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Leading the Charge

Ensuring the Future of Electric Vehicle Charging Infrastructure in California

Zane DeVitre-Shalauta

SCRIPPS INSTITUTION OF OCEANOGRAPHY,
UNIVERSITY OF CALIFORNIA, SAN DIEGO

Abstract

Year after year if you look outside your car window while on the road, it is increasingly likely that you will see an electric vehicle (EV), especially in California. Fantastic as this is for the mitigation of climate change, we are still a long way from roads filled entirely with EVs, and that is partially due to deficiencies in EV charging infrastructure. Believe it or not, this is not the first time the United States has struggled with this specific issue. Our automotive history provides keen insights into the societal forces which aim to prevent the proliferation of EVs. Another of these roadblocks is cost, which can be reduced through creative means such as the use of second-life batteries, renewable energy systems, and load management solutions in our charging infrastructure. Reducing the cost of charging infrastructure and making it more ubiquitous is key, as a process that lacks equity will spell doom for all Americans regardless of their socio-economic background. Legislation historically has been the most effective way to spur the automotive industry into action and that is precisely what I recommend we must do. Passing AB 1738 in California will be a significant step in the right direction, providing a framework to fit existing housing, both single and multi-family, with EV charging infrastructure. Transportation electrification has the potential to remedy specific injustices of the past few centuries, paving the way for a brighter future for everyone.

It was in the 1890s that Alexander Winton, the first American to sell an automobile of his own making, recalls an episode happening in which his banker came calling on him, saying, "Winton, I am disappointed in you." When questioned as to what brought on this outburst, the banker spat back, "There's nothing the matter with me. It's you! You're crazy if you think this fool contraption you've been wasting your time on will ever displace the horse."

To prove the merits of his invention, he produced a newspaper clipping from his pocket, detailing an interview with Thomas Edison. In it, Edison remarks how the bicycle was now seen as essential, where just a decade prior it had been a curiosity. He predicts that this would be the trajectory of the automobile, eventually matching the price of a wagon and two horses and overtaking road transportation altogether. He concludes that because of the increasing burdens of the old paradigm and the opportunity presented in this new one, American cities should seize the opportunity, stating, "A great invention which facilitates commerce, enriches a country just as much as the discovery of vast hordes of gold." This, of course, was not convincing to this particular Cleveland banker (Winton 1930).

But of course, we know that it was Winton who had the last laugh. The relevance of this story is that visionaries like Winton and Edison were right and detractors, like Winton's banker, were wrong. Automobiles are the overwhelmingly dominant form of transportation in the United States and horse-drawn carriages are considered an antiquity. Just as Edison predicted, the American automobile industry became a colossal financial powerhouse and a dominant force in the global market.

Come the 21st century however, the US auto industry is not nearly as prominent as it was the previous one. We face stiff competition across the globe, especially in the unique era we find ourselves in. Transportation electrification is becoming the new paradigm of road transportation. While this paradigm began in the United States, our automotive sector failed to properly invest in the nurturing of this burgeoning industry, allowing for international competitors in China and Europe to lead this revolution. The

United States has a lot of ground to make up if it hopes to restore its status as a global automotive leader.

This was a grave miscalculation by American corporations and politicians, and unfortunately, it is not the first time they have made this specific mistake. The first commercially available electric vehicle was also American made. It was not a Tesla in 2008, nor was it even the ill-fated General Motors EV1 in 1996, but was instead the Baker Electric, which first went on sale in 1899 (Berk 2018). We have this hope that technology will progress ever-forward, but the story of the electric vehicle proves that this is not always the case. EVs are a fantastic example; were you to ask a modern American when the Golden Age of Electric Cars was, they would probably answer right now, where we have more EVs on the road than ever before. While it may be true that the number of EVs on the road are at their highest levels, they still only make up about 1% of all cars on the road.

The Golden Age of Electric Cars, 1900-1911, saw roughly 38% of automobiles running on electricity. In 1910, 90% of New York City's taxi cabs were electric (Kilson 2016). Where today EVs are often framed as an inferior product that only exists because of environmental concerns, EVs of the past were seen as a clear superior to their gas-powered counterparts. Gas cars were noisy, emitted foul-smelling fumes, and were physically intensive to start. However, a multitude of forces conspired to end the EV's reign at the top of automotive totem pole, many of which are the exact same forces attempting to stymie the modern age of electric transportation.

