Independent clean-energy and policy analysis **February 2019** *by Eric Strid*

What Can Accelerate the Electric Vehicle Transition?

Summary:

- *Situation:* The electric vehicle (EV) transition will fundamentally disrupt auto and energy markets. It is driven by massive cost-saving opportunities and resisted by oil companies and incumbent auto dealers. The pace of the transition is uncertain, but clearly dependent upon public policies.
- *Public policy options* include status quo, fees on fuels, fees on inefficient new vehicles, rebates, better financing of vehicles or charging infrastructure, and guiding or funding charging infrastructure.
- *Recommendations:* Define the goals for transportation energy, design policies for the sector, adopt fees on inefficient new vehicles, and efficiently fund charging infrastructure.

I. Situation

A. The electric vehicle (EV) transition will fundamentally disrupt auto and energy markets.

Similar to smart phones disrupting Nokia and Blackberry or digital cameras bankrupting Kodak, EVs will reshape the auto industry. In the second half of 2018 the Tesla Model 3 became the best-selling EV in the world and the best-selling car by revenue of any model in the US. The company showed good margins as well. While Tesla now has a significant first-mover advantage, Bloomberg New Energy Finance (BNEF) notes the heavy commitments of incumbents (Figure 1) and over 300 EV models announced for 2020 launch.

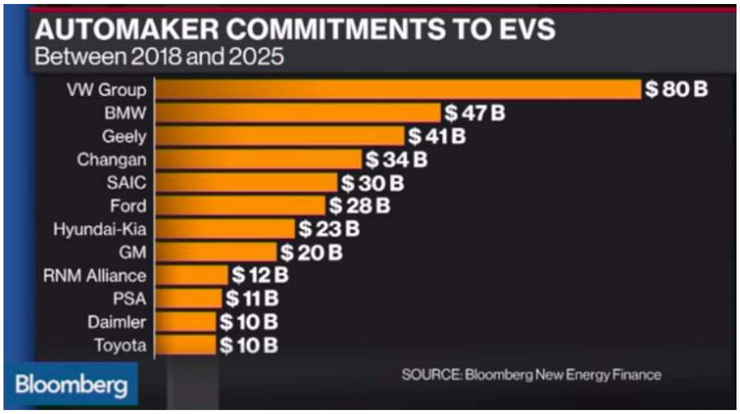


Figure 1. BNEF totaled up more than $346B committed to developing EVs globally.

B. The EV transition is driven by massive cost-saving opportunities and resisted by oil companies and incumbent auto dealers.

1. *Fuel costs:* An EV is about four times as energy-efficient as gas or diesel vehicles, resulting in EV fuel costs averaging less than half of gasoline cars. Americans spend over $2500 per capita on energy annually, the majority of that on transportation fuels. EVs thus enable significant consumer and fleet savings and enable communities to keep consumer spending more local. Electrified transportation also reduces fuel cost volatility and expands options for local energy resilience. The EV transition will create the peak in oil demand and guaranteed opposition by oil companies.
2. *Maintenance costs:* An EV has one moving part in its motor and no transmission, compared with around 2000 moving parts in an internal-combustion car. Auto dealerships earn nearly half of their gross profit from service and parts; thus few dealers are EV advocates because EVs require so much less service, and much of that is generic tire and brake service.
3. *Social (externalized) costs to society of transportation emissions:* Transportation fuels cause the largest sectoral climate emissions in many states and the US. The latest cost studies estimate the social cost of climate emissions for global climate damages on the order of $400 per ton (about $4 per gallon), and the social cost of toxic emissions of gasoline or diesel in the $2 to $3 per gallon range, primarily from local, health-related costs. Oil companies oppose all policies that recognize social costs of emissions.
4. *Capital costs:* While the total economic (not counting social costs) cost of ownership for an EV is often lower than a gas/diesel vehicle already, most EVs are still significantly more expensive to purchase. The key capital cost is battery cost, which has dropped 85% since 2010. As battery costs keep dropping, EV purchase prices are projected to become cheaper than gas/diesel vehicles in 2024-2029, depending upon the vehicle class.

There are thus major economic savings and reasons to encourage an efficient transition to EVs, beyond only reducing the socialized environmental costs of emissions.

While fuel savings is typically ranked the #1 reason to buy an EV, the superior drive-train performance stands out for many buyers—the faster, smoother acceleration and regenerative braking are far better than gas/diesel vehicles.

The EV transition is also a once-in-a-generation growth opportunity for electric utilities and a large demand-response resource for balancing a grid with increasingly renewable generation.

