

## Part 1. Literature

1. [Slides from Prof. Daniel Sperling](#)
2. [The Hydrogen Energy Transition: Cutting Carbon from Transportation 1st Edition](#)
3. [China's electric car surge](#)
4. [Three revolutions: Steering automated, shared, and electric vehicles to a better future](#)

## Part 2. Recent News

1. [California moves to accelerate to 100% new zero-emission vehicle sales by 2035](#)
2. [EV Direction in Singapore](#)
3. [EV Incentives in Singapore](#)
4. [20% of cars in Norway are now electric](#)

## Part 3a. Jinhua Questions

Question: Let's start with consumer behavior. You mentioned that consumers don't look at total cost of ownership. It's myopic. Incentives are necessary but not necessarily paid by taxpayers. There are other instruments available.

Answer: Well, my favorite policy is what's called feebates. You charge a fee to certain vehicles, and in this case, basically all combustion engine vehicles and a rebate to zero emission vehicles. You can make that revenue neutral and it is a basic policy of the economists as you are changing market signals. You can do it in terms of sales tax, and one thing we're starting to look at in California with trucks, is adjusting the registration fees so that you pay a high registration fee if you have a diesel truck, and a lower fee if it's electric or zero emissions. A number of European countries have already done this.

Question: Let's move on to the business side. You mentioned that OEMs tell one story to investors, but tell another story to policymakers. How can the narrative from the investor side and policymaker side converge?

Answer: Yeah, you know, I probably overstated that. What I said was probably correct 2 or 3 years ago. Actually, today, when we passed the news of mandate for 100% EV sales by 2035 in California, not a single car company opposed it. They oppose certain details, like the durability requirements. Or Tesla did not like putting a charge adapter in the trunk. They quibble over details, but not a single one actually opposed it. The companies know they have to do it and a lot of them are just saying okay I'm going to do it. On the compliance side, there's a section and about 15 states are going to adopt it. The car companies are going to send all their cars to those states. So the other 35 states, mostly the red states, they are not going to be getting many cars

because they won't have this mandate and the car companies won't be concerned about compliance.

Question: You mentioned that Norway uses huge amounts of incentives. EU uses aggressive standards. California mandates on the supply side. Here, we see that you can regulate the supply or subsidize the demand created, and they are different for different countries or even different regions in a country. Tell us more about how countries choose their policies.

Answer: In Norway, it's a small country. They have huge taxes on gasoline cars so it was relatively easy for them. They are also a rich country and consumers are rich, so that was an easy choice for them. For the EU, they started with CO2 standards a while ago. Probably about 15 years, it was a natural progression for them. The US did have CO2 standards and greenhouse gas standards and CAFE standards, but politically, EPA has found it difficult to increase it. There's been a lot of opposition, you know. EPA gets beat up in every Republican administration. It's hard for them. They need the political will to be really aggressive. So the one thing that the Biden administration can do easily, was money. It's kind of what Norway did but at a different scale.

Question: Can you give an example of when policy overstepped?

Answer: There are numerous examples. The ZEV Mandata in 1990 when California adopted it. That way way too aggressive way too soon. But you know, I'm going to counter that story. What I learned in the policy world is that if you want major changes of the type we are talking about, you've got to put a stake in the ground. You've got to do something really aggressive that gets everyone's attention, whether it's 100% trucks or 100% cars. We could do something like that with hydrogen if we wanted. In the end, we might have to make adjustments, but they can be made along the way. It just gets everyone on the same page - the car manufacturers, the utilities providers, etc. The best you can do is to put that stake in the ground, tell the people that the State is committed to this, and then all others will hopefully coalesce around. The consumers in the US have relatively less interest in EV than anywhere else, and I think it's because they've not been hearing from our leaders that this is the path forward.

Question: Another policy dilemma we have in recent times is "Made in America". It tries to encourage a local economy, local manufacturing, etc. To what degree should USA open the market? How do we balance protecting local domestic industry and globalization?

Answer: Yeah that's the trillion dollar question. If we think we are going to depend on minerals in the US, you know, for our batteries. You know it's not going to happen and it's going to be disruptive. We did an analysis of Europe and US and trade back and forth will greatly ease the transition and lead to a much more efficient path forward.

## Part 3b. Audience Questions

Question: When discussing EVs as the most important decarbonization strategy for transportation, do we include electrification of all kinds? Including small ones like bikes and stuff. When we talk about this, there are normally two camps. One camp says we need to electrify cars and trucks. The other camp says, actually, cars and trucks are the problem. We need a mode shift.

Answer: I was mostly tailoring my comments to the US. Electrification is still the most important even in the developing countries eventually. Once we get out of the US, then I will call it VMT reduction or flattening. I've been fighting the battle for VMT reduction. We actually have a law in California to do it and it's been a failure. It has not accomplished hardly anything of what it was intended to do. Our vehicles have gotten so big in the US, and there's this range war. Meaning you need to have a 400 mile range and these massive batteries. We talk about a mineral critical materials problem. If we just make our vehicles 200 miles, we solve the problem right there. How do figure out policy incentives such that they don't encourage these large batteries? It's probably even more challenging to do that.

Question: What about Hydrogen?

Answer: I wrote a book on hydrogen many years ago. I'm deeply immersed in that. Hydrogen might be the right thing for the last 30% of customers that do not want an EV! For the big class 8 vehicles and all. It might be the right choice there despite what Elon Musk says.

## Part 4. Summary of Memos

Themes from Two Memos:

1. The crucial role of EVs in reducing emissions and decarbonizing the transportation sector.
2. The challenges facing EV adoption in the U.S., including weak policy and political polarization.
3. The need for policy support and infrastructure development, such as charging stations, to increase EV usage in the U.S.
4. The potential impact on low-income communities if EV options are not affordable and durable.
5. The use of incentives and fee-bates to encourage EV adoption, as well as the role of government and agencies in setting performance requirements for automakers.

My Reflection:

Prof. Sperling gave great insights into policy in today's discussion. I had to Google what "Policy Wonk" meant - he clearly is one. He started off by framing the transition to EVs under the paradigm of it being social determinism instead of technological determinism. To put this plainly,

the transition to EVs is one that is determined by society norms, instead of it simply being a superior technology wins and people will eventually convert. Under this framework, how then can one steer society towards EV? This is where the policy comes in.

Sperling argues that we need government intervention for EVs and gave different examples from around the world. In Norway, huge incentives are given to transit to EVs. However, Norway could only do this because their taxes are in general high and the country is rich. Europe uses very aggressive CO2/CAFE performance standards, but this was an artifact of their past and a natural progression for them. California is starting in 2027 a Zero Emission Vehicles sales requirement. On top of policy for buying EVs, an often overlooked factor is installing charging and hydrogen stations! While these policies across the world might work for each region, Sperling argues that the best policy by far is not incentives, or more chargers, etc. The most important one is a mandate and performance standards for car companies - supply side regulations effectively. Regulate the supply and the market naturally takes care of itself (albeit getting lots of opposition from Ford, GM, BMW, etc. potentially!).

