CICR: Charging the Battery Power Revolution

An Interactive Qualifying Project submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Bachelor of Science degree by:

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Abstract

The goal of this project, working with La Cámara de Industrias de Costa Rica (CICR), was to analyze the current state of electric mobility in Costa Rica and develop a series of recommendations for achieving electric mobility. Through meetings with various groups promoting electric mobility, we collected and analyzed information on the current state of electric transportation as well as obstacles to implementation. These findings were used to develop recommendations for the Chamber to improve the state of electric transportation.

Executive Summary

In response to the threat of climate change, the Costa Rican government has made carbon neutrality a national priority. Despite a nearly 100% carbon neutral electricity sector, the transportation sector lags behind. In 2010, the transportation sector accounted for 66% of Costa Rica's emissions (A. Blanco, personal communication, February 4, 2019). This problem has been recognized by the Costa Rican government, and legislation has already been established to encourage electric mobility. This legislation includes import tax breaks, the assignment of enforcement responsibilities to government ministries, and a requirement for a charging station infrastructure established by the electricity distributors. However, this legislation and the goals of the electricity distributors mainly target the private transportation sector while ignoring the public and freight sectors.

Methodology

In order to accomplish this project's goal, the following objectives were established and pursued:

1. Gain perspective on the groups involved and the relations between them;
2. Learn about the current situation and projections moving forward;
3. Evaluate the energy requirements and financial burdens of electric vehicles and charging stations in which the key players are most interested;
4. Develop a return on investment tool to aid business owners and the government in determining how to price electric vehicle charging station usage;
5. Develop a stance on the transition to clean transportation, taking into consideration business methods, strategies, and recommendations.

Obj.	**Why** was this objective important?	**How** did we obtain the type(s) of information needed to accomplish the objective?	**With whom** did we communicate to accomplish the objective?
1.	To understand the balance of power between the electricity distributors and regulatory bodies	Preliminary research on groups that we interviewed	The CICR, internet sources (company websites, research papers, articles, etc.)
2.	To learn of each group's perspective, goals, and timeline regarding electric mobility	Meetings with different players and groups in the energy sector	Grütter Consulting, the CICR, MiTransporte, the CNFL, the DCC, the University of Costa Rica, the SEPSE, the ICE
3.	To provide the CICR with the necessary technical information based on vehicles of interest to the various groups in order to inform and educate companies and businesses	Obtaining data and resources from the groups we interviewed	Grütter Consulting, the CICR, MiTransporte, the CNFL, the DCC, the University of Costa Rica, the SEPSE, the ICE
4.	To provide numeric support to recommendations and to provide a basis for company-specific numeric feasibility analyses	Synthesis of data and metrics collected via research and interviews	The CICR, internet sources (company websites, research papers, articles, etc.)
5.	To provide the CICR the with information, findings and recommendations needed to further reinforce its position on electric mobility as an advocate for industry	Use of charts and diagrams created from collected data	The CICR

Findings

Over the course of the project, we analyzed electric mobility in the private, public, and freight transport sectors, as well as taking into account legislation and actions affecting public institutions and companies. The most significant act of promotion is the establishment of Law

9518, which mostly affects the private transport sector. Along with establishing several incentives for the private ownership of electric vehicles, it also establishes electric public transport as a national priority, and delegates responsibility to multiple government groups for promoting private sector electric mobility. More points of optimism with regard to the private transport sector include interest shown by Costa Rican car dealerships as a result of the law, legislation in development, the charging station infrastructure that the electricity distributors are responsible for establishing, and the charging point application required by law to allow EV owners to locate available public charging stations. Action in the public and freight transport sectors is not as prominent, and also follows a theme of significantly less government involvement. Our team was exposed to projects aiming to promote electric public and freight transport including leasing models promoted by Grütter Consulting and MiTransporte, and multiple projects involving electric passenger or freight trains. However, our team also found obstacles preventing electric mobility facing each of the three sectors. Private sector electric mobility faces the lack of a vehicle replacement and scrapping plan, the need for projects to spread public knowledge on EVs, the reliance on public cooperation, the proposed charging station locations, probable effects on electricity tariffs, eventual nightly peak grid demand, and San Jose traffic. The main issues facing the public and freight transport sectors are the costs of EVs and necessary technology, and a lack of government involvement compared to the private sector. In terms of public institutions, businesses, and companies, legislation is in development to require public institutions to begin converting their fleets to EVs, and no legislation prevents businesses from installing charging stations for customer use. However, the finances behind the conversion of public institutions' fleets and business-owned public charging stations could become issues in due time.

Recommendations

Our recommendations include a focus on the combination of public and private electric mobility in the Greater Metropolitan Area, reducing Costa Rican traffic, updating the public transportation, appealing to Costa Ricans who are able to afford a new electric vehicle, incentivizing a robust charging station infrastructure in San Jose. We recommend that the public not be held financially responsible for business investments into electric mobility in order to maintain public support. Instead, the burden should be placed on the electricity distributors, as they will see increased profits as Costa Rica sees more electric vehicles on the streets. We recommend promoting the use of self-generation and energy storage in order to decrease grid demand and provide businesses additional benefits and opportunities. As private sector electric vehicle usage increases, self-generation and energy storage techniques could be utilized to reduce an individual's grid demand, which would lower electricity bills and protect the grid. This applies to companies with vehicle fleets that charge overnight as well. We recommend not using legislation punishing those without electric vehicles in order to prevent targeting the poor. This will require ample financial assistance to those who cannot afford an electric vehicle. We urge Costa Rica to consider allowing more standards of charging, to enable Chinese electric vehicles to gain a presence and increase competition within the country. We recommend that the Costa Rican government develop legislation to advance electric mobility in the freight transport sector. This could include government incentives and financial aid to freight transport companies, developing electric train projects, promoting a focus on small electric trucks, and placing limits on investments. We recommend that companies that plan to install charging stations have a tool to help them determine what type of investment to make. This tool should take into consideration the number of employees, whether they use a private vehicle to commute, the average distance of commutes, the number of company cars, and the expected daily travel distances of those cars. We recommend that projects such as MiTransporte should provide education on EVs to the general public to ensure public safety workers know how to handle accidents involving electric vehicles, and to provide the public with information on battery lifespans, replacement, and disposal.

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Chapter 1: Introduction

For over 25 years, climate change has been a motivating factor for countries around the world to take action to preserve the planet. Reports have made it clear that the only way to preserve the Earth as it is now over the next 30 years is to bring the "Global net human-caused emissions of carbon dioxide" to "net zero" by 2050 (United Nations, 2018). The Central American country of Costa Rica has been encouraging clean energy for several years now, promoting environmentally conscious efforts since 1994. The country's government has displayed a willingness to act on the issue by focusing a large portion of its spending on carbon neutrality. In 2017, Costa Rica was able to power its electricity sector solely on renewable sources for 300 consecutive days (Rubio, 2018). This is part of a continuing effort by Costa Rica to become carbon neutral by 2021.

However, Costa Rica's main obstacle in the march toward carbon neutrality is the transportation sector. While the electricity sector is almost 100% carbon neutral, environmentally friendly transportation is far from that goal. In 2010, the transportation sector accounted for 66% of Costa Rica's emissions (A. Blanco, personal communication, February 4, 2019).

The Costa Rican government recognizes this problem and is working to develop solutions. Several pieces of legislation have been proposed or approved that promote electric vehicle usage in the private sector. Costa Rica's electricity distribution companies are working to improve the infrastructure for electric vehicles through a project to install fast charging stations throughout the country. With a national standard for charging stations already in place, it is evident which types of electric vehicles the government is working to make most prominent throughout the country. However, there are still factors that need to be addressed and planned for to increase the effectiveness of the measures being taken.

Many of the proposed/approved projects target transportation in the private sector but leave public and freight transportation as problems to be addressed in the future. While the private sector is the biggest contributor to emissions from the transportation sector, it is more difficult to attack the sector as a whole across the country than it would be to develop a solution that integrates all three sectors, even if only focusing on the greater metropolitan area of San Jose. In order to develop a sufficient course of action, it is important to gain an understanding of current legislation regarding public and freight transportation, and future plans for these sectors. Industries cannot be expected to work toward electric mobility without understanding their options or being aware of the benefits and risks.

The goal of this project was to provide the Chamber of Industries of Costa Rica with analysis of the feasibility, economics, and legality of an industrial transition to electric vehicles. Gaining an understanding of the current progress toward private electric mobility was an important aspect of the project, though the project mainly focused on collecting findings and recommendations with regard to public and freight transportation. These deliverables were preceded by analysis of the implementation and sustainability of electric vehicle charging stations in Costa Rica. These objectives provided the Chamber of Industries of Costa Rica with the necessary data and background to confidently develop recommendations regarding the electrification of transportation throughout the country.

Chapter 2: Background

CICR

The Chamber of Industries of Costa Rica (CICR) is an organization that represents the various industries of Costa Rica and promotes environmentally friendly practices and regulations. This is represented by CICR's mission to "strengthen Costa Rica's industrial sector while promoting the use of sustainable practices with an emphasis on energy efficiency" (Jarrett, Little, Ralphs, Shipulski, & Vasconcelos, 2018). The CICR often takes legislative positions opposite to those of the Instituto Costarricense de Electricidad (Costa Rican Institute of Electricity, ICE), opposing requested electricity tariff increases on behalf of consumers. The CICR keeps an updated website in order to inform companies of their options, with access to studies on renewable energy profiles, environmental considerations, and energy conservation strategies.

The CICR holds conferences that allow experts and advocates for renewable energies to converse with Costa Rican businesses about benefits, functionality, and other factors regarding implementation of sustainable practices. These workshops create in-person interaction between companies in the private sector, environmental advocates, scientists, and members of the chamber in order to encourage an exchange of knowledge. By giving attendees short blocks to give presentations, the chamber presents a problem and allows multiple groups to advocate their solutions. One such conference began with CICR employee Carlos Montenegro addressing the issue of rising electricity tariffs, which was followed by several groups offering data and solutions to help save and generate energy.

Along with electricity tariffs and energy storage, electric mobility is a significant concern of the chamber.

San Jose

San Jose is the capital of Costa Rica and its largest city, located in the midwestern Central Valley. Surrounded by mountains to the north and volcanoes to the south, San Jose sits at the base of the valley. As a result, the city contains some hills but consists of a mostly flat terrain compared to the steep inclines of the surrounding areas. San Jose contains the seat of the national government and is a key focal point of political and economic activity. About 20% of Costa Rica's population calls San Jose home. Although only a fraction of the city's population live in the city center, opportunities for work bring more than one million people to the city each day (CIA, n.d.). Approximately 80% of all cars and commute traffic in Costa Rica occur in the greater metropolitan area of the city (J. Quirós-Tortós, personal communication, February 6, 2019). As San Jose's urban reach expands, it has become apparent that the city's outdated infrastructure is not suited to support the increased volume of traffic.

Energy Breakdown

The Latin America Energy Organization (OLADE) has generated data which analyze the national energy consumption/usage profile of Costa Rica. An OLADE report stated that in 2009, the Costa Rican transportation sector was responsible for 43.9% of the country's energy consumption, the largest percentage of any sector; the industrial sector was second at 25.7%. This report also contained a comprehensive chart of the overall electricity usage of the country, which showed that the residential sector used the most electricity followed by the industrial sector. The difference between the final energy consumption and final electricity consumption is that energy consumption accounts for all primary and secondary energy sources. In the transportation sector, these measures include fossil fuel consumption. The report also provided a comprehensive energy matrix which indicated that an estimated 30 terajoules are distributed nationwide, with 12 of these terajoules being allocated to the residential sector (CEGESTI, 2011).

In 2016, electricity in Costa Rica was priced at US $0.1847 for every kilowatt-hour (kW-h). By comparison, the average cost of electricity in the United States in 2018 was priced at US $0.1301 per kW-h (Choose Energy, 2018), and the average cost in Central America in 2016 was US $0.1348 per kW-h. Costa Rica's high rates can be attributed to the country's use of a single provider electricity system and the recent development of multiple costly power plants (R., 2018).

Electricity Distribution

Only eight companies in Costa Rica are legally allowed to access and distribute energy from the electricity grid. These companies have exclusive rights to sell electricity to domestic, commercial, and industrial consumers. They consist of two public (governmental) companies, two municipally owned companies, and four cooperatives. The governmental companies, the ICE and the National Power and Lights Company (Compañia Nacional de Fuerza y Luz, CNFL), enjoy a significant realm of influence in electricity distribution throughout the country.

While the ICE is mainly responsible for electricity generation, the other seven distribution companies are able to develop generation facilities either on their own or through collaboration with other companies and/or private investors. Private investors sell the energy to ICE and need a permit from ICE covering legal, financial, and technical aspects, an environmental viability permit from the Environmental Secretary (SETENA), and a public service concession permit given by the Public Services Regulatory Authority (ARESEP), among other more specific permits. Any generation project larger than 5 megawatts (MW) must connect to the transmission grid, and therefore needs authorization from ICE. Smaller projects can connect to a distribution company network pending the company's approval (Zamora-Castro, 2018).

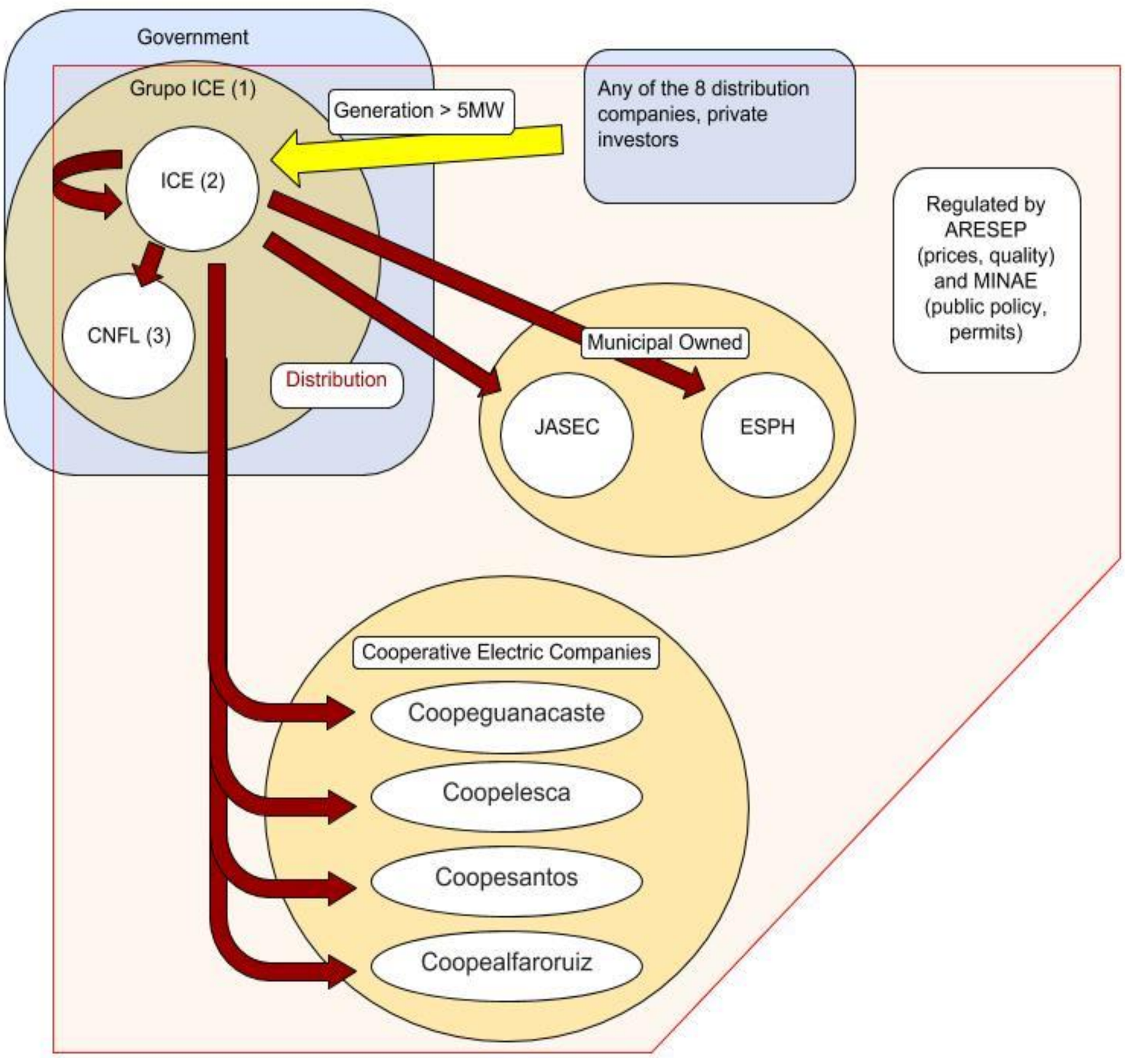

Figure 1. This image was developed to visualize the links between groups responsible for electricity.

ICE

The Costa Rican Institute of Electricity (ICE) is one of the eight national companies responsible for distribution. The ICE is solely responsible for electricity transmission and largely responsible for electricity generation, and is one of the four members of the larger Grupo ICE collective. The CNFL, a telecommunications company and a cable company, is also a member of Grupo ICE. Because the ICE has a government-imposed monopoly over electricity transmission, they are solely responsible for grid reliance. ICE's income comes from a regulated tariff on energy transmitted in the transmission network, per kWh (Zamora-Castro, 2018).

ARESEP

The Public Services Regulatory Authority (ARESEP) is a decentralized public institution that establishes prices and rates for various public services. These services include establishing electricity tariffs for domestic, commercial, and industry consumption. The ARESEP is also responsible for ensuring energy quality and setting tariffs for electricity generation and transmission. In determining electricity companies' profits, the ARESEP must consider factors such as service at cost, economic efficiency, social equity, environmental sustainability, conservation of resources, and efficient regulation (Gutiérrez, 2015).

MINAE

The Ministry of Environment, Energy and Telecommunications (MINAE) is a government ministry with a regulatory role in electricity distribution. The MINAE is in charge of public energy policies, and is responsible for granting certain permits required for energy generation and distribution (Zamora-Castro, 2018).

CNFL

The Costa Rican National Power and Lights Company (CNFL) is the second public/governmental electricity company in Costa Rica. The CNFL is responsible for distributing energy to the 920.9 kilometer greater metropolitan area surrounding San Jose. While the CNFL is a part of the Grupo ICE, it has several objectives separate from the ICE. The CNFL is a major player in the electric vehicle market due to its plan to install 28 fast charging stations throughout the country (Zamora-Castro, 2018).

MiTransporte

MiTransporte is a project being worked on by the German development agency Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) and is funded by the International Climate Initiative (IKI) of the German Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU). The members of MiTransporte are working with the Costa Rican government to facilitate a national transition to climate friendly and clean transportation. MiTransporte will work toward improving legal and institutional frameworks for Costa Rica to pursue its green goals through three main components. First, MiTransporte will support the national government in developing policies and financial strategies to incentivize a shift toward environmentally friendly transportation options. Second, the project will work with local governments, private companies, and NGOs to implement pilot urban sustainable transportation projects. Third, the project will promote the exchange of knowledge and experience to determine and demonstrate the best practices. MiTransporte's main partners are the MINAE and the MOPT, the Ministry of Public Transportation (Changing Transport, n.d.).

AceSolar

The Costa Rican Association for Solar Energy (AceSolar) is a private, nonprofit organization dedicated to promoting renewable solar energy. AceSolar acts as a sustainability activist and aims to generate knowledge on solar energy throughout government, academia and industry via the promotion of solar energy projects and training (AceSolar, n.d.).

Current Vehicle Usage

From 1994 to 2014, the number of vehicles per 1000 inhabitants in Costa Rica has increased from 132 to 263 (CEGESTI, 2015), a trend that does not appear to be slowing down. 2015 and 2016 saw unprecedented numbers of new car registries (Murillo, 2017). 2016 showed a congestion level of 32% (in terms of added travel time due to traffic), a 12% increase since 2008. With more cars continuing to populate the streets, traffic jams will be much more common (Tomtom, 2016). Having a car can provide the safety that public transportation and walking lack, especially in an urban center like San Jose. Due to these factors, Costa Ricans have increasingly turned to cars in the absence of a sufficient public transportation infrastructure, but the resulting increases in vehicle usage have led to new issues that will affect the transition to electric mobility (Lopez, 2012).

Age of Costa Rican Vehicles

Costa Rica continues to see an annual increase of car imports. In 2016, cars represented 5.6% of Costa Rica's total imports (OEC, 2016). As more cars are brought into the country, there is an increased need to regulate these vehicles. Currently, the average age of a vehicle in Costa Rica is 16 years. For decades the government had no regulations concerning the age of imported vehicles, and cars 15 years and older were allowed to enter the Costa Rican auto market uninhibited (Jiménez, n.d.). In 2014, used vehicles accounted for 34% of all imported vehicles. Of these used vehicles, 24% of them were over 15 years old. This has led to large-scale problems with fuel efficiency in Costa Rica. Despite the country using gasoline that is 20 times cleaner than Central American standards, the average fuel economy of a passenger vehicle in Costa Rica is 32 miles per gallon (MPG) (CEGESTI, 2015). Costa Rica's abundance of low-cost vehicles has caused the transport sector to be the leading contributor to CO_2 emissions in the country.

Costa Rican Roads

Costa Rican roads are difficult to navigate for the average driver. Larger buses can handle the impacts caused by potholes and other hazards, but smaller compact cars often do not fare as well. In 2016, Costa Rica ranked in the top ten of Waze's list of worst countries to drive in (Murillo, 2017). These challenges have led Costa Rican drivers to prefer four-wheel drive SUVs that they believe can better handle road travel (Lopez, 2012). However, SUVs are among the worst emitters of greenhouse gases, creating more issues which are impeding Costa Rica's carbon neutrality plans.

Transportation

Costa Rica's electricity sector is performing well in its emission reduction goals, but widespread fossil fuel consumption in transportation will almost certainly prevent the country from achieving its goal of carbon neutrality by 2021. As of 2016, Costa Rica is almost fully reliant on imported fossil fuels for transportation. With an estimated 915,000 vehicles on the road, Costa Rica consumed over 300 million gallons of gasoline in 2015, generating 2.73 million metric tons of carbon dioxide. Carbon dioxide emissions from vehicles running on diesel were even greater. If Costa Rica were to become carbon neutral, it would need to make up for about 10,150 gigawatt-hours (GW-h) of non-renewable energy consumed.

It has been estimated that Costa Rica would need to produce an additional 3,000 GW-h of energy per year in order to sustain the number of vehicles reported to be in Costa Rica as of 2016, in addition to the approximately 10,500 GW-h these vehicles produce for the electricity sector. This would equate to about 500 wind turbines occupying 150 square kilometers of land, or a solar panel farm of 50 square kilometers (Mosheim, 2017).

Electric Vehicles

State of Technology

Work is currently being done to make fully electric vehicles a feasible reality throughout the developed world. Improvements made to electric vehicle batteries can make the vehicles more appealing to businesses and private consumers. Researchers at America's National Renewable Energy Laboratory are working to increase the average mileage per charge of an electric vehicle to 250-300 miles, reducing the cost from US $350-$550 per kW-h to US

$125/kW-h, and adding another 15 years to current batteries' 8-year lifespan (National Renewable Energy Laboratory, n.d.). As work towards these goals progresses, electric cars will become more efficient and generate better returns on investment.

Currently, electric vehicle batteries are most commonly lithium ion batteries, similar to what is found in cell phones and laptops. Electric vehicles utilize preservation methods to make their batteries last significantly longer than those in cell phones. These methods come as a result of a few characteristics, or flaws, of lithium ion batteries. Most notably, the lifespan of a lithium ion battery greatly decreases under consistent 100% depletion and 100% charge. To combat this, electric vehicle battery management systems prevent 100% charges, and treat about 20% capacity as 0% capacity when warning drivers of low range. Costa Rica introduces another problem into the mix, being consistent exposure to high temperatures. Data show that high heat should not affect a battery's lifespan unless the battery is left fully charged in the heat for an extended period of time (Arcus, 2016). To combat this, electric vehicles are typically shipped with only about a 40% charge.

Table 1. Charging Parameters and Electric Vehicle Battery Lifespan (Miles, 2018)

Charging Parameters	Cycles before Capacity Reduced to 85%
100% - 25%	2,010
100% - 40%	2,800
100% - 50%	2,800
85% - 25%	4,500
75% - 25%	7,100
75% - 45%	10,000
75% - 65%	12,000

This table displays how preventing a 100% charge and 100% depletion can greatly increase an electric vehicle's battery lifespan. However, as stated, electric vehicles have the programming and utilize technology to preserve battery life by not charging to 100% and demanding a charge before 100% depletion (Miles, 2018).

Electric Vehicles in Costa Rica

Less than 1 percent of the 1.4 million cars in Costa Rica are fully electric (Alvarado, 2018). An electric vehicle (EV) transition is at the forefront of the government's priorities, and legislation is being developed to incentivize Costa Ricans to discontinue use of non-electric vehicles. Despite this focus, affordability and practicality are large issues getting in the way of a full-scale transition. With only 30 charging stations in the country in total, an increase in EVs on roads would cause massive increases in wait times (El País, 2018). For the average consumer in Costa Rica, buying an electric vehicle at the present time is not worth the financial investment.

According to Alan Blanco of the CNFL, there were 500 electric cars and 600 electric motorcycles in Costa Rica as of February 4, 2019. This level of progress is far above that of the public and freight transport sectors, which the CNFL is not currently prioritizing.

Charging Stations

Costa Rica currently has 30 EV charging stations, but until recently there had not been any large-scale plans to continue installing more. It is unknown if the country's electric grid would be capable of supporting a large-scale introduction of EVs, since it is not yet clear how the energy needed to fuel them would be efficiently stored and sustainably sourced (Tipping, 2018). However, a new DC "fast charging station" for EVs has been implemented at the CNFL facility in Escazu, with 28 more planned for implementation by the end of 2019. These new stations are capable of charging EVs from 0% to 80% in roughly 30 minutes and will be a key component of the push towards electric power in the transport sector (Alvarado, 2018). The implementation of these fast charging stations may help offset the potential concerns associated with electric energy storage by reducing the time needed for EVs to charge and therefore consuming less energy overall. The current planned positions for the charging stations are distributed relatively evenly throughout the country based on the principle that the distance between two charging stations should be roughly 80 kilometers.

