Paving the Way for a Sustainable Municipal Fleet

A Spring 2019 Collaborative Report with Arizona State University's Project Cities & the City of Glendale

Sustainable Cities Network

Arizona State University

Project Cities

Glendale ARIZONA

This report represents original work prepared for the City of Glendale by students participating in courses aligned with Arizona State University's Project Cities program. Findings, information, and recommendations are those of students and are not necessarily of Arizona State University. Student reports are not peer reviewed for statistical or computational accuracy, or comprehensively fact-checked, in the same fashion as academic journal articles. Project partners should use care when using student reports as justification for future actions. Text and images contained in this report may not be used without permission from Project Cities.

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On behalf of the ASU Wrigley Institute and the School of Sustainability, we extend a heartfelt thank you to the City of Glendale for enthusiastically engaging with students and faculty throughout the semester. These projects provide valuable real-world experience for our students and we hope that their perspectives shine light on opportunities to continuously improve Glendale's future livelihood and community well-being.

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To access the original student reports, additional materials, and resources, visit:
links.asu.edu/PCGlendaleEVFleet

ABOUT PROJECT CITIES

The ASU Project Cities program uses an innovative, new approach to traditional university-community partnerships. Through a curated relationship over the course of an academic year, selected Community Partners work with Project Cities faculty and students to co-create strategies for better environmental, economic, and social balance in the places we call home. Students from multiple disciplines research difficult challenges chosen by the city and propose innovative sustainable solutions in consultation with city staff. This is a win-win partnership, which also allows students to reinforce classroom learning and practice professional skills in a real-world client-based project. Project Cities is a member of Educational Partnerships for Innovation in Communities Network (EPIC-N), a growing coalition of more than 35 educational institutions partnering with local government agencies across the United States and around the world.

ABOUT SUSTAINABLE CITIES NETWORK

Project Cities is a program of ASU's Sustainable Cities Network. This network was founded in 2008 to support communities in sharing knowledge and coordinating efforts to understand and solve sustainability problems. It is designed to foster partnerships, identify best practices, provide training and information, and connect ASU's research to front-line challenges facing local communities. Network members come from Arizona cities, towns, counties, and Native American communities, and cover a broad range of professional disciplines. Together, these members work to create a more sustainable region and state. In 2012, the network was awarded the Pacific Southwest Region's 2012 Green Government Award by the U.S. EPA for its efforts. For more information, visit *sustainablecities.asu.edu.*

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ASU Sustainable Cities Network
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Project Cities

Sustainability Through Local Action

ABOUT GLENDALE

The City of Glendale is located in Maricopa County, roughly nine miles northwest of Downtown Phoenix. Glendale's population is about 250,000, comprised of diverse communities, including large Hispanic populations, retirement communities, local businesses, and event-goers. Glendale is home to attractions such as the State Farm Stadium, Westgate Entertainment District, the Gila River Arena, Glendale Community College, and the ASU West Campus. With abundant attractions and temperate climate, Glendale has something to offer for its residents and tourists all year round. In August 2016, 71% of voters supported Envision Glendale 2040, a plan that signaled the City's commitment to sustainability. Glendale has chosen to pair up with Project Cities to find new ways to promote sustainability and engage with their communities to better serve their diverse needs.

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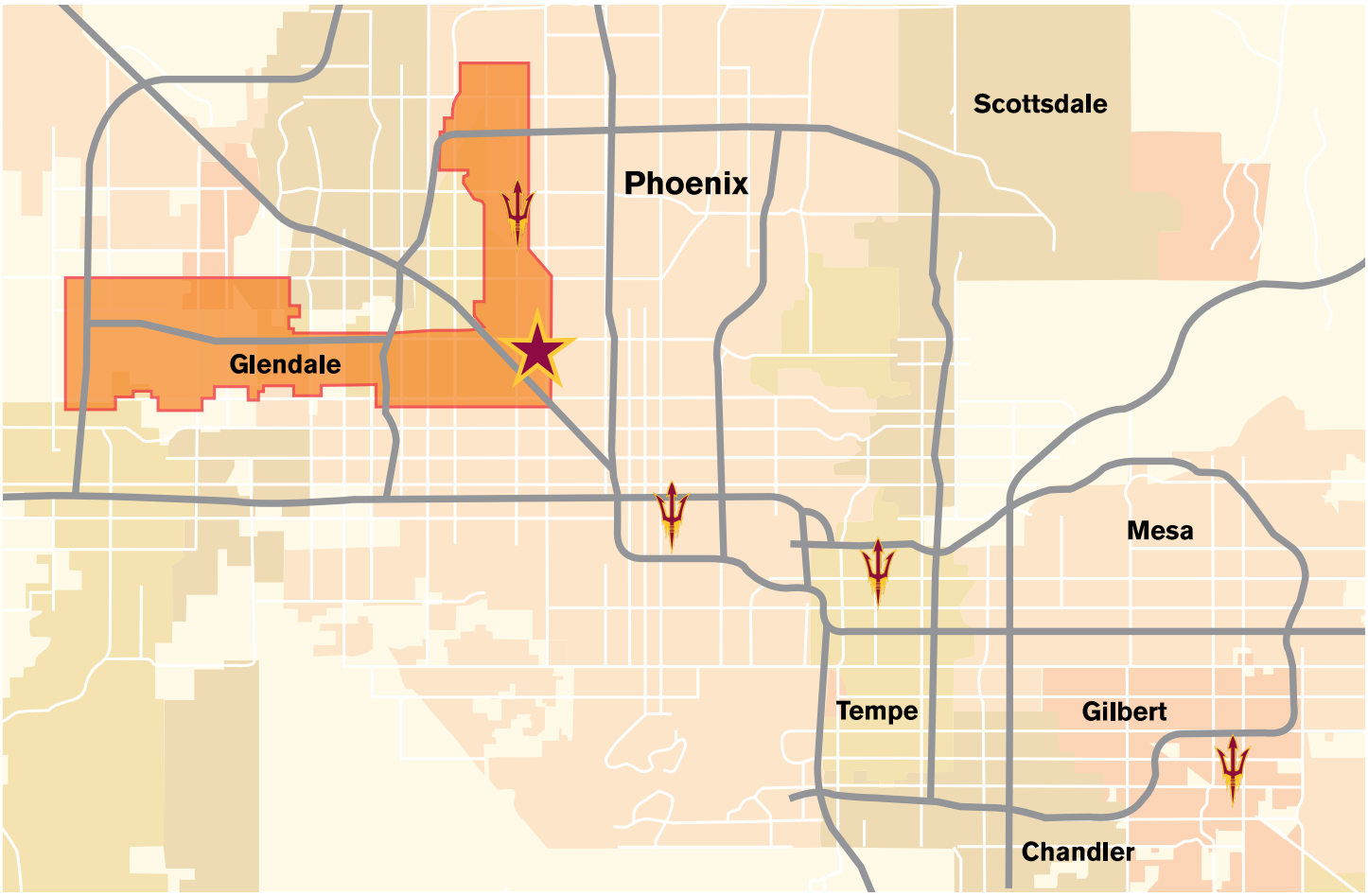
MAP OF GLENDALE & GREATER PHOENIX, ARIZONA



A Message from the City Manager

In 2018, the City of Glendale entered into a partnership with Arizona State University to participate in the Project Cities Program. The goal of this program is to deliver sustainability research, education, and solutions with practical, measurable and meaningful impact to local government. It is a university-community partnership in which ASU students work on research projects that will inform programs or services related to the city's strategic objectives and which have a sustainability component. These projects may include co-creating implementation frameworks or solution pathways for environmental, economic, or social improvement projects all of which will help Glendale prepare for the future.

The leadership team and I can proudly say that ASU's Project Cities program has provided a value-added experience for our staff and fulfilled the need for research on key organizational issues. We have been extremely impressed with the professionalism and relationships our city has developed with the students and ASU's Project Cities staff. They have brought a fresh and unique perspective to challenges that affect our city.

The projects chosen are aligned to the City of Glendale's mission and values and are intended to help advance several of our strategic objectives, initiatives, and existing programs. We specifically sought to gain insights around communication to include social media management and multi-generational engagement, as well as sustainable asset management for the city fleet, facility master plan, and above ground chemical storage tanks.

This valuable experience has been a tremendous learning opportunity for our city as well as for the dedicated students who exhibited their unique skill set. One of the surprising benefits has been for our staff liaisons who were refreshed and invigorated through their interactions with the next generation of leaders, and found the students to be very thoughtful, intelligent, and inquisitive. The opportunity to expose students to potential careers in local government also aids in developing a pipeline of future talent in local government.