The transition to EVs is inevitable - it is a question of when. As with most last mile delivery problems, the last 30% of consumers to capture are the hardest, and Sperling gave the analogy of the vaccine. Will we see the same for EVs? After all, we don't see horse carriages all around the world now, do we?

## Part 5. Other Information

### **Quick Remarks from John Paul MacDuffie**

Question: I very much like the frame of this change being socially determined and not technologically determined. I have an observation. The mandates and policy things that are happening, not just in the US, but around the world. I think we can anticipate that - a movement in a positive direction. There are also some things that go the other way. Since the auto companies are global and plan their product portfolio on a global basis and aim for an efficient scale, how much do the forces for acceleration in some places like the EU standards, and whatever is happening in California, you know, tip the OEM's decision making towards larger EV commitments?

Answer: Senior Executives have a tremendously difficult challenge. They make their money from their combustion engine vehicles, and they're losing money (except for Tesla and some Chinese companies) on these EVs for now. How do you know the plan going forward? GM and Ford are focused on the US. VW has 40% revenue from China. BMW and Mercedes appeal to the Chinese and European market. The companies are all hedging their bets. Toyota, for example, made a play on hybrid vehicles 15 or 25 years ago and they're trying to play that as long as they can. They have been reluctant to get into battery and have made a play with fuel cells but are being tentative on that. It really depends on where their market is, their focus is, what their strength is.

# **EV Policy and Regulation**

## **As Seen by a Regulator, Academic, and Policy Wonk**

Daniel Sperling

Distinguished Blue Planet Prize Professor and Founding Director  
Institute of Transportation Studies  
University of California, Davis

*and*

Board Member, California Air Resources Board

MIT Mobility Forum

9 December 2022

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# My Messages

1. Policy is necessary for transition to EVs
2. EVs will soon be cheaper than gasoline ICEVs (and most diesel trucks)
3. US is falling further behind Europe and China
4. Many challenges along the way
5. Most effective policy is “sales mandates” (not “incentives”)
6. California policy model for cars and trucks

# Future of EVs?

## Technological vs Social Determinism

- Technological determinism: society's technology determines development of its social structure and cultural values.
- Social determinism: society is autonomous force shaping technology, cultural values, social structure and/or history.
- **EVs are mostly “socially determined”.**
  - Transition to ZEVs involves transformation of vast array of institutions, technologies, businesses, and behaviors.
  - It will be disruptive for many businesses, governments, and people.
  - For the automotive industry, it is the biggest change since the Model T
- I believe EVs are not inevitable for at least the next 30 years—without policy intervention

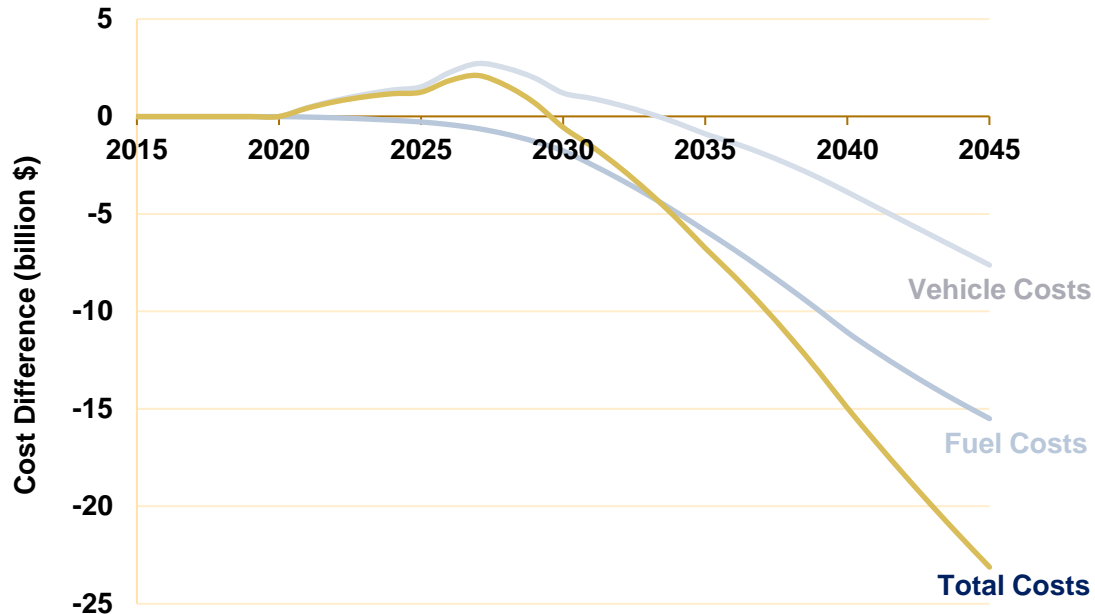
# **EVs are Policy Imperative for Climate Mitigation**

- EVs are THE most important strategy to decarbonize transportation—by far!
- Automakers are responding where policy is strongest

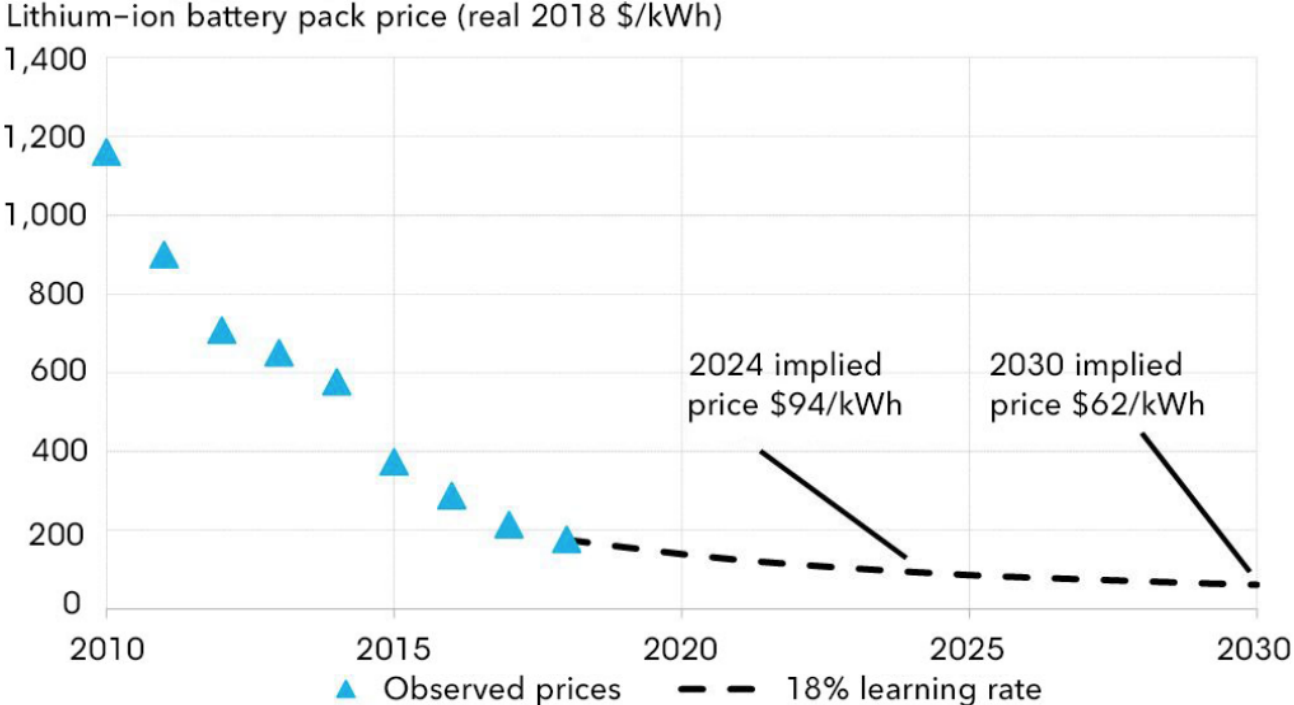


# But EVs Will Also Save Money (Consumers and Economy) and Reduce Health Costs

Strong transportation decarbonization policies will result in net cost savings starting in ~10 years