Figure 2. CNFL Charging Station Locations (Image courtesy of Alan Blanco of the CNFL, February 4, 2019)

Along with the introduction of more charging stations, the Costa Rican government is working to import more EVs through a partnership with Mitsubishi Motors and the Japanese government. In March 2018, about 60 Mitsubishi EVs were delivered to Costa Rica as the first step in its goal to import 100,000 new electric vehicles over the next several decades (*Japan: Mitsubishi Motors delivers fleet of EV and PHEV vehicles to Costa Rican Government*, 2018).

This effort is meant to ensure that an adequate ratio of EVs and charging stations can be maintained through growth in parallel, which will ensure long-term sustainability and a positive environmental impact.

For a city such as San Jose, fast charging stations would be a significant boost to the chances of a successful EV adoption. Rapid chargers currently existing in Japan can charge vehicles fully in 30 minutes, compared to a 200 volt charger taking 8 hours and a 100 volt charger taking 14 hours. However, the implementation of rapid chargers brings about additional obstacles on top of those shared with normal chargers. Rapid chargers require more space, are more complex to install, and are not as versatile in terms of where they will work. They also draw more energy (Nagatsuka, 2013).

Charging Station Technology

There are three main different types of electric vehicle charging stations. The level 1 charger is the simplest form, operating at 120 volts AC, comparable to an average household outlet. This is the most common charging station for residential night charging. Most EVs require 10-14 hours to complete a full charge, with a power input of 15-20 amps of current and around 1.4 kW of energy when charging. The benefits of a level 1 charger include low installation costs and low energy demand, while the downsides include very slow charge times, as one hour of charge only results in a 5-8 kilometer range increase.

The level 2 charger is the second AC charger, operating at 240 volts. For perspective, this is comparable to larger household appliances such as refrigerators. The J1772 connector model (standard in the United States, Japan, and Costa Rica), can provide up to 80 amps of current (19.2 kW), although most vehicles only draw up to 30 amps (3.3-6.6 kW) when charging. The

J1772 semi rapid charger is modeled after the SAE standard. A fully electric vehicle will typically require between 3-7 hours to fully charge. The benefits of level 2 chargers include a greater efficiency than level 1 chargers for shorter duration charges and faster charging times, with competing standards and higher installation costs as the disadvantages.

The DC fast charger is a charging station that uses DC electricity to charge electric vehicle batteries, typically up to 80% in about 30 minutes. The last 20% to reach full charge takes significantly longer, but an 80% charge in 30 minutes is the equivalent of a full refuel at a gas station for internal combustion engine vehicles. DC fast chargers are more expensive than both level 1 and level 2 chargers for equipment and installation costs, and can be even more expensive during time periods when peak electricity tariffs are applicable (Vermont Energy Investment Corporation, 2014). The DC fast charger modeled in accordance with the SAE standard, found in the US and in Costa Rica, is the Combo 1. Japan uses the CHAdeMO fast charger (A. Blanco, personal communication, February 4, 2019).

Electric public transport has begun introducing new methods of convenient rapid charging. Bus companies throughout Europe and elsewhere have begun implementing bus station overhead fast charging, Opportunity charging, in conjunction with electric public buses. As noted for several of the entries in the public transport list deliverable, these overhead chargers provide DC electricity at around 175-350 kW, but some buses handle up to 600 kW. Being able to quickly charge at bus stops greatly reduces the need for a large battery capacity. Many of the buses utilizing this technology have battery capacities in the 100-200 kWh range, but some have as little as 20 kWh. These numbers pale in comparison to the 500 kWh advertised by the BYD K9 2019 model, but with the capability to charge in less than 10 minutes at a properly equipped bus stop, these buses do not suffer. This technology is ultimately a trade-off, however, as it carries with it significant costs (Bigelow, 2017).

Current Regulation within Transportation Sector

As Costa Rica works towards its goal of carbon neutrality, policy makers continue to establish regulations within the transportation sector. In 1994, Law 7447 (Regulation of the Rational Use of Energy) established that vehicle producers must obtain authorization from the Ministry of National Resources Energy and Mines (MIRENEM) to begin building vehicles by verifying their energy efficiency levels. Vehicles that exceed the limits set by the MIRENEM are not permitted to be on the streets of Costa Rica. Lawmakers would continue to promote the idea of fuel efficiency in 2011 with Executive Decree 36372, which mandated a reduction in the sulfur content of gasoline to 50 parts per million (ppm) (CEGESTI, 2015). This decree made Costa Rica's gasoline twenty times cleaner than the standard set by the Central American Technical Regulations for Petroleum Products.

Although Costa Rica has been monitoring the efficiency of vehicles produced within the country for over two decades, it was not until 2016 that a fuel emission standard for all vehicles within the country was established. Executive Decree 39724 (Regulation for the Control of the Polluting Emissions),produced by Motor Vehicles with Internal Combustion Engines, established that new and used automobiles entering Costa Rica must adhere to Euro 6, Tier 3 or higher emission standards as of January 2021 (CEGESTI, 2015). The Euro 6, Tier 3 is the strictest emission standard set by the European Union. In the past twenty-four years, Costa Rica has sought to increase the fuel efficiency of their vehicle fleet, and has also tried to incentivize its citizens into adopting fully electric and hybrid vehicles.

Costa Rica began its EV incentive plan in 2006 with Executive Decree 33096, which encouraged the use of hybrid-electric vehicles as part of a broader "clean technology" push. Subsequently, lawmakers announced Executive Decree 37822 in 2013, which further incentivized consumers to purchase electric-hybrid vehicles (CEGESTI, 2015). Both legislations exempted new vehicles powered by electricity, fuel cells, or compressed air from the selective consumption tax. The selective consumption tax is one of three taxes applied to items imported to the country, along with sales tax and customs tax. These regulations also encouraged public entities to develop infrastructures to support the operation, maintenance and recharging of electric and hybrid vehicles.

In 2015, the Costa Rica Energy and Environment Ministry launched the Efficient Vehicle Acquisition Program (PAVE), which allows owners to trade in their current combustion vehicles for a more fuel-efficient vehicle. The program is backed by the Banco de Costa Rica, which finances 100% of the purchase of the new vehicle at a fixed interest rate of 6.25% for the first three years (Jiménez, n.d.). While Costa Rica's transportation sector is far less progressive than its energy sector, these regulations demonstrate that the government is improving its efforts to reduce transport emissions.

Costa Rica is progressing on a sustainable path towards an increased use of public electric vehicles. The recently passed Bill for Electric Transportation (Central America Data, 2018) provides a tax exemption on imports or sales of purely electric vehicles that cost less than US $30,000 (Alvarado, 2017). The bill will also apply to qualifying forms of public transportation, and demands that more charging stations be built to account for this expected increase in EV usage.

In addition to EV import tax exemptions, the above calculations provided by the CNFL, show that the brackets of incentives are applied to the first US $30,000, the next US $15,000, and the next US $15,000 after that, of any electric vehicle more expensive than US $30,000, US $45,000, or US $60,000 respectively.

Table 2. Incentive and Promotion for Electric Transportation Act Breakdown for Import Tax of Private Electric Vehicles (Tax@hand, 2018)

CIF value of electric vehicle (USD)	Sales tax exemption	Selective consumption tax exemption	Import duty exemption
Up to 30,000	100%	100%	100%
30,001 to 45,000	50%	75%	100%
45,001 to 60,000	0%	50%	100%
Over 60,000	0%	0%	0%

These incentives relieve electric vehicle consumers of the current import tax system which adds up to 55% of an internal combustion engine vehicle's cost insurance freight (CIF) price, as recorded by Costa Rican customs. Import taxes on all items are determined by customs and are calculated as percentages of an item's CIF value. For vehicles, the three component taxes of the import tax are a 13% sales tax, a 30% selective consumption tax, and a 1% customs value tax. These three values are percentages of the product of the CIF value of the vehicle multiplied by 1.25. For example, if a consumer buys an electric vehicle with a CIF of US $30,000 instead of an internal combustion engine vehicle with the same CIF value, they will save US $16,500 in taxes (A. Blanco, personal communication, February 4, 2019).

The Law of Incentives and Promotion for Electric Vehicles, Law 9518, includes further incentives for private EV ownership beyond financial considerations, such as unrestricted use of EVs (currently, vehicles may not be driven in downtown San José and its surrounding areas one day per week). These owners enjoy free use of street parking, preferential parking spaces, and a 10-year exemption from local sales tax and selective consumption tax for spare parts related to the operation of the electric engine and batteries. Finally, staggered benefits for five years of annual property tax payments are provided (Costa Rican Legal Information System, 2018).

While Law 9518 only offers exemptions for purely electric vehicles and not hybrids, it is still a very strong step which approaches the level of incentives offered in countries that have already established infrastructures which promote electric mobility, as illustrated by the following case studies.

Electric Vehicle Implementation Case Studies

Norway

Norway leads the world in electric vehicle market shares. In September 2018, 60% of new cars registered in the country were at least plug-in hybrids, with 45% being completely electric (Lambert, 2018). Norway has set a goal for all new cars registered in the country to be fully electric by 2025. For over 20 years, the Norwegian government has been introducing incentives to aid all-electric vehicles in the market as a response to climate change. These zero emissions incentives include the elimination of purchase or import taxes (introduced in 1990), exemption from the 25% value added tax on purchase (2001) and on leasing (2015), and exemption from the annual road tax (1996). Furthermore, company car taxes are reduced by 50% (2018) from the original value of 40% (2000), and fiscal compensation for the scrapping of a fossil fuel van when switching to a zero-emission van is provided.

Additionally, from 1997-2017, zero emissions vehicles paid no charges for using toll roads. In 2019, toll road charges were reintroduced with a cap of 50% of the full price for non-electric vehicles. Most of these incentives are guaranteed through at least the end of 2020, with many slated for revision at the end of 2021. The Norwegian car tax system aims to grant lower emission vehicles greater economic viability than high emission cars. The vehicle tax is calculated by taking into account a vehicle's weight, CO_2, and NO_2 emissions, allowing EVs to be competitive in the market in spite of facing greater import prices.

In order to handle the large number of electric cars in the country, Norway has developed an infrastructure of over 10,000 public charging stations which can sustain the simultaneous use of more than 1500 fast chargers, in addition to individual charging stations owned by Norwegian homeowners. The world's largest public electric vehicle charging garage is located underneath the capital city of Oslo (Norsk elbilfoening, n.d.).

Japan

Japan is home to several prominent international vehicle companies such as Toyota, Nissan, and Mitsubishi, and therefore has a large influence in the worldwide shift towards electric vehicle adoption. Japan's local market has pushed its car makers toward pursuing electric vehicles. This has been caused by a recent scarcity of natural resources, caused by the country's geographical characteristics as a densely populated series of islands. In 1997, Toyota responded by producing the Prius, the world's first mass-produced hybrid car. Since then, Nissan and Mitsubishi have also developed hybrids, with the Nissan Leaf finding great domestic and international success. Despite this progress, these car manufacturers are still producing internal combustion engines, so Japan has developed a national plan to become emissions-free by 2050.

Similar to Norway, the Japanese government has used pro-EV incentives to encourage consumers to buy environmentally friendly vehicles. This began in the mid-1990s with a policy that provided consumers with a subsidy of up to 50% of the overall cost when buying a zero-emission car. Currently, first-time hybrid buyers can get a one-time subsidy on a new vehicle, capped at around US $7700 and determined by the vehicle's driving range. Additional policies include the waving of one-time taxes such as the tonnage tax, and a 50% reduction of the annual automobile tax.

In order to combat range anxiety (the concern of electric vehicle owners that they will not have access to a charging station if traveling regularly or a far distance), Japan has set a goal to install fast charging stations every 15 km. Japan already has 40,000 EV charging stations and about 46,000 more petrol gas stations. In comparison, the United States has about 9,000 EV charging stations, and 114,000 gas stations (Gibson, 2018).

United Kingdom

In the United Kingdom, EV usage is growing steadily. While EVs only account for a small share of the country's vehicle market (1.4 percent of new cars in 2013), purchasing alternatively fueled vehicles is a growing trend among environmentally-minded drivers (SMMT, 2018). However, concerns still exist regarding the ability of EVs to impact the existing vehicle market, as the majority of UK drivers seeking a vehicle are not seriously considering purchasing EVs. Cost and ease of use are the main barriers preventing EVs from proliferating, as consumers are often unwilling to sacrifice the convenience of a quick gas refill.

In order to facilitate market growth, the UK government approved 400 million pounds of funding for charging stations in the 2017 national budget. However, due to a lack of education amongst local authorities, the money is not being put to good use by local governments, who are more likely to build in open/available areas instead of areas more beneficial to drivers. Without an increase in the amount of charging stations nationwide and a greater effort to educate government officials, range anxiety will still play a large role in holding the public back from making the switch to electric vehicles.

Once the prevalence of charging stations is improved upon, the next task will be to manage the increased load on the electricity sector. The UK's national grid is equipped to support the amount of EVs the government is aiming to introduce, but is not currently prepared to charge them all at the same time. Solutions to high peak consumption include encouraging people to charge their vehicles outside of these peak times, and smart charging which would slow the rate of charging and therefore require less energy at peak times (Priday, 2018). For Costa Rica, energy storage batteries and other techniques at the individual level could aid in handling peak demand to avoid these issues.

Although Norway, Japan and the UK are first world countries with greater access to technology and the funds to support their initiatives, their actions could inspire similar measures in Costa Rica. The CNFL's end goal of installing a charging station every 80 km throughout the country is not as ambitious as Japan's, but will still aid in combating range anxiety. If Costa Rica implements a compensation system for scrapping a fossil fuel vehicle and buying an electric vehicle similar to Norway, Costa Ricans may be more likely to make the switch. A gathering and analysis of public opinion can be used to determine which potential actions by the Costa Rican government would have the greatest effect.

China

An example more pertinent to the CICR, due to their greater focus on an industrial transition to electric vehicles over private sector electric mobility, can be found in China. The

Guardian reported on December 12, 2018 that the Chinese city of Shenzhen has a fully electric fleet of 16000 buses and plans to make all 22000 of its taxis electric by March 2019. The Shenzhen Bus Company has 180 depots with their own charging stations installed, but also rents charging stations from the municipal government in order to charge their fleet. This may be a viable solution for Costa Rican industries if ICE establishes its own charging stations. It will be harder for taxis in both Shenzhen and Costa Rica to make the switch because taxis do not have set routes or mileages per day, and could therefore end up competing for charging stations at peak times. A solution to this mentioned in the article is an app to provide taxi drivers with notifications on which charging stations are available in real time (Keegan, 2018).

Chapter 3: Methodology

Introduction

The goal of this project was to provide the Chamber of Industries of Costa Rica with an analysis of the feasibility, economic requirements, and legality of a nationwide industrial transition to electric vehicles (EVs). This required an extensive study on the implementation of and economic profile behind EV charging stations. The following objectives were generated to guide research and achieve this goal:

1. Gain perspective on the groups involved and the relations between them;
2. Learn about the current situation and projections moving forward;
3. Evaluate the energy requirements and financial burdens of electric vehicles and charging stations in which the key players are most interested;
4. Develop a return on investment tool to aid business owners and the government in determining how to price electric vehicle charging station usage;
5. Develop a stance on the transition to clean transportation, taking into consideration business methods, strategies, and recommendations.

Summary of Work

Table 3. Summary of Methodology

What is the objective that needed to be accomplished?	**How** did we obtain the type(s) of information needed to accomplish the objective?	**With whom** did we communicate to accomplish the objective?
1. Gain perspective on the groups involved and the relations between them	Preliminary research based on groups that we interviewed	Internet sources (company websites, research papers, articles, etc.), the CICR
2. Learn about the current situation and projections moving forward	Meetings with different players and groups in the energy sector	Grütter Consulting, the CICR, MiTransporte, the CNFL, the DCC, the University of Costa Rica, the SEPSE, the ICE

3. Evaluate the energy requirements and financial burdens of electric vehicles and charging stations that the key players are most interested in	Obtaining data and resources from the groups we interviewed	Grütter Consulting, the CICR, MiTransporte, the CNFL, the DCC, the University of Costa Rica, the SEPSE, the ICE
4. Develop a return on investment tool to aid business owners and the government in determining how to price electric vehicle charging station usage	Synthesis of data and metrics collected via research and interviews	The CICR, internet sources (company websites, research papers, articles, etc.)
5. Develop a stance on the transition to clean transportation, taking into consideration business methods, strategies, and recommendations	Use of charts and diagrams created from collected data	The CICR

1. Gain perspective on the groups involved and the relations between them

Our initial background research pointed toward a lack of EVs in Costa Rica, but did not inform us of any initiatives in place or plans in development to fix this. Through meetings with the ICE, the CNFL, and other organizations and key players, we were able to gain more insight on the current state of the problem. However, before these meetings occurred, we needed to learn more about the relations between the different players and where the power lies.

Gathering this information through discussion with our sponsor and supplementary research gave us the necessary perspective and information going into these meetings. Through background research we learned about the ICE’s control over electricity, but were unable to determine how the ICE is regulated, or how it relates to other groups such the CNFL or AceSolar. This information was obtained later on through our interviews with the CNFL and

AceSolar. Understanding the jurisdiction of each group we met with helped us prepare for each discussion and ask the right questions to the right groups.

This understanding of the relationships between each group we met with and interviewed arose from a combination of further research on site and workshops we attended, in addition to resources provided to us by our interviewees such as presentations and statistical research. This information was used to generate charts and diagrams that allowed us to better understand the connections between these groups.

2. Learn about the current situation and projections moving forward

Through our background research, we also discovered a very low prevalence of EV charging stations in Costa Rica. We believed this was a key factor preventing a widespread usage of EVs in the country, as an insufficient ratio of charging stations to EVs would make it impossible to support a robust electric network. The CICR has recognized that the transportation sector is the main obstacle to Costa Rica's goal of carbon neutrality by 2021, but we believed change could not be expected without increased access to charging stations. Through conversations with the groups involved in clean transportation, we needed to understand the stances and strategies present within the country.

Costa Rican newspapers have always reported on optimism and projections, but we needed to find out the players' strategies to reach these goals. It was important to learn whether or not the groups of interest actually supported taking action toward clean transportation, and what their strategies and timelines looked like. We gathered this information through interviews with consultants, government companies, private participants, and climate advocates. These interviewees allowed us to pinpoint the main issues and obstacles in the way of clean transportation. Discussions with our sponsor and other members of the CICR gave us insight into what would be allowed based on existing and proposed regulations for private and industrial involvement in EV charging stations.

Meetings with private participants such as company consultants and EV dealers provided us with information on what the private sector was able to do at the time, what results they had seen, and what they felt was lacking. The two public government entities we met with were the Costa Rican National Power and Lights Company (CNFL) and the Costa Rican Electricity Institute (ICE). From these distinct perspectives we obtained the necessary background information to begin developing a stance for recommendations and conclusions.

Our interview with the CNFL focused on the 28 fast charging stations they were bringing into the country and installing. We conducted the interview with the goal of determining how the CNFL planned to distribute these charging stations and if there were any specific criteria being used to determine this distribution. Additionally, we wanted to determine how these policies might set precedents moving forward for other groups attempting to install charging stations that might want to follow any successful patterns established by the CNFL's charging station installations.

Our interview with the ICE focused on how the government would support an industrial transition and how companies would benefit from owning EVs and EV charging stations. This interview was the final one we conducted, which allowed us to connect much of the information we gained from the previous interviews with the ICE's work during our discussion. The interview was meant to determine the governmental perspective on an electric vehicle transition and how political considerations would come into play for such a transition to be successful.

The information gathered from our interviews with the CNFL and the ICE was the most critical knowledge we gained out of all the groups we met with. This information was useful for assessing the industrial (the CNFL) and governmental (the ICE) perspectives on an electric vehicle transition for Costa Rica. The combined insights from these interviews allowed us to generate our recommendations and conclusions in such a way that best addressed the needs and policies of both sides.

3. Evaluate the energy requirements and financial burdens of electric vehicles and charging stations that the key players are most interested in

An important aspect of this project was to provide the CICR with resources they could use to inform the public and light freight transport industries of the costs of a switch to clean transportation. As we met with each relevant group, we were be able to determine what specific vehicles and technologies the groups were interested in promoting. We were able to research the specific models they utilized and gradually developed collections of data over the course of the project. These collections focused on the electric capabilities, cost, battery capacity, time to charge, and distance per charge of vehicles, as well as information regarding the different types of charging stations that exist.

Once we obtained a sufficient amount of data, we created detailed charts in order to analyze the financial requirements for a company to make an investment in electric vehicles. These charts focused on the number of charging stations required to support a full fleet of electric vehicles, the initial investment required to obtain the electric vehicles and charging stations, and the cost per work day to charge the fleet. An important aspect for the companies we met with to note was the ratio of distance per charge against the distance one of their vehicles would be expected to travel in a day. If all the vehicles in a fleet are driving fewer kilometers than their battery's capacity at full charge, then only slow chargers would be required to charge the vehicles at night.

However, if vehicles were required to travel greater distances, faster or rapid charging stations would be ideal for charging these vehicles quickly during the day as well as at night. Electric vehicles vary in battery capacity, distance per charge, and charging time similar to how vehicles operating on fossil fuels vary in tank size and mileage per gallon. Gathering this data for the electric vehicles that are of interest to the Costa Rican players involved was much more useful to companies than gathering data for other electric vehicles that were not available in Costa Rica at that time.

4. Develop a return on investment tool to aid business owners and the government in determining how to price electric vehicle charging station usage

After the meetings and charts were complete, we developed a return on investment (ROI) tool to allow companies to determine how long it would take to recoup their initial investment. This required an additional section in our existing chart to calculate a company's yearly costs from fuel and maintenance while using their fleet of fossil fuel vehicles. The same yearly cost figure also needed to be calculated for a prospective fleet of electric vehicles and charging stations. These figures were then compared, and the chart calculated how much time it would take for the savings accrued due to the more efficient electric fleet to equal the cost of the initial investment. Users of the chart would also need to take into account the initial costs associated with financing an electric fleet which are not accounted for by the chart.

This is an important tool for the CICR to make available to companies interested in converting to a fleet of electric vehicles. The companies would be able to have a stronger sense of what the process involves, which would be more beneficial than the five-year and ten-year predictions electric companies have offered in advertisements. While the results of the charts might not be appealing to companies, they would still be helpful to the CICR because they would incentivize to the government to take action to achieve their projections and carbon neutrality goals.

5. Develop a stance on the transition to clean transportation, taking into consideration business methods, strategies, and recommendations

We took into consideration the strategies expressed to us through the meetings we conducted and the methods of other countries around the world to present options that would take the financial stress off of companies considering a change to electric vehicles.

Through background research we gained an understanding of how influential the Costa Rican government is in electricity distribution through the ICE and the CNFL. We expected that because of the strict rules surrounding electricity distribution and commercialization, the ICE would be opposed to strategies which created market competition that would threaten their government-enforced monopoly on energy distribution. However, the ICE had already made several large investments into large hydropower plants, which likely will not be paid off for many years. This led the ICE and the CNFL to request increases in electricity distribution tariffs from the public services regulatory authority to increase revenue. We believed that a strategy enabling companies to integrate their own charging stations (with taxes paid to the ICE) would generate opportunities for profit. Such a plan was financially feasible but not legally permissible under regulations at that time.

Based on the background information we collected, it did not seem that the Costa Rican government was in a position to offer subsidies comparable to those available in Norway and Japan. However, if the companies were required to buy their own charging stations, the initial investment involved would be too high for most owners to deem the venture worthwhile. Using the figures generated from our charts in conjunction with business strategies exposed to us through the interviews we conducted, we recommended a balanced strategy, which accounts for both the investment needed from companies and the distribution groups owning all of the charging stations.

Chapter 4: Findings

Over the course of the project, we conducted the interviews and research discussed in our Methodology section in order to analyze the state of electric transportation in Costa Rica. We gained information to better understand various groups' perspectives on electric mobility in the private, public, and freight transport sectors. Since the CICR is an important advocate for the interests of the industrial sector, it was important to focus on both public and freight transportation. However, it was also important to understand the attempts being made on behalf of electric mobility in the private sector in order to construct a platform which would allow us to comment on the overall state of the electric vehicle transition. We identified and analyzed points of optimism and perceived needs in each of the three sectors, as well as how public institutions and companies should be expected to participate in the transition. The table below provides a summary of our findings, organized by transportation sector and influence on outlook.

Summary/Breakdown

Table 4. Summary of Findings

Sector	Optimism	Obstacles and Issues
Private	Law 9518	Vehicle Replacement / Scrapping
	Car Dealership Interest	Spread of Knowledge
	Legislation in Development	Public Enthusiasm, Willingness
	Charging Station Infrastructure	Charging Station Locations
	Charging Point Application	Electricity Tariffs
		Night Time Charging Grid Impact
		Traffic
Public	Grütter Consulting Leasing Model	Finance / Economics
	MiTransporte Leasing Model	Affordability
	Raqueta Terminals	Technology
	GMA Electric Passenger Train	Quality
		Government Involvement
Freight	Grütter Consulting Leasing Model	Lack of Attention / Legislation
	Electric Freight Trains	Technology
	Benefit of Delay	Costs
		Landscape
Public Institutions / Companies	Proposed Legislation	Business Customer Charging
	Early Action	Financing Public Institutions' Upgrades
		Company Employee Charging
		Company / Business Incentives

Electric Private Transport

Optimism

Electric mobility within the private sector is the first priority of the government groups responsible for promoting electric transportation. With the development of the National Electric Transport Plan, the Costa Rican government has recognized the importance of addressing carbon neutrality for the private transport sector. We attended a MiTransporte conference where it was noted that in 2017, 82.6% of fossil fuel usage in Costa Rica came from the transport sector, with private transport being responsible for 50.4% of this usage. It was also noted that an energy council consisting of government regulatory bodies/ministries and electricity distributors is responsible for implementing the necessary changes to reduce these emissions (MiTransporte, personal communication, January 31, 2019). The work accomplished between these different bodies demonstrates a broader climate of cooperation, allowing for a much easier path to develop legislation and actions to take. It makes sense that the electricity distribution companies would support electric mobility as long as they can provide enough electricity to handle the demand that will inevitably be created by a full move away from fossil fuels. Surprisingly, even the Costa Rican Petroleum Refinery (RECOPE) appears to support the abandonment of fossil fuels, having already begun researching on alternative fuels such as ethanol and biodiesel. These fuels would be used in vehicles as mixtures, along with natural gas, liquefied petroleum gas, and hydrogen (RECOPE, 2018). While a fully electric private fleet would be a large demand on Costa Rica's electricity sector, eliminating the need to import fossil fuels would keep a significant amount of money in the country after investments in charging station infrastructure are paid off.