In closing, we truly strive to improve the lives of the people we serve every day and these projects have provided us with insights that will help guide actions and future recommendations for our City Council. We are excited about the strategic direction for Glendale and have set the bar high for success. We feel extremely fortunate to have experienced a great partnership through the ASU Project Cities program which will play an integral role in achieving our goals.

Sincerely,

Kevin R. Phelps
City Manager
5850 W. Glendale Avenue, Glendale, AZ 85301
623.930.2870

The following report summarizes and draws highlights from work and research conducted by students in PUP 424 Planning Methods and SOS 324 Sustainable Energy, Technology and Systems, for the Spring 2019 partnership between ASU's Project Cities and the City of Glendale.

To access the original student reports, additional materials, and resources, visit:

links.asu.edu/PCGlendaleEVFleet

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EXECUTIVE SUMMARY

As the volume of personal vehicles on Arizona roadways continues to grow, cities must discover new ways to reduce traffic and promote alternative modes of transportation. Vehicle emissions are a leading cause of air pollution influencing climate change. Although electric vehicles (EVs) do not necessarily reduce traffic, they do offer the ability for drivers to decrease toxic emissions and lower noise pollution. EVs are suitable for corporate business travel. EVs may be the right choice for municipalities to consider for local travel needs, such as for meetings, routes, and deliveries. They enable cities to reduce their carbon footprint, lower maintenance costs, and demonstrate an investment in more sustainable technologies. Many different types of organizations and companies are electrifying their fleets and experiencing positive results. The City of Glendale has identified an opportunity to jumpstart this transition as they examine new options for upgrading their existing fleet.

Students in Deborah Salon's course PUP 424: Planning Research Methods and Nathan Parker's course SOS 324: Sustainable Energy, Technology & Systems explored strategies for an EV fleet transition and its associated infrastructure for Glendale; this report summarizes those strategies.

PUP 424: Students in this course researched fleet electrification strategy. They were divided into subtopic groups covering city employee perceptions of EVs, a cost comparison of EVs versus combustion-engine vehicles, and benchmarking of EV fleets in other cities in the US, companies, and organizations.

PUP 424 and **SOS 324** both researched EV charging stations. They examined current EV charging technologies and prospective locations for EV charging stations across Glendale. A common theme that emerged from this research indicated that projects that provided a mutual benefit to the community and contracted businesses in the city tend to generate more possibilities to execute an effective transition.

The ensuing recommendations and report summaries are intended to guide Glendale toward a city-wide EV fleet transition. Note that these recommendations are purely for educational and research purposes. The City should consult with its legal team before advancing new organizational policies.

GOALS & RECOMMENDATIONS

This report aims to support the City of Glendale to transition to an Electric Vehicle fleet that takes advantage of public-private partnership options and provides mutual benefit to city residents. Work generated by all students in each course is provided in the topic-specific sections that follow, full student reports can be found online via the links provided at the end of this section. Glendale sought input on six topics:

1. Employee perspectives on EVs
2. Factors affecting long-term battery life
3. EVs in other cities via case studies
4. Technical Overview of EVs
5. Recommended EV charging types for Glendale
6. Recommendations for charging infrastructure locations

Figure 1 *Students tour the Glendale Operations Center*

RECOMMENDATIONS FOR ELECTRIC VEHICLE USAGE

Recommendations for Glendale's EV Program
Recognize that most regular City vehicles are not driven far on a given day, so replacing them with EVs should not present operational challenges.
Acknowledge the benefits of specific EVs such as the Nissan Leaf and consider electrifying the existing sedan fleet (Bhalloo, Brown, Cramer, and Samwick, p.8).
Educate and reassure employees about the driving range of EVs and the increasing availability of charging stations in the Phoenix metro area (Bhalloo et al., p.2).
Leverage the EV fleet transition to promote a public image of an innovative greener city to residents and peer communities (Bhalloo et al., p.8).
Establish partnerships with EV manufacturers and dealers to negotiate bulk order pricing, as per the state of Hawaii (Bitler, Du, Leftwich, Sanchez Luna, and Shultz, 2019).
Incorporate public outreach and marketing to promote EV use by residents (Bitler et al., 2019).
Park EVs in shaded and covered areas during times of extreme temperatures to extend battery life (Rosenberg, Loftus, and Chiesa, p.4).
Park EVs in shaded and covered areas during times of extreme temperatures to extend battery life (Rosenberg et al., p.4).

RECOMMENDATIONS FOR ELECTRIC VEHICLE USAGE (CONTINUED)

Recommendations for Charging Technologies and Infrastructure

Incorporate the JuiceBox Pro 75 EV charging system; despite its higher price point, its features may provide more value to the City (Crippen, Pearson, and Goddard, p.8).

Prioritize charging locations with existing wiring because installation costs increase significantly if new wiring needs to be installed (Crippen et al., p.4).

Consider installing charging stations at the following locations that are either city-owned, popular attraction areas, or easily accessible (Al-Marri, Alhajri, Almarri, Al-hajri, Qarh, p.2):

- Glendale Public Library on Peoria and 59th Avenue—selected because it is city-owned land and has a high frequency of daily visitors that generally have longer stay-times. It is also near two major arterial streets.
- On West Parkside Lane east of North 67th Avenue—selected for its proximity to Thunderbird Conservation Park and Mountain Ridge High School. This location extends the network from the edges of Glendale to the northern part of the city. The destinations in this area could provide high stay-time by travelers.
- The Arrowhead Towne Center shopping location on 75th Avenue and West St. John Road—selected for its access to an arterial street, as well as Hidden Meadows Park north of St. John Street and the shopping district. This location has high stay-times because of the sizable shopping district and the park.
- Next to Dust Devil Park on 107th Avenue and Camelback Road—chosen to extend the charging network south near Dusty Devil Park, Camelback Ranch Baseball stadium, and Copper King Elementary School.
- Near Westgate Entertainment District on West Glendale Avenue and North 91st Avenue—located by two arterial streets close to 101 Loop, and accessible to the entertainment district. The presence of ample dining establishments and a movie theater in the area all but guarantees high stay-times.
- Glendale City Hall and Murphy Park, on West Glendale Avenue and North 58th Avenue—selected for its centrality to the city's downtown and city services, it has places where residents and employees gather for many hours throughout the day. The Murphy Park location could serve to motivate EV drivers to visit and use the park.

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Fleet Electrification Strategy & Infrastructure

A Multifaceted Exploration of Electric Vehicles in Municipal Fleets

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INTRODUCTION

Electric vehicles can be an excellent investment for individuals and communities who seek to decrease their dependence on fossil fuels. EV users enjoy knowing they never need to fill up at the gas station, and those that charge from renewable energy sources can feel good about zero-emission travel. EV fleet transitions are progressing in many cities, companies, and institutions around the world, demonstrating EV benefits are scalable.

EVs symbolize a cleaner and more progressive future. At the city manager's direction, Glendale staff strives to embrace opportunities to engage with residents and encourage EV ownership through a city-wide plan for installing EV infrastructure. Students in the Project Cities program spent the Spring 2019 semester, developing recommendations to aid an effective EV fleet transition. The students' research encompassed two categories: Electric Vehicles and Electric Vehicle Charging Infrastructure.

RESEARCH METHODS

The student groups leveraged a variety of research methods to assess the feasibility of electrifying Glendale's fleet. Most student groups conducted a literature analysis of combined sources, including scholarly articles, consumer reviews, online forums, and other sources. The students also reviewed EV policies in key markets, such as California, Hawaii, Minnesota, New York, and Seattle, comparing municipal standards for EV fleets.

Glendale gave the students access to a database of vehicle use data collected by employees over 18 weeks. That study was initially conducted to explore opportunities for downsizing their fleet, but much of the data were relevant to the EV study. The fleet reduction study was a rich source of information, listing fleet-related purchases, fleet mileage, and more. Also, facility specifications relevant to EV infrastructure planning were made available to the students.

ELECTRIC VEHICLES

As the volume of personal vehicles on Arizona roadways continues to grow, cities are challenged with finding ways to reduce traffic impacts and promote a cleaner means of transportation. Large municipal fleets, such as Glendale's 1,300 vehicles, offer an opportunity to make this transition at scale. For city-owned vehicles that typically only travel short distances, the use of EVs can decrease maintenance and operation costs and serve to lead among peer communities and the public.

COST COMPARISON OF ELECTRIC VS. GAS-POWERED VEHICLES

To understand the costs and benefits of transitioning the City's vehicle fleet from gas-powered to electric, students compared the electric 2019 Nissan Leaf to Glendale's current and newer models of the existing vehicles. The comparative analysis concluded that it is cost-effective for Glendale to transition its fleet to electric models based on fuel costs, initial purchase price, and routine maintenance costs (Alboadani, Almalki, Cleveland, and Fuerte, 2019).