# EV Success Mostly Due to 90% drop in Battery Costs... But Will Trend Continue (7% increase in 2022)?



Source: BloombergNEF (IEA, 2022)

## **Q: So why do we need government intervention for EVs?**

**A: Consumers don't make decisions based on total cost of ownership (TCO)**

- Individual buyers are “conservative”: concern over resale value, future price of energy, loss aversion, range anxiety
- Trucks are a little different: fleet owners are more likely to use TCO as decision variable

➤ *Incentives will be needed for a long time*

*... but some incentives are more effective than others, and they don't need to be paid by taxpayers (feebates, LCFS, non-monetary....)*

# Forces and Factors Inhibiting EVs

- Consumer purchase decisions mostly based on vehicle price (not total cost of ownership)
- “Externalities”: climate change and local air pollution
- Consumers conditioned to ICEVs (range anxiety, refueling)
- Not profitable to build and operate EV charging stations
- .... and many other market failures and market conditions
  - Loss aversion by consumers
  - Principal agent problem (rental cars, new vs used car market, company cars)
  - Network externalities (expanding user benefits from charging and H2 stations)
  - Technology lock-in
  - Market power (cartels, oligopolies, etc)
  - R&D under-investment (due to: R&D spillover, Learning-by-doing spillover, etc)

# How to Accelerate EV Sales?

- Huge incentives... **Norway**
  - Very aggressive CO2/CAFE performance stds ... **Europe**
  - Aggressive ZEV sales requirement ... **California starting in 2027?!**
- ❖ *But also need to do many other things such as installing charging/H2 stations*

# Unique Context

## “Informed” Leaders and Experts In Consensus

- LDVs will be mostly battery EVs (BEVs)
  - Definite some plug-in hybrid EVs
  - Probably some hydrogen H2 FCVs
- Most HDVs will be BEVs ... but some traveling long distances will use:
  - Low-carbon biofuels (not in California and states following California)
  - Hydrogen FCVs

➤ *But how, when, and where? And what is the role of policy?*

# Recent Announcements of OEMs....

BUSINESS | AUTOS & TRANSPORTATION | AUTOS INDUSTRY

## GM to Phase Out Gas- and Diesel-Powered Vehicles by 2035

Auto giant's plan to eliminate tailpipe emissions is part of a goal to be carbon neutral by 2040

*Volvo Plans to Sell Only Electric Cars by 2030*

**VW expects half of U.S. sales to be electric vehicles by 2030**

**Ford Motor Vows To Sell Only Electric Cars In Europe By 2030**

**Honda Will Go Electric- and Fuel Cell-Only by 2040**

➤ *But for investors....*

# But... Tesla = Toyota + VW + GM + Ford + Mercedes + BMW + Honda + Stellantis

## Biggest by market capitalisation

November 15th 2022, \$bn



Source: The  
Economist,  
11/15/22



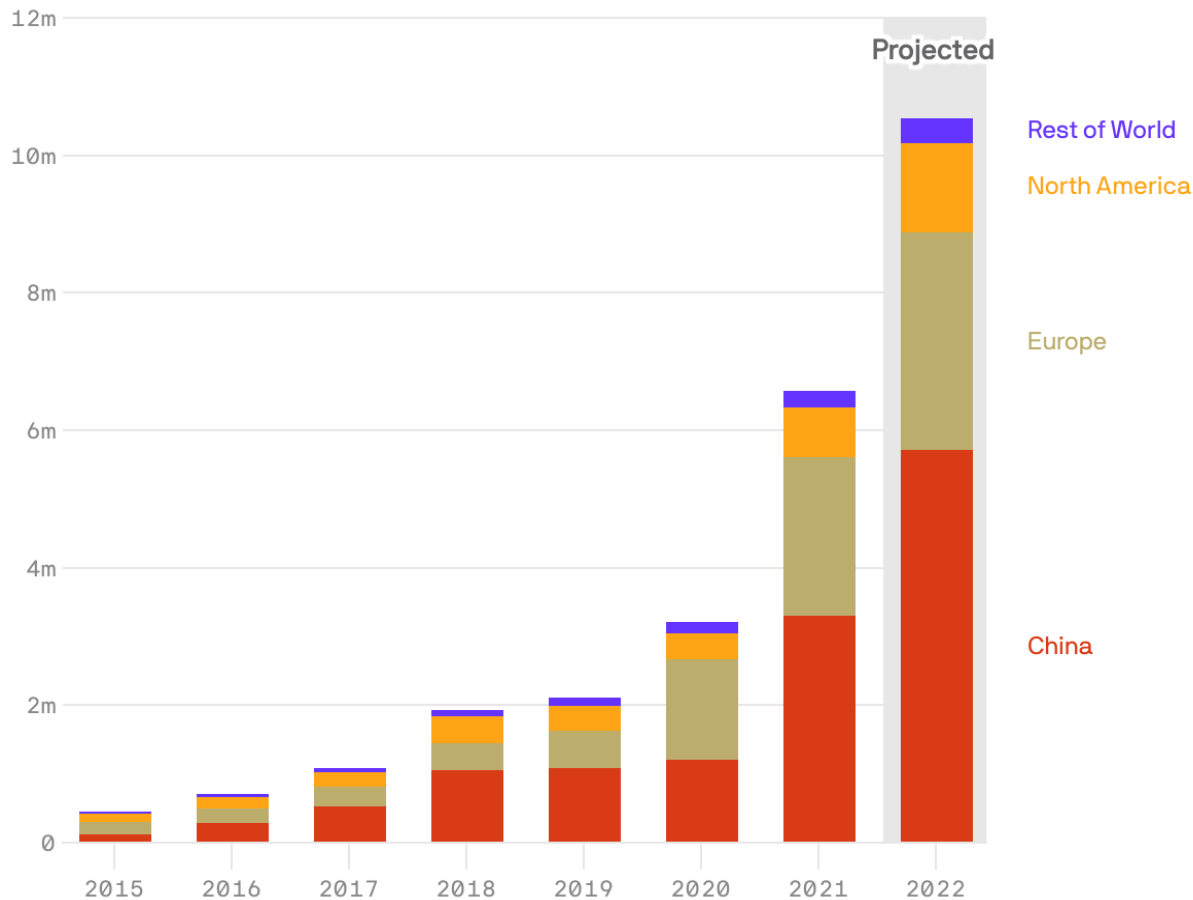
# Tesla is Dominating Not Only Because Appealing Product, But Also Because Many Innovations