The first is the most benign; the infrastructure to support electric vehicles simply had not had much time to develop. Electricity itself was still largely a novelty to most of the world and heavy-duty batteries were still in their infancy. Thomas Edison, the father of electricity, foresaw it as the future of all energy. Unfortunately, Edison's dreams outpaced the available resources of the time. The material to make batteries was still wildly expensive and difficult to find. Combined with the recent discovery of massive amounts of crude oil in Texas, the electric vehicles of the early 20th century were all but doomed (Kilson 2016).

It would, incredibly ironically, be Edison's involvement in the creation of a mass-produced electric vehicle which would ultimately doom the technology's chances in the 1920s. Partnering with his friend, neighbor, and former employee Henry Ford, Ford Motor Company publicized their intention to bring an electric peer to the Model T to the market. However, as time went on, publicity surrounding the project died down and was eventually lost to the ages. So, what happened?

What I believe occurred was the first instance of purposeful self-sabotage in the American automotive industry. Ford, with either malicious or naïve intent, insisted on only using the experimental heavy-duty batteries made by Edison in his project, effectively dooming it. His advisors pleaded with him to use cheaper and more reliable batteries, but according to some historians, Ford felt like this would be a betrayal of one of his closest friends. While this may be the case, it is also notable that Henry Ford was on a path to become the richest man in the world selling gas-powered vehicles. Worth mentioning also was the corresponding plumet in the price for gas at the time. The ludicrous lucrativeness of the fossil fuel industry led to the creation of one of the most powerful lobbies the world has ever seen, and there are known ties between them and Ford Motor Company (Kilson 2016). After all, how else would the oil tycoons become richer than God without a means of selling to a giant swath of gas car-driving consumers?

And so, through the power of money, the gas car came to reign supreme. Oil companies got so rich that they had to be split apart for the good of the economy and the nation, while electric cars seemed to be relegated to the dustbin of history. Cars were bulky and inefficient. But who cared? Gas was cheap and there seemed to be no consequences for the feckless burning of fossil fuels. The automotive industry grew larger; car ownership went from thousands, to millions, to hundreds of millions.

At this point the effects of automotive emissions became impossible to ignore. In geographically unfortunate cities like Los Angeles. Pollution like smog choked the skies, damaging the lungs of the people who lived there. After years of negligently made gas vehicles, the people decided they'd had enough. The California Air Resources Board

(CARB) introduced the first zero-emission vehicle mandate in the 1990s and thus the first significant strides towards vehicle electrification in decades was reignited. However, these efforts were defeated by a lawsuit brought by major players in the automotive and oil industries, which prevented the realization of the mandate (Paine 2006).

The failure of the first zero-emission vehicle mandate was an almost comical repetition of history. Nothing exemplifies this better than General Motors's EV1 project. A fully electric car that was distributed in an experimental lease program in certain cities in the 1990s, it gained a following of adoring fans who loved it for its quietness, the exhilarating driving experience, and their ability to skip the gas station. By nearly every measure, the EV1 was a success, with the key word here being "nearly." The EV1's key failure was threatening the billionaires who had built empires on gas cars and the sale of petroleum products, and that was enough to doom it. Despite literal protests from proponents of the EV1, the EV1 was rounded up by GM and crushed in a junkyard. Today, only a few models still exists, none of which are functional (Paine 2006).

It is through the story of the EV1 that the patterns of greed, corporate shortsightedness, and self-sabotage are clearly illuminated. It also shows the importance of governmental intervention in urging industries to begin deviating from the status quo and how corrupted processes in organizations like CARB aim to preserve that status quo for as long as they are able to. Companies like GM will moan about how they were simply unable to profit from EVs due to deficiencies in supply chains, customer interest, and infrastructure, all while ignoring the fact that the decisions of companies like GM are the very reason why these deficiencies exist.

The EV1's failure is perhaps the most important footnote in modern automotive history. Those who had a taste of transportation electrification were so enthralled with it that they would use their passion to revive the movement. Some of those who were arrested while trying to prevent the destruction of the EV1 eventually went on to found Plug-In America, which to this day is a prominent proponent of the EV movement. Further still, visionaries Martin Eberhard and Marc Tarpenning were appalled by the apparent cannibalization of the EV1 at the request of GM's shareholders and corporate

leadership. This inspired them to found Tesla Motors and begin the creation an EV specific car company (Paine 2006). The rest, as they say, is history.

