Bass Connections in Energy

Final Report

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Duke UNIVERSITY | BASS CONNECTIONS

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I. Executive Summary

The Bass Connections Electric Vehicle (EV) Team aims to prototype an efficient, environmentally friendly urban electric vehicle that could eventually be mass produced. The project breaks down into three main components: developing an efficient prototype, designing a realistic business plan to bring the product to market and determining the environmental impact of the mass produced version of the vehicle.

The urban concept vehicle derives its high efficiency mainly through a carbon fiber monocoque chassis: carbon fiber is by far the most durable, lightweight and easily moldable of assessed materials. The car will be introduced to consumers through an imagined EV car sharing service, named sharEV. The business plan for sharEV offers an exploration into the future car sharing and autonomous vehicle industries, as well as a financial analysis on the prospects of such a company. Finally, the team performs a life cycle assessment (LCA) in order to determine the full environmental impact of the vehicle (from the extraction of its raw materials to the disposal/recycling of the car).

Through constant collaboration between Duke Trinity and Pratt Engineering students, the Bass Connection EV Team hopes to offer a comprehensive analysis of what is required to design, build and sell an innovative vehicle.

II. Introduction to the Problem

According to the *Energy Industry Association,* since 2000 transport energy and carbon dioxide emissions have increased by 28%. The increased greenhouse gas emissions from growing energy consumption have contributed to the growing problem of climate change. As a result, there is a challenge on a global scale to address the rapidly growing demand for energy, while reducing greenhouse gas emissions.

Transportation development is critical to economic growth in developed and developing nations. The provision of reliable and inexpensive transport can help address inequality issues. It is critical, however, that future transportation growth does not compromise environmental integrity.

While major automakers have begun to research, develop and market electric vehicle technology, they have yet to be deployed on a magnitude that can seriously impact the large amount of energy consumed by the transportation industry.

Our project seeks to address these problems of access to transportation and energy emissions by providing a novel vehicle design and deployment strategy.

III. Environmental Analysis and Social Impacts

A. Explanation of project

We conducted a Lifecycle Assessment (LCA) to determine the environmental impact of one of our highway-capable carbon fiber electric vehicles. This section will also delve into the social impacts our vehicle after discussing the LCA methodology and results.

B. Methodology

We used Quantis's 2013 academic-license LCA software to conduct the LCA for our vehicle (**Appendix A**). In order to produce the most accurate LCA possible, we divided our project into two parts: a LCA for carbon fiber (CF) and a LCA for the rest of the car.

1. Carbon Fiber[1]

The EcoInvent 2.2 database used by Quantis does not have Environmental Flow (EF) information for CF. Therefore, it was necessary to build a separate LCA for CF. We divided it into three categories: raw materials, process materials, and energy required.

a) Raw Materials

The three raw materials for CF production are acrylonitrile, methyle acrylate, and acrylic acid. We chose "Sohio process, at plant [kg] - RER" for the Environmental Flow of the CF and knew from our research, that 0.95 kg of acrylonitrile is needed to produce 1 kg of CF. The Environmental Flow chosen for methyle acrylate production was a global measure of an at plant production process producing 0.04 kg. The acrylic acid production process chosen was a European at plant process producing 0.01 kg.

b) Process Materials

Five materials are added as inputs during the production process for CF. Those are DMSO, sizing resin, sodium hydroxide, water, and a silicone oil agent. The DMSO, silicone agent, and resin production processes are all European, at plant, producing 0.19 kg, 0.02 kg, and 0.02 kg respectively. We assigned the sodium hydroxide a 50% in water European, at plant production mix producing 0.05 kg of NaOH. Finally, the water used during CF production was given an ultrapure, global, at plant production mix producing 19.4 kg of water.

c) Energy

We used a US grid mix to log the Environmental Flow of the energy required to produce CF. The CF production process requires 28.69 kWh to produce 1 kg of CF.

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[1] All information on CF production derives from Ellringmann, Tim, Christian Wilms, Moritz Warnecke, Gunnar Seide, and Thomas Gries. 2015. "Carbon Fiber Production Costing: A Modular Approach." *Textile Research Journal* 0 (00): 1–13.

d) Assumptions

A number of assumptions went into designing our LCA for CF. We had to make one raw material substitution. Ellringmann suggests using itaconic acid as a raw material[2] and Park agrees that itaconic acid is the ideal choice.[3] However, the EcoInvent 2.2 database does not include EF information for itaconic acid, so we substituted it with acrylic acid in our LCA. Acrylic acid is an acceptable, though not ideal, substitute for itaconic acid in the CF production process.[4] Acrylic acid is known to be more damaging to human health and the environment than itaconic acid. That substitution would normally inflate our LCA results; however, since we had to forgo some process materials, we cannot say for certain that our results are inflated. Additionally, many of our EFs come from European production processes because EcoInvent 2.2 is a Swiss database. It is quite likely that some of the production processes differ in the United States (where most of our materials would be manufactured). Unfortunately there's no way to know the environmental impacts of those differences, so we cannot tell how the use of European processes changes our model. If our company eventually outsources production, then this LCA might be a more accurate representation of the environmental impacts of our vehicle.

2. Electric Vehicle

The rest of our electric vehicle (EV) was assessed in a single LCA, which had steps for raw materials, manufacturing, distribution, use, and disposal and recycling (**Figure 1**).

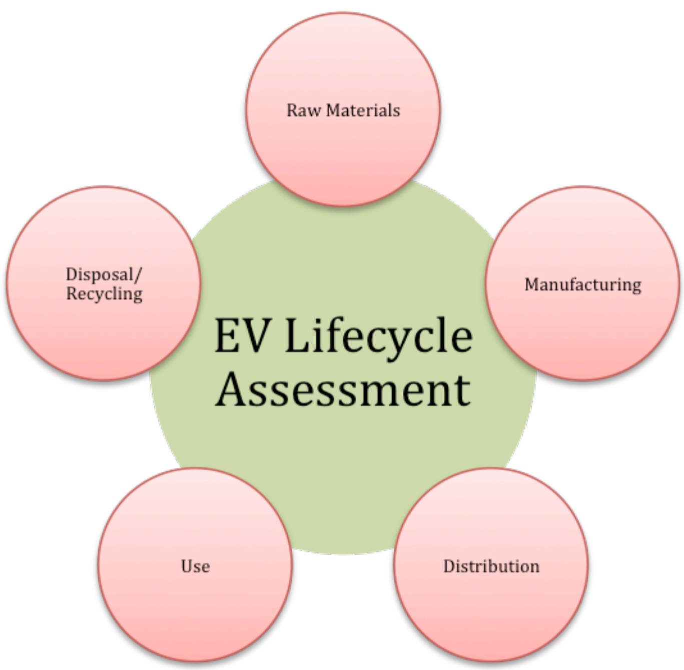

Figure 1. Necessary steps for conducting a LCA of an electric vehicle.

a) Raw Materials

[2] Ibid 1
[3] Park, Soo-Jin. 2015. *Carbon Fibers*. Netherlands: Springer Netherlands.
[4] Ibid 3

The raw materials for the EV were further divided into the categories of the battery, body, mold, brake system, motor/engine, wheel system, windshield system, safety system, electronics, and other miscellaneous materials (**Figure 2**). The EF chosen for the battery was a 34,300 gram, prismatic, rechargeable lithium ion battery with a global, at plant scale. The operation to acquire that battery requires a greater than 28 tonne average Swiss lorry. In all of the raw materials, it was important to consider both their components and how our production plant would receive those components. We used the same transportation operation for receiving all raw materials, this will be discussed more later. The total amount of lorry transport required for all raw materials is 22,259,400 kgkm.

The body of the car is composed of honeycomb material and carbon fiber. The honeycomb is made out of polyester resin, unsaturated from a European, at plant process. 10 kg of honeycomb is required to make our electric vehicle. Epoxy resin is also required as a prepreg for the carbon fiber. 6 kg of that is produced with an at plant, European process in our LCA. Those components are shaped using molds made out of wax and benzyl alcohol. The paraffin and benzyl alcohol are both produced using an at plant, European process at 4kg and 10kg respectively.

The brake system for the car has three components: calipers, fluid, and lines. The 18/8 chromium steel used for both the calipers and the lines is produced at 1 kg using an at plant, European process. The calipers also contain 1 kg of brass and 1 kg of cast iron. The former is produced using an at plant, Swiss process and the latter is produced using an at plant, European process. The brake fluid is produced using 1 kg of oil and 1 kg of butanol. The former is produced with European vegetarian oil at plant and the latter is produced with propylene hydroformylation at a European plant. The last component of the brake lines is 1 kg of synthetic rubber produced at a European plant.

