



City Chrysalis

Using e-bikes to cost-effectively reduce emissions, address inequities, and improve public health.

March 2022



Introduction

City Chrysalis was implemented as a six-month proof of concept in the City of Gilroy, California ('City'). The goal was to demonstrate the intersectional benefits of investing in electric bikes (e-bikes) and supportive infrastructure. The project attempted to displace vehicle miles traveled (VMT), reduce greenhouse gas (GHG) emissions, save participants money, improve physical health, and address unsafe conditions for cyclists in the City.

Combined, the four participants rode nearly 4,300 miles and three of the four participants surpassed 1,000 miles. While the participant pool was small and the proof-of-concept period short, the results were promising. Now, additional field research is needed to validate potentially enormous funding streams related to health and VMT abatement.

Table 1: Summary of Participant Ride Data

Person Number	Total Days Ridden	Total Miles Ridden	Miles Per Person Per Day	Average Miles Per Week
1	152	1,205	7.93	55.49
2	152	1,116	7.34	51.39
3	161	138	0.86	6.00
4	161	1,822	11.32	79.22
Total	626 Days	4,281 mi	6.86 mi	48 mi

The Perils of Single Occupancy Vehicles

According to The National Highway Transportation Survey, more than 20% of vehicle trips are less than one mile, and over 76% are less than ten miles^{1,2}. Trips in single passenger vehicles with internal combustion engines account for 17% of the nation's direct CO₂ emissions; they are the largest source of the country's emissions and a primary contributor to global climate change³.

The country's reliance on personal vehicles for transportation has resulted in its residents not getting enough exercise. The U.S. Department of Transportation (USDOT) declares on their website that: "Almost one in four adults in the United States report that they do not engage in any physical activity outside of their jobs. Sedentary lifestyles are an important reason that two of every three adults in the United States are overweight or obese⁴."

Obesity and sedentary lifestyle are two of the primary risk factors for cardiovascular disease and diabetes, the costliest health afflictions of our time. In the United States, one in seven health care dollars is spent treating diabetes and its complications, at an estimated cost of \$327 billion in 2017⁵. California has the largest diabetic population in the nation, with over half of its residents either diabetic or prediabetic, costing the state \$39.47 billion⁵.

A major barrier to choosing alternate modes of transportation are auto-oriented streetscapes, which are often dangerous for cyclists and pedestrians. For instance, from 2007-2019, an average of 129 Californian's die each year from bicycle accidents⁶. With so many people lacking the means to own a car, unsafe streets are an equity issue that can be found in every city in California.

Despite currently inadequate bike infrastructure, there are several ways cities can improve. The United States Department of Transportation (USDOT) website states: "Investing in public transportation and bicycle and pedestrian facilities creates opportunities for people to exercise. This helps reduce obesity and the risks for developing costly chronic conditions such as diabetes and cardiovascular disease⁷."

For years, doctors and climate scientists have been telling residents and policymakers to ditch cars for alternative modes of transportation. Residents continue to drive because it is more convenient and time efficient than walking, and safer than riding a bike. So far, policymakers have favored solutions like electric vehicles (EV) over active transportation. This keeps roadways auto-oriented and supports the status quo. It's time to invest in alternatives.

The Potential for E-bikes

E-bikes are simply bicycles with an electric motor affixed either at the rear wheel hub or at the cranks which is powered by a rechargeable lithium-ion battery. In 2020, the e-bike industry had a landmark year. Without subsidies or political support, e-bikes outsold electric cars by more than two to one in the US, and forecasts show 100% year over year growth for the next several years⁸. The City Chrysalis pilot highlighted two compelling reasons why e-bikes are positioned for rapid growth:

Cost-effectiveness: An economy class e-bike costs \$2,000-\$3,000, about ten times less than a new economy class vehicle. It costs about \$0.15 to completely charge a dead battery and e-bikes can travel 40-50 miles on a single charge. This results in about 1,000-1,400 miles per gallon equivalent (MPGe), about 56 times more cost-effective than driving a car that gets 25 miles per gallon (MPG). These numbers will improve as gas prices rise.

Inclusivity: E-bikes provide pedal assistance to 20 miles per hour (MPH), making them an attractive form of exercise and transportation for people who do not have the strength or endurance to pedal traditional bicycles up hills, or who do not want to arrive at a destination with visible signs of strain like perspiration. A study of 10,000 adults using different forms of active transportation showed e-bike users exercising more than any other form of transportation and a separate study from UC Davis found that half of e-bike trips displace vehicle trips^{9,10}.