The most significant legislation involved in the national electrification plan is Law 9518 (Law of Incentives and Promotion for Electric Vehicles). As previously mentioned, Law 9518 establishes both financial and practical incentives to encourage consumers to purchase new EVs. In addition to establishing the three tax exemption brackets based on the price in USD of an electric vehicle, the law includes the following incentives:

- Exemption from weekly travel restriction on vehicles moving through the area around and including downtown San Jose;
- Exemption from charges for street parking;
- Access to special parking spaces;
- Exemption from local sales taxes and selective consumption taxes for spare parts related to electric vehicle operation and upkeep, set to last 10 years;
- Benefits for annual payments of property taxes, staggered over five years.

(Tax@hand, 2018).

The Ministry of Environment and Energy (MINAE) and the Ministry of Finance are responsible for enforcing and maintaining these incentives. Our previous Background section discussed Norway and Japan as case studies for the promotion and implementation of electric vehicles in the consumer market. Both of these countries were able to implement significant financial incentives which seem far beyond the capabilities of Costa Rica, but the proposed measures are still a strong first step toward encouraging the public. The practical incentives mostly target drivers in areas of higher traffic, specifically the greater metropolitan area (GMA) of San Jose. However, it is still important to incentivize the use of electric vehicles in the capital, due to factors such as the high percentage of Costa Ricans who work in San Jose's GMA and the large quantity of traffic leading to increased emissions and longer commutes.

As a result of the import tax reductions, car dealerships in Costa Rica have reported significant interest in bringing more electric vehicles into the country. In January 2018, shortly after the import tax reductions were introduced, an article was published in La Nación reporting that Agencia Datsun (Nissan), Grupo Q (Hyundai), Bavarian Motors (BMW), and Grupo Automotriz (Ford) were each planning to bring more electric vehicles into the country as a direct result of the measures (the Nissan Leaf, Hyundai IONIQ, BMW I3, and Ford Focus, respectively). Grupo Q has also expressed interest in introducing the Chevy Bolt to the Costa Rican market. Below is a graphic explaining the technical differences among the various car models.

Autos eléctricos traídos por las agencias a Costa Rica

Estos son autos eléctricos ingresados por las agencias al país, según lo que fue posible corroborar. Entre otros que podrían llegar al país este año, están el E-Golf, de la Volkswagen, y el Chevrolet Bolt, de Grupo Q.

Nissan Leaf

Hyundai IONIQ

	Nissan Leaf	Hyundai IONIQ
Agencia:	**Agencia Datsun**	**Grupo Q**
Autonomía:	**250 km**	**225-240 km**
Carga:	Rápida 30 min y de 7 horas	Lenta 24 h/media 4.5 h./rápida 20 min.
Frenos:	**Sistema regenerativo**	**Sistema regenerativo**
Conexión:	**110** voltios (enchufe)	**110** voltios estándar
Potencia de motor:	**80** kilovatios	**88** kilovatios (118 HP)
Bateria:	Litio	Polímero de litio
Precio actual:	**$44.900**	**$38.535**
Precio con vigencia de la ley:	**$39.800**	**$32.850**

BMW I3

Ford Focus

	BMW I3	Ford Focus
Agencia:	**Bavarian Motors**	**Grupo Automotriz**
Autonomía:	**300 km**	**185 km**
Carga:	N.D.	N.D.
Frenos:	**Sistema regenerativo**	**Sistema regenerativo**
Conexión:	N.D.	**120-240** voltios (puerto CCS)
Potencia de motor:	**125** kilovatios	**107** kilovatios
Bateria:	N.D.	N.D.
Precio actual:	**$65.000**	N.D.
Precio con vigencia de la ley:	**$55.000**	N.D.

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Figure 3. Electric Vehicles sold by Costa Rican dealerships (Leitón, P., 2018)

The above graphic contains a slight error: Grupo Q has reported that the Hyundai IONIQ will actually cost US $33,965 after Law 9518 is passed. The prices of these vehicles after the law as reported by the dealerships are approximately 85% of the original prices, with variation based on the bracket the original vehicle prices land in (Leitón, P., 2018). This is a positive sign for Costa Rica, a country which has traditionally been unable to attract large electric vehicle producers such as Nissan (A. Blanco, personal communication, February 4, 2019).

Other proposed laws and regulations intend to take even more significant steps towards electrification. The goals of this legislation include disallowing the import of used vehicles after 2025, establishing an annual emissions tax, and using dynamic testing during mandatory car inspections to test vehicle emissions. These measures promote electric vehicles and also push for the use of the most up-to-date technology, while implementing taxation for those who do not comply.

Continuing the comparisons to Norway and Japan, the success of these countries in their electric vehicle transitions has also been due to the establishment of a nationwide charging station infrastructure. In the case of Costa Rica, Law 9518 establishes requirements which facilitate the creation of a similar infrastructure. This law delegates the responsibility of establishing and enforcing charging station installation and operation guidelines to the MINAE, but the actual construction and operation of public charging stations is the responsibility of Costa Rica's electricity distributors, which are regulated by the MINAE. Law 9518 mandates one charging station for every 80 kilometers on national roads and one charging station every 120 kilometers on cantonal (secondary) roads. However, these distances can be adjusted by the MINAE if further regulations are introduced. As previously stated, the CNFL is currently importing fast charging stations and installing them throughout the country in compliance with the 80km and 120km specifications.

Figure 4. CNFL Charging Stations in the North East (Image courtesy of Alan Blanco of the CNFL, February 4, 2019)

Figure 5. CNFL Charging Stations in the South East (Image courtesy of Alan Blanco of the CNFL, February 4, 2019)

The above images display the locations in the northwest and southwest regions of Costa Rica where the CNFL plans to install charging stations, as well as the optimal roadway path distances between each of the charging points.

Law 9518 lists a requirement for a recharge center informational board containing information such as nearest charging points, recharge times, consumption statistics, and other data. We attended a MiTransporte conference where a speaker presenting on behalf of the Grupo ICE reported the development of a website application to fulfill these requirements and more. The program's goals and functions are to encourage electric mobility in the private sector by improving the user experience with electric vehicles, reduce range anxiety, identify charging station locations, and determine viable payment methods. The program would also be a useful source of information on the operation requirements for charging stations. In addition to having station locations readily available, the app would support electronic accounts and include payment methods with an electronic billing system, sales record accounting collection, and electronic invoice validation. The speaker also reported that the opportunity to pre-reserve charging stations was being explored, and that members would be able to check their usage history (L. Ramirez Rodriguez, personal communication, January 31, 2019). For charging station operators, the application would allow for remote control and monitoring of the stations and the ability to synthesize patterns for optimization based on analyses of customer usage. This is critical since variation in parameters (location of charging stations, length of time used, demand, etc.) will cause the price of tariffs to vary.

Obstacles and Issues

While Costa Rica has made significant strides to encourage electric mobility in the private sector, there remains work to be done. Over the course of the project, our team identified several major issues that have been obstructing electric vehicle transition efforts, such as a lack of a plan for vehicle replacement/scrapping and trusting the public to make the investment in electric vehicle technology. Additional issues we identified were the differing ideologies on how to determine the locations of charging stations, how investments into stations by electricity distributors will affect electricity tariffs, how peak night charging times will impact the grid, and traffic considerations with the influx of even more vehicles to the already congested greater metropolitan area of San Jose.

A strong incentive for public electric mobility implemented by Norway was a fiscal compensation system for the trade-in of an internal combustion engine vehicle (ICEV) in exchange for an all-electric vehicle. Currently, Costa Rica has no structures in place for either trading in or disposing of used ICEVs. The best options left would be to either expect consumers to sell their old ICEVs to other Costa Ricans when buying a new EV, or to buy a new EV in addition to any vehicles they already own. While selling an ICEV to another Costa Rican could reduce the overall number of ICEVs imported in the short term, it would not address the overall problem. Additionally, Costa Ricans who purchased used ICEVs in this manner would not be as incentivized to switch to an EV in the long term. It is difficult to justify promoting a large scale private transportation upgrade without methods for dealing with the vehicles being replaced. An alternative to scrapping ICEVs would be exporting them to developing countries, but since Costa Rican vehicles are 16 years old on average, finding interested countries would be difficult. Even if this practice succeeded and Costa Rica would be able to export its problematic ICEVs, the solution would not address climate change at all since it is a worldwide problem. That is, the ICEVs exported will still impact the climate, just from the roads of a different country.

Expecting Costa Ricans to buy EVs in addition to the ICEVs they already own would necessitate a minimum US $34,000 investment without any immediate financial benefit (this value is based on the lowest price reported by the dealerships previously mentioned). The average age of vehicles in the country indicates both a lack of financial ability and absence of desire to upgrade vehicles, even before a push for costly EVs. However, comparing the average age of vehicles in the GMA of San Jose to that of the average age of vehicles across the country may indicate a difference in ability for San Jose residents to make a switch. While the operation cost of an EV is undoubtedly lower than that of an ICEV, high electricity tariffs make the margin less appealing than it otherwise would be. Making electricity distributors responsible for the installation of fast charging stations creates problems resulting from the improvement of infrastructure, as electricity prices will likely increase to allow the electricity distribution companies to afford the investments. This would likely be the case until the charging stations are used enough that the electricity distribution companies could make their money back off of that usage alone. Currently, Costa Rica has 500 electric cars and 600 electric motorcycles in the private sector, compared to a total fleet of almost 1.5 million vehicles (A. Blanco, personal communication, February 4, 2019). Multiple news articles we reviewed have indicated the Costa Rican public prefers large vehicles such as SUVs in order to deal with the poor quality of Costa Rica's roads. As mentioned in the literature review, Costa Rica was been ranked as one of the ten worst countries to drive in in the world in 2016 (Murillo, 2017). As a result, most EVs would not be appealing to the average Costa Rican driver (other than those traveling the relatively flat routes in the valley of San Jose) since EVs are designed to be compact and efficient rather than rugged and bulky.

While every company we met with agreed that EV charging stations needed to be spread throughout Costa Rica in some fashion, a major point of disagreement was how this distribution should be determined. As previously mentioned, the CNFL is installing 28 charging stations throughout the country based on the 80 kilometer (km) and 120 km parameters dictated by Law 9518. However, work done by the University of Costa Rica (UCR) proposes a different approach. While installing charging stations based on the distances stated in Law 9518 is an effective approach to reduce range anxiety, the UCR argues that the CNFL's positioning of charging stations does not take into adequate consideration traffic patterns or actual vehicle ranges and capacities. From the UCR's perspective, installing redundant/unnecessary charging points along roads that experience much less activity than those within the GMA of San Jose is a waste of resources. While Costa Rica would ideally be able to pursue the precedents set by Norway and Japan for EV charging station infrastructure, having charging stations every 15 km like Japan would be a very long-term goal that is not yet realistically attainable. According to Dr. Jairo Quirós-Tortós, a professor of electrical engineering at the UCR, an optimized distribution of charging stations (determined by adjusting the CNFL's original locations to better meet expected demand based on traffic patterns and EV capabilities) would be similar to the image below:

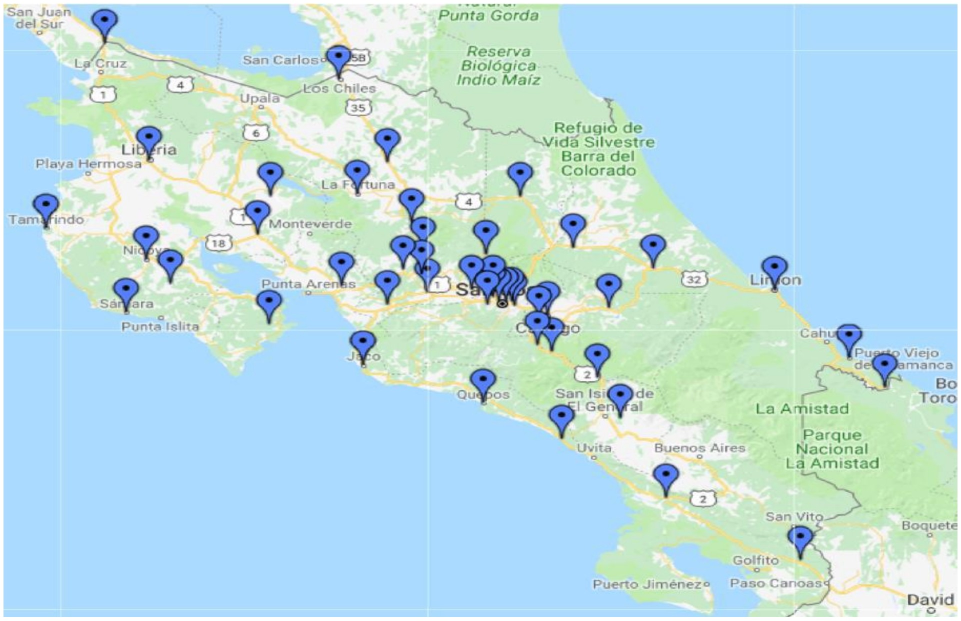

Figure 6. Charging Station Layout based on Battery Capacity determined by the UCR (Image courtesy of Jairo Quirós-Tortós of the UCR, February 6, 2019)

The higher volume of charging stations throughout the GMA of San Jose compared to the rest of the country is necessary due to the high percentage of Costa Rica’s traffic that occurs in this area. While the CNFL plans to install 32 charging stations in Costa Rica, Jairo identifies the minimum effective amount of charging stations as 34. Jairo arrived at this value by analyzing the distances between charging points in terms of kilowatt hours (kW-h) of energy consumed instead of kilometers (km) traveled. An analysis in terms of kW-h used accounts for factors such as the presence of incline changes on the route and vehicle capacities which a distance analysis does not consider. For example, the CNFL’s proposed locations include two charging stations in Barranca and Orotina between the stations in Limonal and San Jose. However, when applying a kW-h analysis to this route, Jairo determined that the charging station in Barranca was not necessary. By diverting resources away from station construction in redundant locations such as Barranca, electricity distributors can either lower their initial investment or install stations in areas with higher traffic and demand within the GMA of San Jose.

Another area of concern addressed by Jairo is the increased grid demand a country full of EVs charging after work hours would cause. It might be possible to avoid addressing this issue in the short term, but it would likely become too significant to ignore as the growth rate of EV ownership increases. Jairo's concern originates from the principle that privately owned EVs are meant to be charged using level 1 chargers in garages at night. However, once some undermined threshold of private EVs is passed, the electricity demand will spike every night when owners plug in their vehicles. This could damage grid transformers and lead to voltage levels too low for owners to successfully charge. A course of action would need to be determined well in advance to avoid a large-scale electricity crisis.

A focus on the electrification of private transportation is important, but it will do nothing to improve the growing issue of traffic in the GMA of San Jose. As mentioned in the literature review, significant traffic delays are a relatively new but growing issue in San Jose, as commuters have been turning to private vehicle usage in place of the inadequate public transportation structure. While private EVs will emit less pollution overall, Costa Ricans will still experience the same loss of time from traffic. Costa Ricans spend more days per year in traffic than they do on vacation (J. Quirós-Tortós, personal communication, February 6, 2019). The electrification of the private vehicle fleet will not address this issue and may even worsen it if a plan to remove ICEVs from the road rather than shift them around cannot be created.

Electric Public Transport

Optimism

Electric mobility for the public sector is a less immediate priority to electricity distributors and regulatory groups than private electrification, but is still very possible. Law 9518 contains provisions for public transport growth, but there is no timeline associated with these provisions which indicates a clear lack of urgency. Fortunately, the arrival of leasing models for public transport companies, plans for an electric passenger train, and the potential for Uber to benefit from legislation for the private rideshare sector are all signs that progress is being made in this aspect of the electrification movement.

It is likely that pilot programs will be necessary to initiate a shift towards a fully electric public transportation network. There are currently at least two leasing models for public transport companies being pursued in Costa Rica, which have been generated by Grütter Consulting and MiTransporte, respectively. The Grütter Consulting model proposes an eight year leasing period based on depreciation of the full charging capacity for EV batteries. This proposal includes the installation of charging stations in a transport company's depot and payment of the electricity costs acquired through the charging of the vehicles. Grütter Consulting would be responsible for maintaining these charging stations, but the companies will retain full ownership. The vehicles offered by Grütter Consulting would most likely be EVs imported from China, as the firm does not see value in investing in hybrid vehicles or other transitional technologies (V. Arauz, personal communication, January 22, 2019). The firm's current priority is to acquire a fleet of EVs; by 2020, they plan on investing in a total of 250 large urban busses, 50 tourist buses, 50 urban delivery trucks, and 500 taxis (all fully electric). According to Verena Arauz, an employee of Grütter Consulting, these vehicles will be only be used on flat routes. In a MiTransporte workshop we attended, representatives for Grütter Consulting reported a target range of 2020-2040 to obtain this fleet. Through this project, Grütter Consulting aims to promote large, standardized, and cost effective industrial EV fleets in conjunction with optimized technologies and an adequate charging infrastructure. Their main advertising strategy is to emphasize the technical and economic advantages of EV usage, which will ideally lead to sustainable market dominance by establishing itself as a first-mover company and disrupting the existing mobility structure and vehicle market (V. Arauz, personal communication, January 31, 2019).

The leasing model MiTransporte is developing is also designed to promote electric mobility in the public transport sector. MiTransporte will offer companies three electric buses for a six-month leasing period, along with slow charging stations that MiTransporte would install. Unlike Grütter Consulting, MiTransporte is funded by the German Environmental Ministry. Germany views Costa Rica as an ideal site for pursuing and implementing renewable technologies and has invested a great deal of resources into this pursuit. MiTransporte plans to obtain EV technology via international bidding, choosing whichever company can offer the best deal. Just like Grütter Consulting's plan, these vehicles will only be used for urban routes. By avoiding long, taxing routes out of San Jose, electric buses will be less likely to encounter travel difficulties. Low grade driving conditions have less possible variation and are less demanding on EV batteries, which in turn slows down the rate of decline in charging capacity. MiTransporte's public regulations board has reported that the average urban bus travels approximately 200 km per day, as it repeats several short routes multiple times each day. Electric buses will either need an autonomous range greater than 200 km or be able to utilize a fast charger during the day. However, MiTransporte claims fast chargers for electric buses may not be economically viable under the current electricity usage and peak demand electricity tariff. The six-month leasing model MiTransporte advertises would act as an educational opportunity for bus operators. The project will also include training for maintenance tasks such as battery replacement, but this aspect did not align with the timeline of our project. MiTransporte cites the spread of knowledge and experience as a key factor that will enable the successful adoption of electric mobility. Both

MiTransporte and Grütter Consulting believe addressing Costa Rica’s transportation issues should begin by incentivizing, upgrading, and electrifying public transport to increase usage.

Additionally, there are early plans to provide electric public transportation in the form of trains. One such plan, the Raqueta project, aims to provide three or four interconnected stations for both electric trains and electric buses. This would be very synergistic with either Grütter Consulting or MiTransporte’s public transport EV leasing plans. The Costa Rican government has expressed a desire to pursue electric passenger train implementation for traversal of the GMA of San Jose. This would be a very large investment and requires long term consideration.

Obstacles and Issues

When comparing positive strides in promoting electric transportation for the public and private sectors, a major difference depends on who is actively participating. In addition to a lack of governmental support, electric mobility in the public transport sector has needs in three main categories: finance; technology; and quality.

Public transport companies in Costa Rica do not have adequate financial incentives to upgrade to EVs. A major factor contributing to this is the current method used by the ARESEP to determine public bus prices. Under this method, the tariff is influenced by operation cost, initial investment, and room for profit. However, the initial investment has a ceiling of US $110,000, meaning that any extra money spent on an upgrade by a bus company will not be considered in a tariff. Additionally, the operational cost of an electric bus would be less than that of a diesel bus, meaning the price a bus company would be allowed to charge for a ride on an electric bus would be less than the prices currently charged. While this would be ideal for bus riders, it would make the bus companies unable to pay off the investment. The leasing programs previously mentioned offer a temporary solution to this issue, but a method to incite a transition from leasing to a full fleet conversion will eventually be needed. Public opinion of electric public transport is directly linked to money and tariffs. Changing the tariffs to be more favorable for the public could convince Costa Ricans that EVs are viable in the public transportation sector. On the other hand, if public transport companies are expected to pay off the investment in electric vehicles by charging more, public enthusiasm for electric mobility may decrease. Maintaining affordability through the upgrade period will be important to keep public support, especially since people who typically use the buses are not in a financial position to fully bear the burden of upgrade costs.

In terms of technical aspects, electric mobility calls for adequate resources directed towards the actual EVs, depot charging stations, and fast charging stations in terminals to allow buses to cover greater distances per day than a single charge would allow. With respect to the vehicles used, bus companies will not have nearly as many options to choose from as taxi companies or Uber drivers do. It will be necessary to determine which international company's electric buses best match the needs of the bus companies of Costa Rica. Taxi companies and Uber drivers could benefit greatly from an increased amount of public fast charging points in the GMA of San Jose and in other cities throughout the country.

To increase EV usage, many groups have cited the need for an increase in the quality of Costa Rican public transportation. As discussed in the literature review, many Costa Ricans have recently switched to private vehicle ownership due to the shortcomings of the public transport sector. Potential improvements to change public opinion could include improving terminals and establishing dedicated bus lanes throughout the city. While these projects would require time, money, and public cooperation, they could eventually have a positive impact on the traffic situation in the country.

An increase in the involvement of government groups and regulatory boards could improve the state of electric mobility in public transportation by addressing all areas of need. Government incentives for bus companies to make the investment could help maintain affordability. The establishment of standards for electric buses may help bring a sufficient amount of EVs into the country with comparable specifications. Ensuring electric buses have the same charging specifications would make a uniform charging infrastructure in depots and terminals significantly easier to establish. Finally, a coordinated government effort to increase the quality of public transport could greatly help increase public usage.

Electric Freight Transport

Optimism

Of the three transport sectors, freight transport seems to be the least prioritized by legislation and the groups of interest with which we have met. However, Grütter Consulting is planning to include electric freight trucks in their leasing program, and the DCC has identified strategies to approach electric freight mobility.

Grütter Consulting aims to introduce 50 electric urban delivery trucks by 2020, leasing these vehicles out to freight transport companies under a similar business model to their public transport leasing business. These urban delivery trucks would most likely be in the small freight category, at 8-12 tons. At a MiTransporte workshop we attended, a representative for Grütter Consulting reported electric trucks will have a range of 150 kilometers when fast-charged to 80% of their battery capacity in 30 minutes, and will have a range up to 250 kilometers when charged with a level 1 or level 2 charger. The required investment in an electric truck would be approximately 2-3 times greater than the investment in an ICEV. However, they provided an operation cost analysis for a vehicle with a one-ton storage capacity, reaching the conclusion that the operational cost for an electric truck is almost 3 times less than that of a fossil fuel truck, with costs of US $0.06 per km and US $0.15 per km, respectively. Grütter Consulting is pursuing smaller electric freight vehicles with urban routes because the valley of San Jose is relatively flat, but leaving the area requires climbing the mountain range surrounding the valley which would negatively impact the power output of an electric truck. Additionally, small electric freight truck technology is significantly cheaper and more readily available than that of larger electric freight vehicles such as 18-wheelers (V. Arauz, personal communication, January 22, 2019). Targeting small electric freight trucks will help reduce the emissions of the sector, because small freight trucks are actually responsible for more emissions than large freight trucks in Costa Rica due to the sheer amount present (insert name of DCC contact from business card, February 5, 2019).

During a conversation with workers for the Department of Climate Change (DCC) the concept of utilizing electric freight trains and old railroads along the Caribbean coast of Costa Rica was brought up. While this idea is not currently being pursued, the use of electric freight trains in conjunction with small electric freight trucks in order to decrease reliance on large diesel freight trucks throughout the country would reduce traffic, reduce emissions from the sector, and reduce traffic caused by the large freight trucks. However, the transport of goods across the Latin American countries will likely still require large diesel freight trucks, as the countries neighboring Costa Rica are not nearly as invested in electric mobility or establishing an EV charging infrastructure. The investment needed for an electric freight train would be significantly less than the investment into the aforementioned electric passenger train for the GMA of San Jose. Additionally, the potential of maritime transport was also noted. However, despite its economic feasibility and a pre-existing infrastructure, ships are not environmentally friendly. Land traffic would be reduced, but without more climate neutral ships Costa Rica would not be any closer to carbon neutrality (insert name of DCC contact from business card, February 5, 2019).

The one benefit to taking a slower approach to promoting electric mobility in the freight transport sector would be giving technology the time to develop. Battery prices are expected to continue falling when charged per kilowatt through 2030, and ranges and battery capacities are expected to continue to increase. Costa Rica could allow its freight companies to invest in better technology by waiting before pushing them to upgrade their fleets. However, this could be said about any of the sectors since technology will inevitably improve as time progresses.

Obstacles and Issues

Currently, there does not appear to be any active legislation citing electric mobility in the freight transport sector as a government priority. This is likely due to the freight transport sector being responsible for 36.5% of the transport sector's emissions in 2017, compared to the private transportation sector being responsible for 50.4% of transport emissions (MiTransporte workshop, January 31, 2019). However, legislation to lay the groundwork would at least allow work to begin.

The general consensus among groups is that electric mobility in the freight transport sector is the least pressing of the three sectors. However, the various types of freight transport vehicles in the country are on average some of the oldest vehicles in the country, with average ages of 18 years for light load vehicles, 19 for heavy load vehicles, 20 for semitrucks, and 26 for trailers and semitrailers (Riteve, 2017). Before any freight company can begin electrification, the government needs to divert more resources and attention to the sector. Without guidelines and specifications, different companies could end up investing in competing standards, making compatibility and common charging points along routes difficult to promote. This is not an issue in the private sector due to the establishment of national standards for chargers. By choosing to use the SAE standard and SAE Combo 1 - CHAdeMO dual fast chargers, the EVs used for private consumption that will be found in Costa Rica have been predetermined to be American and Japanese models that follow these charging standards. If a national charging standard for electric freight mobility is established after companies have already invested in their own electric freight trucks, there is a chance their vehicles will not match the decided standard. Similarly to public transport companies, freight transport companies should not be expected to invest in new vehicles based on the difference in operation costs alone. Without sufficient government incentives, a widespread change is unlikely to happen.

A problem in Costa Rica and other countries is the state of electric freight transport technology. Large electric freight transport vehicles are very large investments, but are likely to become more affordable as technology improves and competition grows, which is common for most technological developments. In the case of Costa Rica, the mountain range around the San Jose area will require a significant power output from large and small electric freight vehicles.