In order for the car to move, it needs a motor/engine and wheels. The motor is made of 15 kg of the same 18/8 chromium steel mentioned previously and the wheels are composed of 3 kg of the same steel. The rubber in the tire (3 kg) and the rubber in the windshield wiper (1 kg) are made from the same rubber mentioned earlier. The windshield system also requires polycarbonate (12 kg), which is made with a European, at plant process. All of the safety system components were also produced in Europe and are all 2 kg. The nylon 66 for the seatbelts and airbags are produced using an at plant process and the small parts of chromium steel for the seatbelts are produced by milling.

The car also requires an electronics system and other miscellaneous metals and plastics to function. 1 kg of the same synthetic rubber as before is required for the electronics system. That system also requires 2 kg of copper from regional, European storage. 74.8 kg of European wire-drawing copper is required for the general wiring of the vehicle. The car also requires 30 kg of aluminum (primary) and 20 kg of ABS plastic, both produced using an at plant European process. The 10g of steel required for the vehicle is average, European milling steel.

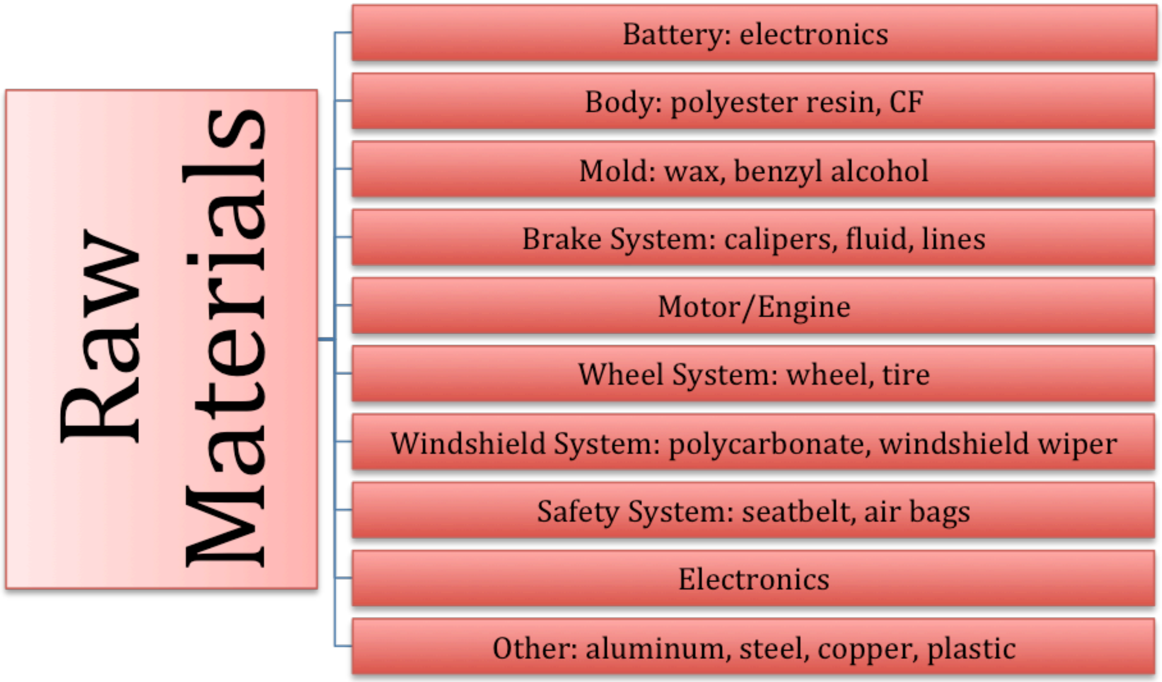

Figure 2. Raw materials required to produce a sharEV electric car.

b) Manufacturing, Distribution, Use, Disposal and Recyling

A 30kW heat pump and a building machine (both European) are the two machinery units necessary to construct our electric vehicle. The cars would be distributed by freight lorry as already established. We used a urban 650 kg battery electric vehicle (BEV) with a 100 kg $LiMn_2O_4$ battery and 70 kg electric motor to determine the environmental impacts of the lifetime use of our electric vehicle. We used the same type of BEV to mimic the disposal and recycling impacts of our vehicle.

c) Assumptions

We had to make many assumptions while constructing the LCA for our electric vehicle. The most glaring is that all of the production processes are European or, specifically, Swiss in origin. The implications of that fact have already been discussed. In order to determine the environmental impact of transporting materials, we had to assume that our small units of input materials would each be individually transported in a large truck. Realistically, every truck that enters into our delivery bay would be full of whatever material it was transporting. We assumed an average delivery distance of 600 km. However, it is possible that delivery distance could be greater or smaller. We also had to make assumptions about the manufacturing equipment, which resulted in choosing the two simplest pieces of machinery that we would definitely have. We also assumed that our car would have the same use impacts of a BEV. In actuality, our car would have lower use impacts because it would be more efficient than a BEV (due to our lightweight, carbon fiber body). Finally, we had to make some substitutions of our raw material inputs. The EcoInvent 2.2 database does not have EF information on NOMEX (the honeycomb material that would be used in the actual construction of the vehicle) nor does it have any information on polyvinyl alcohol (PVA) or castor oil, used in creating the molds to shape the car body and the brake fluid respectively. NOMEX is produced by DuPont, which releases very little EF information about the material. After consulting with a Duke University chemistry professor, we decided that the most similar material we could find in the EcoInvent 2.2 database was a polyester resin.[5] NOMEX and polyester resin have some significant chemical differences, the most important of which is that NOMEX contains secondary amines (**Figure 3**).[6] Secondary amines are known to react in both human and animal bodies and in the environment to form N-nitrosamines, carcinogenic compounds.[7][8][9] If, upon disposal, our car would react with something to form N-nitrosamines, then it could lead to the creation of carcinogens, which is not reflected in our LCA. While our substitute material for NOMEX is less impactful than NOMEX, our substitute chemical for PVA (benzyl alcohol) has a larger environmental impact than PVA. Benzyl alcohol is known to be more toxic than PVA, even though PVA is more persistent in the environment.[10][11][12] Finally, we substituted vegetable oil for castor oil because castor oil is a type of vegetable oil, so the two should not have very different environmental impacts.[13] It is beyond the scope of our project to be able to identify exactly how all of the assumptions we had to make inflate or deflate the results of our LCA. Therefore, we shall assume that our LCA is accurate for the purpose of discussing our results.

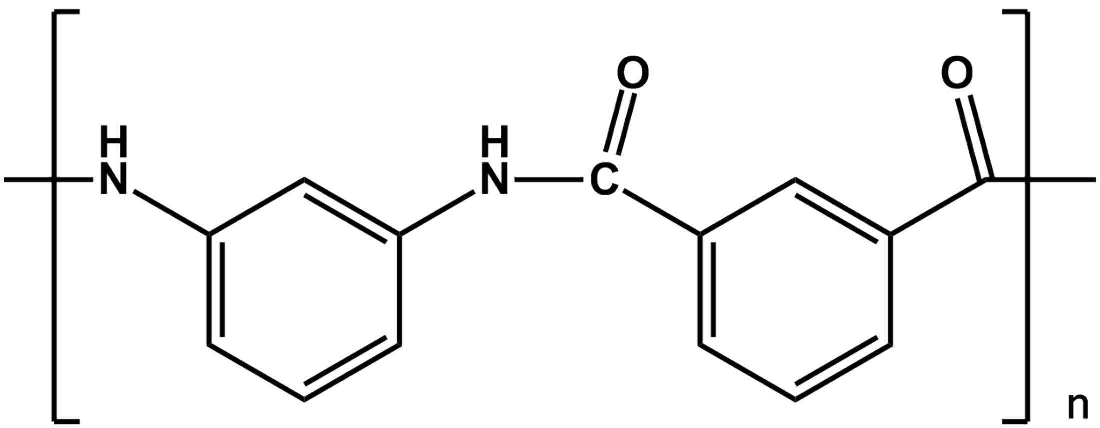

Figure 3. The chemical structure of NOMEX. Note the secondary amines.

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5 Abendroth, Kathryn. “Email conversation with Dr. Valerie Ashby.” April 3, 2016.

6 Unknown. “Kemijska struktura Nomexa.” Accessed May 1, 2016. http://tinyurl.com/jbp99f5

7 Neurath, G.B., M Dunger, F.G. Pein, D. Ambrosius, and O. Schreiber. 1977. “Primary and Secondary Amines in the Human Environment.” *Food and Cosmetic Toxicology* 15 (4): 275–82.

8 Perera, Ana Maria Afonso. 2005. “Chromatographic Analysis of the Environment.” In *Chromatographic Analysis of the Environment*, edited by Leo M.L Nollet, 3rd ed., 419–52. Boca Raton, FL: Taylor & Francis Group.

9 Scientific Committee on Consumer Safety. 2012. *Opinion on Nitrosamines and Secondary Amines in Cosmetic Products*. Brussels.

10 Bruhne, Friedrich, and Elaine Wright. 2007. “Benzyl Alcohol.” In *Ullmann’s Encyclopedia of Industrial Chemistry*, 7th ed., 7–8. Wiley.