Now is the time to validate key questions, unlock massive new funding streams, and ensure that e-bike industry growth is equitable and benefits vulnerable communities.

Pilot Summary

City Chrysalis outfitted participants with a new e-bike, safety equipment and accessories. They were given bike safety information and an in-person orientation with their new e-bike. Participants were encouraged to ride their e-bikes as much as they could, with a suggested minimum of five miles per week.

Their rides were mapped by GPS to learn which roads and intersections are most used by cyclists in the community. The implementation team monitored ride patterns and basic health metrics, periodically checked in with each participant about where they felt unsafe or inconvenienced, and helped the City identify quick, low-cost projects that improve safety.

Participant Selection

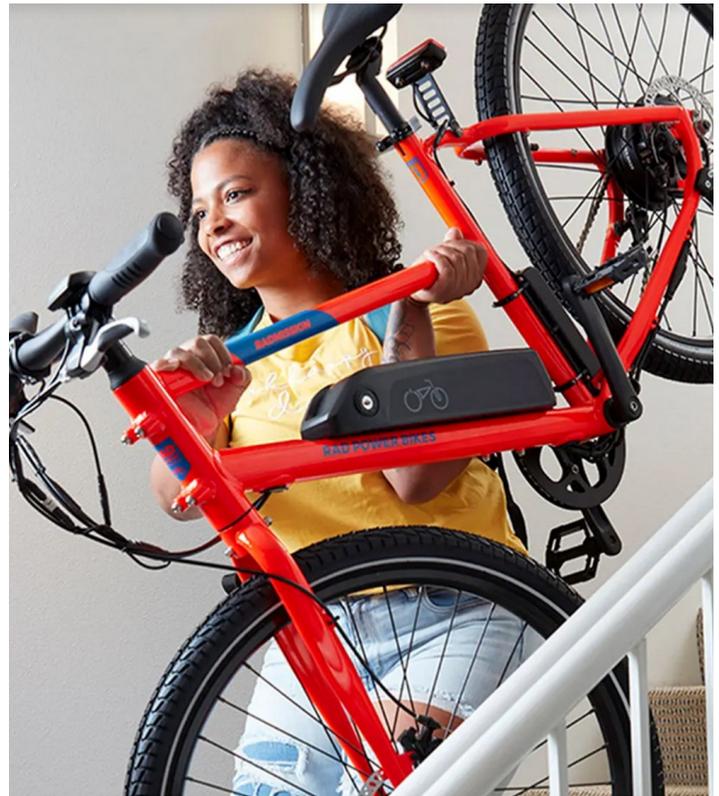
Participants for this project were recruited through local affordable housing operators and social organizers. Locations and introductions were made possible by City Council Member Zach Hilton and members of the Santa Clara County Health Department. The implementation team contacted the managers of several affordable housing apartment complexes, explained the program, and provided them a flyer and survey to share with residents of their complex.

After about a week and a half, more than 30 residents had applied, and the survey was closed. Phone interviews were conducted with the top ten candidates. The project team selected four participants based on their reported travel habits, whether they owned or used a car, and their personal stories. All four participants had preexisting health conditions:

- 73 year old male that is prediabetic, has a metal plate in his leg from bike accident in 2015, had a stroke in 2019, and colon cancer surgery in 2020.
- 65 year old male that is prediabetic and recovering from heart attack and triple bypass surgery in 2020.
- 55 year old male that is diabetic, 330 lbs, and needs reconstructive surgery on both knees. His doctor says he needs to lose 60 lbs before he can undergo knee surgery, but he cannot exercise on a regular bike.
- 46 year old female who regularly drives her SUV behind her family during weekend bicycle outings to the park because she is asthmatic and cannot can keep up.

Technology

Participants had the option of selecting between two e-bike models made by industry leader Rad Power Bikes: RadCity 3 Step-thru or RadCity 4. The team reviewed each model with the participants, helping each person select the best bike based on the size and style of the bike frame. All bikes were class 2 with an adjustable level of pedal assist and an on-demand throttle that provides riders assistance up to 20 MPH. In addition to the e-bike, participants received helmets, u-locks with cables, and pannier storage bags that can be mounted to the integral rear bike rack.