C. The pace of the transition is highly uncertain, but clearly dependent upon public policies.

EV range, capital cost, model availability, and charging infrastructure are all improving rapidly, but many unknowns remain. Not all the 2018 EV sales results have been reported yet, but the wide range of 2018 EV adoption rates (Figure 2) in various jurisdictions provides a variety of policy cases to analyze. Public policies can accelerate the transition through carrots or sticks, and dramatically accelerate the transition by recognizing the social costs of transportation emissions.

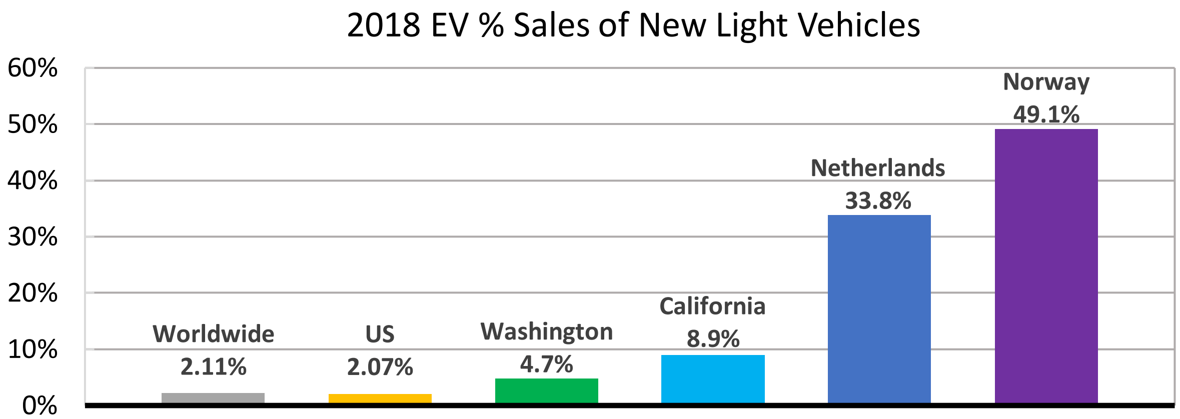


Figure 2. 2018 annual EV sales as a percentage of all new light-vehicle sales in various countries and states ranged from <1% to nearly 50%. Sources: IEA, best-selling-cars.com, Electrek, CleanTechnica, InsideEVs, EVAdoption, West Coast Green Highway. Chart: Eric Strid

Lessons from the rapid adoption of the Tesla Model 3 EV and Norway's EV policies include:

- Consumers will adopt EVs when the price-performance is similar to gasoline or diesel models. In practice, this means that mass-market EVs must have at least a 200-mile range, a comparable purchase price (with some consideration for lower operating costs), a national network of fast chargers, sales and service support, and sufficient production capacity.
- The necessity of general EV education efforts is questionable. Tesla relies on word-of-mouth advertising. Much of the public is still oblivious to EVs, but that is logical since a median-income household in 2016 could not afford the average price of a new vehicle in any of the 50 largest cities in the US.
- The most effective education gap could be teaching car buyers the lifetime costs of fuel and maintenance, as well as the real social (externalized) costs of the lifetime climate emissions and toxic emissions of gas and diesel vehicles. Driving a new hybrid Prius off the lot locks in 30 tons of pollution (MTCO2e) and the most efficient new pickup locks in 60 tons.

The policies that drove the varied results in Figure 2 will drive very different EV adoption trajectories. Like most technology disruptions, EV sales are in an exponential, virtuous growth cycle due to higher sales driving lower prices, which drive higher sales. Figure 3 shows 2018 EV forecasts ranging from 8% to 100% of new light-vehicle sales by 2025, depending on the geography and assumptions.

Most oil companies forecast little or no growth for EVs; those are not plotted in Figure 3, but some oil companies agree with the Bloomberg (BNEF) global forecast. Given that multiple states and countries are far ahead of the BNEF forecast, and the largest automakers will be competing for survival in this transition, all of these forecasts are possible. For example, US adoptions grew by 29% in 2017 and 78% in 2018; BNEF assumes this drops back to 28%, IEA to 35%, and EVAdoption to 43% annual growth rates through 2025. EVAdoption's California forecast maintains its share of about 50% of all EVs sold in the US through 2025.

The "100% by 2035" curve in Figure 3 is a feasible trajectory for achieving one requirement of the 2018 recommendations of the IPCC (Intergovernmental Panel on Climate Change) , that no new fossil-fueled light vehicles be sold after 2035 and thus the light vehicle fleet is zero-emission by about 2050.