Electric Transport for Public Institutions and Companies

Optimism

Both public institutions and businesses in Costa Rica have shown a willingness to pursue and support the electrification of transport. Legislation proposed for implementation in 2019 will require public institutions to convert a percentage of their fleet to EVs in the five-year lifespan of the law, but some groups have already begun to do so. Additionally, some businesses have begun installing charging stations for customers with electric vehicles.

Through research and workshops, the ICE, the CNFL, and the Costa Rican postal company have emerged as leaders in the push for electric mobility of public institutions. The ICE has already invested in 100 Hyundai Ioniqs from Hyundai for US $3.5 million (B. Johst, personal communication, January 22, 2019). The CNFL currently has multiple compact electric vehicles and charging stations in its San Jose facilities. A representative for the Costa Rican postal service presented at a MiTransporte workshop we attended, reporting on the Correos ("Post Office") de Costa Rica's goals to convert its fleet. Their replacement projections were reported to be 348 electric motorcycles over the course of 2019-2023, and 128 electric vehicles over the course of 2019-2025. If this transition is successful, the postal service will reduce their carbon dioxide emissions from 1,351.5 tons to 0 by the end of 2025. There are also plans to implement smart post offices and reduce the distance traveled per day to increase efficiency. The postal service is working to prepare for a piece of legislation set to be enacted in 2019 that, as we currently understand it, would require public institutions to convert 10% of their fleets to electric vehicles every year for the five-year lifespan of the law (B. Johst, personal communication, February 12, 2019).

Obstacles and Issues

As previously stated, malls and banks have begun installing charging stations to be used by their customers. However, businesses cannot charge for the electricity used by charging vehicles because electricity can only be sold legally by the Costa Rican distribution companies. Businesses that install charging stations would likely not see a return on investment, and would therefore install them to improve public opinion and solicit more business. However, the current numbers of privately-owned electric vehicles in the country are less than 1% of the private fleet, so it is unlikely that a substantial amount of business would be generated. If businesses cannot charge customers for the use of these charging stations once electric vehicles become more common, the decision to install them may actually cost the businesses money. The businesses would have to cover the electricity bill generated by customers charging their cars unless current legislation changes. This raise in electricity usage might even push a business's electricity usage into the threshold where it would be subjected to paying the peak demand tariff on top of energy consumption.

The establishment of charging stations by companies for their employees' use could help incentivize electric mobility in the private sector. However, there are not yet any incentives for companies to make this investment. Companies may become overly enthusiastic and make an investment they are not prepared to handle. If employees are charging their vehicles every night, it is unlikely they will need to charge their vehicles at work unless the commuting distance is greater than half the range of the vehicle. For company cars, it will be important to invest in infrastructures that enable optimal charging conditions.

Chapter 5: Deliverables

Over the course of the project, we have gathered technical information including various electric vehicles offered by companies around the world for private, public, and freight use, the specifications of these vehicles including range, capacity, and time to charge, the electricity tariff system used by the CNFL, the import tax exemptions on electric vehicles established by Law 9518, and gas and diesel prices. With this information, we have created charts and calculators for the CICR to use to provide numeric evidence for their stance and arguments they make, as well as to further establish credibility behind the recommendations made in this paper.

Public/Taxi EV:

Basic information on all possible EVs both available and not to CR. Listed specifications include make, model, year, price, connector standard, battery capacity, and range.

Table 5. Deliverable 1: Public and Taxi EVs

Caro	Modelo	Year	En Costa Rica	Precio	Tipo de carga estándar	Tipo	Capacidad de la batería	Distancia	Time to charge (Lvl 1)	Time to charge (Lvl 2)
Tesla	S		Yes	$75,750	Tesla	All electric	100 kWh	539 km		
Tesla	X		Yes	$78,950	Tesla	All electric	100 kWh	474 km		
Audi	A3 e-Tron		Yes	$39,500	SAE level 2	Hybrid	8.8 kWh	133 km		
Hyundai	Ioniq Electric	2019	Yes	$29,500	Combo 1/2	All electric	28 kWh	200 km		4 hr
Smart	Fortwo ED		Yes	$23,800	SAE	All electric	17.6 kWh	84km		
Mitsubishi	Outlander	2018	Yes	$35000 - $41000	Type 1 and CHAdeMO	PHEV	13.8 kWh	45 km electric		4 hr
Mitsubishi	I-Miev	2010	No	$29,146	CHAdeMO	mini	16 kWh	150 km	14 hr	6 hr
Mercedes	GLC350e		Yes	$49,990	SAE level 2	Hybird	85 kWh			
Mercedes	C350e		Yes	$47,900	SAE level 2	Hybird	60 kWh	85 km		
Nissan	Leaf		Yes	$29,990	SAE level 2	All Electric	40 kWh	240 km		

EV Import Tax Calculator:

Using Excel's formulas we can calculate the accurate taxes a car would receive. Mostly based on the retail price of the vehicle. Enter vehicles prices in the cyan cell and you will receive its tax prices under the green cell. This is based on a breakdown of the import tax exemptions on electric vehicles established by Law 9518 provided to us by Sr. Alan Blanco of the CNFL.

Table 6. Deliverable 2: Import Tax Calculator

CIF (Price of Vehicle, USD):	39800
Tax, USD:	1715
Tax on New Fossil Fuel Vehicle of the Same Price	21890
Difference	20175

CNFL Tax Calculator:

Using Excel's formulas we can calculate the accurate taxes specific to recently rate adjustments the CNFL has provided. Inputting the values of Energy and Power consumption into the appropriate cell for the appropriate tax section will result in the calculated price of tax.

Table 7. Deliverable 3: CNFL Tax Calculator

	TMT	T-AP		T-CS
Energy Consumption (kWh)		200		35
Peak	1		Power Consumption (kW)	9
Valley	1		Price of E.C (Under 3000kWh)	2514.4
Night	1		Price of E.C (Over 3000kWh)	0
			Price of P.C	60277.32
Power Consumption (kW)				
Peak	1			
Valley	1			
Night	1			
TAX (COLONES)	20744.43	702		62791.72
TAX (USD)	33.19	1.12		100.47

Public and Freight Transport EVs:

Similar to Public/Taxi EV but more specific to public and freight transport vehicles.

Table 8. Deliverable 4: Public Transport EVs

Size	Make	Model	Year	Type of EV	Battery Capacity	Distance per charge	Charging
12 meters	Volvo	7900 Electric		All electric	76 kWh		Roof Mounted Conductive Opportunity Charging (Fast Charge 300 kW) takes 6 minutes
12 meters	Volvo	7900 Electric Hybrid		Hybrid	"High capacity", 240 hp diesel engine		Roof Mounted Conductive Opportunity Charging (Fast Charge 300 kW) takes 6 minutes
10.3 meters	ADL	Enviro400VE	2015	All electric	61 kWh	30 km	Inductive (en route) 100 kW 5 minutes
12 meters	BYD ADL	Enviro200EV	2016	All electric	324 kWh	>250 km	80 kW 4 hours
10.8 meters	BYD ADL	Enviro200EV	2017	All electric	324 kWh	>250 km	80 kW 4 hours
12 meters	Bluebus		2016	BEV	240 kWh	180 km	50 kW 5 hours
10.7 meters	Bozankaya A.S.	Sileo S10	2015	BEV	200 kWh	235 km	4-100 kW 2-7 hours
12 meters	Bozankaya A.S.	Sileo S12	2015	BEV	200 or 230 kWh	227 or 261 km	4-100 kW 2-8 hours
18 meters	Bozankaya A.S.	Sileo S18	2016	BEV	300 kWh	261 km	4-200 kW 3-8 hours
12 meters	CaetanoBus	e. City Gold	2016	Fully electric	50-250 kWh	up to 200 km	50-150 kW, or overhead at 350 kW
14 meters	CaetanoBus	eCobus	2013	Fully electric	85 kWh	up to 70 km	60 kW 75 minutes
12 meters	Chariot Motors	Chariot ebus	2014	Ultracapacitor electric	21 kWh	22 km	Overhead fast charge 150 kW 85% in 5 minutes
12 meters	Chariot Motors	Chariot ebus	2016	Ultracapacitor electric	21 kWh	22 km	Overhead fast charge 150 kW 85% in 5 minutes
12 meters	Chariot Motors	Chariot ebus	2016	Ultracapacitor electric	32 kWh		Overhead fast charge 340 kW 85% in 3 minutes
	Chariot Motors	Chariot ebus	2017	Ultracapacitor electric	32 kWh	34 km	Overhead fast charge 340 kW 85% in 3 minutes
12 meters	Ebusco	2.1 HV LF-311-HV-2/3	2014	BEV	311 kWh	366 km	75 kW 4.5 hours or 120 kW 3 hours

Table 9. Deliverable 5: Freight Transport EVs

Size	Make	Model	Type of EV	Rated Load	Gradeability	Capacity	Range	Charging
light duty small	BYD	T3	all electric	0.82 tonnes	>30%		250 km	(AC 40 kW) 1 hr
light duty medium	BYD	T5	all electric	2.62 tonnes	>30%		250 km	(AC 100 kW) 1.5 hr, (DC 150 kW) 1 hr
medium duty	BYD	T7	all electric	5 tonnes	>30%		200 km	(AC 100 kW) 1.8 hr, (DC 150 kW) 1 hr
medium duty	DAF	LF Electric	all electric			222 kWh	220 km	80% Fast Charge in 70 minutes

Public/Freight Company Investment:

Would calculate the initial investment a company would make depending on how many vehicles it would purchase. Takes into consideration number and cost of charging stations of each type, electricity tariffs, costs to charge the vehicles, estimated maintenance costs, days of operation out of the year, and daily range necessities against a vehicle's range.

Table 10. Deliverable 6: Public Transport Company Investment

		12 Meter Bus	Taxi	Smaller Bus for City (Currently not Legally Applicable)		Lvl 1 Charging Station	Lvl 2 Charging Station	Fast Charging Station
Number		200	75	50		175	20	4
Cost Per ($USD)		200000	33000	150000		0	12500	75000
Battery Capacity (kWh)		32	25	28			(~$10,000)	(~$60,000)
Night Electricity Tariff (colones / kWh)	120				Kw Output	4	20	75
Peak Electricity Tariff (colones / kWh)	150							
Electricity Tariff Fast Charging (colones / kWh)	200							

Table 11. Deliverable 7. Freight Transport Company Investment

Fill in blue cells			12 Meter Bus	Taxi	Smaller Bus for City (Currently not Legally Applicable)
Fleet	Operational Cost ($USD/Day)				
	Nightly Charging	Lvl 1	1228.8	360	268.8
	(One or the other)	Lvl 2	0	360	0
	(One or the other)	Lvl 3	0	600	0
	Operational Cost ($USD/Year)		270336	290400	59136
	Initial Investment ($USD)	50525000			

Transport Company Return:

This chart will determine how long it will take a company to pay off the initial investment through money saved using electricity to power their vehicles instead of fossil fuels, as well as money saved on maintenance.

Table 12. Deliverable 8: Transport Company Return

Fill in blue cells		
EV Fleet	Initial Investment ($USD)	
	Size of EV Fleet (# vehicles)	
	Average cost to charge overnight per vehicle	
	Average cost to charge daytime per vehicle	
Fossil Fleet	Determine Previous Cost per Day	0
	Intended distance per day (km)	
	Price of Fuel (gas or diesel)	
	Insert old annual maintenance price per vehicle	
	Insert Frequency of Maintenance per vehicle per year	
	Number of old Fleet	
	Cost of Fleet Maintenance per Year	0
	Cost per Year	0
EV Fleet	Estimated Cost of Maintenance per vehicle per year	
	Estimated Cost of Fleet Maintenance per year	0
	Estimated Cost per Year	0
Return	Difference per Day	0
	Workdays per Year	
	Difference per Year	0
	Flipping Point	#DIV/0!

Charging Stations:

Breaks down each kind of charging station option and compares it to others. Useful to estimate charging times and charging costs using each charger.

Table 13. Deliverable 9: Charging Station Specifications and Cost to Charge Calculator

Fill in blue cells	Outlet	Time (hr)	Range added per hour charging	Power Req (kW)	Average Power Req (kW)	Purchase Cost (USD)
Level 1	120V AC	10-14 typically	5-8 km	1.4	1.4	$0
Level 2	240V AC	3-7 typically	16-32 km	3.3-6.6 typically, capable of 19.2	5	$5,000-$15,000
Fast	DC	80% in 30 minutes	N/A	~40	40	$40,000-$100,000
Cost to Charge:		Cost to Charge ($USD)		Cost to Charge per Hour ($USD)		
Night Electricity tariff (colones / kWh):		Lvl 1 Overnight:	0	Lvl 1 Overnight:	#DIV/0!	
Peak Electricity tariff (colones / kWh):		Lvl 2 Peak:	0	Lvl 2 Peak:	#DIV/0!	
Valley Electricity tariff (colones / kWh):		Lvl 2 Valley:	0	Lvl 2 Valley:	#DIV/0!	
Fast Charger Electricity tariff (colones / kWh):		Fast Charger:	0			
Battery capacity (kWh):						
Estimated Time to Full Charge Lvl 1 (hours):	0					
Estimated Time to Full Charge Lvl 2 (hours):	0					
Estimated Time to Full Charge Fast Charger (hours):	0					
colones to USD conversion: (USD / colones):	0.0016					

Company Investment Guide

Considers company employee count, employee methods of commute, distance of average commute, number of new company cars required, and expected daily car travel distance to recommend number of charging stations. Generates recommended numbers of fast charging and level two charging stations with goal of identifying the smallest initial investment that will match daytime charging needs.

Table 14. Deliverable 10: Company Charging Station Investment Calculator

# Level 2 Charging Stations:	0	Cost ($USD):	240000
# Fast Chargers:	4		
# Company EVs:			
EV Type / Instance 1 (vehicle make, model):		EV Type / Instance 2 (vehicle make, model):	
# of this type of vehicle:	25	# of this type of vehicle:	15
Range of vehicle (km):	200	Range of vehicle (km):	200
Battery capacity (kWh):		Battery capacity (kWh):	
Time to charge (Lvl 2) (hours):	8	Time to charge (Lvl 2) (hours):	6
Cost to Full Charge (Lvl 2 Peak) ($USD):		Cost to Full Charge (Lvl 2 Peak) ($USD):	
Cost to Full Charge (Lvl 2 Valley) ($USD):		Cost to Full Charge (Lvl 2 Valley) ($USD):	
Cost to Charge per Hour (Lvl 2 Peak) ($USD):		Cost to Charge per Hour (Lvl 2 Peak) ($USD):	
Cost to Charge per Hour (Lvl 2 Valley) ($USD):		Cost to Charge per Hour (Lvl 2 Valley) ($USD):	
Time to Fast Charge (hours):	1	Time to Fast Charge (hours):	0.5
Cost to Fast Charge ($USD):		Cost to Fast Charge ($USD):	
Expected range per day (km):	250	Expected range per day (km):	150
Requires daytime charge?	YES	Requires daytime charge?	NO

Table 15. Deliverable 10: Company Charging Station Investment Calculator

# Vehicles Requiring Daytime Charge:	37	Daytime Charging Requirements	25	Hours daytime charging Lvl 2	200	Hours daytime Fast charging	25
			0		0		0
Cost Lvl 2 Charger ($USD):	10000		5		15		2.25
Cost Fast Charger ($USD):	60000		7		38.5		4.55
			8		0		0
Price Point 1: Only Fast Chargers ($USD)	240000		8		0		0
	4	Fast Chargers	8		0		0
	0	Lvl 2 Chargers	8		0		0
Price Point 2	260000			Work day Quick Check	0		
	3	Fast Chargers					
	8	Lvl 2 Chargers		Average Lvl 2 Charge Time	6.851351351	Average Fast Charge Time	0.8594594595
Price Point 3	280000						
	2	Fast Chargers		Max # of Needed Lvl 2 Chargers	32	Max # of Needed Fast Chargers	4
	16	Lvl 2 Chargers					
Price Point 4	300000			Cost of Max # Lvl 2 Chargers	320000	Cost of Max # Fast Chargers	240000
	1	Fast Chargers					
	24	Lvl 2 Chargers		Fast Charger Efficiency (Max # Lvl2 / Max # Fast)	8		
Price Point 5	320000						
	0	Fast Chargers		Minimum Price Point:	240000		
	32	Lvl 2 Chargers			4	Fast Chargers	
Price Point 6	N/A				0	Lvl 2 Chargers	
	-1	Fast Chargers					
	40	Lvl 2 Chargers					

Chapter 6: Recommendations and Conclusions

We used our findings to develop a stance on the state of electric mobility in Costa Rica and are making recommendations with the goal of offering solutions to the issues we previously identified. Through interviews and workshops, we developed an understanding of the actions being taken to promote electric mobility in the private, public, and freight transport sectors by government groups, regulatory boards and ministries, academia, international projects, and private companies. We also developed an understanding of the distribution and regulation of electricity in Costa Rica, the current state of vehicles in the private sector, and the technical details and options available for electric mobility. We organized specifications on various electric vehicles in multiple spreadsheets, along with calculators to analyze charging prices based on several different electricity tariffs, and transport company return on investment calculators to be utilized by the CICR and other interested groups.

Summary of Findings

Over the course of the project we gathered information on the legislation and projects promoting electric transportation in Costa Rica. We also were able to identify obstacles hindering electric mobility.

Legislation Focuses on Promoting Private Sector Electric Vehicle Usage

Discussions with the CICR, MiTransporte, and the CNFL informed us of National Electric Transport Plan and Law 9518, which establishes directives and incentives for pursuing private sector electric mobility. Additional pieces of legislation are being developed and considered that will continue to encourage private electric mobility. However, these laws along with the CNFL's fast charger infrastructure project clearly indicate a national focus on the private sector over the public or freight sectors.

Projects and Businesses Focus on Promoting Public Sector Electric Mobility

Through meetings and workshops, our group has been exposed to two leasing models offering electric buses to public transportation companies for specified periods of time, created independently by Grütter Consulting and MiTransporte.

Grütter Consulting offers electric buses with eight-year leasing periods, installation of slow charging stations in bus depots, and compensation for the electricity costs incurred for using these stations. Grütter Consulting also takes on maintenance responsibilities, even though the equipment is owned by the participating transport company during the time period of the lease.

MiTransporte offers three electric buses per company with six-month leasing periods for each bus, and installation of slow charging stations in bus depots. MiTransporte will sell the charging stations to the participating companies. This project includes educating the participating companies on maintenance techniques and battery replacement training.

Multiple Factors are Impeding Electric Mobility in the Private Sector

Over the course of our project, the groups we interviewed informed us of various obstacles that we identified as the main issues obstructing the electrification of private transport. These issues are the lack of a vehicle scrapping or replacement program, public willingness and financial capability to make an investment in EV technology, the long-term possibility of nightly grid demand, and the impact on traffic in the Greater Metropolitan Area of San Jose.

We see the lack of a vehicle scrapping or replacement program as a detriment to electric transportation because vehicle replacement incentives have successfully been implemented in other countries such as Norway. These countries are using government buy-back programs to assist consumer purchase of new vehicles and keeping old ICEVs off the road. If Costa Ricans' old vehicles are not scrapped, they would most likely either be sold to other Costa Ricans, eventually exported, or kept as back-up vehicles or for longer trips. We believe the selling of the vehicles to other Costa Ricans, despite the potential for removing older and less environmentally friendly vehicles from the road, is ultimately an obstruction to electric transportation because the buyer will now be less incentivized to buy an electric vehicle. We also argue that while exporting the replaced vehicles to another country may be good for Costa Rica, it is ultimately bad for the environment in general, as it is just pushing the problem of environmentally damaging vehicles onto other countries since climate change is a global problem. We believe that the best option is for EVs to be added to existing private fleets in place of other options.

Despite the incentives introduced in Law 9518, we do not believe enough has been done to successfully encourage a significant amount of Costa Ricans to buy electric vehicles. Through our background research we have been exposed to a preference for larger vehicles among Costa Ricans that can be attributed to rough road conditions and a desire for comfort on long trips. Additionally, the average vehicle in Costa Rica is 16 years old, which points toward both a lack of willingness and a financial inability to upgrade. These factors combined with the problem of San Jose traffic patterns have led us to develop a stance on wide scale private sector EV ownership which will be explained later on.

In our meeting with Dr. Jairo Quiros of the UCR, he pointed out the potential problems which unregulated wide scale nightly EV charging could cause. A study he performed supported his claim that when a significant portion of the population charges its EVs at night, the peaks in demand can lead to damaged transformers and insufficient voltage levels. His solution to this problem is an automated program that will delegate the ability to charge by turning off the charging of certain vehicles when the demand climbs above certain specified levels, then allowing these vehicles to charge once the demand is reduced. His study showed that most people whose vehicles were affected did not notice, as their vehicles still were able to reach a full charge before they were needed in the morning. We will discuss this solution to this problem later on, as well as advocate for the consideration of cheaper, easier-to-implement solutions.

Multiple Factors are Impeding Electric Mobility in the Public and Freight Sectors

Over the course of the project, various groups have informed us on multiple obstacles that we have identified as being the main issues hindering the electrification of public and freight transport. These issues are the current bus tariff system, the state of electric freight technology, and a lack of government attention.

In our meeting with Sr. Alan Blanco of the CNFL, we learned about the methods the public regulations board uses to determine the prices of public bus rides. It was also expressed that this method discourages public bus companies from investing in electric vehicles. While the tariff is designed to recognize an initial investment into new technology, the ceiling of recognition is US $110,000, which is significantly less than what a bus company would have to spend on an electric bus. However, charging the public significantly more in order to pay off the investment would be counterproductive. We have created recommendations for approaching this problem which will be discussed in more detail below.

Electric freight transport technology is progressing slower than that of electric compact cars, leading to very high prices. Additionally, with the mountain environments that surround San Jose, it is currently most reasonable to encourage the implementation of small electric freight trucks for urban transport. As technology develops, prices will decrease, making stronger support for electric freight transport more financially feasible. We will later discuss recommendations that could be followed once the technology is more affordable.

The main difference between actions being taken to promote electric mobility in each of these sectors is the lack of government action regarding public and freight transportation. Law 9518 addresses the public transport sector, but only establishes some basic guidelines and does not establish a timeline. Two useful approaches for government involvement could involve establishing technical specifications to ensure unity between competing companies, and developing financial plans through either incentives or loans.

Conclusions

Overall, our team has found that Costa Rica is willing to promote electric mobility, and considers it an issue worthy of the attention of government groups. This came as a surprise to our group, as our initial prediction was that there would not be cooperation between government regulation groups, the electricity distributors, and the fossil fuel companies in pursuing electric mobility. While initial progress may be slow, the attention being paid to electric transportation cannot be denied. The optimism shown by the electricity distributors and government groups through their predictions for public adoption is high, but with a solid charging infrastructure and convincing incentives, public action will soon follow. Despite the previously discussed statistics and findings that suggest a lack of public participation, Costa Rica is setting itself up for more aggressive legislation in the coming years to promote electric transportation in the private sector. However, our team believes that correspondence to the recommendations we make in the following section could aid Costa Rica in the pursuit of electric mobility by addressing the obstacles and issues we identified in the Findings chapter. In the following section, we outline our recommendations by main points and subpoints that are necessary in achieving the main points, state through the following table which recommendations address which issues identified in the Findings chapter, then explain in depth our recommendations and the reasoning behind them.

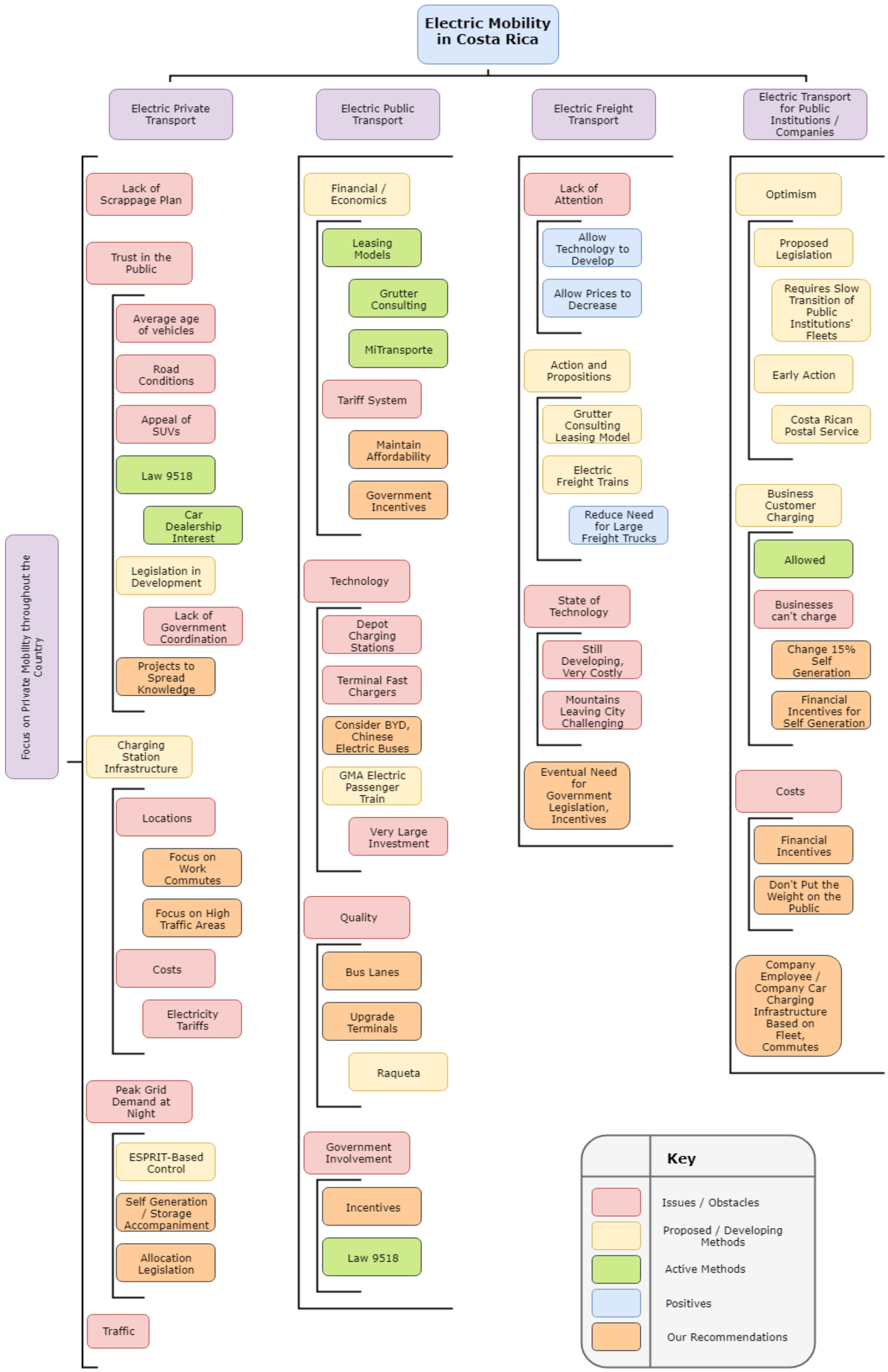

Figure 7. Electric Mobilty in Costa Rica Project Breakdown

Recommendations

We have developed recommendations to offer solutions to the obstacles and issues we identified in our findings section.

