2009

Better Place Feasibility Study: First Draft

CEE 5910: Term Project

December 18th 2009

Pranav Balmoor

Harini Boorgu

Ryan Cummiskey

Josh Einhorn

Gurkan Gunay

Pawan Kodandapani

Jun Ki (Jay) Min

Aaron Nelson

Dan Song

Steven Timothy

Jun Tong

Jackson Wang

Table of Contents

List of Figures

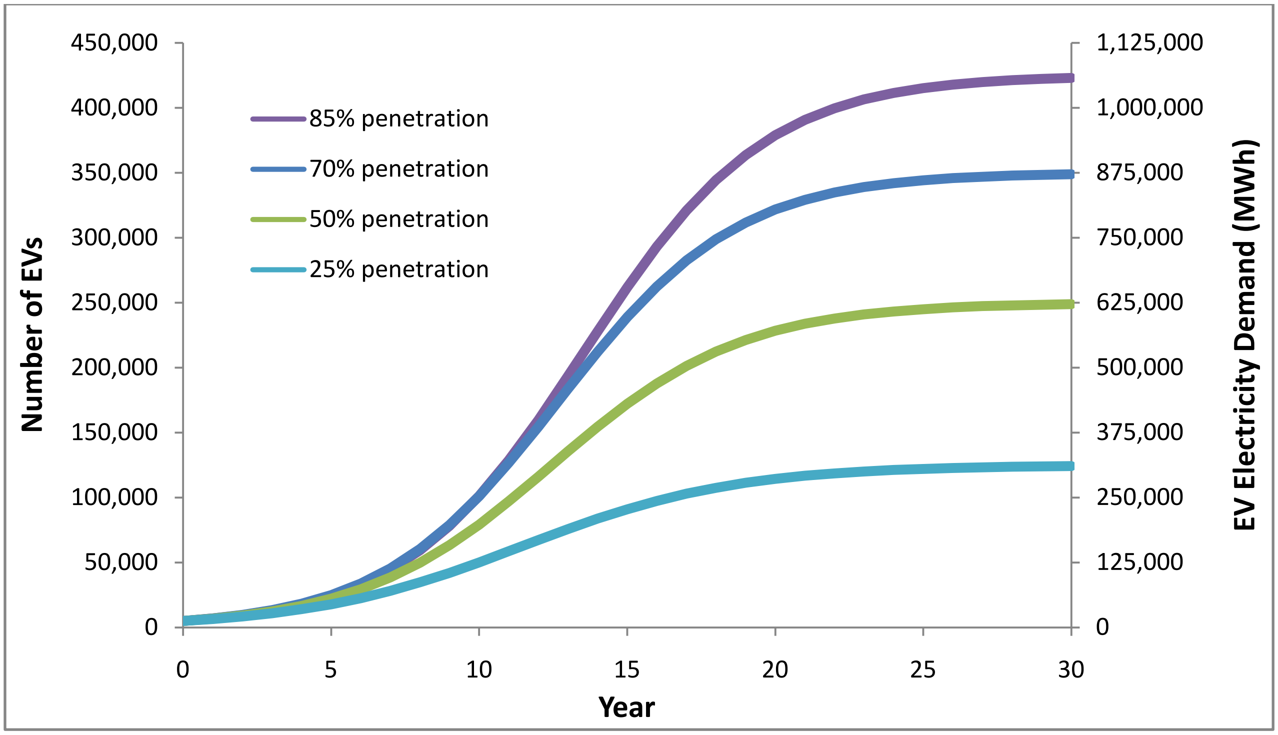
List of Tables

EXECUTIVE SUMMARY

This report summarizes the findings from a feasibility study conducted by twelve Master of Engineering Management students at Cornell University. As a group, we were asked to evaluate the proposed Better Place concept of supporting battery-powered electric vehicles (EVs) using a network of sustainable energy sources, charge points, and battery swapping stations. Better Place is a company that builds and operates infrastructure and systems to optimize energy access and use of electric vehicles. Better Place is currently deploying their business strategy in Israel and Denmark, and is looking to implement infrastructure in strategic locations around the world, including Hawaii. Hawaii is an ideal place to evaluate the Better Place concept due to its relatively high gasoline prices, almost complete reliance on oil as an energy source, and high renewable resource availability. Our goals were to understand the transportation and infrastructure requirements for the transition to EVs, to estimate the required renewable energy capacity needed to support the EVs, and to determine the economic viability of implementing Better Place's business model in Hawaii. Because 80 percent of Hawaii's population lives on the island of Oahu, we focused only on implementing Better Place in Oahu for the purpose of our study.

In order to assess the feasibility of Better Place in Oahu, we needed to estimate the demand for EVs, given that Better Place would provide the necessary infrastructure to support the transition. To do so, we created an implementation model using similar disruptive technologies, such as hybrid electric vehicles, as a benchmark to forecast the market penetration of EVs in Oahu over the next 30 years. This model is shown for multiple market penetration scenarios in Figure ES.1. In order for EVs to penetrate the market, the citizens of Oahu need an affordable EV option and infrastructure to support its use. To provide an affordable EV, Better Place has partnered with Renault-Nissan to provide thousands of battery-powered EVs at an initial cost of $15,000. To support the implementation of EVs, charging stations, where EVs can be completely charged in 4-8 hours, and swapping stations, where a depleted battery can be exchanged for a new one in minutes, must be built. To this end, Better Place has secured partnerships with electronics company Flextronics to supply thousands of charging stations. Further, Better Place will build swapping stations at strategic locations across Oahu, and the Hawaiian government has agreed to offer tax-breaks to help fund Better Place's required infrastructure. Through our research, we determined that these partnerships will allow Better Place to provide the necessary infrastructure to meet demand in Oahu.

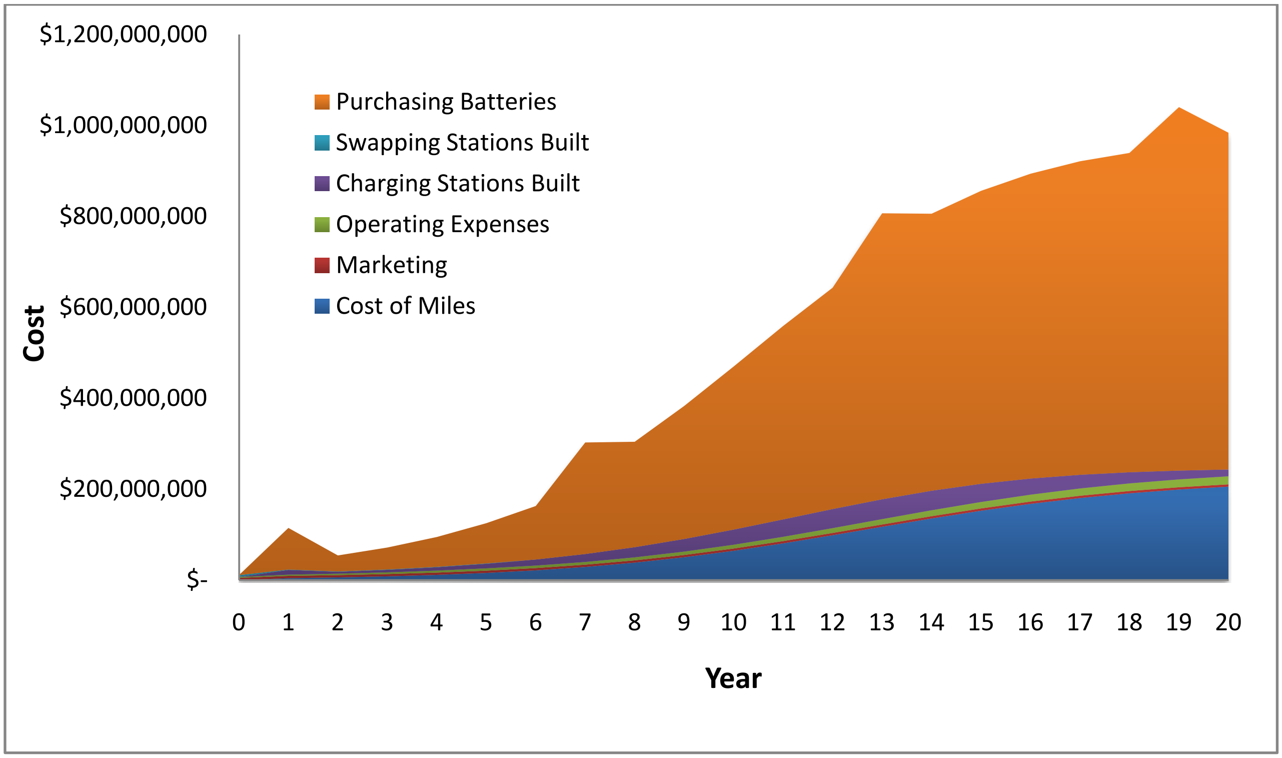
Figure ES.1: Number of EVs and Energy Usage at Different Market Penetration Rates



To decrease Hawaii’s dependence on fossil fuels and to minimize carbon emissions, Better Place has pledged to power its EV infrastructure using only renewable energy. This commitment is supported by the Hawaii-DOE Clean Energy Initiative, which calls for 40 percent of the energy produced in Hawaii to be renewable by 2030. This initiative is crucial because the Hawaiian government will bear the cost burden of renewable energy plants, rather than Better Place. Currently, however, there are no renewable energy plants in Oahu and limited space and local resistance restricts the maximum renewable energy available on the island. Further, Oahu’s electricity transmission lines are isolated from the other Hawaiian islands, although a project to connect the transmission lines of the islands of Oahu, Molokai, and Lanai with undersea cables is projected to be completed by 2030. Using information about vehicle miles traveled and the energy required to charge a battery, we calculated the energy demand required to support Better Place, as shown in Figure ES.1. While many sources of renewable energy are available in Hawaii, our research showed that only wind and solar energy were feasible. Using wind speed and solar radiation data, we modeled the energy supply and determined that the electricity demand of Better Place would exceed the supply in Oahu after the year 2023 for maximum market penetration rates above 30 percent. However, upon completion of the undersea power cables in year 2030, wind and solar energy available on Molokai and Lanai would be able to contribute to meet the demand in Oahu. Even though Better Place cannot potentially fulfill its commitment to using only renewable energy between the years 2023 - 2030, implementing Better Place's model will result in significant carbon dioxide emission abatement each year.

The economic feasibility of Better Place is dependent on the company's ability to be profitable. Akin to a cell phone plan, Better Place will provide the EV at a discounted price and generate the majority of its revenue by charging users a monthly fee based on the number of miles driven. Thus, in order to be successful in Hawaii, Better Place must offer monthly plans that are competitive to the alternative cost of driving gasoline-fueled vehicles. By estimating Better Place's revenues and costs, we constructed a financial model and determined that the breakeven monthly plan will cost the user $231. This monthly plan covers Better Place's expenses, and as shown in Figure ES.2, these expenses are largely driven by the cost of the battery. When car lease payments are factored in, the minimum monthly cost Better Place customers would pay is $416. To compare, the average monthly cost of owning and operating a similar gasoline-powered vehicle is $325, assuming a gasoline price of $3.45 per gallon. As such, except for niche users who are willing to pay a premium for an EV, Better Place is not cost competitive given the current cost of batteries, and thus the business model is not financially feasible.

Figure ES.2: Cost Breakdown of Better Place Expenses



In its current form, Better Place is capable of meeting the infrastructure requirements to support EVs. However, due to limited renewable energy resources in Oahu, Better Place is not able to fulfill its renewable energy commitment above a 30 percent maximum market penetration rate, nor is it cost-competitive to support adoption beyond niche consumers. Better Place will remain financially infeasible until gasoline prices increase, battery costs decrease, or a combination of the two occur to make the breakeven cost of owning and operating an EV equivalent to the cost of owning a gasoline-powered vehicle. Current trends indicate that gasoline prices will continue to increase in the future and battery technology and recyclability is expected to improve, thereby reducing battery costs. Therefore, we are optimistic that the Better Place business model can become feasible in the future if these conditions are met.

SECTION – I: INTRODUCTION

With increasing awareness of global warming and numerous countries' attempts to gain independence from oil, electric vehicles (EVs) have recently received attention. There is little doubt that this emerging technology will have a significant impact on daily life and the automotive and energy industries. However, several factors need to be considered to successfully implement EVs and ultimately replace internal combustion engine vehicles. These factors, which will determine the speed and depth of penetration for EVs in the automotive market include: network infrastructure, battery technology, charging capacity, availability of renewable resources, consumer acceptance, economic viability, and government support.

Better Place is an initiative to free nations of their addiction to oil and implement an EV transportation infrastructure. The company currently has alliances with nations such as Israel, Denmark, and Australia, and has partially completed its first infrastructure in Israel. Better Place's business strategy follows that of the cell phone industry by selling EVs, equivalent of selling cellular phones, and charging customers for mileage, equivalent of charging for talk hours. In order to realize this plan, Better Place will need to create an infrastructure of charging stations and swapping stations that can effectively support hundreds of thousands of vehicles.

The main focus of this project is to conduct a feasibility study of implementing Better Place's EV network in Hawaii. The project involves three main components: infrastructure, energy, and business viability. The infrastructure section analyzes the current automotive technology and battery technology to assess if EVs can be mass produced at a price competitive with traditional gas powered vehicles. In addition, this section discusses how charging stations and swapping stations operate, and how they should be installed and operated in Hawaii. The energy section discusses which and how renewable energy sources can be utilized to power the EVs and the outlook on implementation stages for these resources in the coming years. Finally the business section discusses the economic viability of Better Place's plan in Hawaii at its current level and the steps Better Place should take in order to stay competitive.

SECTION – II: INFRASTRUCTURE

2.1. Electric Vehicles

In order to reduce the carbon emissions of vehicles in Hawaii, the emergence and penetration of EVs on the islands is required. For this to happen, a vehicle must be chosen whose costs are relatively cheap, but can still run like any everyday vehicle. There are many models of EVs that Better Place can consider using via some form of partnership. These include the Tesla Roadster, the Nissan Leaf, and the Renault Fluence Z.E. Of all the battery-run EVs, the most exciting may be the Roadster, which is both aesthetically pleasing and exhibits strong performance qualities. It has a range of 244 miles and can go up to 125 mph. It also comes with plug-in charging capabilities that allow for the use of conventional outlets. However, the main issue with this vehicle is the cost; the current Roadster costs over $100,000 and includes a 53 kWh battery which costs about $30,000 (Tesla Roadster). Given Better Place's plan of leasing these batteries, the price of batteries for these cars would be too steep. In the future, Better Place may be able to include Tesla vehicles in their lineup when their business is established and flourishing, but as of now, the Roadster's price makes it implausible as the leadoff car.

Nissan and Renault have an established alliance for the production of EVs, and both companies have similar EVs in production. Better Place also has a partnership with this alliance for help in beginning the penetration of EVs into mainstream transportation. For the Nissan and Renault vehicles, both have slightly worse performance statistics than the Tesla. Both vehicles have a 100 mile range. The Leaf has a max speed of 90 mph, whereas the Renault's is 75 mph. They also both have similar plug-in charging capabilities to the Roadster. However, unlike the Roadster, both these vehicles are expected to have costs more comparable to that of regular sedans (Nissan Leaf), (Renault Fluence Z.E.). The Nissan Leaf has been guaranteed to have prices ranging from $28,000 to $35,000 while the Renault Fluence Z.E. is estimated to be around $15,000 without the battery. The price of the 20 kWh battery also not been released, but Better Place has estimated it to be around $12,000 (Garthwaite, 2009). This battery is used in both the Leaf and the Fluence Z.E. The specs for all three cars are shown in the Table 2.1 for easy comparison.

	Tesla Roadster	Nissan Leaf	Renault Fluence Z.E.
Cost w/o battery ($)	**$70,000**	**~$17,000**	**$15,000**
Cost of Battery ($)	**$30,000**	**~$12,000**	**~12,000**
Range (miles)	244	100	100
Maximum speed (mph)	125	90	75
Weight (lbs)	2723	-	3527

Table 2.1: Spec comparisons for three EVs

The major difference between the two viable vehicles is the swapping capabilities that the Fluence Z.E. possesses. The Fluence Z.E. allows the battery, located underneath the car, to be easily switched out for another battery. This capability is essential for Better Place to succeed as they have publicly promised to build swapping stations. Unless Nissan implements the same capabilities into the Leaf, the Fluence Z.E. will remain as the optimal choice for Better Place.

2.2. Battery Technology

From all the information given concerning the Fluence Z.E., it seems to be perfect for this project. However, the one factor that has been the main problem for any company promoting EVs is the battery technology, both in terms of cost and battery life. The current battery technology that is in use for EVs is the lithium-ion battery. This form of battery is still in need of improvement, but is the most ideal battery type for EVs due to its advantages over the lead-acid battery and nickel-cadmium battery. Compared to those batteries, the Li-ion battery has much better energy density, which allows for greater capacity for electrical energy due to the light weight of lithium and thus, better range (Anderson, 2009). In fact, it would require eight times as much weight for a lead acid battery to have the same energy capacity as a Li-ion battery, and would require three times as much weight for a nickel-cadmium battery (Battery Space). It also allows for higher open circuit voltage, which is the difference in voltage between the anode and cathode. With a higher open circuit voltage, fewer cells would need to be connected to achieve the same voltage, which would decrease the overall weight of the car battery. In terms of the battery aging, the Li-ion battery has a huge advantage in its low self-discharge rate, which allows for longer idle storage of the battery, and no memory effect, which is a battery phenomenon in which continuous partial discharge of a battery leads to a permanent reduction of the battery's maximum capacity. Both properties decrease the reduction of capacity per charge, increasing the number of cycles that the battery can go through before it needs to be replaced (Dilip Warrier, 2009).

The one drawback of Li-ion batteries is the safety issue. Due to the instability and volatility of lithium, there are many possible problems that can occur that can lead to explosions. The main issue that could occur is thermal runaway, which is an increase of energy leading to further increasing of temperature. This causes the cathode to oxidize due to a loss of stability. Oxygen mixed with extreme heat would then cause diffusion. This is often caused by a short, which would lead to a high voltage between the anode and cathode and thus, cause a large current to pass between the electrodes. The huge current would lead to high heat. At this point, however, there have been many precautions that have been put into place that would prevent such disasters, such as polymer separators that would close up the pores that allow for the lithium ions to propagate through and protection circuits. Separators are thin plates placed between battery cells and the closing for pores would isolate the bad cell, preventing the problem that it's facing from being passed onto other cells. The protection circuits are devices included in the cells to limit peak and minimum voltage, which would help prevent overheating (Dilip Warrier, 2009). Overall, the Li-ion battery is the only one in production which has the capabilities to provide enough electricity to allow for adequate range for a consumer EV.

As we had shown in Table 2.1, the cost of the Li-ion battery is around $12,000, which is considerably high when considering the aging of the battery and how often Better Place would have to purchase replacement batteries. A battery needs to be replaced when its capacity has been reduced to 80% of what it had begun with. This occurs due to many mechanisms including reactions of the active materials with the electrolyte, the aging on non-active components, and most importantly, the self degradation of active materials structure on each cycle due to the formation of dislocations. These batteries tend to last about 1500 cycles (Guy Sarre, 2004). Potentially, since the range of these batteries is approximately 100 miles, a battery can last up to 150,000 miles. However, we can expect the consumer to recharge the battery almost every day to ensure a fully fueled car each trip. This leads us to estimate the 1500 cycles to be reached in about 5-6 years. Since Better Place's plan is to buy the batteries themselves and then lease them to their customers, they will potentially have to repurchase their entire supply of batteries every 6 years. With every car needing one battery pack and every battery pack costing $12,000, it is imperative that the price of these battery packs is reduced for the project to be financially feasible.

To better understand how cost reductions can occur, we must first look at the breakdown of costs for these batteries. For Li-ion batteries, materials costs make up 75% of the total costs of the batteries, with the other 20% being manufacturing costs. The breakdown of the costs of the battery is shown in Figure 2.1 (Linda Gaines, 2000).

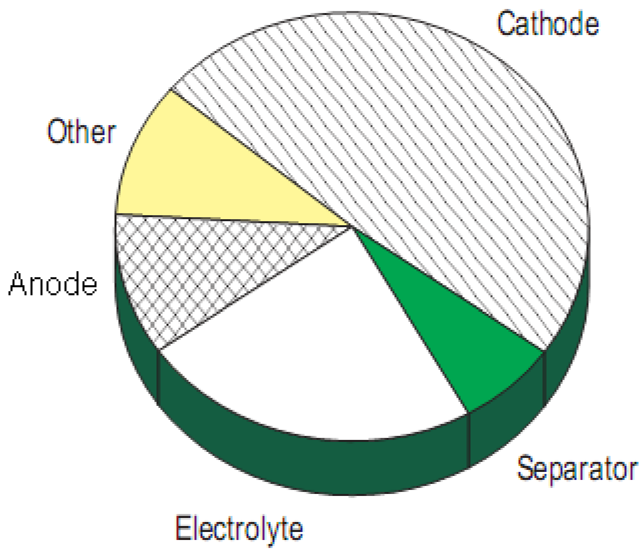


Figure 2.1: High-Energy Cell Material Costs (Gaines, 2000)

As we can see, the cathode and the electrolyte make up the majority of the cost of the battery. The cathode includes the lithium and the metal oxide that make up the cathode end of the battery. For current lithium-ion batteries, this metal oxide is cobalt oxide. The makeup of the cathode is then $LiCoO_2$, with 10% of the weight being lithium and 90% being cobalt. The battery that would be used in our EVs would be estimated to weigh 440 lbs (Vandervelde, 2009); this would mean that about 21.12 lbs of lithium and 190.08 lbs of cobalt would be used to manufacture the battery pack. It is the cobalt portion of the battery that raises the price significantly. In our current market, the price of cobalt is $21.70/lb (Global InfoMine, 2009). With 190.08 lbs of cobalt per battery, this would mean that it would cost $4127.74 for cobalt per battery. To complete the picture of the cathode, we also look at the price of the lithium and the oxide. The actual compound which is reacted with cobalt to form $LiCoO_2$ is lithium carbonate, which is currently $2.60/lb. This would lead to a cost of $54.91 for lithium per battery. The cathode would cost about $4180 per battery. Given our estimates of the expected price of the battery, the percentage of the cost that is accounted by materials, and the percentage of total materials cost that is accounted by the cathode, we see that our estimated price for the cathode is around $4320. The difference in costs is due to the fluctuating market of the materials. As we can see in Figure 2.2 (Stundza, 2009), the past few years have shown a huge decrease in materials cost in general, with cobalt prices decreasing by over 50.

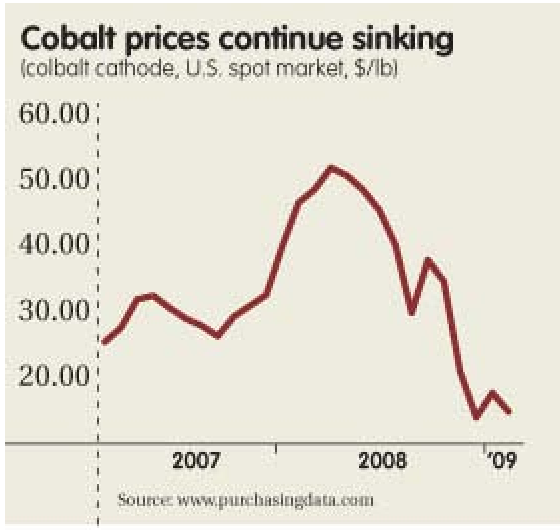


Figure 2.2: Cobalt Prices 2007 – 2009 (Stundza, 2009)

It is not just the prices of cobalt that is dropping; nickel and copper have also shown similar dramatic price decreases. These decreases have all occurred due to the current economy, which has caused businesses that generally use large supplies of these materials, such as aerospace and power generator companies, to decrease their production. It is expected that when Better Place is in need of a mass production of batteries, the price of materials would increase back to the average price of around $25.00, leading to a total battery price closer to $12,000.

Other than the cathode, the other big chunk of the materials costs shown in the pie chart is the electrolyte. This material is necessary as a bridge for the lithium ions to travel through between the two electrodes. The material that has been in use for this part has been lithium salts. There are many different salts that can be used, but the most common form is that of lithium hexafluorophosphate($LiPF_6$). Per pound, the lithium salts are the most expensive material used, at about $55/lb, due to the cost of fluoride. However, they are often mixed in some form of carbonate solution. For every mixture, about 84.3% of the mixture is the solvent. For each battery cell, 23.4% of the total materials cost is the electrolyte, which makes up about 18% of the total weight. The total cost from this portion of the battery would be around $2246.40 (Linda Gaines, 2000). Though it appears that research should also be conducted on electrolytes in order to also help reduce costs, studies on this topic has been stalled for the past decade. Although many experiments have been conducted, progress has not been made. An experiment in 1998 mentioned the discovery of new possibilities for electrolytes with the use of polymers, which is cheaper than the use of lithium salts. Polymers were theorized to be good replacements the lithium salts due to their ionic conductivity properties and their mechanical properties, which would allow for thermal-based reactions (Meyer, 1998). Since that discovery, much research have been run in trying to perfect them, but even after ten years, progress has not been made. Recent developments have led to breakthroughs for use of polymer electrolytes in small Li-ion batteries, but research for those that can be used in an EV is still in the planning stages (Patel, 2009), (Robert Kerr, 2009). The main issue in scaling up is the charging capability. For the current lithium-polymer batteries, charging is limited to 4.235 volts, much lower than the 120 volts that can be used for current lithium-ion EV batteries. Charging a 24 kWh lithium-polymer battery would take too long for it to be feasible (Moore, 2008). However, Hyundai, partnering with LG Chem, have promised to present a vehicle in 2011, the Sonata, using a hybrid lithium-polymer battery. The technology used is undisclosed at this time, but the possible success of this battery could lead to cost reductions in the electrolyte (Cunningham, 2008).