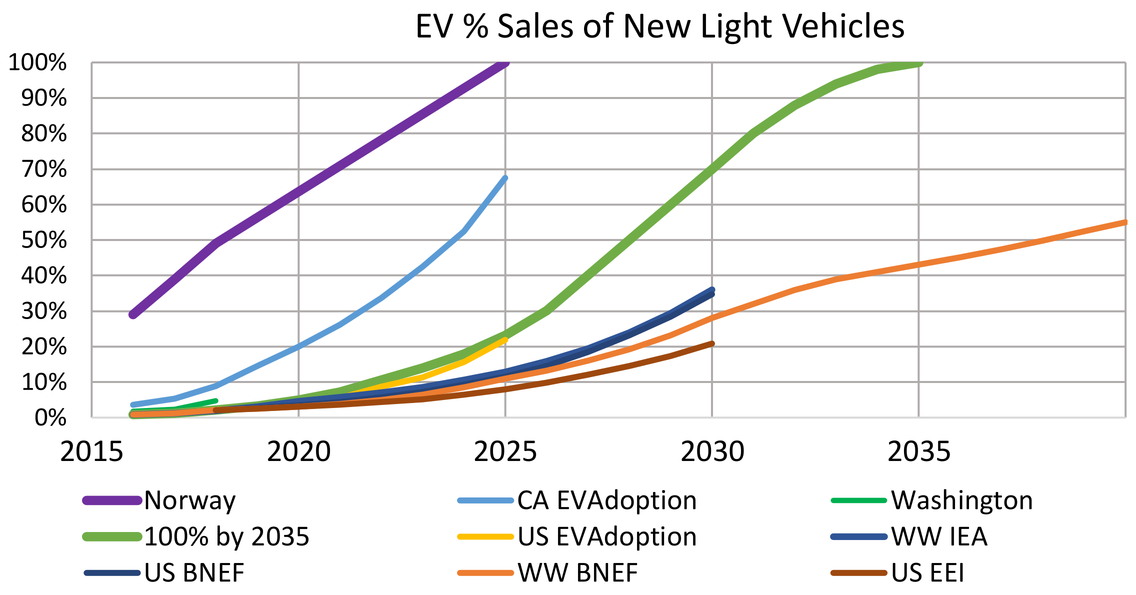


Figure 3. 2018 EV forecasts disagree on adoption trajectories. Norway is targeting 100% by 2025; WW is worldwide; EEI is the Edison Electric Institute; IEA is the International Energy Agency; BNEF is Bloomberg New Energy Finance. Note that the EV portion of a fleet is the time integration of these annual EV additions, minus retired vehicles. Sources: BMI Research, Macquarie Bank, Green Car Reports, IEA, BNEF, best-selling-cars.com, Electrek, CleanTechnica, InsideEVs, EVAdoption, EEI, Auto Alliance. Chart: Eric Strid

II. Public Policy Options

In 2018 why was Norway at 49% EV sales, The Netherlands at 34%, California at 9%, Washington state at nearly 5%, US at 2%, etc.? What can be inferred from these results?

There are multiple good studies of EV policy efficacy, although the market is evolving rapidly. For example, free HOV lane access has been shown to be effective in populous states. But the huge differences in Figures 2 and 3 must be due to major differences in EV policies, and if a detailed regression analysis is necessary to determine whether a policy has any effect, then the policies must not be very potent. What can significantly accelerate the EV transition?

When it comes to organizational change, *if you haven't upset anyone, then you haven't changed anything.* Which policies upset which parties, and are they fair?

A. No new policies

The forecasts in Figure 3 extrapolate expected market forces and existing policies; thus they predict "business-as-usual" baselines for policy design. The forecasts range widely, from 8% to 100% of new light-vehicle sales by 2025, and are comparable to the targets of the federal CAFÉ standards and state Clean Fuels and Zero-Emission Vehicle (ZEV) programs. Those forecast scenarios call into question the targets of existing emission policies. Dave Roberts recently predicted that "EVs will come on so strong that they will lower transportation-sector carbon emissions faster than CAFE standards ever could have." The California Air Resources Board estimates that automakers will need to reach less than 8 percent ZEV sales by 2025 to produce enough credits to meet requirements--coincidentally the lowest forecast in

Figure 3. The Clean Fuels Program targets in California and Oregon, and proposed in Washington, focus on reducing the carbon intensity of fuels used in the state, but zero-emission vehicles are necessary to deeply decarbonize by 2050.