That's not to say the matter is settled. After all, we are continuing to live through history in every moment, and as the stories of Ford's EV and GM's EV1 tell us, history has a nasty habit of repeating itself. This remains the case today, as automakers around the world have begrudgingly begun the electrification of their products, a phenomenon they spent millions of dollars attempting to avoid rather than improve their chances of success. Leaving transportation electrification solely in the hands of the private sector has made for a snail's pace transition. It was only through intervention by the government that mass electrification of transportation began to look viable. This is precisely what I intend to advocate for. CARB's zero-emission vehicle mandate brought about the existence of the EV1 and government incentives for the purchase of EVs have allowed them to become an increasingly common fixture on American streets. New laws and rules have continued to nudge private organizations in the right direction, and for the sake of the planet and humanity, we must continue to do so.

This project aims to support the passage of California Assembly Bill 1738, a bill which alters the California Building Codes to better support the adoption of EVs. Currently, the California Building Codes commands that every new house built must be capable of Level 2 (208-240 Volt) charging and new multi-family dwellings must have 10% of their parking EV charging enabled. While this is an excellent step in the right direction, new buildings only count for a fraction of the buildings that exist in the state. In its current form, the California Building Codes cater almost entirely to those who are well-off. New housing is going to be inhabited by those who are able to afford such a home, and even then, if that housing is an apartment or condo, you're still going to need to contend with only 10% of that parking being suited for EV ownership.

AB 1738 remedies some of these discrepancies by mandating that the California Building Codes be changed to include guidance for fitting EV charging into already existing buildings. Initially, the passage of AB 1738 became a target of this project because it specifically calls out multi-family housing in its text, but the law goes beyond

just that, branching into mandated charging infrastructure at hotels and motels. This will assure that no matter where a given EV owner is resting their head for the night, as long as they are in the state of California, they will be able to charge their car.

The focus on multi-family housing however was my primary focus. It is a fantastic symbol of how class stratification in the United States impedes necessary action like transportation electrification. The longer we allow our transportation sector to continue emitting greenhouse gasses, the more we will inevitably pay for the destruction caused by climate anomalies. In California, that means intensified droughts, wildfires, and even catastrophic storms (California Legislative Analyst 2022). Class stratification has historically meant that it takes many years for the fruits of innovation to reach the middle and working classes. This is something we simply cannot afford to allow, and laws like AB 1738 are a fantastic way we can begin to combat this phenomenon.

Opponents of AB 1738 generally have the same complaints: that property owners should be able to take on the expenses of providing charging on their own time, more in line with the rates at which their tenants are purchasing EVs. While on the surface this seems like a reasonable ask, you now have the historical context as to why it is not. Left to their own devices, property owners have shown that they are resistant to such significant changes, even when there are incentive programs that would cover portions of these property owners' expenses. Just like the EV1, a mandate makes for fantastic motivation to create something new (provided that the mandate is followed through on), often to the benefit of everyone. The same goes for property owners, who will eventually see fewer tenants should they refuse to heed the trends in transportation electrification (Hughes 2020).

It calls back to the age-old question, which came first, the chicken or the egg? Will consumers need to purchase EVs en mass before the infrastructure starts catching up to them, or will EV infrastructure be the thing that allows mass electrification of transportation in the first place? While this might on the surface appear like a conundrum, the question has already been answered. Had it not been for already existing electrical infrastructure, modern interest in EVs likely would never have flourished, and

thus further expansion of this infrastructure to cater to EVs specifically is exactly what needs to happen in order to bring about transportation electrification. Similarly, the egg existed long before the chicken ever did; without the ancestors of the chicken adapting to lay eggs in the first place, it is likely that the chicken never would have come to exist at all. Like the ancestors of the chicken, it is incumbent upon us to make sure that we are all prepared to lay down the foundation of something we may not even fully experience the true value of in our lifetimes, to plant the seed of a tree whose fruits we may never get to enjoy so that our descendants may have a brighter future.

Another purported roadblock and argument against laws like AB 1738 is the cost itself, which today remains high. Level 2 charging systems can cost hundreds of dollars, and should that be compounded by the necessity of multiple units in a multi-family dwelling, these can lead to costs in the tens to hundreds of thousands. Further still is the cost of making sure already existing electrical infrastructure in these buildings are capable of handling such intensive voltage. These are far more reasonable causes for apprehension, but are not justifications for simply giving up since this is the case for every technology that has ever existed. With time and research, technology almost always becomes more reasonably priced.

