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Columbus Yellow Cab Fleet Electrification

The Zofnass Program at Harvard University
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Judith Rodriguez prepared this case study under the supervision of Prof. S.N. Pollalis, Director of the Zofnass Program for Sustainable Infrastructure, as the basis for research and class discussion rather than to illustrate either effective or ineffective handling of the design, the construction, or an administrative situation. Cases are not intended to serve as endorsements, sources of primary data, or illustrations of effective or ineffective project design or implementation.

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Summary

The case study focuses on the electrification of the 200 vehicles of the Columbus Yellow Cab (CYC) taxi fleet. CYC has operated in Columbus, Ohio, as a taxi service since 1928, as well as a Transportation Network Company (TNC) as defined by Ohio House Bill 237. CYC wants to offer an electric alternative to the internal combustion engine vehicles in their fleet. Their first foray into electric vehicles was a Tesla Model S85 acquired in 2016 and run for 65,000 miles.

The scope of this case study is the planning and implementation of the first 10 new electric vehicles (EVs) and 8 mobile solar charging units with 16 Level-2 ports (240 volts), introduced in 2018. The use of 3 existing permanent grid-powered Level-2 charging ports also supports the electrification program. The implementation of the Fleet Electrification project will contribute to emissions reductions in the city of Columbus, and is aligned with the goals of the city's Smart Columbus Electrification Project.

The case study aims to contribute to the understanding of the variables affecting the business case for electrifying the CYC fleet, through the identification of barriers (such as risks, availability of charging, customization), CYC strategy (vehicle selection, test-as-we-go methodology, staggered approach), implementation considerations, and best practices. As part of the CYC strategy, the following main sustainability features are discussed: use of EVs in taxi fleets; solar charging; partnerships (space, charging); decentralized taxi model; keyless entry and reservation app for drivers; app for customers to summon a taxi; car washing with limited water and organic waste.

The sustainability performance of the project was analyzed using the Envision® rating system checklist, which indicated a high performance in Leadership (89% of the credits in the checklist receiving "Yes" responses), Resource Allocation (69% Yes), Quality of Life (38% Yes), and Climate and Risk (36% Yes). The results indicated achievements in improving Columbus' quality of life and mobility, increased safety, effective use of leadership and strategic collaboration, use of renewable energy, optimizing of water savings, and significant reductions in fuel use, greenhouse gas emissions, and air pollutant emissions with zero-emissions vehicles.

The economic performance indicates the importance of incentives and partnerships at the beginning of the project. About $157,000 was saved in sustainability-related incentives and tax credits available for purchasing EVs, and through the creation of a strategic partnership that avoided 16 Level-2 plug installations and leasing costs on the solar charging units.

Project data

Project name	**Columbus Yellow Cab Fleet Electrification**
Sustainability-related savings	$ 105,000 (savings from incentives and tax credits) $ 52,000 (avoided costs from 16 Level-2 chargers and power upgrades) ______________ $157,000 (total savings including avoided costs)
Project type	Transportation: Electric vehicles and solar charging stations
Location	Columbus, Ohio
Area / length / coverage	544 mi² in Franklin County, Ohio
Capacity	10 EVs in 2018, up to 200 in next few years 16 Level-2 solar-powered chargers (mobile units) 3 Level-2 grid-powered chargers
Owner	Columbus Yellow Cab
Project team	Fleet manager, implementer, operator: Morgan Kauffman, CEO/Owner, Columbus Yellow Cab
	Advisor: Katherine Ott Zehnder, VP, HNTB
Project lifespan	Planning (Oct 2017–June 2018) Implementation (car purchase, training, charging unit delivery, etc.)(10 weeks) Operations and maintenance (August 2018 onward)
Current status	Operations and maintenance
Funding model	$3,000 per vehicle incentive from Smart Columbus Program funded by Paul G. Allen Philanthropies Privately funded by Kauffman4Share Holdings Possible funding for future project phases from EPA, Electrify America, and American Electric Power [1]
Overall investment cost	$294,950 for purchase of vehicles
Planning costs	Travel and education: $25,000 CYC time (work hours): $200,000 Support and oversight: $80,000 _______ Total planning costs: $305,000

[1] Katherine Ott Zehnder, VP at HNTB, and Morgan Kauffman, CEO/Owner of CYC, interviews with CYC project team during case study development in 2018.

Abbreviations

BEV	Battery electric vehicle
BCI	Bureau of Criminal Investigation
CYC	Columbus Yellow Cab
EV	Electric vehicle
GHG	Greenhouse gas
ICE	Internal combustion engine
PfMP	Performance Measurement Plan
PGAP	Paul G. Allen Philanthropies
SCEP	Smart Columbus Electrification Project
TSP	Transportation Service Provider
USDOT	United States Department of Transportation
VMT	Vehicle miles traveled

1. Introduction

The Columbus Yellow Cab (CYC) Fleet Electrification project consists of the planning, purchase, and operation of 10 new 2018 Chevrolet Bolt electric vehicles (EVs), along with 8 Solar Eclipse SCT20 charging units providing 16 Level-2 ports, introduced to their taxi fleet in 2018. EVs are used as an alternative to internal combustion engine (ICE) vehicles powered by gasoline that produce polluting greenhouse gas emissions, increase the carbon footprint and fuel consumption of the city, and have higher associated costs related to the maintenance of moving parts and motor efficiency. CYC fleet electrification is improving the sustainability of transportation in Columbus:

> "*We [CYC] have been around for a long time and we've been doing a lot of the polluting for the last 90 years in Columbus. We need to step up and become a pioneer to do it a better way and something that can work into Smart Columbus' playbook. Because if it works in Columbus, there is a good chance it can work in other places as well*."[2]

The main drivers of CYC fleet electrification are lower initial costs through incentives and partnerships, as well as the environmental benefits of reducing the total greenhouse gas (GHG) emissions. The CYC fleet electrification is aligned with the overarching priorities of the Smart Columbus Electrification Plan, listed in table 1, which are aimed at fighting climate change through reducing greenhouse gas emissions.[3] In this context, incentives were available such as the Smart Columbus EV rebates for transportation network companies and federal tax credits, and CYC had an opportunity to create partnerships with key stakeholders. Project stakeholders include DC Solar, HNTB, and the City of Columbus. In addition, the team engaged with the Paul G. Allen Philanthropies (PGAP) Grant's Smart

[2] Morgan Kauffman, CEO/Owner of CYC, transcript from presentation "Columbus Yellow Cab Electrification" at Zofnass Program Workshop, November 12-13, 2018.
[3] Smart Columbus, *Our Path to the Future*, accessed in 2018, https://smart.columbus.gov/projects/

Columbus team, and with several private automotive, technology, and electric vehicle industry companies, and they attended various EV-focused global events.

A major focus of the project planning was the vehicle selection process, which included research, extended test-drives, visits to other companies, and discussions with many in the industry. Due to the rapidly changing EV technology, the project team introduced a test-as-we-go methodology in terms of vehicle purchasing. The team plans to stagger the electrification of the fleet, adding more advanced and efficient models as they become available in the market.

The project timeline ran on multiple paths and has been flexible, as it needed to account for the low availability and slow delivery of EVs and solar charging stations. The delivery of the first 10 EVs was scheduled for June 2018, because the charging stations were estimated to arrive at the end of June. The charging stations arrived in August. The vehicle preparation, which included installing keyless entry and dispatch communication, started on June 11, 2018. CYC created Taxi University, a class to train drivers in EV operation and charging, which was conducted in June and July 2018. Three vehicles were deployed in July, charging at the two existing Level-2 chargers. The remaining 7 vehicles were put in service in August 2018.

Planned future efforts include full conversion of their 200-vehicle fleet; incorporating car top signs for advertising to offset the EV cost; acquiring land to park vehicles at decentralized sites – preferably at sites classified as grayfields or brownfields with good transit access.

> "*At Yellow Cab, we provide more than a ride – we support and connect our employees, customers and community through a commitment to promoting humanity in the way we work and do business*."[4]

CYC has operated taxis in Columbus since 1928. CYC was founded by the Kauffman family and remains a locally owned company, now operated by the family's third generation. CYC has developed a start-up mindset that allows them to take calculated risks that have kept the company profitable and relevant in a rapidly changing industry. They push the boundaries of technology within their framework of customer-first thinking and empowerment, where customers are the passengers but also the drivers and co-workers. Effectively, this project started in 2016 with the addition of a Tesla S85 to their fleet. At the time there was contradictory information about the electric vehicle market, and CYC decided to test whether having EVs as an alternative to ICE vehicles was operationally and financially feasible. Although the test was considered a failure due to the excessive stem miles[5] necessary for charging, the CYC customers liked the Tesla, which reached the 235-mile published range.[6] Ohio's annual temperature fluctuation affected the Tesla's performance by about 20%. The time required to charge the vehicle was relatively long for a vehicle that should be on the road as many hours as possible. 60% of the 65,000 miles put on the Tesla in a year were stem miles. A year after the test, CYC removed it from their fleet. For CYC business to

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4 Morgan Kauffman, CEO/Owner of CYC, transcript from presentation "Columbus Yellow Cab Electrification" at Zofnass Program Workshop, November 12-13, 2018.

