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Eco Hub Green Fueling Station

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The Eco Hub Green Fueling Station

Introduction: The Climate Issue and Our Solution

The warming of our planet and the subsequent environmental disasters is a problem felt by the inhabitants of our entire globe. Yet, despite its global effects, climate change has the potential to be mitigated by local and regional efforts. Because one of the biggest sectors of greenhouse gas emissions is transportation, influencing local drivers to invest in low-carbon vehicles can drastically reduce the collective amount of carbon dioxide emitted into the atmosphere. To give drivers the incentive to invest in electric and hydrogen fueled vehicles and to provide current eco-drivers with resources to sustain their low-carbon lifestyle, we plan to implement an "Eco Hub" fueling station that will serve as an electric and potentially a hydrogen service port for both local drivers within Davis and regional drivers passing through the area.

How Our Project Addresses Climate Change

The Eco Hub Green Fueling Station will be the first of its kind, offering exclusively green fueling options in the form of electric battery chargers as well as the potential for hydrogen fuel cell charging. It will be located just south of Interstate 80, off of Old Davis Road, and is a prime location to provide easy access for commuters along I-80 and serve as a promotional opportunity for the UC Davis campus and its low-carbon initiatives.

In addition to green fueling stations, the site will provide educational, recreational, and retail options for visitors to enjoy. Thus, our Eco-hub represents both a technological as well as a behavioral climate solution. It is technological in that it will implement relatively new green technology (such as clean vehicle fueling, permeable pavement, etc) and will provide clean energy resources for those who it. In addition, our solution is behavioral in that it aims to incentivize drivers to change their lifestyles and adopt greener transportation methods by providing them with the resources to do so. Thus, our Eco Hub represents a local solution that addresses a global problem.

Background Literature and Information

Campus Energy Supply and Process

Currently, UC Davis's energy supply consists of natural gas, electricity from the grid, and electricity produced on-site via solar farms and bio-digesters. However, the campus acquires most of its electricity from outsourced utility companies such as WAPA, PGE, and SMUD. As of 2008, the electricity supply used by the campus was broken down into 45 percent natural gas, 17 percent coal, 15 percent nuclear, 13 percent hydropower, 2 percent biomass, 2 percent wind, and 1 percent solar (Sustainable 2nd Century 2016). All three utility companies are subject to the Renewables Portfolio Standard which, under Executive Order S-14-08, has a target of 33 percent renewable energy use by 2020 (UC Davis Climate

Action Plan 2010). Currently, electricity that would be used for charging EVs costs about 12 cents per kWh. How these costs apply to our Eco-Hub fueling station will depend on energy demand based on local and regional traffic.

Traffic Demand

The Eco Hub will have to meet the demand of a number of drivers, including those within Davis and throughout the greater Davis area who are commuting to campus. Additionally, there is the hope that the Eco Hub will be a transit stop for many travelers coming from the greater Bay area to Lake Tahoe, just an hour outside of Davis. Skiing is an incredibly popular activity and provides quite a lot of traffic to the Tahoe area. It is our belief that people making this drive with plug in hybrids, electric vehicles, or hydrogen fuel cell cars could make use of our eco-fueling station.

In the greater Davis area, more than two thirds of the daily commuters come from within 20 miles of Davis. This includes about 6000 daily drivers from areas such as Roseville, Rocklin, Folsom and the North Bay (Campus Tomorrow 2015). As EV sales continue to grow, we expect that many people driving electric vehicles would use the Eco Hub on their way to campus. New car sales in California are projected to be 67.5% electric by 2025 (EV Adoption 2018), and an initiative proposed by Jerry Brown expects to see 5 million electric vehicles on California's roads by 2030 (Dillon 2018). Therefore, we expect that about 7% of the vehicles on the road by 2025 would be electric. With reasonable growth in the school's population and increases in the faculty and staff, the daily commuters to campus from the greater Davis area is expected to raise from 6,000 to 6,750. With these growth predictions, along with the predicted increase in EVs on the road, we expect there to be about 400-500 EV's parking and using the Eco Hub on a daily and weekly basis coming from the greater Davis area.

In addition to daily commuters, we expect to see an increase in resident parkers as well. Both the Orchard Park Housing complex and the additional student housing in West Village that will be built next year are going to require allocated parking in the lots of the Eco Hub. These spots will be for student and family parkers using their cars every day or student parkers who are just storing their vehicles during the week with the intent of using them on the weekend. In total, there are about 5,000 residents expected from these new housing complexes, and 60% of these residents will own vehicles. Of those whom own vehicles, about 50% will be parking at the Eco Hub, for a total of 1500 vehicles requiring parking. The amount of these cars expected to be electric is difficult to estimate using the EV predictions for all of California, because the focus group is made up of undergraduate and graduate students who are, on average, less wealthy than employed faculty commuters. Therefore it is predicted that of the 1500 remote site vehicles parking in the Eco Hub from Orchard Park and West Village, 3.5% will be electric, giving us a total of 50 EV's from Orchard Park and West Village housing.

Broadening the scope from outside of the city of Davis and UC Davis students, this Eco Hub will attract long-distance travelers and commuters as well. The main commute patterns analyzed for the demand of this hub will be: Sacramento/San Francisco Bay Area, Lake Tahoe/San Francisco Bay Area, and Vacaville/Sacramento, to and from each area. In order to find data on commute numbers for people traveling these routes, we contacted graduate student Wei Ji from the Plug-in Hybrid and Electric Vehicle Research Center at UC Davis. She suggested the *OnTheMap* program, which uses the United States census data to provide the Longitudinal Employer-Household Dynamics (LEHD) Origin-Destination Employment Statistics, or LODES, dataset structure. This program was used by setting Sacramento as the home destination to see where residents in the Sacramento metropolitan core-based statistical area (CBSA) commute to for work and vice-versa. Three different regions were analyzed: Sacramento

(Sacramento, Yolo, El Dorado, and Placer counties), San Francisco (San Francisco, Alameda, Contra Costa, San Mateo, and Marin counties), Vacaville (Solano county), and Stockton (San Joaquin county). Data obtained from this program is presented in Appendix Table 1. These commuter numbers were then combined with the percentage of electric vehicles owned in those regions to calculate the number of EVs commuting through Davis. EV ownership was based off of numbers obtained from the California Clean Vehicle Rebate Project (See Appendix Table 2).

Since these are current estimates, and estimates for the years 2020, 2025, and 2030 were needed, population projections were obtained county-by-county from the California Department of Finance to get a combined projected population for the region (See Appendix Table 3). In order to put these projected population numbers into tangible numbers of projected electric vehicles, the following equations were used:

(total count from onthemap.ces.census.gov) / (total population) = X
(X)(projected populations) = new total commuter count
(new commuter count) x (percentage of residents → Sac) = commuters from region → Sac
(Commuters to Sac) x (percentage of electric vehicles from that region) = commuting EVs
Vice-versa for Sacramento area residents commuting to southern regions

The results of these equations for commuters heading to Sacramento for work are presented in Table 4, and commuters from the Sacramento heading South for work are presented in Table 5. Once combined, these tables provided totals for electric vehicles projected to commute through Davis through 2030 (in Table 6).

Drivers commuting to work are not the only traffic demographic passing through Davis—there are great recreational opportunities all around, but most notably is the traffic from the Bay Area to Lake Tahoe (these projected numbers are given in Table 7). To obtain these numbers, the following equations were used:

(current number of visitors) / (Bay Area population) = X
(X)(projected Bay Area population) = projected Tahoe visitors from Bay Area
Consider carpool: (projected Tahoe visitors from Bay Area) / 2.5 = cars to Tahoe
(cars to tahoe) x (% EVs in Bay Area) = Projected # of EVs traveling to Tahoe

Work commuters were calculated in daily amounts, but Lake Tahoe data was provided as annual estimates. To make this uniform, the daily visitors to Lake Tahoe in EVs from the Bay Area was divided by 365 to provide a daily amount (which of course would vary in actuality because of the varying demands in different times of the year). These daily commuter numbers are presented in Table 8.