For the other materials, their costs are minimal compared to the cathode and electrolyte. The anode is made up of graphite, which is a very common and plentiful material, and the separator is made up of polyolefins which only makes up about 2% of the materials in weight and only 6.9% of the cost. In order to reduce the price of the batteries as a whole, Better Place must hope for a reduction in the cost of the materials of the cathode.

2.3. Cathode Materials Research

For the metal oxide of the cathode, there are a few materials that are being looked at with the potential to be put into use in the near future. One opportunity is the use of nickel or manganese oxides. Since lithium can react with both these elements to form similar structures as with cobalt ($LiNiO_2$, $LiMn_2O_4$), researchers have attempted to find ways to use them as the metal oxide. The main reason for these experiments is the price reductions. Table 2.2 shows the price of the two metals compared to cobalt.

Metal	Price ($/lb)
Cobalt	21.70
Nickel	8.07
Manganese	2.75

Table 2.2: Price of Cobalt, Nickel, and Manganese (CommodityMine, 2009)

As we can see, the price of nickel and manganese is much lower than cobalt. The price of the cathode can be cut down by more than half its current price if the material could be directly replaced, leaving us with batteries that are at a much more ideal price. However, both metals have their own issues. For nickel, it is very unstable in $LiNiO_2$ form and can lead to explosions due to any sudden thermal increases. Nickel atoms also tend to occupy sites in the lithium plane of the cathode, which would impede the movement of the lithium ions. Manganese does not have as much capacity as cobalt, and thus much more of the metal would be required, which would increase the size and weight of the battery. It also goes through phases changes due to temperature change (Fergus, 2009).

Due to the problems with using these alternative metal oxides, researchers have attempted to come up with different chemistries which mix these metal oxides with each other or with other elements, to come up with a more stable cathode that still possesses good electrical capacity. An example of these is the nickel-cobalt-manganese structure (Li[Ni,Mn,Co]O_2). By mixing all three of our mentioned metal oxides together, we can end up with a composition that has higher capacity, good discharge/charge rate, and can operate at high voltage. This composition tends to consist mostly of nickel. The addition of cobalt would reduce the amount of nickel in the lithium layer and the addition of small amounts of cobalt can help improve capacity and decrease loss of capacity over cycling (Fergus, 2009). This composition has great promise, as much research has been conducted on this matter and the potential of its use has been identified. Through development phases and further improvements on the effects of the use of this composition over time, we may eventually reach a point where such batteries would be mass produced in the market.

Another promising new composition that incorporates completely different metals is the use of iron nanophosphates as the metal oxide, which is being developed by A123, the top lithium-ion battery producer in the US. In general, the use of iron is not recommended due to its poor conduction and its weight. The poor conduction would lead to lower voltage, which therefore would require the interconnection of more cells to achieve the same capacity. However, the incorporation of nanophosphates allows for an increase in voltage due to the small structure of the nanophosphates. This would increase the active surface area of the electrode, which would allow more ions to travel through. This structure has many advantages. Since the primary component of the structure is iron, the cost is inexpensive, as we know that iron is still plentiful. Since the bonds between the iron, the phosphate, and the oxygen are much stronger than between cobalt and oxygen, the oxygen is harder to detach and thus, when the system fails, oxidation would not occur and thermal runway would not happen (Dilip Warrier, 2009). The reason this happens is the stability of iron. When in this composition, iron goes from +2 to +3 charge, which are both stable. The aging of these batteries are also improved. As we mentioned before, one of the reasons that a battery ages is the formation of dislocations over each charging cycle. The reason these dislocations form is due to the slow transformation of the electrode when the lithium ions reach either side. Slow transformation generally leads to lattice misfit, as the transformation is not ordered and thus, the lattice sites are not aligned. This leads to dislocations that are removed via diffusion, since dislocations tend to diffuse either to the interface or to grain boundaries. Each diffusion cycle would lead to an accumulation of dislocation damage across the structure as the diffusion of the dislocation causes damage across the structure and eventually, there would be fracture. Since iron nanophosphates are smaller than conventional metal oxides due to the nanostructure, there is smaller misfit and thus less mechanical damage per cycle (Riley, From Nanotech to Reality, 2009). This would increase the battery life dramatically, though exact numbers have not been specified yet. Similar to the nickel-manganese-cobalt structure, this composition appears to be approaching development and production and could be in the market by the time Better Place is in need of replacing their first generation car batteries.

2.4. Recycling Capabilities

Besides the improvement on cathode materials, another possible development that can lead to a reduction of cost for Better Place is the incorporation of recycling plants that would potentially be able to salvage all or part of the solids of the battery and thus, remove those costs from future batteries. This would greatly reduce the cost of batteries, since the cathode materials would be recovered. As we showed earlier, for each battery, the cathode costs around $4200 per battery. The inclusion of recycling in this project would lead to a reduction of $4200 minus operational costs in price per future battery, which would again lead to a much more ideal and feasible price for Better Place. Though as of this time, there are no recycling plants that have the ability to recycle large lithium-ion car batteries, there are many signs that it is almost certain that these plants would be up and running efficiently by the time Better Place batteries would need recycling.

Though large lithium-ion batteries are not being recycled yet, there are many plants recycling small lithium-ion batteries whose processes can be scaled up and be effective for large lithium ions as well. Research shows that 97% of the lithium and 99% of the cobalt on average can be recovered from the smaller batteries and reused for others (Jinhui Li, 2009), (Jessica Frontino Paulino, 2007), (Jiangang Li, 2008). Furthermore, research is being conducted on processes that may lead to the recovery of the electrolyte as well (Jessica Frontino Paulino, 2007). It has also been noted that recycling of batteries furthers Better Place's environmentalist view, as research has shown that there is a 51.3% reduction in use of natural resource use by producing a battery using recycled materials. These savings are based off of decreased mineral dependency, reduced fossil resource use, and reduced nuclear energy demand. The latter two are needed in refining the ores from mines into the metal oxides needed (Jo Dewulf, 2009). While the recovery of the cathode is already established, with research only in finding more efficient methods leading to the possibility of recovering 100 % of the solids, the research on electrolyte recovery is still in the early stages, but show promise. There are still questions on whether it is truly possible to scale up, since it has not been done before, but steps have been taken in developing recycling plants for this purpose. Also, confirmation on its plausibility has been confirmed by both the CTO of A123, Bart Riley, and Professor Michael Thompson of the Materials Science Department at Cornell University. Both members stated that given the processes that are used to recycle smaller batteries now, there is no reason at all that one cannot scale up (Riley, CTO, 2009), (Thompson, 2009).

In Table 2.3, we see the main companies that are looking to develop recycling facilities for large Li-ion batteries.

Company	Development Progress
Argonne National Lab (Gaines, 2009)	Begin development in 2011
Toxco (Coy, 2009)	DOE provide $9.5 million to expand plant starting in 2009
Nissan-Sumitomo (Nissan, 2009)	Complete plant by late 2010

Table 2.3: Schedule of companies looking to construct large-scale Li-ion recycling plants

Of the companies shown in the table, the most important for Better Place's purposes is the Nissan-Sumitomo alliance, due to the partnership in place between Better Place and Nissan. Once the new recycling plant is established, Better Place may be able to build upon their partnership by either setting up a deal for Nissan to recycle their batteries for free or for Nissan to purchase Better Place's used batteries, which would also help refinance future batteries. Assuming no partnership, Better Place can still save a lot from recycling even with the operational costs. As of 2000, for smaller lithium-ion batteries, the cost to recycle a battery was $2.25/lb (Linda Gaines, 2000). Assuming the price for large-scale recycling starts at that price, for the 440 lb battery, Better Place can still end up salvaging $3190 per battery to spend on future purchases.

Lastly, other than research and recycling, the increasing demand for EVs would lead to a similar in demand for Li-ion batteries, leading to mass production of these batteries and thus, reduction in manufacturing costs. An increase in production volume generally leads to a more optimized manufacturing process and a better manufacturing yield. Figure 2.3 shows an estimate on the effects on price that increased demand would have.

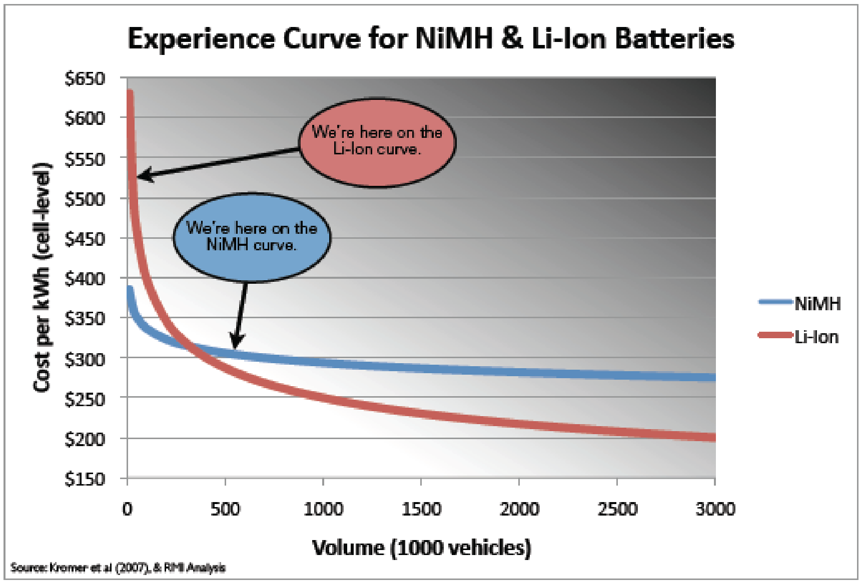


Figure 2.3: Cost vs. Volume for Batteries (Anderson, 2008)

The increase in yield would lead to lower manufacturing costs per battery and thus should also help reduce the cost for each battery in general (Anderson, An Evaluation of Current and Future Costs for Lithium-Ion Batteries for Use in Electrified Vehicle Powertrains, 2009). Though manufacturing costs for batteries are rarely revealed by companies for competitive reasons, we have mentioned before that they account for about 20% of the total battery cost. This may not be as significant as the cathode price, but would still help achieve the eventual goal of a much reduced battery pack cost.

As mentioned before, in 2000, the price of the batteries were $706/kWh, with optimistic views that the price will be cut in half over the next few years (Linda Gaines, 2000). However, as of 2009, the prices have stayed stable. Figure 2.4 shows the average reported prices of Li-ion batteries from 2007 to 2009. NiMH batteries are included as a comparison. The graph shows that the prices for Li-ion batteries have stayed relatively constant the past few years, while also staying above the cost of NiMH batteries. We see that the prices for the batteries each year vary from different sources. These fluctuating prices vary depending on the materials cost at the time the prices were presented, as well as on the different demands for and supplies of their batteries. As we see, the lack of research breakthrough and lack of demand, which we expect to rise as EVs gain popularity, has led to a stall in the decrease in lithium-ion battery price.

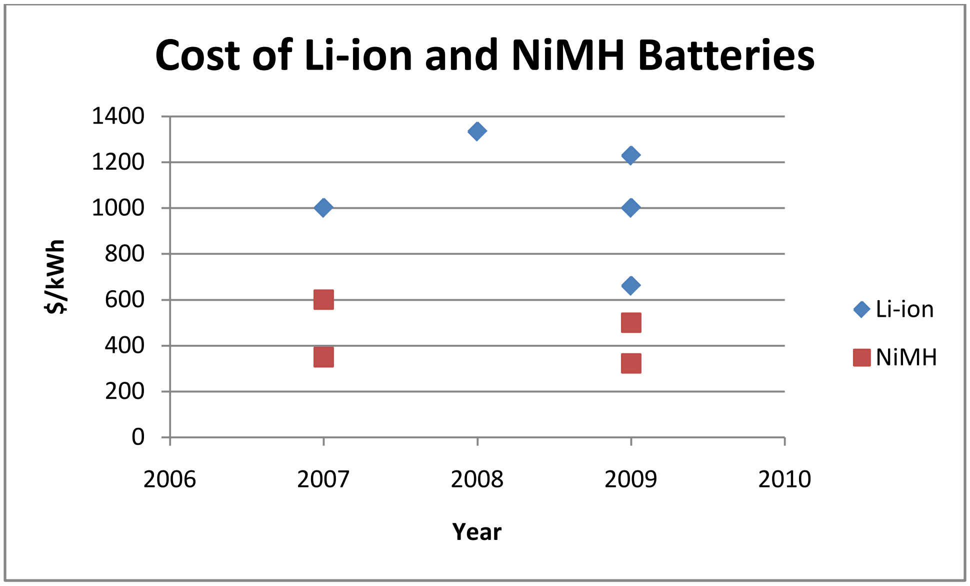


Figure 2.4: Cost of Li-ion and NiMH Batteries over time (Gaines, Cost of Lithium-Ion Batteries for Vehicles, 2000), (Indy Power Systems, 2007), (Ton, 2009), (Peterson, 2009), (Anderman, 2000), (Destries, 2007) (Congress, 2006), (PowerStream, 2009)

Overall, the outlook for Better Place is bright for the future in terms of the car and battery infrastructure. Though our current technology is inadequate due to the costs of batteries, we have shown that research has been taking place that could lead to the development of cheaper and more efficient batteries. There is also hope that once demands for these batteries increase, the price would be reduced due to better manufacturing processes from a greater economy of scale. Lastly, there are efforts taking place supported by the government for the development of large-scale lithium-ion battery recycling plants, which can help Better Place recover cathode materials and further reduce the costs. In the near future, battery prices can potentially be cut in half, leading to much more feasible prices that would help Better Place survive and profit from their project.

2.5. Charging Stations

Charging stations will be supplied by Flextronics, an electronics manufacturer founded in Silicon Valley, CA and now based in Singapore. Flextronics manufactures electronic systems in 30 countries worldwide for the automotive, computing, consumer, industrial, infrastructure, medical and mobile markets. According to Better Place, it was chosen because of its "global scale and expertise across the industries that Better Place intersects, namely automotive, infrastructure and consumer devices." (Better Place, 2009)

There are two competitors to the Better Place charging infrastructure that we have researched. ETec has a high power fast charge system called the Minit Charger that can charge

EVs in 15 minutes (ETec). The other competitor is Coulomb Technologies that makes two charge points, an 8 hour and a 4 hour (Coulomb Technologies).

eTec (An ecotality Company)

- Level 1 8 Hour, 120 V
- Level 2 4 Hour, 240 V
- Minit Charge 15 min
- Proven in Industry (Forklifts)
- Future plans for expansion

Coulomb Technologies (Fueling the Electric Transportation Industry)

- CT1000: 8 Hour, 120 V
- CT2000: 4 Hour, 240 V
- Affiliate in HI: Hawaii Electric Vehicles (HIEV)
- Proven in SF Bay area
- Networked and tracks usage
- Currently ramping up

Table 2.4: Charging Station Manufacturers

Unlike the other companies considered, Coulomb Technologies publishes its specifications. Therefore, we used cost and electricity data from Coulomb to model our implementation by Flextronics. We will build charging stations for $1500 per station. (Leone, 2009) These stations are 90% efficient and form a mesh network with each other to control charging and track miles driven. All that is needed to install a charge point is a parking space and access to power, which can be found almost anywhere that cars drive in Hawaii.

2.6. Pricing

Better Place becomes profitable through a successful charging network. End users will buy their own cars, lease the batteries, and pay Better Place for the miles they drive. These miles will be comparably priced to driving a gasoline car and will become more affordable and green as world oil runs out. Users will pay for a fixed amount of miles at a fixed price per year just as though they were paying for a car lease, except that the lease price includes the batteries and miles driven. This means that in calculating revenue, we need only be concerned with the miles driven in the cars rather than the details of when and where they charge. There will be available rate plans the keep the price around $0.20 - $0.30 per mile. Just as cell phone users choose how many minutes they will use and pay accordingly. Example pricing plan:

Monthly Cost to User (includes battery and 15,000 miles/yr)	***$275***
- Battery Cost to Better Place (depreciation)	$140
- Cost of Electricity (for an actual 12,000 miles driven)	$100
Profit	***$35***

Implementation Model

Many disruptive technologies have penetrated the market in a logistic curve:

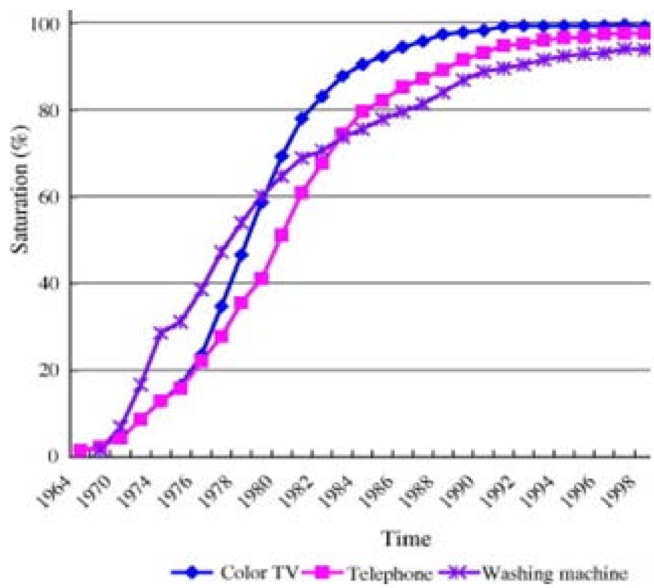
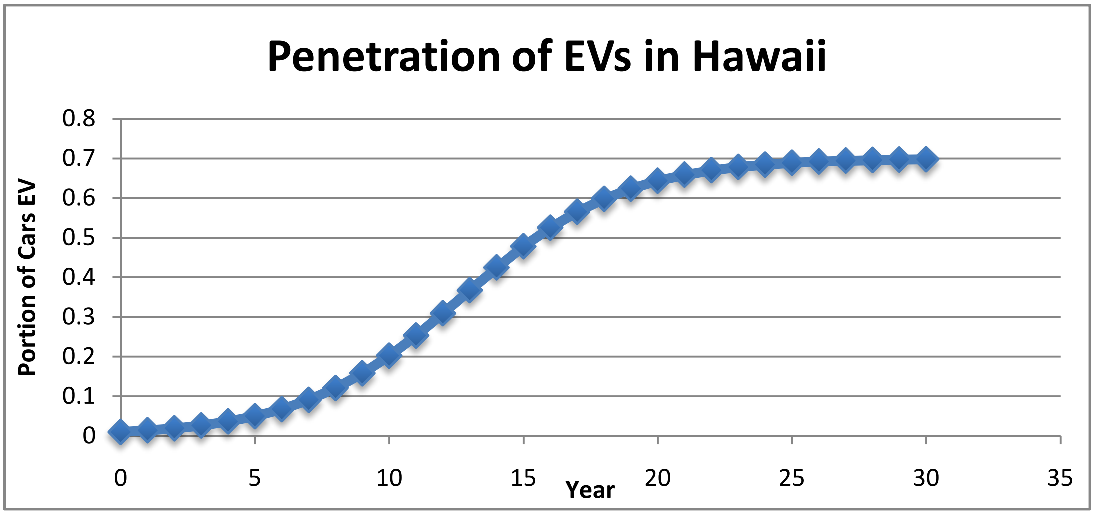


Figure 2.5: Disruptive Technologies

Since these other technologies have resembled the logistic curve, we used it to model the penetration rate of the Better Place Car. Based on previous hybrid sales we have come up with the following parameters:

Number of assumptions:

1. Assume asymptote of 70% Penetration
2. Assume maximum rate of 70% of new cars purchased are EV
3. Implementation rate will follow hybrid rate for world (Sullivan, 2009)
4. Assume logistic curve behavior with a=b=1, x =2.1 (Sullivan, 2009)
5. Charging stations installed simultaneously with cars sold
6. A charging station for every car
7. 10,303 miles driven per year for each car



$$\frac{a \cdot p_o}{bp_o + (a - bp_o)e^{(-at/x)}}$$

Figure 2.6: Penetration Model

a, b, x , and P_o are parameters that can be adjusted to shape our curve like previous hybrid sales to accurately predict how many Electric Vehicles will be in Hawaii by year.

2.7. Charging Locations

The plan to build charging stations as we bring in cars is essential to the development of the EV network. We need both enough charging stations to satisfy users and enough cars on the road to generate revenue to pay for the cost of new charging stations. We will be able to work with drivers at the time of purchasing their EV to locate charging stations where they need them. They will always be located around more populated areas and work to install them at high profile locations to increase publicity at the beginning. These locations include:

1. Honolulu Zoo
2. Waikiki Aquarium
3. Diamond Head Street Parking
4. Sea Life Park
5. Nu'uanu Valley Park
6. Polynesian Cultural Center
7. Haleiwa
8. Ko'Olina
9. Pearl Harbor
10. Ala Moana Mall

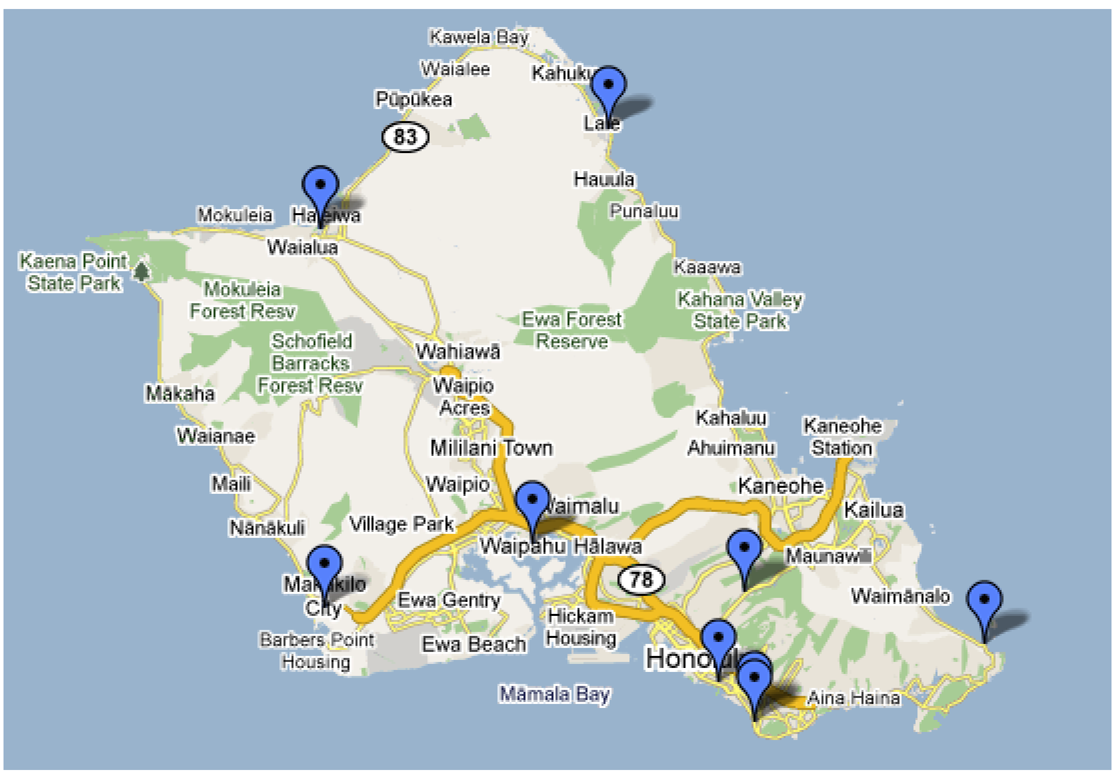


Figure 2.7: Map of Hawaii

To ensure that the charging stations meet the demand for charging, we constructed a simulation for the number of cars parked in a parking lot each day. We used the Polynesian

Cultural Center as an example location because its capacity was available and because it is the largest of the 10 high profile selected locations. We modeled a normal distribution for each of its nine main rooms. These rooms have a normal capacity and a high capacity listed online (Polynesian Cultural Center). The mean was estimated by the normal capacity and the difference between the high and normal capacities was used to estimate the standard deviation. We used a Monte Carlo simulation with 500 trials for each room and then summed the total number of cars driven to the Polynesian Cultural Center for each trial.

Room	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	TOTAL
Mean	200	200	120	600	25	50	200	400	500	2295
SD	67	33	27	67	8.3	6.7	33	116.7	10	

Table 2.5: Table showing mean and standard deviation of cars in Hawaii

We made a histogram representing the number of occurrences of days with various amounts of cars. Using this model, we could change the standard deviations of different rooms and we could combine different types of distributions such as a Poisson when more data of charging stations become available.

