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

100% EV Sales by 2025 Achieves 2030 IPCC Target While Saving the US Trillions

Summary

- The window for reducing greenhouse gas emissions is closing.
- Policies can steer new vehicle purchases to EVs to clean up the fleet with minimal public spending.
- Electric vehicles (EVs) are reaching cost tipping points that will drive rapid adoptions.
- Retooling all US vehicle production to electric by 2025 achieves 45% GHG reductions by 2030.
- We can retool for EVs by 2025 and it's smart business. The federal government should help.

- Historical US vehicle replacement rate is 6% per year
- Full retooling of US production over 6 years enables fuel and vehicle savings by 2023
- Fleet emissions cut 18% by 2025 and another 30% by 2030

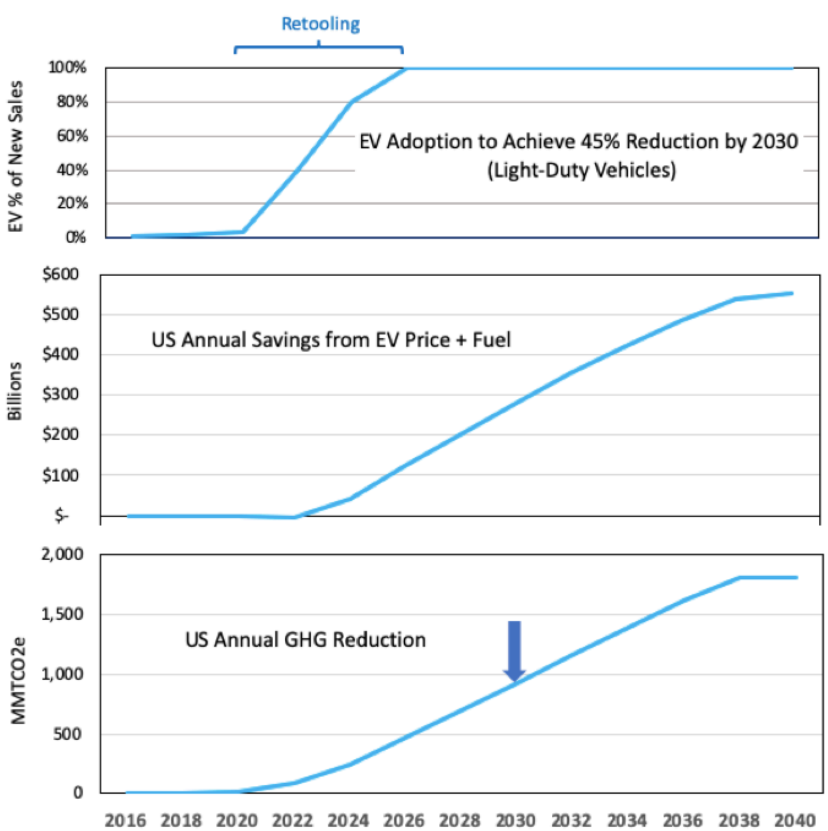


Figure 1. (top) Retooling US production to EVs by 2025 cuts about 6% of fleet emissions annually. (middle) Light-duty vehicle (LDV) fuel savings (net) and lower purchase prices enable massive total savings. (bottom) This scenario achieves the 2030 IPCC requirement of 45% GHG reduction below 2010 levels.

I. The window is closing

The window of time to sufficiently reduce greenhouse gas (GHG) emissions is closing. That is the recent message of the International Panel on Climate Change and 11,000 climate scientists. Specifically, to limit global warming to 1.5C, "Global net human-caused emissions of carbon dioxide (CO2) would need to fall by about 45 percent from 2010 levels by 2030, reaching 'net zero' around 2050." These are physical requirements, and the laws of physics don't negotiate.

The 2030 IPCC requirement is far more urgent and challenging than the 2050 requirement. For example, China's EV investments alone would likely force global decarbonization of vehicles by 2050, but will not achieve the 2030 target.

In 2017, US transportation GHG emissions were the largest sector, at 29% of total US GHG emissions. This grew from about 1,800 MMTCO2e in 2010 to nearly 1,900 MMTCO2e in 2017. 59% of transportation emissions was from light-duty vehicles (LDVs), and 23% was from medium- and heavy-duty vehicles (MDVs and HDVs).

Light-duty EVs may be the largest opportunity to rapidly cut US GHG emissions. Auto markets are highly competitive, and classic technology transitions begin exponentially. The market share of all suppliers gets reset to zero, so there's an existential race for early market share as buyers choose their new favorites and become more and more accustomed to the new technology. Suppliers who can't deliver fare badly, as Nokia experienced after smart phones invaded the cell phone market.