5 Stem miles, in this case, are the miles a taxi needs to drive to its coverage route area or to the charging spot. They lead to downtime and result in lost revenue.

6 Katherine Ott Zehnder, VP at HNTB, and Morgan Kauffman, CEO/Owner of CYC, interviews with CYC project team during case study development in 2018.

depend on EVs, the stem mile challenge needed to be addressed.

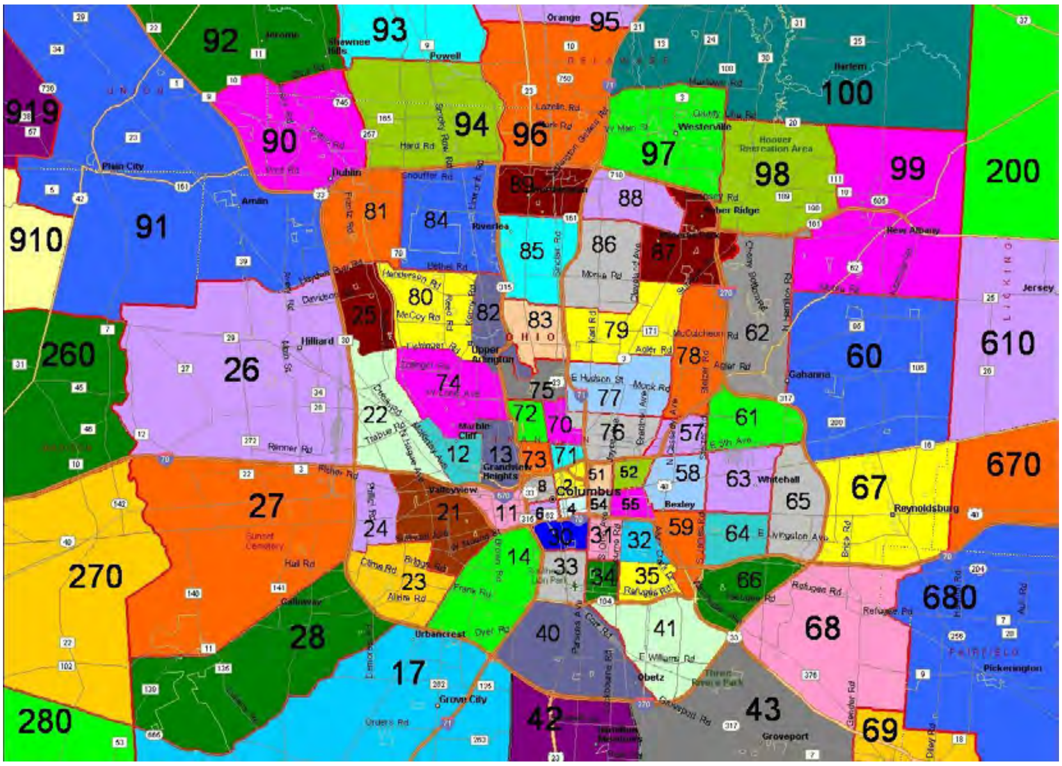

Figure 1. Map of the CYC zoning system and coverage in the greater Columbus area. Each colored block represents a taxi-managing area. The zoning system map has been created by CYC to distribute trips to drivers. The map works with the density of the city, as the smaller areas are more dense. Source: CYC, 2018.

2. Smart Columbus Electrification Project: the fleet electrification context

The private fleet vehicle adoption numbers obtained by CYC as part of their Fleet Electrification project contribute to the performance targets set in the city's Smart Columbus Electrification Project (SCEP). SCEP is an initiative supported by a $10 million grant from Paul G. Allen Philanthropies (PGAP) to change the trajectory of carbon emissions in the 7-county Columbus[7] region (counties of Franklin, Delaware, Fairfield, Licking, Pickaway, Madison, Union) and demonstrate the rewards of using clean energy sources in lieu of fossil fuel-based sources.[8] It started when the City of Columbus pursued and won the grant from PGAP.

The overall goal of SCEP is to measurably decrease light-duty transportation greenhouse gas (GHG) emissions expressed in equivalent metric tons of carbon dioxide (MTeCO2) as a result of grid decarbonization, EV fleet adoption, transit, autonomous and multimodal systems (implemented via USDOT grant agreement), and consumer EV adoption during the

7 Any mention of Columbus in this case includes the entire 7-county region.
8 City of Columbus, Smart Columbus Electrification Project (SCEP).

grant period compared to a baseline year (2016).[9] SCEP also addresses how the city will spend the grant money to meet its five priorities, and through which initiatives and working groups.

SCEP Priorities

Priority 1: Decarbonization
In partnership with power providers, by 2030 install 905 MW of utility scale renewable energy generation capable of serving the Columbus region, procure a minimum of 1.2 million MWh of renewable energy for the City of Columbus between 2017 and 2022 and save 480 GWh consumed through energy efficiency and smart grid programs during the time period of the grant.

Priority 2: Fleet EV Adoption
Work with public, private and academic sectors to place in operation 790 electric vehicles into their fleets by the end of the grant period.

Priority 3: Transit, Autonomous and Multi-Modal Systems in the City
Ensure a comprehensive, multi-modal approach to decarbonizing the Columbus region's mobility options.

Priority 4: Consumer EV Adoption
Increase electric vehicle market adoption as evidenced by the percentage of light duty electric vehicle registrations in Columbus and the surrounding seven county region attaining 1.8% of all new and used light duty vehicle registrations by the end of the three year grant period, representing a 486% increase from 2015 baseline of 0.37%.

Priority 5: Charging Infrastructure
Support the acceleration of electric vehicle adoption through installation of charging infrastructure, with the goal of 925 new charging ports by the end of the grant period.

Table 1. Priorities of the Smart Columbus Electrification Project. Source: City of Columbus, Smart Columbus Electrification Project (SCEP).

9 Ibid.

PRIORITY / WORKING GROUP	INITIATIVE
PRIORITY 1: Decarbonization	**Initiative 1.1:** Utility-Scaled Renewables **Initiative 1.2:** Grid Modernization and Efficiency
PRIORITY 2: Fleet Electric Vehicle Adoption	**Initiative 2.1:** Public Fleets **Initiative 2.2**: Private Fleets **Initiative 2.3:** Transportation Service Providers (TSPs)
PRIORITY 3: Transit, Autonomous and Multi-Modal Systems in the City	Initiatives are covered under the Smart Columbus USDOT and other City of Columbus programs. Coordination with Priority 5 will occur through the end of the grant period.
PRIORITY 4: Consumer Electric Vehicle Adoption	**Initiative 4.1:** Research and Assessment **Initiative 4.2:** Increase Consumer Awareness for EVs **Initiative 4.3:** Drive Consumer Consideration for EVs **Initiative 4.4:** Improving Customer Sales Experience of EVs
PRIORITY 5: Charging Infrastructure	**Initiative 5.1:** Residential Charging **Initiative 5.2**: Public Access Charging **Initiative 5.3:** Workplace Charging **Initiative 5.4:** Fleet Charging **Initiative 5.5:** Building and Zoning changes to support electric vehicle charging

Table 2. Smart Columbus Electrification Initiatives and Working Groups. Source: City of Columbus, Smart Columbus Electrification Project (SCEP).

The CYC Fleet Electrification project falls under Priority 2, Initiative 2.3: Transportation Service Providers (TSPs), the objective of which is to work with TSPs to place in operation electric vehicles in their fleets by the end of the grant period.[10] TSPs include traditional taxi services, transportation network companies, car sharing, ride sharing, traditional transit agencies, private limo services, and others.

A Performance Measurement Plan (PfMP) was developed to support the five priorities of SCEP and their related initiatives. The PfMP provides traceability, verification, and responsibility for the targeted goals that support the implementation of the SCEP initiatives.[11] The PfMP has set the following indicators for SCEP: (1) percentage of greenhouse gas (GHG) emission reductions from the baseline year, and (2) total GHG reductions/savings from the baseline year in metric tons of carbon dioxide (MTCO2).

The objective of Priority 2 is to work with public, private, and academic sectors to integrate a minimum of 780 electric vehicles into the city fleets by the end of 2019 (300 in the public fleets, 450 in private fleets, 30 in transportation network companies). The PfMP indicators for Priority 2, Initiative 2.3 are the number of battery electric vehicles (BEVs) purchased, and the number of BEVs placed in operation by TSPs. GHG reductions associated with each BEV

10 Ibid.

11 City of Columbus, Smart Columbus Electrification Program Performance Measurement Plan (PfMP).

that replaces an ICE vehicle are calculated and included in the overall GHG savings for the program.

