Can Electric 2-Wheelers Play a Substantial Role in Reducing CO_2 Emissions?

—The Report of Electric Bicycle Usage of Western US Residents

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ABSTRACT

Through this project, we interviewed 27 e-bikers in Sacramento-Davis area and found that there are four benefits unique to the riding of e-bikes: Speed, Acceleration, Green, and Enabling. They are fast so that e-bikers can cut down their commute time and allow them to ride more frequently than if they ride traditional bikes, especially during hot and windy days. The ease of acceleration makes obeying stop signs or riding uphill less onerous and provides e-bikers with more confidence when only vehicle lanes are available to bikers. They also provide those who, for various reasons, don't or can't ride traditional bikes an option for green transportation. Finally, they enable people with certain disabilities, because of illness or aging or time constraint, to continue to bike, with the help of electric motors when needed. The barriers to the expansion of e-bike ridership are Cost ($1,500 on average), Heavy weight, Infrastructure (unsafe roads and communities, and lack of emergency charging), and policy (some bike lanes are not open to e-bikes). However, those barriers can be overcome with some small government and business interventions.

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INTRODUCTION

Worldwide, electric bicycles (e-bikes) sales were projected to reach around 30 million in 2010, with China accounting for 25 million or 83 percent of the total (Jamerson and Benjamin). However, according to Chinese media, in 2010, China produced a total of 29.54 million e-bikes. Chinese experts expected that by 2012, China will have 200 million e-bikes (Xinhua News 2011).

In some countries (most notably China) e-bikes are relatively inexpensive and make up a significant portion of transportation mode share, especially in cities (Weinert et al. 2006; Weinert et al. 2008). They are faster and require less physical exertion than a traditional bicycle and are more maneuverable and less costly than a personal automobile. In the extremely densely populated settings where they are most common, traffic congestion means this agility is an important asset in terms of reducing trip times. They also don't require gasoline, and since they are a light vehicle with a low power demand, recharging them is within the budget of many people. Riding e-bikes is a more environment-friendly travel mode than driving, according to the findings of a recent research (Cherry et al. 2009). E-bikes emit substantially less pollution per kilometer than cars based on life-cycle emissions analysis.

In the United States, e-bikes are far less widely utilized. The small size and maneuverability that are such assets in China are perceived as less valuable here, where a much higher proportion of the population has personal vehicles, road speeds tend to be higher on average, and infrastructure is almost hostile to slower modes of transportation. Under these conditions, being one of the smallest, lightest vehicles on the road may lead to a perception of the e-bike as unacceptably unsafe. Additionally, the population is more dispersed and land use is generally less dense, meaning that very few American cities have similar characteristics to the cities where e-bikes are most common in China. In the United States, the e-bike, like all non-auto modes, must struggle against decades of auto-centric development. However, some of its characteristics may allow it to appeal to certain population groups, specifically the aging Baby Boomers, for whom the traditional bicycle is becoming increasingly ill-suited, and possibly allow it to serve as a light duty automobile alternative in situations that are not as acceptable for a traditional bike.

Some early adopters have started using e-bikes for (primarily) transportation and recreation in the United States. Our research team conducted twenty seven interviews in the greater Sacramento area to glean some understanding about the attitudes and experiences of these individuals. Many participants had interesting comments about the way they use their e-bikes,

the feedback they've gotten from their peers and family members, the factors that limit their usage and the reasons that caused them to choose to invest in an e-bike. While each participant had a unique perspective, there were several clear themes that emerged, which could help shed some light on the opportunities and challenges for introducing e-bikes as part of the American transportation solution.

Characteristics of the E-bikes and Batteries

Most of our respondents use e-bikes from two companies, Pedego and BionX. The main difference between these two companies is that Bionx also sells e-bike kits that can be installed on most conventional bicycles, whereas Pedego only sells new e-bikes. The characteristics of the most popular e-bikes from these two companies are listed in table 1.