II. Policies can steer new vehicle purchases to EVs to clean up the fleet with minimal public spending.

About 17,000,000 new light-duty vehicles (LDVs) are sold in the US annually (for around $600 billion), upgrading a fleet of about 264,000,000 vehicles. Thus, about 6.4% of the fleet is being updated every year, with nearly no direct public investments. If all new LDVs were zero-emission vehicles (ZEVs), then LDV emissions would reach the 45% reduction by 2030 required per the IPCC within 7 years and 100% clean after about 16 years, again with negligible public investments.

China sees the EV transition as a once-in-a-century opportunity to overtake incumbent auto manufacturers with a new technology, even while reducing China's local toxic emissions and dependence on oil imports. China is on track to produce about 16 million EVs per year by 2025. About 2/3 of the world's EV batteries are produced in China, and that portion holds for supply-chain investments through the next decade. The US must urgently increase EV production toward China's rate if we expect to save American autoworker jobs.

III. Electric vehicles are reaching cost tipping points that will drive rapid adoptions

Electric vehicles (EVs) of all types are getting cheaper to purchase vs gasoline/diesel vehicles (Figure 2), and they always were about a half to a third the cost to fuel.

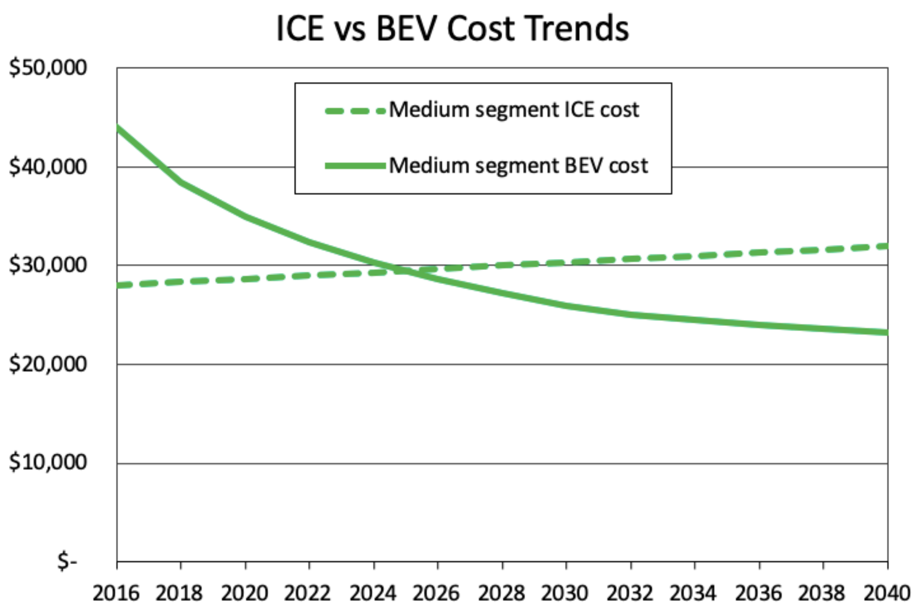


Figure 2. The cost of EV batteries are falling and will continue to fall with production learning, creating predictable dates when battery electric vehicles (BEVs) will be cheaper to build than internal combustion engine (ICE) vehicles. This BEV cost trend could fall even more quickly if EV adoption rates are higher than BNEF estimates. Source: BNEF, chart: Eric Strid

Adding ten years of typical fuel costs to the trends in Figure 2 accelerates the cost crossover about 6 years—to 2019 in this case. In other words, many EVs are already cheaper to own. Fleet managers know this, but most consumers consider only a couple years of operating expenses.

IV. Retooling all US vehicle production to electric by 2025 achieves 45% GHG reductions by 2030

These purchase price trends and fuel efficiencies can be combined with potential EV adoption rates to project fleet savings and emissions, such as in Figure 3. The three adoption cases in Figure 3a are scaled to the savings and emission reductions for 17 million new vehicles per year, the US rate.

Norway is already adding more EVs than ICE vehicles annually; since the average EV purchase prices have been higher than ICEs, Norway's annual spending has been greater than the savings. But the Norway total cost turns to savings around 2021 as purchase prices equalize and more of the fleet is saving on fuel costs. Norway's trajectory then reaps the highest savings and the most emission reductions.

China's case is delayed from Norway's, and is generally paced by ramping up production capacity.