3. CYC strategy

The Fleet Electrification project is fully funded by CYC. Implementation drivers include to stop polluting, be technological change leaders, save money and capital expenses, and available help and incentives for the upfront costs. The costs of the EVs and the solar charging stations constitute the main project elements and the most expensive ones. The initial purchase costs are higher but EV maintenance costs are lower, and there is help from the Smart Columbus grant rebates and tax incentives.

> "*Having sustainability incentives and tax credits of more than $10,000 per car was necessary for the implementation of the first phase of the project.*" [12]

In terms of avoided upfront costs, the largest impact comes from having in-kind access to solar chargers and getting renewable energy that is free of cost. In total, savings and avoided costs are estimated at $157,000. In addition to the avoided upfront costs, there are other factors that help to drive the project, including millennial generation-driven externalities, such as preferring car sharing and environmental friendly cars; technology-driven externalities, such as EVs requiring less maintenance; and emissions reduction inherent to EVs and enhanced by charging with solar energy.

The CYC strategy included research, driving vehicles, talking to people, and visiting other taxi companies. During the research period, the project team went to various EV showcase events such as the EVS30 Electrification Symposium in Germany, the Dutch Smart E-Mobility Tour of the Netherlands, and the CES-Consumer Electronic Show in Las Vegas. The team also met with OpenFleet (app developers) and with TEO Taxi, a 100% electric taxi fleet in Montreal, Canada. In contrast to the US, the Canadian government funds taxi companies. For example, TEO Taxi began 3 years ago as a startup partially funded by the government.

Part of CYC's strategy is planning for the fleet electrification to be staggered, starting with 10 EVs in 2018 and adding more vehicles up to the 200-vehicle goal, which is 100% of the taxi fleet. The gradual swapping of ICE vehicles with EVs is intended to avoid having every vehicle retire at the same time. This staggered approach also helps the project team to account for changes in the technology and the risk of having outdated EVs, and prevented to overinvest upfront. (For instance, new EVs now have a 300-mile range, whereas CYC's first Tesla had only a 235-mile range.)

a. Use of EVs in taxi fleets

The key sustainability feature of the project is the implementation of EVs in the CYC taxi fleet. The use of EVs helps to minimize emissions and consumption of fossil fuel in

[12] Morgan Kauffman, CEO/Owner of CYC, interviews with CYC project team during case study development in 2018.

Columbus. While typical internal combustion engines (ICEs) have more than 2,000 parts, an EV requires less maintenance, as there are only about 20 parts in total.[13]

> "*Vehicle selection is based on battery size and approximate driving miles available on a single charge. This is an aspect that continues to improve with technology upgrades in newer EV models*." [14]

The most important criterion for EV selection was range. Vehicle-for-hire criteria such as backseat access and trunk space were also important. After these were determined to be satisfactory, the price was evaluated.

> "*Availability of vehicles in US or in production is key in the implementation of the project*."[15]

Having US-made vehicles also weighed in their decision. The following five vehicle models were seriously considered for purchase: BYD E6, Nissan Leaf, Tesla model 3, Chevrolet Bolt (purchased), and the Mercedes Smart Car (4-door version, not yet available in the US).

BEV Make and Model	**Year**	**Time to charge (hours at 240v)**	**Battery size (kWh)**	**Driving range (miles)**	**Passenger volume (ft^3)**	**MSRP[16] in U.S. dollars**	**Availability in USA (2018)**	**Manufacture location**
BYD E6	2018	5	91[17]	187	88	46135[18]	No	China
Nissan Leaf	2018	8	40	151	92	21,625	Yes	USA
Tesla model 3	2018	10	80.5	310	97	49,000	Yes	USA
Chevrolet Bolt	2018	9.3	60	238	94	37,495	Yes	USA
Mercedes Smart EQ (4-door)	2018	<6	17.6	148		25,415[19]	No	Germany

Table 3. BEV by selection criterion. Source: US Department of Energy, Find and Compare Cars, accessed in April 2019, https://www.fueleconomy.gov, and Smart UK, Technical data,

[13] Morgan Kauffman, CEO/Owner of CYC, interviews with CYC project team during case study development in 2018, and CNBC, 'Electric vehicles will soon be cheaper than regular cars because maintenance costs are lower, says Tony Seba', accessed in April 2019, https://www.cnbc.com/2016/06/14/electric-vehicles-will-soon-be-cheaper-than-regular-cars-because-maintenance-costs-are-lower-says-tony-seba.html

[14] Katherine Ott Zehnder, VP at HNTB, and Morgan Kauffman, CEO/Owner of CYC, interviews with CYC project team during case study development in 2018.

[15] Morgan Kauffman, CEO/Owner of CYC, interviews with CYC project team during case study development in 2018.

[16] Manufacturer Suggested Retail Price.

[17] WattEV2buy, BYD e6, https://wattev2buy.com/electric-vehicles/byd-electric-vehicles/byd-e6-ev/

[18] Currency conversion from 309800 Yuan to USD, accessed in April 2019, https://www.xe.com/currencyconverter/convert/?Amount=309%2C800&From=CNY&To=USD

[19] Price from Smart EQ for four, https://www.smart.com/content/dam/smart/DE/PDF/smart_EQ_PL_RZ_WEB_2019.pdf
Currency conversion from 22,600 Euros to USD, accessed in April 2019, https://www.xe.com/currencyconverter/convert/?Amount=22%2C600&From=EUR&To=USD

accessed in April 2019, https://www.smart.com/en/en/index/smart-eq-forfour-453/technical-data.html#engine2

Figure 2. 2018 Chevrolet Bolt EVs at CYC. Source: CYC, 2018.

The team's strategic approach to EV purchase is a test-as-we-go methodology, in which more advanced and efficient models can be introduced into the fleet as they become available in the market. For the purchase of the first 10 electric vehicles, the project team went for new 2018 Chevrolet Bolt EVs. The base price for each vehicle is $37,495 with destination freight charge (DFC) and before benefits of federal or state tax incentives.[20] The 2018 Bolt EV is considered a small wagon from the EPA vehicle class with an estimated 238-mile driving efficiency range. The drive system consists of a single high-capacity electric motor with 200 hp that can go from 0 to 60 mph in 6.5 seconds. The electric system has a high-capacity 60 kWh lithium ion battery pack that lies flat, spanning the length of the vehicle's floor. The battery is one of the fastest charging in the market; it is estimated to charge fully in 9.3 hours or 25 miles per hour of charge on a Level-2 240 V charger, or 4 miles per hour of charge on a Level-1 120 V charger, or 90 miles in 30 minutes of charge through a DC Fast Charging system.[21]

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[20] Chevrolet Product Information, Chevrolet, accessed in August 2018, https://www.chevrolet.com/electric/bolt-ev-electric-car

[21] Ibid.