Gil Tal also supplied a GIS tool that can provide a location and anticipated demand for EV infrastructure based on a market location. This tool was used to create a sample map with the example suggested in the tool's instructions of a 20% increase for EV demand (Figure 1). The map provides a good visualization of where demand of EVs will be growing, and projected numbers based off of the 20% increase given as a suggestion are included in Table 9 (including both work commuters and Tahoe travelers separately).

Energy Demand

There are currently around 58 electric vehicle charging stations scattered around the entire campus and West Village that accommodate the approximately 100-200 electric vehicles driving to and from UC Davis. However, by 2020, the estimated number of electric vehicles utilizing campus chargers is projected to increase to approximately 1500. Currently, most stations only have one charger per lot, and all of them have a 4-hour maximum charge time. The limited amount of chargers per station and the short amount of charging time is not ideal for long-term and overnight parkers. In addition, the sparse distribution makes them unrealistic to be found and used by traveling corridor drivers. Thus, a centralized eco hub will greatly serve customers who want to park overnight and have their cars reliably charged by our eco-service. Travelers passing through the corridor will have access to the easy-to-find hub with abundant chargers, allowing them to relax as they charge their vehicle and utilize our projected museum and retail center.

Ideally, our Eco-hub would contain two types of electric vehicle chargers: Level 2 and Level 3 (also known as DC Fast-Chargers). Level 2 chargers supply 240v of AC charging between 15 and 40 amps, which is typical of a household oven or electric dryer. They allow for a wide range of charging speeds up to 19.2 kWh and take about 4-6 hours to achieve a complete charge. Given that we will expect about 400-500 electric vehicles commuting to and from campus per day in addition to the 50 long term parkers from Orchard Park and West village in 2020, we would aim to install about 100-150 Level 2 chargers initially, with the potential to gradually increase to 300 by 2025.

In addition to those commuting to campus, our Eco-Hub would serve as a charging station for those traveling through the I-80 corridor. Given that there are about 1073 EV drivers per day commuting to and from Sacramento from Vacaville, the Bay Area, Stockton, and San Francisco and about 4 EV drivers per day commuting to and from the Bay Area to the greater Lake Tahoe region, we would expect to install about 5 Level 3 DC fast-chargers that allow travelers to utilize our commercial space as their car charges within 30 minutes.

These charging stations would significantly increase UC Davis's electricity use and would therefore require additional construction of renewable energy sources (ideally solar panels at the site) given that the average electric vehicle needs about 30 kwh to power it for 100 miles (which is most cars maximum range). In order to estimate the average energy demand of the Eco Hub facility, two scenarios were looked at in detail. The first uses a 6.6 kW vehicle power acceptance rate, and estimates that each vehicle utilizing a Level 2 charger would charge 4 hours per day for 4 days per week and would utilize about 5, 490 kWh per year. This number is not likely, given that not every driver will need to charge every day, but it gives us a good idea of what the maximum energy demand could be.

The second scenario uses a 48 kW power level for a DC fast charger and estimates that each vehicle would charge 20 minutes per day 7 days per week and require 5,639 kWh per year. Again, this number is unlikely as it assumes that a vehicle driving through the corridor from the Bay Area to Sacramento, for example, would be doing this commute every day. However, these numbers give us maximum possible energy demands and allow us to provide accurate estimations for the implementation of the Eco Hub.

Implementation

EV Charging Regulations and Impacts

The proposed project involves the construction of a Green Transit Hub that will feature electric vehicle (EV) charging stations and hydrogen fueling stations. The most common types of electric vehicles that are currently being used by consumers are: plug-in electric hybrids, extended range electric vehicles, battery electric vehicles, and hydrogen fuel cell vehicles. The several fueling options that are being considered at the Eco Hub for these types of vehicles are Level 2 electric vehicle chargers, DC fast chargers, and hydrogen fuel. These green fueling options have several safety standards associated with each of them.

Table 10 in the appendix provides a summary of the industry standards for the 3 EV charging levels identified by the Electric Power Research institute (ERPI) and released by the Society of Automotive Engineers (SAE), SAE Standard: J 1772 (NFPA, 2011). The table summary was found in a presentation provided by the National Fire Protection Association's (NFPA) Technology and Safety assessment from October 2011, which was prepared by the California Polytechnic University in San Luis Obispo.

As for spacing standards regarding electric vehicle charging stations and parking spaces, Table 11 in the appendix contains the minimum number of EV charging stations by type that are required to comply with section 11B-8121 of the 2016 California building code. The information was obtained from the California State Architect website.

For the layout of EV chargers and parking spaces in relation to normal parking spaces, the building codes for the State of California have many scoping requirements from IB-201 to IB-812. The full list can be found in the link to the State Architect Website in the references section. Some of the major requirements include a minimum width of 144'' for a van accessible EV charging parking space and a 108'' minimum width for a standard EV charging parking space. A no parking space of 60'' minimum must be placed between the two. However, there is an exception where EV chargers which serve more than one EV charging station can be adjacent to, and within the combined projected width of the vehicles being served.(2016, CA building code) Also, vehicle spaces and access aisles must be designed so that the people using them are not required to travel behind vehicle spaces or parking spaces aside from the space where their vehicle is charging.(2016, CA building code)

Some of the potential impacts of EV charging stations on the grid include the following: The need for a battery meter and a consumption meter. An energy management system with charging and discharging regulations would also be need as well as a chord and plug supply connection with an amperage limit. In addition, charging station types would have to be considered since there are three main connector types, which are, Tesla, Nissan, and everyone else.

Moving forward, Noel Crisostomo suggests using a smart charging system to network the level 2 and fast chargers with a good grid network. Using ISO standards, the smart chargers would communicate with the vehicles to ask for codes, billing information, and session info to get full conformity. ISO would act as a translator between the charger and the vehicle to authenticate the information. It could also be used to reduce cost and avoid undercharging vehicles by negotiating between the station and the vehicle to pay for more charge by time user expects to leave. This is more practical and convenient than the current system where EV owners have to download a multitude of files onto their vehicle or carry physical identification cards to access the EV charger in order to charge their cars.

Hydrogen Safety and Regulations

Hydrogen fuel falls under similar regulations to other fuels, such as liquid petroleum fuels. Hydrogen safety regulations are organized in a hierarchy with a decreasing order of importance from Fire and building codes to Hydrogen-specific codes to component standards and equipment design codes being at the bottom of the hierarchy. Table 12 in the appendix contains the order of preference for the size of a hydrogen system in relation to its location in units of roman numerals.

Table 13 in the appendix contains the maximum total amount of liquefied hydrogen storage permitted in units of gallons. The order of preference for the location of liquefied hydrogen storage, determined by the maximum total quantity of liquefied hydrogen, is indicated by Roman numerals. Lastly, Table 14 shows the minimum distance in feet from liquefied hydrogen systems to exposure.

CEQA and Potential Environmental Impacts

According to Matt Dulcich, the Director of Environmental Planning at UC Davis, the campus has one overarching Long-Range Development Plan (LRDP) for the University. The previous LRDP was adopted in 2003, and the most recent version will be adopted by July of this year. Included in the LRDP are broad goals for future development on campus, which include the land for the proposed green transit hub.