Editor's Note
This analysis did not consider costs associated with replacing EV batteries after expired warranties, the use of electricity, and installing the charging infrastructure.

Upfront Cost of 2019 Models of Standard Fleet Vehicles vs the 2019 Nissan Leaf	
* CHEVY MALIBU '19	$27,495
* CHEVY IMPALA '19	$31,395
* FORD TAURUS '19	$31,325
** NISSAN LEAF '19	$31,332
*Based on Average MSRP from Edmunds.com	
**Received purchase price from City of Glendale Fleet Management	
Models above have similar feature packages (Alboadani et al., 2019)	

Table 1 *Upfront cost comparison (Alboadani et al., 2019, p.1)*

Maintenance Costs for first 100,000 Miles of EVs vs. Gas-Powered Vehicles		
First 1,000 Miles Maintenance Cost	**Electric Vehicle**	**Gas-Powered Vehicle**
Tires	$700	$700
Oil Change	$0	$700
Transmission Fluid	$0	$700
Spark Plugs and Wires	$0	$700
Muffler	$0	$700
Brakes	$200	$700
TOTAL	$900	$2,140
Data Retrieved from the World Electric Vehicle Journal		

Table 2 *Maintenance cost comparison (Alboadani et al., 2019, p.1)*

Cost to Fuel Current Glendale Fleet Models				
	Chevy Malibu '06	***Chevy Impala '14***	***Ford Taurus '05***	***Ford Taurus '07***
City MPG*	17	21	18	18
Fuel Capacity* (Gallons)	16	18.5	18	18
Average Gas Cost (Regular Grade)**	$2.775	$2.775	$2.775	$2.775
Total cost to fill gas tank	$44.40	$51.34	$49.95	$49.95
* Retrieved from Kelly Blue Book ** Average Unleaded Fuel Cost of 4 gas stations near Glendale Fleet Management Facility 4/3/19				

Table 3 *Cost to fuel current fleet (Alboadani et al., 2019, p.1)*

Cost to Fuel 2019 Models of Current Fleet Vehicles vs. Charging the Nissan Leaf					
	Chevy Malibu '19	***Chevy Impala '19***	***Ford Taurus '19***	***Ford Taurus '19***	***Nissan Leaf '19***
City MPG/ Miles per charge*	29	22	18	18	150 (Fully Charged)
Fuel or Charge Capacity	15.8	18.5	19	19	40 kWh battery
Average Cost per Unit per gal and per kWh	$2.775	$2.775	$2.775	$2.775	Using 240 volt chargers @ 8.84 cents per kWh
Total Cost to power Standard Fleet vs. EV	$43.85	$51.34	$52.73	$52.73	$3.53
***Retrieved Average Cost from *electricitylocal.com*					

Table 4 *Cost to power between standard fleet and EVs (Alboadani et al., 2019, p.1)*

Cost of Miles Driven by Glendale Departments for 2019 Gas-Powered Models and Nissan Leaf				
Personal Travel Miles	1185.2	**Total Miles**	**Based on City of Glendale consolidated data for an 18 week recording period**	
Department Travel Miles	3299.9	**4485.1**		
	Chevy Malibu '19	***Chevy Impala '19***	***Ford Taurus '19***	***Nissan Leaf '19***
Total Travel miles/full tank	458.2	407	342	150
*Times to fuel up to reach total miles	10	11	13	30
Cost to fill gas tank vs charging Nissan Leaf	429.18	565.73	691.45	105.55
Fuel savings if Nissan Leaf travels total miles	323.63	460.18	585.90	
* Rounded to nearest whole number				

Table 5 *Cost of miles driven comparison (Alboadani et al., 2019, p.1)*

CITY EMPLOYEE PERSPECTIVES ON ELECTRIC VEHICLES

One student group surveyed 18 city staff to understand their daily vehicle use better and assess their perceptions of EVs. The survey questions, responses, and analysis on the next pages may help guide Glendale to a stable changeover to an EV fleet. For complete survey results, see pages 5-8 of the Bhalloo et al. report.

Q1: "What is your number one concern (if any) with using an electric vehicle when conducting city business?"

Nine of the 15 respondents stated that their number one concern was the vehicle either running out of power while in use or not being able to find a charging station when needed. Though the overall sample was not large, the significant proportion of participants expressing this same concern makes this finding of range anxiety notable. To alleviate this concern, the staff responsible for the transition to EVs need to provide information about vehicle mileage and nearby charging stations to city staff (Bhalloo et al., p.2).

Editor's Note
Multiple user-friendly mobile apps help locate charging stations for EVs such as PlugShare, Open Charge Map, and Green Charge. Some apps include built-in navigation and can track battery life and costs.

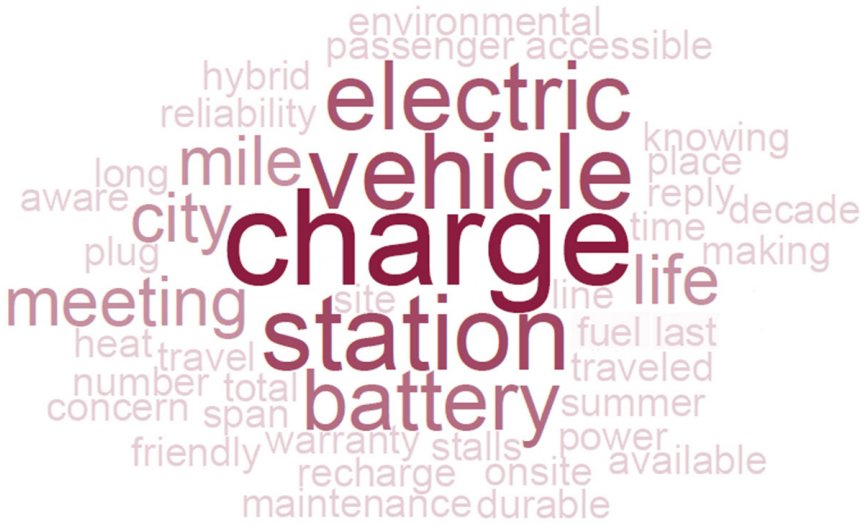


Figure 2 *Word map highlighting the most frequently used words in the survey responses.*

"What is your number one concern (if any) with using an electric vehicle when conducting city business?"

Editor's Note
On a typical single charge, employees could travel to and from Phoenix and Glendale City Hall up to 7 times with no issues.

Q2: "On days when you use a Glendale fleet vehicle for work, on average how many miles do you drive? (your best guess is fine)"

Based on the 15 responses recorded, no employee drives a vehicle over 30 miles daily; and only four employees drive a city car between 20-30 miles per day. The 2019 Nissan Leaf has a driving range of ~150 miles per charge. If the City EVs are returned and charged overnight, Glendale staff should feel confident that they will not run out of charge while on the job. Some respondents said that they must make trips outside the city for work-related trips and were worried they would not have enough charge to complete the trip. However, with 150 miles per charge, they could drive to Phoenix (10-miles away) about 7 times a round trip before having to charge the vehicle.

Participants were asked to weigh in each of the four items listed. They could respond with strongly disagree; disagree; neither agree nor disagree; agree; or strongly agree. **The participants largely agreed that EVs promote the City's environmental goals (Q3A) and a healthy image of the City (Q3C).** Responses for Part Q3B were split on an EV fleet saving the City money. Part Q3D was the most contentious of this question set because only five respondents agreed that EVs are a better option than gas-powered vehicles. Therefore, Glendale should focus on informing City staff about the value EVs provide compared to gas-powered cars.

