov/oiaf/aeo/supplement/sup_elec.xls) of the Energy Information Agency's (EIA) Annual Energy Outlook 2010.
- Electric rate projections are calculated using Pacific Gas & Electric's (PG&E) historical data of the E-19 rate from 2001-2009, which would apply to governments and businesses. The average percentage increase between these periods forms the basis for the extrapolation from 2010 to 2035. EIA data was not used due to the availability of utility-specific numbers for a more tailored analysis
- An assumption that user cannot change, for the purposes of the model, it is assumed that there is only one charge per day per station of 4 kWhs (or about the equivalent of 16.5 miles driving per day).
- The translation of miles driven for the plug-in hybrid vehicles (PHEVs) and electric vehicles (EVs) to kWh is set at 4.11:1, based on technical specifications from correspondence with CalCars. It is also assumed that the bus is capable of recharging during the day to meet the expected range.
- 'Gas Savings' is the difference of the cost of fueling a pure internal combustion engine (ICE) vehicle and the cost to operate the PHEV/EV.
- The model assumes that one charging spot for one vehicle is serviced by a solar system of 1.85 kW. The daily PG&E solar hour radiance is set to 4 hours, an average number used by solar firms in the Bay Area as reported by Envision Solar and Solar City.
- 'Excess Solar' is the amount of solar power produced by the panels after the amount needed for the PHEV/EV is accounted for. This represents the solar power sold back to the grid at the equivalent rate that it was bought (like in net metering) or the forgone cost of buying that power for the owner's building or other entity.
 - If there was an above-market price given to the investor for the excess clean energy produced, as with a Feed-In-Tariff (FIT), then the investment would be more attractive with a higher amount to go into the NPV calculation.
- Revenue is also calculated in this section (if applicable) and put into the NPV calculation.

⇒ GHG Price Projections:

- Electric grid emissions rate is taken from PG&E's Carbon Footprint Calculator Assumptions that is used by its customers.
- Emissions of carbon dioxide (CO₂) from a gallon of diesel come from the EPA's Office of Transportation and Air Quality (OTAQ) (<http://www.epa.gov/oms/climate/420f05001.htm>).

- The greenhouse gas (GHG) reductions resulting from using a PHEV/EV instead of an ICE is the difference between the emissions for the ICE and the PHEV/EV.
 - There are three pricing scenarios (or none) the user can input to incorporate the savings from the reduction in emissions by switching to other types of buses. The first one is based on the type of pricing scheme in the Waxman-Markey bill passed in the House of Representatives in June, 2009. The second is what California might use for their regional cap-and-trade program for CO₂. The third is the social cost of carbon as estimate by Nicholas Stern in the Stern Review from 2006, a controversial report for the British government about the effects of global climate change on the economy.
- ⇒ Charging Station Infrastructure and Solar Costs:
- The cost estimates for the charging stations come from vendors like Coulomb via email correspondence with CEO Richard Lowenthal.
 - Federal incentives come from the DSIRE database.
 - The cost estimates for the solar panels, infrastructure and installation come from correspondence with Bay Area solar companies.
 - State incentives are the declining tiered per watt incentives of PG&E.
- ⇒ Taxes & Depreciation:
- Included in the model are some of the common and important considerations for the investor in terms of having the results be as realistic as possible within the constraints.
 - ‘Negative Tax Impact on Gas Savings’ – For ‘Business’ AND ‘Fleet’ only. Illustrated here is the fact that if the investor’s vehicles that use the stations now do not consume gasoline (because none is being used), then they lose the tax write-off for the fuel. Hence it is a loss for them and appropriately calculated and placed in the ‘Cost’ column of the ‘NPV|Output Calculations’ sheet in the model.
 - ‘Negative Tax Impact on Revenue’ – For ‘Businesses’ only. Since a business is a tax-paying entity, it is taxed on revenues it collects. Illustrated here is that if the user is charged a fee for charging their vehicle, the revenue collected is taxed at the appropriate federal and state rates which apply to the business.
 - ‘Negative Tax Impact on Electricity Savings’ – For ‘Businesses’ only. Since a business is a tax-paying entity, it is assumed for this model that the excess solar power that is produced and is sold back to the grid is treated as revenue and thus taxed. To encourage the adoption of technologies like solar, financing mechanisms like Property Assessed Clean Energy (PACE) or regulatory processes like net-metering for them, it can be expected that excess clean energy sold back to the grid would not be taxed. Given the conservative nature of the model, it is assumed that there is a tax on this variable.