The USA case (also shown in Figure 1) proposes catching up to Norway's EV portion of sales by 2025.

In all cases, the emission reductions and most of the savings accrue directly from reducing fossil fuel usage. The earlier the transition, the greater the fuel savings.

Figure 3a. An illustration of the percentage of new LDV sales that are EVs for three example cases: Norway's actual and trajectory, China's actual and trajectory, and a proposed US ramp. EV % of new sales at 100% would be decarbonizing about 6.4% of the US fleet annually.

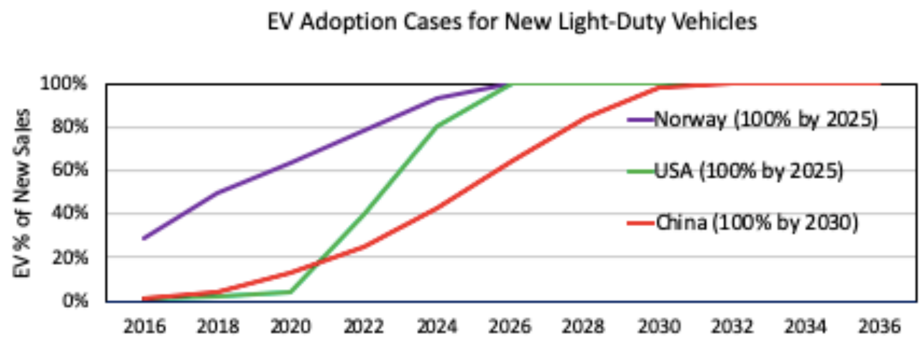


Figure 3b. Annual savings from fuel plus purchase prices, for the adoption cases in Figure 3a, scaled to US volumes. [Cost projections assume] a medium-segment gasoline vehicle vs comparable EV (from BNEF), gasoline at $2.50 per gallon, 26 mpg average ICE fuel efficiency, and electricity at $0.13 per kWh.

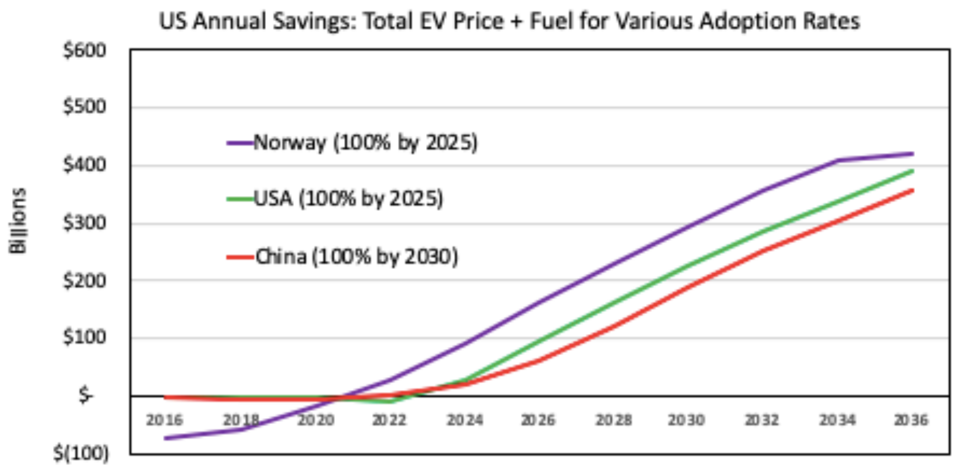
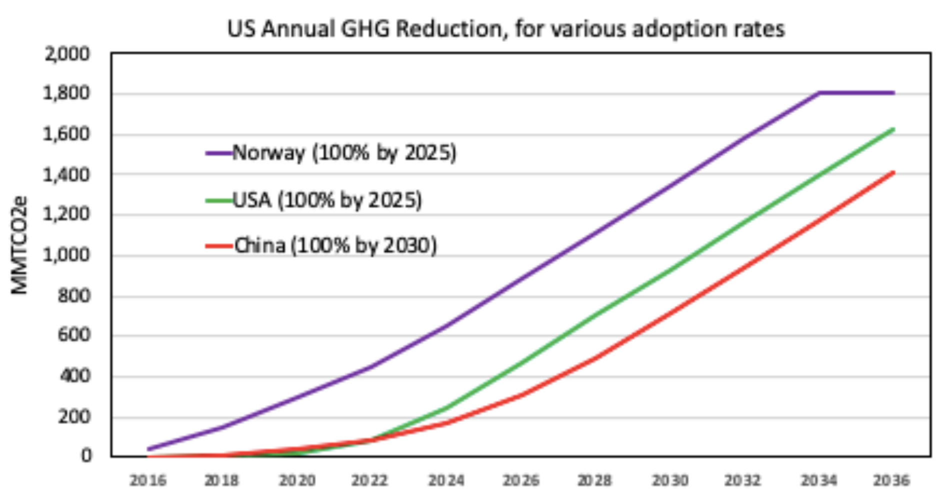