Table 1. Characteristics of the E-bikes and Batteries

	Pedego[1] Classic Comfort Cruiser	BionX[1] Compact/Power/Premium Series
Batteries	Lithium	Lithium
Amps	10 Ah Standard/Optional 15 Ah	9.6/9.6/8.8 Ah
Volts	36 Volt	26/37/48 Volt
Speed	20 MPH	25 MPH
Range	15 - 30 miles[2]	40/56/65 miles (65/90/105 km)[3]
Weight	Bicycle =55 lbs Battery Pack=6 lbs	Motor =10 lbs (4.7kg) Battery=8 lbs or more (3.7kg)
Motor	500 Watt	250/350/350 Watt
Price	$1795.00	$1195.00-$2195.00

1. Source: Practical Cycle website (http://practicalcycle.com/index.php), BionX website (http://www.bionx.ca/en/)
2. It depends on the rider's weight and terrain.
3. Maximum range per battery charge is based on assistance mode level 1, under ideal conditions. Distances will vary depending on road- conditions, cyclist weight, and assistance required.

METHODOLOGY

This report seeks to explore the experiences and attitudes of current e-bike (e-bike) users in the greater Sacramento area, specifically in Sacramento and Davis. Given the time and financial constraint that prevented a large-scale survey in two-months, only qualitative methods were used to analyze the transcripts of interviews to identify commonly mentioned themes and ideas.

Two main methods were employed to recruit people who are e-bike users. First, volunteers were recruited for the interviews primarily by distributing fliers at local businesses that sell e-bikes. The proprietors were asked to pass on the research team's contact information to customers who had bought an e-bike from them. Second, snowball sampling method, i.e. asking a respondent to refer other people who also fit the research requirements, was used to recruit more respondents. All participants we interviewed were then asked if they knew other e-bike users who may be interested in participating. A $20.00 gift card to Target was offered as an incentive to each participant.

Through these methods, 27 participants were recruited. Twenty four of the interviews took place in-person, the remaining three over the telephone. The interviews were conducted at various locations, including some participants' offices and homes, university facilities, and coffee shops. The interviews took between approximately 20 and 45 minutes and were recorded using an mp3 recorder. For most interviews, two members of the research team were present, though four were conducted by only one researcher. All interviews were based on the same set of guiding questions. Most of the questions were open ended, but some asked for specific quantitative information.

The research team transcribed all of the recordings after the interviews had been completed. All transcript files were shared among the research team, and one researcher wrote a preliminary, non-exhaustive list of common themes which was shared, discussed, and supplemented by the rest of the team. Respondent answers to the quantitative questions were compiled into an Excel spreadsheet, and examined for patterns.

PRELIMINARY SURVEY RESULTS

Totally 27 people were surveyed in Sacramento area, all in the cities of Sacramento and Davis. According to their responses, descriptive characteristics of these electric bicycle users were analyzed, as well as their travel behaviors. Additionally, the factors influencing the usage of e-bikes as described by e-bike users were documented. Further, the use of e-bikes by these participants was summarized.

Sample Descriptive Characteristics

Socio-demographic characteristics of the e-bike users we interviewed are shown in Table 2. We also compare these attributes of the participants to California's latest census data. It shows that only 37% of the participants are females, which is much less than the percentage of females (50.3%) in population, implying that relatively more e-bike users in our research are males. People who are 65 years old or over account for a higher percentage (22.2%) in our survey than that (11.4%) of population, indicating that older people are more likely to be e-bike users. One possible reason is that e-bikes may provide easier mobility for older people, a point which was frequently mentioned in their decisions to choose an e-bike. These e-bike users are also found to have higher education and household income levels, which are usually closely correlated. On the one hand, e-bikes, which on average cost US$ 1,500, are relatively expensive. On the other hand, highly educated people tend to be more environmentally friendly, thus, are more likely to choose an environment-friendly transportation mode including e-bikes.

The characteristics of e-bike users in our research can thus be described as the group of people who are more likely to be at middle-age or over and highly educated males with higher income.

Table 2. Comparison of Socio-demographic Characteristics of E-bike Users in Sacramento Area with Census Data

	Number	Females %	Age			Education		Mean HH* size (s.d.)	Median HH* income (s.d.)
			20--34	35-64	>=65	>=High School	>=Bachelor		
CA census	37,253,956[1]	50.3%[1]			11.4%[1]	80.5%[2]	29.7%[2]	2.91[2]	$58925[3]
Survey	27	37.0%	14.8%	63.0%	22.2%	100%	77.8%	2.6 (1.6)	$72708.3 (30395.3)

[1]2010 census data

[2]2005-2009 census data

[3]2009 census data
Cite: http://quickfacts.census.gov/qfd/states/06000.html

Travel Behaviors of E-Bike Users

The participants were asked to report the days and approximate miles they rode e-bikes in an average week with good weather. For the respondents who have regular access to a car, the current weekly days of driving were also reported. Survey questions also focus on trip purposes by e-bike and the change of driving behavior after riding an e-bike. We summarized the e-biking and driving behaviors of the participants in Table 3.

