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Bring Affordable Equitable Charging to Multi-Unit Properties with Lower Power Charging

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Executive Summary

Only ~10% of electric vehicles (EVs) were registered to multi-unit dwellings (MUDs) in the state of California in 2019, due in part to a lack of charging infrastructure. The state plans for 5 million EVs by 2030, but property owners often lack a compelling reason to invest in EV infrastructure due to limited panel capacity and high-priced installation costs. While there is a push to install more public charging, data shows that 86-90% of charging happens at home. The data shows that an EV driver with access to at-home charging will only use a public charger ~6 times per year. For the 44 million Americans who live in multi-unit properties and are adopting EVs, we see a clear path to economically scale the EV infrastructure they need to charge at home. Panel limitations prevent most properties from installing more than a handful of 40 amp chargers before expensive infrastructure upgrades are needed. Some companies have been working to address panel limitations - however, many use software to mask the core issue, lack of power. Orange leverages lower-power 20 amp chargers to augment panel limitation and offer charging to more residents allowing for 10-12 chargers on the same circuit while leveraging lower-gauge wiring, cutting costs by 70% on installations.

1 Building for Disadvantaged Communities

Chargers at MUDs are crucial to EV adoption at every income level. Property owners lack a compelling reason to invest in EV infrastructure due to high-priced network charges and panel capacity issues. Orange started to provide property owners a financial incentive, both in affordability and return on investment (ROI), to install chargers and overcome these drawbacks allowing more people who live in multi-unit properties access to convent equitable charging.

We sought to understand the limitations holding back EV adoption in multi-family properties worldwide to fundamentally build a platform that made economic sense for property owners and drivers. Our research showed that lower-power 240 volts at 20 amps augment panel limitation and offer charging to more residents without requiring a service upgrade. Additionally, we reduce CO2 emissions, reinforce the grid's robustness, and boost profitability to property owners while maintaining equitable energy prices for residents by making the upfront installation and ongoing maintenance cost more affordable.

We have developed and deployed our smart EV charging outlets at numerous apartment complexes, HOA, and workplaces. Solidifying how our unique solution can scale EV charging to more people for less capital deployed, helping reach our future EV adoption numbers, improving local and regional air quality, and reducing Americans' reliance on oil.

1.1 EV Adoption is Limited by Multi-family Access to Charging

To reach CA Assembly Bill (AB) 2127, which anticipates 5 million zero-emission vehicles will be on California's roadways by 2030, [1] we need to find more economical and impactful ways to bring access to affordable energy to everyone. Unfortunately, the infrastructure does not currently exist to support this. Panel limitations imply a typical multi-family property with between 20 - 250 units can only install 2-4 Level 2 chargers. Many companies have been working on these limitations - however, most use software and load management to mask the core issue created by finite power in a building.

As noted, only 10% of EVs were registered to MUDs which showcases that the current marketplace of vehicle chargers does not properly address the needs of the MUD community. By leveraging higher-powered stations originally designed for public charging use in mind, the EVSEs that were available on the market severely missed the mark in addressing these communities' needs.

When looking at single-family homes, where most EV drivers reside, it becomes apparent that there was a major flaw in the initial thought process when bringing charging to people's homes. Single-family homes commonly do not leverage full-scale charging solutions; often, homeowners opt for using simple plugs, either of the Level 1 or Level 2 variety, to charge their vehicles. This is because even if drivers have public stations nearby, they find charging at home a far better option, with over 90% of EV drivers stating they prefer to charge at home or work where one or both are available.

Interestingly, many MUD communities that have installed charging opted for larger charging stations that cost more upfront capital and served fewer vehicles when simple charging plugs would have sufficed. Energy limitations are the leading cause of abandoned projects as the cost to upgrade the service or panel quickly becomes a limiting factor to property owners. Out of the 75+ installs in San Mateo County Orange completed in 2022, every property we worked with was panel limited. It's clear that we need to bring more access to charging at home to maintain the continued adoption of EVs. Power limitations are a limiting factor to adding charging to properties.

2 Property Power Limitations

In many older apartment buildings, the electrical service is limited because when these buildings were constructed, there were typically only a few electrical devices in each unit, such as lights, typically a refrigerator, and a television. However, as tenants have added more electrical devices to their units, the power demand has increased, putting a strain on the electrical service. With a wider push for electric stoves, dryers, and water heaters, more of the unit capacity will become constrained, limiting the amount of spare capacity at all properties even further.