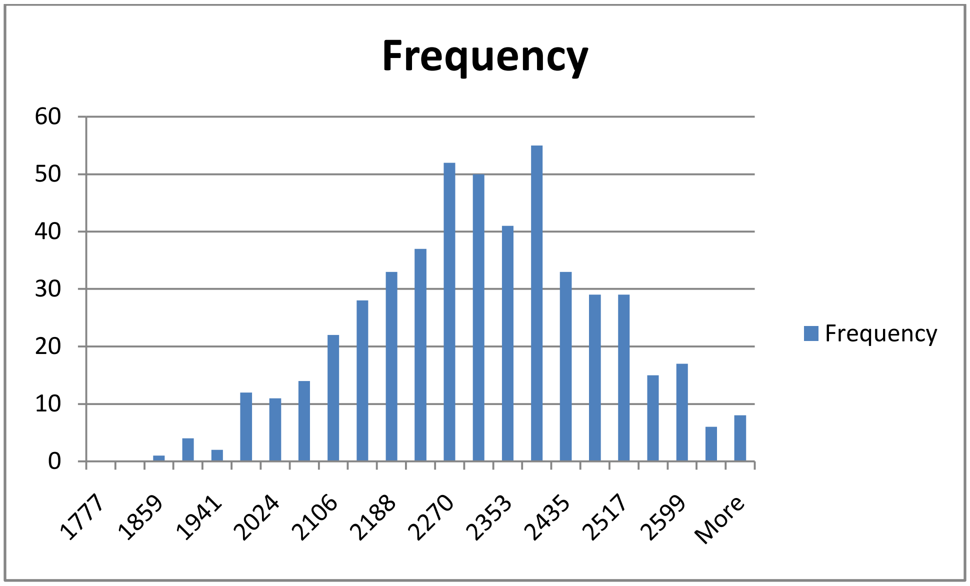


Figure 2.8: Frequency histogram of Cars

At 115% above the normal capacity, we can ensure there will be enough charging stations to meet the demand more than 98% of the time.

2.8. Swapping stations

As announced by Shai Agassi on many occasions, swapping station will be Better Place's solution to long distance travel in an EV. Like a gas station, an EV user will be able to pull into a station, "fill up" by replacing his spent battery, and going on his way. This will all be built into the payment plan of the typical user (Squatriglia, 2009).

Swapping stations will resemble car washes in size and appearance, and users will be able to pull in and out in just minutes (Yarow, 2009). The payment system has not been perfected but will probably be built into the monthly plan that has been set up. Each swapping station will be equipped with a large robotic machine mounted on a track for mobility that will swap the batteries. The swapping system looks something like this:

1. User pulls into swapping station and drives onto a special track which will lock the location of the car on a raised platform
2. The first part of the machine will remove the battery from the bottom of the car and carry it away on the track to a recharging location
3. A second part of the machinery brings in a fully charges battery, raises it into the car, and secures it with special locks
4. The user is then able to drive off the platform and leave (Better Place, 2009)

Better Place offers this service as a convenience for customers who will use more than one full charge in a short amount of time (Squatriglia, 2009). This will apply mostly to long trips, but can be used for all sorts of occasions, like forgetting to charge or replacing an old battery.

2.9. Swapping on Oahu

The island will require ten to twenty swapping stations to insure full availability. There are many additional factors to consider about swapping stations when considering Hawaii. These considerations are cost of land, size of the island, potential use of each station, building time of each station, and battery supply for these stations.

First, a general cost breakdown is shown below. The assumptions for the cost breakdown are as follows:

Station Workers

Each station will require 1 or 2 attendants present at all times to insure smooth operations. Station workers will be paid similar to gas station attendants due to their similar job requirements.

Machinery Maintenance

Professional checks of the machinery should occur at regular time intervals for safety and for maintaining the machine. Repairs should be expected to be necessary if machine is in constant use.

Battery Checks

Some system must be in place to update a database which keeps track of every battery in the station. Information stored might be things like how much charging each battery requires, when the battery needs to be replaced due to loss in capacity, and the general condition of the battery.

Batteries in Stock

The peak hourly customers is an unknown number, but if this number is assumed, then the number of batteries the stations should have should be the average recharge time multiplied by the peak hourly customers so that batteries will be charged by the time they are next needed.

Electricity

We have assumed a constant electricity cost for simplicity. Also it is assumed that batteries will charge for the full 4 hours and the number of charges is the total number of swaps each day (average hourly customers * hours of operation).

Initial Costs

Construction[1]	Property[2]	Batteries
$500,000	$308,000	Not Included
Total:	**$808,000**	

Property

Cost/sq ft	Size (Sq Feet) [1,3]	Total
$77	4000	$308,000

Operating Costs (Annual)

Battery Replace	Station Workers	Machinery Maint.	Battery Checks	Property Upkeep	Electricity
$300,000	$99,280	$10,900	$9,125	$10,000	$201,830
Total:	**$631,135**				

Cost Breakdown

Battery Replacement [4]

# Batteries	f (replace/yr)[4]	Cost replacement[4]	Recycle value?	Total
60	0.5	$10,000	--	$300,000

Station Workers

Workers/shift	Working Hours	Wage[5]	Cost/day	Annual Cost
2	16	$8.50	$272.00	$99,280

Machinery Maintenance

Freq. of Checks	Cost/check	Avg Repair Cost	Frequency of Repair	Total Cost
3	$300	$10,000	1	$10,900

Battery Checks

Freq. of Checks	Cost/check	Total
365	$25	$9,125

Batteries in Stock

Avg recharge t	Peak Hourly Customers	Battery life (yrs)	Req'd Batteries
4	15	2	60

Electricity [6]

Cost/kWh	Charger (kW)	# Battery Charges	Charge hours/batt	Cost/day	Annual Cost
$0.30	7.2	64	4	$553	**$201,830**

Figure 2.9: Swapping Station Cost Breakdown

The first thing to consider is the purchase of land and construction of each station. Unlike charging stations that will be small machines installed in already built parking lots all over the island, swapping stations will be large buildings that will take up about 3,000 to 4,000 square feet as they will resemble car washes (Yarow, 2009). For land this size, land costs on Oahu are shown in the below table. The cost will be about $77/ square foot which comes out to be $250k to $300k for land alone (OahuRE.com, 2009). According to Shai Agassi in numerous reports, the station itself will cost around $500,000 to build which includes the cost of the machine and construction costs. Summing this, each swapping station may cost upwards of $1 million when development costs and soft costs are also factored in. This is a value that will be important in the economic feasibility of Better Place.

Averages for 28 ACTIVE Listings			
Days on Market:	81	Assessed Improvements:	$6,632
List Price:	$350,925	Assessed Land:	$291,100
Sold Price / Ratio:	$0 / 0.00%	Assessed Value:	$297,732
Land (sq ft):	4,672	Assessed Ratio:	170.68%
Interior:	0	Tax:	$126
Year Built:	0	Beds:	0
Avg cost/sq ft:	**$77**	Average Interior:	$0

Table 2.6: Land Prices on Oahu (OahuRE.com, 2009)

Another important factor for the success of Better Place is the actual use of these stations. Because Oahu is a very small area compared to most metropolitan regions, the average distance driven each day by the average user is much less than the range of the car (around 22 miles on the average day compared to the 100 mile range of a car). Thus, swapping will be less necessary than most places for augmenting the range of the car. Swapping will however be used enough by the average user to warrant the existence of them. As an example, according to our implementation model Better Place is expecting around 20,000 customers during the first few years of operation. If each of these customers only swaps once a year, then there will be 55 swaps a day and about 6 swaps per station per day assuming 10 stations are built throughout the island before even full market penetration. Again assuming one swap a year, at the full 70% market penetration, there will be about 800 swaps a day and with only 20 swapping station there will be a demand of about 40 swaps at the average station.

This once-a-year swapping can be justified by a few reasons. Some of these are people forgetting to charge, taking rare long trips, or simply wanting to replace their batteries. It will be up to Better Place to gather more information on swapping demand in the future to optimize the operation and introduction of swapping stations for each of their locations.

An important thing to note about Better Place's business model is that they will not charge specifically for the use of swapping stations. Because they are charging on a basis of miles, a swap will only cost the user whatever a full charge would cost. This means that Better Place will have to run and maintain these stations and factor in the operating a construction costs into the general monthly plan that each user pays. A spreadsheet showing quick calculations determining average operating and building costs is attached. The overall costs and the business plan will be discussed later in the paper.

One last consideration is the delay in supply to the demand for swapping. Better Place will need to either accurately forecast the demand for swapping or create an excessive supply. The delay in supply is of course due to land purchase, permit attainment, and construction time that may take around a year. As shown later, swapping stations are a tiny portion of Better Place's overall costs. Because of this, some initial overbuilding would be recommended given our forecasts of success in the Hawaii market.

2.10. Need for Swapping

Though swapping will be rarer on Oahu, there are a few reasons to implement this system in Hawaii. The most important reasons are marketing and for perfecting the Better Place model.

Perhaps the most important reason for swapping stations in general is their use for marketing Better Place. While there are other electric cars and charging stations already being utilized throughout the world, Better Place can offer more to the average user. Aside from owning the battery, Better Place can provide the guarantee of never running out of charge. For most people, running out of gas is a pretty big ordeal. With Better Place's swapping stations, the average person will require some sort of reassurance that their vehicle will not fall short of a destination. Even though it is irrational to think they would run out of energy on such a small island, people highly value reliability when purchasing vehicles.

The second reason to implement these charging stations in Hawaii despite a smaller demand is to practice and perfect their overall system of operation. Better Place as a new company that wants to break into markets all over the world will need to learn how to best operate their company. Hawaii will be another testing ground for Better Place to try out their model and see what does and doesn't work. In such a small area, it will probably be easier to gather meaningful data and make necessary changes.

2.11. Swapping Station Locations

The Model

In Oahu, for the convenience of users of Better Place, swapping station coverage should be sufficient. To achieve this, the travel demand between each city/town pair is determined. Since this demand determination is a "relative study", i.e. comparing the demand between cities and proportioning them, the exact number of trips is not needed to be calculated.

Most of the travel demand is generated by large cities, as the population increases, the travel demand also increases. However, we also know that as the travel distance becomes longer, the demand from a city to another one decreases. Therefore, we can say that the transportation gravity model is based on the Newton's Law of Universal Gravitation, which is denoted by the following formula:

$$F_g = G\frac{m_1 m_2}{r^2}$$

where, F_g is the force of gravitation, m_1 and m_2 are the masses of two given objects, r^2 is the square of the distance between the objects and G is the universal gravitational constant (Sir Isaac Newton: The Universal Law of Gravitation).

The gravity model is used widely in transportation and the most common formulation of the spatial interaction method (Rodrigue, 2009). Then we assumed the formula below:

$$RD_{ij} = \frac{P_i P_j}{d_{ij}^2} K$$

where, P_i & P_j are the populations of city/town i and j respectively, K is the number of total cars in Oahu, which is constant and equal to 411,000 (80% of the number of cars in Hawaii state, assuming that 80% of population of Hawaii state is in Oahu) (Motor Vehicle Registrations 2007), RD_{ij} is the relative demand between i and j, lastly, d_{ij}^2 is the square of the distance between I and j.

After the application of this formula, the ratios are needed to be multiplied by the distance between i and j, but when we do this, it will change nothing but the denominator of the formula, resulting in change of the power of distance to 1, which will not affect our study. So, the multiplication is not performed here.

For example, let us focus on the Kaneohe – Pearl City pair calculation:

$$P_{Kaneo\,he} = 34{,}970\ , P_{Pearl\ City} = 30{,}976$$

$$K = 411{,}000$$

$$d^2_{Kaneo\,he-Pearl\ City} = (15.6)^2 = 243.36\ mi^2$$

$$RD_{Kaneo\,he-Pearl\ City} = 1.829 * 10^{12}$$

Finally, for convenience to interpret the results, we divided all of the numbers resulting from this formula in the matrix to average of the RD_{ij} values.

$$Average\ RD_{ij} = 6.980 * 10^{11}$$

$$\frac{RD_{Kaneo\,he-Pearl\ City}}{Average\ RD_{ij}} = \frac{1.829 * 10^{12}}{6.980 * 10^{11}} = 2.621$$

Below are the parts of the distance table and trip ratio table of Oahu, HI, so they will fit on the page. The trip ratio table contains the ratios resulted from our calculation. The rest of these tables are in pages 35 and 37, respectively.

Distances(mi)	Ahuimanu	Haleiwa	Kaneohe
Ahuimanu	0		
Haleiwa	36.4	0	
Kaneohe	3.5	35.5	0
Kahuku	22.6	15.8	25.3
Kawela Bay	26.9	11.7	29.6
Pearl City	17.7	21	15.6
Wahiawa	27	10.9	25
Waianae	38	38.5	35.9

Table 2.7: Part of the distance table of Oahu, complete tables located Table 2.9

Trip Ratios	Ahuimanu	Haleiwa	Kaneohe
Ahuimanu	0.000		
Haleiwa	0.008	0.000	
Kaneohe	14.297	0.036	0.000
Kahuku	0.021	0.011	0.067
Kawela Bay	0.003	0.004	0.010
Pearl City	0.495	0.092	2.621
Wahiawa	0.111	0.178	0.532
Waianae	0.036	0.009	0.168

Table 2.8: Part of the trip ratio table of Oahu, complete tables located Table 2.11

The Results

Before talking about the results we obtained, we would like to mention about population of Oahu, HI. The island's estimated 2005 population is 905,266, with 377,379 (2005) of it living in Honolulu, the largest city of the state. The rest of the population is scattered around the island, with Kaneohe as the most populous one, which is 12.1 miles from Honolulu. The rest of the towns and their locations are shown in the map below.

As for the results we obtained from our model, we looked for the "bigger" values of trip ratios, which are bigger than 1.000; and we can see from Table 3 that most of the demand is to/from Honolulu, so a swapping station, maybe more than one, is needed in Honolulu.

When we look at other towns in Oahu, it is obvious that Waianae and Maili are very close to each other, but the demand between two towns is pretty high. Also, they have a considerable demand to and from Honolulu. Since the distance between these two is small, only one of the cities will get a station. When we look at the values in the matrix, we can see that Waianae has bigger demand with other cities/towns compared to Maili's demand, so Waianae will have a station. The same situation also applies for Ahuimanu and Kaneohe. Here, Kaneohe is the one having the larger demand with other places; so, a station will be built in Kaneohe. However, to cover the big demand of Ahuimanu (having 3rd largest value in the matrix), more than one station may be built. Moreover, Makakilo City and Ewa Gentry have the same situation as well. Since Makakilo City has a higher demand to/from Honolulu and Pearl City than Ewa Gentry has with those two, the station will be built in Makakilo City, even though it is only 10 miles from Pearl City and 21 miles from Honolulu.

When we look at Pearl City, we see that it has a big demand with Kaneohe, Wahiawa, Ewa Gentry, Makakilo City and Honolulu, so a station is needed there.

Furthermore, town of Wahiawa has a demand between both Honolulu and Pearl City worth to consider, a construction of a swapping station is required.

Finally, even though there is a demand worth to consider between Waimanalo and Honolulu, no station is needed for the former one since the distance between them is 13.8 miles and there is no other significant demand from/to Wamanalo and another place.

Note: The distances between towns and cities are measured on Google Earth.

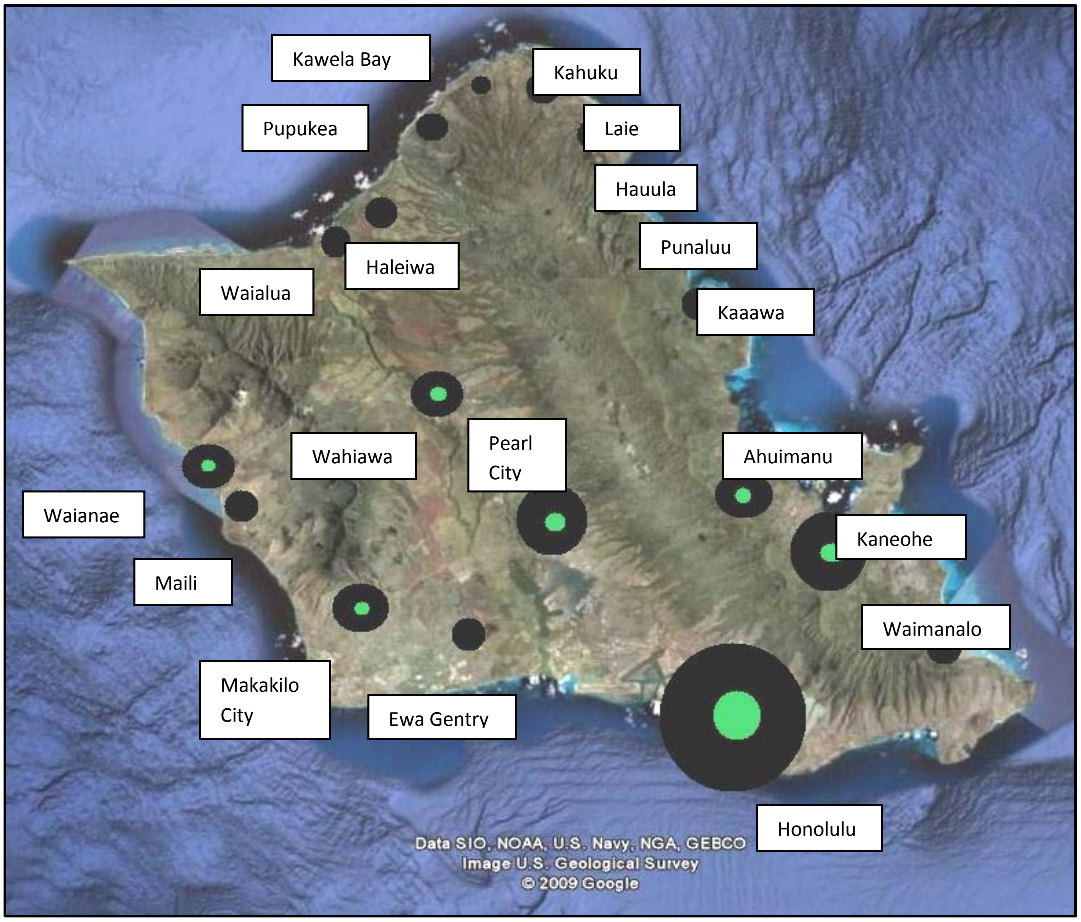


Figure 2.10: Map of Oahu, HI (Google Earth)

Note: Green points show the places for swapping stations to be built.

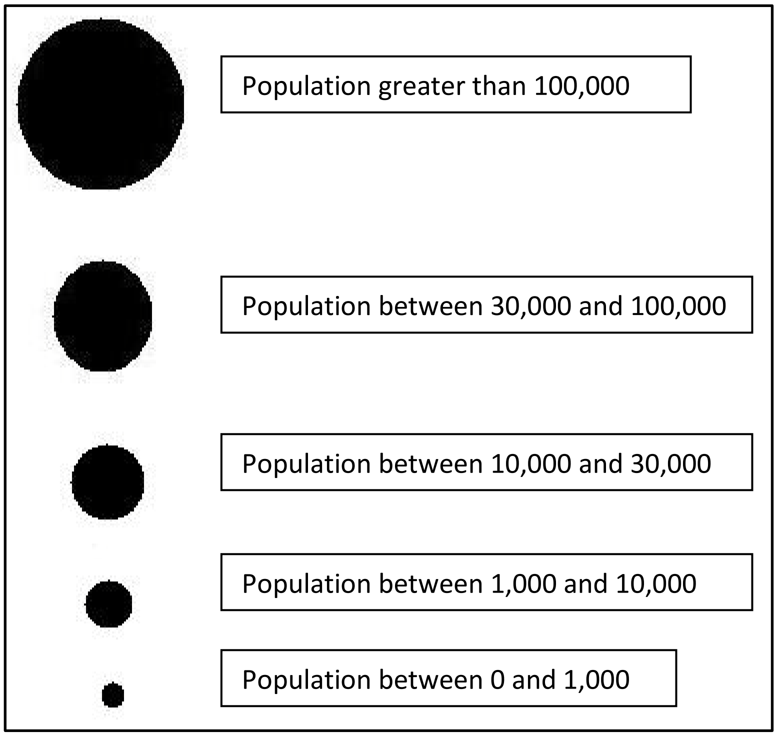


Figure 2.11: Legend for Figure 2.10

Distances(mi)	Ahuimanu	Haleiwa	Kaneohe	Kahuku	Kawela Bay	Pearl City	Wahiawa	Waianae	Waimanalo
Ahuimanu	0								
Haleiwa	36.4	0							
Kaneohe	3.5	35.5	0						
Kahuku	22.6	15.8	25.3	0					
Kawela Bay	26.9	11.7	29.6	5.1	0				
Pearl City	17.7	21	15.6	34.8	30.6	0			
Wahiawa	27	10.9	25	24.7	20.5	10.7	0		
Waianae	38	38.5	35.9	52.3	48.1	21.7	28.9	0	
Waimanalo	11.8	41	8.7	33.6	37.9	22.1	31.4	42.1	0
Hauula	17.7	21.1	20.4	6.1	10.4	35.9	29.9	54.8	28.6
Kaaawa	10	27.7	12.7	12.6	16.9	28.2	37.6	48.3	21
Ewa Gentry	25	21.3	23	39.4	35.2	8.7	16	19.8	29.4
Pupukea	30.3	7.4	33	8.4	4.3	25.6	16.2	43.7	46.3
Punaluu	15.1	22.9	17.8	7.8	12.1	33.3	31.7	53.4	26.1
Laie	19.7	18.2	22.4	3.2	7.5	36.4	27	54.5	30.7
Makakilo City	26.3	26.8	24.3	40.6	36.5	10	17.3	13.5	30.7
Waialua	35.5	2.4	33.5	18.3	14.1	19.2	9.8	37.3	39.9
Honolulu	14	31.4	12.1	35.8	41	11.4	21.8	32.5	13.8
Maili	35.6	35.9	33.6	50	45.8	19.3	26.6	2.3	40

	Hauula	Kaaawa	Ewa Gentry	Pupukea	Punaluu	Laie	Makakilo City	Waialua	Honolulu	Maili
Ahuimanu										
Haleiwa										
Kaneohe										
Kahuku										
Kawela Bay										
Pearl City										
Wahiawa										
Waianae										
Waimanalo										
Hauula	0									
Kaaawa	7.7	0								
Ewa Gentry	41.9	34.2	0							
Pupukea	13.7	20.3	30.1	0						
Punaluu	2.9	5.1	39.7	15.5	0					
Laie	3.2	9.7	40.9	10.8	4.9	0				
Makakilo City	43.2	35.5	5.3	32.2	40.6	45.3	0			
Waialua	23.6	30.1	23.7	9.9	25.3	20.6	25.9	0		
Honolulu	30.9	23.2	18.9	36.8	28.4	33	21.1	30.4	0	
Maili	52.5	44.9	17.8	41.5	50	54.8	11.1	35.1	29.9	0

Table 2.9: Distance between selected towns in Oahu, HI

Town	***Population***
Ahuimanu	8,506
Haleiwa	2,225
Kaneohe	34,970
Kahuku	2,097
Kawela Bay	410
Pearl City	30,976
Wahiawa	16,151
Waianae	10,506
Waimanalo	3,664
Hauula	3,651
Kaaawa	1,324
Ewa Gentry	4,939
Pupukea	4,250
Punaluu	911
Laie	4,585
Makakilo City	13,156
Waialua	3,761
Honolulu	377,379
Maili	5,943

Table 2.10: Populations of selected towns in Oahu, HI (Local Information Data Server, 2005)

Trip Ratios	Ahuimanu	Haleiwa	Kaneohe	Kahuku	Kawela Bay	Pearl City	Wahiawa	Waianae	Waimanalo	Hauula	Kaaawa	Ewa Gentry	Pupukea	Punaluu	Laie	Makakilo City	Waialua	Honolulu	Maili
Ahuimanu	0.000																		
Haleiwa	0.008	0.000																	
Kaneohe	14.297	0.036	0.000																
Kahuku	0.021	0.011	0.067	0.000															
Kawela Bay	0.003	0.004	0.010	0.019	0.000														
Pearl City	0.495	0.092	2.621	0.032	0.008	0.000													
Wahiawa	0.111	0.178	0.532	0.033	0.009	2.573	0.000												
Waianae	0.036	0.009	0.168	0.005	0.001	0.407	0.120	0.000											
Waimanalo	0.132	0.003	0.997	0.004	0.001	0.137	0.035	0.013	0.000										
Hauula	0.058	0.011	0.181	0.121	0.008	0.052	0.039	0.008	0.010	0.000									
Kaaawa	0.066	0.002	0.169	0.010	0.001	0.030	0.009	0.004	0.006	0.048	0.000								
Ewa Gentry	0.040	0.014	0.192	0.004	0.001	1.190	0.183	0.078	0.012	0.006	0.003	0.000							
Pupukea	0.023	0.102	0.080	0.074	0.055	0.118	0.154	0.014	0.004	0.049	0.008	0.014	0.000						
Punaluu	0.020	0.002	0.059	0.018	0.002	0.015	0.009	0.002	0.003	0.233	0.027	0.002	0.009	0.000					
Laie	0.059	0.018	0.188	0.553	0.020	0.063	0.060	0.010	0.010	0.963	0.038	0.008	0.098	0.102	0.000				
Makakilo City	0.095	0.024	0.459	0.010	0.002	2.399	0.418	0.447	0.030	0.015	0.008	1.362	0.032	0.004	0.017	0.000			
Waialua	0.015	0.855	0.069	0.014	0.005	0.186	0.372	0.017	0.005	0.015	0.003	0.019	0.096	0.003	0.024	0.043	0.000		
Honolulu	9.643	0.501	53.072	0.364	0.054	52.961	7.551	2.210	4.275	0.850	0.547	3.072	0.697	0.251	0.936	6.566	0.904	0.000	
Maili	0.023	0.006	0.108	0.003	0.001	0.291	0.080	6.950	0.008	0.005	0.002	0.055	0.009	0.001	0.005	0.374	0.011	1.477	0.000

Table 2.11: Computed RD_{ij} values for each town in Oahu, HI

SECTION – III: ENERGY

3.1. Current Sources and Distribution of Electricity in Hawaii

As an island archipelago spread out across hundreds of miles of the Pacific Ocean, Hawaii does not have an interconnected electric grid like states in mainland North America. Each island has a separate electric grid that is only able to supply electricity to the island from power generated on the island. 95% of Hawaii's residents receive power from Hawaiian Electric Company (HECO) and its subsidiaries, Hawaiian Electric Light Company (HELCO) and Maui Electricity Company (MECO), each of which operate on separate islands (Hawaiian Electric Company, 2009). The geographical grid separation and isolation presents a challenge to Better Place if they wish to use renewable energy to cover all of Better Place's electricity requirements across Hawaii. Because 80% of Hawaiians live on Oahu, it is the most logical and potentially efficacious target for Better Place; consequently, our feasibility study focused on the electricity generation, demand, and distribution on Oahu.