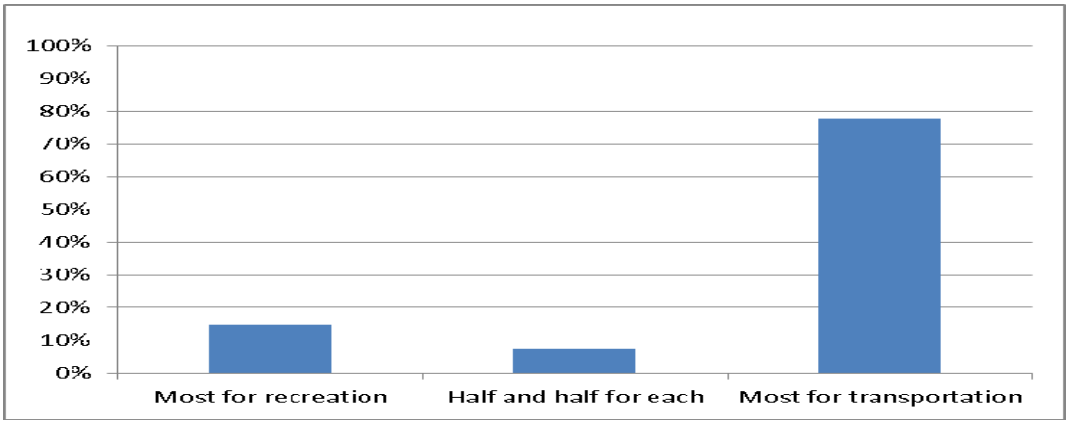
On average, these e-bike users ride e-bikes more frequently (4.26 days/week) than driving a car (2.76 days/week). However, the usages of e-bikes are various. Some people only use it occasionally, e.g. once a week, or ride it for shorter distance destinations; some ride e-bikes more often and travel for longer distances.

Table 3. Travel Behavior of E-Biker Users in a Typical Week

	Days e-biking	Miles e-biking	Days driving
Number of people reported	27	25	25
Minimum	1	2	0
Maximum	7	140	7
Mean	4.26	44.04	2.76
Std. Deviation	1.89	34.18	2.20

The purposes of e-bike trips are categorized into two general groups, transportation (including commuting, shopping, visiting people) and recreation (exercise, pleasure rides, adventure). The participants reported their portion (0-100%) of their e-bike rides for the two categories of purpose. Figure 1 shows that a very high percentage of people interviewed (77.8%) stated that they ride e-bikes mostly for transportation purpose. 37 percent said that they ride exclusively for transportation purposes. Several respondents indicated that they had changed the usage of e-bikes from recreation, which was the reason they first purchased the product, to transportation, after they found it convenient, safe and fun to ride. This finding may suggest that unlike regular bicycles, which are viewed as a recreational tool for many Americans, the bike with an electric motor on it is treated more as a tool to reach relatively long-distance destinations with the faster and easier mobility it provides.