Since the land is owned by UC Davis, which is located in the state of California, the proposed project is subject to CEQA, the California Environmental Quality Act. The two-step LRDP will have its own EIR, while the project design will have a separate EIR. The EIRs will most likely be program type EIRs with a cumulative impact analysis. The lead agency for the project would be the University of California Davis, and the responsible agencies would include the Yolo-Solano air quality district and would involve air quality permits for equipment, like a backup generator and the construction vehicles. Also, the project would likely not qualify for any statutory or categorical exemptions due to its large size.

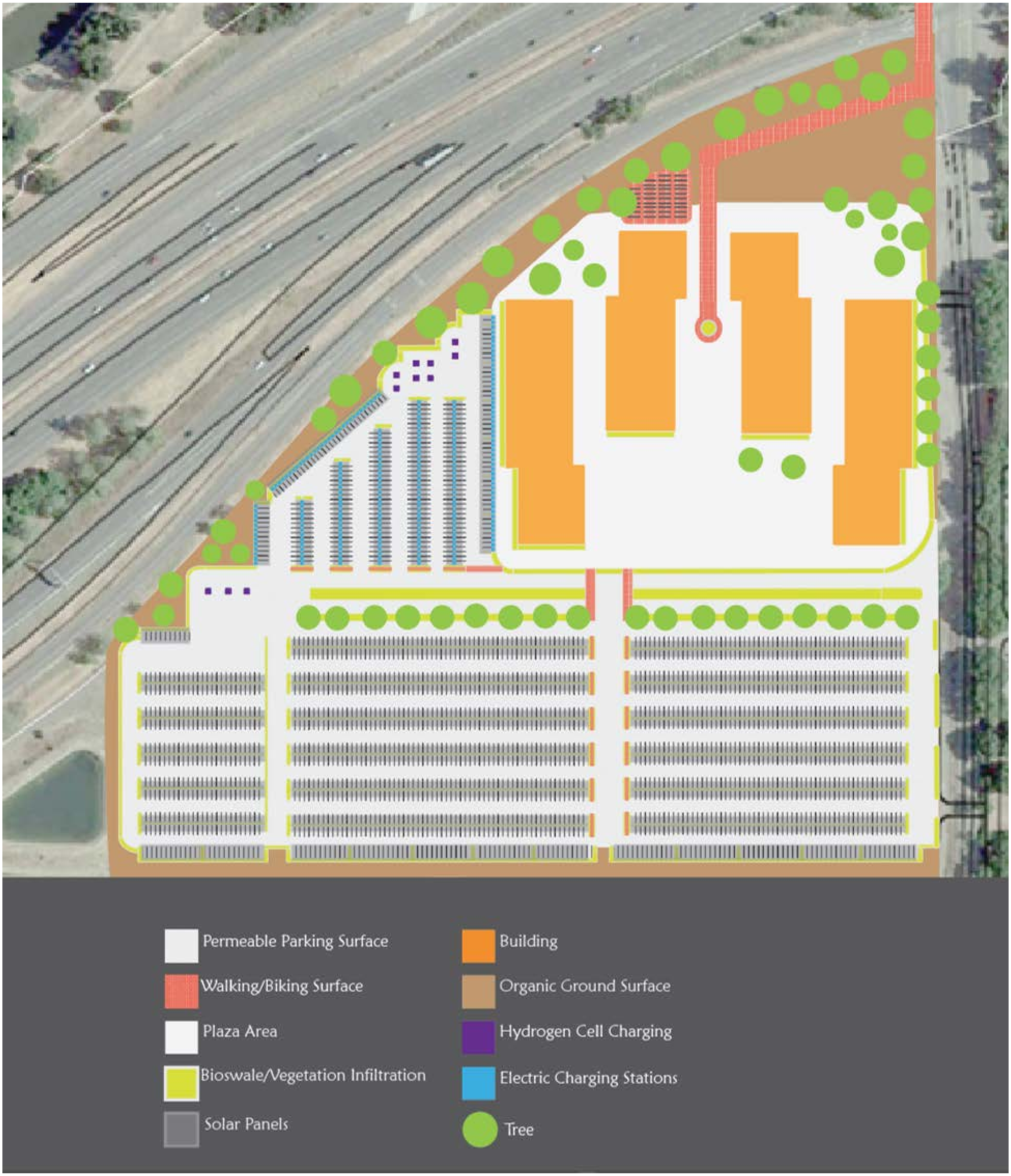
As for environmental impacts, Matt states that there is not anything particularly sensitive in the area. However, the loss of the prime farmland will need to be mitigated, and this resource topic will be covered in the LRDP. Some of the other major impacts to consider would be water quality and storm water runoff from the project site as well as impacts on aesthetics since the site is located next to the freeway. Site surveys would be conducted by separate consulting firms for the different environmental resources like biological and cultural resources.

Design

Planning to locate the Eco Hub South of I-80 on Old Davis road, this parking area will be a reclusive oasis for visitors and campus commuters. The design of the site takes into consideration the charging times of electric vehicles, the types of chargers needed, the types of users (residential, commuter, travel), transportation to and from site (to and from campus), the activities and opportunities for consumers in the space, and the overall sustainability of a parking site considering the future of transportation in California.

As a groundbreaking project in renewable energy, this site should also implement sustainable design strategies that make the physical parking area, and its functions, as revolutionary as its energy system. A traditional asphalt covered, vegetation deserted parking lot, is one of the most unsustainable spaces in urban design. With only a single purpose, that to park a car, parking lots get little attention and thought to becoming a more sustainable and usable space. At this site, there is a lot of opportunity to change the status quo of a parking lot and develop a space that is sustainable through its transportation services, parking services, storm water drainage systems, energy systems, health and safety aspects, and building structure and implementation.

The following image shows the possibility of these design ideas, and how the Green Transit Hub could possibly function and look.


Permeable Parking Surface
Walking/Biking Surface
Plaza Area
Bioswale/Vegetation Infiltration
Solar Panels
Building
Organic Ground Surface
Hydrogen Cell Charging
Electric Charging Stations
Tree

Vehicle Parking

There will be multiple types of parking on the site, considering the different types of vehicles coming in and using this space. Parking areas won't just be used to park vehicles, but to charge renewable vehicles. This creates a priority for the site, providing a service to renewable vehicles over the general parking function of the transit hub.

Electric Vehicle Parking:
-150-300 spaces
-North/West side

Electric vehicles parking should have access to chargers in all spaces. Even if the project concludes that the site can only accommodate 150-300 electric vehicles for the time being (due to price), this number is projected to grow from the number of vehicles owners at UC Davis who will own electric vehicles in the future

- Short Term Parking
  - Level 3, and DC Fast Chargers
    - 30min-40min to charge vehicles.
  - Can charge more money for access to a fast charger but have available student and worker discount.
- Long Term Parking
  - Level 2 Chargers
    - ~4hours to charge vehicles
    - Usage of level 2 chargers could be a free service for commuters coming to campus and who will be staying for the day?

Hydrogen cell and Biofuel Vehicles Parking:

Hydrogen cell and bio fueling, unlike electric charging, is fast and doesn't require a long-term stay. With this in mind, hydrogen fueling and bio fueling stations should be located in brief fueling spaces, where they can quickly fuel their vehicles and continue on their commutes, or then park in another area of the transit hub.

- Special membership/discount to park on site for having a Hydrogen cell or Biofuel vehicle.

Carpooling Parking:

Carpooling is predicted to be the future of California transportation, especially as programs like Lyft and Uber have grown in affordability and popularity.

- Discounted permits for vehicles that are carpooling into the site.
- Opportunity to coordinate carpooling programs for UC Davis commuters.