Figure 3 *Students visit the Glendale Operations Center*

Q3: "Glendale moving toward an EV fleet is important because…"
A) It promotes environmental goals
B) It saves money for the City
C) It promotes a healthy image for the City
D) It provides better fleet vehicles for City workers

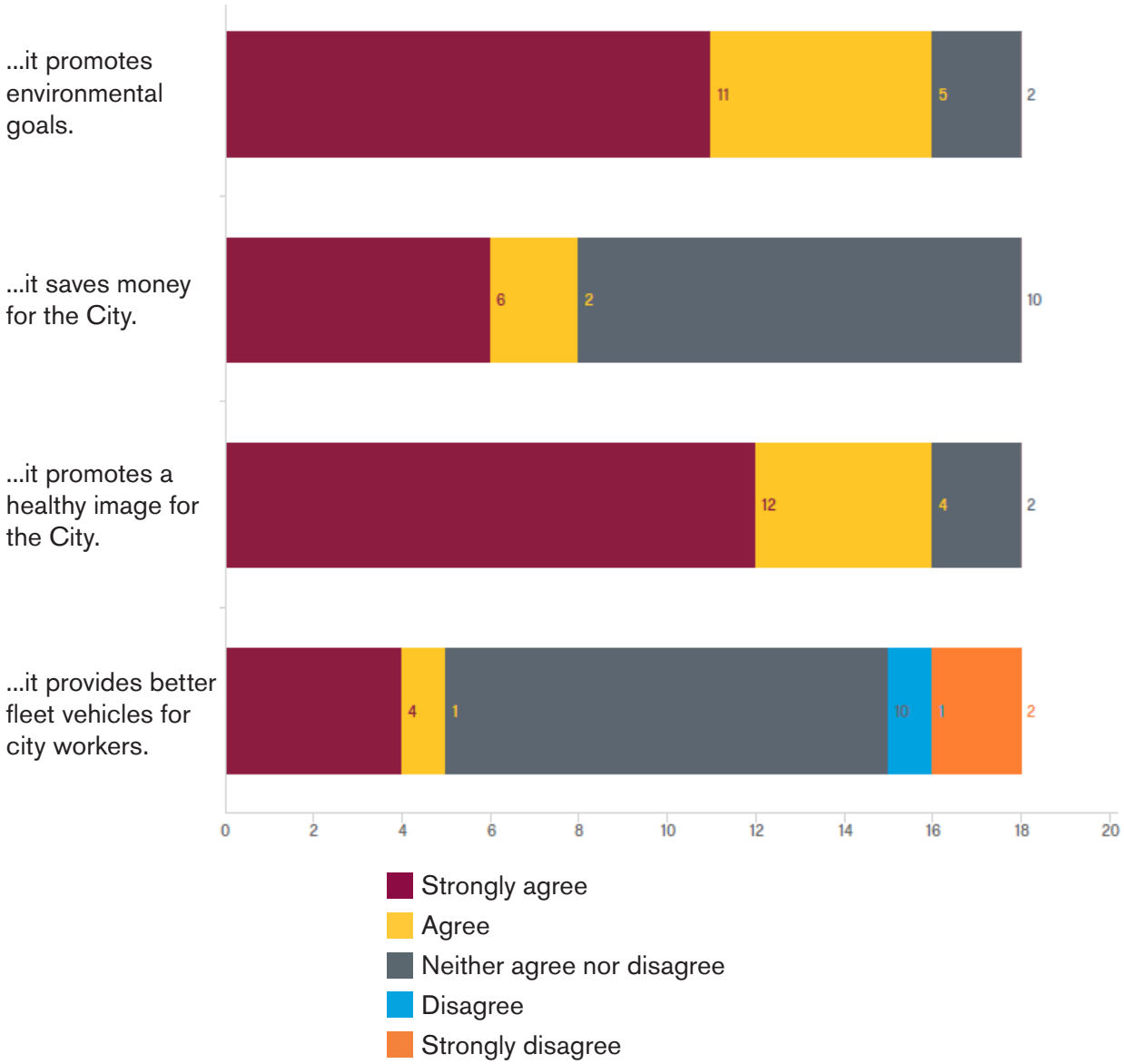


Figure 4 *Perceptions of value of fleet electrification to Glendale "Glendale moving toward an EV fleet is important because..."*

Q4 "What considerations would lead you to choose to drive an electric vehicle over a conventional gasoline vehicle, when conducting city business?"
None. They have all the functionalities of a combustion engine powered passenger vehicles.
We would have no preference
If it's available
Cleaner for the environment
Less mechanical breakdowns
It's better for the environment
Considerations such as those in previous question
I want to do what is best for the environment
Number of passages per vehicle and load bearing capacity
Charging stations
If it's cost effective for the City to add electric vehicles to its fleet
Not sure as I've never driven an electric vehicle
City receives a rebate or other type of incentive to purchase an electric vehicle
If it is locally here in Glendale, I would drive the electric vehicle

This free response question received a wide variety of answers (see the full range of responses at **links.asu.edu/PCGlendaleEVFleet**) Glendale can use these findings better to understand the diverse array of employee opinions on EVs. The student research indicated that EVs are better for the environment, cheaper, and less likely to have problems and breakdowns. The respondents seemed to have no preference for vehicle type as long as the EVs work. The results may influence reluctant employees to be more open to driving EVs.

FACTORS AFFECTING LONG-TERM BATTERY LIFE

Heat and batteries are not a good combination. As with gas-powered vehicles, batteries need to be replaced sooner in hotter climates. With Arizona's extreme summer temperatures, Glendale needs to ensure its EV fleet transition plan considers protecting EV batteries from excessive heat.

Editor's Note
Some factors that affect long-term battery life are driver aggression, heat exposure, mindful driving, and parking under shade.

Research indicates that EV battery range varies based on climate. Cities with extreme temperatures, such as Phoenix and Minneapolis, see a loss of about 500 miles/year in battery range compared to cities with more temperate climates, like Los Angeles. Extreme heat creates a lower electrical capacity and requires EVs to charge for longer durations compared with temperate climates. One simple, proven strategy to lessen the impact of extreme heat and extend the life of an EV battery is by parking vehicles in garages or under covered parking. What seems like a minor consideration can have a significant impact on battery life.

Another way to extend battery life is through more efficient driving practices. The effects of driving styles on EV battery life on the 1st and 10th years is found in the figure on the next page. The black-shaded areas represent the first year, and the colored areas represent the 10th year. The least efficient drivers will lose 1,500 vehicle miles traveled (VMT) over a vehicle's lifetime. The most skilled drivers will lose 700 VMT. Encouraging mindful driving practices is essential for increasing battery longevity.

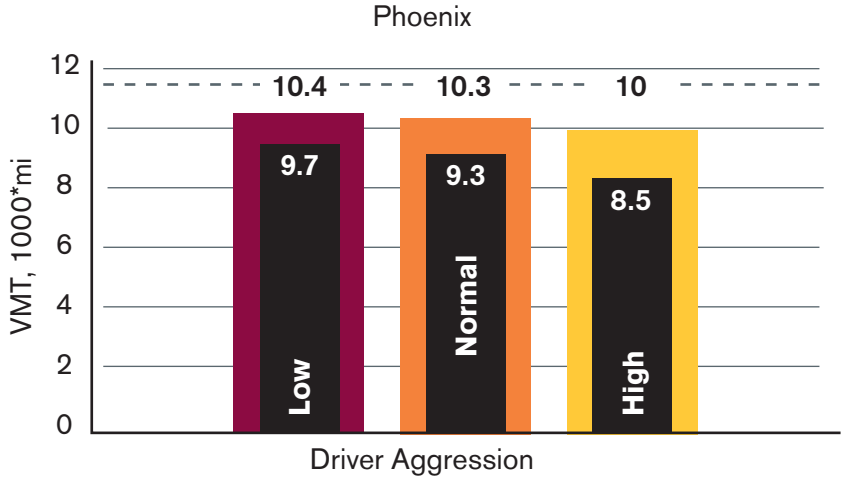


Figure 5 *Effects of temperature and driver aggression on EV battery life when heating, ventilation, and air conditioning are off.*

ELECTRIC VEHICLES IN OTHER CITIES AND ORGANIZATIONS: CASE STUDIES

The students reviewed case studies of other cities and organizations with EV fleets and provided resources to help Glendale in its transition toward fleet electrification.

City of Houston, Texas.

As one of the nation's largest cities, Houston owns the third-largest municipal fleet in the country. **The city integrated EVs into its fleet by reorganizing vehicle operations into a centrally managed vehicle pool and establishing a network of charging stations throughout the city.**

Houston reported both pros and cons to its EV fleet. Houston's EVs have an expected lifespan of 215,000 miles each, and staff expected the batteries would only need to be replaced once per vehicle lifetime. Houston also reported its EV fleets last longer than its gas-powered fleet. However, staff also noted that the lower mileage range on EVs could be problematic. If new, unfamiliar drivers do not adequately charge the vehicles after use, they can potentially leave the next driver with an unexpected disruption in their planned travel (Bitler, Du, Leftwich, Sanchez Luna, Schultz, p.4).

Editor's Note
Perhaps the most critical takeaway from Seattle's fleet transition is long-term comprehensive planning is vital when creating permanent infrastructure changes, as it saves time and capital down the line.