11 Centers for Disease Control and Prevention. 1982. “Neonatal Deaths Associated with Use of Benzyl Alcohol -- United States.” *Morbity and Mortality Weekly Report*..

12 Hallensleben, Manfred L. 2000. “Polyvinyl Compounds, Others.” In *Ullmann’s Encyclopedia of Industrial Chemistry*, edited by Weinheim. Wiley

13 Thomas, Alfred. 2005. “Fats and Fatty Oils.” In *Ullmann’s Encyclopedia of Industrial Chemistry*. Wiley.

C. Results

The results from our LCA can be seen in **Figure 4**. A single car that we produce will require 702.90 m^3 of water and 641,940 MJ of energy to extract all the resources necessary. It will lead to 10,498 potentially disappeared fraction of species in one meter squared of Earth in a year (PDF.m^2.yr). It will also have a human health impact of 0.03313 disability-adjusted life years (DALY) across the entire human population. Finally, the production, use, and disposal of our vehicle will ultimately result in the release of 41,610 kg of CO_2 eq to the atmosphere. Producing, distributing, using, and disposing of one of our electric vehicles requires the same amount of water that the every resident of the town of Chadbourn, North Carolina uses in one year and the same amount of energy that about 16 average American homes use in one year.[14][15][16] Our car would emit less than 2.5 metric tons of carbon dioxide equivalent during its use phase. That is significantly less than the average American car, which emits about 7.1 metric tons of CO_2 eq during its use phase.[17][18] An average car has a lifetime human health impact of 0.02 DALY, an ecosystem quality impact of 4,000 PDF.m^2.yr, and a climate change effect of 50,000 kg CO_2 eq.[19] While our car might be worse for human health and ecosystem quality than the average vehicle, it is definitely superior in terms of climate change impact. The ecosystem degradation is the largest negative social impact of this car. However, the car has the potential to make large, positive social impacts by leading to a decreased carbon footprint from vehicles. Since climate change is one of the largest social concerns of our time, we our proud to state that our vehicle will make strides in mitigating it. For more detailed, per process results of our LCA, please see **Appendix B**.

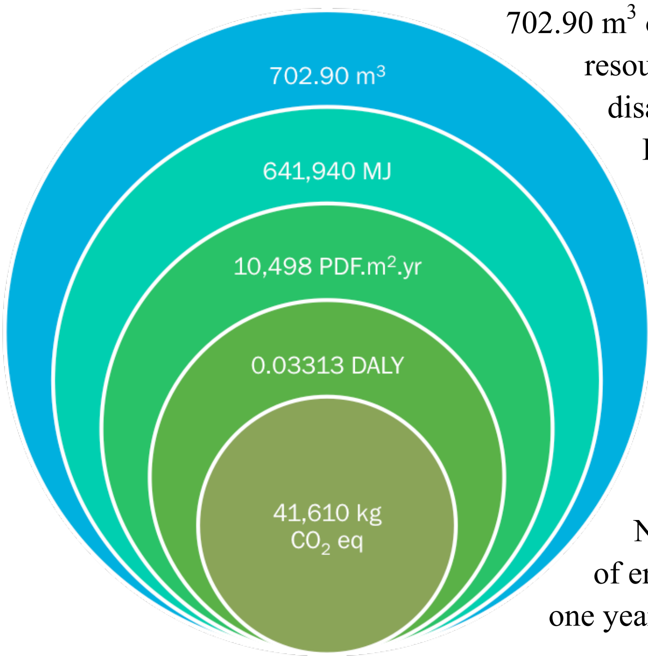

Figure 4. LCA results.

[14] United States Census Bureau. 2015. "Incorporated Places and Minor Civil Divisions Datasets." *Population Estimates*.

[15] United States Energy Information Administration. 2015. "How Much Electricity Does an American Home Use?" *Frequently Asked Questions*.

[16] United States Geological Survey. 2016. "How Much Water Does the Average Person Use at Home per Day?" *The USGS Water School*.

[17] Hedges & Company. 2016. "United States Vehicle Ownership Data, Automobile Statistics and Trends." *Market Research Services*.

[18] United States Environmental Protection Agency. 2016. "Sources of Greenhouse Gas Emissions." *Climate Change*.

[19] Humbert, Sebastien, An De Schryver, Xavier Bengoa, Manuele Margni, and Olivier Jolliet. 2012. *IMPACT 2002+: User Guide*. Lausanne, Switzerland.

IV. Business Plan

A. Explanation of Project

This business plan serves as an exploration as to how our Bass Connections team could conceivably bring to market the innovative electric vehicle we prototyped. Our team recognizes that in order to confer the benefits of the hyper-efficient vehicle on a larger scale, the car must be mass produced and marketed appropriately to consumers.

Through research on the future of the transportation industry, we determined that the industry is on a path towards driverless, energy efficient vehicles. Therefore, we view the best way to introduce our vehicle would be to do so by creating an electric car sharing service. While we will introduce our product as a sharing service, the long-term plan is to automate the car fleet after 10 years of operations. The cars in our fleet will be specifically designed to facilitate the transition to an autonomous fleet, thus providing early mover benefits in the future industry where consumers prefer driverless cars. The business plan acknowledges the regulatory concerns that exist with the path towards autonomization.

We plan to introduce this service into a small, progressive city. This would allow our hypothetical company to further validate customer demand and refine our business model before scaling up operations to other and larger cities. Again, our company's name, for the sake of this paper is: sharEV.

"Once cab companies like Uber get rid of their drivers, they merge with car-club and car-sharing businesses to merge into "one big, convenient and affordable alternative to owning a car" - ZipCar

B. Market Research

1. Future of the Car Sharing Industry

According to a report from Navigant Research[20], revenues for global carsharing services are expected to rise from $1.1 billion in 2015 to $6.5 billion in 2024. Changing preferences on car ownership (more people are less interested in buying cars) and the environmental benefits conferred by car sharing (less cars on the road lead to traffic congestion), have contributed to the

[20] "Carsharing Programs: Carsharing Membership and Vehicle Fleets, Personal Vehicle Reduction, and Revenue from Carsharing Services: Global Market Analysis and Forecasts," PR Newswire, last modified September 24, 2015, accessed April 30, 2016, http://www.prnewswire.com/news-releases/carsharing-programs-carsharing-membership-and-vehicle-fleets-personal-vehicle-reduction-and-revenue-from-carsharing-services-global-market-analysis-and-forecasts-300148927.html.

steady rise in shared cars. As seen in **Figure 5** below[21], as vehicle production slows down, the percentage of shared cars on the road steadily rises until greater than 15% of all cars on the road are shared in 2030.

Figure 5. (The Economist) depicts the forecasted use of shared vehicles on the roads from 2015 to 2030.

Many companies compete in the growing car sharing space, with notable companies in the US including ZipCar and Car2go.

2. Future of the Autonomous Vehicle Industry

While the car sharing industry continues to grow, the horizon continues to approach for the autonomous vehicle industry. Although Google once promised consumers that driverless cars would be ready for the roads in 2018, the Economist notes that the Ford CEO believes they will be ready by 2025, and most analysts believe they will only hit the roads by 2025 or 2030. For the purposes of our business plan, we assume that fully autonomous vehicles should be ready to hit the road by 2027. Thus, if our car sharing service opened in 2017, it would have 10 years to prepare for the autonomization of the fleet. Of course, there still remain large obstacles to the introduction of autonomous vehicles. This includes convincing regulators and consumers that the cars are safe, deciding how to sort the blame of accidents with insurers, and appealing to consumers who still retain preferences for driving.

A 2013 report from the Victoria Transport provides a summary of the potential introduction of autonomous vehicles:

[21] "The Driverless, Car-sharing Road Ahead," *The Economist*, January 9, 2016, accessed April 30, 2016, http://www.economist.com/news/business/21685459-carmakers-increasingly-fret-their-industry-brink-huge-disruption.

Autonomous Vehicle Implementation Projections

Table 1. (Victoria Transport) summarizes projected autonomous vehicle implementation rates based on previous vehicle technology deployment. This assumes that fully-autonomous vehicles are available for sale and legal to drive on public roads around 2020

Stage	Decade	Vehicle Sales	Veh. Fleet	Veh. Travel
Available with large price premium	2020s	2-5%	1-2%	1-4%
Available with moderate price premium	2030s	20-40%	10-20%	10-30%
Available with minimal price premium	2040s	40-60%	20-40%	30-50%
Standard feature included on most new vehicles	2050s	80-100%	40-60%	50-80%
Saturation (everybody who wants it has it)	2060s	?	?	?
Required for all new and operating vehicles	???	100%	100%	100%

Several companies are investing heavily into autonomous vehicle research and development, as described below.