Most buildings were built before the rapid adoption of electrical appliances, and EVs are putting additional strain on the last-mile connection where electricity gets to users. In every case, the electrical infrastructure cannot supply 100% of EV drivers overnight without service upgrades or new transformers switching gears, even if you apply the most sophisticated power management algorithms.

While many companies claim power sharing is the key to addressing power limitation, it creates new issues that undeniably don't scale. These platforms increase the upfront installation cost by requiring high-power charging and large gauge wire, while power-sharing only uses a fraction of the infrastructure capabilities. Faster charging doesn't make people drive more, so the end goal of all these power-shared systems is to lower charge rates to more cars to meet dynamic demand based on a wide range of drivers' behaviors.

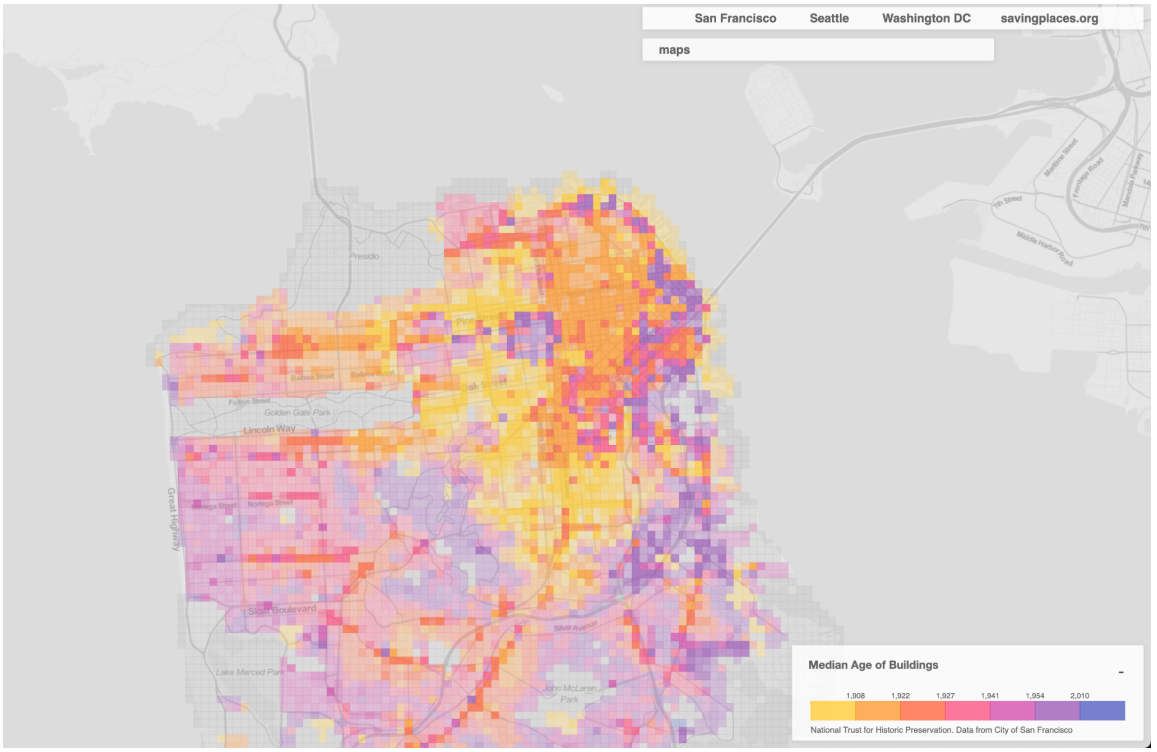

Figure [A] Map showing the average building age in San Francisco.

When it comes to EV charging, the power demand is even higher. These systems draw a significant amount of power, especially when charging quickly. For example, a Level 2 EV charging station can draw as much as 19.2 kilowatts of power, equivalent to several air conditioners' power consumption. This can put a significant strain on the electrical service in an apartment building, especially if multiple EVs are charging at the same time.

To overcome power limitations, many owners must then upgrade the electrical service. This can involve replacing the main electrical panel with a higher-capacity one or adding a second panel specifically for EV charging systems. However, upgrading the electrical service can be expensive and may require approval from the local utility company, which can take time and be outright denied.