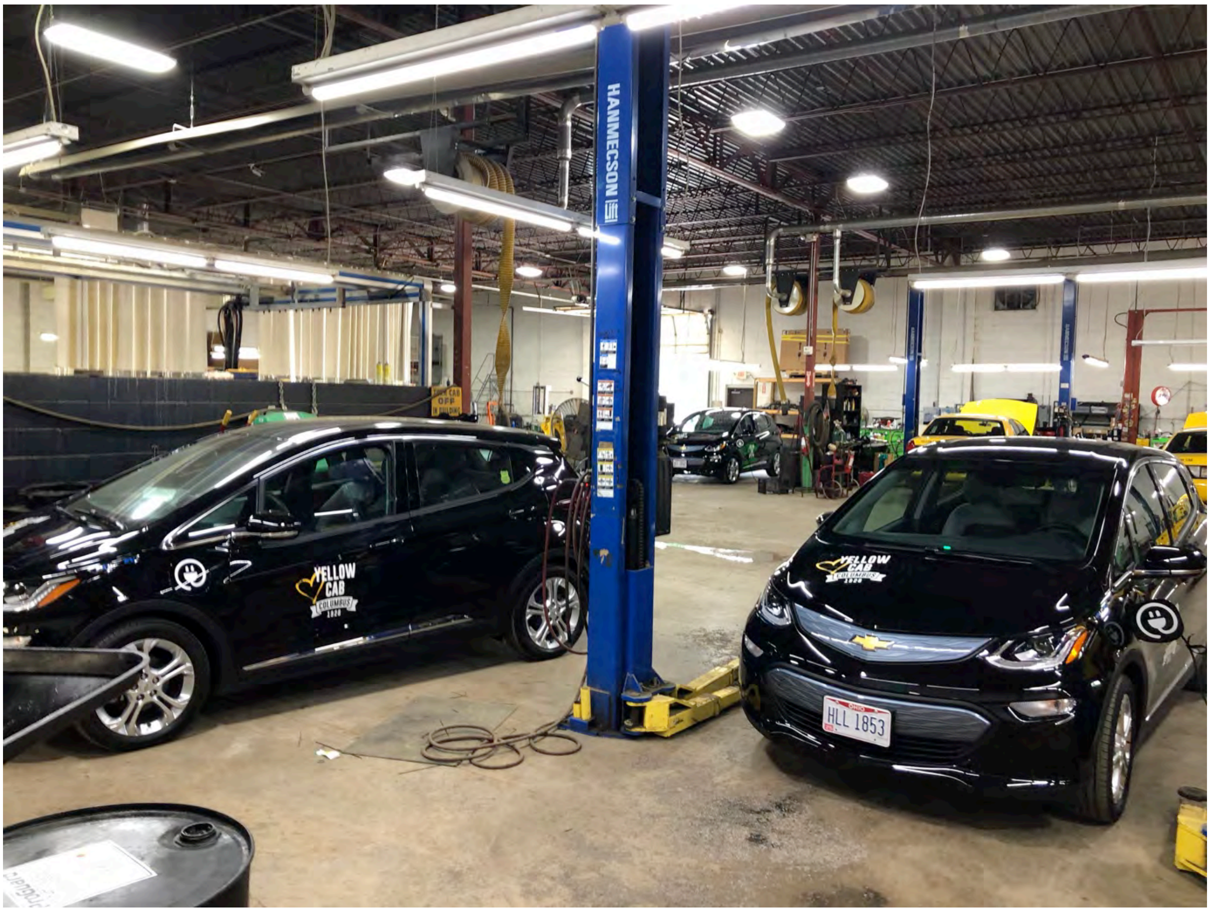

Figure 3. CYC preparation work on 2018 Chevrolet Bolt EVs. Source: CYC, 2018.

Incentives from the City of Columbus helped reduce the cost of each Chevrolet Bolt. The Smart Columbus initiative provides a rebate of $3,000 per car. In addition, there is opportunity to receive a federal tax credit of $7,500 per vehicle. This is a factor in the vehicle purchasing, but there is uncertainty about when the tax credit will phase out. The IRS decides annually whether the $7,500 credit will continue; the tax credit is applicable depending on the year the vehicle is delivered. After these reductions, vehicle cost would be about $26,995 per car, with upfront savings of $10,500 per car and total savings of $105,000 for the 10 initial EVs.

The project has been meeting the Quarter 5 milestone due dates, as the delivery of the EVs was on June 2018 and 3 vehicles have been in operation. CYC also does preparation work on each vehicle that includes installing the keyless entry, dispatch communication system, and GPS in the vehicle. The total initial costs for the project including the purchase and preparation of the EVs was $294,950.

b. Solar charging

Another challenge for the business is not being able to control the price of fuel. Ohio burns a lot of coal to produce electricity. As part of the CYC strategy, solar charging units are introduced in the electrification project. Charging EVs with solar renewable energy helps to reduce the use of fossil fuels in the taxi operations and reduce costs in electricity use. This initiative contributes to the reduction of emissions and consumption of fossil fuel in Columbus.

CYC established a strategic partnership with DC Solar Freedom, a nonprofit entity, in order to have access to solar charging units and further reduce GHG emissions. DC Solar is a California-based clean energy company that specializes in mobile solar technology.[22]

Eight mobile solar charging units will provide 16 Level-2 ports. The units' model is the Solar Eclipse SCT20, which is noise and emissions free, with 2,400 W high-efficiency polycrystalline solar modules, energy storage,[23] 2 Level-2 (240 V) outlets, and 4 Level-1 (120 V) outlets.[24] In terms of delivery, the project team experienced some delay as the units were schedule to arrive in July and arrived in August. This access represents a cost saving of more than $52,000.[25]

CYC will use a combination of solar and level-2 DC fast charging to be able to get more shifts out of the vehicles. The team experimented with operating exclusively on solar charging, but it was not possible to charge all 10 vehicles as fast as they needed using only the solar units.[26] The use of 3 existing grid-powered permanent Level-2 chargers also support the electrification program. DC fast charging Level-2 chargers is being added in early 2019.

Figure 4. Arrival of DC Solar charging units. Source: Katherine Ott Zehnder, 2018.

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22 DC Solar, accessed in August 2018, http://www.dcsolarsolutionsmfg.com/
23 48 volt deep cycle industrial battery.
24 DC Solar, Mobile generators, accessed in August 2018, http://www.dcsolardistribution.com/products/mobile-generators/#solar-eclipse-20k
25 Ibid.
26 Morgan Kauffman, CEO/Owner of CYC, transcript from presentation "Columbus Yellow Cab Electrification" at Zofnass Program Workshop, November 12-13, 2018.

c. Decentralized taxi model

"*The team needed to work in multiple paths because the technology is new. For instance, the keyless entry app is very important as it allows to decentralize the location of EVs, an important lesson learned as the project was unfolding*." [27]

CYC developed a decentralized taxi model that helps drivers save time, which is one of the biggest objectives in order to make the project successful. With the decentralized model, the drivers do not have to spend as much of their time in stem miles. The project team estimates that the driver is able to be 25% more efficient by switching to this new model. Currently there are 3 locations where drivers can pick up the vehicles.

"CYC used to be a centralized business, meaning that drivers needed to drive in their cars to CYC facilities, get in one of CYC cars, go out and work, come back, and then drive back home. Many units of energy, dollars, and time were wasted in that centralized model that was overcome with the simple use of technology." [28]

Once CYC decentralizes their model, they will be able to bring jobs to underdeveloped areas where somebody who can pass an FBI and BCI background check, who may have not graduated from high school but is a safe driver, will be able to work. Furthermore, this driver can help mobilize other people in the community to get out to find jobs, and create jobs within that community.[29]

The project team has also looked with the City of Columbus for small, otherwise-impractical pieces of property, preferably at sites classified as grayfields or brownfields, where CYC can put charging stations and park their vehicles. This may help drivers in the nearby community have a multimodal approach to getting to work. For instance, they can use the city's bus system to get to CYC depots, get in a vehicle, work, then drop the vehicle back off and charge it to be ready for the next driver.

The decentralized model and apps are helping CYC reduce the amount of stem miles significantly, which was one of the biggest challenges encountered by the team when they introduced the Tesla in 2016.

d. Keyless entry and reservation app for drivers

"*There was a lot of work to check out a vehicle. So we [CYC] said, How do we fix that? How do we pull that pinpoint away and make it super easy for a driver to get in a vehicle?"*[30]

[27] Katherine Ott Zehnder, VP at HNTB, interviews with CYC project team during case study development in 2018.
[28] Morgan Kauffman, CEO/Owner of CYC, transcript from presentation “Columbus Yellow Cab Electrification” at Zofnass Program Workshop, November 12-13, 2018.
[29] Ibid.
[30] Ibid.

The keyless entry and reservation app helps streamline the operation of the taxi fleet by reducing the time it takes to enter vehicles, as well as facilitating drivers finding the closest available taxi. The app was developed by OpenFleet and modified for CYC. In addition to the vehicle cost, the keyless entry and dispatch service implementation, which was done at CYC facilities, is calculated at $1,500 per car, which is $15,000 for 10 taxis.

The team worked on an app in which, once drivers are FBI and BCI background-checked and have gone through Taxi University, they can use their smartphones to enter any CYC vehicle. With the app the drivers can see where the cars are and the types of vehicles available; as they approach the vehicle they have reserved, the door opens. The app has improved efficiency and helps CYC to save time and resources, as there is no need to pass out keys or manage money. The drivers can use a credit card to access vehicles and are able to reserve the cars up to a week in advance. If a driver is not bankable, CYC can supply a credit card in order to allow them access to a reservation for a vehicle for the amount of time they would like to work, which can be as little as a few hours.[31]

Through the app a driver can pull out a buffet of all the vehicle options CYC offers. For example, it can be a Ford Crown Victoria, or a Chevy Bolt.

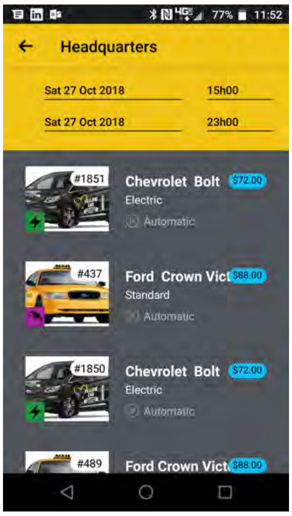


Figure 5. CYC app for drivers featuring keyless entry, by OpenFleet reservation system and modified for CYC. Source: Morgan Kauffman, CEO/Owner of CYC, presentation “Columbus Yellow Cab Electrification” at Zofnass Program Workshop, November 12-13, 2018.

e. App for customers to summon a taxi

Having an app for customers to summon a taxi is another sustainability feature of the project as it helps structure rides according to demand. By using the app CYC saves time optimizing the best route as well as informs the customer that the taxi is an EV.