City of Seattle, Washington

At a student-led interview, Andrea Pratt, Seattle's former Green Fleet Program Manager, shared new details on Seattle's fleet electrification. Pratt noted that the Nissan Leaf had a Level 2 (L2) charging duration of 4–6 hours, and with the 24kWh battery, the Leaf reaches a 90-mile range on a single charge. Through the program, Pratt learned the City did not need a full 40-amp L2 charger for the Leaf, as it is a small vehicle with long dwell times. In her fleet transition plan, she ensured that a larger conduit was installed early on to create increased capacity. Pratt emphasized that every facility is different and that there is no "one size fits all plan" for fleet electrification. (Bitler et al., p.4).

City of New York, New York

In 2015, New York City (NYC) began a fleet electrification initiative called NYC Clean Fleet, placing 1,224 EVs on the road. The City installed 500 L2 chargers for fleet use, 37 of which are solar carport chargers, and 11 are accessible for public use. In the case of Glendale, the city could use solar carport chargers to power an EV fleet through a sustainable energy source such as solar, saving money, and further reducing emissions (Bitler et al., p.4).

The State of Hawaii

- **Hawaii has been a leader in vehicle electrification, with the second-highest rate of EV adoption in the country and 6,748 EV owners across its islands.** In 2017, Honolulu committed to switching its fleet of 1,900 gas-powered vehicles to EVs and investing $10 million on an electric bus program. Hawaii has created an Electrification of Transportation (EoT) Strategic Roadmap. Included in this roadmap are five short-term goals including
- Increase EV adoption by working with automakers and dealerships to help lower costs and educate customers.
- Accelerate the build-out of EV charging infrastructure, especially in multi-unit dwellings and workplaces.
- Support the electrification of buses and other heavy equipment.
- Incentivize EV charging to align with grid needs and save drivers and utility customers money.
- Coordinate with ongoing grid modernization and planning efforts to smooth integration of EVs into energy delivery networks and maximize renewable resources (Bitler et al., p.4).

Editor's Note
Hawaii's EV program is exemplary because it has the state committed to transitioning its fleet to EVs. It is working to shift the resident and private sector perceptions to change individual practice.

FedEx Company

FedEx has begun transitioning part of its delivery fleet to EVs. As one of the world's largest and most influential transportation companies, FedEx has helped present EVs into its industry. The company was initially motivated by the monetary benefits of EVs, particularly the lower variable cost of charging in comparison to fueling gas vehicles.

While powering their EVs has shown to be less expensive than fueling traditional vehicles, the transition requires a high initial investment that may not hit the breakeven point for a few years or more. Some segments of the EV market (i.e., large, heavy-duty vehicles) can cost up to 3x more than a traditional vehicle; FedEx notes that this is a prohibitive cost. FedEx identified additional fees, such as training their maintenance team on these new vehicle types.

Another challenge identified by FedEx was having enough energy capacity in its facilities to house adequate charging infrastructure. Too many EVs charging in a single facility could cause an electrical overload or unexpected costs related to local energy demand (Bitler et al., p.4).

Climate Mayors Electric Vehicle Collaborative

The Collaborative offers advice on EV fleet transitions and networking opportunities with other cities on topics like staff education, community outreach, and marketing support. Glendale can leverage the Climate Mayors network as a resource during its fleet transition.

Recommendations for Electric Vehicle Usage in Glendale

Strategic Recommendations for Education and Outreach

1. Considering the benefits of the Nissan Leaf vs. the City's existing sedan fleet, the City should convert its sedan fleet to the Nissan Leaf (Bhalloo, Brown, Cramer and Samwick, p.8).
2. Educate and reassure employees about the driving range of EVs and the increasing availability of charging stations in the Phoenix Metro area and across Arizona (Bhalloo et al., p.2).
3. Leverage the EV fleet transition to promote a public image of a new-age, greener city to its residents and other peer communities (Bhalloo et al., p.8).
4. Consider establishing partnerships with EV manufacturers and dealers to negotiate pricing for bulk orders, like the State of Hawaii's EV transition strategy (Bitler, Du, Leftwich, Sanchez Luna, & Shultz, 2019).
5. Incorporate public outreach and marketing into the fleet transition to promote electric vehicle use by citizens (Bitler et al., 2019).

Strategic EV Usage Recommendations

1. Park EVs in shaded and covered areas during extreme temperatures to extend the vehicle's battery life (Rosenberg, Loftus, & Chiesa, p.4).
2. Observe low aggression driving practices when operating EVs because it can extend long-term battery life (Rosenberg et al., p.2).
3. Actively train Glendale fleet-driving employees on mindful driving practices that will extend the battery life (Rosenberg et al., p.2).

Additional Resource Recommendations

Students identified additional resources that may be useful to Glendale staff in crafting their EV fleet transition plan:

1. Drive Clean Seattle electrification initiative, City of Seattle, Washington
    - www.seattle.gov/environment/climate-change/drive-clean-seattle
2. Electrification Coalition; US Conference of Mayors
    - www.usmayors.org/alliance-for-a-sustainable-future
    - www.driveevfleets.org
3. C2ES (Center for Climate and Energy Solutions)
    - www.c2es.org/our-work/mayorsbusiness-alliance-for-a-sustainable-future

Editor's Note

Consider using these resources as well:

- Southwest Energy Efficiency Project (SWEEP)
- NARUC – Electric Vehicles: Key Trends, Issues, and Considerations for State Regulators (10/2019)
- Arizona Corporation Commission EV Policy - at https://docket.images.azcc.gov/0000194370.pdf 2/18/2018
- Suggest City participation in ASU Sustainable Cities Network Solar & Energy Efficiency (SEE) Workgroup discussions
- Recommend the City to participate in AZ EV Stakeholder Group
- APS and SRP EV Charger programs

ELECTRIC VEHICLE CHARGING STATIONS

According to the US Census Bureau, the mean household income in Glendale has risen from $61,964 in 2013 to $65,713 in 2017 (Alhajri, Al-Hajri, Al-Marri, Almarri, & Qarh, p.1). Additionally, with a combination of regional policy changes and market expansion in favor of EVs, it is expected that the cost of EVs will decrease. If these trends continue, more of Glendale's population will be able to consider transitioning their vehicles to EVs (Alhajri et al., p.1). Note that municipal investments in public EV infrastructure have shown to influence the open adoption of EVs (Alhajri et al., p.1). With this information, Glendale can plan its EV fleet transition while considering its relationship with the public and EV ownership. **The first charging stations were underway during the class' research but have been installed for several months since the release of this report.** The students focused on identifying appropriate technologies and prospective future charging station locations for an EV fleet expansion with an emphasis on chargers available for public use.

There are three types (Levels) of publicly available EV chargers, categorized by the rate of charge and voltage.

- **Level 1** chargers are rated at 1.9kW, or 120V at 16 amps. These chargers can be plugged into a household outlet and take between 8 and 12 hours for a full charge.
- **Level 2** chargers are rated at 19.2kW, or 240V at 80 amps. They require a much higher voltage outlet, such as the four-pronged 120/240V style outlets to which washer and dryer units are typically connected. Level 2's can charge most EV batteries in 4 to 6 hours.
- **Level 3** chargers are even faster, requiring a 480V power source. They use a direct current (DC) and generally charge a battery 80% in 30 minutes. These chargers are more expensive than the first two levels and are not compatible with some EV vehicles; thus, they are used less often.

TECHNICAL OVERVIEW OF ELECTRIC VEHICLES

Affordability

Charging stations vary in cost depending on the charging capacity and technology involved. New Jersey conducted a study on the purchasing prices for different levels of charging stations. They found that in general Level 1 chargers cost $300–1,500; Level 2s cost $500–$2,600; Level 3s cost $4,500–$17,000; and Level 4s (not discussed in this report) cost $19,000–$40,000.

In addition to purchasing the unit, installation costs must be factored into the total price of the charger. Installation costs vary depending on the type of charger and any additional wiring. Installation costs increase significantly if new wiring needs to be installed, so locations with appropriate wiring should be prioritized when deciding where to install chargers. Level 1 chargers can be plugged into any standard outlet, so if the charger is placed near an outlet, additional wiring is rarely required. Level 2 chargers require a dedicated circuit board and a 240V outlet. A circuit board will generally require a new wire to be run from the circuit breaker to the charging location unless the location already has access to a dedicated 240V outlet.

The installation cost range of chargers by level:

Type	Existing Wiring	New
Level 1	$200-$400	$4,000-$8,000
Level 2	$300-$500	$5,000-10,000

Table 6 *Installation cost range of EV chargers (Crippen, Goddard, & Pearson, p.4).*

The efficiency of charging depends greatly on the total energy required for each charge. High-energy charging sessions, where full energy transfer in the session is >2kWh, are generally more efficient than low-energy sessions. High-energy charges typically occur overnight, when the car is left charging for hours. Level 1 and 2 chargers perform similarly in high-energy situations. The average efficiency of Level 1 during a high-energy charge is 84.2%, while Level 2 efficiency is 86.5%—a 2.3% reduction. Charging efficiency decreases when ambient temperatures are above 70°F. However, Level 2s respond better to a rise in temperature. The difference between Level 1 and 2 chargers increases to 3.2% when ambient temperatures are above 70oF.