Table 16. Table relating recommendations to issues identified in findings section

Sector	Obstacles / Issues	Recommendation(s)
Private	Scrap Plan / Vehicle Replacement	I.
	Spread of Knowledge	VIII.
	Public enthusiasm, willingness	I., III., IV., V.
	Charging Station Locations	I.
	Electricity Tariffs	II.
	Night Time Charging Grid Impact	III.
	Traffic	I.
Public	Finance / Economics	I.
	Affordability	I.
	Technology	I.
	Quality	I.
	Government Involvement	I.
Freight	Lack of Attention / Legislation	VI.
	Technology	VI.
	Costs	VI.
	Landscape	VI.
Public Institutions / Companies	Business Customer Charging	III.
	Financing Public Institutions' Upgrades	II.
	Company Employee Charging	VII.
	Company / Business Incentives	I., III.

Explanations of Recommendations

I. Focus on Combination of Public and Private Electric Mobility in the GMA

This recommendation is the main result of our project, meant to address several prominent factors. These factors are the lack of a vehicle replacement or scrapping plan, a lack of faith in the public, traffic congestion issues, and the need for improvement in the quality of public transportation. We believe narrowing the geographic focus of electric mobility down to the GMA of San Jose will lead to a higher percentage of Costa Ricans in a financial position to invest in an electric vehicle. Additionally, applying this geographic constraint would still encompass 80% of Costa Rican traffic and would reduce the initial investments by electricity distributors while still impacting a significant fraction of the Costa Rican population.

Without a vehicle scrapping plan, we recommend that the Costa Rican government encourage the public to invest in EVs for short distance trips while keeping their old vehicles for long distance trips. Until old vehicles can be scrapped, we recommend that EVs should be additions to private garages instead of replacements. This is because we do not believe Costa Ricans making the upgrade should sell their old vehicles to other Costa Ricans, or that Costa Rica should export the old vehicles. Not getting rid of an older vehicle could help ease range anxiety among the Costa Ricans until a country wide charging station infrastructure is achieved. Ideally, Costa Ricans will use their electric vehicles for all travel throughout the GMA of San Jose, including work commutes and common chores (the old vehicles would only be needed for longer trips). This measure would still have a significant effect on Costa Rica's carbon footprint because of the high volume of the country's traffic that occurs in San Jose. Replacing all the ICEVs sitting in end-of-workday traffic jams each weekday with EVs will significantly reduce transport sector carbon emissions. Additionally, encouraging Costa Ricans to keep their old vehicles to use for travel outside the GMA of San Jose reduces both the need for immediate charging infrastructure outside the city and the investments needed by the electricity distributors. This would allow for a full development of a charging station infrastructure in the GMA of San Jose instead of attempting to introduce a less robust national infrastructure. Once a vehicle scrapping plan is developed, it will be necessary to fully develop the charging infrastructure across the country in order to promote the elimination of ICEVs in the private sector once and for all.

Considering the existing problems with traffic congestion and public enthusiasm for EVs, we have determined that the most effective way to promote electric mobility in the GMA of San Jose would be to develop and upgrade the public transportation sector in conjunction with encouraging private EV ownership. We do not believe it is reasonable or necessary to expect all Costa Ricans in San Jose to own an EV for the immediate present. However, in order for this to eventually happen, the quality of public transportation needs to be increased enough to convince city inhabitants to utilize it in place of their personal cars. Improving public transportation would greatly reduce traffic in the GMA of San Jose. In order to accomplish this, we recommend considering the implementation of bus lanes to give public buses traffic priority, and providing improvements for bus terminals and stations. In order to gain public support, the user experience of public transportation must be improved to be made more user friendly. In terms of vehicle fleet electrification, we believe government financial incentives or a loan model could be worth pursuing. We recommend that the public should not see any upgrades reflected in bus tariffs. If the tariffs increased as a result of the upgrades, it would be even more difficult to convince consumers to stop using private vehicles. Therefore, public transportation must be seen as more economically viable compared to the operation costs and congestion taxes associated with private vehicle use. Allowing the tariffs to increase significantly may cause those already using public transportation to resent the efforts being made toward electric mobility. People who are currently using the public bus system are most likely not in a financial position to take on the costs of public transport upgrades. Because the electricity distributors will eventually directly benefit from the implementation of electric vehicles across all sectors, a partnership between bus companies, the CNFL, and the ICE would need to occur in order to provide financial assistance for pursuing technological upgrades.

At the same time, measures should be considered to encourage the use of public transportation. For example, Law 9518 currently includes incentives for EVs that allow exemption from San Jose traffic restriction laws. These incentives are a useful short-term measure but should eventually be removed as EVs become more common in order to address traffic congestion. Further measures such as additional city usage restrictions for private vehicles or a congestion tax should be implemented in order to further incentivize the use of public transportation.

However, there has been a push for an extended charging station infrastructure from the tourism sector, one of Costa Rica's primary economic focuses. The Greater Metropolitan Area is one such area, along with other areas, such as the coastal towns of Jaco, Manuel Antonio and Tortuguero, or rural areas such as Arenal and Monteverde. Tourists likely have the financial capability to rent an electric vehicle at a higher cost than a fossil fuel rental, which demonstrates the potential for charging stations in tourist-focused locations throughout Costa Rica. However, this does not mean immediate implementation of charging stations along the roads between San Jose and these locations should occur. Tourism in Costa Rica should be the motivating factor behind the electrification of fleets offered by the car rental industry, in conjunction with the availability of charging stations in tourist locations. This appears to have been already taken into consideration by the electricity distributors, as the first electric vehicle charging station installed in the country is located in Jacó (Anders, 2017).

II. The public should not be held financially responsible for investments into electric mobility made by the electricity distributors, public institutions, businesses, or companies

The public should not see rising prices of electricity, public transportation, or public services as a result of investments made to convert fleets to electric vehicles. Because the electricity distributors will benefit directly from EVs due to the use of electricity as fuel instead of fossil fuels, it should be the responsibility of the electricity distributors to assist each of the sectors in affording the necessary investments. In order to ensure this occurs, a law which would require the conversion of public institution fleets over time should include financial options to prevent the public from needing to cover the costs. While it will likely take many years before the electricity distributors see a significant increase in electricity demand due to electric vehicles, it is still important that they hold financial responsibility instead of risking public support by charging the general population for institutional electric mobility. This proposition creates added incentive to reduce the initial focus of the electric mobility movement from the whole country down to the GMA of San Jose, which will reduce the level of investment expected from the electricity distributors. However, promoting the use of self-generation techniques to public institutions to charge their EVs could be used as an incentive to request less of an investment from the electricity distributors.

III. Promote the use of self-generation and energy storage in order to decrease grid demand due to charging

The biggest factor in the prospect of self-generation to charge vehicles on either a home, institutional, business, or company level is the 15% limit on how much consumed energy can be self-generated. As EVs become more prominent and electricity demands increase due to charging, there is no reason to keep the 15% limit active. In terms of the private sector, home level self-generation and storage could be used to prevent grid-threatening levels of peak demand when vehicles are plugged in to charge overnight. If this is not allowed due to the 15% limit, it may result in the electricity companies needing to repair equipment and improve the grid, which would be an entirely avoidable expenditure.

If the electricity distributors are the only groups that can profit from the selling of electricity and businesses are thus unable to charge for electricity usage, then the businesses should be allowed to self-generate that electricity. Otherwise, the only incentive for businesses to install charging stations would be to attract customers and improve their image. But once EVs become more commonplace and demand for charging stations increase, the installation of the charging stations will not be a profitable move. However, if businesses do not have to pay for that electricity and instead are generating it themselves, the installation of charging stations can be a profitable venture.

In order for this self-generation to be possible, self-generation technology must be made affordable through either incentives or loans. The government should assist citizens and businesses in pursuing self-generation solutions. Doing so will not hurt the electricity distribution companies in the long run because the distribution companies will eventually see growth in demand and profits as EVs become more common across all transportation sectors.

IV. Be wary about legislation punishing people who do not own electric vehicles

This recommendation refers to the implementation of emission taxes on ICEVs, as these taxes may unfairly target certain demographics and hurt public opinion on electric mobility. An emissions tax would only be justifiable if there are either EV options or public transportation options available to all people to whom the tax could be applied. The potential issue would be further taxing a citizen who does not have the financial means to afford an electric vehicle, but also does not have access to other means of transportation such as carpooling or public transportation. If public transportation is improved sufficiently, then an emissions tax or a congestion tax applied to those who simply refuse to use public transportation would be justifiable. A country-wide emissions tax should not be developed until there is a sufficient country-wide charging infrastructure and a vehicle scrapping or export plan, as until then, there would still be reason to use a fossil fuel vehicle, in accordance with the first recommendation. However, a San Jose emissions tax could be implemented much earlier on in the process if recommendation one is followed, as a sufficient GMA charging infrastructure coupled with ample, satisfactory public transportation options would eliminate the need for the usage of fossil fuel vehicles in the city except by those coming from other areas of the country.

V. Consider expanding Costa Rica's national charging station standards to provide a greater market share for Chinese electric vehicles

Through our research, we have seen several large efforts being made by the Chinese government and Chinese companies to push toward electric mobility. China has some of the cheapest compact EVs of any company worldwide, and similar technical capabilities to those in

Costa Rica. While Chinese EVs follow a different charging standard than those in Costa Rica, they could still be introduced due to their ranges likely being sufficient for the work commute. These vehicles would not be able to charge at any Combo 1 or CHAdeMO fast charging points, but could still be charged overnight by the owner. Additionally, the Chinese BYD e6 is one of the best EVs for use as a taxi, although it has a unique type of fast charger. While setting a national standard for chargers and cars is helpful in the period of development and helpful for those responsible for establishing the infrastructure, it ultimately limits competition and forces citizens to pay more for comparative vehicles. Competition will benefit the consumer. In addition to the low prices, Chinese car makers already have a presence in Latin America, with a BYD dealership currently in Costa Rica. China as a nation considers worldwide climate activism through electric mobility an important priority.

VI. Develop legislation and proposals to promote progress in electric mobility in the freight transport sector

While it may take several years for electric mobility in the freight transport sector to become a financially feasible pursuit, progress cannot be expected without government involvement. This recommendation should include establishing government incentives and financial aid to freight transport companies, developing electric freight train implementation projects, promoting a focus on small electric freight trucks, limits on investments, and an initial focus on the Greater Metropolitan Area valley. These measures will be essential to the eventual adoption of electric freight transport. For example, the development of legislation to establish a national standard with regard to what types of small electric freight trucks can be used might increase the demand of a specific manufacturer's vehicle to a level where the company would deem it worthwhile to import vehicles into Costa Rica. Additionally, projects involving the implementation of electric freight trains utilizing old railroads on the Caribbean side of the country would reduce the need for large freight trucks, which would lower emissions and traffic, as well as prevent large investments into large electric freight trucks. In accordance, the promotion of small electric freight trucks for urban use in the GMA will avoid the challenge of Costa Rica's steep landscape leaving the city, allowing for cheaper initial investments, as these small freight trucks would not need the large range and high power output capabilities required to make trips over the mountains leaving the valley. Ultimately, though, freight companies should receive financial aid or incentives through the government or the electricity distributors in order to avoid charging the public more for their services to afford the investments.

VII. Companies looking to install charging stations for their employees and company cars should have a tool to help them determine how large of an investment to make into new electric innovations

This recommendation is necessary to ensure companies have the numerical information and equations readily available to be able to calculate the number of charging stations that would match their needs without overinvesting. Factors such as company employee count, employee methods of commute, distance of average commute, number of new company cars required, and expected daily car travel distance must all be taken into consideration when determining the amount of charging stations worth purchasing. Once a company has collected this data, it must take into account the distribution of charging stations that would be most beneficial financially: semi-fast charging stations; fast charging stations; or a combination of both. Fast charging stations can charge multiple vehicles in the time a semi-fast charger would take to charge one vehicle, but this comes at significantly larger purchase and installation prices, along with potentially higher electricity tariffs depending on how the ARESEP develops the fast charging tariff. Having software in place that can collect, assess, analyze, and recommend the appropriate amount and type of charging stations would save time and money.

VIII. Projects such as MiTransporte should spread knowledge on EVs outside of technical circles, to general public

As EVs become more commonplace, the average consumer will need a better understanding of how they work and how to handle technical issues that may arise. It will be necessary for firefighters, police officers and other rescue workers to be fully prepared for dealing with EV accidents and battery fires. The public will need to know what to do with batteries that need to be replaced and those that must be disposed of. Batteries with a capacity too low for effective usage within an EV can still be used for storage purposes in a house, as it will be several more years from that point until the charge capacity is too low for practical usage. The public will need information on a battery's capabilities after removal from a vehicle. Before that, EV owners will need to be taught what they can do to maximize battery life. Most EVs operate using lithium ion batteries, which experience decreases in battery life from extended exposure to high temperatures at full charge, or when completely depleted multiple times. Consumers attempting to maximize the number of cycles their EVs can handle should avoid leaving the vehicle fully charged for extended periods of time and should charge before significant battery depletion occurs (Arcus, 2016). While it will likely be eight to ten years before consumers need to worry about battery replacement, projects such as the one promoted by

MiTransporte should consider developing and promoting general public usage guides explaining this critical information.

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Appendix A: Meeting Questions Addressing Methodology Objectives

Our conversations with the groups we met with were not dictated by our objectives outlined in our methodology, but rather they were reflective of what we knew about electric mobility in Costa Rica at the times of the meetings, and our overall project goals. This is because the groups we met with were well educated on the topic of electric mobility, and many meetings gave us information covering multiple objectives. We did not realize the gaps in our initial research until arriving in Costa Rica. We quickly realized we needed more perspective on the inner workings of electricity in Costa Rica, as the relationships between electricity distributors and the government are significantly different than those in the United States. This led to the establishment of our first objective. We needed to gain an understanding of the distribution of power in terms of electricity generation, transmission, distribution, and regulation. After this research, we needed to confirm with our sponsor that the information we gathered was correct.

Objective 1.

Addressed to our sponsors, the CICR

- Are we correct in our research, that ICE is solely responsible for electricity transmission, only the eight distribution companies have access to that grid, that ICE is responsible for most of the country's electricity generation, and that the ARESEP determines the electricity tariffs?

The questions involved in completing objective 2 did not change very much from the prep term, as our group realized early on the importance in learning of the different groups' actual perspectives and actual government action regarding electric mobility, as there was a good chance this could be different than what is told to the news outlets. The interest in whether or not the Costa Rican government would allow for private ownership of EV charging stations came from learning of the relationship between the ICE and the government, and the power the ICE holds. Also, as we were exposed to the intricacies of the Law 9518, we began to ask those we met with why electric public and freight transportation are not prioritized the same way electric private transportation is

Objective 2.

Addressed to correspondents for Grütter Consulting, the CICR, MiTransporte, the CNFL, the DCC, the University of Costa Rica, the SEPSE, and the ICE

- What legislative action is currently in place to promote electric mobility?
    - Private sector?
    - Public sector?
    - Freight sector?
    - Public institutions?
- Will the Costa Rican government allow for private ownership of EV charging stations?
    - If Yes,
        - Will the Costa Rican government offer subsidies to businesses looking to obtain EV charging stations?
        - What kind of regulations would you put on private ownerships?
    - If No,
        - Where will EV charging stations be located?
        - Will businesses have the opportunity to profit from state-owned charging stations on their property?
- What legislation is in development?

- What is your timeline / predictions for the adoption of electric mobility?
- What is the range of government subsidies?
- Why is electric mobility in public transportation not as large of a legislative priority as it is in private transportation?

While in Costa Rica, we decided that compiling lists of electric vehicles on the market along with their technical specifications would be a useful tool for the Chamber to have numerical data behind their arguments. In order to decide which vehicles to focus on including, we began asking those we interviewed which types of electric vehicles they were interested in purchasing, leasing, or seeing in the country. It was also important to learn about the charging stations and the technological relationships between electric vehicles, charging stations, and the grid.

Objective 3.

Addressed to correspondents for Grütter Consulting, the CICR, MiTransporte, the CNFL, the DCC, the University of Costa Rica, the SEPSE, and the ICE

- What electric vehicles are you interested in pursuing / promoting / purchasing?
    - Private?
    - Public?
    - Freight?
- What electric vehicles are the country's charging stations supporting?
- Where did the charging stations come from?
- How much money is the government willing to spend on charging stations?
- Will the government work with businesses to supplement the charging station infrastructure?

- Can the electricity grid handle the demand of 40,000 electric vehicles charging at night?

This objective refers to our group's desire to provide the Chamber with the technical information necessary to sufficiently inform a business or company on the transition to an electric fleet.

Objective 4.

Addressed to the CICR

- What information will businesses and companies need in order to be well informed on electric mobility?

This objective was necessary in order to ensure the usefulness of our project to the Chamber.

Objective 5.

Addressed to the CICR

- Does the opinion our research is pointing us toward reflect the beliefs and values of the chamber? Does the chamber support the recommendations and conclusions we have come to?

Appendix B: Meeting / Workshop Notes

Verena Arauz - Grütter Consulting: 1/22/19

Minutes:

- Verena Arauz's background
    - Studied mechanical engineering
    - Works at a small consulting firm
    - Firm designs energy and financial solutions for cities
        - Most people are unwilling to pay for energy infrastructure
        - Many European countries are clinging to fossil fuel
        - Asian countries showing more willingness to expand
- Workshop on Thursday 1/31
    - One or two of us requested to attend
    - Will focus on transportation sector energy
- Determining viability of public transportation vs. private usage of electric vehicles
    - Verena: Hard to assess when an EV would be economically viable
    - Depends on financial benefit to stakeholders (owning or renting)
    - Charging stations are expensive and have a slow ROI
    - Verena's firm promotes vehicle sharing, installs charging stations
    - Station would be property of company using it but maintained by firm
    - Leasing period of 8 years, dependent on battery life
    - Energy storage considerations regarding sale/purchase of energy
    - Cheap electricity during peak hours is most desirable state
- Electric Buses: normal 12 meters long, 45 seats
    - Appear identical to fossil fuel busses
    - How many buses are there? What routes would electric ones be able to use?
        - Flat routes, stay in city or avoid mountains
    - Technology for electric vehicles to handle harsh roads exists but too expensive
    - Private companies will not be willing to disclose EV usage information
- Possible expansion to electric cars
    - Model would change to normal leasing
    - Firm doesn't care if EVs used for taxis/Ubers
    - Autos would be new Hyundai Ioniqs
    - Verena does not support law which allows importing of used fossil fuel tech
    - Sees it as hypocritical of government to do so while promoting sustainability
    - No recycling facilities exist for batteries
        - Problem with maintenance
    - Will it be possible to transition Costa Rica to purely electric transportation?
        - What government incentives would be needed to make it happen?

- Approach with working with ICE or CNFL to see if they are serious about taking action
    - Verena does not agree with their positions
    - Need for a platform and incentives to promote EVs, but neither can be done
    - CR is raising electricity prices but this is the wrong approach
    - Private vehicle don't really serve as a solution, less cars are ideal
    - Smartphone analogy: you buy it when it becomes affordable to upgrade
    - Government should not dictate usage of private EVs
- Buses need to be appealing to the poor in terms of prices
    - Cheaper to charge a battery than to fill a tank because mostly done at night
    - Higher cost charging requires government subsidies to offset impact
    - The speech is too centralized around lobbyists who know nothing
    - Do the Bomberos know what happens when an EV overheats/how to respond?
        - Very minimal education on electrical vehicle safety
- Leasing project started in CR because the barrier to entry is very high for EV technology
    - Verena's firm needs to "overthink" everything due to legal barriers
    - Seeing barriers to entry as well as benefits to market
    - Costa Rica has no infrastructure for manufacturing vehicles
    - Initial costs of purchasing EVs are too high for industry to justify purchasing
    - Mexico has electric scooters for public use
        - Designed for low milage/short distance public transportation
- ICE and other companies are buying EV's more as a show and tell thing
    - Many cars in Costa Rica are large SUVs, people have 2-3 cars
    - Goes against supposed promotion of sustainability
    - People generally prefer commodity and convenience of traditional cars
        - Dislike waiting for longer EV charging times compared to gas
        - Prefer not to carpool with others
    - Public needs incentives that will drastically change their perspective on EV ownership
        - Younger Costa Ricans are beginning to switch to EV usage
    - Jairo Quiros knows about this
- Some malls offer use of EV charging stations for free
    - Incentivizes owners to visit mall for charging, good for business
    - Malls eat cost of electricity
- Verena says Costa Rica's 40,000 EV goal is nonsensical
    - Is not supported by sufficient goals/plans to make it realistic
    - Most cars are not scrapped, left on roads
    - Minimal capacity for reduction of total # of vehicles in CR
    - Private ownership may therefore not be viable
    - Concerns about climate change vs. public health
        - Does not make sense to pursue EVs for climate concerns

        - 200 new EVs will not solve climate change, but will improve health
    - German packaging/shipping corporation designed its own fleet of electric trucks
        - Are relatively affordable and sustainable
        - Designed in response to banning of diesel vehicles in certain cities
- Talked with Correo de Costa Rica
    - People tend not to be communicative outside of WhatsApp
        - Verena often ghosted when attempting to set up meetings via email
    - Without connections, very hard to make progress
- No taxes on EV ownership if vehicle costs less than $60,000
    - Would have been fine if it only applied to cars
    - Includes larger vehicles which are impossible to make cheaper than $60,000
    - Destroys incentives for truck owners to switch to electric
- Verena's firm imports EVs from China
    - $90 million joint investment with ICE for new EVs
    - 250 buses, 50 trucks, 500 automobiles, and full charging infrastructure
    - ICE would take responsibility for necessary loans
    - Have not considered leasing hybrid vehicles because they are outdated
    - Intended as a transitional technology, no longer viable
    - Mitsubishi Outlander SUV is a good hybrid vehicle for private use
- Company leasing prices for EVs
    - 1 bus: $24000 for 4000/month, bulked in 100's
- Industry interest
    - Bus rapid transit lanes are possible, Verena doesn't believe it will happen
        - High capacity buses 20m long only
        - Subway style
- Need a city of at least 1 million people for subways to be a feasible investment
    - Public transportation has zero gov subsidies, has led to differing rates
    - Far too expensive to travel via bus
        - 800 colones for 10 km distance
        - Not affordable for the average Costa Rican
- Highly politicized sector and has been corrupted by lobbyist interests

CICR Workshop - Feria y Charlas Técnicas de Eficiencia Energética: 1/28/19

Carlos Montenegro (CICR): Bienvenida

Notes

- Goal: Improve the competitiveness of the Costa Rican energy industry
- CNFL, ICE, JASEC, ESPH request price increase
    - 7.57% increase in tariffs from ICE
    - CNFL 7% overall increase

    - 0% increase in generation rate for Jan. 2019
    - JASEC distribution request of 8.34% in 2019
        - 0.45% in 2020
        - 2.35% in 2021
- Borders of regulation
    - MINAE
        - Geothermal
- Workshops
    - CICR
    - ARESEP
    - ICE
- Developing a National Energy Plan
    - Bus CO2 emissions → electric busses
    - % of fossil/renewable fuels used (8% methane by 2022)
    - Install charging stations by electricity distributors (EV); 69 by 2022
    - Install smart meters (1,091,178 by 2022)
    - RECOPE storage spheres (75% by 2022)
    - Rapid train transit, goal of 100% funding by 2022
    - Pacific Ocean oil port
- Law No. 20,641: Ley De Combustibles
    - Advancement in the elimination of combustibles (fossil fuels)

August 10 2019: will invite opposition to the legislative assembly

Agustin Rodriguez (CICR): Energy Efficiency in the Industry

Notes

- 4 Basic Considerations saving energy
    - Change of tech
        - 66% increase in efficiency of air compressors, but minus 20 HP
    - Productivity Improvements
        - Investment in equipment ($100K)
        - Savings in both productivity and efficiency
            - savings of 400$/day
    - Optimize existing equipment
        - Opportunity for conservation of energy (OCE)
            - Decrease network operating pressure
            - Decrease in demand
            - Decrease in consumption
    - Hours used annually
        - Energy savings equation has two components
            - Magnitude of electricity

        - Amount of time annually
- Opportunities
    - Reduce costs
    - Improve control of process
    - Green finance
    - Reduction of carbon footprint
    - New market niches
    - Greater competitiveness
- Downfalls of refusing to change
    - Energy price increases
    - Fluctuations of price of petrol derivatives

Luis Valerio (TEC, Costa Rica Institute of Technology): Environmental Benefits from Energy Efficiency

Notes

- Energy Administration
    - "The judicious and effective use of energy to maximize profits (minimize costs) and enhance competitive positions"
- Food Products
    - Need to be safe, ethical, natural, and sustainable
    - Democratization of food products
    - Importance of personal diet
    - Formulas to save time and money
- Environment
    - Carbon footprint
    - Reduce costs of controlling environment
- Social
    - Cultura organizacional
    - Mejora calidad
- Economic
    - Reduce utility costs
    - Reduce consumption
- Energy consumption = tapped energy + pollution
- Big companies bunker energy demand 78% CO_2
- Diesel - 82% energy impact (small company)
- Cargo handling and good practices can save energy, and money
    - Change in energy price along with change to LED lights
- Liquefied petroleum gas (LPG) vs gasoline
    - Almost 50 kg less CO_2 emissions
    - 2 kg less per liter

    - Half the cost

Hector Calderon: Quality of the Energy

Notes

- Relationship of quality and efficiency of energy
- Goal: to look for a measure of efficient energy; continue doing the same thing but with a lower cost
- Two kinds of correlations between efficiency and quality
    - Before and after efficiency actions
- Infrastructure looking older now
- Quality is essential to ensure upgrades to increase efficiency will work and be worth it
- Improper wiring will lead to large heat loss, less economic benefits