Volvo announced plans to make a semi-autonomous feature on the new S90. This feature essentially allows the car to drive itself when the road is marked with well-defined lanes and stop signs or red lights are clearly visible. This is similar to the autopilot feature that Tesla is developing.[22]

Toyota is investing $1 billion in its robotics division which incorporates autonomous research and development. As part of this investment they are hiring researchers from Stanford, MIT, and Google to work in the autonomous division. The automaker also plans to expand the division and hire an additional 200 workers in the near future[23]

Nissan announced it will have at least 10 models of autonomous or semi-autonomous vehicles on the road by 2020. Nissan will be launching semi-autonomous features similar to Volvo later this year, and a more advanced autonomous system that can change lanes in 2018. By 2020 the company has committed to a fully autonomous model, which is unique in that no other automaker has made such a promise so far. On the R&D side, Nissan has also hired a senior-level executive from the world's largest auto-mapping company, Nokia's HERE, to run the autonomous program. A deal was struck last summer between Nokia and Daimler, BMW, and Audi for the German automakers to purchase HERE.[24]

Google began testing their proprietary self-driving technology with the Toyota Prius on freeways in California in 2009. In 2012, they began testing the technology with the Lexus RX450h, at that point, they had run over 300,000 miles of testing. More recently, they have shifted their focus to

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[22] Mike Ramsey. Who Will Win the Race to Autonomous Driving? –Tech Talk, *The Wall Street Journal*, Podcast Audio, MP3, 7:44, January 11, 2016, Accessed April 30, 2016, http://www.wsj.com/podcasts/who-will-win-the-race-to-autonomous-driving/7C8D662C-9164-47D3-92E7-A0ECCE37E899.html.
[23] Ibid.
[24] Ibid.

city streets, which are far more complex traffic environments than freeways.[25] In 2014, Google unveiled their first fully autonomous prototype vehicle. After months of tests and various iterations, they delivered the first real build of the prototype in December 2014. Today, Google vehicles have driven over 1.5 million miles and are on the streets of Mountain View, California; Austin, Texas; Kirkland, Washington; and Metro Phoenix, Arizona. The Google fleet includes both the prototype and modified Lexus SUVs.[26] Google is the first company to build and test a vehicle designed as purely autonomous. From production to transportation use, the prototype is built to be entirely self-driving.

Apple, according to a *Wall Street Journal* Report from September of last year, will release its first electric vehicle in 2019. The company has also had meetings with the California Department of Motor Vehicles about regulations surrounding autonomous vehicles.[27] Some do not believe that Apple will bring a mass-produced autonomous vehicle to the market anytime in the near future, however, and that the efforts are to familiarize itself with automotive technology for future integration of Apple products.[28] Reports also show Apple has hired people away from positions related to autonomous research from other competitors in the space.[29]

It is important to note however that no producer has determined how much their fully autonomized fleets will cost. The Victorian Transport institute, as of 2013, predicts that even with fully matured markets, autonomizing a car (as we propose to do in our project) will add $5,00-$20,000 to vehicle prices and several hundred dollars in additional maintenance and service costs. There will also be financial benefits to autonomous cars, such as fuel and insurance savings, which are not recognized in **Table 1** above.

C. City Choice

1. What considerations should be taken into account in choosing a city?

We evaluated potential target cities to launch sharEV on a set of criteria. The launch city needed to have a favorable demographic makeup, a progressive and forward thinking local government, and a conducive climate for charging the vehicles.

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[25] "Google Self-Driving Car Project: Monthly Progress Reports," *Google*, Accessed May 01, 2016, https://www.google.com/selfdrivingcar/reports/.
[26] Ibid.
[27] Daisuke Wakabayashi, "Apple Targets Electric-Car Shipping Date for 2019," *The Wall Street Journal*, September 21, 2015, accessed April 30, 2016, http://www.wsj.com/articles/apple-speeds-up-electric-car-work-1442857105.
[28] Kyle Campbell, "Daily Drive-thru: Apple Cars Aren't Coming Any Time Soon (Or Ever), Autonomous Volvo to Take Over London, and More," *New York Daily News*, April 28, 2016. accessed April 30, 2016, http://www.nydailynews.com/autos/news/no-apple-icar-autonomous-volvo-london-article-1.2617335.
[29] Daniel Howley, "The Apple Car: Everything We Think We Know So Far," *Yahoo! Finance*, April 20, 2016, accessed April 30, 2016, http://finance.yahoo.com/news/the-apple-car--everything-we-think-we-know-so-far-174542294.html.

2. Description of Austin, Texas

a) Demographics of Austin

The population of Austin inside the city limits has increased by over 130,000 people since April of 2010, which represents an increase of about 17%.[30] There have been even greater increases in population growth in the larger region surrounding the city.[31] In addition to the growing population of Austin, the city is also home to the University of Texas at Austin – one of the nation's largest with a student body of over 50,000.[32]

Due in large part to the influence of the university, the city of Austin is considered to be one of the most progressive areas in an otherwise traditionally conservative state.[33] The mayor, Steve Adler, and other city officials recently traveled to Washington D.C. to meet with technology and transportation leaders,[34] demonstrating the local government's commitment to improving its transportation system.

Finally, Austin also has about 220-230 days of sun per year, or 60% of all days.[35] As a startup that will rely heavily on solar power, this feature of Austin's climate is crucial to the success of sharEV. In conclusion, Austin is a growing city with many young people, a political leadership with a forward-thinking mindset on transportation, and a climate well-suited for solar energy. All three of these factors will allow sharEV to succeed in Austin.

b) Austin's Transit Problems

In spite of the population growth, the average weekday ridership across the Capital Metro System (Austin's public transportation system) has decreased 4.5% from 2013 to 2014.[36] Also interesting to note is that the ridership in 2011 was the same as 2014.[37] Some of this decrease is due in part to the changing living arrangements of the University of Texas at Austin students as

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[30] "Demographics," City of Austin, accessed April 30, 2016, http://www.austintexas.gov/demographics.
[31] Terrence Henry, "Austin's Growing Fast, But Why Isn't its Public Transit?" *KUT 90.5, UT Austin*, January 29, 2015, accessed April 30, 2016. http://kut.org/post/austins-growing-fast-why-isnt-its-public-transit.
[32] "Facts and Figures," University of Texas at Austin, last updated April 4, 2016, accessed April 30, 2016, https://www.utexas.edu/about/facts-and-figures.
[33] Kirk Goldsberry, "Mapping the Changing Face of the Lone Star State," *FiveThirtyEight.com*, November 4, 2014, accessed April 30, 2016, http://fivethirtyeight.com/features/mapping-the-changing-face-of-the-lone-star-state/.
[34] "Austin Officials Seek Out Tech Leaders to Help Fix Traffic Woes," *Austin American-Statesman*, April 3, 2016, accessed April 30, 2016, http://www.mystatesman.com/news/news/local/austin-officials-seek-out-tech-leaders-to-help-fix/nqxyr/.
[35] "Days of Sunshine per Year in Texas," Current Results: Weather and Science Facts, accessed April 30, 2016, https://www.currentresults.com/Weather/Texas/annual-days-of-sunshine.php.
[36] Terrence Henry, "Austin's Growing Fast, But Why Isn't its Public Transit?"
[37] Ibid.

many have moved to different parts of the campus. There was also a decrease in spending on Cap Metro by the university.[38]

The most important figure involving decreased ridership is that the number of service hours provided by the system is down, and absolute ridership is up.[39] This represents a huge opportunity for a business such as sharEV.

Other reasons for decreased average ridership is that the most popular bus line was cut.[40] The changes to Austin's bus system have brought complaints from many commuters.[41] At the end of 2014 Austin voters also voted down a proposition to add a line to the city's rail system.[42]

What all of this demonstrates is that Austin does have issues in providing access to public transit. While large gaps between consumer demand and public provision of transit are bad for commuters, they present an opportunity for sharEV to fill those gaps.

Austin also has a strong track record of embracing car-sharing. Car2go, a main competitor in the region, now has a reported 55,000 users after its initial launch in Austin in 2010.[43] That kind of success in Austin is encouraging because it shows Austinites' willingness to venture into alternative modes of transport. As a startup that wants to help improve access to transportation efficiently in terms of price and environmental impacts, Austin is a perfect fit for sharEV.

D. How will sharEV work?

1. Competitive Advantage

We believe that our company can feasibly compete for market share in any major U.S. city. Our hyper efficient vehicle design, based on our unique carbon fiber monocoque and aerodynamic efficiency, and our low emissions to do being electrically powered, appeal to the environmentally conscious consumer. If introduced as the first EV car sharing service in an environmentally conscious city, we believe that our company can even charge a premium for our services.

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[38] Ibid.
[39] Ibid.
[40] Ibid.
[41] Kevin Schwaller, "MetroRapid Faces Mixed Reviews After Launch," *KXAN – NBC*, February 4, 2014, accessed April 30, 2016, http://kxan.com/2014/02/04/metrorapid-faces-mixed-reviews-after-launch/.
[42] Terrence Henry, "After Ridership Drops, Where Does Cap Metro Go from Here?" *KUT 90.5, UT Austin*, January 30, 2015, accessed April 30, 2016, http://kut.org/post/after-ridership-drops-where-does-cap-metro-go-here.
[43] Richard Whittaker, "Car2Go Closes Ranks: Concentrates on Higher-Demand Areas," *The Austin Chronicle*, September 25, 2015, accessed April 30, 2016, http://www.austinchronicle.com/news/2015-09-25/car2go-closes-ranks/.