- Vertical integration, including minerals (following Henry Ford)
- Integrated design of vehicles and factories
- Software leader (in house, allowing re-programming of chips)
- Pioneered over-the-air software updates
- Built its own charger network
- Partial vehicle automation (aka “Full Self Driving”)
- No dealer network (direct sales)

➤ *Large profit margins*

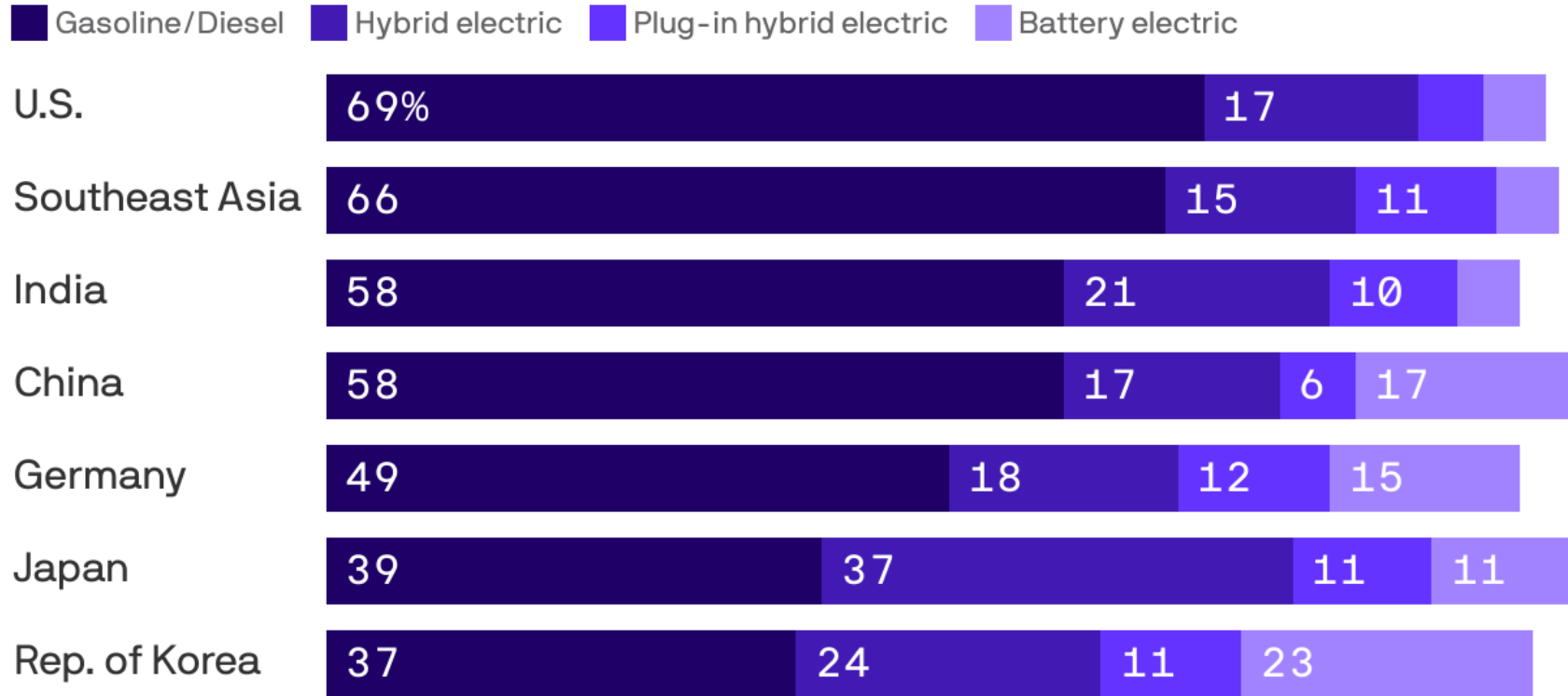
# Passenger electric vehicle sales

Battery electric and plug-in hybrid electric vehicles



**US is falling far behind EU and China in EV sales**

# Consumer preference for next vehicle type ...US lagging

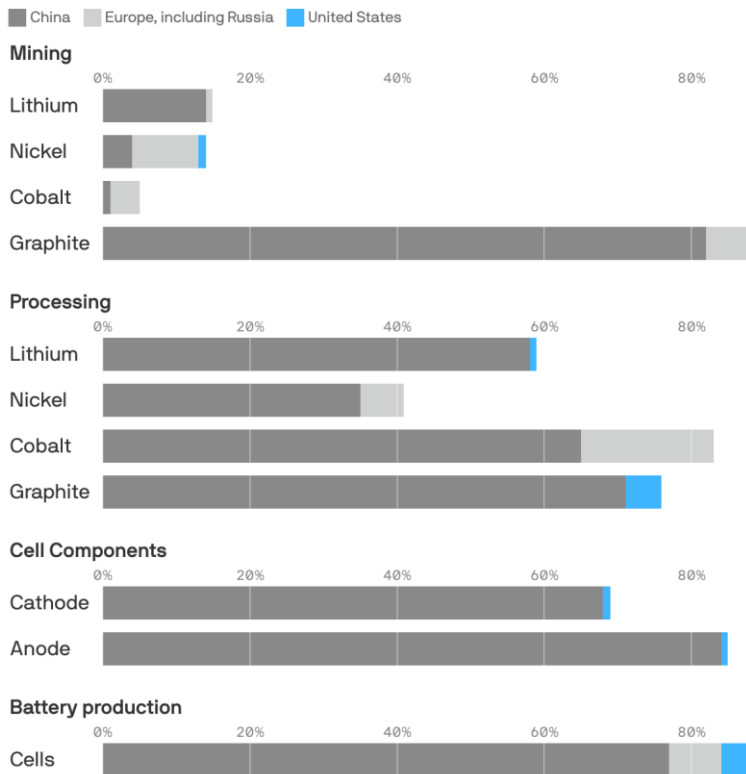


# Cause for Concern

## Rising Prices and Supply Shortfalls for Minerals/Metals...

### Will NIMBYism and Sustainability Concerns Overcome Market Forces—in US and Elsewhere?

Distribution of select EV battery supply chains, 2022



IEA, 2022

# **Many Process and Product Innovations to Reduce Costs, Improve Performance and Safety, and Reduce Dependence on Critical Materials**

- Battery chemistries
- Battery design
- Vehicle/battery designs
- Manufacturing processes