Pierre Lambot (Purasol): Energy Efficiency and Solar Energy

Notes

- Solar energy is good
- Photovoltaics are the future of renewable technology
- New ways of using existing renewables
- Integration of solar and battery technology
- Energy regulations are uniform/consistent nationally in CR

Fernando Rivera (CICR): Efficient Illumination

Notes

- 3 things to consider for lights and savings:
    - Security
        - For people and installations
    - Quality of the lights
    - Capacity to produce colors // Efficiency
- Appearance of physical lights
    - Psychological issue
- Capacity to produce different colors
    - Many cases for different colors
    - Ceramic Metal Halide
    - Low/High pressure sodium
        - Low has little color
    - Triphosphor fluorescent
        - Highest range color
- Using software to find more efficient ways of illumination
- Dialux

Procoen: Thermal Insulation as an Opportunity to Conserve Energy

Notes

- Thermal jackets for insulation
    - Totally demountable
    - Put on meters to stop heat
- Economic saving greatly increased
    - Temperatures dont exceed 40C
- Quality of vapor and work safety
    - This protection fights against workers injuries
    - OSHA
- Reduction of vapors also signify lowering of chemicals
    - As well as reductions of releasing of fossil fuels into the atmosphere

RSF CR: Efficient Refrigeration

Notes

- Cycle for refrigeration
    - Evaporation
    - Compression
    - Condensation
    - Expansion
- Efficiency == ER/W
    - W = work of compression
    - ER = effectiveness
- General classification of systems of refrigerations
    - Direct expansion
    - Flood System
    - Recirculating system
- Secondary refrigeration
    - Byproduct of other system in use
    - Feeds off other energy
- 77-90% of consumption of the system comes from compression
    - 5-15% air cooler
    - 3-5% condenser
    - 2-3% pump
- Many factors in each component that play into the possible savings of the over system (both electricity and money)
    - Temp of the thermal load
    - Temp differential
    - Precision

Grupo Clima: Efficient buildings + climatization

Notes

- More than 84% of the “big” buildings are electrically inefficient
    - Responsible for over 30-40% of global consumption
- Process to improve
    - What is the tech that we need?
    - How much does it cost?
        - 8.5% saving annual with a 1 year payback
    - After 1 year:
        - Marginal costs
- Possible recommendations
    - Change in tariffs
    - Change in lighting
    - Change in air conditioning
- What else can we do?
    - Comercial payback of solar/photovoltaic and air conditioning
        - 4-6 years
        - Industrial: 7-10 years

Carlos Montenergro - CICR: 1/29/19

Notes

- Goal: Improve the competitiveness of the Costa Rican energy industry
- CNFL, ICE, JASEC, ESPH request price increase
    - Last year, 7.57% increase in tariffs from ICE
        - 3.3% increase approved by ARESEP
    - New proposal in December asking for 20.37% as of April, changed as of last week to 9.5% but for longer time period 21 months
    - Tariffs are meant to help cover operating costs of energy infrastructure
    - CNFL 7% overall increase
        - 117 colones per kWh
    - 0% increase in generation rate for Jan. 2019
    - JASEC distribution request of 8.34% in 2019
        - 0.45% in 2020
        - 2.35% in 2021
    - ICE profits from interest rates on energy usage
        - Reduces customer burden of payment
    - Charge factor
        - Energy usage depends on demand
        - Users are charged based on amount used during peak times
        - Determines cost of electricity for user

    - If this requirement were eliminated, more companies would qualify for tariff
    - Certification for ISO 50001 international energy standard
    - Massive spike in pre investment studies tax from 2017 to 2018 (2635% increase)
        - Likely due to the shutdown of a major dam
        - Fear it may continue
- Borders of regulation
    - MINAE
- Developing a National Energy Plan
    - Bus CO_2 emissions → electric busses
    - % of fossil/renewable fuels used (8% methane by 2022)
    - Install charging stations by electricity distributors (EV); 69 by 2022
    - Install smart meters (1,091,178 by 2022)
    - RECOPE storage spheres (75% by 2022)
        - RECOPE is company related to importation of fuels?
    - Rapid train transit, goal of 100% funding by 2022
    - Pacific Ocean oil port
- **Law No. 20,641: Ley De Combustibles**
    - Currently being proposed, prepared by team from RECOPE
        - RECOPE is fuel company, proposition can be seen as attempt to save RECOPE
    - RECOPE wants to hold monopoly on natural gas, currently can compete
    - Freedom to RECOPE to make new companies in biofuels field
    - CICR against relying on government companies to pursue new technologies
    - Advancement in the elimination of combustibles (fossil fuels)
    - August 10 2019: will invite opposition to the legislative assembly
- ICE and CNFL responsible for 80% of distribution
- Residential consumers do not pay by demand, only industrial companies
    - Less than 3000 kWh per month does not have to pay for TMT (demand)
    - TMT companies pay by demand and kWh
- MINAE
    - Wants to regulate electricity distribution
    - CICR critiqued proposal
    - CICR wants new renewable energy solutions, government may oppose involvement of private companies?
    - ARESEP more operator sided than consumer sided
    - CICR wants to support private sector while gov't will want new developments to be through public companies

MiTransporte: 1/30/19

Notes

- Our project relates to MiTransporte's current focus on EV infrastructure and logistics of implementation
- Andrea: employee at MiTransporte focusing on renewable technologies
- Daniel: electric mobility advisor, student at UCR working with Jairo in energy research
- CR government annually allocates budget for EV-related expenses (purchase, charging stations, etc.)
- Concerning possibility that if fleet were converted to EVs, grid crash would make it impossible to recharge
- MiTransporte (MT) presentation on their work
    - Company operates in 30 countries around the world
    - Working in Costa Rica because it is an ideal site for pursuing renewable technologies
    - Transportation sector contributes 44% of Costa Rica's carbon emissions
    - Autonomous vehicles and public transportation are changing the way Costa Ricans commute
    - Globally, there are 2 million EVs vs. 1.7 billion traditional vehicles
    - German Environmental Ministry funding MT via initiative supporting renewable research
    - MT operates at national and local levels, focusing on EVs in public transport and community outreach
    - MT has introduced various laws, regulations, and policies to CR government promoting EV technology
    - ICE promotes semi-fast charging stations (but these are different from fast charging stations)
    - MT will be installing slow charging stations at bus depots for private leasing of electric buses
- Market has “skipped” the hybrid step and is focusing on pure EVs
    - Only for heavier larger vehicles
    - Hyundai Ioniq
    - Mitsubishi Outlander (PHEV)
    - Lexus and BMW hybrids
    - Hyundai Sonata hybrid?
- Encourage government to improve transportation sector
    - To reduce traffic, not necessarily encouraging everyone to own a vehicle
- Specific allocation of charging stations will be determined in conjunction with ICE
    - Slow charging in depots for buses
- Importing of charging stations would be a good business opportunity
    - However, a market for this does not exist currently
    - The scale of the needed purchases is beyond the scope of MT’s current plans
- ICE could make a large scale investment into charging stations and turn a profit later on

- RECOPE only refines and stores fuel since CR has no oil of its own
    - Needs to adapt to overcome changing energy profile
    - Is invested in pursuing alternative energy and does not oppose EVs
- Ministry of Transport is focusing on faster response times to vehicle accidents
    - MOPT usually good and agreeable, although their influence is wide ranged
- Maintenance
    - Train the companies
    - Battery replacement is not within time range of project
    - Battery replacement training will be included
- Battery Recycling
    - Recognize gap
- Taxis are not a focus of the project, although they are encouraged
- Urban bus will run approx 200 km in a day (ARESEP with JSP research)
    - Referring to total distance (usually a 5km route repeated 40 times per day)
    - 90% of urban routes are less than 200 km a day
- Keep in city, avoid rough terrain, steeper roads leaving the city
- Various buses have various specifications
- Electricity tariff based on sum of energy cost and power cost (peak demand)
    - Can affect even a medium fleet charging overnight
    - Fast charger is pantograph, might not be applicable, might not be necessary
    - Peak demand aspect of tariff is discouraging to fast chargers
- Fast chargers would be in stations, used by multiple bus companies, chance for monopolization
- Santiago de Chile
    - 100 electric buses into the city

MiTransporte Workshop - Mitigation of Emissions in the Transport Sector: 1/31/19

National Transport Plan

Notes

- 2017 energy matrix: 63.2% fossil fuels, 20.8% electric, 13.7% biomass
- 2017: 82.6% of fossil fuel usage came from the transport sector
- 2017: hydropower was 77.4% of electricity generation
- Private transportation was 50.4% of transport consumption, freight was 36.5%
- National plan - Law 9518
- Implementation coordination
    - Energy sector
        - Energy council
        - MINAE
        - Secretary of planning

        - ARESEP
        - ICE
        - CNFL
        - JASEC
        - ESPH
        - RECOPE
        - Cooperatives
- Expected Impacts
    - Approaches
        - Efficiency
        - Renewables
        - Low in emissions
        - Sustainability
    - Impact
        - Transformation of the energy matrix
        - Compliance with GHG commitments (compromisos)
- Emissions from the transport sector compared with NDC (tonnes CO2)
    - 12,441,260 in 2012
    - Projected 5,964,988 in 2030
- Transporte Privado
    - Infrastructure
    - Consumer information
    - Energy offer
    - Financial incentive
    - Incentives not financial
    - Availability and support
    - Tourism sector
    - Generation of capabilities
    - National TE Industry
- Transporte Publico
    - Concessions (Concesiones)
    - Technology
    - Public service rates
    - Service train
    - Public train
    - Pilot project
    - Consensus
- Transporte Institucional
    - Guidelines
    - Information

    - Institutional Agreements
- Actions and results for private transportation
    - Infrastructure
        - Regulate public charging infrastructure
        - Establish geographic locations of charging centers
        - Rate for recharging centers
        - Regulate recharging centers in parking lots and buildings
    - Consumer info
        - Develop and implement communication strategies
    - Demand for assured energy
        - Planned future demand in PEG
        - Hourly rates
- Energy sector actions
    - Coordination of electric companies and ARESEP
    - Technical equipment of electric vehicles
    - Standards of recharge centers
    - Aiming to install 53 semi-fast charging stations throughout CR
- Cartago semi-rapid charging station
- Regulations for exoneration
    - No. 41092-MINAE-H-MOPT, public 25th of May
    - Decreto Ejecutivo No. 41426
    - Decreto Ejecutivo No. 41427-MOPT
    - Derectriz No. 033-MINAE
- Rapid recharge infrastructure
    - Regulation art. 31 implementation of charging centers
    - Electricity distributors are responsible
    - Workshops to achieve national coordination
- Recent decrees and directives
    - Executive Decree No. 41426 of November 7, 2018. Incentives for used electric vehicles
- Tariffs on busses
    - Design a tariff to facilitate electric busses
- Conclusions
    - The country is looking for an energy transition towards the substitution of petroleum derivatives for electricity in transport
    - There is a policy and the instruments are being created to accelerate this transition
    - Changes require joint work between the energy sector and other relevant actors

Entrega, Zero Emissions

Notes

- Who are we
  - Correos de CR
  - 18 regional distribution centers
  - 2 centers of classification
  - 36,717 daily deliveries
  - 1,931 collaborators
  - 110 sucursales
  - 83 API (apartado postal inteligente)
- Data:
  - 36 cents million monthly
  - 26.832km 24/7
- Motorcycles: focus
  - 536 total - 188 rented, 348 owned
- Vehicles
  - 5 passenger vehicles
  - 16 trucks
  - 88 compacts
  - 17 4x4s
- 10 metropolitan routes
- Projected total of 128 EVs by 2025
  - Paneles - minicars
- Their network
  - Routing
    - 16 units
    - 4-8 tons per unit
    - 10 metropolitan routes (>1000 km am, 646 km pm)
    - 5 national routes
    - 347 km average daily per unit
  - Delivery
    - 348 motorcycles
    - 98 vehicles
    - 18 postmen centers
    - 110 branch offices
    - 21,624 km daily
- Environmental footprint
  - CO_2 - 1,351.5 tons
  - 56,932 decibels
  - 319,616 km/mes

- Nuestro reto
    - Gradually convert to CR post in: zero emission delivery
- Integral process
    - Projection of substitution
    - Total 348 motorcycles 2019-2023
        - 221 125cc-150cc
        - 123 200cc-250cc
    - 128 vehicles 2019-2025
        - 89 compact
        - 19 4x4
    - API - smart post office
    - More deliveries in one place

Grütter Consulting

Notes

- Experience example - Shenzhen bought 500 and Sao Paulo 200 garbage trucks
- Freight trucks using solar panels over storage compartment for cooling?
- Electric trucks
- Batteries
    - Type: Long charge at night as well as rapid charging
    - Capacity up to 200kWh for trucks
    - With a slow charge, enough batteries must be (poner) to guarantee travel
    - Fast charge: 30 minute charge = 150km range
    - 8 years 80% capacity guaranteed by SOC
    - Re-utilization or reuse of the batteries for fixed installation
    - Ranges are flexible and depend on the amount of typical batteries are 100-250km with slow charge and 150 km with fast charge
- Investment
    - It depends basically on the type of truck and its use (recommended distance)
    - Streetscooter example
        - Cargo capacity 8m^3 or 960 kg
        - 48 kW motor
        - 190km range
        - Cost about 45,000 USD
    - The investment in a electric truck is approximately 2-3x comparable fossil fuel vehicle
- Costs of operation
    - Type: 1 ton storage capacity
    - Use of energy per km: 0.3 kWh/km

        - Cost of energy per KM: 0.05 - 0.06 USD/km
        - Cost of maintenance: 30-50% less than cost for diesel
        - Operation cost: 0.06 USD/km
        - Operation cost for diesel vehicle: 0.15USD/km
    - Windows for business
        - Positive environmental impact
            - Lower emissions GEL
            - Less pollution
            - Less noise
        - Positive image of the company and potentially more 7 / or better clients
        - Lower cost of operations
        - Improve mediums of communication to the public, appear innovative
    - e-Move
    - Have a movement to electric vehicles that are accessible and competitive

Verena Arauz (Grütter Consulting Part Two)

Notes

- E-move
    - 2020 - 2040 plan
- Areas of Focus
    - Large standardized cost effective fleets
    - Optimized EV tech
    - Fast charging infrastructure
    - Strategic advantages leading to a sustainable market dominance by being first-mover and disrupting the existing mobility structure
- Business Components
    - E-bus
        - Focuses on urban public transport and tourist buses; target 2020: 250 large urban buses and 50 tourist buses
    - E-truck
        - Urban delivery up to 12t; target 2020: 50 electric urban delivery trucks
    - E-taxi
        - 500 by 2020
    - e-car sharing
    - e-infrastructure
    - E-bus leasing model

Grupo ICE Corporate direction of electrical negotiations for distribution and commercialization

Notes

- 25 fast charge centers through Grupo ICE
- Platform
  - Location information, charger section, technical support, maintenance
  - (banking) Customer's electronic account, payment method, collection account
  - (@CE and equivalents) Sales record accounting collection
  - (FISCO and equivalents) Electronic billing system
  - Validation of electronic invoice
  - Control center, operation information, information outputs
  - Membership, payment method, App, call center, recharge service
- Exploring possibility of pre-reserving charging stations for use
  - When traveling, could plan route to stop at one
- Operators
  - Remotely monitor and control the chargers
  - Possibly look for patterns for optimization
  - Conditions change the variable tariffs
    - Place, time, change of politics
- Website for Users (Grupo ICE)
  - Electric vehicle charger
  - Members can check usage and history through their account
  - Operation of shippers by type of company
  - Characteristics of the loaders
  - The operator can remotely monitor and control the loaders
  - The operator can see the status of the charger online and remotely control it
  - It is possible to analyze patterns
  - Electric rates can be adjusted for various conditions: seasons, time, policy changes, etc.

Alan Blanco, CNFL: 2/4/19

Notes

- Costa Rica has National Standard
  - Semi-fast charger = SAE J1772 Yazaki
  - Fast charge
    - Combo 1
    - CHAdeMO
- LAW 9518
  - Law for 5 years for new ones as of publication

- Taxes, ISC(selective consumption tax) (30%) + IV(sales tax) (13%) + Customs (1%) according to the table with a ceiling of 24 salaries based on the Judicial Power
- Exoneration spare parts own technology to ten years
- Exemption for parts of assembly and production on I.V.
- Subsidies to the right of circulation according to table
- Depreciation of 10% during the first 3 years
- Exemption from vehicular restriction
- Exemption from payment of municipal parking meters
- Use of blue parking lots
- The state institutions will schedule the substitution
- Electricity distributors must develop infrastructure
- The public administration must develop education campaigns
- It is obliged to support the representative brands
- Only requires that 10% in taxi concessions be electric

Table 17. Law 9518 Import Tax Exemptions for Private EVs

Amount exempted from the CIF (Cost, Insurance, Freight) value	Sales tax	Selective Consumption Tax	Tax on the customs value
$0-$30,000	100%	100%	100%
$30,001-$45,000	50%	75%	100%
$45,001-$60,000	0%	50%	100%
>$60,000	0%	0%	0%

- Ex. $30,000 CIF EV vs fossil fuel vehicle
  - EV: Tax = ($30,000 * 1.25) * (0.13*0+0.30*0+0.01*0) = $0
  - Gas: Tax = ($30,000 * 1.25) * (0.13*1+0.30*1+0.01*1) = $16,500 (55% of CIF)
- Ex. $60,000 CIF EV vs fossil fuel vehicle
  - EV: Tax = ($60,000-$45,000)*1.25*(.13*1+.30*0.5+0.01*0) + ($45,000-$30,000)*1.25*(.13*0.5+.30*0.25+0.01*0) = $7,875
  - Gas: Tax = ($60,000 * 1.25) * (0.13*1+0.30*1+0.01*1) = $33,000
- So from the examples given, it appears the tax incentives are applied in a bracket manner, with the first $30,000 paid on a vehicle still exempt from the import taxes

- 32 charging stations 80 km apart
  - Already purchased

        - Barcelona, Portugal, some American companies, but American chargers are expensive
        - Only owned by CNFL, ICE
    - Installed before end of year
    - He doesn't think will be less
    - 3-4 years projected large increase in range
    - Probably more chargers in same area but not closer in cluster range
    - At beginning only one station per point
        - Eventually expand per point
- Jasec, banks, malls are bringing in semi-fast chargers
- 2023 over 30,000 EV (PROJECTION)
    - Have everyone charge at home
- Most stations come from charging stations
    - Electricity is free RN
    - At malls and shopping centers, banks
        - Not part of 32 total because are SEMI rapid
- Currently about 500 EV and 600 EV motorcycle
- Problem with bus tariffs
    - ARESEP decides which tariff to charge
        - Calculate operation cost
        - Initial investment
            - $110 k is the max
                - Does not cover EV bus investment
        - Profit inclusion
    - EV buss tariff is old and not updated to fit today's prices
    - If a bus company were to upgrade to an EV, their operation cost would go down, causing the tariff to go down instead of increase to cover the investment
- 120 colones per KW-h commercial rate for semi-fast chargers
- ARESEP fast charge tariff incoming
    - Charge per time not KW-h
    - Peak
        - Approx ¾ cost of filling gas tank
    - Valley
        - Approx ½ ""
    - Night
        - Approx ⅓ ""
- Ten year study total cost of ownership shows driving over 14km/day worth in CR for EV
    - Take into account costs / maintenance / long term
- Nissan EV 200
    - Going to japan to entice business

    - Finding difficulty attracting big market EVs to CR
- National transport plan
    - All organizations report fleet numbers and transition plan to 10% EV by 5 years
        - Not set in stone / signed
        - In development
    - Ready by june
- What to do with leftover older / gas cars during transition
    - Making plan to recycle most parts of cars
- If you sell an EV, you are responsible for battery disposal
    - But battery problem likely does not need to be addressed for 12 years or more
    - Battery can keep being used after taken out of car, will still have capacity, just less than 80% after 8 years
- Mall with charging station:
    - Park for 2 hours = charge 14 kWh (110 colones per kWh = 1500 colones)
    - Return on investment very long, malls are doing it more so for the image
    - Attract consumers with EVs
- Importation of charging stations, batteries will be tax free
- Will be tax table for importation of vehicles (incentives end after $60k)
- Executive Decree 41425-H-MINAE-MOPT, November 7, 2018
  Article 1-. Repeal Executive Decree number 33096 of March 14, 2006, which encourages the use of Hybrid-Electric Vehicles as part of the Use of Clean Technologies, as well as its reforms. Sole Transitory.- The exemptions established in Executive Decree number 33096 of the March 14, 2006 will be maintained for a period of 12 months from the entry into force of this decree.
- Executive Decree 41426, November 7, 2018
  Article 2 ° .- Economic incentive for the used electric vehicle. For used electric vehicles, the Selective Consumption Tax is exempted.
  Article 3 - Economic incentive limit. The economic incentive will be applied only to vehicles with a CIF value at customs not greater than the amount equivalent to $ 30,000.00 (United States of America dollars). This limit will not apply to public transport vehicles or freight transportation**
  Article 12.- Issuance of badge. The used electric vehicles will be equipped with a badge, issued by the Ministry of Environment and Energy, which will allow their identification for the use of the spaces designated as blue inside the parking spaces.
- Executive Decree 41427, November 7, 2018
  Article 2 ° .- Economic incentive for the used electric vehicle. For used electric vehicles, the Selective Consumption Tax is exempted.
  9) Establishment of recharging spaces for electric vehicles, in the extent possible.
- Price per km for EV is about 6 times cheaper than diesel or gasoline. (REVISE eye).

DCC / MINAE: 2/5/19

Notes

- Collaborating with ICE, ARESEP, MINAE, GIZ, CRUSA, AutoEnvironment
- Working on pilot program with 3 electric buses to establish fleet
    - Also attempting to change pilot project to not charge more money to consumers
    - Changing tariffs to reflect consumption levels (to a point, it's cheaper as consumption increases)
- Planning to construct an electric train to travel throughout greater metropolitan area
    - Electric train/bus infrastructure that will interface to provide better transportation
- Recycling of scrapped vehicles was not viable because not enough was available for feasible use
    - Would have had to import vehicles from other countries, which made no sense
    - Sell fossil fuel vehicle and purchase an electric vehicle to initiate switch
    - Government considering stricter limits on fossil fuel vehicle imports
- Internal combustion engines are not easily disposed and no one has a large-scale conversion plan
    - Attempts to incentivize people who are selling their vehicles to switch to EVs for next purchase
    - Imports of traditional vehicles are decreasing but tax revenue is therefore falling as well
    - Balance between environmental concerns and current CR fiscal issues is threatening progress
    - In order to decarbonize CR, environmentally-minded financial reform is needed to avoid a collapse
    - Very minimal pollution data available which could justify a greater push for EVs
- Caribbean coast has train lines which have fallen out of use, can use electric freight trains to re-establish usage
    - Thousands of container trucks travel inland from coasts, creates massive traffic jams
    - Trucks are all North American brands and not suited for mountainous terrain
- CR government is not prioritizing transportation reform due to unrelated federal issues
    - Has been difficult to push programs, legislation, etc. as a result
- Much more efficient/cheap to transport goods by ship than by truck
    - However, ships are emitting even more exhaust
    - By 2020, 500 parts per million must be reached for all ships
- Impossible to improve public transportation without taking away from private ownership
    - NYC, Stockholm, London are using or considering “congestion charges”
    - Commuters needing to pay to use roads and drive
    - Bike share programs a potential avenue to offset costs
- Decarbonization plan is not prioritizing transitional technology (hybrids)

    - Government only wants to invest in purely electric technology
    - Requires massive public education/transition, funding
    - Socio Psychological impact could be dangerous
    - Pollution is free, depollution is expensive
    - Central London has successfully banned non-electric vehicles
- Land use needs to become more efficient
    - Zoning has been a large issue, forcing longer commutes
    - Private transportation tends to be the only viable method of getting to work
    - Most people in San Jose live in suburbs, outside of city center
    - Makes it harder to push non-fossil fuel vehicle zones
- Most CR citizens have parking garages in their homes, would be simple to accommodate charging stations both at home and at businesses
    - People tend to charge during downtime, range anxiety should not be an issue
    - Change in behavior from traditional vehicles needed, but not very difficult
- Ministry of finance is suffering due to decreasing import rate of internal combustion engine vehicles
- Household fiscal problems?
- Around 22% of gov't income through taxes related to oil
    - Need green financial reform of gov't
- Not a lot of research on air pollution, but air pollution and traffic congestion both reflect quality of life and can be marketing pushes for electric public transportation
- 1.43 billion USD investment for electric passenger train through metropolitan area
    - Overpasses, second opposite direction rail line will be needed to promote train transportation
- Potential for electric freight trains in conjunction with short range light freight electric trucks
    - Caribbean side has train lines no longer in use, could be revived
    - Investment for electric freight train would be less than passenger train
    - Could also reduce traffic
- Light freight trucks pollute more than big freight trucks because of the amounts of them
    - They are easier to convert, also have shorter travel distances
- Maritime transport could be a solution as well if ships become more environmentally friendly
    - Already economically feasible, infrastructure is already there
    - Climate change goal: by 2020, every ship worldwide has to have fuel be 500 ppm
- Congestion tax exists in big cities around the world (RESEARCH)
- Electric bikes, public bike parks, bike sharing programs slowly being implemented
- Public institutions are required to have travel plans for employee travel, determining measures to move toward more sustainable transport (relatively new decree)
- Gov't plan, aims focus on end goal tech, no incentives for hybrids

- Land use has not been planned to optimize transportation, zoning system does not help traffic
    - If people live in suburbs outside of city and commute into city for work, public transportation may not work for them
- Could charge vehicles based on fuel consumption to promote efficiency
- No faith in Taxis, but maybe for Uber drivers?