Through the app the customer can book a taxi in 3 clicks, get a fare estimate by entering both pickup and destination addresses, see vehicle information, receive confirmation and

[31] Morgan Kauffman, CEO/Owner of CYC, transcript from presentation “Columbus Yellow Cab Electrification” at Zofnass Program Workshop, November 12-13, 2018.

notifications once the reservation is dispatched, as well as monitor the progress of the taxi vehicle on a map.

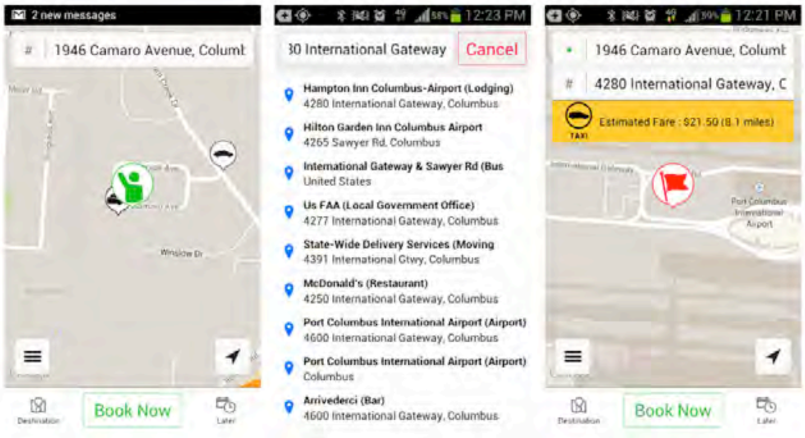
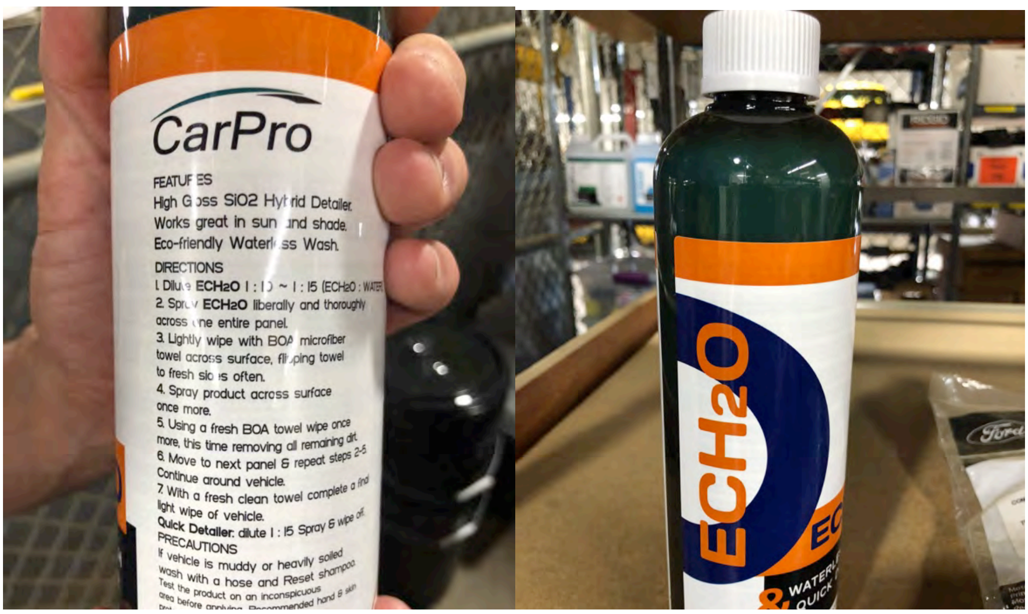


Figure 6. CYC ride hailing app for customers. Source: Google Play Apps, Yellow Cab of Columbus,
https://play.google.com/store/apps/details?id=com.apcurium.MK.YellowCabColumbus

f. Waterless car washing

Consistent with the energy savings, CYC has addressed water conservation in their operations. They experimented with using a water replacement formula for car washing that initially was cost- and time-prohibitive from a labor standpoint. During the development of this case study, using the sustainability criteria from the Envision® rating system, the team assessed the water required when using water to wash vehicles and experimented with other formulas. CYC started to use an eco-friendly formula, CarPro ECH2O, that reduces potable water consumption in operations. This is a good example of how Envision optimizes the sustainability of a project.



Figures 7 - 8. Water replacement formula used to wash vehicles in CYC facilities. Source: CYC, 2018.

4. Sustainability performance: Envision® rating system checklist assessment[32]

The Envision® rating system is applicable to the Fleet Electrification project, illuminating how the introduction of CYC's EV taxis contributes to the overall sustainability of the city of Columbus. Beyond the reduction of GHG emissions, Envision® helps analyze more comprehensively how the Fleet Electrification project contributes to improvements in communities' quality of life, effective leadership strategies, saving limited resources, reducing environmental impact, as well as preparing for climate change. This analysis also helps optimize a project by pinpointing which areas the team can easily improve, and which ones would require more effort and investment.

Envision® measures sustainability through credits organized in five dimensions or categories: Quality of Life, Leadership, Resource Allocation, Natural World, and Climate and Risk. For the assessment, the project team recorded answers of "Yes," "No," or "Not applicable" to each credit question. Given the particular scope of the project, 29 out of 60 credits or 48% were considered not applicable by the team, as this is not a typical construction project.

As shown in table 4, Leadership is the highest-achieving category, with "Yes" responses to 89% of the credit questions. This reflects the team's efforts to establish partnerships in the implementation of the first stage of the project. Resource Allocation shows the next highest achievement, which demonstrates the team's care in selecting project features such as the use of renewable energy and car washing with a water replacement formula. Quality of Life is the third best performing category, as the fleet electrification helps stimulate sustainable growth, improve safety, minimize noise and vibrations, and improve the mobility of the community. The fourth best performance is in Climate and Risk, as the project reduces greenhouse gases and pollutant emissions. The Natural World category and 5 other subcategories were found to be not applicable.

The following summary groups the answers by category and subcategory.

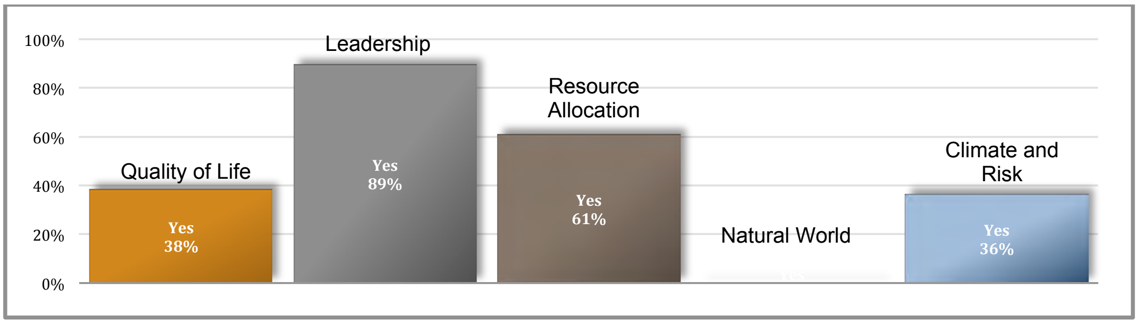


Table 4. Envision® checklist results by category. Source: Project team interviews and Envision® Rating System Self Assessment Checklist.

[32] The Envision® rating system checklist is a quick assessment tool to give an overview of the sustainability performance of a project. The checklist is based on Envision® v2.

Quality of Life

no.	Cat.	Subcategory	Credit	Y	N	NA	Performance	Results
1	QUALITY OF LIFE	PURPOSE	QL1.1 Improve community quality of life	2	0	1		2 of 2
2			QL1.2 Stimulate sustainable growth and development	3	0	0		3 of 3
3			QL1.3 Develop local skills and capabilities	2	1	0		2 of 3
4		COMMUNITY	QL2.1 Enhance public health and safety	1	0	0		1 of 1
5			QL2.2 Minimize noise and vibration	1	0	0		1 of 1
6			QL2.3 Minimize light pollution	0	1	0		0 of 1
7			QL2.4 Improve community mobility and access	1	0	2		1 of 1
8			QL2.5 Encourage alternative modes of transportation	0	0	2		0 of 0
9			QL2.6 Improve site accessibility, safety and wayfinding	0	0	3		0 of 0
10		WELLBEING	QL3.1 Preserve historic and cultural resources	0	0	2		0 of 0
11			QL3.2 Preserve views and local character	0	0	2		0 of 0
12			QL3.3 Enhance public space	0	0	2		0 of 0
			TOTAL	10	2	14		10 of 12

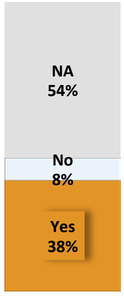


Table 5. Quality of Life credit-by-credit results. Source: Project team interviews and Envision® Rating System Self Assessment Checklist.