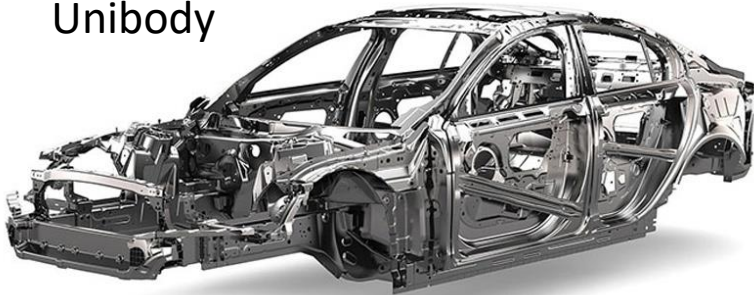
# Innovations in Battery Chemistry Reduce Costs and Dependence on Critical Metals

- COBALT → Scarce, concentrated (nearly 50% in Congo) where mining is linked to human rights abuses
  - **RESPONSE:** Battery companies switching from NMC (Nickel Manganese Cobalt) to Lithium Iron Phosphate/LFP), reducing dependence and cost
- NICKEL → Scarce, concentrated (50+% in Australia, Indonesia, South Africa, Russia, Canada)
  - **RESPONSE:** New formulations using less nickel
- LITHIUM → Abundant, but supply lags demand (prices increased 400-600% since January 2022)
  - **CHALLENGE:** Widespread resistance to new mines (role for policy?!)

# Innovations in Battery/Vehicle Design Reduce Costs and Weight

- Battery makers are eliminating modules (cell-to-pack)
  - OEMs are packing cells directly into the chassis (cell-to-chassis)
    - Like using airplane wings to hold fuel
- *Both save weight and reduce manufacturing costs*
- *But reduce ease of repair and recycling/repurposing*

Unibody



Skateboard



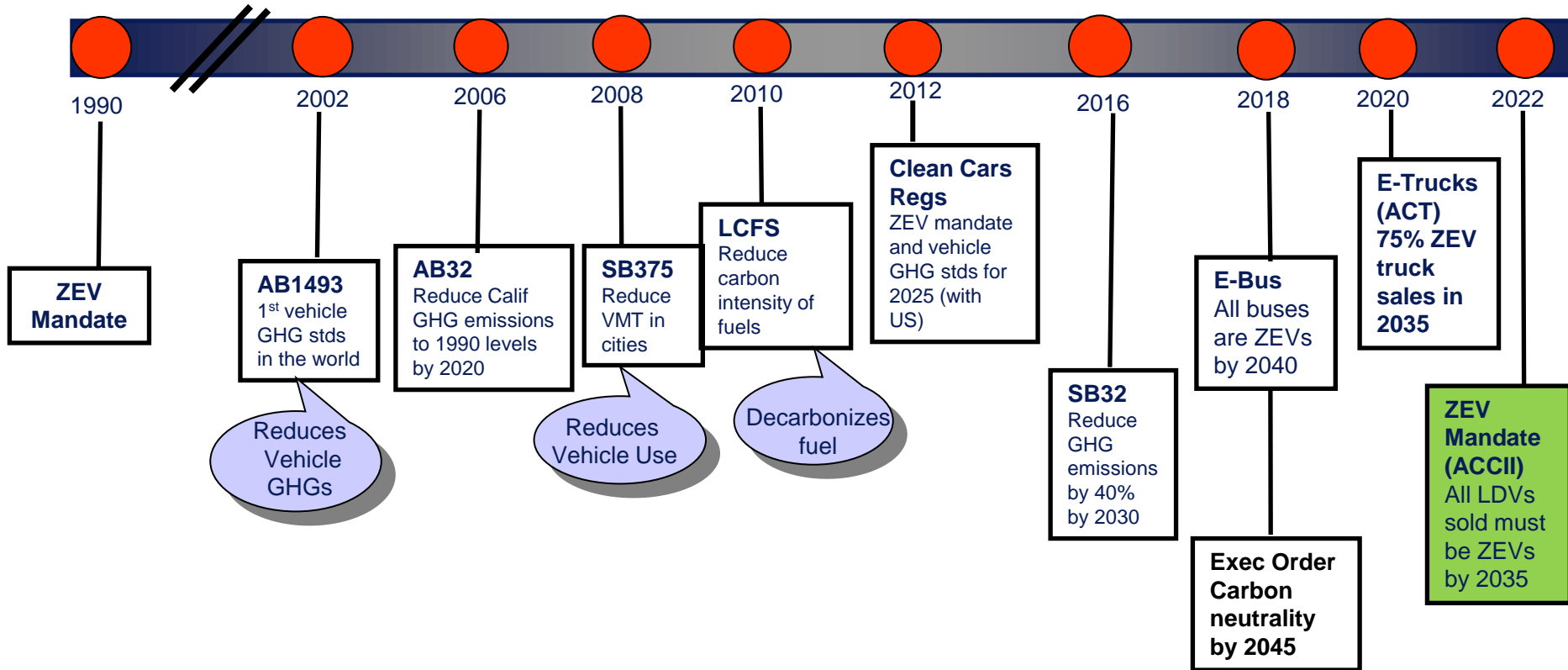
# Supply-Side Regs Are Most Effective Policy to Accelerate ZEVs

- EU CO<sub>2</sub> vehicle performance standards effectively require large sales of EVs
  - Schedule to update standard to be 0 g/km by 2035 (by end of 2022)
- US also has “CO<sub>2</sub>/GHG standards (equivalent to CAFE), but much weaker.”
  - New standards proposed by Biden Administration (but not yet adopted) would require automakers to sell ~18% EVs by 2026
- California ZEV mandate requires EV sales.



# California Leadership is Pivotal for US

...Far More Aggressive than Feds, and Many States Follow CA  
Plus, ecosystem of supportive policies