Figure 3c. Annual GHG reductions for the vehicles in Figure 3b, also scaled to US volumes. Norway's trajectory achieves the IPCC target of 45% reduction by about 2030, due to their mix of BEVs and pluggable hybrid electric vehicles (PHEVs) in their electric vehicle count.



<u>Disclaimer:</u> This illustrative model does not consider myriad smaller factors such as vehicle type mix, highway taxes, model availability and prices, social costs, maintenance costs, oil prices, electricity emissions, etc.

The logic behind the proposed US ramp is illustrated in Figure 1: five years at 6% fleet decarbonization per year achieves 30%, and a linear ramp up to 6% achieves another 18% over six years, starting in 2020. Delaying the ramp would require more than 6% annual fleet decarbonization, implying higher production to supply exports or incentives that increase sales beyond 6%, such as a major cash-for-clunkers program.

V. We can retool for EVs by 2025 and it's smart business. Federal policy should help.

A. Is such a ramp feasible?

To achieve the 2030 IPCC target with LDVs, US factories would have to dramatically ramp up EV production (from about 400,000 per year currently to 17,000,000). Norway has demonstrated the carrots and sticks necessary to incentivize this adoption rate, and Norway is the only country on track to achieve IPCC's 2030 target for LDVs (Figure 3c). But Norway's sales volume is only about 1% of the US volume, thus the larger task is ramping up ZEV production.

Business-as-usual EV adoption forecasts vary widely, from oil companies who predicted fewer EVs in 2040 than are already on the road, to pundits who predicted zero ICE sales by 2024, replaced by one third as many autonomous EVs. Predicting technology progess is challenging, but recent developments indicate that:

- Achievement of societal expectations for autonomous vehicle safety is far more difficult than demonstrating a car that usually works. Level 5 autonomy may occur by 2030, but auto companies are not expecting a major transition in the foreseeable future.
- Global EV adoption will be paced by production capacity. Norway has demonstrated rapid adoptions on a small scale with imported vehicles, whereas China, the largest auto market, is paced by ramping up battery factories and EV production lines.
- As EV markets mature, automakers will provide less visibility of new model availability, prices, or details. Like the secrecy around the next smartphone model, automakers have little to gain from pre-announcing products that compete with their existing models. Vehicle production capacity data will be public only as necessary, and battery pack production will mostly be sourced from other companies. The stage is set for surprise announcements from major automakers.

Partly to counter bad press from more dieselgate investigations, Volkswagen Group has announced a target EV production of one million by 2022 and 22 million by 2028. 22 million is twice their current vehicle production and about 21% of global production in 2028. Like China, VW also sees the EV transition as a major opportunity to gain market share.

GM and Ford together produce more vehicles than VW, and they certainly see the need to retool for EVs to keep pace with VW and China. GM, Ford, and Tesla would be negligent if they didn't have EV plans totaling more than 22 million by 2028. Again, US production needs to reach 17 million by 2025 to achieve the 2030 physical requirement.

Automakers are retooling for new models and platforms continuously. With $600 billion of annual revenue at stake in the US, the cost of retooling for 17 million EVs over five years is not extraordinary.

Battery packs: GM just announced this battery factory, costing $2.3 billion for 30 GWh of capacity, or enough for about 300,000 vehicles per year; these costs are similar to this BYD announcement. Scaling GM's factory to the US volume equals $130 billion for new battery factories over five years or $26 billion per year.

The cost to retool a vehicle production line for EVs depends on the degree of the changes needed. A worst-case cost would be the cost of a new production factory, which is around $1 billion for a volume of 200,000 cars. At that rate, new factories for 17 million vehicles would be an investment of $85 billion over five years, less than the battery factories.

Thus, the EV retooling cost is less than $40 billion per year for five years, which less than about 7% of the US revenue. It is difficult to tell how much automakers are normally spending on retooling. There are millions of complexities implied by such macro numbers, such as whether the supply chains could deliver at that pace. The efficiency strategy in scaling up factories is to “copy exact”, which copies every physical detail and process in an existing factory. Once you have a factory working well enough, stop tweaking and copy it exactly.