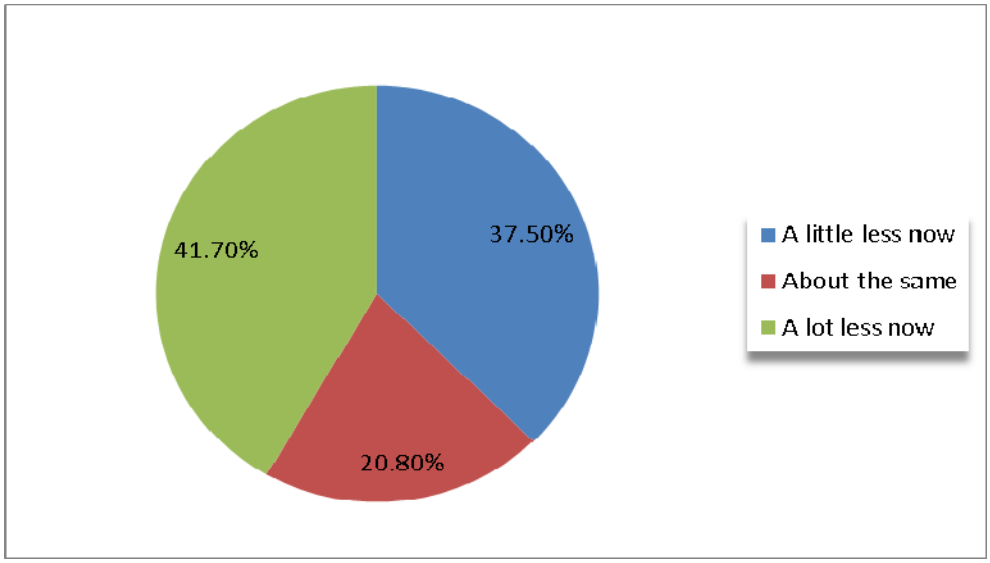
Figure 1 Trip Purpose by E-Bike



Further, whether the usage of an e-bike can fully or partly substitute driving was examined by asking change of the driving behaviors of the respondents after they receive an e-bike. Not

surprisingly, a higher percentage (79.2%) of people stated that they drive a lot less or a little less now compared with the time when they did not get an e-bike. Only 20.8% of them drive about the same as before (Figure 2). Even so, many of these people used to be regular bicyclists before they got an e-bike.

Figure 2 Change of Driving Behavior of E-Bike Users after Riding an E-Bike



Factors Influencing E-Bike Usage

Themes Identified By Respondents: Benefits

There were several themes that emerged repeatedly in the participant interviews, and many of them were instances of wide agreement of the positive aspects of e-bikes, which make the e-bike attractive and encourage the users to ride them more. They can be summarized as SAGE: Speed, Acceleration, Green, and Enabling.

Speed

The first and most obvious advantage over a conventional bicycle is that the e-bike is faster (per unit of rider effort). While this seems extremely simple, respondents described a whole range of implications for this fact. First and most common, the users noted that the faster speed allowed them to cut down their commute time. For some people, e-bikes allowed them to ride their bike to work more frequently than they might otherwise, due to time constraints. Multiple respondents

expressed that they got a new job or a new housing situation and initially rode their bike to work. After discovering the time and effort implications of continuing biking, they began using their cars. Investing in the e-bike was seen as a way (usually motivated by pro-environmental values) to enable a bicycle commute.

Acceleration

Another oft-cited advantage of the e-bike is acceleration. E-bikes allowed their riders to negotiate traffic conditions and regulations. Many of the respondents noted that their ability to travel around 20 to 25 miles an hour made them more confident on the occasions that their travel route requires them to occupy a vehicle lane, as opposed to a bike lane or path. The pedal assist or throttle of the e-bike also makes obeying stop signs or going uphill less onerous. Respondents mentioned that the ability to use the throttle to accelerate quickly out of a stop sign reduced the time it took for them to traverse downtown areas, where stop signs are frequent, made them less worried about making cars waiting for them impatient, and greatly decreased the physical effort needed to start from a complete stop.

All of these factors were seen as enabling the e-bike to interact, on the road, more like an automobile. It was repeatedly mentioned that these advantages were magnified by the fact that the current traffic rules and road facilities are overwhelmingly designed to accommodate cars. In this way, and due to the aforementioned implications of greater speed, e-bikes are well suited to the particular American transportation challenges presented by auto-centric design and relatively low density land use. The e-bike can function, in some ways, more like a car, without losing some of the environmental and economic benefits of a bicycle.

Green

The other category of advantages that respondents described had to do with their attitudes and desires, instead of the ways that it eases the logistics of transportation. Many respondents looked into the e-bike specifically so that they could meet their goals that were motivated by their environmental values to drive their cars less frequently. They specifically cited desires not to burn gas, which contributes to global warming and poor local air quality. It is fair to say that a major portion of the respondents were people with extant environmental values (but no specific attachment to bicycling), who invested in e-bikes because it was their best option for low-environmental-impact transportation. Another major group, though, were people who were

already bicycle enthusiasts and were trying to shift some of their remaining car trips to the bicycle. Adding an e-bike to the family's possessions allowed some respondents to get rid of one or multiple cars, since the e-bike expands the types of trips that can be completed on bicycle, with some motorized help. Respondents in both of these categories were very likely to note, unprompted, that one of the things they like most about the e-bike is it's fun. There were a few respondents who did use their e-bikes exclusively for recreation (3.8%), but even those who purchased one for pragmatic transportation reasons often mentioned how enjoyable the e-bike is to ride.