The backbone of the sharEV car sharing service includes: 1) A membership program, where users pay an upfront fee to use the services of the cars and then pay for each trip they take 2) investing in a growing fleet of cars, scheduled to reach 500 cars within 5 years 3) Investing in a large parking garage with solar paneled charging equipment 4) Developing (or purchasing the rights to) an application that will allow users to track available cars 5) Developing a rebalancing program (described further below) to ensure cars do not only move from high demand areas to low demand areas and stay there 6) Preparing our fleet to become driverless in the near future (by 2027), therefore conferring first mover advantages.

2. Introduction of fleet

a) Fleet Size

SharEV will introduce 100 cars into Austin, Texas in year 1, with 150 total, 200 total, 350 total and 500 total at the end of each of the next four years. This scale of introduction was based on the experience in Indianapolis of a competitor BlueIndy, and on the current competition in Austin, Texas. In Indianapolis, BlueIndy began by introducing 50 of 500 initial vehicles and 25 of an eventual 200 charging stations[44]. Car2go, a main competitor of efficient car sharing vehicles in Austin, Texas, currently has 300 cars. Doubling BlueIndy's initial introduction of EVs will be facilitated by the decision to invest upfront in a full, 500 car parking garage with charging built in. Furthermore, the company conservatively plans to overtake Car2go's 300 vehicles within 3-4 years assuming car2go does not add more cars to their fleet.

b) Target Market

The target market, as discussed above, includes the University of Austin, Texas students, young urban professionals and the average environmentally conscious consumer.

c) Infrastructure

SharEV invest upfront for a parking garage with solar panels that provide charging capabilities. The garage is projected to cost $5,600,000 in year one and have 500 spots. In the first four years, while sharEV plans to have less cars than the 500 spots, the company will lease out the extra spots to EV owners throughout the city. Although not included in the financial analysis provided below, sharEV also would receive tax incentives from the city to build out these spots and would be able to supply electricity to the grid for additional revenue.

d) Application and Rebalancing

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[44] "BlueIndy Electric Car Share Launches," Indianapolis Convention and Visitors Association, accessed April 30, 2016, https://www.visitindy.com/indianapolis-blueindy-launch.

Just like an Uber app, car2go and other leading car sharing companies have developed advanced applications to allow their customers to determine the availability of their cars and to monitor the cars' fuel levels. sharEV will introduce a similar application, but the envisioned application would have several additional functions. The first function would help sharEV address the common problem of "rebalancing" that many car sharing businesses face. Recently, one-way car sharing services, in which customers pick up the car where it is and drop it where they want, without returning it, have become increasingly popular.[45] These services allow customers to use the cars for more frequent, impulsive, shorter trips. However a problem arises in that the cars oftentimes end up far away from the centers of demand. The problems of cars moving away from the center of demand is further enhanced by customers that may rent the car at the city center at the end of their work day and take the car to the suburbs. Although the pricing structure disincentivizes this type of behavior, the problem of cars moving away from the city center is especially problematic for EVs which need to be charged.

Therefore, in the rebalancing portion of the mobile application there will be a feature showing the areas of high demand for sharEV. A customer can then determine if he or she would want to "rebalance" the fleet for a lower cost or points towards a free ride in the future. Unfortunately, this feature may not suffice to completely rebalance the sharEV fleet on its own. As a response sharEV will also need to employ workers whose sole jobs are to drive cars from areas of low demand to areas of high demand.

e) Projected number of users

The number of projected users is difficult to quantify. Knowing that Car2Go has 300 vehicles and 54,000 users, we next wanted to find the ratio for users/vehicles for another large car sharing company. In 2012, the last year the ZipCar was a standalone company, it had 9,763 vehicles and 777,689 users worldwide[46]. The ratio for users/vehicle was therefore 180 users/vehicle for car2go and 80 users/vehicle for ZipCar. We therefore assume that sharEV user/vehicle ratio will sit roughly between the two 130 user/vehicle. A lower user/vehicle ratio is important for providing the best service to customers, and a lower user/vehicle ratio (and a higher usage ratio/customer) than that of car2go, provides benefits to sharEV consumers. However, the need to attract users and the fact that ZipCar's scale allows them to purchase more vehicles for each user are both recognized.

f) Pricing Structure

[45] "Carsharing Programs: Carsharing Membership and Vehicle Fleets, Personal Vehicle Reduction, and Revenue from Carsharing Services: Global Market Analysis and Forecasts," PR Newswire.
[46] "Zipcar Reports Fourth Quarter and Full Year 2012 Results," Zipcar, February 15, 2013, accessed April 30, 2016, http://www.zipcar.com/press/releases/zipcar-reports-fourth-quarter-and-full-2012-results.

sharEV pricing structure is based on the current pricing structure of Car2Go in Austin, Texas. It is more accurate to calculate prices based on consumer demand than sharEV's cost structure. Furthermore, the most accurate way to gauge consumer demand is to use an established company's pricing structure since we do not have the ability to speak to customers in Austin. sharEV will employ a penetration pricing strategy, in which it offers discounted prices to Car2Go's for two years in order to attract customers. After offering the same prices as car2go does now in sharEV's third year, sharEV will charge a 10 and 15% premium in the following two years. sharEV will be able to charge a premium because of its competitive advantage: it offers the only electric vehicle car sharing program, and its cars have increased efficiency. The pricing structure, in **Table 2** below, includes a registration fee for access to the sharEV fleet, and variable charges based on how much the person drives. There is an additional $250 deductible in case of an accident, and the driver is always charged a $1.00 protection fee in case of an accident.

Table 2. Outlines sharEV's pricing structure including pre minute, per hour, and per day rates.

5 Year Plan					
	2017	**2018**	**2019**	**2020**	**2021**
Number of Cars	100	150	200	350	500
Registration Fee	$33.20	$34.13	$35.00	$38.50	$43.75
Per Minute	0.39	0.40	0.41	0.451	0.51
Per Hour Maximum	14.24	14.62	14.99	16.489	18.74
Per Day Maximum	80.74	82.87	84.99	93.489	106.24
Per Mile After 150 Mile Per Trip	0.43	0.44	0.45	0.495	0.56
Driver Protection Fee	$1.00 + Tax	$1.00 + Tax	$1.00 + Tax	$1.00 + Tax	$1.00 + Tax

g) Revenues

The main revenues for the business include New User Registrations, Projected Operating Vehicle Revenues and Parking Space Rentals. New User Registrations is calculated by multiplying the Registration fee by the number of new users, which in the first year, is just total users (which is calculated by multiplying the 100 cars on the road by the users/vehicle metric, described above) and in following years total users - previous year total users. Projected Operating Vehicle Revenues is calculated based on the usage revenue/vehicle/day statistic for ZipCar. ZipCar's latest 10K reports highlight that it had a usage revenue/vehicle/day of $64; while we understand our business will be less efficient at deploying vehicles than ZipCar, because we plan to charge a higher price than the company, we estimate our total revenue per member to be $100 (approximately a 56% increase).

Finally, because sharEV will invest in a 500 space parking garage in its first year of operation, the garage will have available parking spaces (which include the capability to charge one's vehicle) for the first four years of operation. In the fifth year, when sharEV produces 500 cars, the company will no longer be able to sell parking spaces. Based on average parking space rentals throughout Austin[47], we believe a competitive monthly parking pass that includes charging is estimated at $135/month. Each year, it is assumed that sharEV can rent out every available parking space.

The company will also be prepared for the case in which customers want to directly purchase our vehicles. In the successful car sharing program known as the Autolib, which is prominent in Europe and has spread recently to Indianapolis, USA, customers began to demand the car used in the program after enjoying the car sharing service. Bolloré, the producers of the vehicle, entered a partnership with Renault and began to sell to customers at a price point similar to our total cost of the vehicle. Thus, sharEV envisions additional revenue and profit if it decides to directly sell its cars to consumers in the future.

h) Costs

Costs are broken into five main areas, presented below:

Fleet Operations: expenses consists of fuel, insurance, gain or loss on disposal of vehicles, accidents, repairs and maintenance as well as employee-related costs (rebalancers, or employees who return cars to the parking garage and areas of high demand, make up a large portion of these costs).

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[47] "Downtown Parking in Austin," Parkme, accessed April 30, 2016, https://www.parkme.com/austin-parking/downtown.

Member Services and Fulfillment: expenses consist of personnel expenses related to member support teams and credit card processing fees. Member services and fulfillment costs are expected to increase as the membership base increases.

Research and Development: consist primarily of research into manufacturing and production efficiency improvements.