2.1 Power Sharing Works Only to a Point

One of the first ways charging providers sought to overcome this hurdle was to introduce power sharing, often referred to as power management or power splitting. This involves simply sharing the available capacity to a set number of stations or intelligently managing the power needed to roll off vehicles as they reach their maximum capacity.

This intelligent power-sharing technique did have promising results early on when electric vehicle adoption was still relatively low. While it lowered some upfront costs to the building, allowing properties to use up available capacity intelligently, the capital investment remained high. Additionally, due to the power-hungry nature of EVs, it failed to address the underlying issues with EV charging in apartment buildings. A traditional Level 2 port may cost between $8,000 to $12,000 to install, whereas a power-managed Level 2 port may cost as low as $3,600 [2], and a Level 1 outlet costs even less, around $1,800. Utilizing these technologies also allows sites to install more chargers than possible.

For example, let’s install 10 charges on a 100-unit apartment complex with 200 amps panel or 160A of usable capacity. Each 40 Amp circuit connected to a 32 amp Level 2 charger will cost, on average, $8k for hardware, and installation adds up to $80,000 without a service upgrade or panel upgrade. The issue here is that with ten 240 volts 40 amp chargers, the total power draw is 400 amps, yet the building only has 160

amps that can be used before you trip the panel breaker. This means that if all the charges are being used simultaneously, they could only pull 16 Amps each. So you are effectively power managing to charge rates slower while paying far more in upfront costs so that, in some cases, you can charge a few EVs faster from time to time.

Now, let's install 10 lower-power 20 amp outlets, the cost of the hardware, both charging equipment and installation, on average, would be $2,000 per outlet or $20,000 for the entire project, and the results would be similar if not the same for the majority of tenants daily driving needs. Each outlet would pull 16 amps based on the 80% rule for continuous loads, and for 98% of drivers, daily commutes would allow them to wake up fully charged. This upfront cost reduction has compounding effects, allowing the charging system to return and invest to rational time frames, even when paid for out of pocket, making incentives less of a deciding factor for the growth of EV charging at multi-unit properties.

At some point, buildings will need to invest in additional electrical infrastructure upgrades to fully address the needs of the vehicle owners, no matter how intelligently stations share power. Because power-sharing stations are often higher power, this forces building owners into another large capital investment which usually does not happen as the properties realize they cannot afford to upgrade their electrical infrastructure indefinitely.

2.2 Real-world Driving Data Makes Lower Power More Compelling

While faster-charging sounds like something we all need, the data behind our driving habits tells a vastly different story. Orange surveyed ~1800 people and then augmented that information data from the DOT [3] and Interix to confidently determine daily driving habits. This is key to understanding how many kilowatt hours a driver needs daily to top off an electric car based on a wide range of EV efficiencies. Today we have more data from Orange Outlets to solidify that 16.8kWh per day is the average energy needed per driver.

So with a lower powered 3.8kWh outlet at home overnight, it would take 5 hours to recharge someone's daily 16.8kWh requirement. This foundational idea led to Orange realizing lower-power chargers would meet 94% of drivers' needs, even when installing a standard Level 1 outlet at 1.98kWh. We worked with Peninsula Clean Energy (PCE) to develop a program for Level 1 outlets in multi-family properties. Working with Clear Result, PCE published a more detailed report [4] on lower power charging that helped solidify their incentive program.

To break down this idea that we need more public charges per driver seems to assume we won't have a one-to-one ratio of chargers per electric vehicle. Suppose each EV was paired to a lower-power home charger to meet 98% of their driving habits. In that case, the money spent on Level 2 charging at inconvenient and irrational locations could go to a few DC fast charging stations for road trips and occasional quick fill-ups.

We should consider the long-term reliability and user behavior of current electric charging from the 1M drivers in CA to effectively spend incentive money. We have enough data now to make an informed decision and more effectively utilize capital to have a greater impact. Considering the state 2035 ban on internal combustion car sales, 35% of vehicles are expected to be fully electric. Of the 31,247,270 vehicles registered to CA's DMV, 10,936,545 electric vehicles must pull 183.73 Gigawatt hours (TWh) of energy from the grid daily to operate.