In the Purpose subcategory all the credits scored high (see table 5). For QL 1.1, a sustainable form of transportation will increase the mobility of citizens by introducing electric vehicles in the CYC taxi fleet. The Fleet Electrification project will eliminate negative environmental impacts of the CYC fleet in the Columbus metropolitan area by taking ICE vehicles off the roads. In QL 1.3, developing local skills and improving local capacity and competitiveness are achieved by training local drivers in EV operation and charging best practices through the CYC Taxi University and by providing information for the general public through daily interactions with their EV drivers and through public events such as the CYC interactive exhibit at the opening of the Experience Center on June 30, 2018.

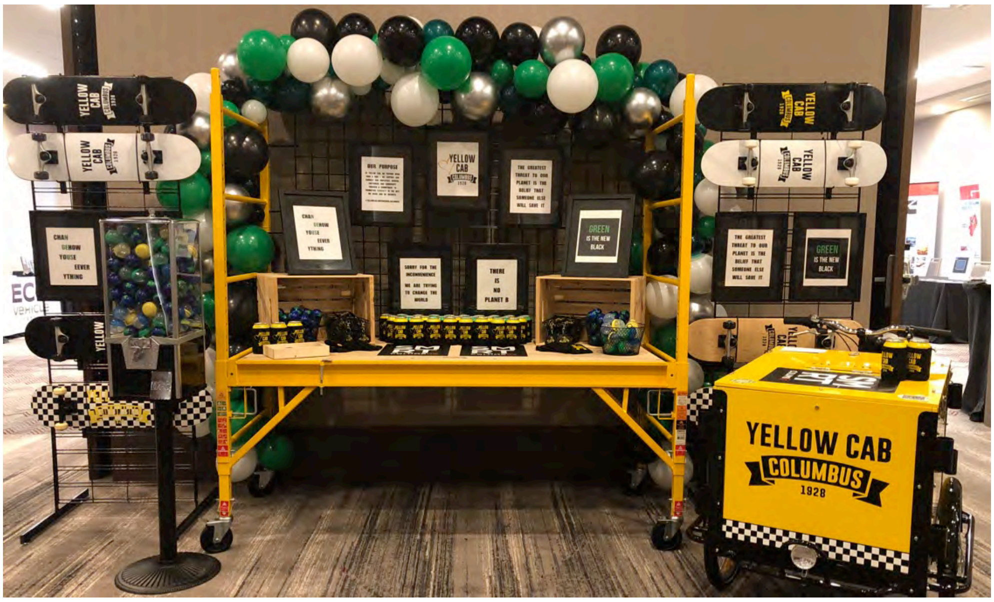


Figure 9. CYC exhibit at the Midwest Green Fleets Conference September 24, 2018. Source: Katherine Ott Zehnder, 2018.

In the Community subcategory 3 out of 4 credits scored high, QL 2.1, 2.2, and 2.4. For QL 2.1 Enhance public health and safety, the project reduces risks and exposures by replacing ICE vehicles with EVs, which are considered safer vehicles in part, since they have a lower center of gravity and are harder to flip. In QL 2.2, the project scored high as the EV motors will reduce noise and vibrations significantly compared to internal combustion engines. Like many other EVs, the 2018 Chevrolet Bolt is very quiet while operating; an artificial sound is used as a safety measure for low speed. The project did not score in QL 2.3, as it has not been designed to reduce excessive lighting, prevent light spillage, or preserve the night sky. The vehicles operate at all times of day. In QL 2.4, CYC achieves improvement in Columbus by offering increased mobility and access with the EVs.

The Wellbeing subcategory credits were considered not applicable to the scope of the project, as this project does not include a site in which to preserve historic and cultural resources or to enhance public space. This includes credits QL 3.1 to 3.3.

In future phases of the project, there are opportunities for improvement in the Community subcategory when CYC moves to a distributed system and leases or purchases space for surface parking, parking carousels, and charging throughout Columbus. Columbus Yellow Cabs is looking to acquire parking sites classified as grayfields or brownfields, which can be improved to preserve local character and cultural resources, and to enhance public space. The carousels also have the potential to make meaningful enhancements to public space if they serve as EV educational points, as planned.

Leadership

no.	Cat.	Subcategory	Credit	Y	N	NA	Performance	Results
13	LEADERSHIP	COLLABORATION	LD1.1 Provide effective leadership and commitment	3	0	0		3 of 3
14			LD1.2 Establish a sustainability management system	1	0	0		1 of 1
15			LD1.3 Foster collaboration and teamwork	3	0	0		3 of 3
16			LD1.4 Provide for stakeholder involvement	3	0	0		3 of 3
17		MANAGEMENT	LD2.1 Pursue by-product synergy opportunities	0	0	1		0 of 0
18			LD2.2 Improve infrastructure integration	2	0	1		2 of 2
19		PLANNING	LD3.1 Plan for long-term monitoring and maintenance	2	0	0		2 of 2
20			LD3.2 Address conflicting regulations and policies	2	0	0		2 of 2
21			LD3.3 Extend useful life	1	0	0		1 of 1
			TOTAL	17	0	2		17 of 17

Table 6. Leadership credit-by-credit results. Source: Project team interviews and Envision® Rating System Self-Assessment Checklist.

The subcategory that performed the best is Collaboration, with “Yes” responses to all the credits in LD 1.1 through LD 1.4.

The project team participated in numerous EV industry events to test new models and learn from other electrification efforts. The team learned from, dialogued with, and collaborated with experts in the field during:

- The 30th International Electric Vehicle Symposium & Exhibition in Stuttgart, Germany, October 9-11, 2017,
- Smart e-Mobility Tour NL, Netherlands, October 12-13, 2017,
- International Consumer Electronics Show, Las Vegas, NV, January 10-11, 2018,
- Visit to Teo Taxi and OpenFleet, Montreal, Canada, February 2018.

Figure 10. (Left to right) Kevin McSweeney from City of Columbus, Morgan Kauffman from CYC, Bud Braughton from City of Columbus, and Katherine Zehnder from HNTB at EVS30. Source: Katherine Ott Zehnder, 2018.

In the Management subcategory one credit was not considered applicable by the team, LD 2.1 (Pursue by-product synergy opportunities), as the project does not produce unwanted by-products and materials during this phase. Future phases can consider a program to locate, assess, and make use of EV batteries after the vehicles finish their useful life. In credit LD 2.2, the team seeks to optimize sustainable performance at the infrastructure component level and at the system level.

The Planning subcategory featured “Yes” responses to all the credit questions. In LD 3.1, the team responded positively to having a plan for long term monitoring and maintenance, that is sufficiently comprehensive, and that covers all the aspects concerning the EV fleet. In LD 3.2, the team asserted that an assessment of applicable regulations, policies and standards was done, to identify those that may run counter to the project's sustainable performance goals, objectives and targets. In addition, the project owner and team-members are active in approaching decision-makers to improve the climate for EV adoption. In LD 3.3, the project is designed to replace the fleet in phases to allow the team to shift with the industry and incorporate new EV technological upgrades as they become available, which extends its useful life.

Future phases can look to pursue synergistic opportunities with public agencies and private companies to optimize charging and vehicle use.

Resource Allocation

no.	Cat.	Subcategory	Credit	Y	N	NA	Performance	Results
22	RESOURCE ALLOCATION	MATERIALS	RA1.1 Reduce Net Embodied Energy	2	0	0		2 of 2
23			RA1.2 Support Sustainable Procurement Practices	2	0	1		2 of 2
24			RA1.3 Use Recycled Materials	0	0	2		0 of 0
25			RA1.4 Use Regional Materials	0	0	2		0 of 0
26			RA1.5 Divert Waste from Landfills	0	0	3		0 of 0
27			RA1.6 Reduce Excavated Materials Taken off Site	0	0	3		0 of 0
28			RA1.7 Provide for Deconstruction and Recycling	3	0	0		3 of 3
29		ENERGY	RA2.1 Reduce energy consumption	3	0	0		3 of 3
30			RA2.2 Use renewable energy	2	0	0		2 of 2
31			RA2.3 Commission and monitor energy systems	3	0	0		3 of 3
32		WATER	RA3.1 Protect fresh water availability	4	3	0		4 of 7
33			RA3.2 Reduce potable water consumption	3	0	1		3 of 3
34			RA3.3 Monitor water systems	3	0	1		3 of 3
			TOTAL	25	3	13		25 of 28

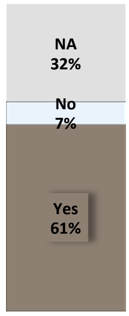


Table 7. Resource Allocation credit-by-credit results. Source: Project team interviews and Envision® Rating System Self Assessment Checklist.