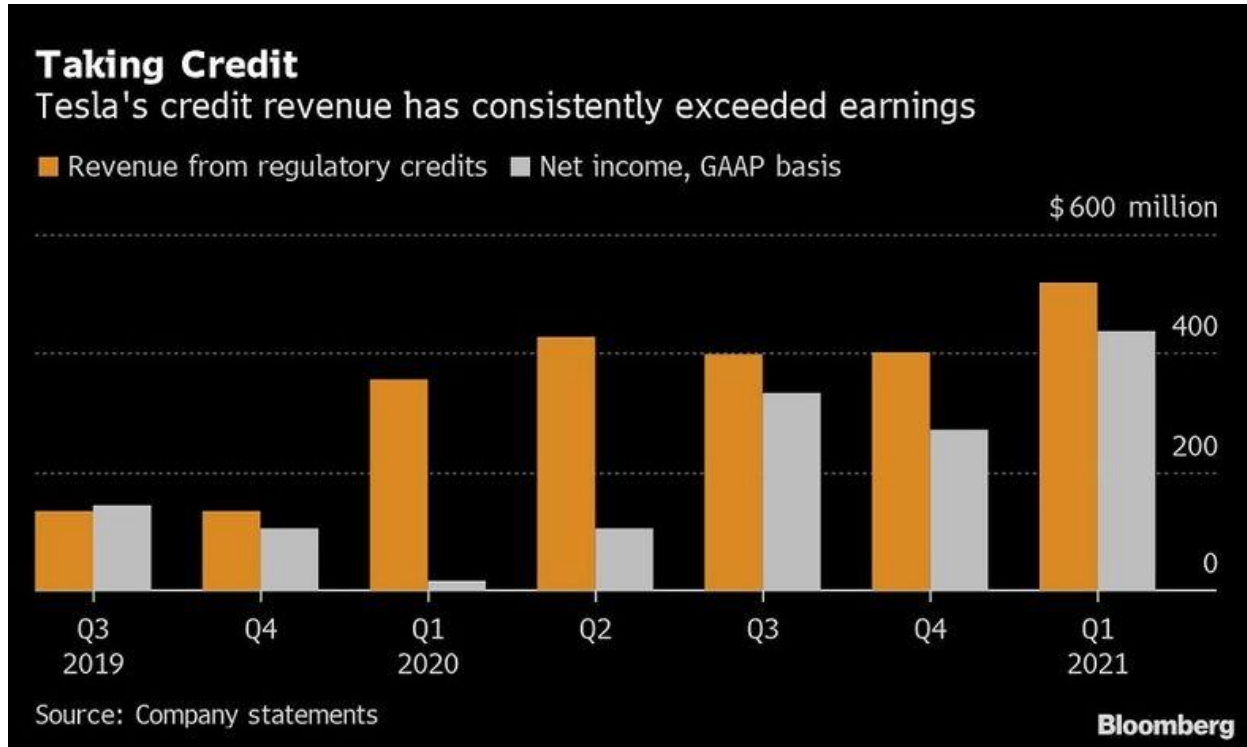


# Controversial History of California ZEV Mandate

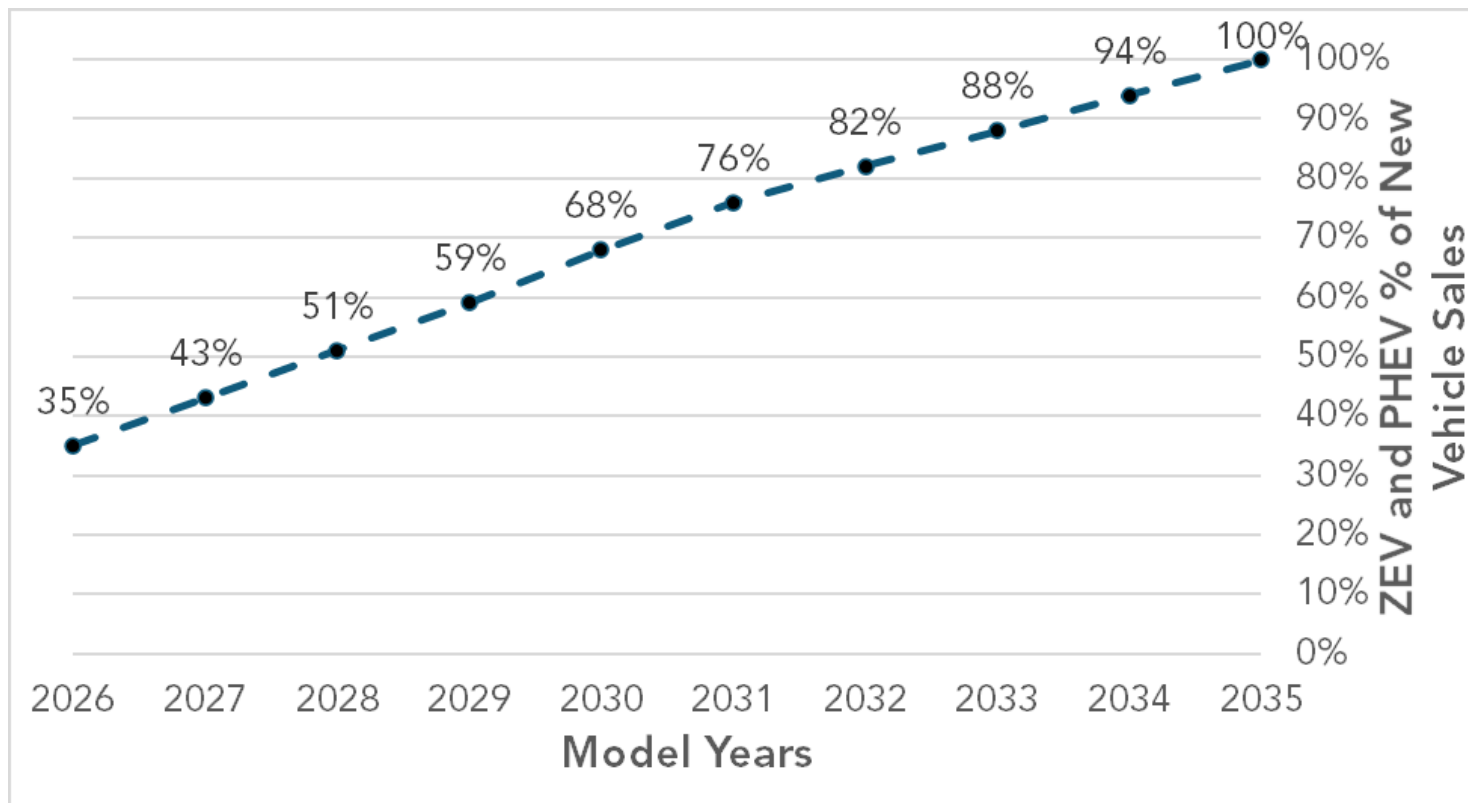
1990	<b>ZEV mandate adopted:</b> 2% ZEVs in 1998, 5% in 2001, 10% in 2003—measured as % of new car sales
1996	<b>Weakened:</b> Eliminated 2% 1998 requirement and replaced with much softer requirement of 3750 BEVs
1998	<b>Weakened:</b> % ZEV requirement further reduced by allowing very clean gasoline (and other alt fuel) vehicles as partial substitute (“PZEV”)
2001	<b>Weakened:</b> % ZEV requirement further reduced by allowing small numbers of FCVs to satisfy requirement
2008	Minor strengthening: 12,500 BEVs or 5000 FCVs, plus 58,000 PHEVs by 2014
2012	<b>Major strengthening:</b> PEVs + FCVs = ~15% of LDV sales in 2025
2022	<b>Revolution:</b> 100% ZEV sales by 2035