10,936,545 vehicles times 16.8kWH equals 183.73 Gigawatt hours (TWh) of energy needed to make it through the grid daily.

10.936MM EVs * 16.8kWh (daily need) = 183.73 GWh load requirement.

3 Impact on the Grid

This 183.73 Gigawatt hours (TWh) of energy requirement means effectively managing when electric vehicles charge is key to maintaining grid stabilization, especially as renewables generate more of CA's energy. A recent study found that charging during peak solar loads in the afternoon has the greatest impact on clean energy being used for transportation, but this ignores that there is and will always be a baseline amount of power produced. During the night, that energy needs to be consumed.

In 2022 California used 277,764 GWh [5] of energy, meaning that 760 GWh of energy is needed on an average day. Now, let's imagine that in 2035, we want to charge 10 million cars which will require producing 24% more power each day. That is only a 2.4% yearly increase in energy for the next ten years to meet that demand.

Now let's say that of those ten million vehicles, 25% lived in apartments and didn't have access to overnight slower charging, so utilize DC fast charging 2 - 3 times after work per week. It would require

2.5MM * 125kWh(Avg DC Fast Charger Power) = 312,500 GWh of peak load.

If all those vehicles tried charging simultaneously, the impact on the grid would be many multiples of the current grid capabilities.

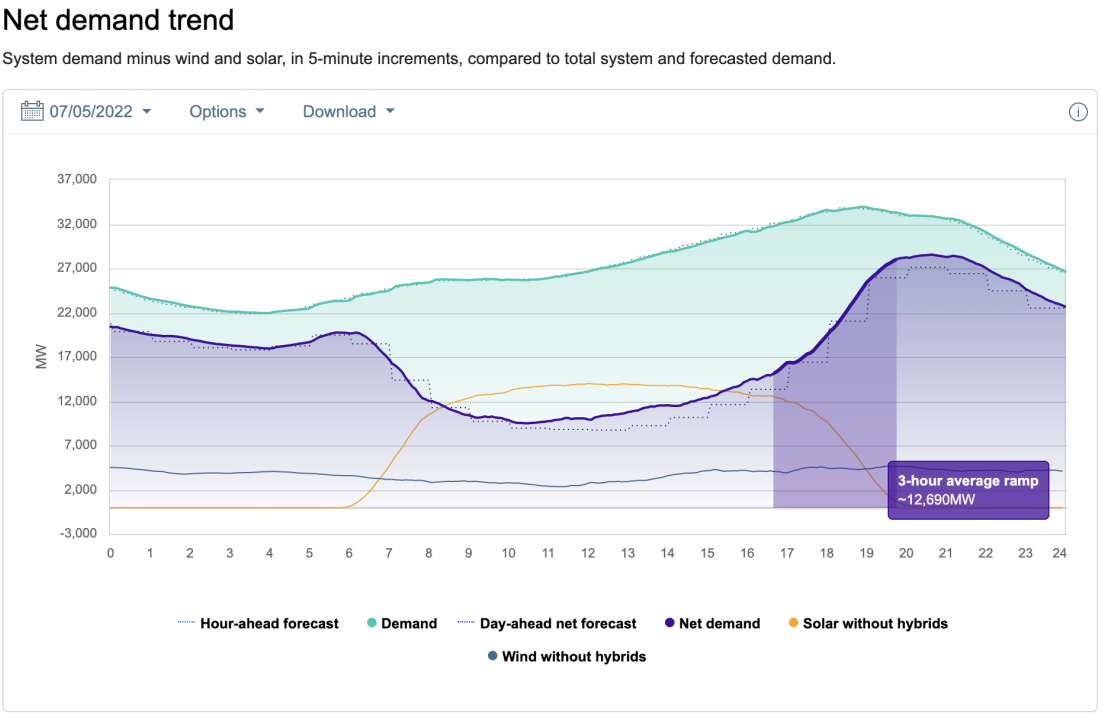

Figure [B] July Summer Day with High Peak Demand, note that demand has two spikes, in the morning and the evening when everyone goes home.