The Boomerang by CycloTrac device was selected to serve a dual purpose of bike security and GPS tracking. The Boomerang was attached to the bike frame and plugged directly into the e-bike battery, allowing it to be charged continuously while the e-bike was on. The Boomerang continuously collected data on speed, distance traveled, elevation change, and time of trip. It also offered useful features such as a participant dashboard and easy data export.

In addition to monitoring the bike, the team also gave each participant a Fitbit Charge 4 health watch to monitor health metrics. Fitbit devices allow users to monitor and interact with their progress through a smart phone application that updates regularly via Bluetooth. It has a low profile, is comfortable to wear, waterproof, and lasts 7-10 days on a single charge. The Fitbit collects data such as resting heart rate, sleep patterns, step counts, and other fitness related data.

Throughout the pilot, the implementation team shared data updates with participants. Personal metrics such as weekly miles ridden and improvements in resting heart rate were highlighted to celebrate success. This was done by text message and direct phone calls.

Technology Package

- RadCity e-bike
- Boomerang CycloTrac
- Helmet
- Pannier bags
- U-lock & cable
- Light
- Fitbit

Results

The proof-of-concept ran from late April through September of 2021; participants logged almost 4,300 miles across hundreds of trips that covered the entire City of Gilroy. The purposes of trips ranged from running daily errands like going to the market and to doctors' appointments, to getting exercise/recreation.

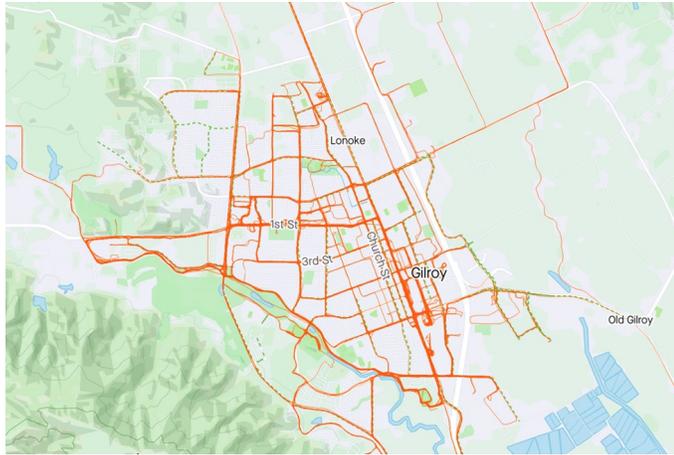


Figure 1: Heatmap showing nearly 4,300 miles of rides from throughout Gilroy, CA from all four participants. The darker orange lines symbolize higher frequency of rides.

Environmental and Economic Impacts: Participants stated that they were able to do many or most of their local trips on their e-bike instead of using their cars, resulting in fuel cost savings and avoided GHGs. Without knowing the percentage of e-bike miles that displaced VMT, it is not possible to establish accurate estimates for GHG and fuel cost savings. However, if the entire 4,281 miles displaced vehicle trips, fuel cost savings across all participants would be approximately \$700 (171 gallons) and 3,209 lbs of CO_{2e} would have been abated.

Health and Wellbeing Impacts: All four participants experienced measurable changes to their resting heart rate. The three people who exceeded 1,000 miles experienced double-digit reductions of 10, 13 and 20 beats per minute.

One participant had weight loss as a personal goal; he reported losing 25 pounds between April 30, 2021 and September 30, 2021. That individual also shared pre and post data on their blood pressure, blood glucose, and hemoglobin A1c with the team. At the start of the project, the person was considered at extreme risk of having a heart attack or a stroke. After six months and 1,100 miles ridden, all three metrics had improved dramatically.

Participants also shared anecdotal impacts that the project had on their lives. For instance, the three participants who exceeded 1,000 miles said that their mental health benefitted, and the bikes have changed their life. Participants reported having a sense of freedom and more confidence after routinely riding their e-bikes. Everyone reported having more energy, stamina, and muscle mass after the first 2 months of riding, and that long rides elevated their mood.

Community Impacts: The participants shared their experiences riding on the streets of Gilroy. Common stories from participants included safety issues such as narrow lane widths and cars not yielding, concerns about bike theft, and lack of bike parking at apartment complexes and other destinations. Their recommendations were passed on to Gilroy City Staff, and when appropriate, to local business owners.

The City was a willing partner; within one week of delivering recommendations to City Staff, the City striped new bike lanes on two of the recommended street locations. One of the streets that was improved is shown below in Figure 2.