*ZEV mandate was too aggressive too soon, but now “best” policy?*

# Tesla Survived Bankruptcy Because of ZEV Credits Sold to Legacy Automakers ... Policy Intervention!



# California Adopted Rule Requiring 1/3 of sales to be ZEVs in 2026, 2/3 in 2030, and **100% in 2035**

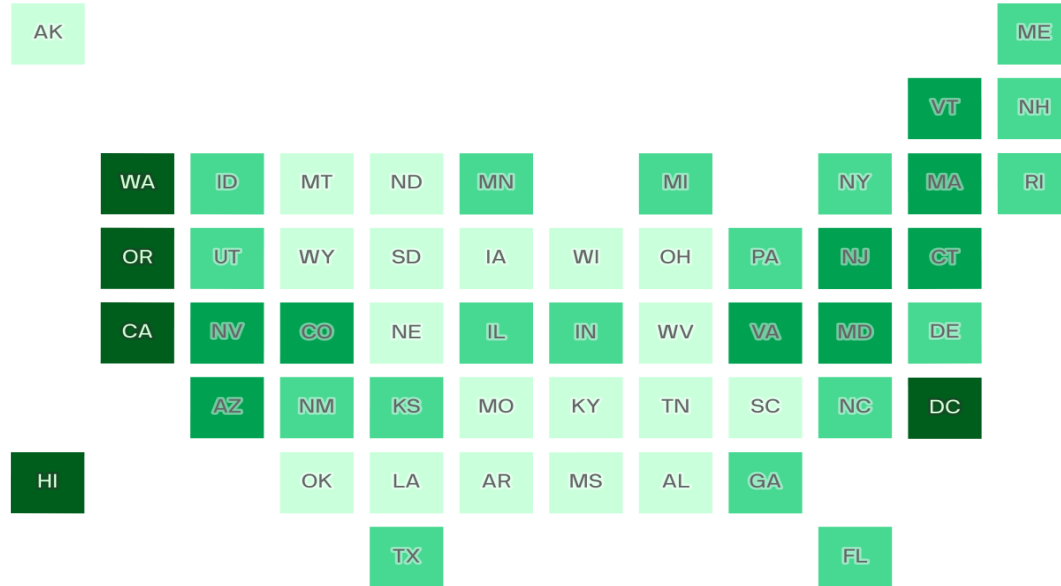
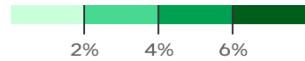


**The Nuances of Policy Design Are  
Very Important ... and Ignored by  
Academics**

# Cause for Concern

## Other States (§177) Must Adopt Every Detail of California's ZEV Mandate ... Is that Good Policy?

Electric vehicles' share of new light-duty registrations, 2021



# Major change for 2026

## All Vehicles Are Equal

- **BEVs = PHEVs = FCVs**
- PHEVs: Minimum of 50 miles of electric range (35 miles in 2026-2028)
  - Capped at 20% of ZEV compliance

### ➤ Outcomes

- PHEVs play limited role
- Vehicles and batteries get huge (exacerbating supply problems with batteries and critical materials)
- No incentive for H<sub>2</sub>FCVs

**Major change for 2026**

# **Durability Requirements ... for 10 years/150,000 miles**

- 2026-2030: 70% of certified range for 70% of fleet (excluding outliers)
  - 2030+: 80% of range for all vehicles (on average)
- Motivation: protect the consumer, and also make sure that when middle and low income people finally get the vehicles, that the batteries are reliable



## Also a Truck ZEV Mandate

# California Requires Most Trucks to be Zero Emissions by 2035 ... With Likely Update to **100% of Sales by 2040** or sooner



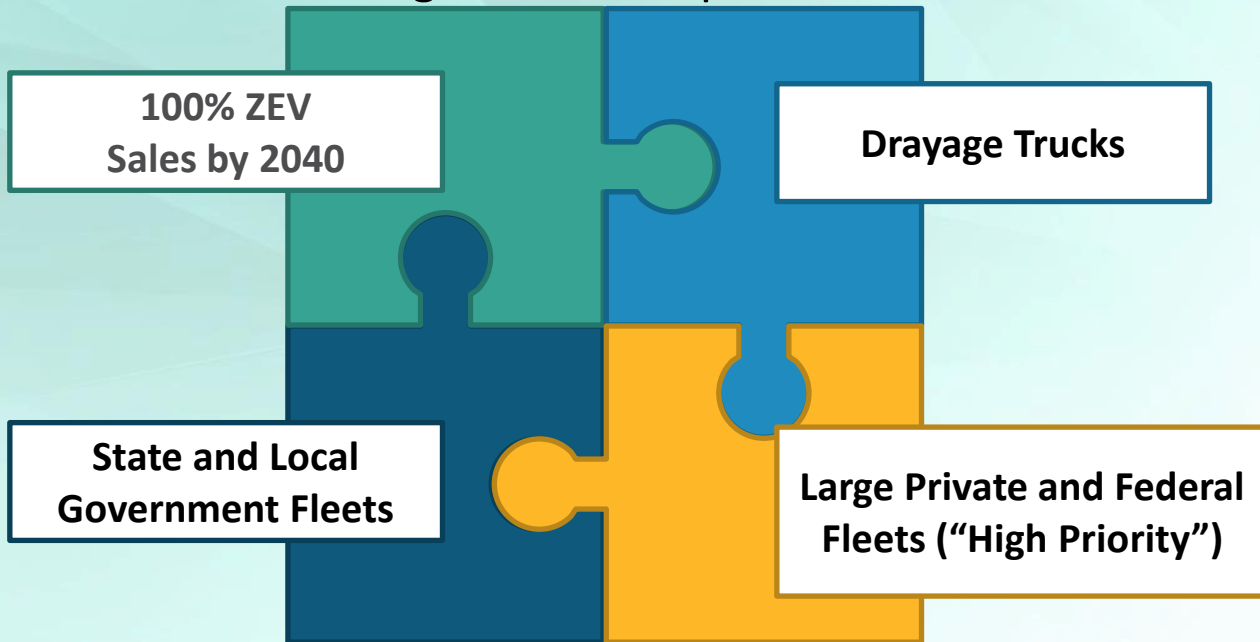
- Adopted June 2020, effective 2024
- Applies to large truck manufacturers who sell trucks in California
- Credit trading allowed
- Partial credits allowed for PHEVs (based on all-electric miles)

Model Year (MY)	Class 2b-3	Class 4-8	Class 7-8 Tractors
2024	5%	9%	5%
2025	7%	11%	7%
2026	10%	13%	10%
2027	15%	20%	15%
2028	20%	30%	20%
2029	25%	40%	25%
2030	30%	50%	30%
2031	35%	55%	35%
2032	40%	60%	40%
2033	45%	65%	40%
2034	50%	70%	40%
<b>2035</b>	<b>55%</b>	<b>75%</b>	<b>40%</b>

## Another Policy Innovation from CA

# Proposed “Advanced Clean Fleet” Rule (likely adopted in April 2023)

### 4 Regulation Components



# **Some Thoughts on Incentives**

# IRA (signed August 16, 2022)

## Federal Consumer Incentives (through 2032)

### New Vehicles: Up to \$7500/veh

- Manufacturer caps eliminated (200k/OEM)
- Vehicle must be assembled in North America, 40% of critical minerals and 50% of battery from US or countries with free trade agreements (~20 countries) (with 40% ratio increasing to 80% in 2027)
- One credit per vehicle: not based on size of battery
- Income limited to \$150k/\$300k
- MSRP < \$80k for LDTs, \$55k for cars
- Point of sale (based on dealer disclosures)

### Used Vehicle Credit: Up to \$4000/veh

- 30% of value of used EV with \$4,000 cap; vehicle price <\$25k
- 2+ years old
- Conditions: purchased from a dealer; vehicle qualifies for credit only once in its lifetime; must be an individual; once per three years/individual; income cap of \$75k/\$150k
- At time of sale by dealer.
- No requirements for “made in USA”