⇒ Graph interpretation:

- The Present Value graph displays the time value of money for annual cash flows for the investment. Points below the x-axis (\$0) in Year 0 show the initial capital costs of purchasing the stations. For the Present Value W/Loan graph, this represents the initial down payment of the loan.
- The Cumulative NPV graph displays the accruing cash flows up until the user-selected year for the time horizon of the investment. At points below the x-axis (\$0) the project is not profitable and above it is profitable and represents the value-added that it brings. The year at which the scenario line intersects x-axis is when the project *breaks even*.

Assumptions for Financial Feasibility Model (Buses)

⇒ General Assumptions:

- The model's output results are linear, meaning that purchasing 1 bus and 10 buses does not take into account any bulk purchasing that would reduce the per unit cost for the investor. It is unlikely that such an arrangement would not be made, indicating that this aspect of the model is conservative, overestimating the capital cost as quantity input increases which would allow the user-investor to get a discount on the purchase, like a personal economies of scale.

⇒ Gas Price Projections:

- Gasoline price projections are taken from the EIA's Annual Energy Outlook 2010 (<http://www.eia.doe.gov/oiaf/aeo/>).

⇒ For this model, forecasts that are used are for the South Atlantic Region

(http://www.eia.doe.gov/oiaf/aeo/supplement/suptab_15.xls), under which North Carolina falls under.

- The EIA uses 2008 real and nominal dollars per mmBTU. This was converted into dollars per gallon by dividing the EIA numbers using the formula that 1 gallon = 125,000 BTU.
- The amount of vehicle miles traveled (VMT) was set at a stagnant level of 23,688 starting in 2011, the first year of operation of the investment, and going through the timeframe of the model (15 years). This is the average amount of miles a Duke bus travels in one year, as reported by the Duke University Parking & Transportation Services for 2008/2009 by email correspondence.
- 3.5 miles per gallon (MPG) was set as the stagnant level for Diesel bus(es) starting in 2011.
- The assumptions for the Diesel Hybrid bus(es) is(are) the same for VMT but assumes 8 MPG, as reported by the Durham Area Transit Authority (DATA) by email and letter correspondence.
- The 'Fuel Savings' used to calculate Net Present Value (NPV) for the Diesel Hybrid bus(es) is(are) the difference between the use of diesel fuel for Diesel and Diesel Hybrid bus(es).

⇒ Electric Price Projections:

- Electric price projections are taken from the Supplemental Tables (http://www.eia.doe.gov/oiaf/aeo/supplement/sup_elec.xls) of the EIA's Annual Energy Outlook 2010 for the SERC Region (http://www.eia.doe.gov/cneaf/electricity/chg_str_fuel/html/serc.html).
- The translation of miles driven for the bus(es) to kWh is set at 1:2.2, based on technical specifications from emails with the Electric bus manufacturer, Proterra.

It is also assumed that the bus is capable of recharging during the day to meet the expected range.

- The 'Fuel Savings' used to calculate Net Present Value (NPV) for the Electric buses is the difference between the use of diesel fuel for the Diesel bus(es) and electricity for the Electric Bus(es).

⇒ GHG Price Projections:

- Electric grid emissions rate is taken from the Environmental Protection Agency's (EPA) Emissions & Generation Resource Integrated Database (eGRID) for the SERC Virginia/Carolina region.
- Emissions of carbon dioxide (CO₂) from a gallon of diesel come from the EPA's Office of Transportation and Air Quality (OTAQ) (<http://www.epa.gov/oms/climate/420f05001.htm>).
- The greenhouse gas (GHG) reductions resulting from switching from Diesel bus(es) to Diesel Hybrid and/or Electric bus(es) is the difference between the emissions for the Diesel Bus(es) and the Diesel-Hybrid/Electric Bus(es).
- There are three pricing scenarios (or none) the user can input to incorporate the savings from the reduction in emissions by switching to other types of buses. The first one is based on the type of pricing scheme in the Waxman-Markey bill passed in the House of Representatives in June, 2009. The second is what California might use for their regional cap-and-trade program for CO₂. The third is the social cost of carbon as estimate by Nicholas Stern in the Stern Review from 2006, a controversial report for the British government about the effects of global climate change on the economy.