Enabling

Bicycle advocates must remember that all of the potential advantages of shifting more trips to the bicycle mode are essentially only open to the very able-bodied. This is also true, to some extent with automobiles, so clearly any transportation mosaic that truly aspires toward equity and accommodation of all user groups, including the disabled, should have a sizable public transportation element. However, some of the respondents to our interviews pointed out the ways in which the e-bike enables people with certain disabilities or symptoms of aging to begin or continue participating in bicycle transportation. One participant has a nerve disorder that limits her ability to ride a conventional bicycle. She has obligations at the UC Davis campus and around Davis, and finds that even with a handicapped parking tag, it is difficult to find parking close enough to her buildings to meet her various time constraints. When UC Davis opted to focus so much of its energy on making biking convenient, it was also, in practice, creating a campus environment that was convenient primarily for able bodied people. The e-bike allows her to participate in that and fulfill her desire to use her car less frequently to save on parking costs. More encouraging for potential e-bikers in other regions, some respondents mentioned that acceleration helps when riding up hills and bridges.

Several respondents who were long-time bike commuters found their commute had become difficult as they grew older and began to have knee and back pains or other physical issues. They invested in e-bikes to help them continue to receive the benefits they see in bicycle commuting. The e-bike was described as being particularly helpful in alleviating the pain and effort required to start from a dead stop, and in allowing the riders to carry more of their belongings. It was also noted that the decreased physical effort to cover the distance from home to work (in particular) meant that e-bike riders are able to arrive at their destination and not be particularly sweaty, or require shower facilities. These advantages are notable in the ways that they allow users to avoid some of the usual explanations offered by people as to why they are unwilling to commute by bike. Female respondents, in particular, were likely to note the importance of being able to arrive

to their workplace and not be as disheveled as if they had ridden a conventional bicycle. They could ride back home without motor assistance and take shower. For doctors and nurses who have access to shower at work, they could bike to work in the morning and return home with motor assistance after a long and exhaustive day (The Sacramento Bee, 2011). This may represent another way that the electric bicycle could help make bicycling possible for new groups of people in an increasingly aging society.

Themes Identified By Respondents: Barriers

Respondents also talked about the ways in which their e-bikes were less than ideal for their uses, the external challenges to using their e-bikes more frequently, and the factors that people they talked to cited as barriers to getting e-bikes of their own. These themes were remarkably consistent across the board, but to the extent that they varied, it seemed that certain factors played a larger role according to whether the participant lived inside Davis or elsewhere in the Sacramento Area. Those factors can be summarized as CHIP: Cost, Heavy Weight, Infrastructure, and Policy.

Cost

The main barrier to buying an e-bike that the respondents reported hearing from their family and peers is cost. In the Sacramento area, e-bikes sold at dealerships start at around $1,500, including e-bikes that are electric conversion kits installed on a bicycle the customer already owns. There are some kits available on the internet that are less expensive, but require some technical knowledge to install. Additionally, if less expensive assembled models are found on the internet, the difference in cost is usually a product of the fact that battery life is shorter or the battery chemistry is less advanced and batteries are heavier per unit of charge. In China, e-bikes with lithium batteries start at roughly the equivalent of $ 470. While these particular models may not be perfectly suited to the American setting for the aforementioned reasons, it is clear that bringing the cost down could be possible, particularly if a substantial market for e-bikes is emerging. Due to the high cost, respondents often expressed that theft of their e-bike was a cause for concern.

Heavy Weight

The weight of the e-bike was mentioned as a negative factor across all groups of participants, but especially prominently among women and older respondents. The fact that the motor and battery

pack add about 50 pounds to the weight of the bicycle caused some respondents to have trouble maneuvering the bike with the motor off, such as when they are trying to park it, or lock it into a rack. The weight also contributed to the already often expressed issue of range anxiety. Participants mentioned that the fact that the bike is very heavy means that once the battery dies the e-bike does not simply function as a regular bike, but instead takes a great deal of effort to pedal. This is another way in which the needs of American e-bike users are affected by the generally less dense land use and longer commute distances; less expensive models with shorter battery life will not be as appropriate in this setting.