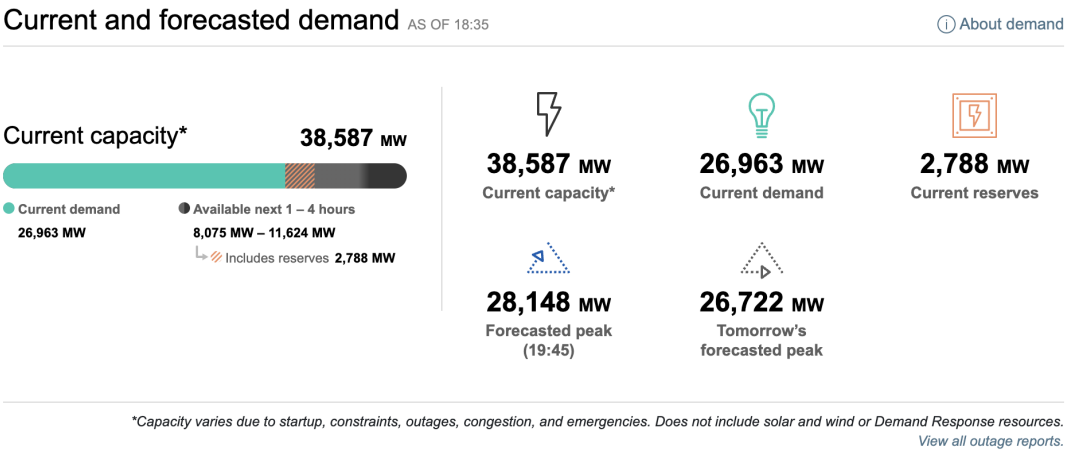

Figure [C] March 21st Daily Energy Capacity in California [6]

That days forecast peak was only 28,148 MW [6], meaning that to meet our 2035 goals without a more intelligent solution, the impact on the grid would be catastrophic. Now let's assume those 2.5MM cars only pulled 3.8kWh from 9 pm to 9 am daily and only needed 16.8kWh of electricity.

$$2.5MM * 3.8kWh = 9.5GWh \text{ of energy per hour.}$$

We are oversimplifying this greatly for this argument. An entire paper could be written on the future impact of EVs on the grid, including the use of EVs to stabilize the grid and how storage will help more effectively utilize renewable energy.

Based on current DC fast charging data from Tesla, it's clear that the most common times people fast charge are when they get off work around 5 - 6 pm or before work between 7-9 am, the same time when the grid is under the most strain [Figure B]. By providing more overnight lower-power charging, we help reduce the number of drivers who will impact these peak demand requirements. [7]

This means the decisions we make today and the solution we adopt today will impact equitable access to charging for electric vehicles and the cost required to upgrade the grid infrastructure to meet future demand. By installing more low-power charging, we help reduce peak events and distribute energy consumption over a longer period. We are not just saving money during the installation and making more for the property owner; we are helping reduce the cost of upgrading the grid by helping limit peak events.

4 High Costs and Low Return on Investment

The largest issue with EV charging in MUDs is entry-level costs. Originally, EV charging providers treated MUDs like public charging infrastructure and forced a square peg into a round hole.

The circumstances between MUD and public charging are vastly different and should not be treated the same. Public chargers need higher power because, in most instances, the vehicle is only parked for 1-3 hours, and EV drivers want to maximize their charge. However, MUDs don't have this issue, as vehicles typically park for 8+ hours and can leverage a lower-powered solution over a larger period.

By understanding this, lower-powered stations cut costs by upwards of 70% on installs [Figure D], dramatically reducing entry-level costs. Additionally, because lower-powered stations are typically outlets, they carry almost no maintenance cost as the main failure point, the charging cable, is not attached. These two factors alone make lower-powered charging outlets compelling even without incentive programs.