In the Materials subcategory, the project performed highly in credit RA 1.1 as its key components are composed of the 10 Chevrolet Bolt EVs, while the 8 solar charging stations reduce the net embodied energy by enabling the EVs to charge with renewable energy. (If EVs are charged from the grid, there is a lesser reduction of net embodied energy. When the Bolt is charged from Ohio's grid, approximately 180 grams of CO2e per mile are produced, which is still 47% less than for an ICE vehicle running on gasoline.[33])

In RA 1.2, the team responded with "Yes" to establishing a preference for using manufacturers, suppliers, and service companies that have strong sustainability policies and practices. A significant proportion of the project's equipment, supplies, and services are sourced from these companies.

The Chevrolet Bolt EVs are built at the General Motors Orion Assembly plant in Michigan. Fifty-four percent of power at this plant is generated from methane captured from decomposing waste at a nearby landfill. The plant is considered to be the 8th largest user of green power generated onsite in the US.[34] In addition, GM has a global sustainable manufacturing commitment, and according to their 2017 Sustainability Report, they institute

> "*a global mixed-materials strategy to incorporate the most appropriate materials for each part of the vehicle to maximize performance and minimize weight of vehicles, improving fuel economy and reducing material use.*"[35]

As shown in table 7, credits RA 1.3 to RA 1.6 were considered "Not applicable" by the team as there is no site construction or handling of use and sourcing of construction materials for the implementation of this project. These credits can be revisited in future phases of the project that require construction.

The project performed well in credit RA 1.7, as vehicle parts can easily be separated for

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33 "How Clean Is Your Electric Vehicle?", Union of Concerned Scientists, accessed in 2018, https://www.ucsusa.org/clean-vehicles/electric-vehicles/ev-emissions-tool#z/43004/2018/Chevrolet/Bolt

34 "Chevy Bolt EV Plant Ranks 8th among Green Power Users," General Motors, accessed in August 2018, https://www.gm.com/mol/m-2016-jul-0725-orion-boltEV.html

35 "What We Measure. Products," in General Motors 2017 Sustainability Report, General Motors, accessed in August 2018, https://www.gmsustainability.com/measure/products.html

disassembly or deconstruction. CYC will replace car parts when necessary to extend the useful life of vehicles. Parts can be reused or recycled when needed or at the end of a vehicle’s useful life.

The Energy subcategory was the best performing, with “Yes” answers for all credits. In credit RA 2.1, the team will conduct reviews to identify options for reducing energy consumption and maintenance of the EV fleet. The project is expected to reduce energy consumption from the grid by its use of solar charging and to lower fuel consumption in Columbus. In RA 2.2, the CYC team intends to operate all 10 EVs primarily with solar power. In credit RA 2.3, the project will have third party commissioning of all the electrical and mechanical systems of EVs and charging stations. Throughout all taxi operations, the team will incorporate advanced energy monitoring from the EVs systems to have more efficient taxi operations.

The Water subcategory obtained good scores, as the team answered “Yes” to 12 of 15 criteria questions. In credit RA 3.1, the team is assessing the water requirement of the project’s operations and the long-term impacts on water availability. CYC is using a water replacement formula for car washing, an aspect that was optimized during case study development. A higher performance in this credit would require the team to achieve a net-zero impact on water supply quantity and quality or to replenish the natural water supply source.

In credit RA 3.2, the team indicated a reduction in the overall potable water consumption by using the water replacement formula in the washing of vehicles, which utilizes 16 ounces of water instead of 908 liters per car. The team can also encourage the use of graywater, recycled water, and storm water in future project phases. Higher performance in this credit would require future phases of the project to generate a net positive effect on water by up-cycling or purifying water on site.

Credit RA 3.3 involves implementing programs to monitor the water system’s performance during operations. It also addresses the impact on receiving waters. The team indicated the use of independent monitoring of the project's water systems, means to monitor water performance systems during operations, and mitigation of negative impacts. Additional monitoring of the water systems can be incorporated in future stages of the project, although the primary program goal will continue to be reducing GHGs.

Natural World

no.	Cat.	Subcategory	Credit	Y	N	NA	Performance	Results
35	NATURAL WORLD	SITING	NW1.1 Preserve prime habitat	0	0	5	0 of 0	NA 100 %
36			NW1.2 Protect wetlands and surface water	0	0	3	0 of 0	
37			NW1.3 Preserve prime farmland	0	0	1	0 of 0	
38			NW1.4 Avoid adverse geology	0	0	3	0 of 0	
39			NW1.5 Preserve floodplain functions	0	0	6	0 of 0	
40			NW1.6 Avoid unsuitable development on steep slopes	0	0	2	0 of 0	
41			NW1.7 Preserve greenfields	0	0	2	0 of 0	
42		LAND & WATER	NW2.1 Manage stormwater	0	0	2	0 of 0	
43			NW2.2 Reduce pesticide and fertilizer impacts	0	0	5	0 of 0	
44			NW2.3 Prevent surface and groundwater contamination	0	0	3	0 of 0	
45		BIODIVERSITY	NW3.1 Preserve species biodiversity	0	0	4	0 of 0	
46			NW3.2 Control invasive species	0	0	3	0 of 0	
47			NW3.3 Restore disturbed soils	0	0	2	0 of 0	
48			NW3.4 Maintain wetland and surface water functions	0	0	5	0 of 0	Yes
			TOTAL	0	0	46	0 of 0	0%

Table 8. Natural World credit-by-credit results. Source: Project team interviews and Envision® Rating System Self Assessment Checklist.

The Natural World category looks at the impact a project might have on the environment such as impacts to habitats, species, and nonliving natural systems. Table 8 shows that this category was not considered applicable for assessment at this phase, as there are no new areas of siting as part of the Fleet Electrification project. In future phases of the project, the team considers incorporating grayfield or brownfield parking areas. This strategic action would increase the sustainability performance of the project and generate high scores in the Siting, Land & Water, and Biodiversity subcategories.

Climate and Risk

no.	Cat.	Subcategory	Credit	Y	N	NA	Performance	Results
49	CLIMATE	EMISSION	CR1.1 Reduce greenhouse gas emissions	2	0	0		2 of 2
50			CR1.2 Reduce air pollutant emissions	2	0	0		2 of 2
51		RESILIENCE	CR2.1 Assess climate threat	0	0	1		0 of 0
52			CR2.2 Avoid traps and vulnerabilities	0	0	2		0 of 0
53			CR2.3 Prepare for long-term adaptability	0	0	1		0 of 0
54			CR2.4 Prepare for short-term hazards	0	0	2		0 of 0
55			CR2.5 Manage heat islands effects	0	0	1		0 of 0
			TOTAL	4	0	7		4 of 4

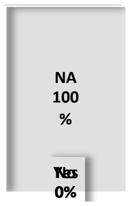

Table 9. Climate and Risk credit-by-credit results. Source: Project team interviews and Envision® Rating System Self Assessment Checklist.

The Emissions subcategory is the best performing one, as EV vehicles reduce greenhouse gas and air pollutant emissions. Both credits in this subcategory scored "Yes." EVs do not produce GHG tailpipe emissions and produce significantly lower pollutants such as NOx when compared to ICEs. The 2018 Chevrolet Bolt was the EV model selected for this initial phase of the project. According to the vehicle manufacturer the Bolt is a zero emissions vehicle.

In addition, the Fleet Electrification project includes solar charging of the EVs. This combination of 10 high-efficiency EVs and renewable energy charging allows this project to drastically cut emissions.

Figure 11. CYC EVs and DC Solar charging units. Source: CYC, 2018.

The Resilience subcategory was considered "Not applicable" in this phase of the project, as there are no new areas of siting to assess. Nevertheless, the team should consider evaluating credit CR 2.1, to protect the project from climate variation and natural hazards. The team considered that Ohio has low climatic or earthquake risks. According to the EPA, more extreme hot days, higher temperatures, heavy precipitation, and flooding are expected to increase in the next decades.[36] These factors can reduce the operability and efficiency of the CYC taxi fleet.

There is room for improvement in the resilience credits in future phases of the project. In CR 2.2, the project team can perform a comprehensive review to identify the potential risks and vulnerabilities that may occur and try to reduce or eliminate the risks. In CR 2.3, the project team can prepare the EVs' infrastructure systems to be resilient and adaptable to altered climate conditions or to long-term change scenarios. In CR 2.4, steps can be taken to improve protection measures beyond existing regulations towards likely natural or man-made hazards in the project area. The team can look at strategies for the project to recover quickly and cost effectively from short-term hazards events.