Infrastructure

Many participants also mentioned that despite the increase in speed and acceleration, they still felt unsafe interacting on the road with cars, in many settings. This particular complaint was more common among respondents who do not live and work (or attend school) in Davis, a city known for bike-friendly. Respondents were asked if infrastructure improvements to their commonly used routes would increase the frequency of their e-biking. Among Davis participants, most people expressed that infrastructure was adequate, and was not limiting their e-biking frequency. Among respondents outside of Davis, lack of access to safe facilities was often described as a limiting factor. Some respondents also described altering their routes to work so as to avoid excessive interaction with automobiles.

Beside road facilities, safe and e-bike/bicycle friendly community or neighborhood is also a key factor that works positively on participants' e-biking/biking behavior. Most Davis participants emphasized that the town is nice to bike; with convenient facilities, bike-friendly drivers, and safe neighborhood. Respondents in Sacramento area worried about homeless people and other elements that might pose unwanted intrusions when e-bikers stopped at intersections. They had changed their e-bike routes or turned to driving facing potential threats. Several participants said they were very cautious and nervous when they crossed the traffic, since car drivers usually ignored them.

The charging station for e-bikes is another infrastructure improvement that almost all the respondents expect. Because of the range anxiety, the respondents carefully calculate their battery range. This reduces the fun and frequency of riding e-bikes for transportation and recreation purposes. Providing charging stations will encourage people to use more e-bikes.

Policy

A few respondents mentioned one specific policy that they would like to see changed, to better accommodate e-bikes. Currently, California state law prohibits e-bikes from using Class One separated bike paths. Cities can override this law to allow e-bike-use within their jurisdiction and several Davis respondents are involved in a campaign for the change. In Davis, on-road routes between locations in the city are often much longer and perceived as less safe than routes that involve some time on Class One bike paths. Several of these respondents noted, however, that operating at the maximum possible speed of the e-bike (current models are governed at 20 mph) would be inappropriate on these facilities, and may be scary or unsafe for pedestrian and non-electric bicycle users, especially on the bike-crowded routes. Fifteen mile per hour speed limits already exist for these paths, and if enforcement is consistent and signs are more prevalent, these paths should be safe for both bikers and e-bikers.

Future Use of Electric Bicycle

Most participants stated that they would use e-bikes more. Many of the users feel that the more they e-bike, the more likely they will use e-bikes for their trips. Incentives such as subsidies given by employers to e-biking and biking to work, or at-the-pump gas price increases to $6/gallon (E-bikes are much more popular in Europe), or improving the infrastructure on the routes from home to work to increase safety, comfort, and range-confidence for e-biking, or simply finding ways to reduce the cost of e-bikes, or some combination of these measures.

Furthermore, as a reflection of the aging of Baby-Boomers, some participants we interviewed saw the e-bike primarily as a tool for transportation, as opposed to recreation (shown in Figure 1). Most of them described using the e-bike as an “equalizer” allowing them to keep up with a spouse, friend or family member who is a faster cyclist. This widely held perception (about the e-bikes being primarily for transportation) among the interview participants seems to run counter to dominant idea in the general population that a bicycle is primarily for exercise or recreation. When the participants were asked what their families, peers and colleagues thought about their e-biking, though some viewed as “interesting” and “cool,” a very common response was that they were told using a bike with an electric motor was “cheating.” If the primary purpose of a bicycle is indeed to get exercise, then this contention makes sense. However, it makes no sense when talking about something that is primarily a transportation vehicle; it would seem ludicrous to most people to make the suggestion that using a motorized car was “cheating.”

One participant, who sells e-bikes, eloquently expressed his frustration with this perception of bikes and e-bikes as recreational equipment.

> "I know a lot of people view them as toys, and recreational equipment. I wish people would take it a little more seriously. This is transportation. They come in and laugh and say, maybe when I'm old. And then put their 5,000 dollar carbon bike on the back of your SUV because you're too scared to ride on the road. And you call that a road bike. It's like, come on, let me change your life. I'll give you an e-bike, a real one with some big fat tires on it so you can take the potholes, and you don't have to show up all sweaty and you really can take this seriously as an alternate form of transportation."