Thus it is reasonable to ask if any further policies are necessary to reach, for example, the 100% by 2035 trajectory. Norway appears likely to achieve their goal of 100% EV sales by 2025. California, at 8.9% in 2018, is arguably solidly on a trajectory to reach 100% by 2035. Probably. For all other states, even Washington, reaching 100% by 2035 is not at all certain. No new policies upsets no one, but also maintains a high risk of failure. Adopting some level of Norway's polices, for example, can provide a structure to accelerate adoptions as necessary to achieve a target trajectory.

B. Fees on fuels

Policies implementing fees on fuels include carbon taxes, cap-and-trade/"cap-and-invest" systems, Clean Fuels Programs, or similar policies that increase fuel prices.

Bicycle commuters understandably favor taxing fuels to force more people out of their cars. But our built infrastructure is not dense enough to enable most people to significantly replace their automobile travel with walking or bicycling. Most people are stuck with the vehicles they can afford, and must buy fuel to commute to work and visit family, etc.

One problem with fees on fuels is that low-income families have the least ability to change their fuel consumption, and their fuel costs as a portion of income are higher than other income levels.

The incremental fee on a gallon of gasoline is lost in the fuel price volatility, and demand for energy is highly inelastic anyway. So the price difference of the fee won't have any effect on demand, and investing the revenue in vehicle rebates or zero-emission infrastructure, especially for the affluent people who can afford new vehicles, is the definition of a regressive tax.

One of the main problems with Washington's failed i1631 carbon tax ballot measure was that few voters could tell what they'd get for this new tax. A gasoline tax upsets everyone, especially if they can't see the benefits.

C. Fees on inefficient new vehicles

Policies implementing fees on new vehicles include vehicle fees or taxes, the ZEV Program, or similar policies that increase prices on new vehicles, whether visible to the buyer or not.

1) The California ZEV Program is a fee/rebate (or "feebate") program that causes emitting vehicles to cost more and zero-emission vehicles (ZEVs) to cost less. Its cleverness is that the money is transferred between automakers to buy or sell ZEV credits; thus consumers never know the purchase fees or rebates they're paying or receiving. The ZEV Program tends to upset only laggard automakers, since it's not visible to consumers.

   Nine states have adopted California's ZEV program; these "ZEV states" correlate with higher EV state-level adoption results.

2) Lifetime emissions fees on new vehicles avoid the market failures typical of energy-efficient appliances. Buyers don't consider the annual energy costs of an appliance over a 10-, 20-, or 30-year lifetime; instead they consider operating costs for only 2-3 years. They are not rational consumers, but it's reality. One path around such market failures is to charge the lifetime social cost of an emitting product upon purchase.

Christina Bu of the Norwegian Electric Vehicle Association notes, *"When the EV price is comparable to the petrol vehicle price, people will adopt."* That's Econ 101, but it's a refreshing signal in the noise of EV policy debates. *"We tax the heck out of new gas guzzlers,"* unlike countries where we let consumers and companies socialize the costs of their polluting decisions. And most revealing, *"Nearly 50% of new vehicle sales in Norway are EVs."* Norway is simply making the lifetime emission fees high enough that EV prices are similar to comparable gas/diesel vehicles. Their biggest problem now is installing enough chargers.

Norwegian buyers of new cars "pay to pollute"; that is, they pay up-front for the social costs of the pollution they lock in. In this way, the party deciding to bring a vehicle into the fleet is the party who pays the social costs of that decision. Norway's CO_2 fee rate is progressive, from about $74 per ton of pollution for the lifetime emissions of a 29 mpg vehicle and about $241 per ton for a 24 mpg vehicle (US EPA, not European, ratings).

At least one vehicle fee structure similar to Norway's has existed in the US since 1978. The US Gas Guzzler Tax discourages cars with poor gas mileage (Figure 4), by taxing cars (no coverage of trucks or SUVs) with fuel usage in excess of a 25 mpg threshold; above that fuel usage it effectively charges a fee rate of about $110 per ton for pollution over a 150,000-mile vehicle lifetime. Few people have heard of this tax because so few cars are now worse than 25 mpg.