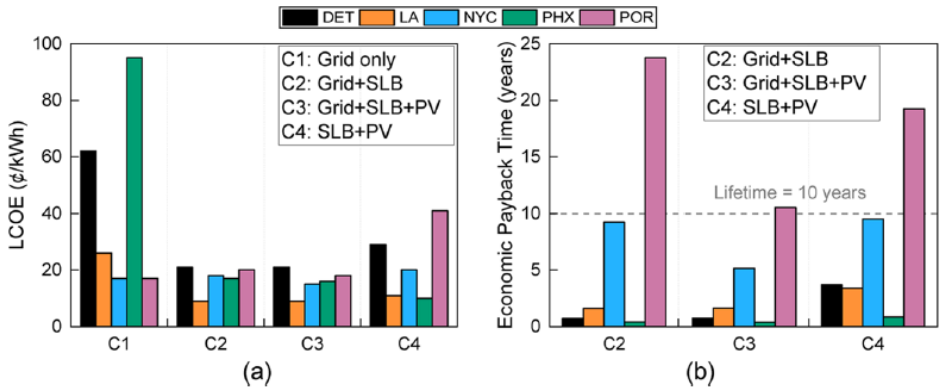
This research is already underway as EV charging companies strive to make their services more affordable and ubiquitous. In addition to the formation of supply chains and new sources of the natural resources necessary for this transition there are several ideas that seek to bring down the cost of charging by reducing factors like the levelized cost of electricity (LCOE). A few proposals that are being tested are the use of second-life batteries in charging systems, the integration of renewable energy into chargers themselves, and load management solutions.

Load management solutions refer to how the energy in a system with multiple chargers is distributed. Localized Load Management (LLM) has the potential to save money on the installation of charging stations by optimizing the efficiency of a building's existing charging infrastructure (EV Connect 2022). This in itself can also lower the cost of charging to the owner of a building by only purchasing as much electricity as is

needed. There are a couple of forms of load management in development; we will briefly touch on adaptive charging and charge controllers. A charge controller is a device that acts as an intermediary between the charging stations and the grid. This controller is capable of adjusting the power flowing to each individual station, cutting off the flow if it isn't in use or reengaging it when the time comes. This also acts as a safety device that prevents a system of charging stations from overloading the grid. Adaptive charging is similar in that it is a system that can control how much electricity is flowing to a given charging station, but does so using ever-improving algorithms and artificial intelligence. Such software considers factors like time of day, the number of vehicles charging, the miles an EV needs before leaving, and when that departure time will be. In this kind of system, adaptive charging software will cut off charging when an EV reaches the necessary range, allocating that energy to the vehicle that is scheduled to leave next. These systems are already being made available, like PowerFlex's Adaptive Load Management (ALM) system, which boasts a 60% reduction in costs of electrical upgrades for their customers (PowerFlex n.d.).

Another method of reducing the cost of charging is the integration of renewable energy directly into the charging systems themselves. While this idea remains novel, it is already being used in some charging stations. Beam Global, for example, sells a system they call the EVARC. It consists of a solar panel that serves as an awning that the EV will pull under. The panel energizes batteries that feed up to two charging stations. While the system is capable of connecting to the grid, it is also usable completely disconnected from it. This has the potential to bring transportation electrification to even the most remote areas in the world, provided there is significant sunlight. This essentially means free EV charging in these scenarios, and reduced cost of charging in systems that are linked to the grid. In the American southwest, including traditionally underserved communities like Indigenous nations, this has the potential to equalize availability to charging infrastructure in places where the grid remains a deficient source of energy. With the advent of bidirectional charging (the ability to use an EV as a large battery to energize something else), this could also serve as a boon to areas with energy insecurity.

Finally, the use of second-life batteries in charging system holds great potential for recycling the rare earth materials housed in an EV's batteries. Charging stations will often have battery systems on board to help meet demands even if they are unable to draw electricity from the grid for a time. This, however, has the unfortunate effect of further depleting the already limited amount of lithium available. With their usage in cars, charging systems, and home battery storage, recycling batteries will become a necessity sooner rather than later. Second-life batteries are batteries in EVs that have lost around 20% of their charge capacity. It is usually at this point that the battery is replaced, but what happens to the removed battery? Undoubtedly some are finding themselves cast aside, but this is an obvious waste of a battery that still functions. Why not then use them in charging stations to further reduce the cost of charging and give the battery a new life?