B. It’s smart business

While such retooling is feasible and affordable to survive the EV transition, company earnings would feel major pain at 7% of revenue, or even a fraction of that.

As in any technology disruption, market share is earned in the ramp and the revenue and margin advantages from the higher share can be maintained after the transition. Thus, there will be a period of poor financial returns for the next five years as auto companies vie for market share in the new technology. The plans of automakers won’t be visible, but they are already hotly debated on Wall Street. Incumbent automakers have to choose how much to invest in this fight, and some will surely go the way of Nokia phones or Kodak’s film business.

In 2018 GM asked the federal administration to back an EV mandate, partly to rationalize EV investments to shareholders.

The federal government could provide financial incentives to ensure the adoption and production rate of 100% by 2025, and to help automakers with ramping up US production through the transition.

C. The federal government should help by reducing risks

Policies to stimulate zero-emission vehicle (ZEV) demand: Government policies should ensure sufficient demand for the new vehicles. Car buyers love the performance of EVs and the low fuel costs, but tend to object if they feel the fueling networks (chargers) are insufficient, or if the dealer lacks information or inventory, or if the purchase-price gap is too high. Of these, Norway has proven that closing the price gap is the key to adoptions. The price gap can be closed with carrots and/or sticks, which could apply at the automaker level or the customer level, or both. Different policies have different costs to taxpayers and different fairness, but any combination that closes the gap will result in EV adoptions.

- Carrots for buyers are popular, but expensive and usually regressive. Carrots could take the form of cash rebates or tax waivers, such as sales taxes.
- Sticks for fueling existing vehicles, such as fuel fees, punish parties who can’t afford more efficient vehicles and are minimally effective at steering purchases of new vehicles.
- Sticks for vehicle buyers are less common. Norway uses a very effective lifetime emissions fee for new gasoline or diesel vehicles (in addition to tax waiver carrots). The buyer of a new vehicle is the party responsible for locking in its lifetime emissions, and thus the party who

should pay the social costs of that purchase decision. Norway is demonstrating a trajectory that achieves the IPCC 2030 target.

- The California ZEV program requires an increasing portion of new sales to be ZEVs. ZEV credits are bought and sold at the automaker level, so buyers only feel the price effects indirectly. This is a carrot for automakers who can sell ZEV credits and a stick for those who must buy credits. Federal policy should adopt California's program, but raise the target to 100% near 2025 (the current targets ensure only about 8% ZEVs by 2025). China has adopted the California program with higher targets, among other policies. This is the policy that GM has advocated.
- The Clean Fuels Programs (CFP) in California and Oregon create similar systems to decarbonize fuels used—fuel distributors must purchase credits if their GHG emissions are not decreasing enough and sell credits if their emissions are decreasing beyond the targets. Such programs will see lots of impact from EVs, but continuing internal combustion engines with incrementally cleaner fuels is not nearly aggressive enough to reach the IPCC targets.

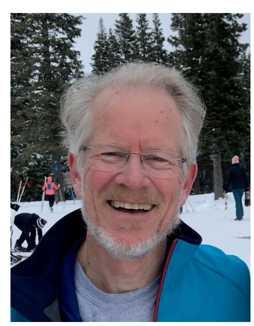
Policies to stimulate ZEV production: Government policies should ensure sufficient production of the new vehicles. Given the stated production goals of VW and China, increasing US EV production to 17 million by 2025 is arguably in line with a prudent plan to maintain or increase market share.

An amplified California ZEV program would provide incentives to produce more EVs, but most automakers will struggle with the costs of the transition.

- To mitigate the impacts to automakers and speed the transition while creating many jobs, the federal government should provide low-interest loans for transportation electrification, to build battery plants, retool existing production lines, or transition related infrastructure.
- The federal government should increase pre-competitive battery R&D spending by at least 10X, as rapidly as practical. It's unthinkable that we invest so little in this critical new technology. No one has identified a physical limit to the energy density possible in batteries, so the race is on to figure out the best chemistries and how to build reliable cells with higher energy density or lower costs. Applications include vehicles, airplanes, grid storage, boats, and other functions now powered by fossil fuels.

Such programs can be easily justified by the massive co-benefits of decarbonization: savings from fuel and lower purchase costs (Figure 2), much lower vehicle maintenance costs, lower healthcare costs due to lower toxic emissions from vehicles, and various benefits to the electric grid. Rural communities especially value increased resilience from local (electric) fuel generation.

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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