HECO is the power company responsible for Oahu's electricity needs and their generation facilities have a maximum capacity of 1,727 MW (Hawaiian Electric Company, 2009). Compare that with Oahu's net peak demand of 1,216 MW and it is evident that spare capacity is available for Better Place vehicles; however, much of the environmental benefits of EVs would not be realized if HECO's petroleum-based power plants were used to supply the EV's electricity. It is the environmental benefits of renewable energy that require a change of generation methods from Hawaii's current scheme.

Another difference between Hawaii and the mainland states is the resources Hawaii uses to generate its power. Petroleum derivatives, such as heavy fuel oil and distillate fuels, account for over 80% of electric power generation (Energy Information Administration, 2008), a stark contrast from the predominately coal and nuclear power plants on the mainland. See Figure 3.1. Renewable resources like water, wind, and biodiesel only provide 6% of Hawaii's electricity generation.

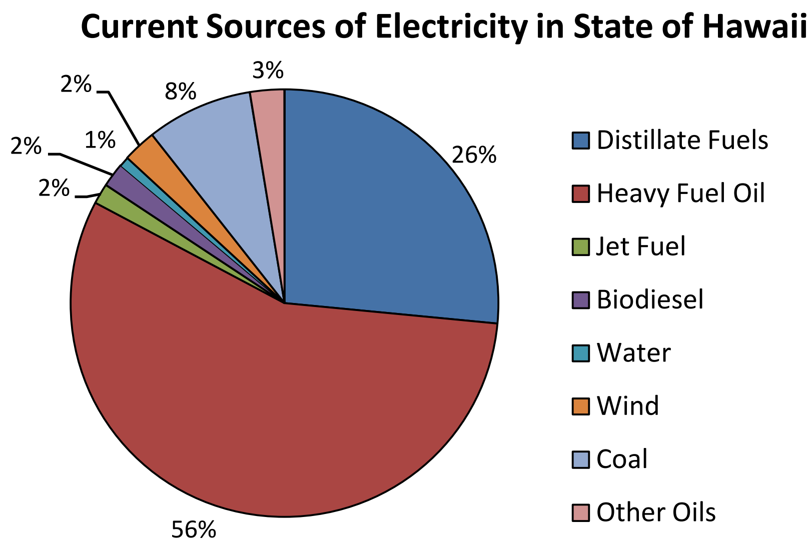


Figure 3.1: Current Sources of Electricity in State of Hawaii

The island of Oahu is virtually 100% dependent on petroleum derivatives for its electricity generation resources. Heavy fuel oil is the heaviest, thickest, and most polluting commercial fuel that can be obtained from crude oil (Fuel Oil, 2009) and accounts for 87% of Oahu's electricity generation. Distillate fuel oils can be a mixture of diesel, kerosene, and heavy fuel oils; they account for the remaining 13% of electricity generation on Oahu (Energy Information Administration, 2008). See Figure 3.2.

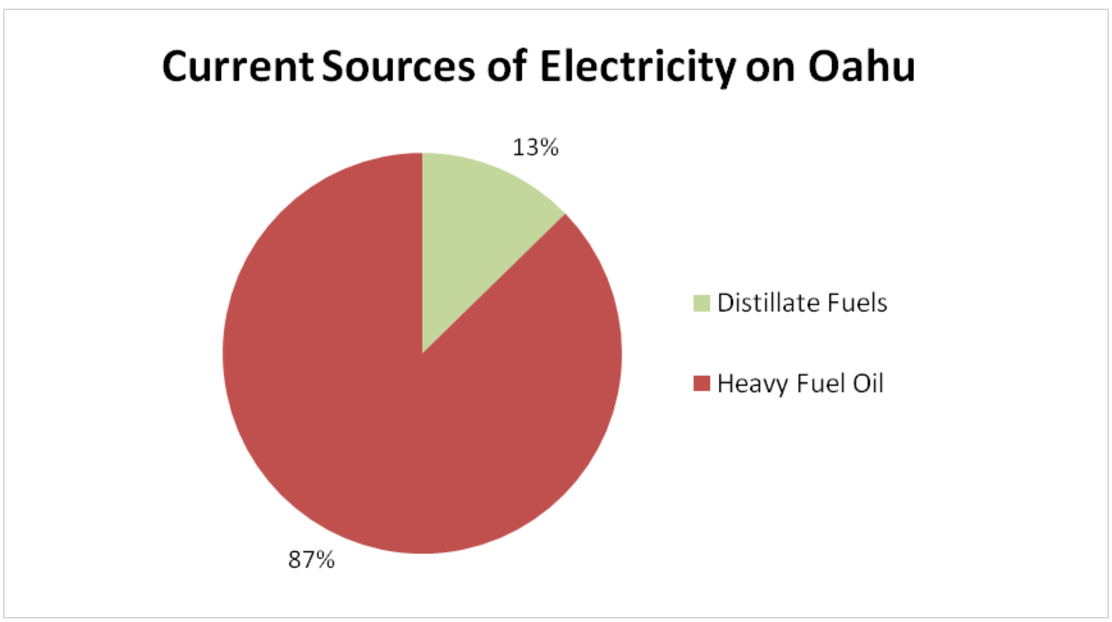


Figure 3.2: Current Sources of Electricity on Oahu

Our study of the individual Hawaiian Islands' power transmission systems and the load Better Place vehicles would place on those systems indicate that the existing power grid is generally suitable for Better Place EVs. Transmission lines spread over most of the individual islands. See Figure 3.3 for an example. Short connector lines would need to be installed for access to new renewable energy power generation facilities. Additional small distribution lines would be required for powering the charging stations.

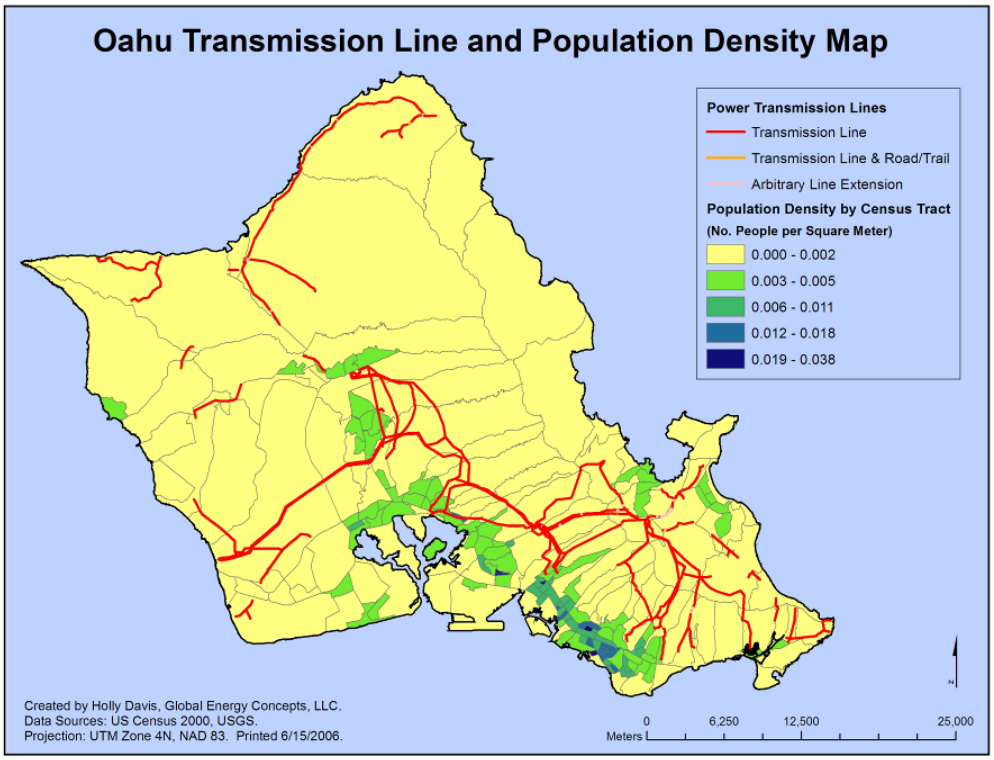


Figure 3.3: Oahu Transmission Line and Population Density Map

Each island has different voltages and schemes for their electricity distribution systems (Hawaiian Electric Company, 2009), but that should present a problem for Better Place implementation. A current power distribution example for Oahu is shown in Figure 3.4.

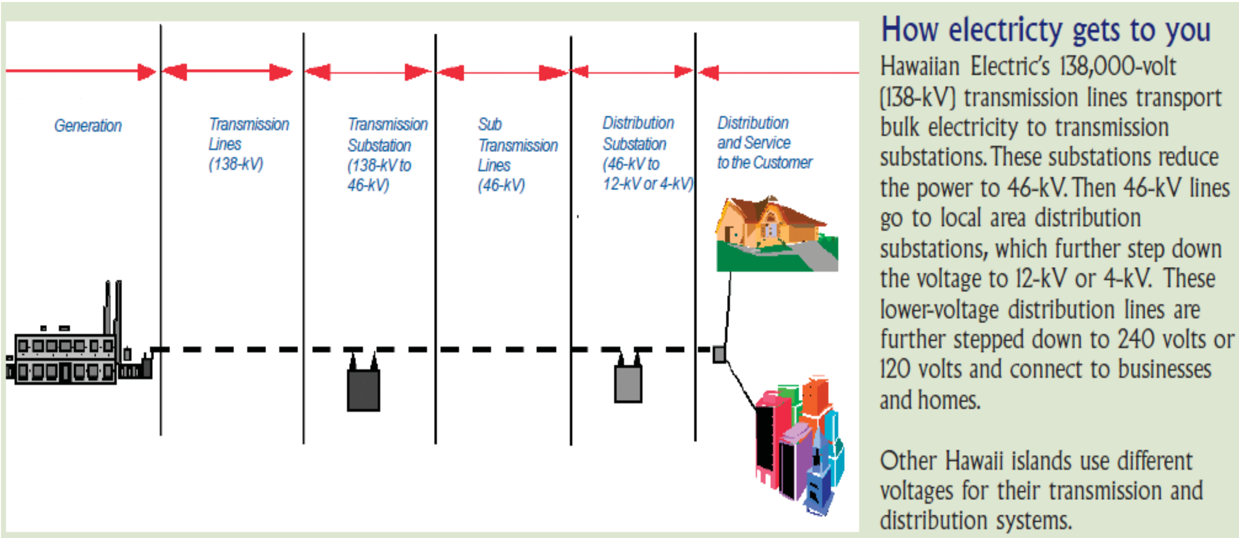


Figure 3.4: Transmission on Oahu

In January 2009, Governor Linda Lingle signed the Hawaii-DOE Clean Energy Initiative which aims to reduce dependency on oil and increase the use of renewable energy resources such that by 2030, 40% of Hawaii's energy demand will be supplied by renewable energy sources including wind, solar, geothermal, biomass, hydroelectric, OTEC, and wave energy. Hawaii's dependence on oil for 85% of its energy makes it vulnerable to disruptions in supply and has led to the highest electricity costs in the nation (Boyd, 2009).

There are several significant barriers to achieving the Hawaiian government's 70% clean energy goal. Each island has an isolated micro-grid, meaning that in its current state, renewable energy on one island cannot be used to meet the demand on the other islands (Boyd, 2009). 68% of Hawaii's population resides on the population dense, resource-limited island of Oahu. Instead, some of the richest sources of renewable energy are on smaller, more rural islands like Maui, which has large waves, and Lanai, which has strong winds. Sharing that power across the island chain will require building expensive underwater cables. Current estimates project that the underwater cables will link each island's isolated grid by 2030 (Hawaii Plans Undersea Power Cable, 2009).

An environmental impact study is being planned by the government to study the impact of the cables on the ocean floor, coral reefs, and marine life (Hawaii Plans Undersea Power Cable, 2009). The cost of the project is estimated to be between $600 million to $2 billion, but the project has received considerable support from the Hawaiian government due to its commitment to 40% renewable energy by 2030 - a commitment that is only feasible if the independent island grids are connected (Mckinsey & Company, 2008).

Underwater power cables are not a new technology and have been used with great effectiveness in many parts of the world. One of the more notable underwater power cables is the Neptune RTS cable which runs from New Jersey to Long Island and became operational in the summer of 2007 (Howe, 2007). Other projects include the Cross Sound Cable between Long

Island and Connecticut which transports 330MW and went into service in 2004, and a 55-mile cable under San Francisco Bay. Current technology allows for 2GW of transmission, which is double Hawaii's proposed plan (ABB).

If Better Place is committed to developing a truly renewable infrastructure, they will have to coordinate short and long term plans that are consistent with Hawaii's energy goals. We investigated the potential sources of renewable energy that were available in Hawaii such that Better Place could meet its commitment to using only renewable energy to power its infrastructure. As mentioned previously, the following sources of renewable energy could potentially be available on Hawaii: wind, solar (photovoltaic and parabolic trough), geothermal, wave energy, and OTEC (Global Energy Concepts, LLC, 2006). Because our analysis focused specifically on Oahu due to its high population density, we discovered that many of the potential sources of renewable energy were not feasible.

3.2. Wind Energy

The Kahuku (northeastern) area of Oahu provides the biggest opportunity for wind development on the island. Further, the southeastern, southwestern, and northwestern tips of Oahu also have some wind resources (Global Energy Concepts, LLC, 2006). However, land-intensive renewable energy projects must compete with other uses. Oahu is the most densely populated island in Hawaii, and there has been considerable backlash from locals regarding the installation of wind farms (Mckinsey & Company, 2008). The northwestern corner of Molokai appears to have the most substantial resources for wind power. Optimistic projections for wind power suggest that up to 320MW could be generated on this island alone by 2030. (Mckinsey & Company, 2008). Lanai, like Molokai, has significant wind potential, with up to 300MW capacity estimated by 2030. However, much of Lanai is privately owned. Luckily, David Murdock, a billionaire who owns 98 percent of Lanai, has proposed creating a wind farm on the island. His plan would build 125 turbines spread over 10,000 to 12,000 acres and then export power to Oahu via undersea cables (Cable Directory, 2009).

The following wind map shows wind power density Figure 3.5 for Hawaii. Much of the available wind resources appear to lie offshore. However, due to the volcanic origin of the island, there is a large drop-off in depth a short distance from the shore. The technology for deep-water off shore wind turbines is not yet available, and as such, off-shore projects would not be feasible for a significant period of time (Global Energy Concepts, LLC, 2006). In terms of Better Place's implementation strategy, off-shore wind would not be an immediate consideration due to the limitations in the current technology.

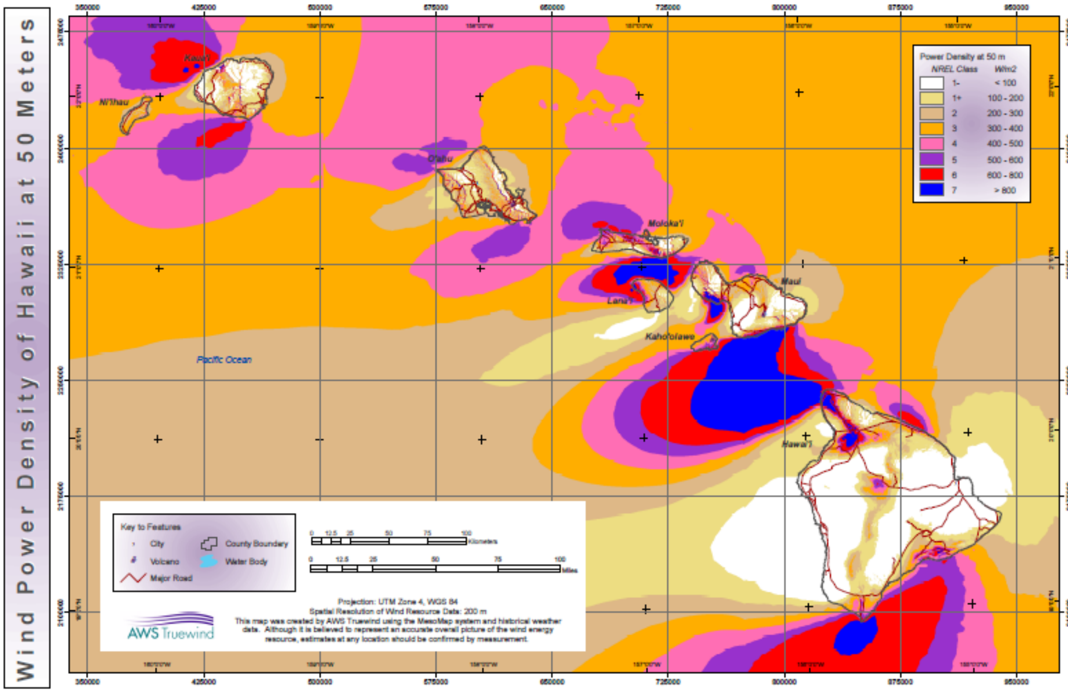


Figure 3.5: Hawaii Wind Power Density Map (AWS Truewind)

3.3. Geothermal Energy

Use of geothermal energy as a renewable energy supply would not be feasible for Better Place if they were to focus strictly on Oahu. Large scale geothermal energy in Hawaii is limited to two locations: the Island of Hawaii and Maui. Between each island, seven sites have been identified as geothermal resource areas. Currently there is only one geothermal plant operating in Hawaii. Located on the island of Hawaii, it has a capacity of 30MW which accounts for 20% of the island's total electricity output. On the island of Hawaii, the Kilauea East Rift Zone (KERZ) has an estimated 778MW of potential capacity while the Kilauea Southwest Rift Zone has up to 393MW of total capacity. Unfortunately, land rights issues makes it impossible to access all of the potential resources, as a substantial portion of these areas is part of national parks and forest reserves. Also on the island of Hawaii, the Mauna Loa Southwest Rift Zone contains about 125MW of estimated capacity. Maui has several rift zones that each could potentially provide up to 70MW of capacity (GeothermEx, Inc., 2005). Figures 3.6 and 3.7 below identify the locations where geothermal energy is most readily available (Global Energy Concepts, LLC, 2006).

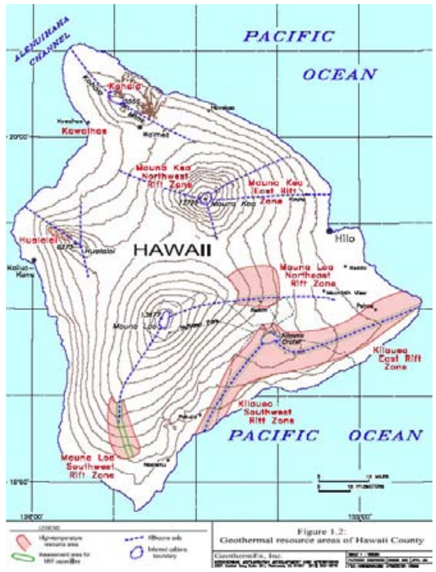


Figure 3.6: Geothermal Resources on the Island of Hawaii

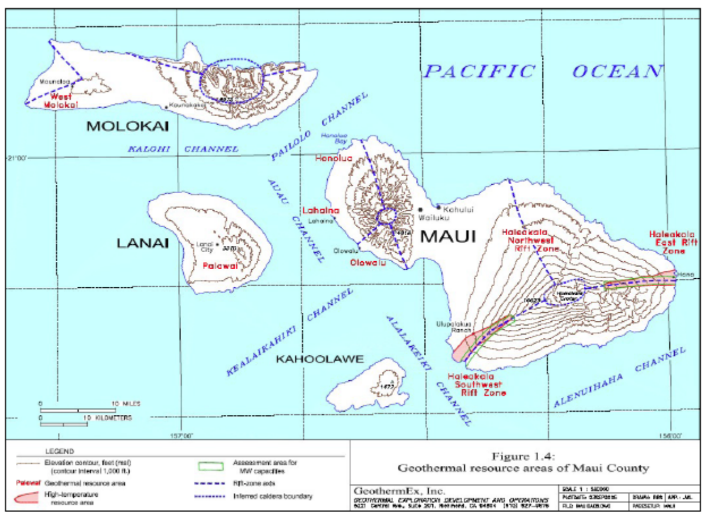


Figure 3.7: Geothermal Resources on the Other Islands

3.4. Hydroelectric Energy

Like geothermal energy, hydroelectric power has limited potential for Better Place. Hydroelectric power is achievable mainly on the Island of Hawaii and Kauai. Several projects are being planned on Hawaii, Maui, and Kauai, but each plant is extremely small scale. One plant on the big island will be able to produce 15MW of power, but the rest of the proposed projects are only the scale of 3MW-7MW. Again, given the focus on Oahu, Lanai, and Molokai, hydroelectric power on these islands would not be able to support Better Place. (Global Energy Concepts, LLC, 2006).

3.5. Solar Energy

With regard to large scale solar energy, up to 100 MW of power could be generated using parabolic troughs or up to 10 MW using photovoltaics on Oahu (Mckinsey & Company, 2008). The West Loch of Pearl Harbor appears to be the best of four potential solar project locations on Oahu. The terrain around the West Loch is level, near numerous transmission lines, and at the center of HECO's load while data collected in 1993 and 1994 shows that solar resources are high. The Ewa Plains and Lualualei Valley are two good sites on Oahu that both have flat land and several transmission lines already in their areas. No solar resource data has been collected for either of these sites, but sunshine is expected to be abundant (Global Energy Concepts, LLC, 2006).

The North Ewa area of Oahu is also a potential solar project site, but it has lower solar resources than the aforementioned coastal locations on Oahu. Being an inland site, North Ewa might be more readily available for development, but could encounter resistance if it displaces agricultural land (Global Energy Concepts, LLC, 2006).

The Manele Bay area in the southeast region of Lanai could be a high-quality location for a solar project. There is currently limited load and transmission on Lanai, but the load is expected to grow and the Manele Bay location is flat and suitable to all types of solar generation systems. Good solar resources are expected, but have not been confirmed (Mckinsey & Company, 2008).

3.6. Ocean Thermal Energy Conversion (OTEC) Offshore of the Hawaiian Islands

OTEC is currently not a feasible solution for large-scale electricity generation in Hawaii. The largest capacity for a single project so far has been 1 MW at Kona on Hawaii. A couple OTEC demonstrations have taken place in the past decades at Keahole Point on Hawaii but neither generated more than 105 kW (Global Energy Concepts, LLC, 2006). Currently, the technology is not mature enough to play a role, but it could still play a role in Hawaii's 40% renewable plan if the technology evolves sufficiently.

3.7. Wave Energy Electricity Generation Offshore of the Hawaiian Islands

Using energy from waves is currently not a feasible solution for large-scale electricity in Hawaii. A demonstration has taken place in 2004 on Oahu at Kaneohe Bay where 20 kW was generated and the site is planning to expand to 1 MW. However, the cost and the technology is still quite prohibitive to bring it up to this scale (Global Energy Concepts, LLC, 2006). Also, given the expected demand for Better Place, which is discussed below, 1 MW would not have much of an impact on the total energy required to support the demand.

3.8. Summary of Potential Renewable Resources in Hawaii

The following map summarizes the projected renewable energy capacity in Hawaii by the year 2030. The solar energy projection on Oahu is inflated by the assumption that individual housing units would have small scale PV units on the island. Given that Better Place plans on purchasing renewable power from the energy companies, these small scale units would not serve Better Place's purposes. As mentioned previously, only the energy that is produced on Oahu, Lanai, and Molakai will be of any use to Better Place as those are the only islands from which Oahu will be able to draw renewable energy once the underwater power cables are implemented.