While these systems will vary in their efficiency based on the location of the station and whether or not it's supplemented with renewable energy, a study found that using second-life batteries can reduce the levelized cost of electricity by 12%-41% in most scenarios, as seen in the charts above (Kamath et al. 2020). This is excellent news for reducing the cost of charging. Factors that the study took into consideration include the multiple locations in which it was tested (Detroit, Los Angeles, New York City, Phoenix, and Portland), four different configurations (with or without renewable energy, grid connection, battery storage), how the cost was affected, and the environmental impacts of each. Concerningly, the environmental improvements in each appeared to be minimal, with only incremental changes in global warming potential (GWP). On the

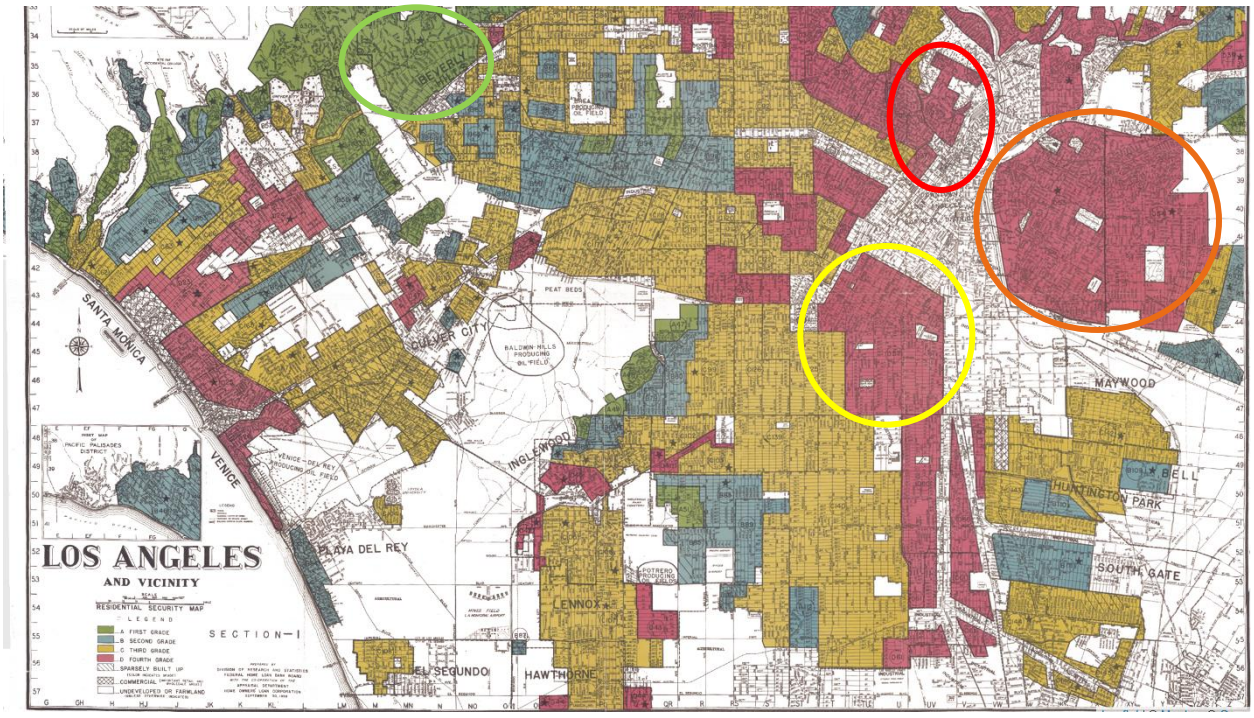
other hand, there were only a few scenarios in which the grid-only configuration came out as the most economically efficient, meaning that we could be saving money right now by using a mix of second-life batteries and renewable energy to charge our EVs. The most extreme example was Phoenix; at every power level they tested, the most economical configuration was disconnected from the grid, using only solar energy and second-life batteries (Kamath et al. 2020).