Sales, General and Administrative:primarily of labor-related expenses for sales and marketing, administrative, human resources, internal information technology support, legal, finance and accounting personnel, online search and advertising, trade shows, marketing agency fees, public relations and other promotional expenses, professional fees, insurance and other corporate expenses including certain acquisition-related costs.

Cost of Goods Sold (COGS): the cost of producing the sharEV cars.

Tax Rate: 0.75% of Gross Margin (Revenue - COGS)

The first four costs are based on ZipCar's 10K, but tailored to our business model. **Table 3** below demonstrates how and why we changed our costs as percentages of total revenue compared to ZipCar's costs as percentage of total revenue.

Table 3. Describes the rationale for sharEV's costs as a percentage of revenues.

	ZipCar	SharEV	Rationale for change
Fleet Operations (as % of total revenue)	62.3%	42.3%	70% of ZipCars, constant over 5 years. Our fuel costs are lower and the gap should increase, and repairs and maintenance cheaper. Our "rebalancers" make up a substantial portion of this cost.
Member services and fulfillment	7.2%	2%	Member support team is minimal with the number of users sharEV will have in relation to ZipCar. Number grows as we gain more members.
Research and development	1.6%	1.6%	Same R&D costs, although sharEV's focuses on improving efficiency of their own cars (ZipCar doesn't produce vehicles).
Selling, general and administrative	25.7%	20%	We will focus on PR as a means of marketing, using our story of being a "green company" (more PR entails less sales/marketing expenses).

Because we only have the cost of producing one prototype at Duke, we needed to extrapolate to determine the COGS for each car in the fleet. Using the total cost of raw materials for our product (Raw material cost EV $9,960,25 + Raw material cost Carbon Fibre $171.68) we determined an accurate COGS for the mass produced vehicles using McKinsey's Auto Industry

Manufacturer's Cost Contributions to MSRP.[48] The report details the main cost contributors to a vehicle, and the percentage of the MSRP that these costs are. Using our raw material cost, and eliminating the costs of selling the car to a dealer and the margin the dealer takes on the car, we determined that our car should cost 22,183.82575 to produce. Because it will be cheaper to buy materials in bulk as vehicle production increases slightly each year, we reduced the COGS by 5% each year for 5 years until it reaches $18,068.86.

Finally, in Austin, Texas the corporate tax rate is the lesser of .75% of the margin (Revenue - COGS) or 70% of revenues. For our financials, .75% of the margin is the lesser metric in the first 5 years of operation.

E. Financial Analysis

In the Discounted Cash Flow model presented below, our company is projected to have a total Enterprise Value (or the market value of a business) of -$5,697,480.06 (see exhibit 4). It is important to understand that all of the assumptions used in the model are just assumptions, and any change can dramatically alter our company's valuation either positively or negatively. However, while our valuation is negative, it is promising for several reasons.

First, the most important cost consideration is the cost of producing the vehicles. However, once production slows down (assuming sharEV doesn't expand cities or build cars to sell directly to consumers), the COGS go down while users presumably increase. If COGS are assumed to be 0 for the first five years of operation, then the Enterprise Value of sharEV jumps to over $15 million. While this is unrealistic, it is realistic to assume that COGS become zero after year five; in this case, because membership and prices are higher in year five than year zero, revenues would increase more than in the previous unrealistic scenario, and the Enterprise Value would jump to far higher than $15 million.

Second, our company plans to be a first mover in the driverless auto space that surfaces within the next 10 years. It is unrealistic to make projections that far out, especially given all of the current uncertainties, but once the cars become driverless they will more efficiently pick up customers, will cost less to operate and maintain, and will no longer require the expensive "rebalancers" that must bring them back to areas of high demand and to the parking garage. While autonomizing the vehicles will require a large software purchase, the electric vehicles will be conducive to this upload, and we imagine the shift will be very beneficial for our bottom line.

[48] "Automobile Industry Retail Price Equivalent and Indirect Cost Multipliers," Alex Rogozhin, Michael Gallaher, and Walter McManus, U.S. Environmental Protection Agency, February 2009, accessed April 30, 2016, https://www3.epa.gov/otaq/ld-hwy/420r09003.pdf.

Third, if we eventually sell vehicles directly to consumers, we can charge a high margin on the unique vehicles. This would require major design changes and improvements to the vehicle to better meet customers demand for a car they own.

Fourth, these financials solely represent the company's introduction into Austin, Texas. If our production increases as we move into more cities, ideally, the company achieves economies of scale and reduces overall costs. It is not uncommon, in fact, likely more common than uncommon, for early electric vehicle car sharing companies to be operating at a net loss.

Thus, with a strong proof of concept and sound business model, it is likely that investors would have a strong interest in sharEV.

V. Conclusion

This current report does not include the prototype vehicle specifications or vehicle testing results. Nevertheless, it was still possible to conduct a comprehensive LCA of sharEV's electric vehicle. Our car has a smaller greenhouse gas footprint then the average car, yielding both environmental and social benefits. The business plan demonstrates that if an imagined company scaled up production of the prototype, and introduced the car as part of an EV car sharing service, there is potential for long-term profitability. This profitability relies on a number of highly variable assumptions (including on reception of a city to the car sharing service, numerous costs and revenues), but offers what we believe is an encouraging sign for the marketability of novel, efficient vehicles.

VI. Appendices

Appendix A: How-To Guide for Quantis Software

Hello future Bass Connections in Energy students! This is your how-to guide for constructing a fabulous LCA for your future prototype. Constructing a LCA is a difficult and grueling process. I definitely recommend tracking down the LCA software that you would like to use during the Fall Semester so that you are fully prepared to begin constructing the LCA as soon as Spring Semester starts. If you choose to go with the Quantis software (highly recommended), here are the steps you should follow:

1. Contact Carter Reeb (carter.reeb@quantis-intl.com).

He should be able to set you up with a student license for Quantis like he did for us. The three-month academic license only costs $40!

2. Set up every LCA that you need to build as a separate project in Quantis to keep them organized.

3. Divide your LCA categories into logical steps along the lifetime of your prototype.

For instance, we did Raw Materials, Manufacturing, Distribution, Use, and Disposal and Recycling.

4. Insert each input as another category in the LCA categories and don't be afraid to add multiple Environmental Flows per input.

This is possible and encouraged!

5. If the EcoInvent 2.2 does not have an EF for the material you are interested in, try to find a viable substitute.

This is where conducting and LCA can be very time consuming. You want to find the best substitute possible, which might involve hours of journal research and contacting Duke professors who are experts on the material that you're interested in. After that, you have to make sure that you can justify your substitute and explain the effects of making the substitution. Don't leave your substituted materials to the last minute!

6. Once you have all your inputs, Quantis can help you analyze your data visually and export graphics and spreadsheets of your data to your computer.