⇒ Infrastructure and Bus Costs:

- The cost estimates come from the manufacturers of the buses as obtained by phone correspondence and estimate numbers cited in the popular media. Maintenance is assumed to be the same as for the traditional diesels due to a lack of a timely response to this inquiry from the proper contacts.

⇒ Graph interpretation:

- The Present Value graph displays the time value of money for annual cash flows for the investment. Points below the x-axis (\$0) in Year 0 show the initial capital costs of purchasing the buses.
- The Cumulative NPV graph displays the accruing cash flows up until the user-selected year for the time horizon of the investment. At points below the x-axis (\$0) the project is not profitable and above it is profitable and represents the value-added that it brings. The year at which the scenario line intersects x-axis is when the project *breaks even*.

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Figures

Figure 1 – See: http://www.solargazette.net/news/2009/images/map_pv_national_lo-res.jpg

Figure 2 – See: http://www.coulombtech.com/subscribers/images/main_mcdonalds.jpg

Figure 3 – See: <http://solar-wind-power-energy.net/wp-content/uploads/2009/11/How-it-works.jpg>

Figure 4 – See: <http://homepower.com/basics/solar/>

Figure 5 – Refer to Solar Charging FFM in excel file.

Figure 6 – Refer to Solar Charging FFM in excel file.

Figure 7 – Refer to Solar Charging FFM in excel file.

Figure 8 – Refer to University Bus FFM in excel file.

Figure 9 – Refer to University Bus FFM in excel file.

Figure 10 – Refer to University Bus FFM in excel file.

Figure 11 – Refer to Solar Charging FFM in excel file.

Figure 12 – Refer to Solar Charging FFM in excel file.

Figure 13 – Refer to University Bus FFM in excel file.

Figure 14 – Refer to University Bus FFM in excel file.

Electric Avenue: Two Case Studies on the Economic Feasibility of the Electrification of
Transportation (Solar Charging Stations in CA & University Buses in NC)

by

Daniel Kolomeets-Darovsky

May 2010

The 2007 IPCC report solidified that global climate change is occurring due to the release of greenhouse gases by the anthropogenic activity of burning of fossil fuels. The effects reach beyond the realms of the environment and into health, public policy, national security and the economy. In the U.S., transportation is the largest energy user by end-use sector and I have chosen to focus on the electrification of transportation as one of the more promising approaches to the sector that addresses at the same time multiple facets of the environmental crisis. This is accomplished through the building of bottom-up, spreadsheet-based financial models because economic considerations are the main drivers of the adoption of these kinds of alternative solutions. Two types of solutions are considered: (1) solar charging stations for plug-in hybrid electric vehicles (PHEV) and electric vehicles (EV) in California, and (2) a comparative look at diesel hybrid vs. electric buses for Duke University.

The Financial Feasibility Model (FFM) for solar charging stations in California shows there are many combinations of user-selected inputs that yield profitable investment outcomes. This is applicable for all three scenarios with Scenario 1 achieving the break-even point quicker than Scenario 2 and, in turn, Scenario 3 due to the higher upfront costs of the latter scenarios. The option of financing the project with user-specified loan parameters can yield added Net Present Value (NPV) if the interest rate for borrowing is below the discount rate. The FFM for university buses in North Carolina indicates that switching from traditional diesel buses employed on university campuses such as Duke to alternatives like diesel hybrid or electric buses also makes financial sense. Over the life of the service of the vehicles, a comparative cost-benefit analysis indicates that both technologies come out ahead of diesels with diesel hybrids breaking-even first before electric buses due to the higher upfront cost of the latter.

While air quality, noise pollution, branding, public relations and other intangible assets have clear value, they are not included in both models due to the difficulty of assigning monetary values to such variables. The take away from the project is that both models use conservative parameters to underestimate the benefits for better financial decision-making for the stakeholders, that the results show that there are many avenues towards profitability and that these models are some of the first, if not the first, publicly-accessible of their kind.

Approved

Dr. Lincoln Pratson

Date

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