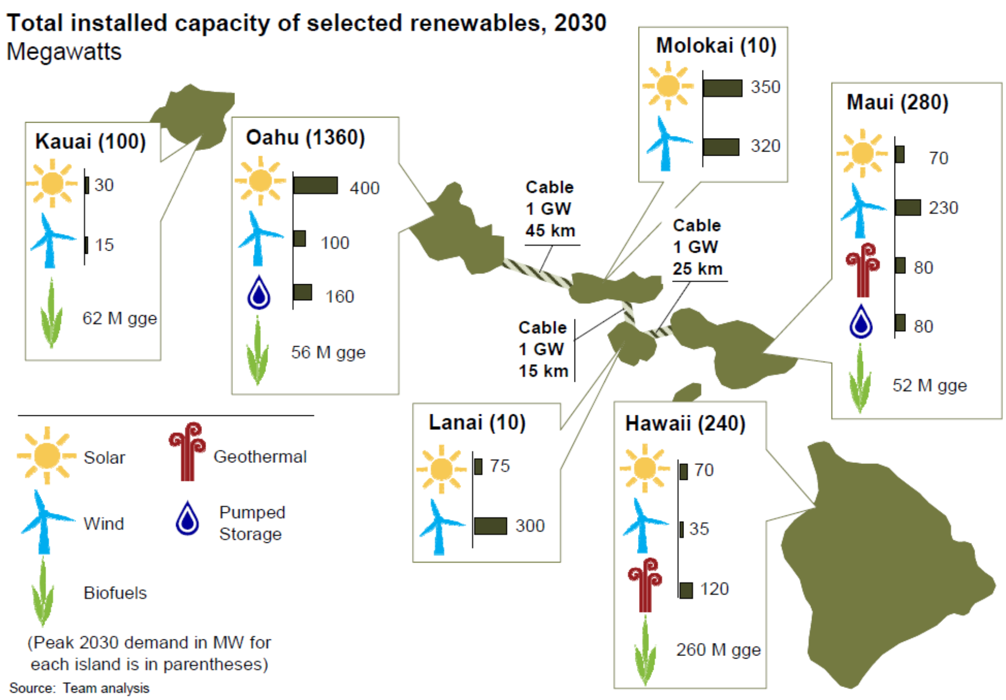


Figure 3.8: Total Installed Capacity of Potential Renewable Energy Projects (Mckinsey & Company, 2008)

3.9. Selecting Viable Renewable Energy Projects to Support Better Place

As stated previously, Better Place is committed to only using renewable energy to power its electric vehicle infrastructure. To fulfill this commitment, Better Place signed an agreement with the Hawaiian Electric Company (HECO) to purchase electricity from renewable sources to match the electricity used by the number of electric cars put on the road. As part of the agreement, Better Place will enter into long-term contracts with HECO to buy electricity at a premium in order to help fund renewable energy projects (Star Bulletin). As such, the amount of premium paid for the electricity will depend on the type of renewable resource that is being funded.

In order to determine whether HECO will be able to meet the increased demand for renewable electricity that will be experienced as Better Place brings electric vehicles onto the road, we researched the availability of renewable resources in Hawaii. We found that even though the Hawaiian Islands collectively have a great amount of renewable resources, each island has its own, separate transmission lines such that renewable electricity generated on one island cannot help to offset renewable electricity demand on another island until 2030 when the aforementioned undersea power cables come online. This is important to Better Place because the majority of electric cars in Hawaii will be operational on the island of Oahu since 80 percent of Hawaii's population resides on Oahu. This means that Better Place would not be able to utilize the renewable electricity generated on the other islands to offset the electricity used on the island of Oahu until 2030. Thus, the most important aspect to determine is how much renewable energy is available on the island of Oahu to meet the demand between now and 2030.

According to our findings and other published studies, there are approximately 50 megawatts (MW) of wind power and 100 MW of solar power on the island of Oahu. To determine whether this 150 MW of total power could meet Better Place's energy demand, we modeled solar and wind data in order to convert the 150 MW power rating into a measure of energy production. Utilizing solar data from Oahu (See Figure 3.9), we were able to model the amount of electrical energy generated over the course of one year (See Figure 3.10). Using the result from Figure 3.8, we determined that a 50 MW plant on Oahu operating at 12 percent efficiency would generate 100,000 kWh of electrical energy over the course of one year. Online data confirms that the energy generation for an equal -size wind plant is similar to that of solar. Thus, we calculated that the 150 MW of power capacity on the island of Oahu would provide 300,000 kWh of electrical energy for use by Better Place.

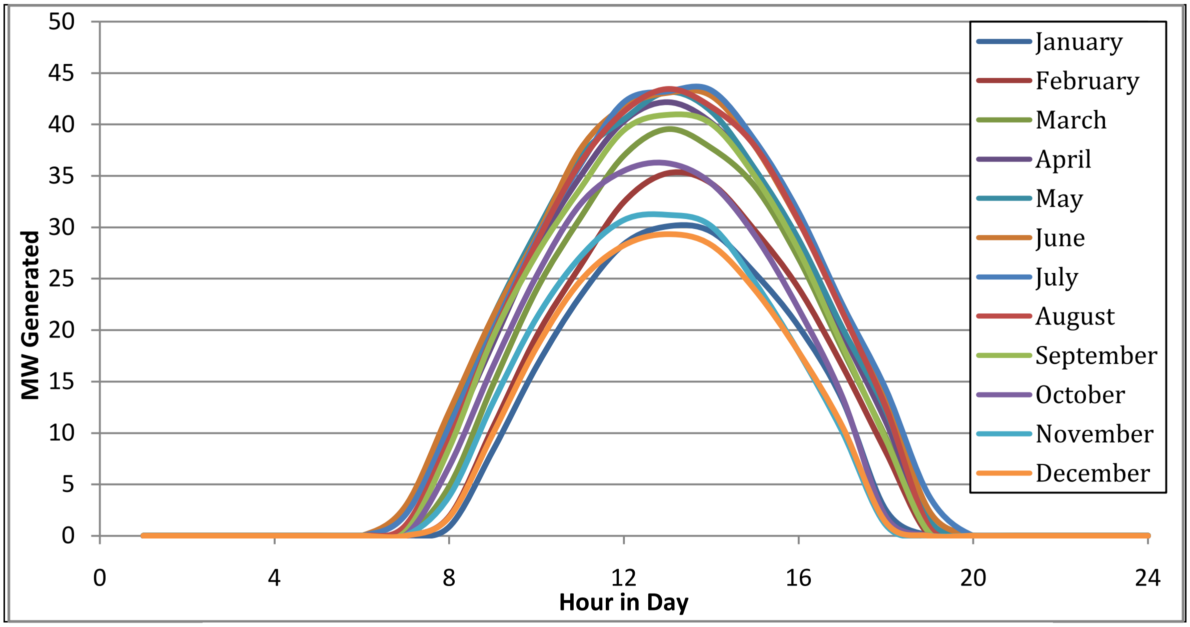


Figure 3.9: Solar energy data (Renewable Resource Data Center, 2005)

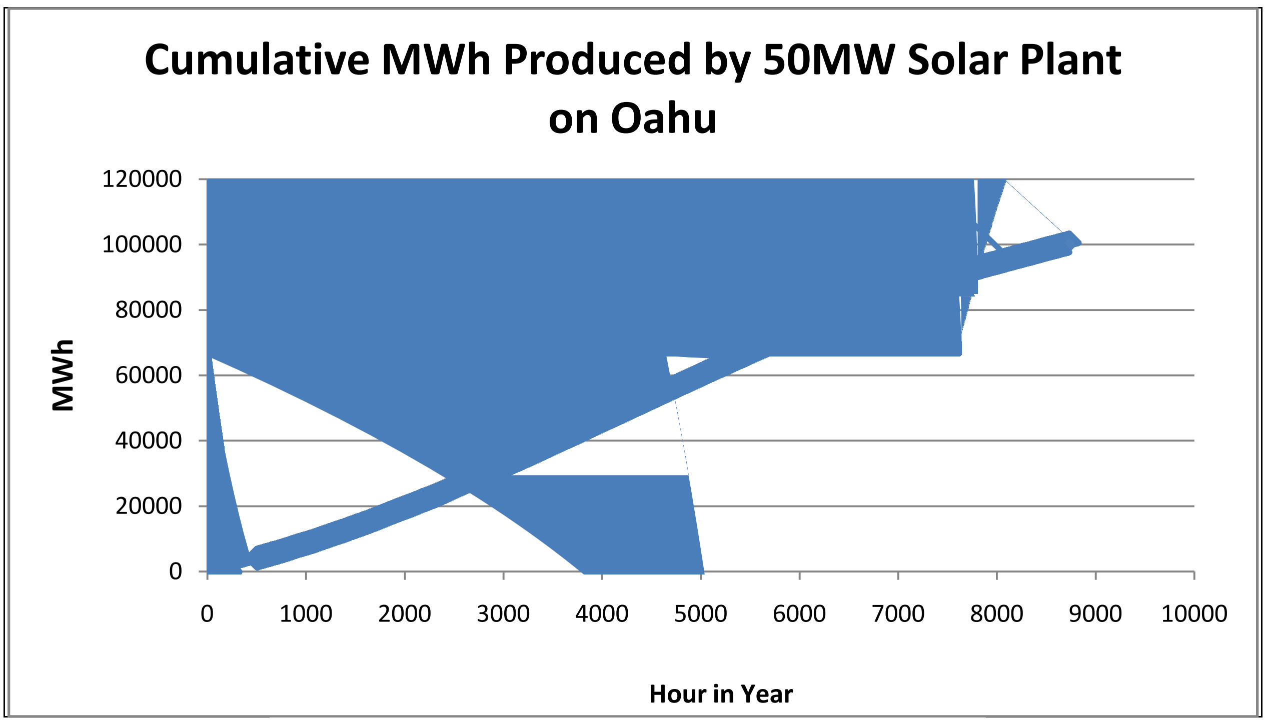


Figure 3.10: Electrical energy generated by solar on Oahu

Now, we must determine the electricity demand that Better Place will require as electric vehicles come onto the road. Using the logistic curve to represent the market penetration of electric vehicles on Oahu, we calculate the electricity demand according to equation below:

$$Vehicles \; \frac{Miles}{Vehicle\ Year} \; \frac{kWh}{Miles} \; \frac{MWh}{1000\ kWh} = \frac{MWh}{Year} \; electricity\ demand$$

Using the assumption that the miles traveled per vehicle per year on Hawaii is 8,000 miles and that electric cars can travel 100 miles on 24 kWh charge, we were able to chart the electricity demand versus renewable electricity supply as seen in Figure 3.9. The dotted lines in Figure 3.9 represent the electricity demand according to different market penetration scenarios. The solid lines represent the amount of renewable energy that may be produced on to offset Better Place's electricity demand on Oahu. As evident from Figure 3.9, the amount of electricity necessary to power Better Place vehicles cannot be met by renewable energies on Oahu.

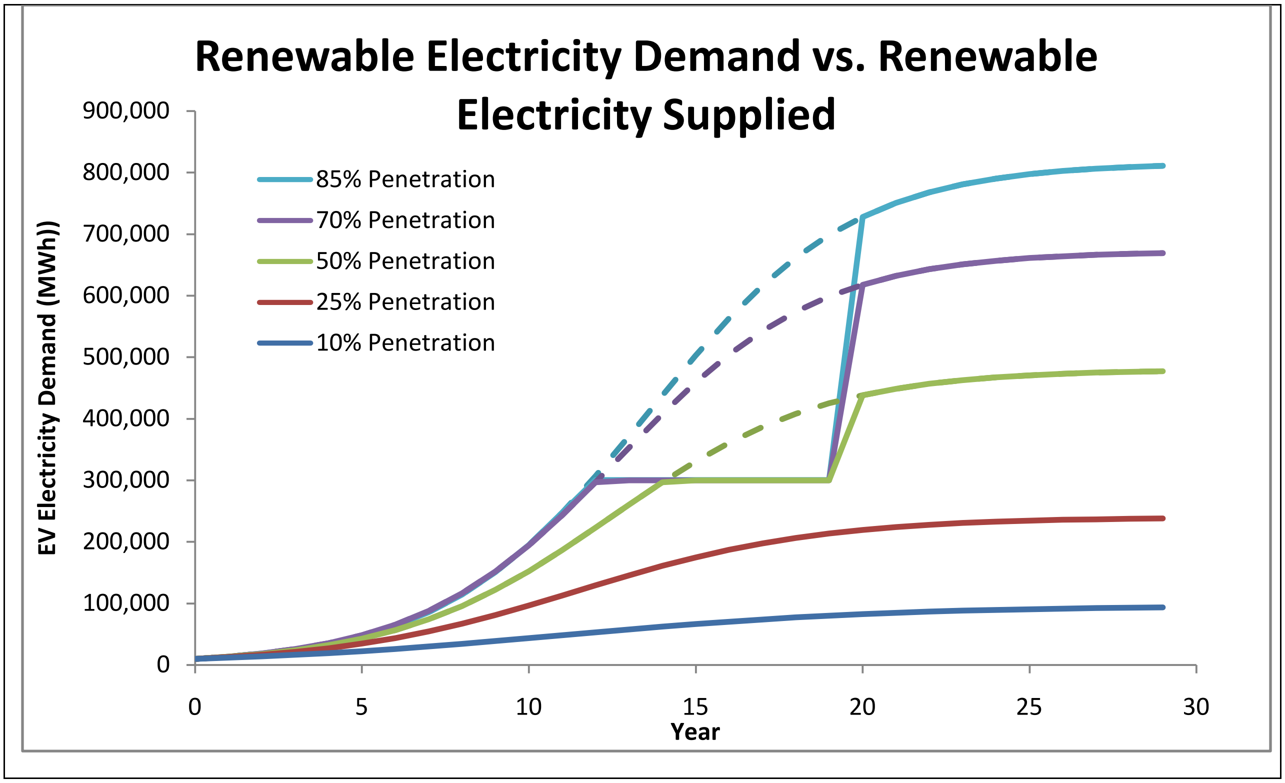


Figure 3.11: Renewable electricity demand vs. renewable electricity supply

As shown in Figure 3.11, starting in year 20 the amount of renewable energy increases dramatically because of the undersea power cable connection between Lanai, Molokai, and Oahu. Table 3.1 shows the necessary year when renewable energy projects must go online in Oahu to meet Better Place electricity demand, and shows the great influx of wind energy when the transmission lines of Molokai, Lanai, and Oahu are connected in year 2030. However, from year 2023 – 2030 Better Place will not be able to fulfill its commitment to offset all electricity used by electric vehicles with renewable energy.

Year	Solar (MWh)	Wind (MWh)			Cost
	Oahu	Oahu	Molokai	Lanai	
2010	-	100,000	-	-	$ 59,000,000
2018	100,000	-	-	-	$ 168,300,000
2022	100,000	-	-	-	$ 168,300,000
2030	-	-	260,000	260,000	$ 306,800,000

Table 3.1: Proposed Renewable Projects and Costs

Since, as mentioned before, the premium on electricity paid by Better Place depends on the renewable energy project being funded, the cost of implementation is an important factor in the Better Place business model. As shown in Table 3.1, a wind plant will be implemented on Oahu first because wind energy is much less expensive than solar power. Because only a limited amount of wind energy is available on Oahu, solar will be developed after wind as an equal-size plant costs almost three times as much at current prices. Breakthroughs in solar technology may lead to lower costs in the future, however.

Despite the inability to meet electricity demand between years 2023 – 2030, Better Place will still meet its objective to decrease carbon dioxide emissions as there will still be 300,000 MWh of electricity offset by renewable production. Figure 3.12 demonstrates the *cumulative* level of carbon dioxide abatement throughout the first thirty years of Better Place at various market penetration scenarios in the logistic implementation curve. In 2030 there is a large increase in CO_2 abatement—evidenced by the doubling of the slope for penetration rates above 30%—as the transmission lines between the islands are completed and renewable energy can substitute the energy previously supplied by petroleum fuels on Oahu between 2023 and 2030.

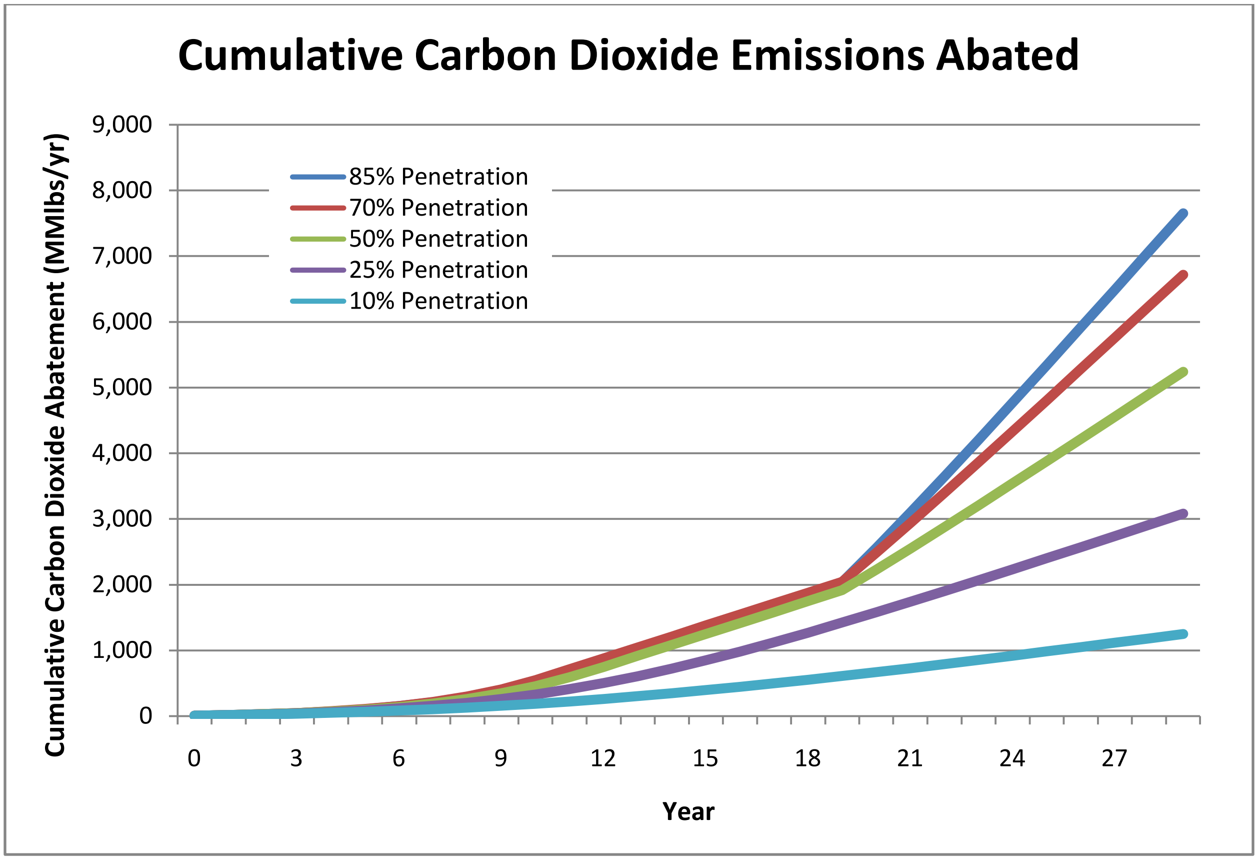


Figure 3.12. Cumulative Carbon Dioxide Emissions Abated

SECTION – IV: BUSINESS

4.1. Comparison of Locations

Better Place is actively pursuing a global presence, initially in Israel, Denmark (Copenhagen), United States (Hawaii), and Australia. Better Place's vision is to become a global provider of EV networks and services accelerating the transition to sustainable transportation. To initiate this transition, these locations have been strategically chosen for the following attributes: high gas price, abundance of renewable resources, high population density, and isolation from other cities. In this section, we examine the above mentioned locations and assess their feasibility in adopting an EV network in their current state.

In this comparison analysis, Israel, Denmark, Hawaii, and Australia were examined to select the ideal location for the feasibility study the rest of the paper discusses. The analysis focuses on potential market size, implementation cost, energy demand, and availability of renewable resources. We understand that factors of consumer acceptance, government support, network infrastructure, battery technology, consumer acceptance, and environmental concerns are significant. However, those factors were not included in this initial study due to limitations on scope. Currently, Better Place has selected Israel as its first location and plans to expand its market to Denmark and Hawaii by 2012 (Better Place Global Progress, 2009).

Better Place's plan mainly consists of two components, EVs and the charging and swapping stations. In essence, charging stations and swapping stations function as gas stations. In the first phase of implementation, Better Place must establish enough charging stations and swapping stations to provide accessible service to early adopters of EVs. In order to remain economically viable, it is essential that Better Place targets heavily populated cities to minimize the installation and operation cost of charging stations and swapping stations.

	General (2009)				Transportation (2005)						
	Population	Area (mi^2)	Population Density (person/Km^2)	Average Gas Price (USD)	Average Annual Population Growth Rate, 1980-2000	Road traffic (million vehicle-kilometers)	Passenger Cars per 1000 People	Total Road Network (km)	Total Vehicles per km Road	Disel Oil Consumption (Liters per person)	Motor Gasoline Consumption (Liters per person)
Hawaii	1,288,198	6,470	72.9	$3.37	0.9%	13 318	319	11 242	115	409	1,029
Australia	21,885,016	2,967,909	2.6	$3.79	1.3%	215,120	520	812,972	17	415	924
Denmark	5,519,441	16,640	127.9	$7.53	0.2%	45,505	360	71,847	33	463	432
Israel	7,411,000	8,522	342.0	$5.87	2.4%	39,118	232	17,253	115	191	402

Table 4.1. General and transportation statistics on Hawaii, Australia, Denmark, and Israel

Table 4.1 illustrates general and transportation statistics of each location. While large population alone does not equate the market size, population along with the number of passenger cars per 1000 people provides a clearer picture of potential market size. These 4 locations have a large number of passenger vehicles per 1000 people. Hawaii has a population of approximately 1.3 million and 319 cars for every 1000 residents, this equates to approximately 410,000 vehicles. Denmark has a population of roughly 5.5 million and 360 cars per 1000 people, this translates to approximately 2 million vehicles in the country. Israel, which is Better Place's first destination to implement its infrastructure, has a population of 7.4 million and 40,000 vehicles per 1000 people which equates to 1.7 vehicles. Israel also has the advantage of having the most vehicles per square mile (Friedman, 2008) (GoHive: Global Statistics, 2009).

While Australia has the largest population and the most vehicles per 1000 people, it has the lowest population density of 2.6 persons/km^2, far below the other 3 locations. The other three locations have much higher population densities. Hawaii has a population density of 72.9 persons/km^2; Denmark has a population density of 127.9 persons/km^2; and Israel has a population density of 342 persons/km^2. As a comparison, the average population density in the United States is 31 persons/km^2. High population density translates to lower installation and operating cost of swapping stations which are essential for Better Place to stay economically viable (GoHive: Global Statistics, 2009).

Furthermore, these locations have a unique attribute of being an "island" in a sense that these locations are isolated and most of traffic is self contained within its borders. Hawaii, Australia, and parts of Denmark are physically isolated to prevent any EVs leaving the island. While Israel is not an island, its political climate with neighboring countries has isolated the country from surrounding nations, and there is virtually no cross border traffic.

Another criterion in selecting the ideal location is the gas price. With current limitations on battery technology, the majority of expenses Better Place will derive from periodically buying new batteries for its customers. Currently, price of driving an EV is significantly higher than the price of driving a traditional gas car or hybrid vehicle. Although some of these locations have a significantly higher gas price than the United States average of $2.67, these prices will have to increase in order for Better Place to stay competitive against gas powered vehicles. Currently, Hawaii and Australia have slightly higher gas prices at $3.37 and $3.79, respectively, while on the other hand, Israel and Denmark have significantly higher gas prices at $5.87 and $7.53. The main reason behind these high gas prices is various taxes each government imposes. In Israel where approximately 90% of oil imports come from former Soviet Union countries, only 35% of the final gas price is the price of oil, and the rest is represented in various forms of government tax and profit margin (GoHive: Global Statistics, 2009), (PM raises energy issue in Moscow, 2006).

Denmark, which has one of the highest gas prices in the world, is one of the few nations that gained energy independence from foreign oil through focused and systematic efforts since the late 1970s. By implementing high taxes on gasoline, carbon dioxide, and building and appliance efficiency standards, Denmark has halted its growth in energy consumption while continuing to grow its overall economy and creating one of the most competitive clean energy industries in the world. Denmark's high tax on gas has had a positive impact on its economy and society. It has created numerous jobs in clean energy industry, most notably in the wind industry. Denmark currently generates 20% of its total energy from wind power (World Resources

Institute, 2009). In addition, the high gas price has encouraged its citizens to take bicycles to work, leading to a healthier lifestyle.

	Electricity Consumption (2005)		Energy Production by Source (Thousand Ton of Oil Equivalent) (2005)				Trade in Energy - Import (Thousand Ton of Oil Equivalent) (2005)		
	Electricity Consumption (kWh per person)	Total Electricity Production (GWh)	Total Energy Production	Coal and Coal Products	Natural Gas	Oil and Petroleum Products	Coal and Coal Products	Natural Gas	Oil and Petroleum Products
Hawaii	8,203	10,567	428*	0	0	0	13,370	78	42,542
Australia	11,221	245,140	268,192	206,507	33,416	0	0	0	31,096
Denmark	6,662	36,355	313,353	0	9,402	0	3,561	0	8,759
Israel	6,759	49,843	2,064	0	0	0	7,943	0	14,509

*All Hawaii's energy production derives from renewable sources

Table 4.2. Energy production and energy import of Hawaii, Australia, Denmark, and Israel

Table 4.2 illustrates electricity consumption, energy production, and each location's dependency on oil. None of these locations produce oil or petroleum products. All of their oil and petroleum products are imported and mostly used to fuel vehicles. In Hawaii, however, fossil fuel is used to fuel cars as well as to generate electricity. With the exception of Denmark, it is clear these locations are heavily dependent on fossil fuel. Australia imports about 31,000 thousand tons of oil; Denmark imports about 9,000 thousand tons; Israel import about 14,000 thousand tons; and Hawaii imports approximately 43,000 thousand tons. Given the variation in population among these locations, Hawaii by far imports the largest amount of oil and petroleum products per resident (GoHive: Global Statistics, 2009).

A major concern for implementing an EV infrastructure is the extra load EVs will put on the current grid system. However, as our analysis of Hawaii in Section 3.1 previously shows, electricity load from Better Place vehicles will be small compared to the current consumption of electricity.