Non-Renewable Vehicle Parking:

Non-renewable vehicles should be treated like all other vehicles that park on campus, requiring a permit, or using the coin meter machines. Less parking should be allocated for these vehicles, since the site is focused on renewable energy vehicles and creating a sustainable transportation system.

- Paying for parking is one of the most effective ways of getting people to not drive. (Mumby, 2009)
- On site management could take care of ticketing and observing parked vehicles

Orchard Park Parking:

-400 spaces
-South/West corner

Having parking located far away from apartment complex encourages residents to use vehicle less often and engage with other methods of transportation in town; biking, busing, walking.

- The parking area for these vehicles should be clearly defined, and somehow appear more inaccessible to other commuters.
    - Bollards, fencing, or vegetation can create this sort of barrier.
- Onsite management of parking.
    - Campus program for student job opportunities.
- Main walking path leading to this parking area, which residents could follow and gain easy access their vehicles
- Some bike parking should also be at this area, so people can more accessibly get to their vehicles.

Transportation

Transportation to and from the site will be incredibly important for the Green Transportation Hub, the sites location being far away from the main campus. Multiple modes of transportation will be flowing through the site periodically. These include commuters driving in and out to use parking facilities, a public bus transit system, bicycle paths, and areas for pedestrians to safely and comfortably walk. There will be different users of the site, different times of stay, and different needs of those users

Transit Oriented Development (TOD) is a focus in urban planning and design that considers a sites transportation as a key element for its success. The Eco Hub, housing so many vehicles right next to the highway, and creating a new edge to the UC Davis campus, should focus on this kind of design method. With a site designed around the way transportation flows and connects people, better methods at dealing with Davis traffic can develop.

<u>Transit</u>:
-Available at least every 10 min.
-Using Unitrans system

- Having public transit come out to this location will create new routes for the Unitrans bus system and providing more places to house buses on campus.
- UC Davis Unitrans; 6 new electric plugs in buses.
    - Can charge in the far Western edge of the site.
    - Having buses on site can create transparency of the bus system at UC Davis, showing consumers how buses are maintained, cared for, and run.
- Starting area for possible tour bus system; electric double decker bus, going to far areas of the campus.

<u>Biking:</u> Bikes should have access to the site through the North tunnel bike path.
Bike Paths

- Clearly marked roads, in a different color from other parts of the site.

Bike Share Program

- Bike share parking located at the North Eastern corner of the site, right next to the bicycle path connecting back to UC Davis.
    - JUMP Electric Bike system program (Sacramento Area, 2018)
        - Coming to the Sacramento and Davis area
    - Additional parking spots for those who own their own bikes.

  - Bike parking should also be available near the orchard park apartments

Costs:
-JUMP's annual membership for bike users: $65
-Bikes: $50-100

Walking: Pedestrians walking around the site have to be able to get to their vehicles efficiently without putting themselves at risk of getting hit.

- Walkways clearly defined and protected throughout parking area.
- Tree barriers, bollards next to paths near street.
- Speed bumps located before pedestrian crossing areas.

As a complex site, with many types of parking and charging stations, there needs to be a simple visual method of communicating to users how to use and move easily through the facilities.

Identity and Colored Road Ways:

- Interlocking concrete pavements are inherently pleasing, with their homey brick style, adding a lot of aesthetic value and identity to an area (ICPE).
- Signage can be implemented by changing the color of the bricks throughout the site. For a parking area so large, and with so many different types of chargers available and limited to the different customers coming in, clear colored pathways using the permeable brick surface might be strategic in helping commuter flow and legibility of the site (Boults, 2018).
  - This can also translate into the sites identity, reflecting the campus and emphasizing UC Davis's character.

Storm Water Drainage

Storm water drainage is a way of managing our urban water systems. Runoff from paved surfaces can damage the surrounding environment by eroding landscapes, spreading urban pollution into watersheds, build up silt in rivers/lakes/streams, and Many urban storm water drainage systems are inefficient, pollute our water ways, and don't replenish the ground water table (COUNTY, 2017). UC Davis is a campus that lacks good storm water systems (looking at the pollution that infiltrates the Arboretum water way), an issue that is slowly being acknowledged and dealt with throughout campus.

Permeable Pavers:
Definition: Interlocking concrete bricks, which allow rainwater to move around the paver's mosaic shapes, and percolate into surrounding surfaces. The pavement surface is built atop three layers of different open-graded aggregate material, the top layer being the smallest in aggregate size and depth, and the bottom layer being the biggest in aggregate size and depth.

- Low Impact Development (LID).
- Able to withstand heavy traffic.
- Can use recycled concrete materials.
- More expensive upfront cost, but have a lower life cycle cost overall.
  - No underground drainage pipping, reduce need for expanding drainage infrastructure.
- Have a lifespan of ~29 years according to ICPE life cycle cost benefits.
- High-reflecting colors (light colors), can reduce the heat island effect.
- Need yearly maintenance, so that water can continue to flow through surface effectively.

Costs:
Interlocking concrete pavers: $7.1 per foot squared (Greenvalue

Bio Swales:
Definition: Strategic landscaping feature that is built to naturally collect rainwater and urban runoff. Generally structured to accommodate a large amount of storm water, plants living in the swale need to be drought tolerant and able to withstand heavy watering.

- Low Impact Development (LID)
- Soft engineering that relies on the biological functioning of a landscape, where storm water filtration occurs naturally with plants present.
- Phytoremediation:
  - Extracting pollutants from soil, root storage, biochemical breakdown, absorbed as nutrients
- Native Grass bio swale completed at UCD Brewery, Winery, Food Pilot Facility

Costs:
$15 per foot squared.

Benefits**:** Creating a responsible, sustainable drainage system can help prevent the damage of urban runoff and support the water cycle of Davis's natural system. Permeable pavers and bio swales can reduce total suspended solids (TSS) levels to EPA mandated standards, reduce the spread of polluting material, control flooding, support on site tree growth, bring tax incentives to the project, and recharge the local underground water table (COUNTY, 2017). Over time, the benefits of a low impact, natural, and sustainable storm water drainage system, will be apparent in the health and low maintenance costs of the site and its surrounding landscapes.

Energy

A complex system of energy is being designed on site, where chargers will be available to potentially charge the projected 1,500 electric (and other renewable) vehicles owned by UC Davis students and staff. Hydrogen and bio fueling stations will be available throughout the Eco Hub, and ease the usage of renewable vehicles on campus.

Solar Panels:
Definition: Are a renewable energy technology that collects the sun's energy throughout the day and convert it into direct current (DC) electricity. This energy can then be used to power on site buildings or be sent back to the UC Davis grid (depending on WAPA contracts).

- Strategic for Davis area, where a lot of sun exposure is expected year-round.
- Energy from solar panels can go into powering hydrogen cell fueling stations.
- Covering most of the site, in order to maximize energy production.
  - Over parking spaces and on buildings
    - EX: West Village, UC Davis Viticulture and Enology Building
- Used as predominant form of shading through the site.
  - Reducing the Heat Island Effect.
- Require little to no maintenance over 25-35 years of power generation.
- Increases property value of the site.
- Declining prices and increasing financing options for solar power installation.
  - PPA & PPA's, Solar Loans

Costs:
$3.75 per Watt
-average payback time = 7 years and 1 month

Smart Grid System:
Definition: A system of electric energy that is interconnected through computer technologies, controls, and automation. The energy system is efficient, as consumers can communicate and understand their energy consumption, and the system itself will recalibrate where energy is coming from based on what technologies are currently making energy (solar panels during the day).