Appendix B: Environmental/Social Impact by Process Step

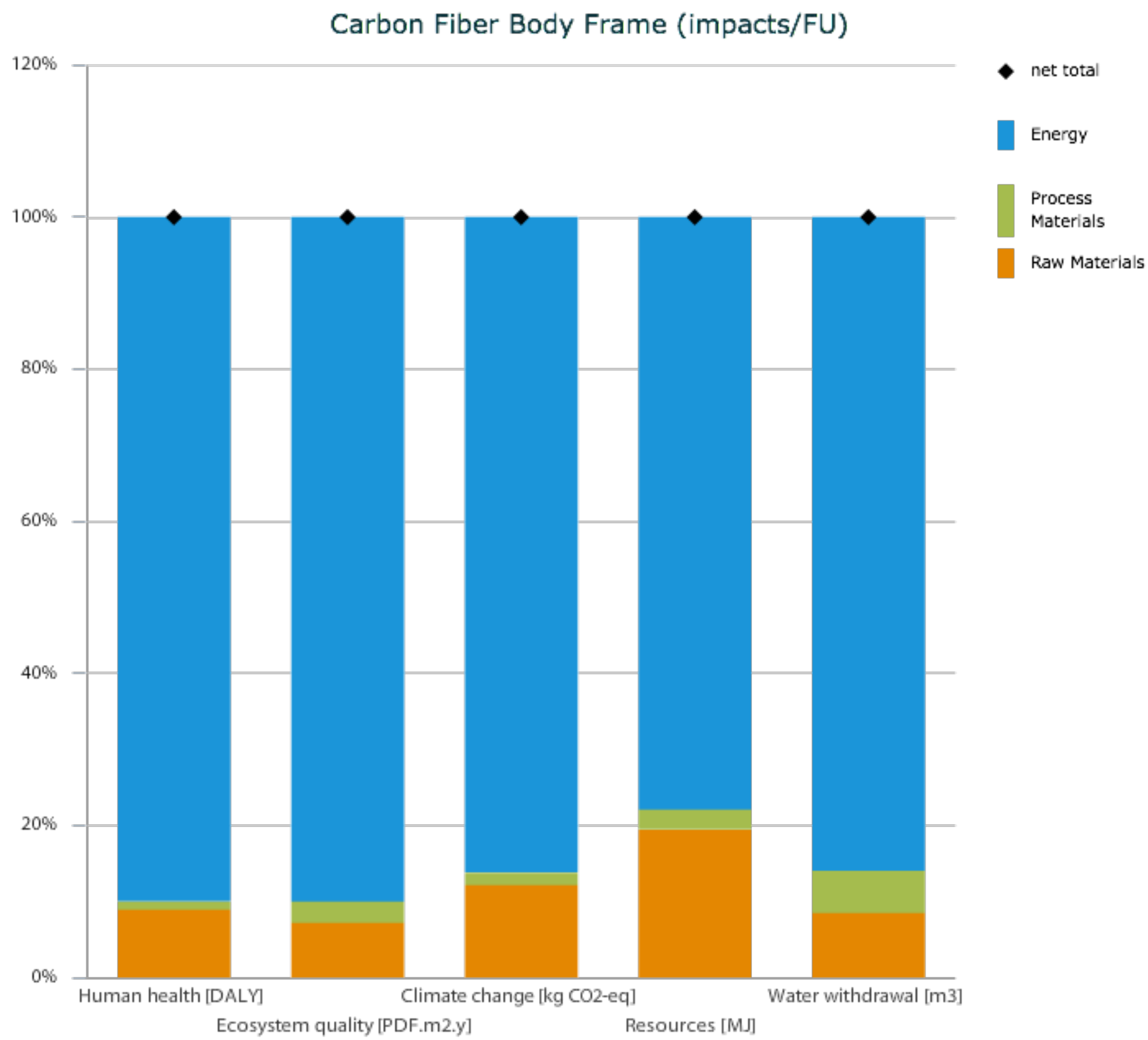

Exhibit 1. LCA results by process step for CF production. The functional unit is 31.5 kg of carbon fiber (the amount that would be in one highway-capable electric vehicle).

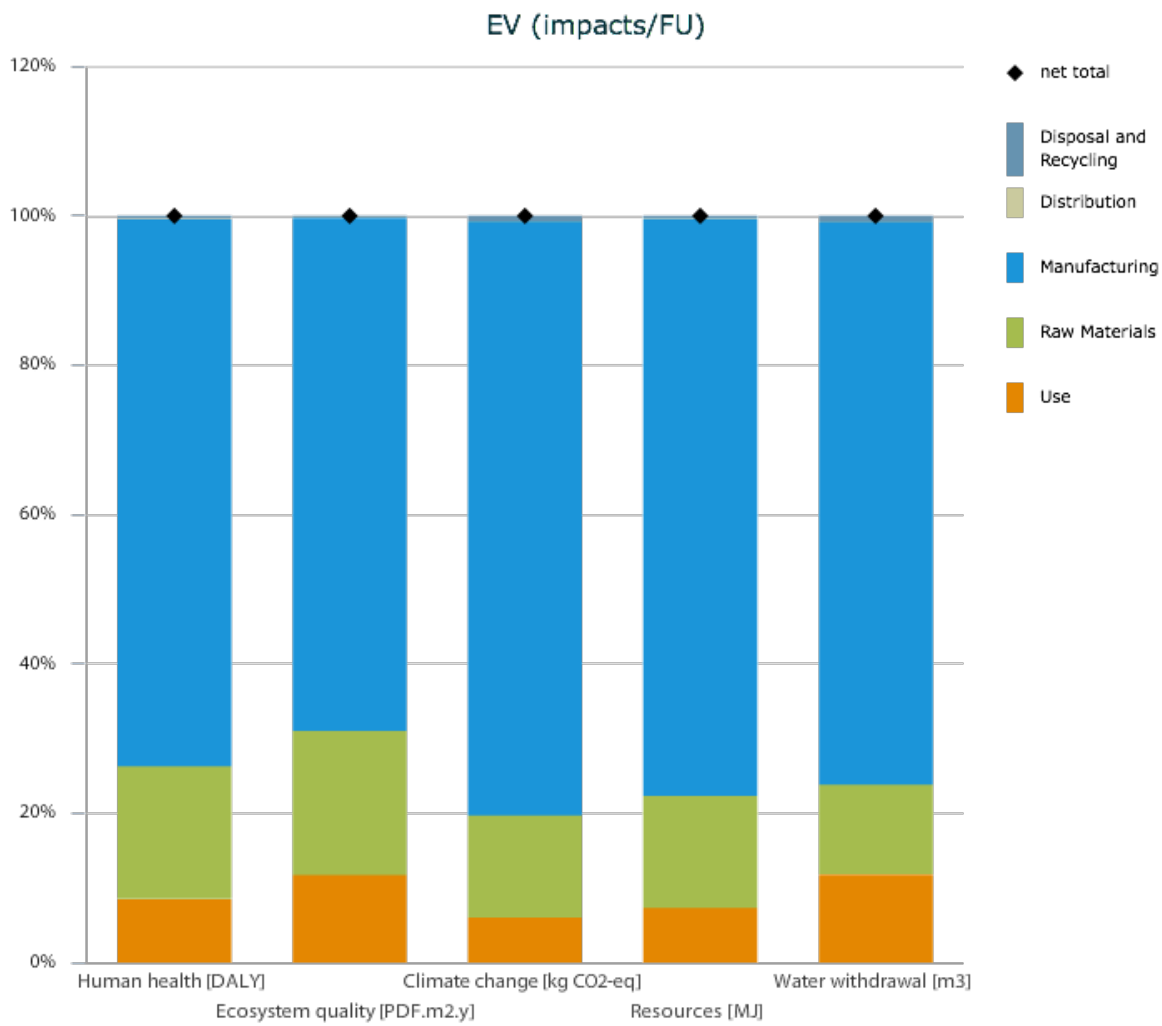

Exhibit 2. LCA results by process step for EV production. The functional unit is one highway-capable electric vehicle.

Appendix C: Additional Business Information

General Assumptions:

Tax Rate	0.75%
Depreciation	10.00%
Growth Rate	3%
Discount Rate	25%
Parking Garage	$4,000,000.00
Charging infastrucutre	$1,600,000.00
Total CapEX	$5,600,000.00
Users/Vehicle	129.8
Usage Revenue/Vehichle/Day	$100.00
Usage Revenue/Vehicle/Year	$36,500.00

Exhibit 1. Outlines basic assumptions such as tax, depreciation, growth, and discount rates used to for a forecasted valuation of sharEV.

Pricing Assumptions:

Pricing Assumptions	2017	2018	2019	2020	2021
Registration Fee	$ 33.25	$ 34.13	$ 35.00	$ 38.50	$ 43.75
Per Minute	0.39	0.40	0.41	0.45	0.51
Per Hour Maximum	14.24	14.62	14.99	16.49	18.74
Per Day Maximum	80.74	82.87	84.99	93.49	106.24
Per mile after 150 Mile per trip	$ 0.43	$ 0.44	$ 0.45	$ 0.50	$ 0.56
Drive Protection Fee	1.00 + Tax	1.00 + Tax	1.00 + Tax	1.00 + Tax	1.00 + Tax
Parking Space Monthly Rental	135.51	135.51	135.51	135.51	135.51

Exhibit 2. Forecasts the pricing assumptions of sharEV used to calculate future revenues and cash flows.

Operating and Cost Assumptions:

Operating Assumptions	2017	2018	2019	2020	2021
Projected Cars on Road	100	150	200	350	500
Projected Users	12,980	19,470	25,960	45,430	64,900
New Users	12,980	6,490	6,490	19,470	19,470
Cost Assumptions (costs as percentage of total revenue)					
Fleet Operations	44%	44%	44%	44%	44%
Member Services and Fufillment	2%	3%	4%	5%	6%
Research and Development	2%	2%	2%	2%	2%
Sales, General and Administrative	20%	21%	22%	23%	24%
COGS	$ 22,184	$ 21,075	$ 20,021	$ 19,020	$ 18,069

Exhibit 3. Depicts the operating and cost assumptions used in the valuation of sharEV.