	Nationwide/Statewide Energy Consumption by Source (Thousand Ton of oil Equivalent per Year) (2005)								
	Biogas and Liquid Biomass	Solid Biomass	Coal and Coal Products	Hydroelectric	Natural Gas	Nuclear	Oil and Petroleum Products	Solar, Wind, Geothermal, and Wave	Energy Consumption per Capita (Kg of oil equivalent per person)
Hawaii	N/A	700	13,370	77	78	0	42,542	791	6,145
Australia	247	4,818	53,176	1,336	23,045	0	37,882	150	5,897
Denmark	91	1,648	3,714	2	4,398	0	8,199	490	3,634
Israel	0	4	7,633	2	1,289	0	9,979	691	2,816

Table 4.3. Energy consumption by source of Hawaii, Australia, Denmark, and Israel

Better Place's main goals of reducing oil dependency and creating a cleaner form of transportation by the use of EVs relies on these locations' ability to generate clean energy to power the infrastructure. Although these locations generate a fair amount of energy from renewable resources, most of their energy is derived from fossil fuels. While some of these locations have an abundance of renewable energy resources, they have not been fully developed to provide a steady source of energy. In order to fulfill Better Place's commitment to only using renewable energy to power its EVs, these locations must explore their energy options and develop alternate ways to generate electricity (Better Place Global Progress, 2009).

4.2. Business Assessment

Better Place wants to bring in a shift to EVs and their major strength if they are successful would be to eliminate the dependence on rising gas prices as a result of limited oil reserves, provide new job opportunities and reduce the emission of CO_2 into the environment (BetterPlace, 2009). However, an innovative marketing strategy is required for the success of this project in Hawaii. In order to build a strong marketing strategy, various factors have to be considered.

Better Place's business model is related to creating an infrastructure for charging and running EVs. This infrastructure will consist of charging stations at home as well as at public places, swapping stations, and software grid. Software grid is a soft ware platform which tells the customers where to charge there batteries, it also helps the process engineers to mange thousands of vehicles that have entered their power grid to charge their vehicles. Better place would be the owner of the batteries and the customers would buy miles from the company as we buy minutes from a mobile company. Hence Better Place must keep track of all the information regarding batteries such as their capacity, no. of miles driven on that battery and when it needs to be changed so that they can bill the customers accordingly. The software system called AutOS directs the customers to a swapping station if a fresh battery is required. This software system operates on Microsoft's Windows Embedded software on an Intel Atom processor. A video tells the customer about the closest charging station and also gives information about how far the EV can still go without charging. (WOODY).

Though Better Place is trying to establish a strong hold on the world recharging networks, other equally competitive companies have emerged, including Coulomb and Project Get Ready(a branch of the Rocky Mountain Institute). Also ECOtality, a charging network company based in Scottsdale, Arizona is fast making an impact with its 10-15 minute fast-charging capabilities. eTec is a subdivision of ECOtality. The company has deals with Vancouver, British Columbia, Tucson, Arizona and Ireland for battery car charging deals and offers a huge threat to Better place. It's also working with the Renault-Nissan Alliance, another competitive infrastructure provider (Motavalli, 2009).

4.2.1. Market Research

Better Place conducted a multinational survey to evaluate the market response for electric cars. Better Place specially made global market research firm Ipsos to find out if there is enough market potential for electric vehicles (O'Dell, 2009). The polls were conducted in five different countries, U.S, Israel and Denmark, the greater Toronto area of Canada, and the Brisbane, Melbourne and Sydney areas of Australia during March and April of 2009. During this period, the gas prices were relatively low compared to the average prices. The polls were conducted in the worst case scenario. Hence EV's cannot be called economically feasible until and unless the gas prices go very high.

Better Place conducted a market research where more than 8000 people were asked about their preference to EVs over gasoline vehicles for their next vehicle. The U.S. came last in the research, with only 30 percent of consumers expressing their interest in an electric car for their next vehicle purchase. Though it came last, it still indicates 1 in 3 consumers will purchase an EV. However, according to the trade analysts, EVs won't take up more than 15 cent of the U.S transportation market (O'Dell, 2009).

4.2.2. Market SWOT Analysis

Strengths

Better Place has a huge government support as well as government funding in Hawaii. This is evident from the fact that Obama Administration announced $8 billion in conditional loan commitments for the development of innovative, advanced vehicle technologies. (DOE, 2009) Better Place will not use petroleum to generate electricity in order to have a zero carbon footprint. Hawaii Governor Linda Lingle agreed to offer tax breaks and various other offers so that more and more customers buy electric vehicles but the state won't provide any funds to build the infrastructure. (place)The project has generated huge publicity and is a visionary idea with which Shai Agassi, CEO of Better Place was able to raise 300 million for the project. (LaMonica, 2009). He was ranked among the 100 most influential people by TIME magazine in 2009 and was also among the "Heroes of the Environment 2008. (BetterPlace, 2009)

Weaknesses

The company Better Place is relatively a new brand and has to work on improving its brand image. The company has limited man power (Dun & Bradstreet, 2009) and since it's new in this field it does not have an expertise in car technologies and energy resources. From our estimation of costs EV's are more expensive than gasoline vehicles. Better place was officially launched in 2008. (BetterPlace, 2009)

STRENGTHS • Government support • Visionary idea • Publicity	**WEAKNESS** • No expertise in car and energy segment • Limited man power • Expensive
OPPORTUNITIES • New Technology • Independence from gasoline • R&D for new technologies in electricity generation	**THREATS** • Electricity being produced from fossil fuels • Failure of idea and investment • Customer dissatisfaction • Insufficient market for the product • Threat from petroleum industry

Table 4.4. SWOT Analysis

Opportunities

Hawaii has potential sources of renewable energies like wind, solar, geothermal and wave power to generate energy for the electrical infrastructure. Hence it gives us an opportunity to develop new technologies as well as independence from petroleum. And in countries like Israel where the gas prices are relatively higher, EV's are an economic option.

Threats

From the "penetration model" the electricity demand can be fully met up to a 30% maximum market penetration level without the undersea cables. Hence there is a threat of electricity being produced from fossil fuels. Another major threat for Better place is failure of the idea. Though Better place has done a brief market research it was limited to around 8000 people only. From the "competitor analysis" it's evident that EV's are relatively more expensive than Gas and HEV's. Hence the market for Better Place is pretty slow. Since this project aims at independence from the petroleum, this industry may impose a major threat to Better Place as it has a monopoly on the Transportation Industry for the past 100 years. (BetterPlace, energy, 2009)

4.2.3. Development of a Marketing Strategy and Implementing a Plan

Product, Branding, and Advertising

Since Better Place is a new company, an advertising campaign needs to be launched in order to become popular with the customers. Advertising is one of the most successful ways to make a car buyer aware of the new car with various promotional and discount offers. Various marketing strategies are packaging, innovations, push pull strategy, internet marketing and quality control. Better Place must provide many innovative features to attract car lovers. (Marketing strategies) Internet advertising is another major source of advertisement. Of the different types of internet advertising, the most effective one is by introducing the brand through video clipping and interaction on various websites. By offering a video Better Place can make a major impact on the consumers' minds. Common strategies include contributing informational videos, emphasizing on quality and service and creating an online community that relates to the company. By offering Better Place as not only a company, but also a "friend," initial interest from a customer can turn into brand loyalty.

Pricing and Product Strategy

There are various factors to be considered to evaluate costs of a Better Place plan. From our estimation the costs are evaluated as $231 for a plan without a car. Better place can have various discounted plans that can be introduced in various intervals to attract customers. As far as the product is considered Better Place can have a contract with various other car companies and give wider car options to customers (Marketing strategies).

Place

The Dealership Better Place signs is very important. A company's commercial success depends a lot on the dealership. There can be various channels of distribution. The physical location and method of distribution plays an important role in the success of the company. Hence Better Place must employ staff and maintain a good data base record and design a linear flow model such that there are enough buffers at various points and none of the tasks are delayed (Marketing strategies).

Maintenance and Support

Service is another important marketing strategy for most of the customers to choose the right car. Hence Better Place should have a good service system by having a well maintained grid system for charging electric cars and replacing batteries at regular intervals (Marketing strategies).

4.3. Economic Feasibility

4.3.1. Background

Upon analyzing the infrastructure and energy feasibility of Better Place in Hawaii, research was done to answer the question "Is Better Place economically feasible right now?" Before diving into the details of modeling and the assumptions, it is important to define what it means to be economically feasible. There are two elements for economical feasibility in this case, 1) is it going to be profitable for Better Place Group? 2) Is it going to be economically feasible for the consumer? If both the answer to both of these questions is yes, then it could feasible for Better Place to enter the Hawaiian market.

4.3.2. Modeling Parameters

To evaluate the economic feasibility for Better Place, a financial model was created based on all the assumptions and information gathered through research. From this financial model, break even prices for monthly plan costs could be determined based on inputted parameters.

Assumptions

Before running the financial model, it was important to gather credible parameters as inputs for the model. One of the assumptions for the model was the length of time modeled, which was

20 years. Although 20 years in the future is very uncertain and usually start-ups are valued up to 10 years, the assumption of modeling out 20 years was used in order to outline the full potential of EV's. Other assumptions of the financial model are:

- Tax rate of 35%
- Interest Rate of 5%
- MARR of 10%

Revenue

From extensive research on the business plan of Better Place, it is clear that the main source of revenue comes from the monthly plan fees from the user. Like a cell phone plan, the user pays a monthly fee for allowable minutes (miles), and different plans are available for those who talk (drive) more and those for less. The amount of users using Better Place was modeled using a penetration curve of 70%. An assumption made was that Hawaiians drive about 8000 miles annually. In the results section of this report, more analysis will be done on the quoted price for the monthly cost- specifically finding the breakeven price of the monthly plan cost.

Another form of revenue for Better Place will come from the resale of its old batteries. At the end of the reusable life of the battery (usually 6 years), Better Place plans on selling these batteries to other customers, and/or recycling them and re-using them again. For the current model, we assumed that Better Place would be selling the old Batteries at a market value determined by recyclable potential. As of 2000, for smaller lithium-ion batteries, the cost to recycle a battery was $2.25/lb (Cost of Lithium Ion Batteries for Vehicles, 2000). Assuming the price for large-scale recycling starts at that price, for the 440 lb battery, Better Place can still end up salvaging $3190 per battery to spend on future purchases.

Costs

There are several costs associated with Better Place's business model. One main assumption for our model was that these costs stay constant over the 20 years of modeling. Although this is not particularly realistic, forecasting future costs could be just as uncertain and was out of the scope of the project.

Charging stations: As mentioned earlier, the charging stations cost $1500 to build (Leone, 2009). To estimate the amount of charging stations Better Place would initially build in Hawaii, a ratio of charging stations/cars was used from the Better Place Israel Project. This was a ratio of 5 charging stations per car (Macdonald, 2008). We assumed that the number of charging stations built after the first year would increase with the number of subscribers at a ratio of 1.1 charging stations/ car.

Swapping Stations: The swapping stations cost $500,000 each (Macdonald, 2008) for the infrastructure and about $300,000 for the property. The operating costs per year were estimated at $300,000 to include managing the infrastructure (i.e. employees, electricity, etc.) and transporting the batteries from other charging stations. An estimated depreciation of $40,000/year, based on car washing station depreciation amounts (Car Wash Business Plan, 1995). The model assumes 5 swap stations being built in the first year, then increasing by one each year until 10 swap stations are built.

Batteries: The cost of batteries used is $12,000 (Garthwaite, 2009), which will be provided by A123Systems. The life of the battery, assuming members drive 8000 miles yearly is 6 years. The residual value of the battery is calculated from potential recycling capabilities at $ 3190. Depreciation assumed to be straight lined over 6 years, (Initial Price - Residual Price)/6 year, which comes out to $ 1560/yr.

Cost Of Miles Sold: The cost of miles sold is essentially energy costs. Better Place plans to pay a premium to buy power from new incremental renewable power projects on long-term contracts to match the number of Better Place cars on the road. The cost is estimated at 0.3 $/kWh (Sudick, 2008). An assumed charge efficiency of 90% was used along with a vehicle efficiency of 4.17 miles/kWh, which translates into a cost of 0.08$/mile.

Other: Estimated marketing costs were $5 million per year. A tax rate of 35% and an interest rate of 5% were used in the calculation. The model did not take into account of the interest payments for capital raised, as no information for funding was available for the Better Place Hawaii project.

4.3.3. Model Construction

Income Statement

One of the elements of the model was the income statement. Essentially, this part of the model captured revenue from monthly plans and gain on sales of batteries while also the costs of miles sold, operating expenses, depreciation and taxes. An assumption made was that no taxes were paid if the EBIT (earnings before interest and taxes) was negative.

Cash Flow

The cash flow statement calculates the operating cash flow, cash flow from investment activities and financing activities. The operating cash flow adds back depreciation, while the investment activities include purchasing swapping stations, charging station, and batteries. No cash flow from financing activities was present in this particular model.

4.3.4. Results

Breakeven Price

One of points of interest from the financial model was determining the breakeven cost for Better Place's monthly plan. With a MARR of 10%, Better Place would need to charge at least $231 a month to be profitable. At this monthly plan cost, Better Place would have a payback period of almost 17 years. This makes it unlikely that Better Place would only charge $ 231 a month because it would be very difficult to encourage potential investors to invest with that long of a payback period.

MARR Sensitivity: A hurdle rate of 10% was chosen to calculate the breakeven price for the Better Place model because it reflects historical returns of the S&P 500. Typically, the S&P yields returns somewhere between 9% and 11% (istockanalyst, 2008), which is why many companies use these values as their hurdle rate. Generally larger values of MARR are used for more risky projects, so an analysis of MARR sensitivity is valuable.

MARR	Breakeven Monthly Price
8%	$ 214.70
9%	$ 223.11
10%	$ 231.70
11%	$ 240.44
12%	$ 249.35
13%	$ 258.49
14%	$ 267.85
15%	$ 277.39
16%	$ 287.17

Table 4.5: Breakeven prices

Cost Breakdown

The cost breakdown can be seen visually by referring to the Figure 4.1. From the graph, it is easy to see that purchasing batteries accounts for the majority of the costs. Repurchasing a large majority of the fleet of batteries every 6 years can become very costly to Better Place. Cost of miles sold appears to be the second most significant cost. The cost of actually building the infrastructure is surprising very minimal when compared to the battery costs.

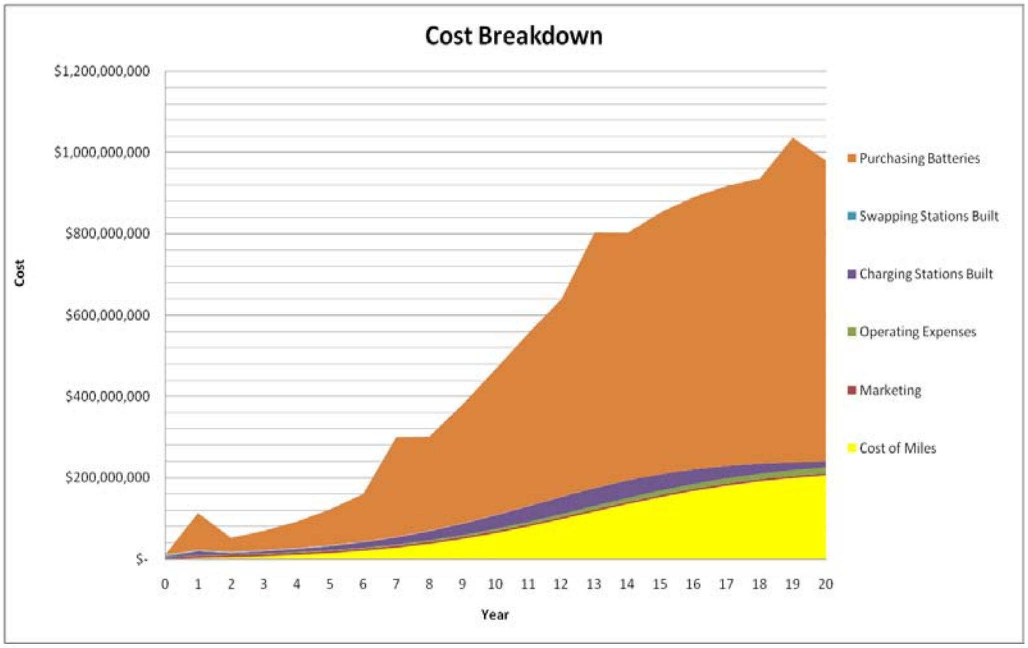


Figure 4.1: Cost breakdown graph

4.4. Discussion

4.4.1. Current Economic Feasibility

Given that a Better Place plan will cost at least $ 231 a month, it is logical to state that Better Place is not the most purely economical choice currently in Hawaii. For example, when compared to the gasoline version of the Renault Fluence:

Car Lease Payment(EV)

Initial Price		15000
Lease months		36
Residual %		0.6
Residual Value		9000
Rate		7%
Monthly Payments	$	185.26
BP plan	$	231.70
Total Monthly Cost	**$**	**416.96**

Car Lease Payment (gas)

Initial Price		20875
Lease months		36
Residual %		0.6
Residual Value		12525
Rate		7%
Monthly Payments	$	257.82
Gas Cost	$	66.67
Total Monthly Cost	**$**	**324.49**

Figure 4.2: Comparison of price of an EV and a conventional vehicle

Note that the gas Fluence has an average MPG of 35 (Renault Fluence engines, 2009), but costs $6000 more than the EV. The gasoline cost per month is calculated by using Hawaii's current gasoline price $3.45/gallon (www.hawaiigasprices.com, 2009). According to this comparison, the EV would cost at least $ 100 more per month to drive around Hawaii. The price of gasoline has to be above $ 8.00/gal before the gasoline vehicle would cost as much as the Better Place EV. Another way one could look at it is that the government would need to put a carbon tax of $ 510 per metric ton of C02, which is equivalent to adding a tax of $ 4.5 per gallon of gasoline purchased (assuming Better Place's vehicles use only energy from renewable sources). These results may seem surprisingly large, but the fact is that Hawaiians drive only 8000 miles every year, making the payback for the EV much longer than if they drove more miles. However, if an individual were to drive 15,000 miles/yr, then the gasoline cost threshold of switching to the Better Place EV would be $ 6.00 / gallon – which is comparable to the cost of gasoline in Better Place's pilot market, Israel.

4.4.2. Future Feasibility

Although Better Place is not the most economical option in Hawaii right now, it could be soon in the future. There are two realistic events that would really encourage drivers to move towards Better Place and electric vehicles. The first is a reduction in the monthly plan cost of Better Place through improved battery technology and the other is an increase in fuel prices. If both of these events simultaneously occur, then the shift towards electric vehicles could occur sooner than later.

Batteries

From figure 3.1, it is clear to see that the cost driver for Better Place is the purchasing of batteries. There are three main solutions that could minimize the cost for Better Place in this area, they are: 1) Decrease in battery price 2) Increase in battery life 3) Increase in battery recyclability.

	Current State	Needed Improvement
Battery Price	$12,000	$8,000
Battery Life	6 years	10 years
Battery Recyclability (% of initial value)	33%	60%

Table 4.6: Battery price comparison

The Current State column in Table 4.6 highlights the current costs, life and recyclability of batteries. The Needed Improvement column highlights what costs, life and recyclability need to be in order to cost the same to own as the gasoline version of the Renault Fluence. However, it should be noted that the improvements were calculated independently from each other, so a smaller combinations of events (i.e. 40% recyclability with a longer life) could result in the same effects as one large improvement.

Rising Price of Oil

As gas prices become more expensive, the cost to operate internal combustion engine (ICE) vehicles becomes more expensive as well. Eventually, the cost of both operating an EV and an ICEV would equilibrate and users would be more inclined to move towards EVs. As mentioned previously, the price of gasoline would need to reach $8/gallon in Hawaii to reach this equilibrium. However, for users who drive more, this equilibrium price becomes much lower. Also, if battery costs decrease at the same time thus decreasing the price of driving an EV, the equilibrium price will also be lower.

4.4.3. Competition

Better Place wants to use the technology currently available to reduce gasoline dependence. Since battery technology is holding back electric vehicles, Better Place is taking responsibility for the battery by leasing it out and implementing battery swapping stations. However there are many other companies looking to compete in the electric vehicle market that pose threats to Better Place.

Consumers have a wide selection in fuel efficient and electric vehicles. They can choose from cars with ICE, hybrid electric vehicles (HEV), plug in hybrid electric vehicle (PHEV), and EVs Each presents its advantages and disadvantages. ICE and HEV despite improved fuel efficiency, up to 48.4mpg (Toyota Prius), still rely on gasoline as its only source of fuel. Currently batteries in EV's are too expensive and do not hold enough charge for a mass consumer market. The added cost of the battery in a PHEV is also significant. These costs were calculated by considering the fixed and variable costs for each vehicle.

PHEV: HEV + cost of batteries + cost of gasoline + cost of electricity
HEV: Cost of HEV + cost of gasoline
EV: Cost of EV + cost of electricity
ICE: Cost of ICE + cost of gasoline

Hawaii's cost of electricity is $.22/KWh and $3.45/gallon of gasoline. The fuel efficiencies used are real experimental results from Google, where they simulated real life driving conditions. (RechargeIT, 2008) The PHEV was a converted Prius with a 5 KwH battery installed. The average MPG and total variable cost/ 100 miles are show in Figure 4.3 and Figure 4.4 respectively.

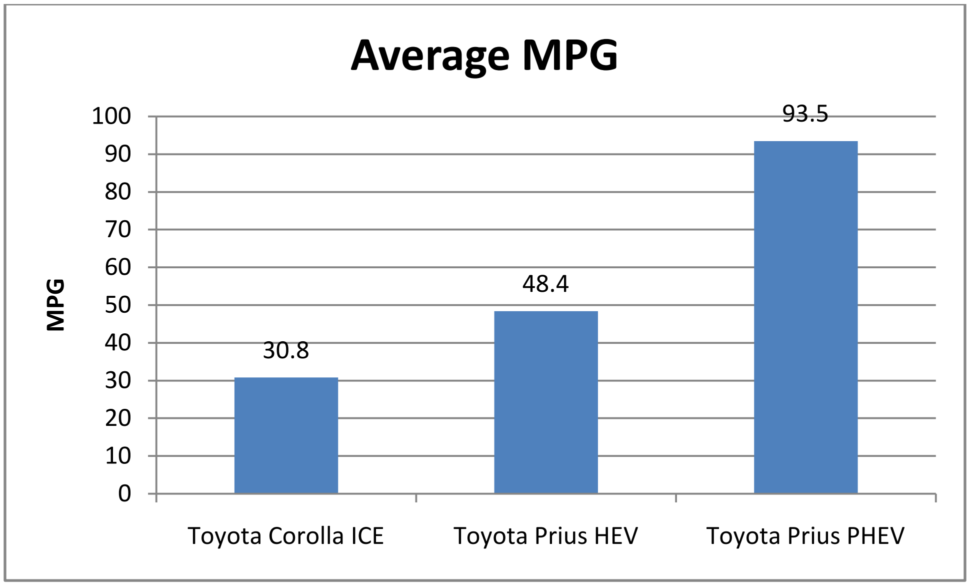


Figure 4.3: Gasoline Fuel Efficiency of cars.

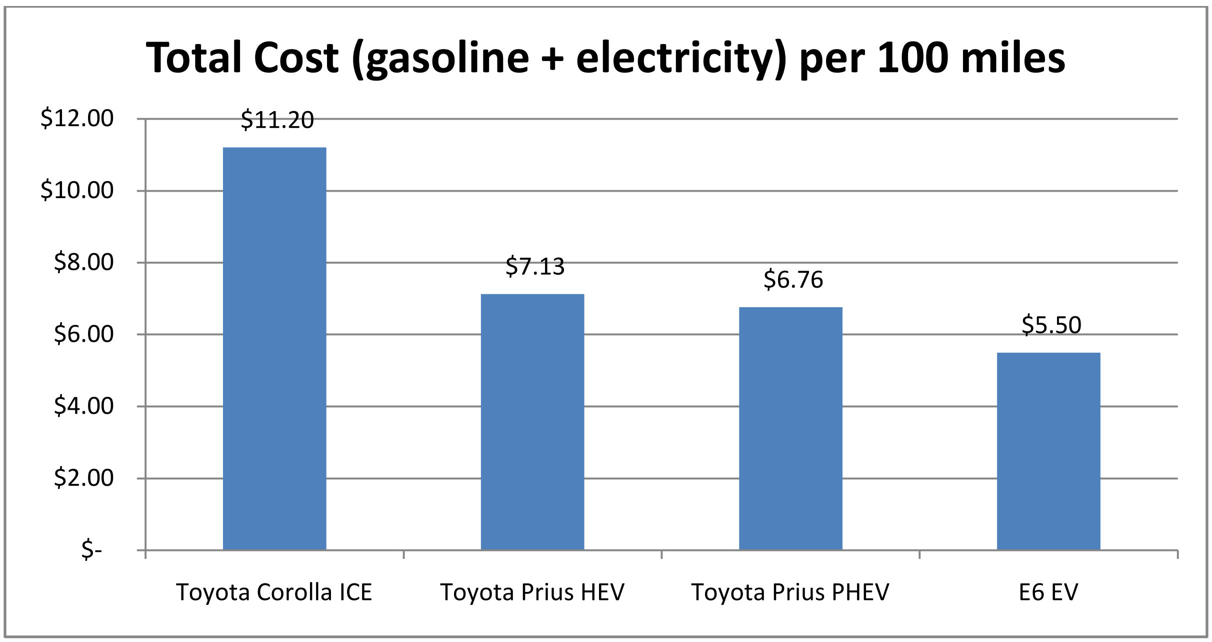


Figure 4.4: Total Cost: variable cost / 100 miles

Hawaiians on average drive 8000 miles/ year. Taking a 15 year lifetime of the cars the total cost/year is show in Figure 3.