Low-energy charging sessions (<2kWh transfer of energy) are typical at roadside public charging stations where users stop for a short charge during a trip. Low-energy charging is less efficient than high-energy load, and the difference between Level 1s and 2s is much more pronounced in these situations. Level 1s perform with 70.7% efficiency, whereas Level 2s perform with 83.5% efficiency—a 12.8% difference. In situations where a charging session is shorter than 41 minutes, the difference is even more pronounced. Level 2s are 15.8% more efficient in these situations (Crippen et al., p.4-5).

Lifetime

Estimates of charging station lifetimes range from 7–10 years before a unit must be replaced. Many manufacturers provide factory estimates on station lifetimes. Because this technology is relatively new to the mass market, however, lifetime estimates remain challenging to verify via academic literature or industry publications. Factory warranty details may vary by model.

Maintenance

Operations and maintenance costs for EV charging stations include "charges for electricity, software subscriptions, station management, billing, site rental or lease, preventative maintenance, and corrective maintenance" (Crippen et al., p.6). Level 2 chargers are generally more efficient than Level 1s, especially in short-term and low-energy situations. Electricity costs for Level 2s are lower than those of Level 1s.

A smart charger is part of a charging system where electric vehicles, charging stations, and charging operators share data connections. Through smart charging, stations may monitor, manage, and restrict the use of charging devices to optimize energy consumption. Smart chargers incur an additional charge for the network fee. This fee varies among different service providers. An annual fee ranging from $100–$900 is assessed for chargers connected to a wireless network. These are usually exclusive to Level 2 smart chargers and higher.

Maintenance costs vary based on the complexity of the chargers. Level 1s and their components are generally low cost, so maintenance is low. The NEMA (National Electrical Manufacturers Association) outlet used by Level 1 chargers must usually be replaced after several years, which will cost approximately $100. The cord set of the charger is also vulnerable to damage, and replacement costs are around $70. Level 2 chargers are often modular, so any replacement of components does not require replacement of the entire unit. The expenses of parts depend on the unit. The only additional costs that Level 2 chargers may incur are technician fees for networked smart chargers. The owner can do most cleaning and component replacement for Level 1 and 2 chargers. More extensive repairs may require a technician. Level 2 smart chargers will also generally need a technician to perform maintenance.

Level 2 Options Matrix	1	1	1	1	1	5
	75%	10%	5%	5%	5%	100%
Charging Option	**Cost**	**Amperage Capacity**	**Output Power**	**Space required**	**Length of Charging Cable**	**Score**
ChipperCreek HCS-40	76	42	42	100	100	73
ClipperCreek Share2 HCS-60	13	62	54	100	100	29
Juice Box Pro 32	77	52	42	100	96	75
Juice Box Pro 75	64	98	99	100	96	73
Siemens VC30GRYU Versicharge 30-Amp EV Charger	77	39	40	100	56	71
Webasto EV Charger	69	0	40	100	80	63
Bosch EV 220	76	39	40	100	72	72
Bosch EV 410	78	42	42	100	100	75
Bosch EV 620	69	52	53	100	72	68
Bosch EV 810	60	52	40	100	72	61
ChargePoint Hard Wired Station**	74	42	42	100	100	72
PowerCharge P10DW	0	21	18	100	72	12

Figure 6 *Level 2 Charging Station Matrix (Crippen et al., p.7).*

Based on the results of the above matrix, the JuiceBox Pro 32 system and the Bosch EV 410 system are equally recommended as the best two options for the City of Glendale. Both systems are comparatively affordable and competitive in five variables, as examined by the students. An important thing to note from the matrix is that the JuiceBox Pro 75 charging system may not have been quite as affordable as the other two systems. However, it performed above average in all four of the remaining categories. It was not dramatically more expensive than either of the two most recommended systems.

In the decision matrix above, installation costs vary depending on the site and existing wiring. The matrix was unable to code for that variable, so the user will want to manually add installation costs to the current price of each system to utilize this decision matrix fully. That said, for the most part, the Level 2 charging options cost around the same amount to install because of their similar specifications. In addition to improved

performance across the five variables, the JuiceBox Pro 75 offers smart charger technology that could help Glendale better monitor the system, collect data, track usage, and send notifications about vehicle availability and charge levels.

RECOMMENDED CHARGING SYSTEMS FOR GLENDALE

The **JuiceBox Pro 32** Level 2 EV charger is a 32-amp plug-in model with a 24-foot cable. The JuiceBox plugs into a NEMA 14-50 standard RV power outlet and can be used indoor or outside with its waterproof and fireproof metal case.

Level 2 - JuiceBox Pro 32:

Price: $579

Amperage Capacity: 40 Amps

Output Power: 7.7kW

Mounting: Wall

Length of Charging Cable: 24 feet

Figure 7 *Level 2 Charger - JuiceBox Pro 32 (Crippen et al., p.9).*

The **Bosch 410** is an easily movable plug-in with a 25-foot cord. It can charge up to 6 times faster than the standard cord-set that is provided with your electric vehicle.

Level 2 - Bosch EV 410:

Price: $549

Amperage Capacity: 12-32 Amps

Output Power: 7.6kW

Mounting: Wall

Length of Charging Cable: 25 feet

Figure 8 *Level 2 Charger - Botch EV 410 (Crippen et al., p.9).*

The **JuiceBox Pro 75** is considered the most potent and intelligent EVSE: at 75A, the JuiceBox Pro 75 offers to charge speeds to match the Tesla HPWC (dual chargers). It is excellent for both residential or commercial charging. With the JuiceNet software control platform, a person or company can manage to charge with a smartphone. Commercial features include energy metering, fleet control, load sharing, and centralized administration and reporting.

Level 2 - JuiceBox Pro 75:

Price: $899

Amperage Capacity: 75 Amps

Output Power: 18 kW

Mounting: Wall

Length of Charging Cable: 24 feet

Figure 9 *Level 2 Charger - JuiceBox Pro 75 (Crippen et al., p.10).*

ChargePoint Express 200 CPE200 generates revenue, branding, and sustainability opportunities while charging popular electric car models, including Nissan LEAF, BMW i3, Chevrolet BOLT, and SPARK, Volkswagen e-GOLF and all Tesla Models (use of adapter).

Level 3 - ChargePoint Express CPE200:

Price: $35,800

Amperage Capacity: 125 Amps

Output Power: 50kW

Mounting: Pedestal

Length of Charging Cable: 8 feet

Figure 10 *Level 2 Charger - ChargePoint Express CPE200 (Crippen et al., p.10).*

SWOT Analysis Recommending Charging Systems

This strategic planning technique can help organizations or a city identify the strengths, weaknesses, opportunities, and threats when planning a project. This tool for evaluation is for the preliminary stages of a decision making process.