In CR 2.5, the team can reduce localized heat accumulation and manage microclimates created by the deployment of EVs, charging stations, and future parking areas and carousels. This can be achieved by minimizing surfaces with high solar reflectance index, and reducing heat contribution from sources such as engines, batteries, or charging stations.

Although these actions will help make the CYC project more comprehensively sustainable, the team indicated a preference to achieve more environmental benefits faster by focusing investments on a systematic conversion of their fleet from ICE vehicles to BEVs.

5. Next Steps

The next steps for the team are to continue with the full and gradual conversion of the 200-vehicle fleet into BEVs.

> "*Right now we are to deploy DC fast charging units at key locations, the BEVs require fast charging in order to keep vehicles running maximum hours per day. We are working on an agreement between the city and CYC to locate charging units. In addition CYC is looking to install solar energy systems into the CYC headquarters grid to further offset carbon emissions."* [37]

[36] "What Climate Change Means for Ohio," EPA, 2017, accessed in August 2018, https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-oh.pdf

[37] Katherine Ott Zehnder, VP at HNTB, communications during case study development in 2019.

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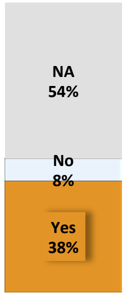
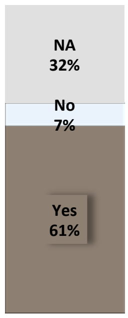
7. Appendix

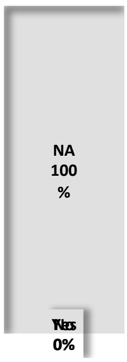
Exhibit A. Envision® credit-by-credit results. Source: Project team interviews and Envision® Rating System Self Assessment Checklist.

Envision Rating System
Self-Assessment Checklist
For Public Comment Only - Not for Project Use

no.	Cat.	Subcategory	Credit	Y	N	NA	Performance	Results
1	QUALITY OF LIFE	PURPOSE	QL1.1 Improve community quality of life	2	0	1		2 of 2
2			QL1.2 Stimulate sustainable growth and development	3	0	0		3 of 3
3			QL1.3 Develop local skills and capabilities	2	1	0		2 of 3
4		COMMUNITY	QL2.1 Enhance public health and safety	1	0	0		1 of 1
5			QL2.2 Minimize noise and vibration	1	0	0		1 of 1
6			QL2.3 Minimize light pollution	0	1	0		0 of 1
7			QL2.4 Improve community mobility and access	1	0	2		1 of 1
8			QL2.5 Encourage alternative modes of transportation	0	0	2		0 of 0
9			QL2.6 Improve site accessibility, safety and wayfinding	0	0	3		0 of 0
10		WELLBEING	QL3.1 Preserve historic and cultural resources	0	0	2		0 of 0
11			QL3.2 Preserve views and local character	0	0	2		0 of 0
12			QL3.3 Enhance public space	0	0	2		0 of 0
			TOTAL	10	2	14		10 of 12
13	LEADERSHIP	COLLABORATION	LD1.1 Provide effective leadership and commitment	3	0	0		3 of 3
14			LD1.2 Establish a sustainability management system	1	0	0		1 of 1
15			LD1.3 Foster collaboration and teamwork	3	0	0		3 of 3
16			LD1.4 Provide for stakeholder involvement	3	0	0		3 of 3
17		MANAGEMENT	LD2.1 Pursue by-product synergy opportunities	0	0	1		0 of 0
18			LD2.2 Improve infrastructure integration	2	0	1		2 of 2
19		PLANNING	LD3.1 Plan for long-term monitoring and maintenance	2	0	0		2 of 2
20			LD3.2 Address conflicting regulations and policies	2	0	0		2 of 2
21			LD3.3 Extend useful life	1	0	0		1 of 1
			TOTAL	17	0	2		17 of 17
22	RESOURCE ALLOCATION	MATERIALS	RA1.1 Reduce Net Embodied Energy	2	0	0		2 of 2
23			RA1.2 Support Sustainable Procurement Practices	2	0	1		2 of 2
24			RA1.3 Use Recycled Materials	0	0	2		0 of 0
25			RA1.4 Use Regional Materials	0	0	2		0 of 0
26			RA1.5 Divert Waste from Landfills	0	0	3		0 of 0
27			RA1.6 Reduce Excavated Materials Taken off Site	0	0	3		0 of 0
28			RA1.7 Provide for Deconstruction and Recycling	3	0	0		3 of 3
29		ENERGY	RA2.1 Reduce energy consumption	3	0	0		3 of 3
30			RA2.2 Use renewable energy	2	0	0		2 of 2
31			RA2.3 Commission and monitor energy systems	3	0	0		3 of 3
32		WATER	RA3.1 Protect fresh water availability	4	3	0		4 of 7
33			RA3.2 Reduce potable water consumption	3	0	1		3 of 3
34			RA3.3 Monitor water systems	3	0	1		3 of 3
			TOTAL	25	3	13		25 of 28
35	NATURAL WORLD	SITING	NW1.1 Preserve prime habitat	0	0	5		0 of 0
36			NW1.2 Protect wetlands and surface water	0	0	3		0 of 0
37			NW1.3 Preserve prime farmland	0	0	1		0 of 0
38			NW1.4 Avoid adverse geology	0	0	3		0 of 0
39			NW1.5 Preserve floodplain functions	0	0	6		0 of 0
40			NW1.6 Avoid unsuitable development on steep slopes	0	0	2		0 of 0
41			NW1.7 Preserve greenfields	0	0	2		0 of 0
42		LAND & WATER	NW2.1 Manage stormwater	0	0	2		0 of 0
43			NW2.2 Reduce pesticide and fertilizer impacts	0	0	5		0 of 0
44			NW2.3 Prevent surface and groundwater contamination	0	0	3		0 of 0
45		BIODIVERSITY	NW3.1 Preserve species biodiversity	0	0	4		0 of 0
46			NW3.2 Control invasive species	0	0	3		0 of 0
47			NW3.3 Restore disturbed soils	0	0	2		0 of 0
48			NW3.4 Maintain wetland and surface water functions	0	0	5		0 of 0
			TOTAL	0	0	46		0 of 0
49	CLIMATE	EMISSION	CR1.1 Reduce greenhouse gas emissions	2	0	0		2 of 2
50			CR1.2 Reduce air pollutant emissions	2	0	0		2 of 2
51		RESILIENCE	CR2.1 Assess climate threat	0	0	1		0 of 0
52			CR2.2 Avoid traps and vulnerabilities	0	0	2		0 of 0
53			CR2.3 Prepare for long-term adaptability	0	0	1		0 of 0
54			CR2.4 Prepare for short-term hazards	0	0	2		0 of 0
55			CR2.5 Manage heat islands effects	0	0	1		0 of 0
			TOTAL	4	0	7		4 of 4







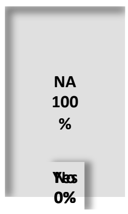


Exhibit B. 2018 Chevrolet Bolt EV. Source: Chevrolet Product Information, Chevrolet, accessed in August 2018, https://www.chevrolet.com/electric/bolt-ev-electric-car

Chevrolet Product Information

2018 CHEVROLET BOLT EV SPECIFICATIONS

EFFICIENCY

Driving Range:	EPA-estimated 238 miles (255 city / 217 hwy)

BATTERY SYSTEM

Type:	Rechargeable energy storage system comprising multiple linked modules
Mass (lb / kg):	960 / 435
Battery chemistry:	Lithium-ion
Cells:	288
Energy:	60 kWh
Warranty:	eight years / 100,000 miles

ELECTRIC DRIVE

Type:	Single motor and gearset
Motor:	Permanent magnetic drive motor
Power:	200 hp / 150 kW
Torque: (lb-ft / Nm):	266 / 360
Final drive ratio (:1):	7.05:1

CHARGING TIMES

120 V:	4 miles / 6.4 km of range per hour
240 V:	Full charge in 9.3 hours
SAE Combo DC Fast Charge:	Up to 90 miles in 30 minutes

CHASSIS & SUSPENSION

Front Suspension:	Independent MacPherson strut-type with direct-acting solid stabilizer bar
Rear Suspension:	Compound crank (torsion beam) with coil springs
Steering Type:	Column-mounted electric power steering
Turning Circle (ft. / m):	35.4 / 10.8
Brake Type:	Power four-wheel disc with ABS; electro-hydraulic; partially regenerative; dynamic rear brake proportioning
Brake Rotor Size: (in. / mm)	Front: 11 / 276 vented Rear: 10 / 264 solid
Wheel Size:	17-in. aluminum
Tire Size:	Michelin Energy Saver A/S 215/50R17 all-season