This information may indicate that the market for e-bikes is a subset of the portion of the population that views bicycling as a legitimate form of transportation, instead of recreation. This involves public education in the Unite State, where cycling should not only limit to recreation and exercise. Our participants have proven the feasibility of biking for transportation. Expanding this perception is likely an important step to increasing bicycle mode share in general; the advantages of e-bikes that were identified by participants also have potential to expand the subgroups for whom using a bicycle as transportation is feasible. Therefore, improving conditions for conventional bikers is just as important as for e-bikers. A bike-friendly community is in general an e-bike friendly one.

ECONOMICS AND CO_2 EMISSIONS

We compare the fuel cost and CO_2 emissions between e-bikes and cars used for two different daily trips, one between Sacramento and Davis (15 miles) and the other within the city (5 miles). We don't consider motorcycles, because motorcycles were never a consideration in our respondents' decision for their transportation mode. Two-third of the e-bikers we have interviewed said that they ride e-bikes for at least four days a week and 85 percent of them use e-bikes for transportation or for both transportation and recreation. On average, 67 percent of those interviewed ride e-bikes for 5 miles or more per day; 44 percent for 10 miles or more, and 22 percent for 20 miles or more.

Table 4. Assumptions and Sources

Assumptions and Sources	Value	Unit
PG&E: 0.524 lbs CO_2 per kWh	0.524	lbs/kWh
USEPA: Burning 1 gallon of gasoline produces 19.4 lbs CO_2	19.4	lbs/galon
C. Cherry, etc: A standard electric bike requires about 2.1 kWh/100 km or	29.59	miles/kWh
A standard car can go 27.5 miles per galon (current CAFE)	27.5	miles/galon
Average gas price as of 10/31/2011 in Sacramento (Costco+Chevron)/2	$3.74	$/kWh
Average electricity cost per bill of PG&E in August in Davis	$0.123	$/kWh
Distance between Davis and Sacramento	15	miles
Distance within the City	5	miles

Based on the assumptions listed in Table 4, we can conclude that while riding e-bikes presents substantial economic savings, its environmental benefits are even more significant (Table 5). Rather than subsidizing electric vehicles, a targeted, small incentive for e-bikes could reap a much larger CO_2 emissions reduction in California and in the United States. Utilities could also provide programs that disperse the initial cost of e-bikes with a higher first year electricity rate or arrange to purchase e-bikes in large quantity from cheap sources with discount price. In the end, e-bikes provide new and welcome business for them, given the fact that many of the batteries will be charged during the off-peak period of the day.

Table 5. Fuel Cost and CO_2 Emissions for Daily Round Trips, e-Bike vs. Car

Distance	Round Trip per Day		200 Days per Year		300 Days per Year	
	by Car	By e-Bike	By Car	By e-Bike	By Car	By e-Bike
15 Miles	$4.08	$0.12	$816	$25	$1,224	$37
5 Miles	$1.36	$0.04	$272	$8	$408	$12
CO2, lbs per Year						
15 Miles	21	0.53	4233	106	6349	159
5 Miles	7	0.18	1411	35	2116	53

CONCLUSIONS AND DISCUSSIONS

From the interviews in the Sacramento-Davis area, we found that potentials for developing the e-bike as a new transportation method in the United States is high. In our 27 interviews, all the participants felt safe, confident and comfortable when riding e-bikes. Most respondents expressed that they will use e-bikes more in the future. The increase in speed and acceleration bring e-bike owners more fun when they are on road. Those who use e-bikes for commuting could avoid sweat when they arrive at work and they can continue to exercise when they pedal back with motor-off and take shower at home. These are key characters which encourage

respondents to ride more for transportation. For those people with certain disabilities or symptoms of aging or physical discomfort on long range cycling, e-bike offers an ideal choice to begin or continue or even extend their participation in bicycle riding. These advantages are notable in the ways to involve more people using e-bike for either transportation or recreation.

Price and technology limitations are two main obstacles that stand in e-bike development. All the respondents agree that the price becomes an obstruction. Even to those owners, the price forces them pay extra attention on the e-bike, as safety and weather issues. The current technology on battery and weight are two main topics that respondents discussed a lot. Since e-bikes can be heavy when they are trying to pedal it without electricity assistance, respondents expressed anxiety on battery range and life. This prevents them using e-bike for longer rides. The need to pay close attention on battery usage also reduces the enjoyment of riding an e-bike. Heavy weight is talked about among women and older respondents, who have trouble maneuvering the bike with motor off. In addition, attached cargo or large basket is an improvement on e-bike that the interviewers hoped, which may also increase their use frequency.