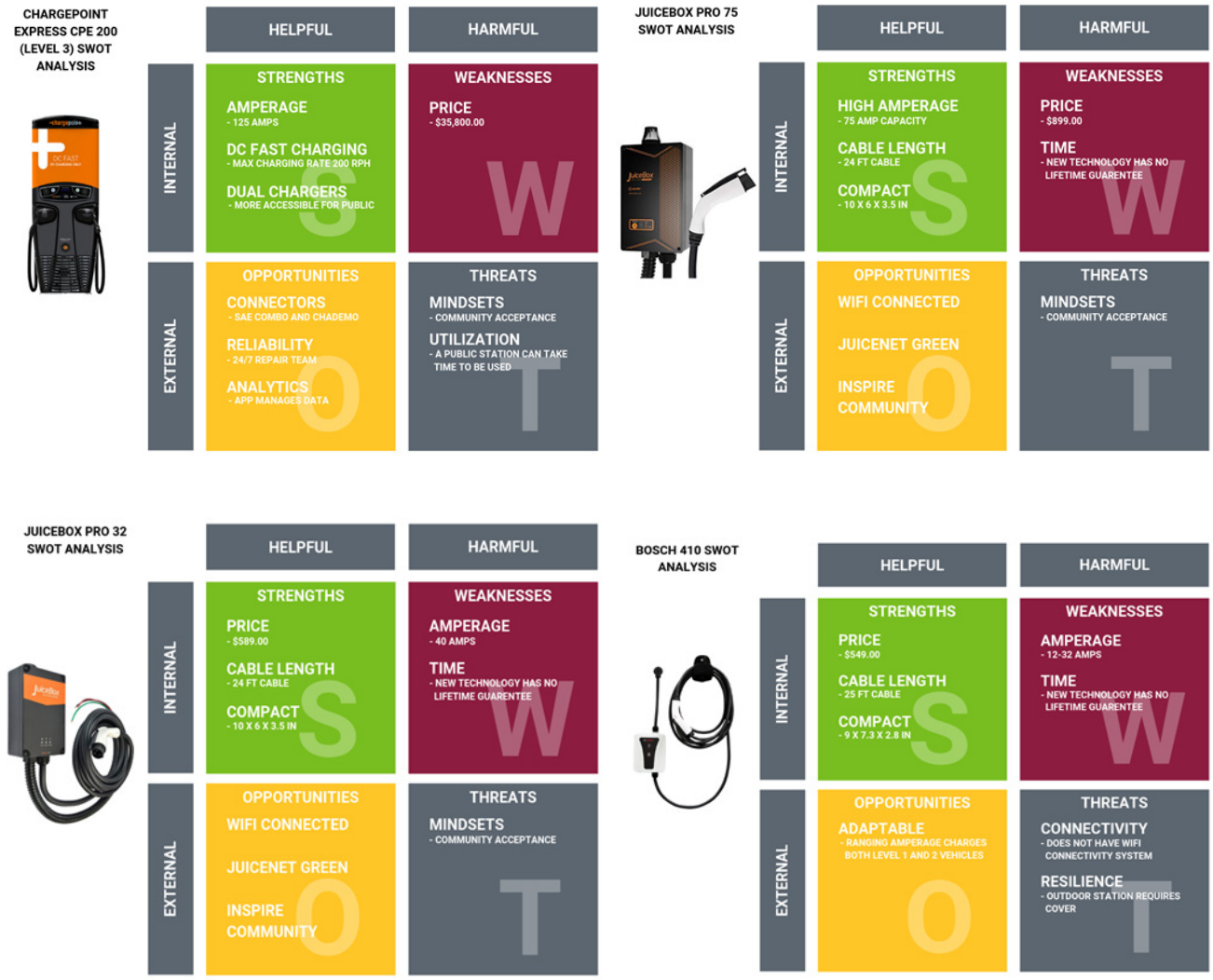


Figure 11 *SWOT Analysis for students' most highly recommended charging systems. Taken directly from student content (Crippen et al., p.12).*

RECOMMENDED CHARGING STATION LOCATIONS

Students recommended EV charging locations central to parks and other public spaces because more people come to areas that offer events, activities, and are day-to-day areas of visitation. Location suggestions include Glendale Community College, Glendale City Hall, and the city's entertainment district. Students conducted a spatial analysis to identify locations allowing residents to spend more leisure time in public spaces. Stations should be in areas of higher stay time, so it is convenient for people to leave their cars charging while away in leisure time. Implementing JuiceBox Pro 75 charging systems would be advisable, as Glendale could leverage its smart-tracking features to collect and assess the system and user behavior. This investment would be strategic in the pilot phase, as it could provide valuable information to facilitate future expansion plans. Installation costs increase significantly if new wiring needs to be installed, so Glendale should prioritize locations with sufficient wiring when choosing locations.

Figure 12 *Strategically placed charging stations enable EV users to take care of other business while their vehicle charges.*

Highlighted Locations:

1. Glendale Public Library on Peoria and 59th Avenue—selected due to factors such as: being city-owned land, having a high frequency of daily visitors that have longer stay-times, and proximity to two major arterial streets.

2. On West Parkside Lane east of North 67th Avenue—selected for its proximity to Thunderbird Conservation Park and Mountain Ridge High School. This location extends the network to the edges of Glendale to the northern part of the city. Primary users would likely be hikers, school students, and faculty. The destinations in the area could provide high stay-time by travelers.

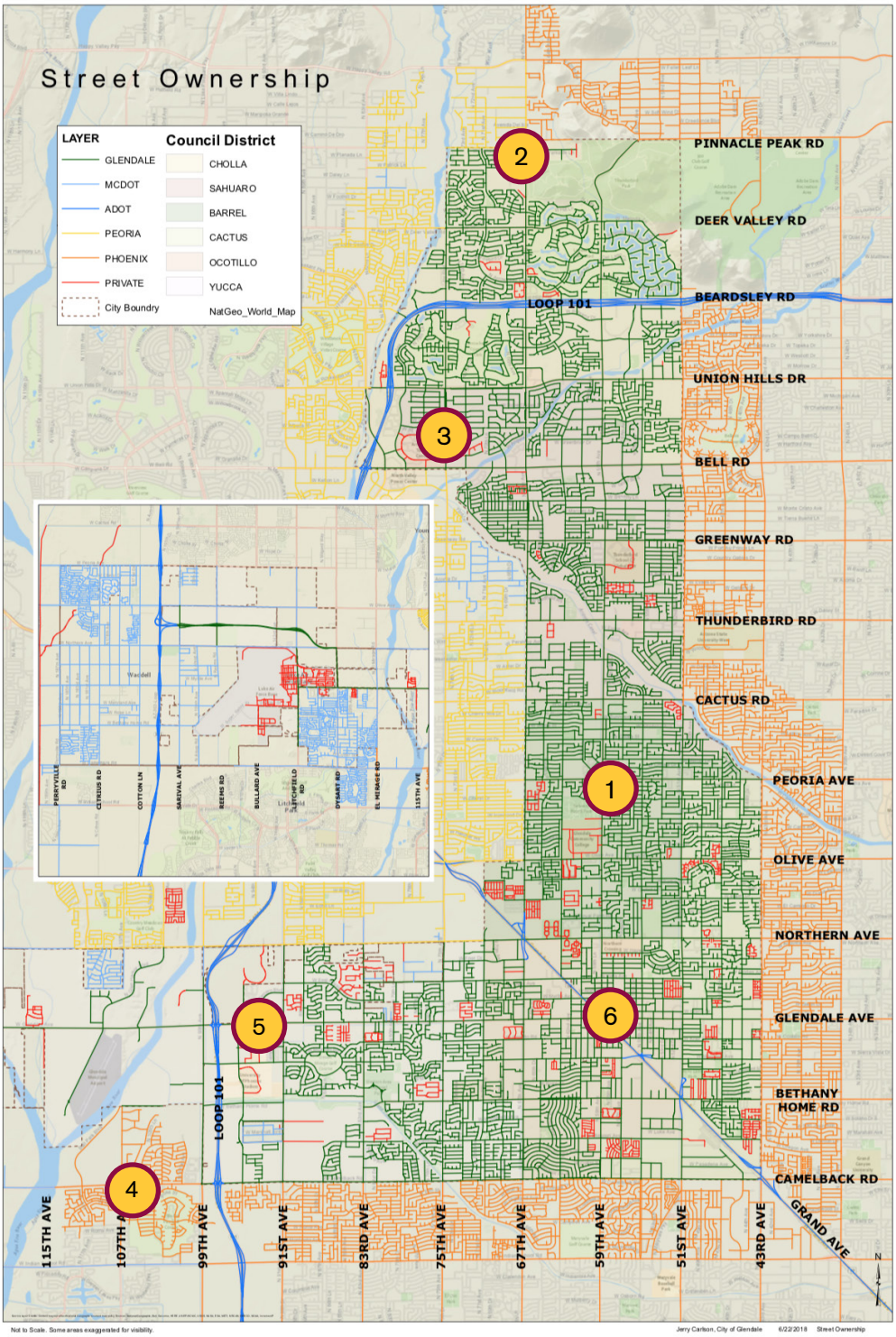
3. The Arrowhead Towne Center shopping location on 75th Avenue and West St. John Road—selected for its access to an arterial street, as well as access to Hidden Meadows Park north of St. John Street and access to the shopping district. This location has high stay-time because of the sizable shopping district and the park.

4. Next to Dust Devil Park on 107th Avenue and Camelback Road—chosen to extend the network south and be close to the park, Camelback Ranch Baseball stadium, and Copper King Elementary School.

5. Near Westgate Entertainment District on West Glendale Avenue and North 91st Avenue—selected for its location on two arterial streets, chosen for its proximity to the 101 Loop, and access to the entertainment district. The presence of ample dining opportunities and a movie theater in the region all but guarantee high stay-times.

6. Glendale City Hall and Murphy Park, on West Glendale Avenue and North 58th Avenue—chosen because they are central to the City and places where residents and employees gather for many hours throughout the day. The Murphy Park location could serve to motivate EV drivers to use the park.