- More efficient transmission of electricity
- Multiple sources of electricity generation.
  - On site solar panels, UC Davis main grid, hydrogen bio fueling
- Improved usage of renewable energy systems.
- Reduce operations and management costs.
- Can help support Plug-In Electric Vehicles charging, recognition of individual vehicles, and automatically charging ced consumer through banking account.

Payment for Renewable Energy:
Another interesting opportunity from creating a Green Fueling Station will be developing system of payment for charging electric vehicles. As renewable vehicles grow in the consumer market, many of the encouraged benefits of having an electric vehicle (such as subsidies, and free charging) may change.

- Co-Op membership, monthly payments for constant access to site
- Free parking spaces for Orchard park residents, but must pay for the energy charging vehicle
  - Free/cheaper charging by using Level 1 electric chargers
  - Have to pay full amount for charging when using Level 2, Level 3, or DC Fast charging
- Sustainable discount card for the site, special benefits for owning an electric vehicle
  - 10-20% discounts on all amenities of the site

Benefits: Developing a conscience smart grid system on the site, which can manage the many different energy structures (solar panels, hydrogen/bio fueling stations, electric chargers etc…) is an essential step to creating an efficient, cost effective, and environmentally responsible energy system.

Vegetation

Expanding Davis's famous urban forest into the site, not only creates more of an identity for the transit hub but develops a more attractive habitat for people to enjoy. Already, Davis has created an incredibly diverse system of vegetation, through its green belt system, the UC Davis arboretum, and its urban forestry management and programs.

Trees:
Trees can be located on the northern part of the site, to create a noise barrier against the highway's traffic and to avoid shading any solar panels on site.

- Trees for this parking lot should be big, tough, from dry climates, and need little management (Parker, 2018).
  - Larger trees will provide a vaster canopy, creating more shade and a comfortable environment for passengers in the site.
- Parking lots are a stressful environment.

  - Need hardy trees that can sustain themselves in an urban setting.
- Minimal seasonal droppings (foliage, fruit, branches).
  - Minimize management.
  - Minimize damage to other facilities.
- Species currently being tested for resiliency through the Arboretum parking area near the Veterinary School (Parker, 2018);
  - EX: Turkish Oak, Valley Oak, Lacey Oak, Cork Oak, Redbud, Fromosan Flame Tree, Gingko, Silver Tilia, Hybrid Oak, Torri Pines (young and big), and Gunuey Eyed Eucalyptus.

Costs: $275/tree or $20/ft sq
Sources:
-Interview with Stacey Parker

<u>Silva Cells Technology:</u>
Definition*:* A pioneering bio retention system that supports large tree growth in urban areas by leveraging the soil underneath the pavement surface and allowing tree roots to expand and thrive (Silva Cell, 2017).

- The technology creates a less stressful environment for trees in a parking area, and helps grow larger and healthier trees, that can more efficiently intercept and evapotranspire rainwater than smaller trees (Silva Cell, 2017).

Costs:
-**$**8,000-$15,000 per project (Silva Cell, 2017)
-$14-$15 per foot squared (Silva Cell, 2017)
Sources:
Silva Cell Facts Sheet (2017). DeepRoot Green Infrastructure, LLC. San Francisco, Ca.

<u>Native Plants:</u>

- California native plants are more drought tolerant and able to survive in the harsh summers in Davis
- Would save money, water, and maintenance time, as plants from this area are already genetically engineered to live in Davis's climate zone.
- Celebrate California culture and identity by keeping local species present in our landscapes.
- Support local pollinators.

Benefits: There are many benefits to growing trees and vegetation in the Eco Hub parking area. According to the EPA, vegetation in urban areas not only reduce the heat island effect by 2-9 degrees F through shading and evapotranspiration, but can;

- 1; save energy of shaded buildings, using less AC in the end.
- 2; improve air quality by sequestering carbon dioxide and encouraging less use of energy consumption for cooling,
- 3; improve storm water management by reducing runoff and filtering rainwater thereby improving water quality,
- 4; alleviate maintenance of concrete areas by protecting surface from the harsh UV radiation of the sun, and
- 5; creating a better general quality of life by providing habitat for multiple species and establishing aesthetic quality to the site (U.S. Environmental, 2008).

Health and Safety

Human health and safety are important social aspects of the transportation hub. Safety encourages usage, and more usage of a space, the safer it becomes.

Lighting:

The sites perceived safety, during the day, at night, and throughout the week is another important aspect to take into consideration for the hubs design. Lighting

- This locations isolation could feel very scary at night.
    - Lots of lighting at night will create a safer atmosphere and encourage usage during later times
- California Technology Lighting Center (CTLC)

Heat Island Effect:

The heat island effect is the increase of temperature in a metropolitan area due to human activity and heat absorption in concrete surfaces. This issue is a huge concern for the Davis area, where temperatures during the summer average in the high 90's F, and little cloud cover occurs. This site in particular is risky, being so far away from our urban forest, and near the largest part of our high way system.

- Solutions:
    - Providing lots of shade either through foliage or solar panel cover.
    - Light colored permeable pavement material.
    - Vegetation, trees, provide evaporative cooling services, and can bring temperatures down from 2-9 degrees Fahrenheit.

Amenities:

Amenities of this rest stop area should be free and well taken care of. This creates a place that is welcoming to the public, outwardly supporting their comfort and health through the services of the site.
Facilities:

- Public Bathrooms
    - Big bathrooms, especially women's bathroom.
    - Gender neutral.
    - Both indoor, and outdoor
    - Grey water system?
- Free, clean water
    - Drinking fountains accessible on site and inside buildings.
    - Fountains for filling up personal water canisters.
- Eating Areas,
    - Outdoor picnic tables, moveable seating.
    - Indoors seating; tables, couches, moveable seating.

Health Happens here at UC Davis:

On campus organization that advocates for student health through rest, hydration, and healthy eating.

- Provide online maps of where students can find water fountains, places to nap, and places to eat healthy food.

- Received grants to create more places for students to be able to rest, hydrate themselves, and eat healthy food
- Hammocks
    - Driving while sleep deprived or tired is just as dangerous of an act as driving while drunk.
        - This rest stop can provide areas to rest and nap for drivers who are sleep deprived and need to recharge themselves for a safer commute

Buildings

41% of the U.S.'s total energy consumption comes from buildings (LEED, 2017). With this in mind, the buildings of this Green fueling station should also be green in themselves. Many buildings on campus incorporate these ideas of sustainable building, providing this project with other companies and programs for this project.

<u>LEED Certification:</u>

LEED is a green building rating system, popularly used around the world. The ranking of buildings sustainability is based on a buildings materials, management, operation, human health, waste, water, and energy systems. Its rating system ranges from LEED certified (least sustainable), LEED Silver, LEED Gold, and LEED Platinum (most sustainable).

- UC Davis has committed all future campus projects, to being at least LEED silver certified (UC Davis Design Guidelines).
- Site buildings could attempt LEED Platinum status.
    - Having a higher LEED status emphasizes this projects dedication to sustainability and acts as an example to other future projects on the UC Davis campus.

  Costs:

  Total costs directly associated with LEED: $37,200

  -Include registration, certification review, modeling, credit, commissioning, management fees, design fees, and construction fees

<u>Orientation:</u>

Strategic orientation of the buildings, in relation to sun exposure, could save energy from passive heating and cooling.

- Short ends of buildings facing North/South, long ends facing East/West.
    - Important to consider as the site will be fully exposed to the sun, for maximum solar energy creation.
- Less energy needed to power buildings.

Benefits: Green buildings are cost-effective, generally perform better, use energy and resources efficiently (bringing down overall price of the building down over time), and are transforming the building market (LEED, 2017).