The participants also reported locations that lacked bike racks and infrastructure. For example, all four reported being unable to shop at Grocery Outlet because it lacked bike parking. After communicating this to the general manager, he agreed to install a bike rack.



Figure 2: This street was the safest way for one of the participants to leave from and return to her house. Approximately 200 people live at the same apartment complex as the participant. By increasing the width of the bike lane and adding a striped buffer, the city addressed a significant safety concern for approximately several income-qualified residents.

Next Steps: Research to Achieve Equitable Adoption

Historically, clean energy movements like solar, EVs, and energy efficiency have focused on the affluent early adopters who can afford the new technology, instead of the vulnerable communities who could benefit most from being included in the transition. Even more so that other clean energy movements, the potential benefits afforded by e-bikes are greatest among vulnerable communities.

Thus, today’s challenge is finding ways to put e-bikes in the hands of minority communities and low-wage-earning residents who spend disproportionate amounts of their income on transportation and are disproportionately impacted by chronic illnesses such as diabetes and hypertension. The City Chrysalis pilot highlighted two possible ways to accelerate equitable e-bike adoption.

Diabetes and Hypertension Prevention

The Center for Disease Control (CDC) recommends getting 150 minutes of moderate aerobic exercise per week (like riding a bike at a medium pace on flat streets)¹¹. But in auto-oriented cities—which is most of U.S.—many people do not get enough exercise, contributing to widespread health problems such as diabetes and hypertension.

For instance, research from UCLA found that 55% of Californian adults have diabetes or prediabetic conditions¹². In 2020, diabetes accounted for about one-third of outpatient visits and costed California alone \$39.47 billion¹³. The annual estimated cost of diabetes in United States is \$327 billion, with each diabetic patient incurring about \$16,752 in medical expenditures each year¹³.

Furthermore, diabetes does not impact everyone equally. In 2018, 10.5% of Americans had diabetes, but 26.8% of Americans over 65 had diabetes¹⁴. In addition to age, there is also a notable difference in rates of diabetes for different ethnicities and education levels (see Table 2).

Table 2: Demographic Analysis of Diabetes Impacts¹⁵

Education	
Less than High School Education	13.3%
High School	9.7%
More than High School	7.5%
Ethnicity	
American Indian / Alaskan Native	14.7%
White, non-Hispanic	7.5%
Black, non-Hispanic	11.7%
Hispanic	12.5%
Asian	9.2%

In addition to diabetes, high blood pressure (or “hypertension”) is another major health problem in the U.S. About one in three adults—around 75 million—have high blood pressure¹⁶. High blood pressure kills about half a million Americans every year and costs the nation \$48.6 billion annually¹⁶. Moreover, people with lower income levels are significantly more at risk, so much so that every \$25,000 per year increase in income lowers the rate of hypertension occurrence in adults by about 5% nationwide, and 3% in California (see Table 3)¹⁷.

Table 3: Rates of Hypertension by Income Level

Income	<\$25k	\$25-\$49k	\$50k-\$74k	>\$75k
High Blood Pressure Rate (CA)	35.8%	32.4%	29.3%	26.4%
High Blood Pressure Rate (US)	43.8%	38.0%	34.6%	28.9%

For the millions of Americans suffering from health conditions such as diabetes, hypertension and obesity, and those rehabilitating from a knee or hip surgery, a 30-minute e-bike trip 5 days a week would satisfy the CDC’s recommendations for weekly exercise.

Given that the cost savings to an insurance company from one person not becoming diabetic because they regularly ride their e-bike could subsidize e-bikes for several other individuals, it is possible to envision a future where insurance companies prescribe at-risk populations e-bikes, partner with e-bike manufacturers to monitor and encourage usage, and pay for maintenance—all as a preventive measure for chronic illnesses. Senior living centers could lead daily rides for residents and employers could give employees e-bikes for commuting in exchange for savings on the company health insurance policy.

RECOMMENDATION

Given the significant annual cost and the widespread nature of chronic illnesses like diabetes and hypertension, additional research is needed to determine the cost-effectiveness of doctors prescribing and insurance companies paying for e-bikes as a health, wellness and illness prevention measure.

Vehicle Miles Traveled Mitigation

In 2018, the California Senate passed Senate Bill (SB) 743. This new bill requires cities to mitigate the impacts of development by offsetting the VMT created by the project. Under the prior model of mitigating a project’s transportation impacts, developers paid fees to minimize the delays their project created for vehicles. This promoted investments into auto-oriented street design and often compromised safety for cyclists and pedestrians.