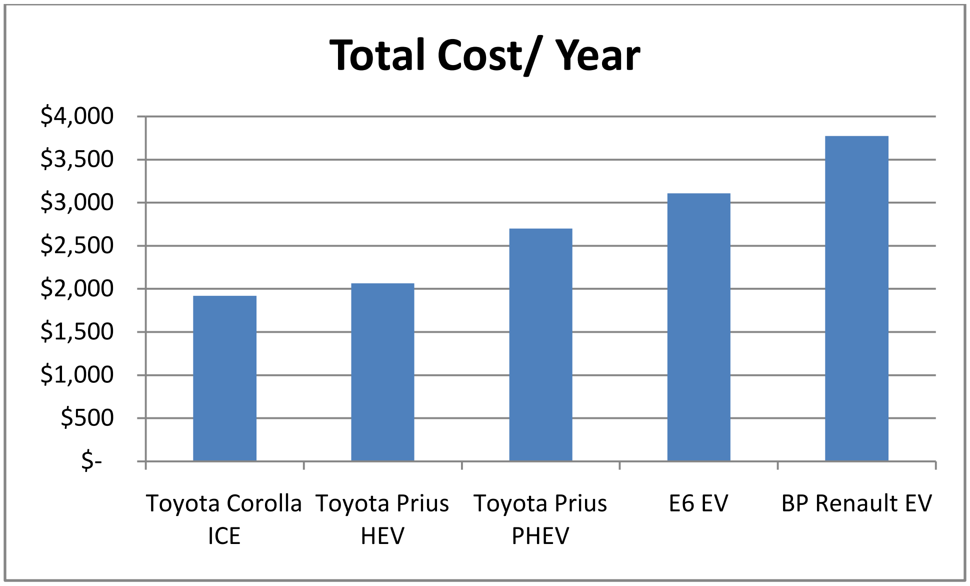


Figure 4.5: Total Cost/ Year of each type of car

These results show that currently ICE and HEV are is still the cheaper options for consumers. The high cost/year of EV and PHEV is due to the higher initial cost of buying the vehicle but money is saved on driving. With these current conditions, Better Place is at risk versus the other options avaliable. They will have to rely heavily on the green aspect of the company for consumers to pay the premium however this market base may not enough for Better Place to be successful.

Better Place can benefit from a carbon tax since EVs and PHEVs can be all or part carbon free. Based off of Figure 4.6, Figure 4.5, and 8000 miles driven for year, a carbon tax of $.3/lb carbon emitted will make the BP Ranoult EV break even with the Toyota Corolla. This was caluculated by setting the total cost/year of the Toytota Corolla equal with the BP Ranoult EV. Figure 4.7 shows the total cost of each type of car with the proposed carbon tax. Tax incentives can also be given for carbon saved so a $.3/lb will lower the yearly cost to the Corolla price.

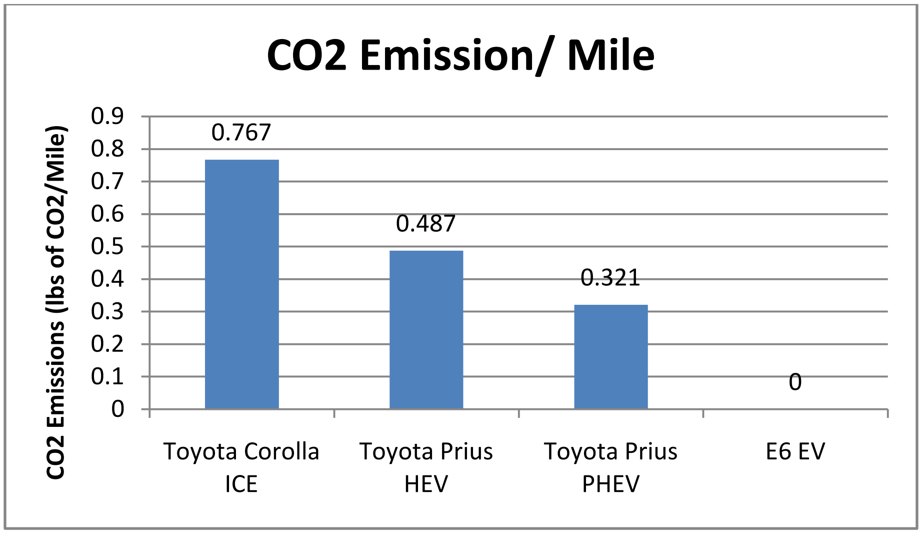


Figure 4.6: CO_2 Emissions/ Mile for each type of car

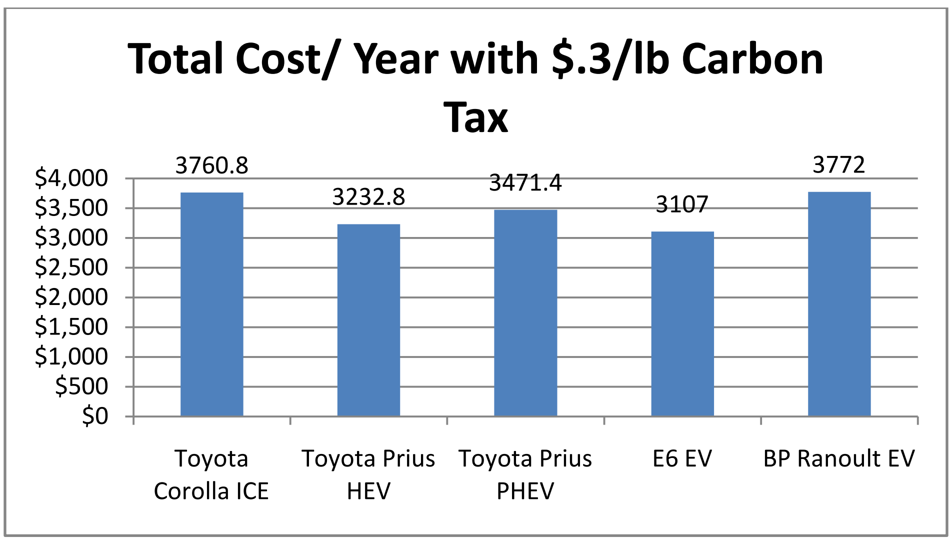


Figure 4.7: Total Cost/ Year for each type of car with carbon tax

Other car companies, particularlly Build Your Dreams (BYD) will effect Better Place's success. BYD, an automaker in China, who's expertise has been in battery technology has released PHEV and EVs in the Chinese market at average consumer prices ranges. The F3DM and F6DM are the PHEV models priced at $20,000 US with 60 miles of electric range (Blanco, 2009). The EV6 is an EV with 186 miles on a full charge with quotes prices just over $40,000 US with a 2010 release date (Korzeniewski, 2009). These cars were shown at the 2009 Detroit autoshow. If these cars really perform as stated, they will revolutionize the PHEV and EV market due to its performance at low prices. A niche market willing to pay more for "green cars" will most likely choose the EV6 over Better Place, epecially since average Hawaii's drive 24 miles/day.

The EVs and infrastructure are part of Better Place's overall plan but their real strength is in setting up the car-electricity network. Better Place consists mostly of software engineering from Shai Agassi's former company SAP (Roth, 2008). This network will allow cars to tell the grid how much charge they were carrying and how much more they required. The system has to know where the car is when telling the driver battery swapping locations. These cars had to communicate with the electric utility companies to regulate when charging can take place so electric cars will not overload the grid. However General Motors is looking to do the same. GM makes its own cars and has been operating OnStar since 1997 (OnStar, 1997). OnStar has 5 million subscribers and can use its audio interface to contact OnStar representative for emergency services, vehicle diagnostics and directions. Meanwhile the system can monitor a car's location, speed, if air bags are deployed, and maintenance records (OnStar, 1997). As the carmaker GM is in the position to package the service charges directly with the car. As Byron Shaw, who manages GM's advanced technology office in Palo Alto, states "Do you want another bill from another service provider that has nothing to do with your vehicle? Buying the battery from General Motors with the vehicle and the financing agreement in one integrated package is the advantage an OEM (original equipment manufacturer) provides" (Goldstein, 2009) Despite GM's competition, it is still possible that Better Place work with other EV makers to install the Better Place network in their cars. For example, BYD's E6 can ultimately be charged and managed with Better Place technology.

4.4.4. Government Incentives

For Better Place to be successful in Hawaii or the U.S. in general, government incentives play a major role. Better Place's success so far in Israel has been mainly because of the various incentives given by their government through federal loans and tax incentives. For the U.S., the government has been introduced for financing research, development and promotion of the electric vehicles. Development of electric vehicles would be an important aspect for Better Place to be successful, as it would improve the quality and help build cost-effective components, reducing the monthly expenditure of the user and make Better Place more attractive to the customers.

In June 2009, the US government announced $8 billion in loans to various car manufacturers to develop and improve various aspects of electric cars. (U.S Department of Energy, 2009) The loan includes $5.9 billion given to Ford Motor Company to develop fuel efficient vehicles in its various factories located all over US and $1.6 billion to Nissan North America, Inc. to develop electric vehicles and build an advanced battery facility. Since the battery is the main cost driving factor in an electric car, reducing the battery cost would reduce the monthly expenditure of the user. This would make Better Place become more feasible in Hawaii. There was also $465 million loaned to Tesla Motors to manufacture and develop their existing electric vehicles. "These were part of the first round of conditional low cost loan commitments reached from the $25 billion Advanced Technology Vehicles Manufacturing loan program, a federal program aimed at helping automakers develop and produce more fuel-efficient vehicles." (U.S Department of Energy, 2009)

In addition to the above loans the Department of Energy also announced $2.4 billion (U.S Department of Energy, 2009) in loans to develop and manufacture next generation of batteries and electric vehicles. Out of the $2.4 billion, $1.5 billion is being given to US car manufacturers to develop highly efficient batteries which would help manufacturing better batteries and potentially lead to the reduction of the breakeven cost of Better Place. $500 million of the loan was granted to manufacturers to produce various other components required for electric cars. The remaining $400 million was granted to the development of infrastructure for these electric vehicles such as charging stations and swapping stations and also to train technicians about the nuances of how to operate the charging and swapping stations by providing education and work force training.

Tax Incentive

Tax incentives are a major driving force for customers to buy electric cars. Plug-in electric vehicles will qualify for a tax credit from January 2010. The credit can range from $2500 to $7000 depending on the battery capacity. (U.S Department of Energy, 2009) Also, the first 200,000 vehicles sold by each manufacturer will be eligible for a full tax credit. This would be ideal for Better Place to introduce the electric cars in Hawaii because the consumers would show a keen interest in buying the cars due to the tax incentives and also help the manufacturers price the cars in the competitive market.

Better Place signed a Memorandum of Understanding (MOU) with the Hawaiian government to build the battery charging and swapping stations and use specifically renewable sources of energy to power them. This collaboration with Better Place will help strength the Hawaii Clean Energy Initiative which is to meet the energy requirement of 70% clean energy by 2030. (Hawaiian Electric Company, 2008)

The Hawaiian government collects a gasoline tax of about 62.8 cents per gallon including a federal tax of 18.4 cents per gallon (Motor fuel taxes, 2009). To offset this gasoline tax caused due to decrease in gasoline sales and rise in the no. of electric vehicles, the government can charge a little more to the amount of electricity that Better Place buys from the government in whole sale.

4.4.5. Petroleum Industry Response

The petroleum industry does not see a major threat from the electric vehicle until a few years from now. (Voser, 2009) The major hurdle that the petroleum industry could face in the future could be from the hybrid vehicles. This is because the electric cars still have a long way to go and have to overcome many hurdles like the cost of the car and better battery technology; the recharging and swapping time of batteries has to increase in order to compete with the hybrid vehicles. The hybrid vehicles could combine both electricity for shorter distance travel and gasoline for longer distances. Also, the petrol and diesel are popular due to their convenience and there are efforts to make them cleaner by selling them with bio-fuel blended into them (Voser, 2009). Also for electric cars resource scarcity plays a major role. For example, lithium which is one of the most important components of the battery is available in large quantities, only in a few places in the world. The way electricity should be generated to power these electric cars also poses a huge challenge. Emphasis should be laid more on producing electricity from renewable sources of energy rather than generating electricity from conventional sources like coal. This would help reduce the emission of green house gases into the atmosphere and hence reduce the pollution.

Hence, in the near future the major threat the petroleum industry could face could be from the hybrid vehicles. If the battery technology, charging and swapping time are improved and renewable sources of energy are used to generate electricity then people are more likely to go in for an electric car.

In addition to this the US government is also providing $3 billion for various renewable energy projects. Thus helping in the development of clean energy which Better Place can make use of and lessening the dependency on fossil fuels to develop electricity (Green Energy News, 2009)

SECTION –V: CONCLUSION

In many ways, Better Place has been an innovative force to help countries free themselves from the reliance on fossil fuels. With the numerous alliances in the public and private industries and the expertise of successful individuals, it is evident that Better Place has a solid foundation of financial and social support. Evidence of success for the company has been seen in its first pilot market in Israel. Already there are a few hundred charge points, over $200 million in funding from Morgan Stanley, Vantage Point, and the Israeli government, and around 20,000 users already signed up to purchase an electric vehicle.

While keeping Better Place's progress in other markets in mind, this study has extensively explored the possibility of a market for Better Place in Hawaii. The main perspectives taken into account are in terms of infrastructure, energy and business. We have evaluated the individual feasibility of each of these perspectives, and then evaluated the project as a whole. We have also identified factors that could both help Better Place succeed and factors that pose as potential threats.

In term of infrastructure, Hawaii has the ability to support the use of charging and swapping stations. The Hawaiian government, along with the Hawaiian Electric company, has been taking action to promote the use of electric vehicles. This includes allocating spots for charging stations and developing a smart grid system. The infrastructure development is an essential aspect of Better Place's business model, which makes this aspect of the feasibility study very important but not pivotal.

On the energy side, the Hawaiian Islands have great potential for renewable energy, which is what makes them a good fit for Better Place. The DOE clean energy initiative hopes to increase the amount of energy produced by renewable sources by a significant amount by 2030. Better Place is also committed to buy energy from only renewable sources even if it is at a premium. However, since there are currently not many renewable energy sources on Hawaii, a large quantity of resources need to be put into developing them. Also if the penetration rate of Better Place is above a threshold of 30%, Better Place will not be able to follow through on their commitment to use only renewable energy to power their EV's. Regardless, at any penetration rate, carbon emissions will be abated each year.

Lastly, the economic analysis has identified the strengths and weaknesses of Better Place's business model, while attempting to evaluate the feasibility from a consumer standpoint as well. The breakeven analysis gave us an idea on how much Better Place will likely charge to use their plan. The battery cost has been a clear cost driver in the equation, to a point where the future feasibility relies largely on it. Currently, the cost of driving a comparable gasoline or hybrid vehicle is much cheaper than operating an EV from Better Place-thus not proving to be economically feasible.

Taking all these considerations into account, it is clear that our study has a more quantitative standpoint when evaluating feasibility. From the quantitative standpoint it is evident that Better Place in Hawaii is not currently feasible. Much of the feasibility hinges on the economic viability of such a large scale project, which is inhibited by the current costliness of the batteries. Also, there are potential competitors in the market that could take market share from Better Place. Nonetheless, it is fair to state that Better Place could be feasible in the future. For example, if costs associated with batteries decrease, while the price of gasoline increases, there could be a shift to demand to electric vehicles. Further research can also be done to understand consumer behavior. Our feasibility study has solely focused on the general consumer that will choose the most economic alternative. However, there is a small niche of individuals will purchase electric vehicles at a premium if they know that they're helping the environment. Although not included in our analysis, these types of qualitative factors could prove to be pivotal in the future success of Better Place.

WORKS CITED

(n.d.). Retrieved 2009 01-December from Star Bulletin: http://www.starbulletin.com/news/20081203_Electric_car_proposal_has_state_charged_up.html

(1997 йил 1-Jan). Retrieved 2009 11-November from OnStar: http://onstar.internetpressroom.com/releases_detail.php?ItemID=86

ABB. (n.d.). *Submarine Power Cables.* From http://library.abb.com/global/scot/scot245.nsf/veritydisplay/7c507e0313549a2bc1256e83003e6609/$File/Submarine%20Power%20Cables.pdf

Anderman, M. (2000). *Advanced Batteries for Electric Vehicles: An Assessment of Performance, Cost, and Availability.* Sacramento, CA: Battery Technology Advisory Panel.

Anderson, D. (2009). *An Evaluation of Current and Future Costs for Lithium-Ion Batteries for Use in Electrified Vehicle Powertrains.* Durham, N.C.: Nicholas School of the Environment of Duke University.

Anderson, D. (2008). Status and Trends in the HEV/PHEV/EV Battery Industry (Presentation). *Rocky Mountain Institute* .

AWS Truewind. (n.d.). Hawaii Wind Power Density of Hawaii at 50M.

Battery Space. (n.d.). Retrieved 2009 3-December from Battery Space: www.batteryspace.com

Better Place Global Progress. (2009). From http://www.betterplace.com/global-progress/.

Better Place. (2009 15-September). *Press Release.* Retrieved 2009 14-Oct from Better Place: http://www.betterplace.com/company/press-release-detail/better-place-debuts-ev-services-platform-at-frankfurt-motor-show/

BetterPlace. (2009). From http://www.betterplace.com/company/leadership-detail/shai_agassi/

BetterPlace. (2009). *energy*. Retrieved from http://www.betterplace.com/opportunity/energy/

BetterPlace. (2009). *The company*. Retrieved from betterplace: www.betterplace.com

Blanco, S. (2009 13-January). Retrieved 2009 йил 10-November from autoblog.com: autoblog.com

Boyd, R. (2009 1-June). *Hawaii Renewable Energy.* From Scientific American: http://www.scientificamerican.com/article.cfm?id=hawaii-renewable-energy

Cable Directory. (2009 19-June). From http://thecablediretoryblog.com/2009/06/19/hawaii-studying-locations-for-undersea-power-cable-for-offshore-windfarm/

Capital IQ. (n.d.).

Car Wash Business Plan. (1995). From bplans.com.

Cobalt Price Comparison of Different Time Periods. (2009 3-December). Retrieved 2009 3-December from Global InfoMine: http://www.infomine.com/investment/historicalcharts/showcharts.asp?c=Cobalt

CommodityMine. (2009 3-December). Retrieved 2009 йил 3-December from Global Infomine: www.infomine.com/commodities

Comparison between NiMH, Lead Acid, and Li-Ion Battery at Similar Energy Level (360 WH). (n.d.). Retrieved 2009 3-December from Battery Space: www.batteryspace.com

Congress, G. C. (2006, May 30). *Electro Energy's Prototype Bi-Polar NiMH Battery Pack for Plug-in Hybrids*. Retrieved December 10, 2009, from Green Car Congress: http://www.greencarcongress.com/2006/05/electro_energys.html

Cost of Lithium Ion Batteries for Vehicles. (2000). *Argonne National Lab* .

Coulomb Technologies. (n.d.). *Coulomb Technologies*. Retrieved 2009 14-October from http://www.coulombtech.com/

Coy, T. (2009 11-August). *Toxco Inc. is Awarded 9.5 Million from DOE to Support U.S. Lithium Battery Recycling.* Retrieved 2009 3-December from Toxco: www.toxco.com

Cunningham, W. (2008, November 20). *Hyundai shows off hybrid power train for Sonata*. Retrieved December 10, 2009, from CNET: http://reviews.cnet.com/8301-13746_7-10104995-48.html

Destries, M. (2007, March 22). *General Motors Commits To 40 Percent Emissions Cut By 2010*. Retrieved December 10, 2009, from GreenOptions: http://michaeldestries.greenoptions.com/2007/03/22/general-motors-commits-to-40-percent-emissions-cut-by-2010/

Dilip Warrier, J. O. (2009). *The Race for the Electric Car: A Comprehensive Guide to Battery Technologies and Market Development.* San Francisco, CA: Thomas Weisel Partners.

DOE. (2009, june 23). *Obama Administration Awards First Three Auto Loans for Advanced*. Retrieved from U.S Dept of Energy: http://www.atvmloan.energy.gov/public/pr-062309.pdf

Dun & Bradstreet, I. (2009). *Project Company Profile*. Retrieved from Capital IQ: https://www.capitaliq.com/CIQDotNet/company.aspx?companyId=38656695

Energy Information Administration. (2008). *Electricity Generating Capacity*. Retrieved 2009 йил 14-October from Energy Information Administration: http://www.eia.doe.gov/cneaf/electricity/page/capacity/capacity.html

ETec. (n.d.). *ETec*. Retrieved 2009 14-October from Minit Charger: http://www.etecevs.com/

Fergus, J. W. (2009 6-September). Recent Developments in Cathode Materials for Lithium Ion Batteries. *Journal of Power Sources* , pp. 939-954.

Friedman, T. (2008 8-August). *Flush with Energy.* From http://www.nytimes.com/2008/08/10/opinion/10friedman1.html?_r=2.

Fuel Oil. (2009 November). Retrieved 2009 йил 3-December from Wikipedia: citation http://en.wikipedia.org/wiki/Heavy_fuel_oil

Gaines, L. (2000). *Cost of Lithium-Ion Batteries for Vehicles.* Argonne, Illinois: Argonna National Laboratory.

Gaines, L. (2009 21-May). Lithium-Ion Battery Recycling Issues. *Presentation* . Argonna National Laboratory.

Garthwaite, J. (2009 21-August). Retrieved 2009 йил 3-December from http://earth2tech.com/2009/08/21/better-place-batteries-expected-to-cost-almost-12k-apiece/

Garthwaite, J. (2009 21-Aug). *Better Place Batteries Expected to Cost Almost $12K Apiece*. From earth2tech.com: http://earth2tech.com/2009/08/21/better-place-batteries-expected-to-cost-almost-12k-apiece/

GeothermEx, Inc. (2005). *Assessment of Energy Reserves and Costs of Geothermal Reserves in Hawaii.*

Global Energy Concepts, LLC. (2006). *A Catalog of Potential Sites for Renewable Energy in Hawaii.*

Global InfoMine. (2009 3-December). Retrieved 2009 йил 3-December from Global InfoMine: http://www.infomine.com/investment/historicalcharts/showcharts.asp?c=Cobalt

GoHive: Global Statistics. (2009). From http://www.geohive.com/default1.aspx.

Goldstein, M. (2009 16-October). Retrieved 2009 йил 11-November from Reuters: http://www.reuters.com/article/mnGreenAutos/idUS427988708320091016

Green Energy News. (2009 August). From http://www.renewable-energy-news.info/renewable-energy-funding/

Guy Sarre, P. B. (2004 March). Aging of Lithium-ion Batteries. *Journal of Power Sources* , pp. 65-71.

Hawaii Plans Undersea Power Cable. (2009 30-October). From Global Energy Network Institute: http://www.geni.org/globalenergy/library/technical-articles/transmission/associated-press/hawaii-plans-undersea-power-cable/index.shtml

Hawaiian Electric Company. (2008 December). From http://www.heco.com/portal/site/heco/menuitem.508576f78baa14340b4c0610c510b1ca/?vgnextoid=f8b10c9853afd110VgnVCM1000005c011bacRCRD&vgnextfmt=default&cpsextcurrchannel=1#mainContent%20idmainContent

Hawaiian Electric Company. (2009 July). *Power Distribution.* Retrieved 2009 йил 3-December from Hawaiian Electric Company: http://www.heco.com/vcmcontent/staticfiles/pdf/powerdelivery_07-2009.pdf

Hawaiian Electric Company. (2009 September). *Power Facts.* Retrieved 2009 3-December from Hawaiian Electric Company: About Us: http://www.heco.com/vcmcontent/staticfiles/pdf/powerfacts_07-2009.pdf

Howe, P. J. (2007 14-February). *Boston.com.* From The Boston Globe: http://www.boston.com/business/technology/articles/2007/02/14/undersea_cable_could_bring_green_power_to_hub/

Hua Xie, Z. T. (2008). PVDF-HFP Composite Polymer Electrolyte with Excellent Electrochemical Properties for Li-ion Batteries. *Journal of Solid State Electrochem* , 1497-1502.

Indy Power Systems. (2007). *Hybrid and Electric Vehicles.* Retrieved from Indy Power Systems: http://www.indypowersystems.com/products/hybrid-and-electric-vehicles.html

istockanalyst. (2008). *Historical Annual Returns For The S&P 500 Index*. From istockanalyst: http://www.istockanalyst.com/article/viewarticle/articleid/2803347

Jessica Frontino Paulino, N. G. (2007 22-October). Recovery of Valuable Elements From Spent Li-Batteries. *Journal of Hazardous Materials* , pp. 843-849.

Jiangang Li, R. Z. (2008 6-June). Preparation of LiCoO2 Cathode Materials from Spent Lithium-Ion Batteries. *Ionics* , pp. 111-113.

Jinhui Li, P. S.-C. (2009 22-September). A Combined Recovery Process of Metals in Spent Lithium-Ion Batteries. *Chemosphere* , pp. 1132-1136.

Jo Dewulf, G. V. (2009 12-August). Recycling Rechargeable Lithium Ion Batteries: Critical Analysis of Natural Resouce Savings. *Resouces, Conservation, and Recycling* , pp. 1-6.