Another serious topic is on the weather influence. It surprises us that most participants enjoy riding their e-bike in hot and windy weather, because they do not need to pedal hard as they do with regular bikes. For extremely hot weather, several people will change to drive. However, almost all the e-bike owners avoided e-biking on raining days. They did not want the battery and motor kit to be wet or wringing, which they believed may cause damages to e-bikes. Again, the high cost of e-bikes forces owners paying more attention on them. Furthermore, the quick acceleration and speed could get riders and e-bike itself mucked up, which is probably hard to clean up. This could mean that e-bikes work better in sunny, dry area. But due to the location limitation, there is no feedback on how people use e-bike when it is cold or snowing.

An interesting finding is that many e-bike users we interviewed still ride their regular bicycles occasionally. The notion that bicycle is for exercise is popular among many Americans. Most people choose e-bikes mainly for transportation purpose because it provides a faster and easier way to get to destinations. Furthermore, most participants think driving is still necessary and indispensable for carrying heavy or big loads, and for traveling far distances, although they agreed that e-bikes can substitute driving to some extent by running small errands, or going to some destinations too long for bicycling.

However, there are examples, in the world, of e-bikes constituting a significant portion of mode share. These examples differ in important ways from the transportation environment in the United States. The participants in this interview process illuminated several ways in which e-bike technology, infrastructure and attitudes affect the feasibility of e-bike usage here. They also suggested that e-bikes could be an important tool for expanding the groups of people for whom bicycling for transportation is feasible. There are not yet enough e-bikes on the roads to find meaningful data on how e-bikes interact with conventional bicycles, but at the current concentration there do not seem to be frequent conflicts. In the American setting, efforts to promote and provide infrastructure for e-bikes specifically, may only be minimally necessary. The best market for e-bikes seems to be people who are already interested in bicycling for transportation or for low impact transportation in general. The most important steps to achieving more e-bike mode share are probably to lower the initial cost, continue promoting and providing infrastructure for conventional bicycling, and possibly increasing awareness of e-bikes' existence and potential benefits.

Given the positive externalities e-bikes bring about—good for environment as well as reducing the traffic congestion—encouraging e-bike usage may be an effective complementary way for developing sustainable communities in the U.S. There are several parts where the Government can make progress on, that would increase the possibility and frequency of more people using e-bikes/bikes. The facilities, including parking racks, charging stations, and pavement situations, are the preconditions. Well designed facilities provide convenience for riding, which will encourage people to change from driving to e-biking or even biking. Given the relatively fast speed of e-bikes, respondents have high requirement on the smoothness of pavement in bike paths/lanes. Legal use of bike paths is a policy-related issue that the Government can resolve. Meanwhile, maximum speed (15 mph) should be enforced consistently on the paths, and this could guarantee safe interaction among e-bikers, bikers and pedestrians. For long term improvement on bicycle and e-bike friendly community, drivers' awareness of riders is key. Public education, including emphasis on bicycle as a transportation mode, could inspire more people biking/e-biking in the future.

FUTURE RESEARCH NEEDED

Research on e-biking behavior in the U.S is limited, particularly in comparison with the recent explosion of studies on bicycling. Academically, this study tries to fill this important gap in the transportation research field, but more importantly, it sheds some light on the potential of e-biking in the United States by offering valuable insights into the importance of socio-demographical, attitudinal, infrastructure, and other factors including policies in explaining the usage of the e-bike. Obviously, this is just the first step, additional research is badly needed. First, a larger sample of e-bike users and perhaps non-e-bike users is needed to explore more

representative attributes of the population who may ride e-bikes in place of cars if certain conditions are met. Second, the significant role of individual attitudes shown in the interviews also suggests a need for further cultural and behavioral probe, e.g. why do some people like e-bikes and others don't? What leads to greater comfort riding an e-bike? Third, potential relationships between some social factors need to be further explored. Can a bicycle-friendly community like Davis also accommodate and welcome e-biking? Short of technology breakthrough in battery range and cost, is there anything else a community can do to promote e-biking as a transportation mode? The answers to these questions will help policy makers to identify special needs of e-bike users and provide effective and comprehensive strategies for sustainable transportation.

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