Jairo Quiros Tortos - UCR: 2/6/19

Notes

- Dr. Jairo is associate professor UCR Head of energy systems department
    - PHD 2009
    - Working on EV since 2009
    - EPER lab
    - Working with MINAE
    - Works on system, not power electronics or internal energy management
- Distributors more focused on profit, as shown by restrictions on photovoltaics
- Everybody charging at home is going to bring a large demand overnight in Costa Rica
    - Possible solution is remote charging management
- Opportunities for batteries once capacity is too low for vehicle
    - But legislation must change first
- Power and Energy Magazine (30,000+ readers around world)
    - How EV and the Grid work together (IMPORTANT ARTICLE)
- IEEE international electrical engineers society
- Need to consider relation between EVs and grid
- 2014-16 UK project: charging
    - 200K charging events
    - Found delay between getting home and charging car battery
        - Travel surveys only take into account when people get home
        - Driving habits that consume more energy
            - Music, ac, traffic jams
    - 3% error with respect to avg
        - Jairo will be sending the presentation showing this data
    - 2 different charging model, one taking into account time independence and state of charge
- EV Economics
    - Developed methodology to calc total cost of ownership
    - About 8 years as of 2016?
    - Distance is important to consider
    - Electrification MAG
- UCR TCO tool

    - Quantify whether a vehicle is better to be electric or Internal Combustion Engine economically
    - Worked on with Daniel from MiTransporte
- EV integration will lead to many challenges involving electric grid
    - Understanding of grid impacts
    - Adequate management to mitigate these impacts
    - Revised business models
    - New forms of energy measurement
- Market challenges have to include...
    - Power utilities
    - Service providers
    - Ev Providers
    - Gov't
    - User
- 2017 world bank: photovoltaic
    - Sim tool for the grid
    - Open source
    - Using openDSS
    - Short Circuit
    - Snapshop
    - Daily powerflow
- QGIS
    - Geographic information system
    - Upgraded to python 3
    - Large scale electric vehicles will cause grid overloads, low voltages
    - Transformer congestion is main constraint from 40% of EV penetration
    - Important for electricity distributors to know
- Cables won't be a big issue, already sizeable due to power quality standards
- Household electricity demand w/o electric vehicle in CR hovers around 1 kW
    - Compared to 1.5 kW in CR
- Time of use tariff will only be effective with correct data
- ESPRIT Based Control
- With charging delay
    - 50% of users unaffected
    - 30% see less that 2x expected time
    - Myelectricavenue
- 80 km average distance between CR charging stations national roads
    - 120 km between secondary roads
    - How/why was this specific distance chosen?
    - Jairo feels that laws should not contain a technical detail like this

        - Should be as open as possible to facilitate future growth
    - Possible meeting with [ASOMOVE] through Jairo's contacts
    - Jairo feels not as many are needed
    - Location study focuses on areas of high population vs destinations (workplaces)
        - Traffic flow
- 9 charging stations placed in the greater metropolitan area of San Jose
    - Locations placed based on intersection of routes
- Mountainous terrain throughout Costa Rica increases energy consumption/forces
    - Important to consider gradeability on fast charger locations
- Jairo argues that quite often, certain charging stations aren't needed along national roads, but there should be a fair density within the greater metropolitan area
- Fast charging station is $60K roughly (might be overshoot)
- Jairo recommends more charging stations in San Jose, less along the borders of the country, as 80% of cars in and around San Jose
- The timing of this EV transition is ideal for Costa Rica
    - Jairo thinks transition is feasible and already progressing well

Carlos Meza - ACESOLAR: 2/6/19

Notes

- Solar energy association began in 90s, first of its kind in Latin America
- Executive order promoting renewable energy generation 2010-2011?
    - Companies design photovoltaic systems
    - Right now, more about the companies now a part of the association
- See themselves as an association that promotes innovation in the energy sector
- Very important to start moving faster toward electric mobility
- Utility companies are not interested in solar energy
    - They think there is enough energy right now
    - No EV by 2026 we will have more than enough energy
- Not yet any communication between photovoltaics and fast charger implementation
- Average electricity demand patterns change daily
- The limits on electricity generation are more political than technical
    - CR power sector's structure has issues with over-regulation
    - A company probably could generate more than that on their own
- City projects for self-consumption have been quite successful
    - Demand is there for bigger projects despite high price
    - Approval period is about 6 months, can take a whole year for approval
- Guanacaste provides info on energy storage to better quality of energy
    - Small installations utilizing the lithium ion battery
- Solar Edge?
- Bigger scale: companies attempting to implement storage techniques

    - CR energy bills require payment for average usage and peak consumption
- Tariff makes solar energy less competitive?
    - Cheaper to pay the tariff than install solar cells?
- Public institutions required to buy electric vehicles depending on how many vehicles they own
- CR implementation of electric vehicles and photovoltaics is entirely dependent on ICE
    - ICE is one of the largest companies in Central America
    - Carlos is focusing on integrating small enterprises for their innovations
- ICE seeking new business model to change how they work
    - President Irene Canas is pushing this
    - Smart meters threaten jobs of workers who would be manually metering buildings
        - Issues between ICE and energy sector worker unions
- Minae supposed to check ICE but didn't (on hydroelectric investments)
    - Unions protect public workers, ICE had to put them to work
- Coops building power plants now
    - 2 options: Generate their own or buy from ICE
    - Price of Elec. from ICE will go up if they choose to generate

Randall Zuñiga Madrigal - MINAE / SEPSE: 2/7/19

Notes

- Randall - SEPSE director of energy: working with AceSolar
    - worked with Jairo in the past
- Law 9518 again: rules about charging cars, charging stations every 80km
    - ready to be proposed officially
- The SEPSE plans to introduce 80 intelligent charging stations in next 2 years
    - High priority on determining location of charging stations
    - Big issue is figuring out how to pay for charging (cash or credit?)
    - ICE is trying to purchase 25-30 of these for the SEPSE
- Working on regulations for EV license plates, tax exemptions
    - 190 new EVs and some used EVs being included
    - Factory equipment currently exempt from import taxes
    - Applies to zero emissions, Hyundai Murai: hydrogen-powered car
- A percentage of all buses used on transportation routes (and taxis) need to be electric
    - Non-electric vehicles (off-roaders, ambulances) require justification to avoid taxes
- Annual taxes for emission usage calculated and scales based on emission level
    - Older Vehicles taxed more, thus lower-class targeted
    - Unable to afford a typical used EV and get stuck paying taxes
- After 2025, CR will no longer be allowed to import used cars of any type
- Reteva: annual inspection needed for private owners to certify vehicle

- Public Bus/train transport prioritized over charging stations
- Low parts per million emission is the priority
- Political challenges due to influx of high emission trucks from Nicaragua
- There have been many attempts to incentivize public transport and electrification
- Raqueta: idea to create 3-4 large stations interconnected via electric trains/buses
- Very long term solution due to many barriers (public opinion, financial barriers)
- CR has 5 EVs used by Uber and plans to import more in the future
- There are multiple decarbonization/electrification plans all in conflict
- Exonerating used electric cars in 2 months – all electric, hydrogen (4 in the country)
- Banks will help finance electric vehicles with interest / credit rates
- Inspections will check emissions through dynamic tests
- Buses and trains after cars, and then cargo / freight
- Euro 6 standard pursued by RECOPE, CR already has very high standards
- 3-4 big bus stations with electrical trains (RAQUETA)
- Every institution talks, but they all have their own programs instead of pushing one big plan (problem with electric public mobility)

Ramírez Rodríguez Luis Diego - ICE: 2/18

Notes

- Law 9518 10% rate
- MINAE/ARESEP involved with regulation of 9518 for EV usage
- MINAE did a consultation to determine the distances the law declared (80/120km)
- Presented a list of potential locations for charging stations
- South Korean, Portuguese and United States collaboration for EV usage
- ICE opinion on need for scrapping plan
- EV, capacitor, and inductor imports
- Electric potential of motor/battery
- Classification of batteries (low, medium, high) - analogous to charging stations
- ICEVs emit far more fossil fuels and are tariffed much higher
- 100 EVs replacing 100 ICEVs, ICE will find a way to cover lost tariff revenue
- The 100 ICEVs will be resold within Costa Rica
- Operating with loan from national bank
- ARESEP would be allowed calculate new tariff for charging station users
- If ARESEP chooses to maintain tariff, cost of EV technology much higher
- Auction off ICEVs to highest bidder
- Public use, charging at banks, restaurants, etc.
- Energy distributors are responsible for installing charging stations
- Private stations are not allowed to sell energy or charge users
- Large company that wants to self-install stations for their use can do so
- Can also operate leasing model with ICE, where ICE will pay for costs of stations

Appendix C: Deliverables and In-Depth Breakdown

Public / Taxi EVs

This chart lists electric vehicles marketed toward private consumers from various manufacturers around the world. This list includes all or fully electric vehicles, battery electric vehicles, plug hybrid electric vehicles, and hybrids. Body types include mini vehicles, compact cars, sedans, crossovers, hatchbacks, and SUVs. Information included in order is company name, model name, year, presence in Costa Rica (yes or no, yes confirms presence), price, type of charger / charging specifications, type of electric vehicle, battery capacity (kWh), range (km), time to charge on a Level 1 charger, time to charge on a Level 2 charger, and time to charge on a DC Fast charger.

Caro	Modelo	Year	En Costa Rica	Precio	Tipo de carga estándar	Tipo	Capacidad de la bateria	Distancia	Time to charge (Lvl 1)	Time to charge (Lvl 2)	Time to charge (Fast)
Tesla	S		Yes	$75,750	Tesla	All electric	100 kWh	539 km			
Tesla	X		Yes	$78,950	Tesla	All electric	100 kWh	474 km			
Audi	A3 e-Tron		Yes	$39,500	SAE level 2	Hybrid	8.8 kWh	133 km			
Hyundai	Ioniq Electric	2019	Yes	$29,500	Combo 1/2	All electric	28 kWh	200 km		4 hr	
Smart	Fortwo ED		Yes	$23,800	SAE	All electric	17.6 kWh	84km			
Mitsubishi	Outlander	2018	Yes	$35000 - $41000	Type 1 and CHAdeMO	PHEV	13.8 kWh	45 km electric		4 hr	80% in 25 minutes
Mitsubishi	i-Miev	2010	No	$29,146	CHAdeMO	mini	16 kWh	150 km	14 hr	6 hr	30 minutes
Mercedes	GLC350e		Yes	$49,990	SAE level 2	Hybird	85 kWh				
Mercedes	C350e		Yes	$47,900	SAE level 2	Hybird	60 kWh	85 km			
Nissan	Leaf		Yes	$29,990	SAE level 2	All Electric	40 kWh	240 km			
BMW	I3		Yes	35,500 euros	SAE level 2	SUV	30 kWh	178 km			
BMW	225xe Active Tourer		Yes	31215 euros	SAE level 2	Hybrid	7.7 kWh	181 km			
BMW	330e		Yes	$31,414	SAE level 2	Hybrid	7.6 kWh	27km Electrico 629 Hybrid km			
BMW	530e		Yes	$53,400	SAE level 2						
BMW	X5 40e		Yes	$74,950	SAE level 2						
Kia	Soul EV		Yes	$32,790	SAE J1772 or CHAdeMo	SUV	30 kWh	167 km			
Renault	Zoe		Yes	21,250 euros	SAE level 2	Crossover?	41 kWh	210 km			
Chevrolet	Bolt		Yes	$36,620	SAE level 2	SUV	60 kWh	450 km EPA			
Volvo	XC90 T8 PHEV		Yes	66630 euros	SAE level 2						
Volkswagen	e-Golf		Yes	$30,495	Combo 1/2	All Electric	35.8 kWh	208 km			
Volkswagen	Golf GTE		Yes	~32000 euros	Combo 1/2 / SAE	All Electric					
Volkswagen	Passat GTE		Yes	36360 euros	Combo 1/2 / SAE	All Electric					
Ford	Focus Electric		Yes	$29,120	SAE	All Electric		185 km			
Fumero Green Motors	E-Freed Sport RS900		Yes		SAE	all electric bicycle	468 Wh		3-5 hr		
Fumero Green Motors	YD EM29A		Yes		SAE	all electric moto bike	48V AH12		4-6 hr		
Fumero Green Motors	YD-EM200		Yes		SAE	electric slow motorcycle	36V 12AH	30-35 km	6-8 hr		
Fumero Green Motors	YD-EM171		Yes		SAE	electric scooter	72V 20AH	50-60 km	6-8 hr		
Fumero Green Motors	C-UMI		Yes		SAE	electric scooter	60V 20AH	50-55 km	6-8 hr		
Fumero Green Motors	Chok-A		Yes		SAE	mini car	14 kWh	140 km	8-10 hr		
Fumero Green Motors	Chok-S		Yes		SAE	mini hatchback	14 kWh	140 km	8-10 hr		
Fumero Green Motors	Chok-G2		Yes		SAE	mini SUV	20 kWh	180 km			
BYD	F3DM		No	$28,800	SAE	Hybrid	16 kWh	60 km electric		8 hr	
Chery	eQ	2015	No	$24,980-$25,270	SAE level 2	all electric compact	23.6 kWh	200 km		10 hr	
BYD	Qin		No			Hybrid		70 km electric			
Great Wall Ora	R1	2018	No	$9,080-$11,140	SAE level 2	All electric compact	30.7, 33 kWh	310, 351 km		9.7, 10.5 hr	80% in 40 minutes
BYD	e6		No	$35,000	SAE Level 2 / VTOG fast	All electric Crossover	80 kWh	400 km urban			2 hr
JAC	iEV7	Launched in 2016	No			All electric sedan	24 kWh	200 km		8 hr	
JAC	iEV7s	2017	No	$31,258							
JAC	iEV5+	Launched in 2014	No			All electric sedan	23.2 kWh	200 km		8 hr	
JAC	iEV6S	Launched in 2016	No			All electric SUV	33 kWh	251 km		11 hr	
BAIC	EC200	2017	No			All electric Hatchback	22 kWh	162 km		7 hr	
Changan	Eado EV460		No			All electric sedan	53 kWh	430 km			
Changan	Eado PHEV		No			PHEV sedan	12.4 kWh	60 km (NEDC)		4 hr (220V)	
Changan	CS15 400 EV	2018	No			All electric SUV	49 kWh	351 km (NEDC)			
Changan	CS75 PHEV		No			PHEV SUV	13 kWh	60 km			

Table 18. Deliverable 1: Public / Taxi EVs

Public Transport EVs

This chart lists electric buses meant for public transportation. This list includes buses made by various manufacturers around the world. This list includes mostly all electric or battery electric vehicles, but also includes some hybrids and some buses that utilize alternative fuels such as bioethanol. The information included in order is size, company name, model name, year, type of EV, battery capacity (kWh), range (km), and charging specifications.

Size	Make	Model	Year	Type of EV	Battery Capacity	Distance per charge	Charging
12 meters	BYD	K9	2019	all electric	500 kWh	410 km	"has its own special charger, 2.5 hr to full charge, 500 kWh battery capacity, 500 kWh * ¢94.72 = ¢47,360
92 Passengers	Yutong	E12		all electric	295 kWh	220 km	(150 kW DC) 2 hr
92 Passengers	Yutong	H12		Hybrid	"Super-capacitance"	no recharge needed	
59 Passengers	Yutong	ICE12		All electric	295 kWh	200 km	
14 Passengers	Green4U			all electric	69.1 kWh	145 km	1.4 hr fast charging
32 Passengers	Green4U			all electric	100.5 kWh	174 km	2 hr fast charging
85 Passengers	Green4U			all electric	249.8 kWh	322 km	5 hr fast charging
40 Seats, 12 meters	Proterra	FC	2016	All electric	79 kWh	79 km	J1772-CCS 60 kW or Proterra overhead fast charger 350 kW
40 Seats, 12 meters	Proterra	FC+	2016	All electric	105 kWh	100 km	J1772-CCS 60 kW or Proterra overhead fast charger 350 kW
40 Seats, 12 meters	Proterra	XR	2016	All electric	220 kWh	219 km	(two ports) J1772-CCS 60 kW or Proterra overhead fast charger 175 kW
40 Seats, 12 meters	Proterra	XR+	2016	All electric	330 kWh	310 km	(two ports) J1772-CCS 120 kW or Proterra overhead fast charger 260 kW
40 Seats, 12 meters	Proterra	E2	2016	All electric	440 kWh	404 km	(two ports) J1772-CCS 120 kW or Proterra overhead fast charger
40 Seats, 12 meters	Proterra	E2+	2016	All electric	550 kWh	487 km	(two ports) J1772-CCS 120 kW or Proterra overhead fast charger
40 Seats, 12 meters	Proterra	E2 Max	2016	All electric	660 kWh	563 km	(two ports) J1772-CCS 120 kW or Proterra overhead fast charger
28 Seats, 11 meters	Proterra	FC	2016	All electric	79 kWh	79 km	J1772-CCS 60 kW or Proterra overhead fast charger 350 kW
28 Seats, 11 meters	Proterra	FC+	2016	All electric	105 kWh	100 km	J1772-CCS 60 kW or Proterra overhead fast charger 350 kW
28 Seats, 11 meters	Proterra	XR	2016	All electric	220 kWh	219 km	(two ports) J1772-CCS 60 kW or Proterra overhead fast charger 175 kW
28 Seats, 11 meters	Proterra	XR+	2016	All electric	330 kWh	310 km	(two ports) J1772-CCS 120 kW or Proterra overhead fast charger 260 kW
28 Seats, 11 meters	Proterra	E2	2016	All electric	440 kWh	404 km	(two ports) J1772-CCS 120 kW or Proterra overhead fast charger
10.9 meters	Scania (VW)	CityWide LF		Biogas / Natural Gas	9 Litre	280-320 hp	
12 meters				Biodiesel / HVO	7 Litre	280 hp	
18 meters					9 Litre	250-320 hp	
12 meters	Scania (VW)	CityWide LE		Bioethanol	9 Litre	280 hp	
12.7 meters				Biogas / Natural Gas	9 Litre	280-320 hp	
13.7 meters				Biodiesel / HVO	7 Litre	280 hp	
14.8 meters					9 Litre	250-360 hp	
18.1 meters							
2 Axle	Scania (VW)	CityWide LE Suburban		Bioethanol	9 Litre	280 hp	
3 Axle				Biogas / Natural Gas	9 Litre	280-320 hp	
				Biodiesel / HVO	7 Litre	280 hp	
					9 Litre	250-360 hp	
12 meters	Volvo	7900 Electric		All electric	76 kWh		Roof Mounted Conductive Opportunity Charging (Fast Charge 300 kW) takes 6 minutes
12 meters	Volvo	7900 Electric Hybrid		Hybrid	"High capacity", 240 hp diesel engine		Roof Mounted Conductive Opportunity Charging (Fast Charge 300 kW) takes 6 minutes
10.3 meters	ADL	Enviro400VE	2015	All electric	61 kWh	30 km	Inductive (en route) 100 kW 5 minutes
12 meters	BYD ADL	Enviro200EV	2016	All electric	324 kWh	>250 km	80 kW 4 hours
10.8 meters	BYD ADL	Enviro200EV	2017	All electric	324 kWh	>250 km	80 kW 4 hours
12 meters	Bluebus		2016	BEV	240 kWh	180 km	50 kW 5 hours
10.7 meters	Bozankaya A.S.	Sileo S10	2015	BEV	200 kWh	235 km	4-100 kW 2-7 hours
12 meters	Bozankaya A.S.	Sileo S12	2015	BEV	200 or 230 kWh	227 or 261 km	4-100 kW 2-8 hours
18 meters	Bozankaya A.S.	Sileo S18	2016	BEV	300 kWh	261 km	4-200 kW 3-8 hours
12 meters	CaetanoBus	e. City Gold	2016	Fully electric	50-250 kWh	up to 200 km	50-150 kW, or overhead at 350 kW
14 meters	CaetanoBus	eCobus	2013	Fully electric	85 kWh	up to 70 km	60 kW 75 minutes
12 meters	Chariot Motors	Chariot ebus	2014	Ultracapacitor electric	21 kWh	22 km	Overhead fast charge 150 kW 85% in 5 minutes
12 meters	Chariot Motors	Chariot ebus	2016	Ultracapacitor electric	21 kWh	22 km	Overhead fast charge 150 kW 85% in 5 minutes
12 meters	Chariot Motors	Chariot ebus	2016	Ultracapacitor electric	32 kWh		Overhead fast charge 340 kW 85% in 3 minutes
	Chariot Motors	Chariot ebus	2017	Ultracapacitor electric	32 kWh	34 km	Overhead fast charge 340 kW 85% in 3 minutes
12 meters	Ebusco	2.1 HV LF-311-HV-2/3	2014	BEV	311 kWh	366 km	75 kW 4.5 hours or 120 kW 3 hours

Table 19. Deliverable 4: Public Transport EVs

Size	Make	Model	Year	Type of EV	Battery Capacity	Distance per charge	Charging
18 meters	Ebusco	18M HV LF-414-HV-3/4	2017	BEV	414 kWh	325 km	75 kW 6 hours or 120 kW 4 hours
8 meters	Evopro Bus	Modulo C68e	2016	BEV	144 kWh	200-230 km	Conductive 60 kW 5 hours
9.5 meters	Evopro Bus	Modulo C88e	2016	BEV	84 kWh	120-140 km	Conductive 60 kW 5 hours
12 meters	Heuliez Bus	GX 337 ELEC	2017	BEV	349 kWh	200 km	150 kW 3-5 hours
18 meters	Heuliez Bus	GX437 ELEC	2017	Electric Opportunity C	106 kWh		pantograph Opportunity Charging 300-450 kW a few minutes
12 meters	Hunan	CRRC C12		BEV	201 kWh	200 km	99-137 kW 2 hours for 100 kW
12 meters	Hybricon	Arctic Whisper HAW 18	2016	BEV	40-120 kWh	20-90 km	4 hours, or Opportunity Charging 650 kW 4.5 minutes
12 meters	Irizar	i2e	2014	BEV	376 kWh	250 km	80-100 kW 6-7 hours
18 meters	Irizar	i2e 18m	2017	BEV	120-180 kWh		80-100 kW 2 hours or Opportunity Charging 500 kW 5-10 minutes
9.2, 9.9 meters	Optare	Solo EV	2012	BEV	138 kWh	270 km	42 kW 2.5 hours
10.8 meters	Optare	Metrocity EV	2014	BEV	138 kWh	206 km	42 kW 2.5 hours
10.4, 11.1 meters	Optare	Versa EV	2013	BEV	138 kWh	206 km	42 kW 2.5 hours
10.5 meters	Optare	Metrdecker EV		BEV	200 kWh		40 kW 6 hours
12 meters	Rampini	E12	2016	BEV	180 kWh	120-130 km	15-30 kW, 3-6 hours
10.5 meters	Safra	Businova Midibus	2017	PHEV	132 kWh	120 km	18-22 kW, 4-6 hours
12 meters	Safra	Businova Standard	2017	PHEV	132 kWh	120 km	18-22 kW, 4-6 hours
12 meters	Škoda Electric	Perun HE	2013	BEV	230 kWh	164 km	100 kW max, 4-6 hours
12 meters	Škoda Electric	Perun HP	2014	BEV	80 kWh	57 km	Overhead Opportunity Charging 600 kW 10 minutes
9 meters	Solaris	Urbino 8.9 LE electric	2011	BEV	160 kWh	200 km	80 kW 2 hours, 300 kW 30 minutes
12 meters	Solaris	Urbino 12 electric	2012	BEV	240 kWh	266 km	80 kW 3 hours, 450 kW 30 minutes, 200 kW 72 minutes
18 meters	Solaris	Urbino 18 electric	2013	BEV	240 kWh	184 km	80 kW 3 hours, 450 kW 30 minutes, 200 kW 72 minutes
12 meters	Ursus	City Smile	2016	BEV	175 kWh	218 km	30 kW 7 hours
12 meters	Ursus	City Smile	2016	FCEB	70 kWh		Constant Charging during Driving
18.6 meters	Van Hool	Exqui.City 18m	2016	BEV	215 kWh	120 km	80 kW 4 hours, 250 kW 10 minutes
10 meters	VDL	Citea LLE-99 Electric	2016	BEV	180 kWh		270 kW 40 minutes - 4.5 hours
12 meters	VDL	Citea SLF-120 Electric	2014	BEV	63-240 kWh		350 kW 15 minutes - 4.5 hours
18 meters	VDL	Citea SLFA-180 Electric	2015	BEV	63-180 kWh		270 kW 15 minutes - 4.5 hours
12 meters	Vectia	Veris.12	2017	PHEV	24 kWh		Overhead Opportunity Charging 150 kW 3-5 minutes

Table 20. Deliverable 4: Public Transport EVs

Freight Transport EVs

This chart lists electric vehicles made for freight transport. This list includes vehicles made by various manufacturers from around the world. This list includes all electric freight trucks, and one plug in hybrid. Included information in order is size, company name, model name, type of EV, rated load, gradeability, battery capacity (kWh), range (km), and charging specifications.