Korzeniewski, J. (2009 23-August). *autoblog*. Retrieved 2009 10-November from http://www.autoblog.com/2009/08/23/report-byd-pushes-american-ev-launch-ahead-to-2010/

LaMonica, M. (2009 23-april). *Cnet news*. From http://news.cnet.com/8301-11128_3-10225464-54.html

Leone, M. A. (2009 13-September). *Hawaii Electric Vehicles.* From Invitation to Maui Energy Expo 2009: http://www.hiev.us/

Linda Gaines, R. C. (2000). *Cost of Lithium-Ion Batteries for Vehicles.* Argonne, Illinois: Argonna National Laboratory.

Local Information Data Server. (2005). From IDcide - Local Information Data Server: www.idcide.com

Macdonald, A. (2008). *reuters.com*. From Electric car venture unveils charge stations in Israel.

Marketing strategies. (n.d.). Retrieved from http://www.malaysiaminilover.com/marketing-strategies-of-tata-motors

Mckinsey & Company. (2008 17-20-June). Reducing Hawaii's Oil Dependence and Greenhouse Gas Emissions.

Meyer, W. H. (1998). Polymer Electrolytes for Lithium-Ion Batteries. *Advance Materials* , pp. 439-448.

Moore, A. (2008, November 14). *Lithium Polymer Battery Guide*. Retrieved December 10, 2009, from Prototalk.net: http://prototalk.net/forums/showthread.php?t=22

Motavalli, J. (2009, april 2). *Wiring Wars: The Race to Charge the World's EVs*. Retrieved from Bnet: http://industry.bnet.com/auto/10001091/wiring-wars-the-race-to-charge-the-worlds-evs/

Motor fuel taxes. (2009 October). From http://www.api.org/statistics/fueltaxes/

Motor Vehicle Registrations 2007. (n.d.). From Bureau of Transportation Statistics: www.bts.gov

Nissan Leaf. (n.d.). Retrieved 2009 3-December from Nissan: http://www.nissanusa.com/leaf-electric-car/#/battery

Nissan. (2009 20-October). *NISSAN AND SUMITOMO TO INITIATE "SECOND-LIFE" BUSINESS*. Retrieved 2009 3-December from Nissan: http://www.nissan-global.com/EN/NEWS/2009/_STORY/091020-03-e.html

OahuRE.com. (2009). From oahure.com

Obama Administration Awards First Three Auto Loans for Advanced. (2009, june 23). Retrieved from U.S Dept of Energy: http://www.atvmloan.energy.gov/public/pr-062309.pdf

O'Dell, J. (2009, july 13). *5-Nation Survey by Electric Vehicle Backer Shows Strong Consumer Interest in EVs* . Retrieved from edmunds.com: http://blogs.edmunds.com/greencaradvisor/2009/07/5-nation-survey-by-electric-vehicle-backer-shows-strong-consumer-interest-in-evs.html

Patel, P. (2009, March 27). *Better Lithium-Ion Batteries*. Retrieved December 10, 2009, from Technology Review: http://www.technologyreview.com/energy/22351/

Peterson, J. (2009, April 6). *Lithium-ion Batteries: 9 Years of Price Stagnation* . Retrieved December 10, 2009, from Seeking Alpha: http://seekingalpha.com/article/129570-lithium-ion-batteries-9-years-of-price-stagnation

place, b. (n.d.). From http://www.usatoday.com/money/autos/2008-12-03-electric-cars_N.htm

PM raises energy issue in Moscow. (2006 19-October). From http://www.jpost.com/servlet/Satellite?pagename=JPost/JPArticle/ShowFull&cid=1159193473859.

Polynesian Cultural Center. (n.d.). *Experience Polyneisa*. Retrieved 2009 3-November from http://www.polynesia.com

PowerStream. (2009). *Batteries and Battery Packs*. Retrieved from PowerStream: http://www.powerstream.com/

RechargeIT. (2008). Retrieved 2009 10-November from http://www.google.org/recharge/experiment/index.html

Renault Fluence engines. (2009 2-November). From carengineranking.com: http://carengineranking.wordpress.com/2009/11/02/renault-fluence-engines/

Renault Fluence Z.E. (n.d.). Retrieved 2009 3-December from Renault: http://www.renault.com/en/Innovation/vehicule-electrique/Pages/fluence-ze-concept.aspx

Renewable Resource Data Center. (2005). *Index of /solar/old_data/nsrdb/1991-2005/statistics/hsf*. Retrieved from Renewable Resource Data Center: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/statistics/hsf/911820_2005.hsf

Riley, B. (2009 19-November). CTO. (J. Tong, Interviewer)

Riley, B. (2009 19-November). From Nanotech to Reality. *Powerpoint Presentation* . Ithaca, NY: A123.

Robert Kerr, S. M. (2009). New Type of Li Ion Conductor with 3D Interconnected Nanopores via Polymerization of a Liquid Organic Electrolyte-Filled Lyotropic Liquid-Crystal Assembly. *Journal of the American Chemical Society* , 15972-15973.

Rodrigue, D. J.-P. (2009). *The Gravity Model*. From The Geography of Transport Systems, Hofstra University, Department of Global Studies & Geography: http://www.people.hofstra.edu/geotrans/eng/ch5en/meth5en/ch5m2en.html

Roth, D. (2008 18-August). Retrieved 2009 11-November from Wired Magazine.

Sir Isaac Newton: The Universal Law of Gravitation. (n.d.). From utk.edu: http://csep10.phys.utk.edu/astr161/lect/history/newtongrav.html

Squatriglia, C. (2009 13-May). *Better Place Unveils an Electric Car Battery Swap Station*. From http://www.wired.com/autopia/2009/05/better-place/

Stundza, T. (2009 18-February). *Cobalt Prices are 52% Off Cyclical Peak*. Retrieved 2009 йил 3-Decemmber from Purchasing.com: http://www.purchasing.com/article/229295-Cobalt_prices_are_52_off_cyclical_peak.php

Sudick, J. (2008 Dec). *Electric car proposal has state charged up*. From Starbulletin.com: http://www.starbulletin.com/news/20081203_Electric_car_proposal_has_state_charged_up.html

Sullivan, F. &. (2009 2-October). *Clean Transportation.* Retrieved 2009 14-October from Altenergystocks: http://www.altenergystocks.com/archives/clean_transportation/

Tesla Roadster. (n.d.). Retrieved 2009 3-December from Tesla Motors: www.teslamotors.com

Thompson, M. (2009 19-November). Cornell University Professor. (J. Tong, Interviewer)

Ton, D. T. (2009). *Solar Energy Grid Integration Systems - Energy Storage (SEGIS-ES).* Albuquerque, NM: Sandia National Lab.

U.S Department of Energy. (2009 23-June). From www.atvmloan.energy.gov/public/pr-062309.pdf

U.S Department of Energy. (2009 June). From www.atvmloan.energy.gov/public/pr-062309.pdf

U.S Department of Energy. (2009 August). From http://www.energy.gov/7749.htm

U.S Department of Energy. (2009). From http://www.energy.gov/recovery/taxbreaks.htm

Vandervelde, J. (2009 2-August). *2011 Nissan Lead: Batteries*. Retrieved 2009 йил 3-December from All Cars Electric: http://www.allcarselectric.com/blog/1033848_2011-nissan-leaf-batteries

Voser, P. (2009 13-October). From http://www.shell.com/home/content/media/news_and_library/speeches/2009/voser_ft_guest_column_13102009.html

Voser, P. (2009 13-October). From http://www.shell.com/home/content/media/news_and_library/speeches/2009/voser_ft_guest_column_13102009.html

WOODY, T. (n.d.). *Better Place Unveils Electric-Car Software*. Retrieved from New york times: http://greeninc.blogs.nytimes.com/2009/09/15/better-place-unveils-electric-car-software/

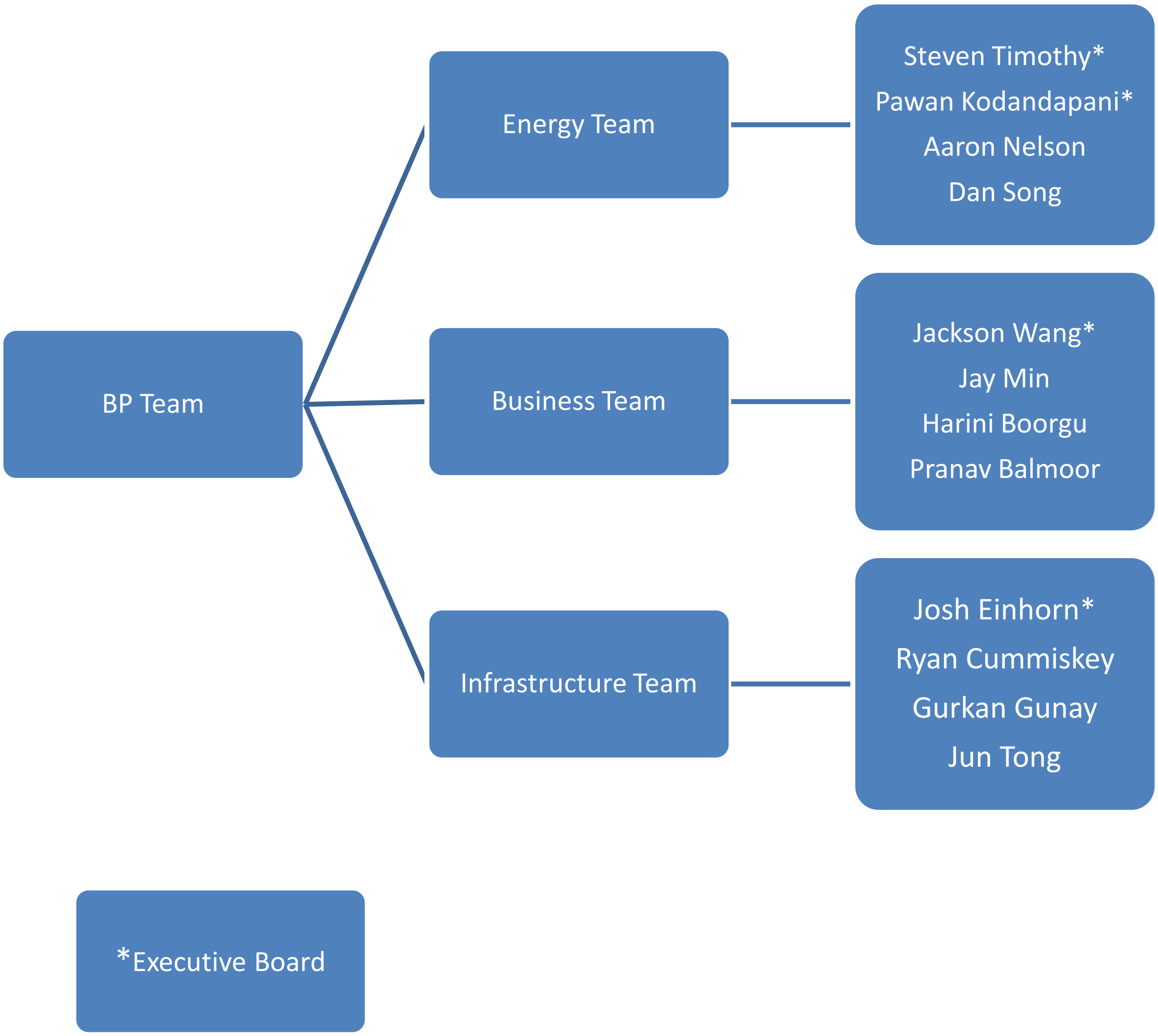
World Resources Institute. (2009). From http://earthtrends.wri.org/.

www.hawaiigasprices.com. (2009). From www.hawaiigasprices.com

Yarow, J. (2009 April). *The Cost Of A Better Place Battery Swapping Station: $500,000*. From http://www.businessinsider.com/the-cost-of-a-better-place-battery-swapping-station-500000-2009-4

TEAM STRUCTURE AND ROSTER

BETTER PLACE TEAM STRUCTURE



BETTER PLACE TEAM ROSTER

Pranav Balmoor

City & Country of Origin: Hyderabad, India
Undergraduate University: Osmania University, Electronics & Comm Engineering
Area of Research for Better Place: Government Incentives, Reaction of Petroleum Industry
Post-Graduation Goals: Consulting Industry

Harini Boorgu

City & Country of Origin: Hyderabad, India.
Undergraduate University: Osmania University, Electronics & Comm Engineering
Area of Research for Better Place: Business Assessment, Marketing, Competition Analysis of PHEV
Post-Graduation Goals: Consulting Industry

Ryan Cummiskey

City & Country of Origin: Syracuse, NY, USA
Undergraduate University: Cornell University, Mechanical Engineering
Area of Research for Better Place: Infrastructure Implementation
Post-Graduation Goals: Mechanical Engineering in Aerospace Industry

Josh Einhorn

City & Country of Origin: Philadelphia, PA, USA
Undergraduate University: Cornell University, Civil and Environmental Engineering
Area of Research for Better Place: Swapping Stations and General Business Plan
Post-Graduation Goals: Construction Management or Consulting

Gurkan Gunay

City & Country of Origin: Istanbul, Turkey
Undergraduate University: Bogazici University, Civil Engineering
Area of Research for Better Place: Transportation Data, Swapping Station Model, Competition Analysis

Pawan Kodandapani

City & Country of Origin: Shrewsbury, MA, USA
Undergraduate University: Cornell University, Chemical Engineering
Area of Research for Better Place: Renewable Energy Research & Modeling
Post-Graduation Goals: Business School and Management
Post-Graduation Goals: Transportation Industry

Jun Ki (Jay) Min

City & Country of Origin: Vienna, VA, USA
Undergraduate University: Cornell University, Mechanical and Aerospace Engineering
Area of Research for Better Place: Comparison of Locations, Government Incentives
Post-Graduation Goals: Consulting, Business School

Aaron Nelson

City & Country of Origin: Glen Allen, VA, USA
Undergraduate University: Cornell University, Chemical Engineering
Area of Research for Better Place: Renewable Energy Projects & Costs
Post-Graduation Goals: Engineering Management in the Oil & Gas Industry

Daniel Song

City & Country of Origin: Somerset, NJ, USA
Undergraduate University: Cornell University, Chemical Engineering
Area of Research for Better Place: Better Place Competition and Energy Demand
Post-Graduation Goals: Manufacturing, Consulting, and Energy Industry

Steven Timothy

City & Country of Origin: Salt Lake City, UT, USA
Undergraduate University: Cornell University, Chemical Engineering
Area of Research for Better Place: Better Place Energy Demand and CO_2 Abatement
Post-Graduation Goals: Operations and Management Consulting

Jun Tong

City & Country of Origin: Guangzhou, China → Brooklyn, NY, USA
Undergraduate University: Cornell University, Materials Science
Area of Research for Better Place: Vehicles, Battery
Post-Graduation Goals: Consulting Industry

Jackson Wang

City & Country of Origin: Vancouver , B.C. , Canada
Undergraduate University: Cornell University, ORIE
Area of Research for Better Place: Financial Model and Breakeven Analysis
Post-Graduation Goals: Business Technology Consulting and MBA School

EVALUATION SUMMARY

The most notable trend in the second of group evaluations is the value everyone placed on learning how to work in groups and manage projects. Nearly everyone mentioned that one of the most valuable things they took away from this project was the experience of working in a large group of engineers towards one common goal. In addition to this, most people mentioned the diversity of the group and explained how the different ways they learned to deal with cultural, personality, and work discrepancies. It seems that during the second half of the project, most people had already learned their share about the content and focused in on the people and management aspect of group work.

For overall group progress, there was only one real significant change from the first half to the second. This change was the implementation of an Executive Board to facilitate communication, delegate work, and make decisions. Though this group was at first meant to be specifically a communication tool like a liaison between groups, we saw a different aspect of such a board. This was the managerial aspect. In the first half of the semester, decisions were made by a democracy of twelve and work was only voluntarily taken. The exec board made a change in this behavior. Exec members were able to delegate work to any member and made quick decisions that the whole group itself might have argued over for days. An example was when the E-board formed a task group to deal with Better Place competitors and delegated work to members who were interested in this section of the report. We believe that this ability to make decisions and delegate work was due to the board's ability to see the big picture of our project and not be bogged down by details. Overall, we believe that the implementation of the Exec Board was a good decision that allowed for easier group management and a smoother finish to our study.

Though the Exec Board was successful in solving a few of our groups initial problems, a number of issues were seen throughout the project that could have been solved with enough intuitive guidance in the beginning on the project. The group has a few recommendations. First is compiling a type of resume database for the group that includes work experience, skills, and most importantly interests. This would allow the group to assign initial tasks in the most efficient and objective manner. The second recommendation is much less formal but should still be encouraged. It was not until the time of the presentation that our group fully merged together. This was due to increased exposure time to each other in both work and social settings. If the group was initially exposed to more social and interactive activities outside of specified working meetings, a tighter group might form that would overcome the diversity mentioned earlier. One last recommendation is to keep the suggestion for breaking the large group into smaller units. This made the entire project much more manageable. Despite our few problems however, we believe that we had a solid group with members who always stepped up in times of need and came together to create an end product we're all proud of.

INDIVIDUAL EVALUATIONS

Pranav Balmoor

The Better Place project helped me gain valuable experience in working in a project team. I now understand how a project team functions, the kind of roadblocks it could run to and how to overcome some of them. I got an opportunity to work with people from different backgrounds and cultures. I got to develop my inter personal skills interacting with people. One of the most important things I leant was to manage my work and also manage people with different personalities.

I also got an opportunity to look into the future means of transport which one of the most important advances in engineering that is taking place. I got to understand how efficiently and effectively can renewable sources of energy be used to power future modes of transport.

Harini Boorgu

Better Place has been a great learning experience for me, more through the second half of the project I learned a lot about team work and advantages and frustrations of working in a team. Most of my team members taught me to perfect my work. It was hard at times but the learning experience was great. I got a chance to work with people with different work ethics. My skills of working in a team have improved. The presentation was a great experience. My knowledge about the subject has improved vastly and the overall project was a great experience.

Ryan Cummiskey

By working on the Better Place Project Team, I have learned a great deal about both electric vehicles, and the dynamics of group projects. I set out to gain knowledge about the technical aspects of implementing electric cars, and I have surpassed this goal by learning more than I thought was possible about the details of charging, energy distribution, and the true benefits and drawbacks of electric cars.

Additionally, by presenting, guiding meetings, collaborating remotely, and compiling reports, I have learned numerous techniques to facilitate group work. I feel that in the second half of the project, many of the people who were light on work initially, stepped up and took on important responsibilities. We were able to shift roles successfully to bring the presentation together as well.

Our plan to establish an executive board to improve intra-group communication was successful, and I feel I was better updated on other subgroups consequently.

Josh Einhorn

Perhaps the most valuable part of working on this project team was the things I have learned about working in semi-large groups with a diverse range of people. Aside from learning a great deal about energy systems and the rise of electric vehicles, I feel I will be more adept in the future in dealing with work groups which consist of all kinds of people. I think this group has taught me that every person has a totally different way of doing work and the differences must be somewhat accommodated.

I was pleased to see that people who were lighter on work earlier in the semester seemed to step up voluntarily and take on more responsibility. Thus, no member of our team in the end was a weak link.

The plan to use the executive board to facilitate communication was an interesting idea though it seemed to be a bit more talk than action. That being said, there were definitely a few decisions made by the exec board that needed to be made in a smaller group. I have learned that leadership and executive power are indeed necessary to group success.

Gurkan Gunay

This Better Place project gave me really valuable experiences. Here, I saw how things are executed in a project, and I was very happy and satisfied to work with the group. Sometimes, we faced some differences between each other, but these are the nature of projects, and I believe that those differences mainly caused by the cultural differences and different personalities. In terms of these issues, not only was this project a feasibility study, but also a new social experience. Moreover, I also learned new technical and managerial issues during this project. Overall, I emphasize again that working in this project with this group was a unique experience.

Pawan Kodandapani

The biggest learning experience of this project was working with a diverse set of people, and I think I have come away from this project far more skilled at working with many different people with unique and diverse talents. In fact, the diversity of the group provided some challenges but also some opportunities. The diversity allowed the team to function smoothly as different members of the team were able to work on tasks that were in their comfort zone. However, because of the diverse nature of the group, when members of the team were forced to work on things that they were unaccustomed to, it created a situation where several members of the team had to take on extra work to help facilitate work on these tasks.

The executive board was only moderately effective, but it gave me a look into the dynamics of the other sub-teams and allowed us to share ideas to coordinate our efforts as a team better. I learned from this experience that not everyone on the team needs to take leadership, but having a select group of strong leaders can be a significant asset to the team when it comes to getting work done.

Finally, it was refreshing to see that issues regarding work output from certain members at the midpoint were resolved without conflict. Members of the team who were identified as not performing to the level of their capability definitely made a much more concerted effort in the second part of the semester to contribute more, even taking leadership positions on certain tasks.

Jun Ki (Jay) Min

Through this project experience, I learned some valuable lessons. I learned about the energy industry and the need for developing renewable resources to gain independence from oil. More importantly, I learned about how to work in a group. Our group consisted of people from fairly diverse backgrounds. Communication between different subgroups and even within my own subgroup was difficult at first, but it improved as the semester went by. By the final presentation, we solved most of our problems and functioned as a team pretty well. Overall, I think my personal goals and the group's goals were met. Every subgroup completed their tasks. My experience in working in a relatively large team environment will help me in my career as knowing how to work with a team may be more important than technical skills. This project was an enjoyable and valuable experience.

Aaron Nelson

Our Better Place team has been well coordinated this semester. We have remained split into our three functional sub-teams, each with the same particular focus area as the first half of the semester. The Energy sub-team has been focusing on the future energy demand resulting from Better Place vehicle usage and ways to meet that demand with renewable energy. Our functional sub-teams each do relevant work and seemed to contribute equally to the final presentation and final project report. A few of people on the team make an extra effort to coordinate the sub-teams, act as liaisons with Professor Vanek, and post information electronically where all team members have access to it. We have the whole team meet once per week to share our sub-team progress, address whole-team issues, and generate ideas for future Better Place project work. Initially, the overall group did not do an adequate job of proofreading our deliverables, but that problem has been remedied because the group identified it and acted on a solution. Our final report even had a proofreading meeting. Our group has been successful with fixing organizational and communications challenges from the first half of the semester.

Daniel Song

Our group has adapted to changed we felt necessary. After the midterm presentation, I along with Harini and Gurkan moved into a competition group. Here we focused on what other companies are doing with electric vehicles and how Better Place can be successful. This sub team gave me experience working outside of my comfort zone. Before this, I was with the energy group who are all chemical engineers. Now I had the opportunity to work closely with international students. I learned to explain ideas in a clear fashion and organize group tasks that need to be completed. Additionally, to address the communication issue that came up, an executive team was set up to coordinate between the three sub teams. From this, I learned that people will step up

I feel this group worked out well. People always stepped up when something needed to be accomplished. Because of this, I learned much about the energy and competition issue but also how to analyze a project. Meanwhile the large group contributed to the learning about other issues that I did not have time to figure out myself. The chance to work with a large diverse group of students was rewarding when I saw final products come out.

Steven Timothy

Working in this Better Place group for my M. Eng. project was nothing like I had ever done before. The experience of working on a team of 12 people is much different than a team of 3 or 4, which I had grown much accustomed to during my undergraduate years. The ability to give everyone on a 12-person team meaningful work is very hard, and often times the work ended up being completed by a few rather than as a whole (keeping in mind that too many people working on the same thing sometimes decrease the efficiency of a smaller group). As for the Executive Board, although it did not fully fix the communication issue between sub-team members, I did feel like the Executive Board was beneficial because we established a leadership team that always knew what was going on in the other teams and set dates for the completion of deliverables. All in all, I learned very much from this group project as far as how a large group functions, how to divide up work amongst sub-teams and group members, and ways in which to form a “hierarchy” such that there are certain leaders who know what’s going on and make executive decisions for the sake of the group.

Jun Tong

All my goals from working in the Better Place feasibility project group was met and more. The large group process that we had to deal was at first a challenging endeavor. We had split the large group into thirds and each member knew everything going on in their subgroup. However, the communication between the three groups was fairly rocky. However, we were able to develop a strong group identity towards the end, especially as we prepared for our presentation, and eventually figured out ways to learn the project as a whole. Overall, I feel that I have learned ways to deal with large groups and would be able to successfully work in such environments in the future.

Other than working in a large team environment, I also learned a lot about the overall goal of transitioning to electric vehicles. I had not known about the infrastructure available and all the economic issues that would have to be dealt with. As I was in charge of the vehicles and the battery, I ended up learning a lot about the Li-ion battery and understand how much work will be needed to make this endeavor feasible. I also honed my research skills, which I had been confident of beforehand, and now am even more certain about. Overall, I am really glad that I was able to take part in this study and am very grateful for the opportunity.

Jackson Wang

I've learned more from the Better Place project than any of my classes at my time here at Cornell. It has combined all the essential elements needed to be a successful engineer: good technical skills, good people skills, and good management skills. I set out to gain knowledge about each one of these aspects at the beginning of the semester, but I didn't expect to learn as much as I did. The most useful tool I experienced was learning how to manage and work with different types of engineers and personalities. I felt like group dynamics really came into place during different stages of the project.

Another aspect I really enjoyed about the project was the final presentation. This allowed us to showcase our findings to the public and see what they thought of our hard work. It also allowed me to improve my public speaking skills. Although my background has been in ORIE, I've learned a great deal about other aspects of engineering such as energy and sustainability. I feel like this is the future of engineering and I am excited to be learning about it.