Income Statement and Valuation Metrics:

Income Statement	2017	2018	2019	2020	2021
Revenues					
New User Registration	12,980	19,470	25,960	45,430	64,900
Projected Operating Vehicle Revenues	3,650,000	5,475,000	7,300,000	12,775,000	18,250,000
Parking Space Rentals	650,448	569,142	487,836	243,918	-
Total Revenues	$ 4,313,428	$ 6,063,612	$ 7,813,796	$ 13,064,348	$ 18,314,900
COGS	$2,218,383	$3,161,195	$4,004,181	$6,656,950	$9,034,432
Gross Margin	2,095,045	2,902,417	3,809,615	6,407,398	9,280,468
Fleet Operations	$ 1,881,086	$ 2,644,341	$ 3,407,596	$ 5,697,362	$ 7,987,128
Member Services and Fufillment	86,269	181,908	312,552	653,217	1,098,894
Research and Development	69,015	97,018	125,021	209,030	293,038
Sales, General and Administrative	862,686	1,273,359	1,719,035	3,004,800	4,395,576
Depreciation	$ 560,000	$ 560,000	$ 560,000	$ 560,000	$ 560,000
EBIT	$ (1,364,010)	$ (1,854,209)	$ (2,314,589)	$ (3,717,011)	$ (5,054,169)
Tax	15,713	21,768	28,572	48,055	69,604
EBIT*(1-T)	$ (1,379,722)	$ (1,875,977)	$ (2,343,161)	$ (3,765,067)	$ (5,123,772)
FCF to the Firm (to all stakeholders)					
EBIT*(1-T)	$ (1,379,722)	$ (1,875,977)	$ (2,343,161)	$ (3,765,067)	$ (5,123,772)
Depreciation	560,000	560,000	560,000	560,000	560,000
CAPEX	5,600,000	-	-	-	-
FCF to the Firm	$ 4,780,278	$ (1,315,977)	$ (1,783,161)	$ (3,205,067)	$ (4,563,772)
Terminal Value					(1,034,151)
PV(FCF)	$ 3,824,222	$ (1,052,782)	$ (1,426,529)	$ (2,564,053)	$ (4,478,338)
EV	$ (5,697,480)				

Exhibit 4. Illustrates a hypothetical income statement and then a final enterprise valuation for sharEV using the assumptions from **Exhibits 1**, **2**, and **3** from above.

VII. References

Abendroth, Kathryn. “Email conversation with Dr. Valerie Ashby.” April 3, 2016.

“Austin Officials Seek Out Tech Leaders to Help Fix Traffic Woes.” *Austin American-Statesman*. April 3, 2016. Accessed April 30, 2016. http://www.mystatesman.com/news/news/local/austin-officials-seek-out-tech-leaders-to-help-fix/nqxyr/.

Bruhne, Friedrich, and Elaine Wright. 2007. “Benzyl Alcohol.” In *Ullmann’s Encyclopedia of Industrial Chemistry*, 7th ed., 7–8. Wiley.

Campbell, Kyle. “Daily Drive-thru: Apple Cars Aren’t Coming Any Time Soon (Or Ever), Autonomous Volvo to Take Over London, and More.” *New York Daily News*. April 28, 2016. Accessed April 30, 2016. http://www.nydailynews.com/autos/news/no-apple-icar-autonomous-volvo-london-article-1.2617335.

Centers for Disease Control and Prevention. 1982. “Neonatal Deaths Associated with Use of Benzyl Alcohol -- United States.” *Morbity and Mortality Weekly Report*.

City of Austin. “Demographics.” Accessed April 30, 2016. http://www.austintexas.gov/demographics.

Current Results: Weather and Science Facts. “Days of Sunshine per Year in Texas.” Accessed April 30, 2016. https://www.currentresults.com/Weather/Texas/annual-days-of-sunshine.php.

“The Driverless, Car-sharing Road Ahead.” *The Economist*, January 9, 2016. Accessed April 30, 2016. http://www.economist.com/news/business/21685459-carmakers-increasingly-fret-their-industry-brink-huge-disruption.

Ellringmann, Tim, Christian Wilms, Moritz Warnecke, Gunnar Seide, and Thomas Gries. 2015. “Carbon Fiber Production Costing: A Modular Approach.” *Textile Research Journal* 0 (00): 1–13.

Goldsberry, Kirk. “Mapping the Changing Face of the Lone Star State.” *FiveThirtyEight.com*. November 4, 2014. Accessed April 30, 2016. http://fivethirtyeight.com/features/mapping-the-changing-face-of-the-lone-star-state/.

Google. “Google Self-Driving Car Project: Monthly Progress Reports.” Accessed May 01, 2016. https://www.google.com/selfdrivingcar/reports/.

Hallensleben, Manfred L. 2000. “Polyvinyl Compounds, Others.” In *Ullmann’s Encyclopedia of*

Industrial Chemistry, edited by Weinheim. Wiley.

Hedges & Company. 2016. "United States Vehicle Ownership Data, Automobile Statistics and Trends." *Market Research Services*.

Henry, Terrence. "After Ridership Drops, Where Does Cap Metro Go from Here?" *KUT 90.5, UT Austin*. January 30, 2015. Accessed April 30, 2016. http://kut.org/post/after-ridership-drops-where-does-cap-metro-go-here.

Henry, Terrence. "Austin's Growing Fast, But Why Isn't its Public Transit?" *KUT 90.5, UT Austin*. January 29, 2015. Accessed April 30, 2016. http://kut.org/post/austins-growing-fast-why-isnt-its-public-transit.

Howley, Daniel. "The Apple Car: Everything We Think We Know So Far." *Yahoo! Finance*. April 20, 2016. Accessed April 30, 2016. http://finance.yahoo.com/news/the-apple-car--everything-we-think-we-know-so-far-174542294.html.

Humbert, Sebastien, An De Schryver, Xavier Bengoa, Manuele Margni, and Olivier Jolliet. 2012. *IMPACT 2002+: User Guide*. Lausanne, Switzerland.

Indianapolis Convention and Visitors Association. "BlueIndy Electric Car Share Launches." Accessed April 30, 2016. https://www.visitindy.com/indianapolis-blueindy-launch.

International Energy Agency. "Transport." Accessed April 30, 2016. http://www.iea.org/topics/transport/.

Neurath, G.B., M Dunger, F.G. Pein, D. Ambrosius, and O. Schreiber. 1977. "Primary and Secondary Amines in the Human Environment." *Food and Cosmetic Toxicology* 15 (4): 275–82.

Park, Soo-Jin. 2015. *Carbon Fibers*. Netherlands: Springer Netherlands.

Parkme. "Downtown Parking in Austin." Accessed April 30, 2016. https://www.parkme.com/austin-parking/downtown.

PR Newswire. "Carsharing Programs: Carsharing Membership and Vehicle Fleets, Personal Vehicle Reduction, and Revenue from Carsharing Services: Global Market Analysis and Forecasts." Last modified September 24, 2015. Accessed April 30, 2016. http://www.prnewswire.com/news-releases/carsharing-programs-carsharing-membership-and-vehicle-fleets-personal-vehicle-reduction-and-revenue-from-carsharing-services-global-market-analysis-and-forecasts-300148927.html.

Ramsey, Mike. Who Will Win the Race to Autonomous Driving? –Tech Talk. *The Wall Street Journal*. Podcast Audio. MP3, 7:44. January 11, 2016. Accessed April 30, 2016. http://www.wsj.com/podcasts/who-will-win-the-race-to-autonomous-driving/7C8D662C-9164-47D3-92E7-A0ECCE37E899.html.

Rogozhin, Alex, Gallaher, Michael, and Walter McManus. "Automobile Industry Retail Price Equivalent and Indirect Cost Multipliers." U.S. Environmental Protection Agency. February 2009. Accessed April 30, 2016. https://www3.epa.gov/otaq/ld-hwy/420r09003.pdf.

Schwaller, Kevin. "MetroRapid Faces Mixed Reviews After Launch." *KXAN – NBC*. February 4, 2014. Accessed April 30, 2016. http://kxan.com/2014/02/04/metrorapid-faces-mixed-reviews-after-launch/.

Scientific Committee on Consumer Safety. 2012. *Opinion on Nitrosamines and Secondary Amines in Cosmetic Products*. Brussels.

Thomas, Alfred. 2005. "Fats and Fatty Oils." In *Ullmann's Encyclopedia of Industrial Chemistry*. Wiley.

United States Census Bureau. 2015. "Incorporated Places and Minor Civil Divisions Datasets." *Population Estimates*.

United States Energy Information Administration. 2015. "How Much Electricity Does an American Home Use?" *Frequently Asked Questions*.

United States Environmental Protection Agency. 2016. "Sources of Greenhouse Gas Emissions." *Climate Change*.

United States Geological Survey. 2016. "How Much Water Does the Average Person Use at Home per Day?" *The USGS Water School*.

University of Texas at Austin. "Facts and Figures." Last updated April 4, 2016. Accessed April 30, 2016. https://www.utexas.edu/about/facts-and-figures.

Unknown. "Kemijska struktura Nomexa." Accessed May 1, 2016. http://tinyurl.com/jbp99f5

Wakabayashi, Daisuke. "Apple Targets Electric-Car Shipping Date for 2019." *The Wall Street Journal*. September 21, 2015. Accessed April 30, 2016. http://www.wsj.com/articles/apple-speeds-up-electric-car-work-1442857105.

Whittaker, Richard. "Car2Go Closes Ranks: Concentrates on Higher-Demand Areas." *The Austin Chronicle*. September 25, 2015. Accessed April 30, 2016. http://www.austinchronicle.com/news/2015-09-25/car2go-closes-ranks/.

Zipcar. "Zipcar Reports Fourth Quarter and Full Year 2012 Results." February 15, 2013. Accessed April 30, 2016. http://www.zipcar.com/press/releases/zipcar-reports-fourth-quarter-and-full-2012-results