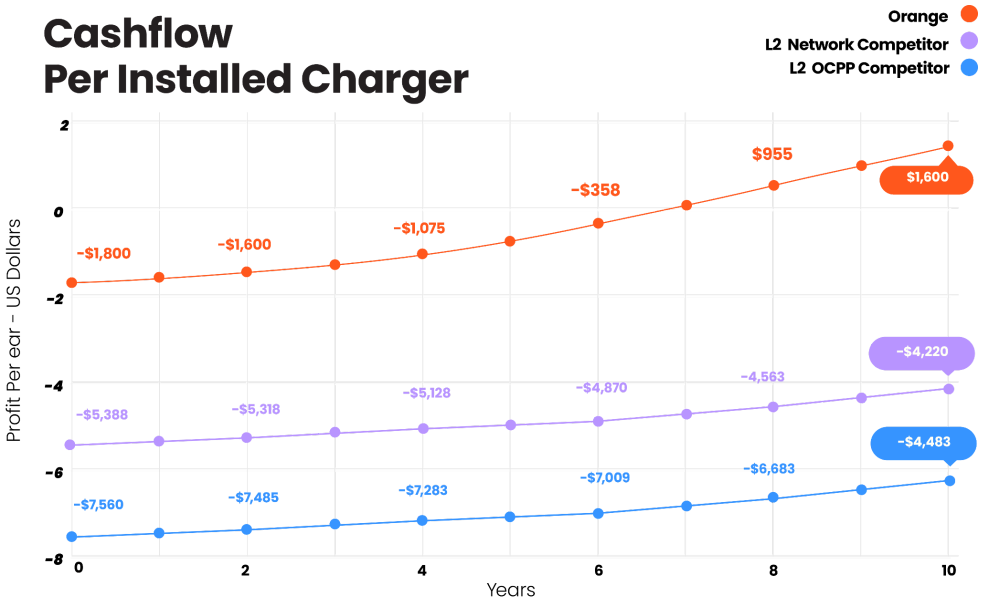

Figure D - Cash Flow and ROI over a 10-year period with Orange vs. Competitors

Furthermore, by lowering installation costs, property owners can recoup their costs by marginally marking up the cost of electricity. Capping property owners to fair margins ensures energy costs remain affordable for the community but still allows for an ROI to the property.

4.1 Why Orange Built a Smart Outlet

The core of our platform is the Orange 620 [Figure E]. This internet-connected, access-controlled energy meter and outlet use WiFi, Bluetooth, and cellular data. That balances the need to keep costs to a minimum while providing enough energy to the EV to cover all potential daily driving needs.

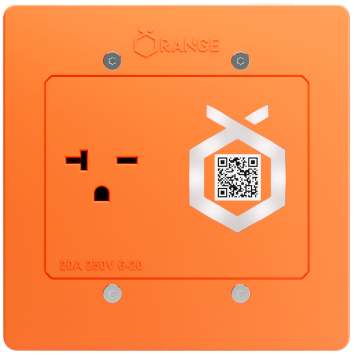

Figure E - Orange 620

In our system; the driver can defer charging until electricity costs are low and receive a full charge by morning. By incentivizing offset peak charging and reducing CO2 emissions, Orange reduces strain on the grid while saving drivers money. As mentioned before this incentive to charge off peak hours slower not only saves the property owner money but the ratepayer's money because we keep the overall peak load on the grid lower, reducing the investment in peaker plants of alternative generation to meet peak demand events.

We typically install Orange 620 Outlets on at least 20% of the parking spots per property. The Orange 620 variant offers the best cost per kilowatt hour (kWh) of all the market solutions managing payments between drivers and properties. [Figure F]

While the Orange 620 can provide 3.84 kWh of energy, lower than the standard 6.6kWh Level 2 charging stations, it provides more than enough to cover daily driving needs. Delivering between 120-150 miles of range overnight. As the average driver only drives 47 miles per day in the bay area, this more than covers daily commutes.

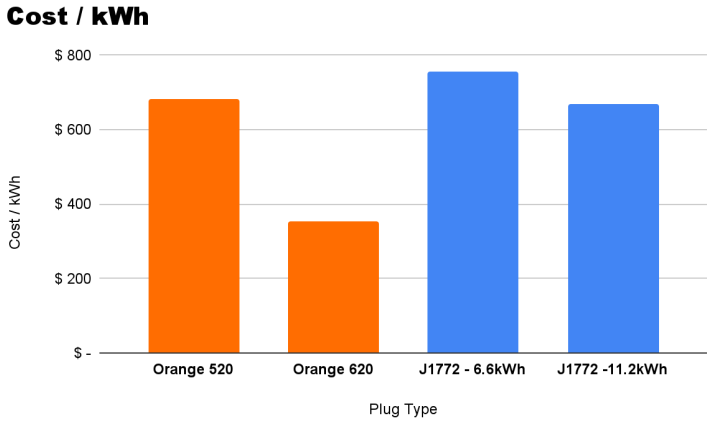

Figure F - Cost per kilowatt hour vs. competing plug

Orange researched the market extensively to solve the issues with charging in MUDs. By understanding the infrastructure limitations and time to charge, it was obvious that lower-power charging is the best fit for these communities.