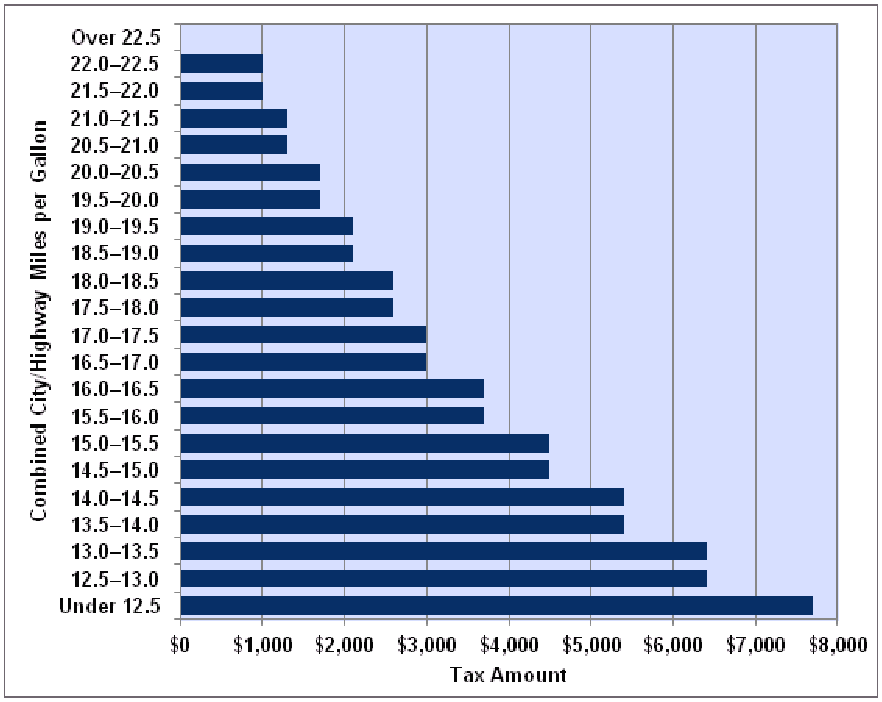


Figure 4. The federal Gas Guzzler Tax rates on cars haven't been updated since 1991.

Fees on inefficient new vehicles will tend to upset some purchasers of inefficient vehicles, a subset of affluent car-buyers who lock in emissions. Oil companies would no doubt feed them with some kind of messaging about freedoms and free markets, but oil companies are already blaming customers for using their products.

Norway's very high EV share demonstrates the potential efficacy of such a structure. It is also progressive and generates revenue, although the revenue rate is somewhat unpredictable and will decrease over time as more EV models become available.

D. Rebates

Rebate options include cash rebates, tax exemptions, tax credits, or similar policies that decrease prices on new EVs.

Rebates or tax credits for vehicles or charging infrastructure can be effective to move the cost of an EV closer to a gas or diesel equivalent. But even a $2000 rebate gets very expensive for tens of thousands of vehicles in a state. Rebate efficiency can be low--$2000 has little effect when the gap is $10,000 or more, or already zero. And why should public money subsidize relatively affluent buyers of new cars?

E. Better financing of vehicles or charging infrastructure

As with other clean-energy technologies, the operating costs of EVs are lower than incumbents but the acquisition costs are higher. A proven business model for selling solar arrays is to finance them through a portion of the operating savings. Green bonds, green banks, the Washington Clean Energy Fund, or similar revolving-loan funds are variations on this theme—businesses and consumers want the new infrastructure, so it becomes a financing hurdle.

Green banks use public money to leverage private funds on clean-energy projects, even while paying back the initial funding plus interest. For example, the Connecticut Green Bank has programs for financing EV charging infrastructure, both residential and commercial, and EV rebates for Nissan. The only party who doesn't win from a green bank is fossil fuel providers.

F. Guiding or funding charging infrastructure

High EV adoptions imply lots of EV chargers everywhere, and chargers everywhere help to sell more EVs. Public charging infrastructure is a key to growing the electric vehicle market. Jurisdictions can help by coordinating charging network planning and rules for utility participation, or help to fund charger network buildouts.

III. Recommendations

A. Define the goal(s) for transportation energy

"Begin with the end in mind." Setting a goal clarifies the resources and steps necessary.

The EV transition will save consumers money and time, reduce fuel cost volatility, cut local toxic emissions, and make a more efficient electric grid.

But our children and grandchildren aren't just looking to us for signs of hope—they're needing us to respond appropriately to the climate emergency we've created. Specifically, the IPCC's latest strong recommendations imply zero fossil-fuel vehicles sold after 2035. A less stringent goal doesn't make sense for society, especially given the economic cost savings inherent in the EV transition. And the IPCC process is communicating a politically filtered message that is watered down for public consumption and excludes serious positive-feedback loops.