Contrary to the prior methods, the new VMT requirements promote investments in public transit, active transportation, and remote work programs. The VMT reductions are valid if

they occur in the same jurisdiction as the project. However, while promising for bike, pedestrian and climate advocates, this shift is confusing cities and developers at a time when the state is trying to double housing production. If this happens, residential development alone could become a trillion dollar per year industry.

To mitigate their project’s VMT, developers could fund e-bike programs for income-qualified residents. Developers can move their projects along quicker, lower income residents can gain access to e-bikes that they could not otherwise afford, and cities can benefit from reduced emissions and VMT. Over time, this could even reduce road maintenance costs .

A sample VMT reduction program’s key assumptions and fees is provided in Table 4. Using conservative assumptions, providing and providing 152 e-bikes to income-qualified residents would fully mitigate the VMT created by a 29-unit housing project in Gilroy, California. The assumptions used for this example may even be conservative—if the results from the City Chrysalis proof-of-concept hold true for multiple years, four e-bikes could provide about 9% of the total VMT needed to mitigate the project impacts. Depending on how effective e-bikes are at displacing VMT, purchasing and giving away e-bikes could be developers’ most cost-effective VMT mitigation measure .

Table 4: VMT Mitigation Assumptions and Fee Calculation

Citywide Average VMT Per Capita	18.92	miles per day
Project VMT Per Capita	18.89	miles per day
Target VMT Per Capita to Satisfy OPR Guidance	16.08	miles per day
Housing Units Proposed	29	single-family homes
Drivers per Household	2.00 ¹⁸	drivers per household
Average E-bike Weekly Usage	15 ¹⁹	miles per bike
Mode Shift Miles	50% ²⁰	of total e-bike miles traveled
Total Annual Miles Created by Project	399,901	miles per year
Threshold of Significance	340,456	miles per year
Annual VMT that Must Be Abated to Mitigate Project VMT	59,445	miles per year
Bikes Needed to Mitigate Project VMT	152	class II e-bikes
E-bike Unit Cost	\$2,500 ²¹	per e-bike
Fee charged to Developer	\$380,000	

RECOMMENDATION

Given the potential for e-bikes to displace VMT, additional research is needed to determine the cost-effectiveness of developers funding e-bike programs as a VMT mitigation measure.

End Notes

- https://nhts.ornl.gov/tables09/fatcat/2009/vt_TRPMILES.html
- <https://www.next10.org/publications/2020-gii>
- <https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions>
- <https://www.transportation.gov/mission/health/active-transportation>
- <https://www.diabetes.org/resources/statistics/cost-diabetes>
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- <https://electrek.co/2021/06/29/the-affordable-electric-vehicles-outselling-electric-cars-around-the-world/>
- <https://electrek.co/2019/08/11/electric-bike-riders-more-exercise-than-cyclists/>
- <https://escholarship.org/uc/item/3mm040km>
- <https://www.cdc.gov/physicalactivity/basics/adults/index.htm>
- <https://www.uclahealth.org/u-magazine/majority-of-california-adults-have-prediabetes-or-diabetes>
- <https://www.diabetes.org/resources/statistics/cost-diabetes>
- <https://www.diabetes.org/resources/statistics/statistics-about-diabetes>
- <https://www.cdc.gov/diabetes/library/reports/reportcard/national-state-diabetes-trends.html>
- <https://www.cdc.gov/bloodpressure/facts.htm>
- https://www.americashealthrankings.org/explore/annual/measure/Hypertension/population/hypertension_50_74k/state/CA
- Assuming two drivers per household; should be amended for local context.
- Fifteen miles per bike per week is 30% of the City Chrysalis pilot’s average of 48 miles per bike per week.
- This figure is from the UC Davis study linked in footnote 10.

About Outthink

Outthink is a consulting company that focuses at the intersection of technology, policy and market strategy to accelerate an equitable zero-carbon future. Outthink works with mission-aligned clients to make the world better. Learn more at <https://out-think.com/>.

Additional Information

Pilot funding was provided by the Silicon Valley Clean Energy (SVCE) Innovation Onramp program. SVCE is a not-for-profit, community-owned agency providing clean electricity from renewable and carbon-free sources to 13 Santa Clara County jurisdictions. Learn more at <https://www.svcleanenergy.org/>.