Orange balances the driver's need for affordable charging; the communities must provide access to every resident without sharing, and the property owners must keep installation costs low to achieve some return on investment.

When we couple this with the ease of deployment and scale while collecting payments and data for utility providers, we ensure that EV charging is possible in MUD communities and desirable.

4.2 Scalability & Replicability

The access-controlled Orange Outlet can be deployed quickly and inexpensively compared to our competitors. Orange Outlets scale easily and affordability due to the simplicity of the product. We can use lower-gauge wiring (10-12 gauge) by leveraging lower-power solutions, saving site owners significant capital. Further, lower power is easier to work with. Once installed, it is as simple as switching a standard household outlet, reducing ongoing costs as certified electricians are not needed once the product is installed.

This also means once a property sign off, it deploys rapidly, as the system's design isn't much different than that of an ordinary household outlet. Meaning installations take hours, not days.

This solution benefits all involved: the property owner cuts install costs, the driver benefits from access to power and lower costs through Orange's proprietary software, and the utility providers fill peak energy reserves for later use and minimize shared demand across the grid.

Installing charging ports immediately will be more important while EV ownership gains traction at MUDs and disadvantaged communities.

5 A Scalable Future of Lower Power Charging

As it stands when writing this paper, the world is rapidly pushing to ban the sale of new gasoline-powered vehicles by the mid-2030s. Along with all the manufacturing hurdles that will come with completely retooling production facilities, a reliable, scalable, and equitable charging infrastructure must be created to ensure those plans can come to fruition. Additionally, this new infrastructure will significantly impact our aging electrical grid and must ensure that it does not overwhelm the already severely taxed grid systems.

While many of the incentive programs have allowed nationwide public charging networks to be built, as we have discussed, this is only a small piece of the needed ecosystem. These stations are excellent for long-haul journeys or topping up in an emergency but are a poor solution for everyday usage. What's needed most is charging stations where people live as it's the most convenient place to charge and allows them to enjoy electric vehicle ownership to the fullest extent.

When assessing the needs of the larger world, we must solve at-home charging, especially in disadvantaged communities and multi-unit housing. These places have proven to be the most difficult to bring charging into as there is simply not enough available capacity to support the large energy requirements of EVs. Adding higher power stations only exacerbates the problem and asks property owners to foot the bill for future infrastructure upgrades.

Lower-powered charging solutions are the key to addressing these issues and allowing vehicle charging to scale easily in these communities. By embracing the larger charging time window of eight or more hours, higher power is unnecessary. Lower-powered stations like the Orange 620 Outlet bring more than enough energy to replace any driver's daily needs even after long haul journeys as it will add back more than a driver's daily need and over the week will bring a drivers battery back to 100% or desired set state of charge in the vehicles app.

These stations also bring two critical factors for the continued growth of the EV marketplace, driving down installation and maintenance costs by upwards of 70% and scaling more easily on limited energy capacity, allowing more stations to be installed to satisfy the charging needs of the community.

By forgoing faster charge times and understanding that residents commonly park their vehicles overnight for at least eight hours, lower-powered stations allow buildings with limited capacity to bring in multiple charging stations on-site affordably. These stations don’t require sharing, every user gets equal access, charging speeds don’t vary, and everyone gets enough energy to satisfy their daily needs. In short, lower-powered vehicle charging stations solve the problem of EV charging at apartments.

Presenter Biography

Nicholas Johnson is the CEO and founder of Orange, an electric vehicle charging company specializing in multi-unit dwellings. He has pioneered the use of lower-powered smart outlets in apartment communities that not only drastically reduce installation costs but also provides building owners with a positive return on their investment. He has worked on electrical designs for Tesla's Model 3, energy

storage projects for Africa, and A.I.-powered cloud-based traffic management software.

[1]https://www.gov.ca.gov/2020/09/23/governor-newsom-announces-california-will-phase-out-gasoline-powered-cars-drastically-reduce-demand-for-fossil-fuel-in-californias-fight-against-climate-change/

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