Alternative Benefits

Many alternative benefits are possible with the Green Transit Hub. As a parking area where cars must stay for long periods of time, and where commuters find themselves far from UC Davis and the city, this site becomes more than just a space to leave vehicles, but a space for people. Acting as a focal point to the new systems of transit for our future transportation systems in California, the Green Transit Hub can. Currently, sites for refueling gasoline powered vehicles are available at multiple intersections, within cities and hugging highways. These areas are predominantly full of large fast food companies (McDonalds, Burger King, Starbucks, Wendy's etc…), expanses of wasteful concrete, and in existence solely for the sake of profit. Consumers, when in these areas, find themselves overwhelmed by the unsustainable messages and practices that these rest stops perpetuate. Since this renewable fueling station will be providing a central space supporting sustainable travel, so too should it inspire the cultural, economic, and social aspects of sustainability, in contrary to "traditional" American parking lots stops.

Local Food System

Local businesses are important for creating community identity and developing sustainable systems in an area. This site has a lot of potential to host local agriculture, business, and UC Davis affiliated production and services.

<u>Farmers Markets:</u>

- Functioning as a sort of business incubator, farmers markets offer an easy and cheap outlet to local family farming businesses to get direct contact with consumers, while being able to set the price of their product (Kelly, 2012).
- Markets develop community by creating face to face relationships between consumer and producer and adding an event of identity to an area (Kelly, 2012).
- Markets are also sustainable, as the packaging and the promotion of produce are only minimally used, and vendors only really require a vehicle and a stand to participate (Kelly, 2012).
    - Full-time farmers, part-time retailers
    - Focusing economic exchange into one communal slot of time, where sales are huge and produce is fresh (Saul, 2017).
- Markets are incredibly educational and can change cultural values, where American consumers can learn about their local farmers, food systems, and about issues of food security and nutrition (Kelly, 2012).
- They can act as an event of identity for a community, where social and civic engagement is practiced and supported (Saul, 2017).
    - Opportunities to discuss city matters
    - Opportunities for community members to volunteer
    - Opportunities for connections to grow between urban and rural dwellers of a region in a friendly market environment (Saul, 2017).
- Area in building to store farmers market equipment and supplies, making set up and preparation on site, easy and efficient.
    - Tables, chairs, canopies, umbrellas, hand washing stations.

<u>Café:</u> A coffee shop could give this space a very nice and relaxed vibe, and provide commuters with an area to do work, hang out, etc,

- High demand for coffee in an area of coffee consumers.
    - Davis already hosting a diverse community of coffee retailers.

        - Ex: Starbucks, Peets Coffee, Mishkas, Dutch Bro's, Cloud Forest Café, Philz Coffee, The CO-OP, The Nugget, Coho etc…
- Commuters coming into Davis early, could get their morning coffee here before they go into campus to get to work.
- UC Davis Coffee Center
    - The first multidisciplinary university research center of its kind, promoting the research of coffee science and education.
    - Collaborating with this on campus resources to create an onsite café, that practices a holistic and sustainable manner of production could be a great project of innovation.
    - Already affiliated with Peet's coffee: easy startup at hand?
- Connected to campus coffee lab with laboratories located directly north of the site.
- Student job opportunities.
- Free Wi-Fi and work space inside and outside of the café.

<u>Local Produce Outlet:</u> A small storefront area, maybe within the café, selling locally produced grocery goods.

- Making local food production easily accessible to commuters.
    - Providing an easy opportunity to get some grocery shopping done, without having to travel too much.
    - UC Davis Student Farm programs:
        - The Market Garden
        - Fruit and Veggie Up
        - The Pantry

<u>Food Trucks:</u> Food trucks are commonly used on campus and would have easy access to a parking lot.

- Food trucks can be a very sustainable form of business, and like Farmers markets, help create community identity.
- UC Davis, the Davis farmers markets, and The Davis Dirt's hosted event the "Food Truck Rodeo", have all noticed the flexibility and benefits of incorporating Food Trucks into Davis's food systems.
- Lower GHG emissions compared to restaurants, when considering their smaller space and overall usage of energy.
    - The lack of rent, heating/air conditioning, and limited efficient menus, catering to the small kitchen space, can make food trucks more conscientious to sustainable production.
- Possibly this project, or departments involved in the spaces of the site, could put together a grant program to fund an all-electric or hydrogen celled food truck.
    - The Green Initiative Fund; $100,000 dollars in grant money.

UC DAVIS

At the entrance point of the UC Davis campus from I-80, this parking area is an ideal location for university retail and tourism. Retail, tours, and outreach have a lot of potential getting involved with this project, which will put UC Davis on the map as a campus that is leading in the sustainable innovation and the design of our future modes of transit.

The site is also close to many key locations of the Davis area, such as the Mondavi Center, the Arboretum, the Manetti Shrem Museum, Putah Creek, the Solar farm, and the Amtrack railway. The proximity to these locations opens up an opportunity of outreach and connection from the site to these areas for users of the site to go explore.

Tourism:

UC Davis is already the main point of tourism for the whole Davis area. On campus tours happen daily, and

- The Hyatt is close to the site, and can use the parking area as a space for hotel users to park their vehicles.
- University products sold on site; Olive Oil, Meats, Honey, Coffee, Wine
- Maps of the free museum collections on campus.
    - Advertising the locations and hours of the campuses public facilities
        - Manetti Shrem Museum of Art
        - Garage Student Gallery
        - Special Collections at UC Davis Shields Library
        - Bohart Museum of Entomology
        - The Haagen-Dazs Hone Bee Haven
        - Botanical Conservatory
        - C.N. Gorman Museum
        - Department of Anthropology Museum
        - Museum of Wildlife and Fish Biology
        - Design Museum
        - UC Davis Center for Plant Diversity and Herbarium

Research:

The four buildings that will be located on the site will provide indoor space to certain research departments on campus. As one of the very first green fueling stations in California, this transit hub could act as an example project for future renewable fueling stations in the United States, and as an opportunity to explore the behavior of consumers interacting with the specific dynamics of the transit hub.

- Community Development Research
    - Healthy Food Access; Catherine Brinkley
    - Political Economy
- Economic research
    - Davis Energy Economics Program
        - Consumer Behavior
        - Energy Markets
        - Climate Policy
        - Transportation and Fuels
- Energy research
    - California Lighting Technology Center
    - Center for Water-Energy Efficiency
    - Plug-In Hybrid & Electric Vehicle Research Center
    - Wester Cooling Efficiency Center
    - China Center for Energy and Transportation
    - Program for International Energy Technologies and D-Lab
    - Policy Institute for Energy, Environment and the Economy
- Psychology research
    - Emmons Laboratory

- Neural Mechanisms of Attention (Magnum) Lab
- Social Environment and Stress (SES) Lab (Hostinar)
- The Learning and Decision Making (LDM) Lab (Boorman)
- Attitudes and Group Identity Lab (Ledgerwood)

- Transportation Research
  - Institute of Transportation Studies
  - Energy & Transportation Senior Policy Fellowship Program
- Renewable Vehicles Research
  - Hydrogen Cell
  - Biofuel
  - Energy grid systems

Data Collection:

- Mass data can be collected from the transportation hub to provide critical information for the future construction and development of California's state transportation system.
  - Survey opportunities.
  - Free day of parking in exchange for participating in surveys
  - Document the usage of the site, what type of consumers are coming in and using renewable energy vehicles.

<u>Education:</u>

The site itself is educational, as the first ever Green Fueling Station and Eco Hub in California. Transparency of the site, informative paneling, can create a more educational experience for people when staying in the facilities.