The IPCC requirement is to cut net greenhouse gas emissions to zero by about 2050, so a plan to cut one sector's emissions by less than 100% also doesn't make sense. This allows a sort of separation of variables--each sector needs to be completely decarbonized, and those which cannot be decarbonized need to figure out a negative-emission strategy to reach net-zero. Compared to other emission sectors, we know very well how to decarbonize vehicle emissions--there are 5 million solutions driving around already.

B. Design policies for the sector

Sectoral situations require policies that are effective and efficient for the sector. Most sectors need significant deployments of new infrastructure to reduce emissions, and most of the new clean-tech options are enabling lower operating costs. But the maturity level of the solutions varies from mass deployment of wind and solar power, to early deployment of EVs and short-term storage, to pilot projects for seasonal storage, to research efforts on aviation fuels, various industrial processes, and negative-emission technologies. The policies needed for each productization phase are different—for example, a cement company needs help with pre-competitive R&D, not emission penalties that will just force the company out of the state.

Design for transportation emissions: The forecasts in Figure 3 predict "business-as-usual" baselines for policy design. But the wide spread of possible futures complicates planning. As a minimum, policy makers should account for a likely range of EV business as-usual possibilities. In the wildly volatile semiconductor equipment business, companies routinely plan for a wide range of possible revenue cases--the business plan must maintain positive cashflow in the lowest revenue scenario, and acceptable product lead times in the highest revenue scenario. The analogous requirements for transportation policy design would be something like:
- achieve a ramp to the goal, such as the 100% zero-emission light vehicle sales by 2035, in any market scenario (Norway has proven this to be feasible); and
- minimize costs to all parties if market forces drive EV adoptions faster than the targeted ramp.

States should provide business-as-usual guidance to counties and cities for their energy planning, with respect to the range of EV adoption trajectories expected in the state.

Existing transportation emission policies, such as CAFE, Clean Fuels, and ZEV program targets, should not be scrapped yet; but their necessity and targets should be revisited in light of the EV trajectories likely in the state. Cap levels in cap-and-trade systems that include light-vehicle emissions would need to be adapted to rapid EV adoptions.

Only the federal government or California can mandate vehicle performance, but state policies can steer purchases with financial incentives, whether carrots or sticks or both. States need to plan policies that can achieve their emissions goals in any likely market scenario.

C. Adopt fees on inefficient new vehicles

Simple state-level policies, such as expanding the 1978 federal Gas Guzzler Tax (Figure 4), are demonstrably progressive and effective for steering vehicle purchases to EVs, while also raising revenue.

As hundreds of EV models become available in 2020, light trucks and SUVs will have many more EV options. Thus a state could simply expand the schedule in Figure 4 to cover all light vehicles. The fee rate (currently about $110 per ton) and threshold (currently 25 mpg) could be adjusted over time to throttle zero-emission adoptions as necessary.

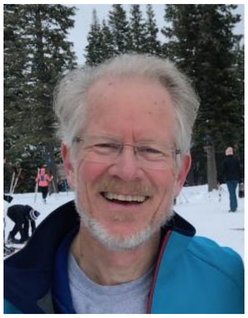
Light trucks are necessary for business transportation, and policy should not punish buyers who have no choices for cleaner vehicles. A more complex structure could apply such fees by EPA vehicle class, perhaps triggered by the availability in the state of at least two affordable EVs in the vehicle class.

The administrative overhead could be as simple as periodically updating the fee schedule and tracking which vehicles have paid the fee. (At a state level, the fee for registering used vehicles from other states could be as if the vehicle model were purchased in the state, but prorated for the lifetime mileage remaining.)

The revenues raised from the fees could be used to fund EV chargers or other clean-energy infrastructure. Voters want to know what they'll get for the fees or taxes, such as a clear plan for EV infrastructure that will be part of a superior transportation system for the state.

D. Efficiently fund charging infrastructure.

The EV transition will require many thousands of EV chargers of various types throughout the state. The state should develop a charger plan to guide siting and coordinate with charger companies, electric utilities, and local merchants. The state could use funds from the new-vehicle fees to help fund or finance charger projects.



Bio: Eric Strid is a retired high-tech entrepreneur and CEO, now working for our children on climate policy. Schooled as an electrical engineer at MIT and UC Berkeley, he worked as a microwave engineer and then cofounded Cascade Microtech in Beaverton, OR in 1983. Eric served as CEO, took it public in 2004, transitioned to the CTO role in 2008, and retired in 2012.

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