Size	Make	Model	Type of EV	Rated Load	Gradeability	Capacity	Range	Charging
light duty small	BYD	T3	all electric	0.82 tonnes	>30%		250 km	(AC 40 kW) 1 hr
light duty medium	BYD	T5	all electric	2.62 tonnes	>30%		250 km	(AC 100 kW) 1.5 hr, (DC 150 kW) 1 hr
medium duty	BYD	T7	all electric	5 tonnes	>30%		200 km	(AC 100 kW) 1.8 hr, (DC 150 kW) 1 hr
medium duty	DAF	LF Electric	all electric			222 kWh	220 km	80% Fast Charge in 70 minutes
tractor-trailer	DAF	CF Electric	all electric			170 kWh	100 km	Quick charge in 30 minutes, Full charge in 1.5 hours
tractor-trailer	DAF	CF Hybrid	plug-in hybrid			85 kWh	30-50 km all electric	80% in 20 minutes, Full in 1.5 hours
small trailer	Emoss	EMS 10 Serie	all electric	GVW 10,000 kg		60-120 kWh	50-150 km	3 hours
small trailer	Emoss	EMS 12 Serie	all electric	GVW 12,000 kg		120-200 kWh	150-200 km	3-5 hours
small trailer	Emoss	EMS 16 Serie	all electric	GVW 16,000 kg		120-200 kWh	125-210 km	3-5 hours
small trailer	Emoss	EMS 18 Serie	all electric	GVW 18,000 kg		120-240 kWh	100-250 km	3-6 hours
medium duty	Ginaf Duratruck	E2114	all electric	GVW 13,500 kg		100-180 kWh	100-150 km	11 kW, 22 kW, 44 kW
light duty small	Ginaf Duratruck	E2104	all electric	GVW 3,500 kg		54 kWh	100 km	
medium duty	Ginaf Duratruck	E2112 L	all electric	GVW 12,000 kg		120 kWh	110 km	
heavy duty	Ginaf Duratruck	E2119 T	all electric	GVW 44,000 kg		180 kWh	50 km	
medium duty	Ginaf Duratruck	E2120	all electric	GVW 19.500 kg		120 kWh	100 km	
heavy duty	Ginaf Duratruck	E3126	all electric	GVW 26,000 kg		180 kWh	75 km	
heavy duty waste	Iveco	Acco	all electric	GVW 23,500 kg		220 kWh	250 km	8 hours
	Mercedes-Benz	eActros	all electric	GVW 18 tonne		240 kWh	200 km	80 kW 3 hours, 20 kW 11 hours
	Mercedes-Benz	eActros	all electric	GVW 25 tonne		240 kWh	200 km	80 kW 3 hours, 20 kW 11 hours

Table 21. Deliverable 5: Freight Transport EVs

CNFL Electricity Rates Breakdown

Main summary:
https://www.cnfl.go.cr/documentos/direccion_comercializacion/resumen_tarifas.pdf
Commercial breakdown:
https://www.cnfl.go.cr/documentos/direccion_comercializacion/tarifas_vigentes_comerciales.pdf
Residential breakdown:
https://www.cnfl.go.cr/documentos/direccion_comercializacion/tarifas_vigentes_residenciales.pdf
Industrial breakdown:
https://www.cnfl.go.cr/documentos/direccion_comercializacion/tarifas_vigentes_residenciales.pdf

ALL PRICES ARE WRITTEN IN ENGLISH FORMAT
ALL PRICES ARE IN COLONES

Time Periods:
1. Peak: 10:00am to 12:30pm and 5:30pm to 8pm
2. Valley: 6:01am to 10:00am and 12:30pm 5:30pm
3. Night: 8:00pm to 6:00am

COMMERCIAL

Trades and Service Tax (T-CO):

For all non-residential customers throughout CNFL distribution system not specified in other taxes. Includes:

- Cabins
- Recreation areas
- Hotels
- Shops
- Workshops
- Services combined with house store (casa pulpería)

PRICES:
Consumption of less or equal to 3000 kWh block = 106.68 c per kWh
For energy consumption:
  Fixed charge of 0-3000 kWh block = 192,660 c
  Price per kWh after over 3000 kWh block = 64.22 c per kWh
Charge for Power:
  0-8W block = 80,426.32 c
  More than 8W block = 10,053.29 c per kW

Medium Voltage Rate (TMT):

Optional rate for customers in half voltage, single-phase or three-phase, nominal values and amplitudes of the service voltage, under normal operating conditions. Must consume a minimum of 120000 kWh per calendar year. If minimum not reached, will be added in price of energy peak on the 12th month.

PRICES:
Energy Consumption (Per kWh):
- Peak = 54.42 c
- Valley = 27.21 c
- Night = 19.59 c

Power Consumption, kW:
- Peak = 9,542.79 c
- Valley = 6,790.00 c
- Night = 4,310.42 c

Preferential Rate of Social Character (T-CS):

Applicable to:

- Drinking water pumping
- Education
  - Strictly dedicated to education
  - Excludes residencies and other facilities on campus even under schools name
- Religion, Church temples
- Childhood/Senior protection
- People with ventilatory support at home due to respiratory disability transient or permanent

PRICES:
Consumption of 30 kWh to 3000 kWh = 71.84 c per kWh
For energy consumption:
- Fixed charge of 0-3000 kWh block = 124,110 c
- Price per kWh after over 3000 kWh = 41.37 c per kWh

Charge for Power:
- 0-8W fixed block = 53,579.84 c
- More than 8W = 6,697.48 c per kW

Tribute to Firefighters:

All energy distributors are required by law 8992 to contribute 1.75% of their monthly electricity invoicing to the Firefighters of Costa Rica
Will by applied to the first kWh up to the 1750th kWh (maximum)
Subscribers who are consuming <= 100 kWh will be exempt

Public Lighting Tax (T-AP):

In any places, where by contract with the municipalities, take charge of street lighting.

PRICE:
3.51 c per kWh

RESIDENTIAL

Hourly Residential Rate (T-REH):

This rate is exclusive for residential customers served at low voltage and consumption exceeding 200 kWh per month

Operating voltage: low voltage, one phase, three wires, nominal value
120/240 volts.

Measurement: A single system, consisting of a three-phase single-phase meter, with multi-tariff register.

PRICES (Per kWh): In Colones

Table 22. CNFL Residential Electricity Rates

	Peak	Valley	Night
0-300 kWh	133.89	55.51	22.86
301-500 kWh	152.39	62.04	26.13
501+ kWh	180.69	72.93	33.75

Residential Rate (T-RE):

Residential is understood as the service for houses or apartments that exclusively serve as accommodation. Does not include apartment buildings served by a single meter.

PRICES:

Block of 0-30 kWh = 1,893.9 fixed
Block of 31-200 kWh = 63.13 per kWh in this block
Block of 201-300 kWh = 96.87 per kWh in this block
Block over 300 kWh = 100.14 per kWh additional

INDUSTRIAL

Same as T-CO

Industrial Tariff (T-IN):

PRICES:

Consumption of less or equal to 3000 kWh block = 106.68 colones per kWh

For energy consumption:

Fixed charge of 0-3000 kWh block = 192,660 c

Price per kWh after over 3000 kWh block = 64.22 c per kWh

Charge for Power:

0-8W block = 80,426.32 c

More than 8W block = 10,053.29 c per kW

Same as T-CO

Promotional Tariff (T-PRO):

PRICES:

Consumption of less or equal to 3000 kWh block = 106.68 c per kWh

For energy consumption:

Fixed charge of 0-3000 kWh block = 192,660 c

Price per kWh after over 3000 kWh block = 64.22 c per kWh

Charge for Power:

0-8W block = 80,426.32 c

More than 8W block = 10,053.29 c per kW

EV Import Tax Calculator

This sheet calculates the import tax for an electric vehicles of an inputted CIF price based on the breakdown of the Law 9518 electric vehicle tax exemptions given to the group by Sr. Alan Blanco of the CNFL.

CIF value is inputted into cell B3. The Bracket 3 Value, cell B6, is how much greater the cost of the vehicle is than $60,000. If the price is under $60,000, this cell will return a negative number. The Bracket 2 Value, cell B5, is how much greater the cost of the vehicle is than $45,000, with a $15,000 cap due to the third bracket starting at $60,000. If the price is under $45,000, this cell will return a negative number. The Bracket 1 Value, cell B4, is how much greater the cost of the vehicle is than $30,000, with a $15,000 cap due to the second bracket starting at $45,000. If the price is under $30,000, this cell will return a negative number. These numbers are important to the calculation because each of these brackets are taxed differently. As shown in the rectangle of cells I2 through L5, the first $30,000 of an electric vehicle has a coefficient of 0 applied to each of the three taxes listed across cells C1 to H1, making the import tax on the first $30,000 equal to $0. The rectangle of cells D4 through H6 contain the brackets multiplied by the percentages of each tax. The three tax bracket cells, B8, B9, and B10, calculate the amount of tax due to the three taxable ranges: $30,000-$45,000, $45,000-$60,000, and $60,000+. This is done by multiplying the corresponding Bracket # value by the coefficient in cell A2, then by the sum of the products of tax percentages and exemption fractions found in the rectangle D4 through H6. B8, B9 and B10 are then summed to give the import tax, B12. This value is then compared to the import tax on a fossil fuel vehicle of the same price, which is calculated by multiplying the price by the coefficient in cell A2 then by the sum of the tax percentages.

Table 23. Deliverable 2: EV Import Tax Calculator

Coefficient:	1.25	Sales Tax:	0.13	Selective Consumption Tax:	0.3	Customs Value Tax:	0.01	Brackets:			
								30000	0	0	0
CIF (Price of Vehicle, USD):	75000		0		0		0	45000	0.5	0.25	0
Bracket 1	15000		0.065		0.075		0	60000	1	0.5	0
Bracket 2	15000		0.13		0.15		0	>60000	1	1	1
Bracket 3	15000		0.13		0.3		0.01				
Tax Brackets:	2625										
	5250										
	8250										
CIF (Price of Vehicle, USD):	75000										
Tax, USD:	16125										
Tax on New Fossil Fuel Vehicle of the Same Price	41250										
Difference	25125										

CNFL Tax Calculator

This sheet works in conjunction with the CNFL price breakdown to allow consumers to calculate their expense.

SEE CNFL BREAKDOWN	ENTER INFORMATION IN THE BLUE SECTIONS											
	TMT	T-AP		T-CS		T-CO		T-REH		T-RE		T-IN / T-PRO
Energy Consumption (kWh)		200		35		3001			E.C (kWh)	10000		3001
Peak	1		Power Consumption (kW)	9	Power Consumption (kW)	9	Peak	200			Power Consumption (kW)	9
Valley	1		Price of E.C (Under 3000kWh)	2514.4	Price of E.C (Under 3000kWh)	0	Valley	200			Price of E.C (Under 3000kWh)	0
Night	1		Price of E.C (Over 3000kWh)	0	Price of E.C (Over 3000kWh)	192724.22	Night	200	Block 0-30?	1893.9	Price of E.C (Over 3000kWh)	192724.22
			Price of P.C	60277.32	Price of P.C	90479.61			Block 31-200?	0	Price of P.C	90479.61
Power Consumption (kW)							Peak Price	26778	Block 201-300?	0		
Peak	1						Valley Price	11102	Block 300+?	973251.9		
Valley	1						Night Price	4572				
Night	1											
TAX (COLONES)	20744.43	702		62791.72		283203.83		42452		975145.8		283203.83
TAX (USD)	33.19	1.12		100.47		453.13		67.92		1560.23		453.13

Table 24. Deliverable 3: CNFL Tax Calculator

Charging Stations

This sheet contains information on the three types of charging stations including required voltage, average time to charge an electric vehicle, average range added per hour charging, average power requirement (kW), and price ranges. This sheet also contains a calculator which allows a user to plug in information about an electric vehicle and electricity tariffs and receive charging costs for all three chargers for a full charge and per hour. Because electricity tariffs are dependent on energy (kWh), the time it takes to charge does not factor in, only the electric vehicle's battery capacity and the time at which the charging is done. However, according to the CNFL, the ARESEP is considering building a fast charging tariff based on time, because of the high power demand of fast charger use. The cost to charge per hour cells are dependent on time to charge, however.

Fill in blue cells	Outlet	Time (hr)	Range added per hour charging	Power Req (kW)	Average Power Req (kW)	Purchase Cost (USD)
Level 1	120V AC	10-14 typically	5-8 km	1.4	1.4	$0
Level 2	240V AC	3-7 typically	16-32 km	3.3-6.6 typically, capable of 19.2	5	$5,000-$15,000
Fast	DC	80% in 30 minutes	N/A	~40	40	$40,000-$100,000
Cost to Charge:		Cost to Charge ($USD)		Cost to Charge per Hour ($USD)		
Night Electricity tariff (colones / kWh):		Lvl 1 Overnight:	0	Lvl 1 Overnight:	#DIV/0!	
Peak Electricity tariff (colones / kWh):		Lvl 2 Peak:	0	Lvl 2 Peak:	#DIV/0!	
Valley Electricity tariff (colones / kWh):		Lvl 2 Valley:	0	Lvl 2 Valley:	#DIV/0!	
Fast Charger Electricity tariff (colones / kWh):		Fast Charger:	0			
Battery capacity (kWh):						
Estimated Time to Full Charge Lvl 1 (hours):	0					
Estimated Time to Full Charge Lvl 2 (hours):	0					
Estimated Time to Full Charge Fast Charger (hours):	0					
colones to USD conversion: (USD / colones):	0.0016					

Table 25. Deliverable 9: Charging Stations

Public Transport Company Investment

This sheet allows a public transport company to input desired amounts of electric vehicles and charging stations, along with prices, and receive charging costs and an initial investment estimate. This chart could be used in conjunction with the Public Transport EVs list to compare the costs of different options, although prices are difficult to come by without contacting a manufacturer or distributor to express interest. This can also be a useful tool for the CICR to emphasize how expensive the initial investment is without government subsidies.

Fill in blue cells			12 Meter Bus	Taxi	Smaller Bus for City (Currently not Legally Applicable)		Lvl 1 Charging Station	Lvl 2 Charging Station	Fast Charging Station	
	Number		200	75	50		175	20	4	
	Cost Per ($USD)		200000	33000	150000		0	12500	75000	Depends on kW output, manufacturer
	Battery Capacity (kWh)		32	25	28			(~$10,000)	(~$60,000)	
	Night Electricity Tariff (colones / kWh)	120				Kw Output	4	20	75	
	Peak Electricity Tariff (colones / kWh)	150								
	Electricity Tariff Fast Charging (colones / kWh)	200								
	Time to Charge									
		Lvl 1	8	6.25	7					
		Lvl 2	1.6	1.25	1.4	Colones to USD:	0.0016			
		Lvl 3	0.4266666667	0.3333333333	0.3733333333	Days in Operation:	220			
Per Vehicle	Cost to Full Charge Overnight ($USD)		6.144	4.8	5.376					
	Cost to Full Charge Daytime ($USD)		7.68	6	6.72					
	Cost to Fast Charge ($USD)		10.24	8	8.96					
	Cost to Charge Per Hour ($USD)									
		Lvl 1	0.768	0.768	0.768					
		Lvl 2	3.84	3.84	3.84					
		Lvl 3	24	24	24					
	Range (km)		275	220	220					
	Range Increase per Hour Charging (km)									
		Lvl 1	34.375	35.2	31.42857143					
		Lvl 2	171.875	176	157.1428571					
		Lvl 3	644.53125	660	589.2857143					
	Intended Range Per Day (km)		200	250	200					
	# Charges Per Day		0	1	0					
	Cost to Charge per Day Operating									
	(One or the other)	Lvl 2	0	4.8	0					
	(One or the other)	Lvl 3	0	8	0					
Fleet	Operational Cost ($USD/Day)									
	Nightly Charging	Lvl 1	1228.8	360	268.8					
	(One or the other)	Lvl 2	0	360	0					
	(One or the other)	Lvl 3	0	600	0					
	Operational Cost ($USD/Year)		270336	290400	59136					
	Initial Investment ($USD)	50525000								

Table 26. Deliverable 6: Public Transport Company Investment

Freight Transport Company Investment

This sheet allows a freight transport company to input desired amounts of electric vehicles and charging stations, along with prices, and receive charging costs and an initial investment estimate. This chart could be used in conjunction with the Freight Transport EVs list to compare the costs of different options, although prices are difficult to come by without contacting a manufacturer or distributor to express interest. This can also be a useful tool for the CICR to emphasize how expensive the initial investment is without government subsidies.

Fill in blue cells			Small	Medium	Heavy / Trailer		Lvl 1 Charging Station	Lvl 2 Charging Station	Fast Charging Station	
	Number		200	75	50		175	20	4	
	Cost Per ($USD)		200000	300000	500000		0	12500	75000	Depends on kW output, manufacturer
	Battery Capacity (kWh)		32	25	28			(~$10,000)	(~$60,000)	
	Night Electricity Tariff (colones / kWh)	120				Kw Output	4	20	75	
	Peak Electricity Tariff (colones / kWh)	150								
	Electricity Tariff Fast Charging (colones / kWh)	200								
	Time to Charge									
		Lvl 1	8	6.25	7					
		Lvl 2	1.6	1.25	1.4	Colones to USD:	0.0016			
		Lvl 3	0.4266666667	0.3333333333	0.3733333333	Days in Operation:	220			
Per Vehicle	Cost to Full Charge Overnight ($USD)		6.144	4.8	5.376					
	Cost to Full Charge Daytime ($USD)		7.68	6	6.72					
	Cost to Fast Charge ($USD)		10.24	8	8.96					
	Cost to Charge Per Hour ($USD)									
		Lvl 1	0.768	0.768	0.768					
		Lvl 2	3.84	3.84	3.84					
		Lvl 3	24	24	24					
	Range (km)		275	220	220					
	Range Increase per Hour Charging (km)									
		Lvl 1	34.375	35.2	31.42857143					
		Lvl 2	171.875	176	157.1428571					
		Lvl 3	644.53125	660	589.2857143					
	Intended Range Per Day (km)		200	250	200					
	# Charges Per Day		0	1	0					
	Cost to Charge per Day Operating									
	(One or the other)	Lvl 2	0	4.8	0					
	(One or the other)	Lvl 3	0	8	0					
Fleet	Operational Cost ($USD/Day)									
	Nightly Charging	Lvl 1	1228.8	360	268.8					
	(One or the other)	Lvl 2	0	360	0					
	(One or the other)	Lvl 3	0	600	0					
	Operational Cost ($USD/Year)		270336	290400	59136					
	Initial Investment ($USD)	88050000								

Table 27. Deliverable 7: Freight Transport Company Investment

Transport Company Return

This sheet allows a transport company to input variables in order to see how many years it would take for the savings on fuel and maintenance due to using electric vehicles instead of their current fleet to equal the initial investment spent on the electric vehicles and charging infrastructure.

Fill in blue cells			
EV Fleet	Initial Investment ($USD)		Reference Applicable EV List Sheet and Charging Stations Sheet if unsure of prices
	Size of EV Fleet (# vehicles)		
	Average cost to charge overnight per vehicle		Reference Charging Stations Sheet
	Average cost to charge daytime per vehicle		Reference Charging Stations Sheet
Fossil Fleet	Determine Previous Cost per Day	0	
	Intended distance per day (km)		
	Price of Fuel (gas or diesel)		Estimate $3.99 per gallon for gas, $3.69 per gallon for diesel if unsure
	Insert old annual maintenance price per vehicle		
	Insert Frequency of Maintenance per vehicle per year		
	Number of old Fleet		
	Cost of Fleet Maintenance per Year	0	
	Cost per Year	0	
EV Fleet	Estimated Cost of Maintenance per vehicle per year		
	Estimated Cost of Fleet Maintenance per year	0	
	Estimated Cost per Year	0	
Return	Difference per Day	0	
	Workdays per Year		
	Difference per Year	0	
	Flipping Point	#DIV/0!	Years

Table 28. Deliverable 8: Transport Company Return

Company Investment Guide

This sheet is our group's proposed tool to fulfill Recommendation 7. This sheet allows companies to input variables in order to see the optimal combination of fast and semi fast charging stations they could invest in to meet their demand while making the smallest investment. This sheet could be used in conjunction with the Charging Stations calculator and the Public / Taxi EVs list in order to compare the worth of a more expensive electric vehicle with a greater battery capacity, or just to see an estimated initial investment price for a charging infrastructure. The sheet first has the company input information about electric company cars and employees' electric vehicles, including amounts of vehicles, battery capacity, range, expected travel distance per day / commute, and time to charge using fast and Level 2 chargers.

Fill in blue boxes	# Level 2 Charging Stations:	0	Cost ($USD):	240000						
	# Fast Chargers:	4								
	# Company EVs:									
	EV Type / Instance 1 (vehicle make, model):		EV Type / Instance 2 (vehicle make, model):		EV Type / Instance 3 (vehicle make, model):					
	# of this type of vehicle:	25	# of this type of vehicle:	15	# of this type of vehicle:	5				
Reference Public/Taxi EV Sheet if unsure	Range of vehicle (km):	200	Range of vehicle (km):	200	Range of vehicle (km):	50				
	Battery capacity (kWh):		Battery capacity (kWh):		Battery capacity (kWh):					
Use Charging Stations Sheet Calculator if unsure	Time to charge (Lvl 2) (hours):	8	Time to charge (Lvl 2) (hours):	6	Time to charge (Lvl 2) (hours):	3				
	Cost to Full Charge (Lvl 2 Peak) ($USD):		Cost to Full Charge (Lvl 2 Peak) ($USD):		Cost to Full Charge (Lvl 2 Peak) ($USD):					
	Cost to Full Charge (Lvl 2 Valley) ($USD):		Cost to Full Charge (Lvl 2 Valley) ($USD):		Cost to Full Charge (Lvl 2 Valley) ($USD):					
	Cost to Charge per Hour (Lvl 2 Peak) ($USD):		Cost to Charge per Hour (Lvl 2 Peak) ($USD):		Cost to Charge per Hour (Lvl 2 Peak) ($USD):					
	Cost to Charge per Hour (Lvl 2 Valley) ($USD):		Cost to Charge per Hour (Lvl 2 Valley) ($USD):		Cost to Charge per Hour (Lvl 2 Valley) ($USD):					
	Time to Fast Charge (hours):	1	Time to Fast Charge (hours):	0.5	Time to Fast Charge (hours):	0.45				
	Cost to Fast Charge ($USD):		Cost to Fast Charge ($USD):		Cost to Fast Charge ($USD):					
	Expected range per day (km):	250	Expected range per day (km):	150	Expected range per day (km):	75				
	Requires daytime charge?	YES	Requires daytime charge?	NO	Requires daytime charge?	YES				
	# Employee EVs:									
	EV Type / Instance 1 (vehicle make, model):		EV Type / Instance 2 (vehicle make, model):		EV Type / Instance 3 (vehicle make, model):		EV Type / Instance 4 (vehicle make, model):		EV Type / Instance 5 (vehicle make, model):	
	# of this type of vehicle:	7	# of this type of vehicle:	2	# of this type of vehicle:		# of this type of vehicle:		# of this type of vehicle:	
Reference Public/Taxi EV Sheet if unsure	Range of vehicle (km):	80	Range of vehicle (km):	75	Range of vehicle (km):	60	Range of vehicle (km):	60	Range of vehicle (km):	60
	Battery capacity (kWh):		Battery capacity (kWh):		Battery capacity (kWh):		Battery capacity (kWh):		Battery capacity (kWh):	
Use Charging Stations Sheet Calculator if unsure	Time to charge (Lvl 2) (hours):	5.5	Time to charge (Lvl 2) (hours):	6.5	Time to charge (Lvl 2) (hours):		Time to charge (Lvl 2) (hours):		Time to charge (Lvl 2) (hours):	
	Cost to Full Charge (Lvl 2 Peak) ($USD):		Cost to Full Charge (Lvl 2 Peak) ($USD):		Cost to Full Charge (Lvl 2 Peak) ($USD):		Cost to Full Charge (Lvl 2 Peak) ($USD):		Cost to Full Charge (Lvl 2 Peak) ($USD):	
	Cost to Full Charge (Lvl 2 Valley) ($USD):		Cost to Full Charge (Lvl 2 Valley) ($USD):		Cost to Full Charge (Lvl 2 Valley) ($USD):		Cost to Full Charge (Lvl 2 Valley) ($USD):		Cost to Full Charge (Lvl 2 Valley) ($USD):	
	Cost to Charge per Hour (Lvl 2 Peak) ($USD):		Cost to Charge per Hour (Lvl 2 Peak) ($USD):		Cost to Charge per Hour (Lvl 2 Peak) ($USD):		Cost to Charge per Hour (Lvl 2 Peak) ($USD):		Cost to Charge per Hour (Lvl 2 Peak) ($USD):	
	Cost to Charge per Hour (Lvl 2 Valley) ($USD):		Cost to Charge per Hour (Lvl 2 Valley) ($USD):		Cost to Charge per Hour (Lvl 2 Valley) ($USD):		Cost to Charge per Hour (Lvl 2 Valley) ($USD):		Cost to Charge per Hour (Lvl 2 Valley) ($USD):	
	Time to Fast Charge (hours):	0.65	Time to Fast Charge (hours):	0.5	Time to Fast Charge (hours):		Time to Fast Charge (hours):		Time to Fast Charge (hours):	
	Cost to Fast Charge ($USD):		Cost to Fast Charge ($USD):		Cost to Fast Charge ($USD):		Cost to Fast Charge ($USD):		Cost to Fast Charge ($USD):	
	Employee's Commute Both Ways (km):	100	Employee's Commute Both Ways (km):	60	Employee's Commute Both Ways (km):		Employee's Commute Both Ways (km):		Employee's Commute Both Ways (km):	
	Requires daytime charge?	YES	Requires daytime charge?	NO	Requires daytime charge?	NO	Requires daytime charge?	NO	Requires daytime charge?	NO

Table 29. Deliverable 10: Company Investment Guide

The sheet then calculates the number of vehicles that would be charging during the day based on tallying up whenever a vehicle's expected daily travel distance is greater than its range. This number is then used with the average time to charge of all the vehicles in consideration using a Level 2 charger to determine how many hours per day would be required if every vehicle needing to charge would charge with a Level 2 charger. The same is done for a fast charger. The sheet then divides these values by the amount of time in the work day, eight hours, to return the max number of Level 2 chargers needed and the max number of Fast chargers needed. What these numbers mean is if a company wanted to install only one or the other, these two numbers are how many they would need of either to meet their demand in an eight hour work day. The sheet then calculates the initial investment price of these two numbers. The sheet then calculates an equivalency value between a fast charger and a Level 2 charger, essentially how many vehicles a fast charger can charge in the time a Level 2 charger takes to charge one, on average. The sheet uses this value to come up with other options for the company in between investing in either all fast chargers or all Level 2 chargers. The sheet picks out the option with the cheapest initial investment and displays the numbers at the top, in cells C1, C2 and E1.

Table 30. Deliverable 10: Company Investment Guide

	# Vehicles Requiring Daytime Charge:	37	Daytime Charging Requirements	25	Hours daytime charging Lvl 2	200	Hours daytime Fast charging	25
				0		0		0
(Estimate $10,000 if unsure)	Cost Lvl 2 Charger ($USD):	10000		5		15		2.25
(Estimate $60,000 if unsure)	Cost Fast Charger ($USD):	60000		7		38.5		4.55
				8		0		0
Initial Investment	Price Point 1: Only Fast Chargers ($USD)	240000		8		0		0
		4	Fast Chargers	8		0		0
		0	Lvl 2 Chargers	8		0		0
	Price Point 2	260000			Work day Quick Check	0		
		3	Fast Chargers					
		8	Lvl 2 Chargers		Average Lvl 2 Charge Time	6.851351351	Average Fast Charge Time	0.8594594595
	Price Point 3	280000						
		2	Fast Chargers		Max # of Needed Lvl 2 Chargers	32	Max # of Needed Fast Chargers	4
		16	Lvl 2 Chargers					
	Price Point 4	300000			Cost of Max # Lvl 2 Chargers	320000	Cost of Max # Fast Chargers	240000
		1	Fast Chargers					
		24	Lvl 2 Chargers		Fast Charger Efficiency (Max # Lvl2 / Max # Fast)	8		
	Price Point 5	320000						
		0	Fast Chargers		Minimum Price Point:	240000		
		32	Lvl 2 Chargers			4	Fast Chargers	
	Price Point 6	N/A				0	Lvl 2 Chargers	
		-1	Fast Chargers					
		40	Lvl 2 Chargers					