- Field trips to the site not only could expose students to the Eco Hub's innovative ideas, but also inform them about climate change, sustainable transportation systems, and how Davis is getting involved in transforming these aspects of California.
- Davis school systems- connected through Davis Joint Unified School District
  - High Schools:
    - Davis Senior High School
    - Da Vinci Charter Academy
    - Davis School for Independent Study
    - King (Martin Luther) High (Continuation) School
  - Middle Schools:
    - Oliver Wendell Holmes Junior High School
    - Frances Ellen Watkins Harper Junior High School
    - Ralph Wald Emerson Junior High School
    - Da Vinci Charter Academy
  - Elementary Schools:
    - Robert E. Willett Elementary School
    - Pioneer Elementary School
    - Birch Lane Elementary School
    - Cesar Chavez Elementary School
    - North Davis Elementary School
    - Patwin Elementary School
    - Fred T. Korematsu Elementary School at Mace Ranch
    - Marguerite Montgomery Elementary School
    - Saint James School
    - Marryhill School

        - Davis Waldorf School
        - Fairfield Elementary

Benefits- A voice in California's future policies and system designs of transportation and fueling stations. By collecting data on the site, researching different aspects of California's green transportation systems, and educating the public, through tourism activities or school field trips, the Eco Hub can have a significant impact on raising awareness of California's population. This awareness can then support and fuel initiatives that will continue to improve our states sustainability and contribution to bending the curve of GHG emissions.

Recreation

Following the original tradition of the highway rest stop, this transit hub will have spaces where commuters can enjoy the outdoors. Paths to and from site, will connect the Transit Hub to the UC Davis Arboretum, the greater Davis greenbelt system, and the Putah Creek water way. This will create opportunities for people to really see Davis as it is and be able to appreciate the outdoor areas that we spiritually hold important.

<u>Hiking Routes:</u>

- Map of the Arboretum and Putah Creek
    - Drawn out loops for either walking or biking, with estimated amount of time it will take people to complete (if people want to go running while their car is charging, or go on a bike ride too)

<u>Playground for Adults and Children:</u>

- Located on the North end where large trees could reside, right before accessing the bike path.
- Community development project, where community can come and help build the structure together.
    - EX: Rainbow City Park, Davis, Ca.
- Exercise structures, for people who want to skip the gym and do their exercise regime outdoors.

<u>Yoga/Meditation Room:</u>

- Yoga, meditation, and prayer rooms are a common space of refuge now found in airports around the world. These spaces give people the chance to recharge in silence.
- Yoga has been proven as an extremely beneficial form of movement and exercise. Not just
- Mats provided.
- Can do outdoors yoga, when weather is nice.
- Classes in the morning and afternoon for commuters looking to stretch and exercise before their work day begins or after it ends.

Benefits: Encouraging recreational activity would be an opportunity to advocate for healthier living styles, and communicate to people physically and mentally, the importance of our outdoor environments. The United States is currently struggling with an obesity epidemic and losing its younger generations to the addiction of technology and the comfort of indoors. By using this site as an area to get people out and about in Davis's natural systems, more people will be exposed to the health benefits of physical activity and interacting with nature, and opportunity to change culture.

Appendix

Table 1: Numbers of Electric Vehicles Per Region Commuting Through Davis

Geographic Region	Where Commuters to Sacramento are From	Commuting Electric Vehicles → Sac	Commuters From Sacramento Region (and percentage)	Commuting Electric Vehicles From Sac
SF Bay Area	43,918 (5.3%)	(0.01145)(43918) = 502.9	65,832 (7.8%)	(0.00384)(65832) = 252.8
Vacaville	17,256 (2.1%)	(0.0033)(17256) = 56.9	25,869 (3.1%)	(0.00384)(25869) = 99.3
Stockton	18,777 (2.2%)	(0.00249)(18777) = 46.8	19,332 (2.3%)	(0.00384)(19332) = 74.2

Column 2 and 4: "OnTheMap", LEHD, US Census Bureau, https://onthemap.ces.census.gov/

Table 2: Percentage of Electric Vehicles Per Region

Geographic Region	Number of Electric Vehicles (PHEV & BEV)	Number of Registered Vehicles (autos, trucks, motorcycles)	Percentage of Electric Vehicles
SF Bay Area	42,937	3,751,221	1.145%
Sacramento	7405	1,927,930	0.384%
Vacaville	1245	377,745	0.330%
Stockton	1429	573,679	0.249%

Column 2: "California Clean Vehicle Rebate Project", California Air Resources Board, https://cleanvehiclerebate.org/eng/rebate-statistics
Column 3: "Estimated Vehicles Registered by County for the Period of January 1 Through December 31, 2017", California Department of Motor Vehicles, https://www.dmv.ca.gov/portal/wcm/connect/add5eb07-c676-40b4-98b5-8011b059260a/est_fees_pd_by_county.pdf?MOD=AJPERES

Table 3: Projected Population Per Region

Geographic Region	Population (2016 estimate)	2020 Projected Population	2025 Projected Population	2030 Projected Population
SF Bay Area	4,679,166	4,845,359	5,071,694	5,282,532
Sacramento	2,296,418	2,388,853	2,532,533	2,680,142
Vacaville	440,207	453,784	480,712	507,219
Stockton	733,709	782,662	838,755	894,330

Columns 3—5: "Total Population by County", Population Projections, California Department of Finance, http://www.dof.ca.gov/Forecasting/Demographics/Projections/

Table 4: Projected Commuters TO Sacramento:

Region Resident Of	*% of Population Commuting to Sac.*	*2020 Commuters*	*2020 Commuting EVs*	*2025 Commuters*	*2025 Commuting EVs*	*2030 Commuters*	*2030 Commuting EVs*
SF Bay Area	2.2%	45,248.7	518.1	47,362.3	542.3	49,331.2	564.8
Vacaville	10.1%	17,849.7	58.9	18,906.1	62.4	19,948.6	65.8
Stockton	7.7%	20,045.5	49.9	21,480.7	53.5	22,904	57
Totals for EVs			**627**		**658**		**688**

Table 5: Projected Commuters FROM Sacramento

Region (Destination)	*% of Sac. Population Commuting*	*2020 Commuters*	*2020 Commuting EVs*	*2025 Commuters*	*2025 Commuting EVs*	*2030 Commuters*	*2030 Commuting EVs*
SF Bay Area	7.8%	68,684.3	263.7	72,812.3	279.6	77,056.2	295.9
Vacaville	3.1%	27,296.5	104.8	28,938.2	111.1	30,624.9	117.6
Stockton	2.3%	20,252.2	77.8	21,470.3	82.4	22,721.7	87.3
Totals for EVs			**446**		**473**		**501**

Table 6: Total Amount of EVs Commuting for Work Through Davis

Year	*2020*	*2025*	*2030*
Amount of EVs	**1073**	**1131**	**1189**

Table 7: Projected Tahoe Traffic from Bay Area

Annual Visitors to Lake Tahoe	Visitors from SF Bay Area (SF, N & E Bay)	Number of Visitors to Lake Tahoe from Bay Area	Number of Vehicles → Tahoe (assuming an average carpool of 2.5)	Percentage of EVs in Bay Area	Current Number of EVs Traveling to Tahoe
2.7 million	12%	324,000	129,600	1.145%	1483.9

Column 1: "Annual Visitors", South Lake Tahoe, https://www.southlaketahoe.com/lake-tahoe
Column 2: "Table 6: California Market", Lake Tahoe Visitors Authority Visitor Profile Study, http://ltva.org/wp-content/uploads/2016/11/161104-Lake-Tahoe-Visitors-Authority-2016_5.0.final_.pdf