➤ ***No EVs will get full rebates for many years; OEMs (and many countries) unhappy***

# ... And Many Other Incentives Across US

**These are  
California  
Vehicle  
Purchase  
Incentives....**

Rebate Type	Fuel Cell Electric Vehicle	Battery Electric Vehicle	Plug-in Hybrid Electric Vehicle <sup>1</sup>	Zero-Emission Motorcycle
<b>Increased Rebate for Low-Income Applicants</b> Households with income less than or equal to 400% of federal poverty level	\$7,000	\$4,500	\$3,500	\$750
<b>Standard Rebate</b> Available for: Individual tax filers whose income is greater than 400% of the federal poverty level but less than or equal to \$135,000 Head-of-household tax filers whose income is greater than 400% of the federal poverty level but less than or equal to \$175,000 Joint tax filers whose income is greater than 400% of federal poverty level but less than or equal to \$200,000	\$4,500	\$2,000	\$1,000	\$750
<b>Above Income Cap<sup>2</sup></b> Individual tax filers whose income is greater than \$135,000 Head-of-household tax filers whose income is greater than \$175,000 Joint tax filers whose income is greater than \$200,000	\$4,500	Not eligible	Not eligible	Not eligible

# New Federal Incentives—by Themselves—Will Have Small Impact

- Few buyers will receive \$7500 rebate for many years because of the aggressive “protectionist” conditions
- Income cap of \$150k/\$300k and MSRP cap of \$80k for LDTs and \$55k for cars is good (cost-effective and equitable) policy, but significantly limits effect on sales
- California’s ACCII (ZEV mandate), likely to be adopted shortly by ~1/3 of the market (~10-15 states), will swamp effect of incentives (doubly so because OEMs will be diverting sales to states with the rule in place, and not to other non-ZEV states, in order to be in compliance)
- With current (pre-IRA) incentives, Tesla and GM vehicles did not receive the \$7500 credit the last few years, and yet Tesla sold 2/3 of all EVs, and GM was second.

➤ *Given all this, I expect small marginal impact of federal consumer EV incentives*

IRA is not just for consumers

## Incentives for Automotive, Battery, Mining, and Recycling Industries ... More Impactful Than Consumer Incentives??

- Tax credit of \$35/kWh for each U.S.-produced battery cell (~35% of cost)
- Tax credit of \$10/kWh for U.S.-produced battery modules (~1/3 cost of assembling battery pack)
- 10% tax credit for critical materials and minerals produced in U.S.
- \$2 billion in grants to retool existing auto plants to make clean vehicles
- Up to \$20 billion in loans to build new factories.

➤ ***Reflects “new” approach where incentives go to industry, and less to consumers***

# Cause for Concern

## Last 30% of Consumers

- Vaccine analogy
- Buyers in multi-family dwellings
- Ideological opposition (EVs are politicized?)

➤ *Will PHEVs and H2 FCVs gain more appeal??*

### HYDROGEN

Gasoline • Methanol • Turbogas





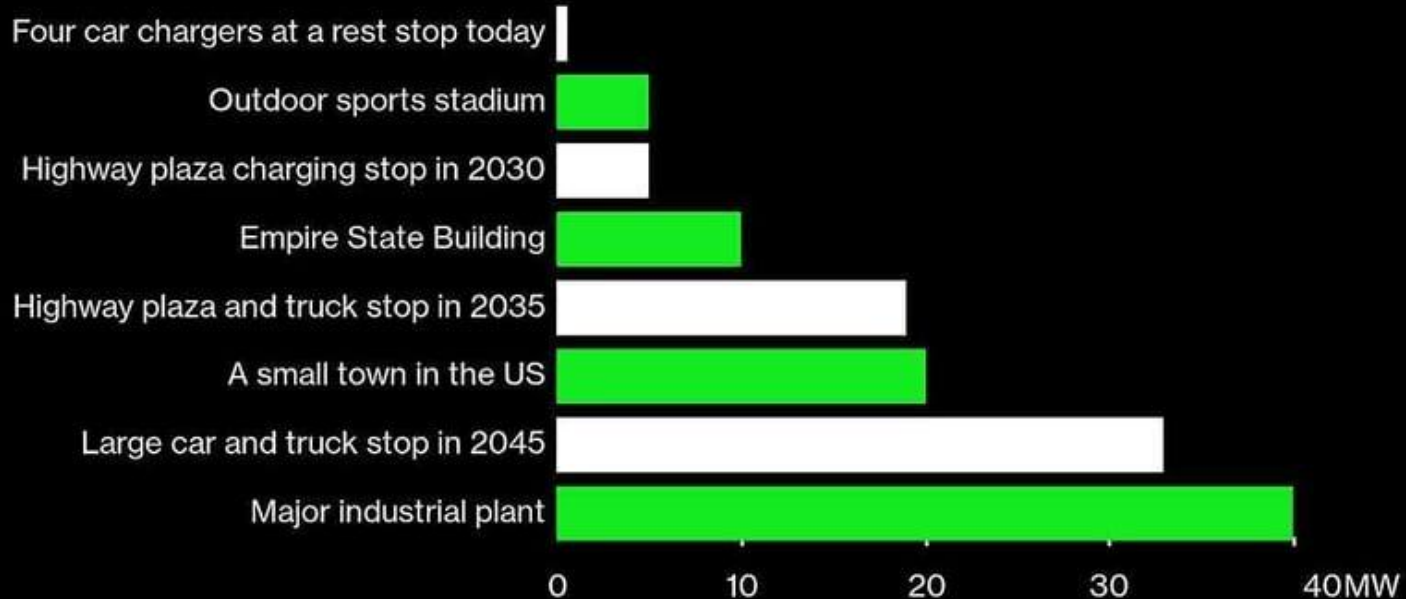
## **Cause for Concern**

# **Will Enough Public Charging Infrastructure Be Built Fast Enough?**

- Need is not urgent for next 5 or so years, but then becomes critical
- Subsidies from national and state governments, electric utilities
- Concern: permitting, reliability of chargers, accountability of operators of chargers

# Charging Stations Will Soon Need as Much Power as Stadiums

Electricity needs of highway rest stops compared to buildings and towns



Sources: National Grid, RMI

**Bloomberg Green**

# Charging Infrastructure Policy

- Resolve jurisdictional disputes (municipal, PUC, state, federal) over installing charging
- Accelerate/approve/fund infrastructure and grid enhancements—esp for trucks
- Address unprofitability ..... Encourage partial subsidies by businesses
  - Operations or installing equipment.....
  - Employers (workplace)
  - Retail stores (enticement for customers)
  - Behind-the-meter make-ready by utilities
- Strategic investment/subsidies by local, state and federal governments (IIJA)
  - Link to reliability (97% up-time required?!)
  - Ease of use (confusing and competing apps, use of credit cards, unbanked)
  - Network coverage (every 50 miles, underserved communities)

# **Why Is US Lagging and What Do We Do About It?**

“We can not solve our problems with the same thinking [and institutions and research] we used when we created them.”

- Albert Einstein

*Thank You*

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