The above locations were chosen because of their potential to stimulate travel to iconic Glendale locations, facilitate longer stay-times, and ultimately create more effective use of the charging stations. The students prioritized shopping districts with movie theaters because EV owners attending movies are more likely to charge their vehicles for longer durations than non-moviegoers. With this same logic, the students did not consider supermarkets and big-box stores such as Wal-Mart or Target, because for those locations to provide a useful EV charging experience, the chargers would need to be high-capacity, fast charging, and therefore more expensive to install.



*Not to scale. Some areas exaggerated for visibility. Jerry Carlson, City of Glendale 6/22/18 Street Ownership.

Figure 13 *Map of the six recommended locations for new EV charging stations in Glendale (Abdulla et al., p.3).*

Appropriate placement of charging infrastructure requires consideration of multiple factors to be successful. A primary consideration students identified is the approximate time it takes for an EV to charge which is different for each kind of charger (Fuhad et al., p.2).

Level 1	Full charge in 8-15 hours
Level 2	Full charge in 3-8 Hours
Level 3	80% charge in 30 minutes

Other data featured in the student report was how many miles on average can an EV drive before it needs to be charged again. The prominent feature of this applied project was that students analyzed data from the City of Glendale, Department of Vehicle Downsizing Analysis, in order to understand the average routine miles driven by municipal employee service vehicles. After analyzing the information from several city departments during the vehicle downsizing weeks, it turned out that the total of miles driven was around 3,300 miles as shown below:

Type	***Miles driven***	***Time period***
Municipal Facilities	1729.5	100 weeks
City Fleet	400	12 weeks
Solid Waste Department	1171	58 weeks

Table 7 *Total miles driven by municipal employee service vehicles.*

Based on this information, the recommended charging station locations are depicted with GIS mapping from the Glendale Arizona Planning Index. Students recommend (Albadain et al., p.5):

- Keep the four current charging stations with no changes in the base, unless the City will increase the number of EVs to the fleet.
- Add one back up charging station just in case the four existing ones have technical issues.
- Implement level 2 public charging stations in public spaces to ensure high activity during the day in mixed use areas.
- Place charging stations near shopping centers, City Hall, Glendale Community College and Glendale Public Library.

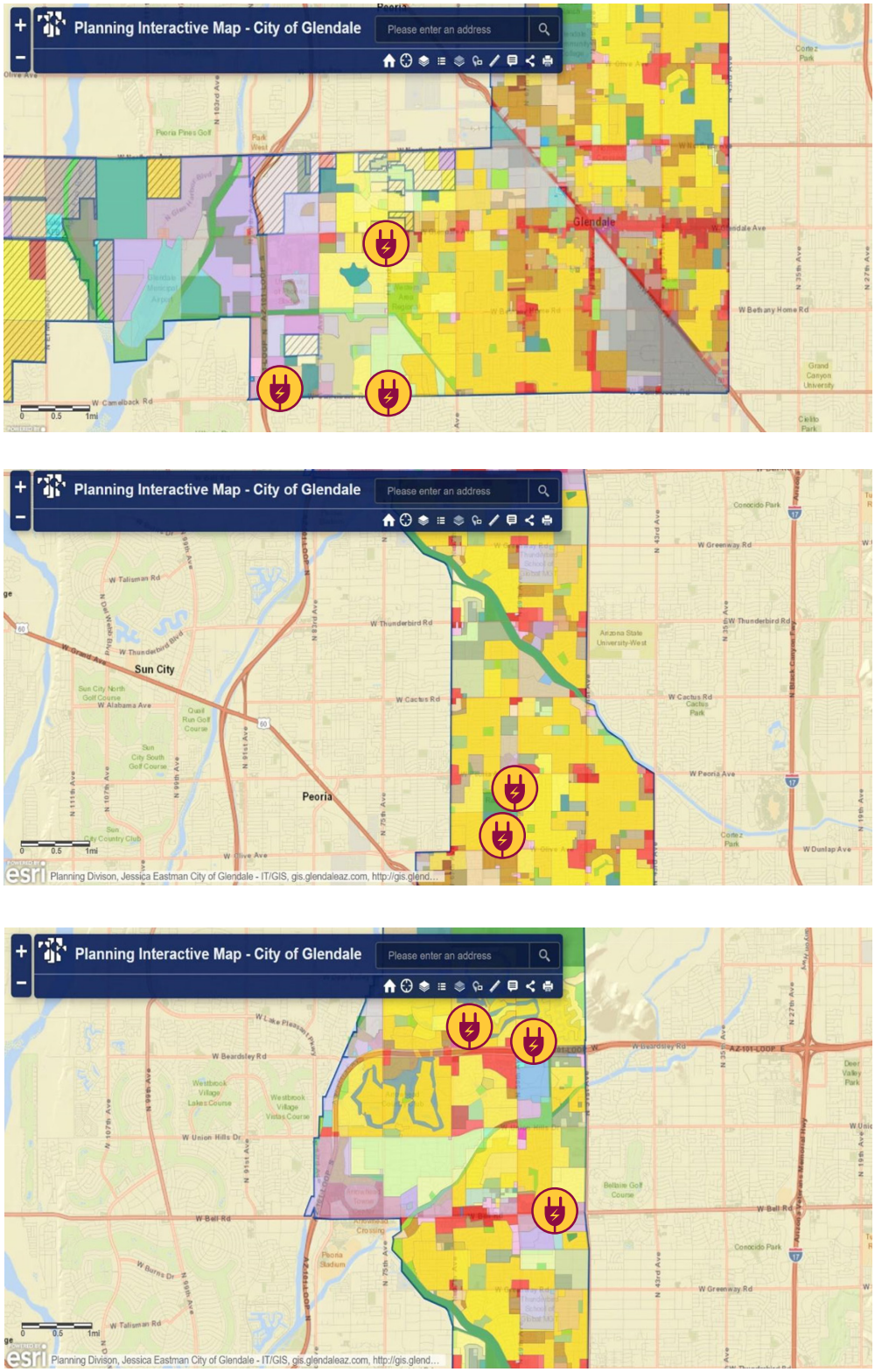


Figure 14 *High Potential Areas for EV Charging Stations with Level 2 Chargers from (Albadain, Alhazza, & Bawazair, p.6-8).*

Recommendations for EV Charging Stations

- Choose a strategic installation of the JuiceBox Pro 75 as it would be the best EV charging device for Glendale to purchase for the first stages of its EV transition.
- Consider the importance of chargers installed in the initial phase of the transition to be easy to use and effective.
- Prioritize versatility and future compatibility of charging stations as the City's EV Fleet will grow and transform over time.
- Gain traction by implementing the JuiceBox Pro 75 system as it has both a higher capacity amperage and output power giving it the ability to serve a broader range of vehicles and charging uses.
- Consider the multi-usefulness of the JuiceBox 75 as it can inform the City of when it is free to use and provide critical data that will help with the expansion of the EV transition program in the future.
- Invest in at least some JuiceBox Pro 75 systems, in order to collect user data and inform the City of Glendale how the chargers are performing. User data will help inform choices the city must make in the future.
- Consider placing EV infrastructure at the locations identified on pages 37 and 39.

Figure 15 *Strategically placed EV charging stations also convey a message to visitors, as a visual manifestation of the community's commitment to sustainability.*

CONCLUSION

Glendale's transition towards an electric fleet marks a commitment to a greener and healthier future for the city. There are numerous benefits to be realized by Glendale's residents and city departments and staff in a fleet electrification initiative. Benefits include reducing carbon emissions that are otherwise produced by gas-powered fleets. Although there is a higher upfront cost to purchase electric vehicles, chargers, and to build the infrastructure, purchasing EVs could save money for municipalities in the long run because they are longer lasting. Many would consider EVs to be more convenient when compared with gas-powered vehicles because they can be charged at home or the business meaning that costs are more predictable. Battery electric vehicles are mechanically much more straightforward than a conventional car because of the updated technology, so they are easier to maintain. For example, drivers do not have to regularly change the motor oil, replace the spark plugs, or worry about engine tune-ups.

Additionally, in a broader sense, EVs help with national energy security by reducing demand and the need for fossil fuel consumption. By developing and implementing a well-informed transition plan, Glendale can reap the benefits of public-private partnerships and develop more positive relationships with citizens. The EV and EV charging industries are rapidly growing and evolving, so it is essential to evaluate the opportunities presented by this research and the other options offered by literature review, businesses and new data from further investigations. If Glendale looks to expand the program in the future, we recommend evaluating options using the criteria presented in the decision matrix.

Figure 16 *Students wave an enthusiastic "hello" to Glendale staff during a virtual meeting, on project orientation day.*

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To access the original student reports, additional materials, and resources, visit:

links.asu.edu/PCGlendaleEVFleet