Table 8: Lake Tahoe EV Visitors "Per Day"

	2020 EVs Traveling	2025 EVs Traveling	2030 EVs Traveling
Annual Numbers	**1536.6**	**1608.3**	**1675.2**
Daily Numbers	**4.2**	**4.4**	**4.6**

Table 9: Daily EV Projections Considering an Increase in Demand of 20%

	2020	*2025*	*2030*
Number of EVs Commuting to Work	**1288**	**1357**	**1427**
Number of EVs Passing Through to Tahoe	**5**	**5.3**	**5.5**

Table 10: Industry Standards for EV Chargers

Charger Type	ERPI	SAE(AC)	SAE(DC)
Level 1	120 VAC, 12 or 16A	120V single phase, Configuration current 12A≥16A Configuration power 1.44≥1.92 kW	200−450 V Rated current ≤ 80A Rated power ≤ 36 kW
Level 2	240 VAC, 40	240V single phase Rated current ≤ 80A Rated power ≤ 19.2 kW	200−450 V Rated current ≤ 200A Rated power ≤ 90 kW
Level 3	480 VAC	Incomplete data	Incomplete data

Source: Society of Automotive Engineers (SAE),SAE Standard: J 1772.(NFPA, 2011).

Table 11: Minimum Charging Station by Type

# of EV chargers	Van accessible	Standard Accessible	Ambulatory
1-4	1	0	0
5-25	1	1	0
26-50	1	1	1
51-75	1	2	2
76-100	1	3	3
101 and above	1 plus 1 for each 300 or fraction over 100	3 plus 1 for each 60 or fraction over 100	3 plus 1 for each 50 or fraction over 100

Source: California State Architect

Table 12: Sizes of Hydrogen Systems

Type of Location	Size less than 3000 CF	Size 3000-15000 CF	Greater than 15000 CF
outdoors	I	IDI	
Separate building	II	II	II
Special room	III	III	Not permitted
Inside building but not in a special room and exposed to other occupancies	IV	Not permitted	Not Permitted

Source: National Renewable Energy Laboratory Hydrogen Safety Document

Table 13: Maximum Total Quantity of Liquified Hydrogen storage permitted in units of gallons

	Size of Hydrogen storage capacity	Size of Hydrogen storage capacity	Size of Hydrogen storage capacity	Size of Hydrogen storage capacity
Nature of location	39.63-50 gallons	51-300	301-600	More than 600
Outdoors	I	I	I	I
Separate building	II	II	II	Not permitted
Special room	III	III	Not permitted	DO.
Inside building but not in a special room and exposed to other occupancies	IV	Not permitted	DO.	DO.

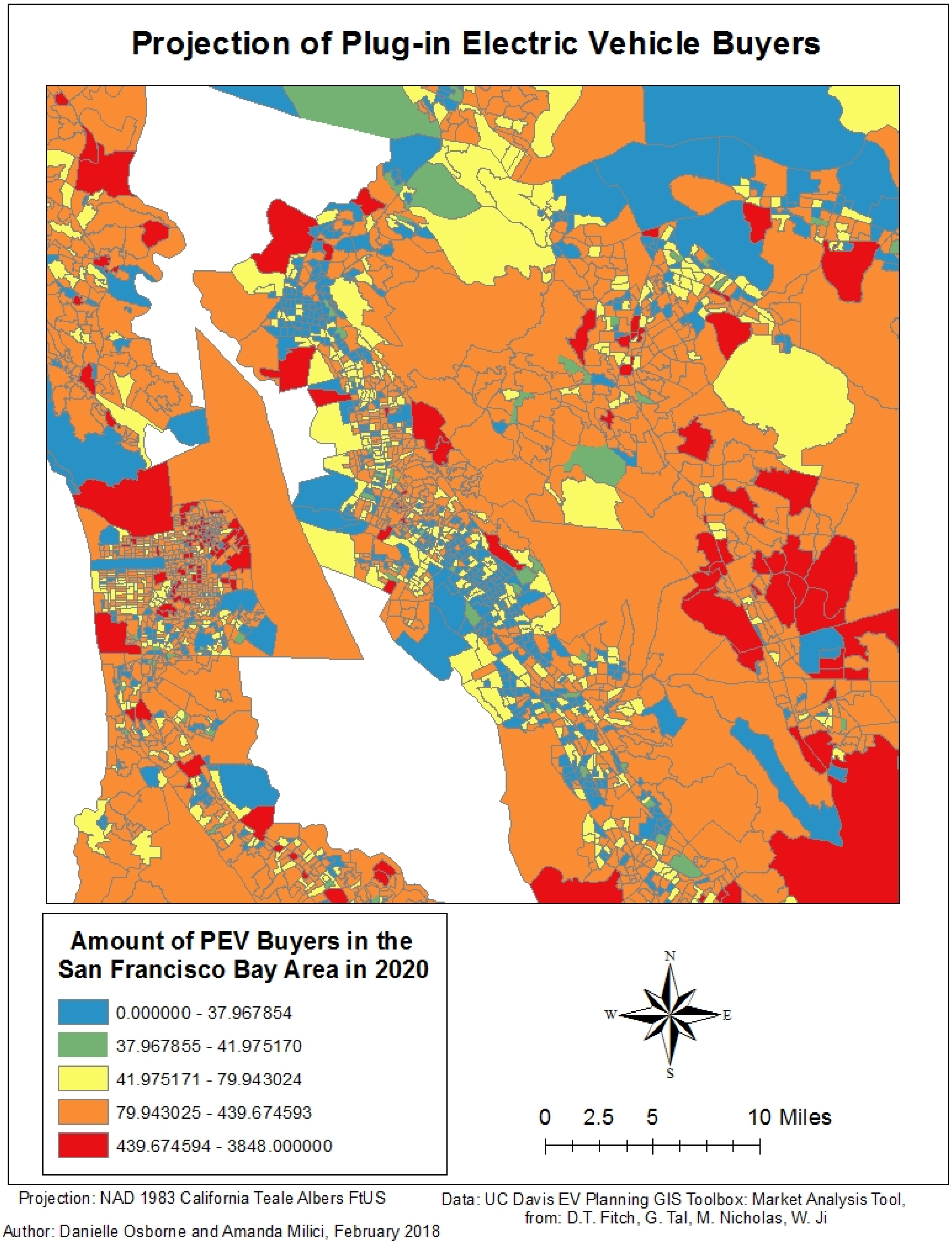
Source: National Renewable Energy Laboratory Hydrogen Safety Document

Table 14: Minimum Distance in Feet from Liquefied Hydrogen Systems to Exposure

	Liquid H storage capacity	Liquid H storage capacity	Liquid H storage capacity
Type of Exposure	39.63-3500 gallons	3501-15000 gallons	15001-30000 gallons
Fire-resistive building and fire walls	5ft	5ft	5ft
Non-combustible building	25ft	50ft	75ft
Other buildings	50ft	75ft	100ft
Wall openings, air-compressor intakes, inlets for air-conditioning or ventilating equipment	75ft	75ft	75ft
Flammable liquids (above ground and vent or fill openings if below ground)	50ft	75ft	100ft
Between stationary liquefied hydrogen containers	5ft	5ft	5ft
Flammable gas storage	50ft	75ft	100ft
Liquid oxygen storage and other oxidizers	100ft	100ft	100ft
Combustible solids	50ft	75ft	100ft
Open flames, smoking and welding	50ft	50ft	50ft
Concentrations of people	75ft	75ft	75ft

Source: National Renewable Energy Laboratory Hydrogen Safety Document

Figure 1: Increased Demand of Electric Vehicles by 20%



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