Los Angeles also was found to benefit economically from the use of second-life batteries and solar energy systems in their charging systems, but that likely pales in comparison to a benefit that often gets overlooked: public health. The city makes for an excellent case study in this case because, as mentioned earlier, Los Angeles's unique topography makes it one of the worst places on Earth to experience air pollution (Nazari-Heris et al. 2022). Both of my parents were raised there and tell me stories of days where the air was so choked with smog (ground-level ozone) that they were unable to go outside. Smog forms when volatile organic compounds (VOCs) emitted by gas cars interact with the heat of the sun, forming ozone. This occurs in cities across the United States and the smog eventually billows outwards and dissipates. Not so in Los Angeles, which exists in the Los Angeles Basin, buttressed by the San Gabriel Mountains. Further still, LA experiences subsidence inversions, meaning that layers of atmosphere closest to the surface are unable to mix with the layers above like normal, thus acting as a sort of lid keeping the smog in.

In addition to smog, gas cars also produce $PM_{2.5}$ (a microscopic particle that is small enough to enter and damage the lungs), nitrogen oxides, carbon monoxide, and other pollutants, all of which have caused damage to the health of Angelenos (United States Environmental Protection Agency 2018). Money that could go towards improving the lives of themselves and their families instead need to be spent on inhalers, air filters, and medical treatment for asthma, chronic bronchitis, and other medical conditions caused by this pollution. These conditions affect everyone in the city, though unfortunately and predictably, it does not affect everyone equally.

Environmental racism describes a phenomenon where polluting practices and industries (like factories, major roadways, and heavy agriculture) are placed in the same areas as minority populations and the poor. This is due to the practice known as redlining. In New Deal era America, the government subsidized the purchase of houses in order to help Americans rebuild their wealth during the Great Depression. However, these subsidies also had a distinct and sinister effect: segregating nearly every city in the country. These subsidies were only able to be used in qualified areas, which were almost exclusively "whites only" neighborhoods. People of color were shut out from this process and instead forced into urban housing projects. These projects were often sharing the area with factories or freeways, and little has been done to change this in the last century so many of these neighborhoods remain as polluted, poor, minority-majority areas (Gross 2017).

Los Angeles is no different in this regard. Observe the map below which details the redlining in the city put into place in 1939 (University of Richmond 1939):



The areas in red indicate the places marked as "hazardous" at the time. Circled above are Central Alameda (yellow), East Los Angeles (orange), and Chinatown (red). Each of these areas are either Latino or Asian majority neighborhoods and were made to remain

that way thanks to this map. For comparison, also circled (in green) is Beverly Hills, a wealthy, white-majority neighborhood that made it into the "best" category.

Based on the concept of environmental racism I mentioned previously, which areas do you think have higher rates of pollution? If you answered, "the ones in red," you would be absolutely correct. Pollution is significantly worse around the Downtown area due to its many major roadways and industrial centers. Looking specific at something like $PM_{2.5}$, reveals a distinct disparity. Central Alameda, East LA, and Chinatown all have $PM_{2.5}$ levels at 151%, 175%, and 211% above average respectively. Meanwhile, Beverly Hills sits at 52% above average (Reichmuth 2019). You read that correctly; Beverly Hills, while much lower in $PM_{2.5}$ pollution, still registers above average. This is an excellent example of how even though minorities and the poor are disproportionately affected by the pollution caused by gas cars, they are not the only ones. Even the wealthiest, most historically catered to populations will feel the effects of air pollution. Because of the fluidity of the atmosphere, simply electrifying all the cars in Beverly Hills is not going to eliminate this issue; electrification must happen at every socio-economic level to begin bringing these pollution levels to zero.

Transportation electrification can be one of the greatest boons our country has ever seen, but only if it is available to everyone. It was initially shunned because it did not provide an obvious path to make its proponents rich as quickly as gas transportation did, and now, over a century later, we are reaping the consequences in the form of catastrophic climate anomalies, polluted air, and an industry decades behind our chief global rival. Refusing to rise to this challenge will undoubtedly be our downfall, and that is why legislation like AB 1738 are necessary to start bringing us up to speed. It is time private industry be forced to stop viewing their decisions through a quarter-to-quarter lens, as that is precisely how we found ourselves in this mess to begin with. We can no longer afford to wait for them to see the light; if they are wholly unwilling to make the obviously correct choices that take our collective fates into account, then we the people must make it for them, for the sake of our families, our friends, our health, our country, our planet, and our future.

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