

# State of the **Electric Vehicle**

Consumers, Markets, Environment, and Motorsports

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Pubspeak at Telluride House on April 12 2019

# On the Table

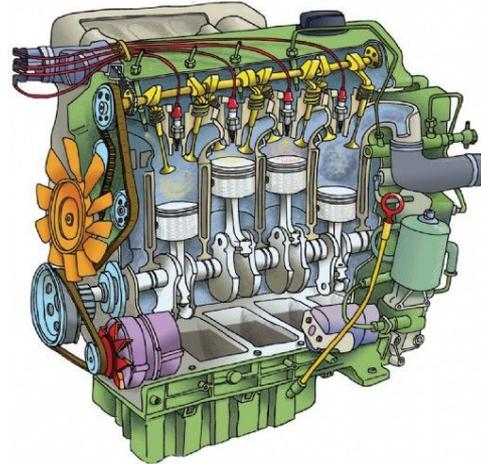
- What are EVs? Why EVs?
- **Consumer** projections for next decade
- How EV-makers affect the **Market**
- EVs' impact on the **Environment**
- The role of **Motorsports**

What are EVs? Why EVs?

# Internal Combustion Engines

A **gas-powered car**  $\Rightarrow$  driven by an Internal Combustion Engine (**ICE**)

- Gas (petrol, natural gas) ignited to force down pistons.
- Pistons move up and down, rotating a crankshaft  $\Rightarrow$  rotates wheels.



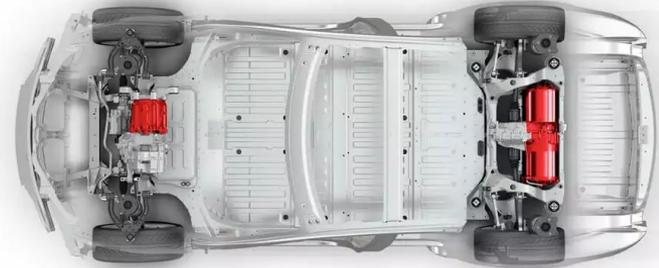
# Internal Combustion Engines

- ICEs quite inefficient at turning fuel into energy to rotate crankshaft
  - Most energy lost in heat
  - Typical petrol/diesel ICEs have 20-35% “thermal efficiency”
  - Mercedes F1 engine recently achieved 50% thermal efficiency - huge deal!
- Quite loud
- Stalls below certain rotations/min (RPM)  $\Rightarrow$  engine runs even when idling
- Fossil fuels and carbon emissions!
- + Cars quick to refill
- + Unlimited range
- + Adrenaline-inducing rev (for a motorsport fan)

# Electric Vehicle/Motor

Powered by on-car **batteries**

- Electricity from batteries to magnetic coils in electric motor
- Magnetic field induced, which rotates the magnetic head of driveshaft  $\Rightarrow$  rotates the wheels



# Electric Vehicle/Motor

- + **Efficient**; most of produced energy harnessed to rotate
  - + **~60%** electrical energy to wheel power
- + Less moving parts ⇒ **less maintenance, long-lasting**
- + Extremely **silent**; need artificial noise to prevent eerie motion
- + Instant torque ⇒ **faster acceleration** from idling
  - + Tesla S P90D 0-60mph in 2.6s
- **Charging** time
- **Limited range** (usually 250mi these days)
- Shrill screech when running

# Why talk about EVs now?

Interesting period: EVs become **affordable** and **attractive**

EVs **comparable in performance** to ICEs

**Companies bullish** on consumers' EV acceptability

Government regulations in the world kick in by **2030**

**More research** indicating environmental impacts of EVs

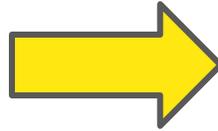
**Accelerated** R&D, and testing  $\Rightarrow$  will **fuel** cars of tomorrow

# Consumers and Markets

# Attraction & Appeal



2001 REVAi by Mahindra  
~7000 USD, 80 kph max  
~75 mi



2019 Model S by Tesla  
~100,000 USD, 250 kph max  
~250 mi range

# Attraction & Appeal

Appeal impacts consumer impressions

Companies introducing high-end models before affordable models to build impressions





# Attraction & Appeal

Appeal impacts consumer impressions

Companies introducing high-end models before affordable models to build impressions

... especially after decades of poor appeal in exchange for low prices



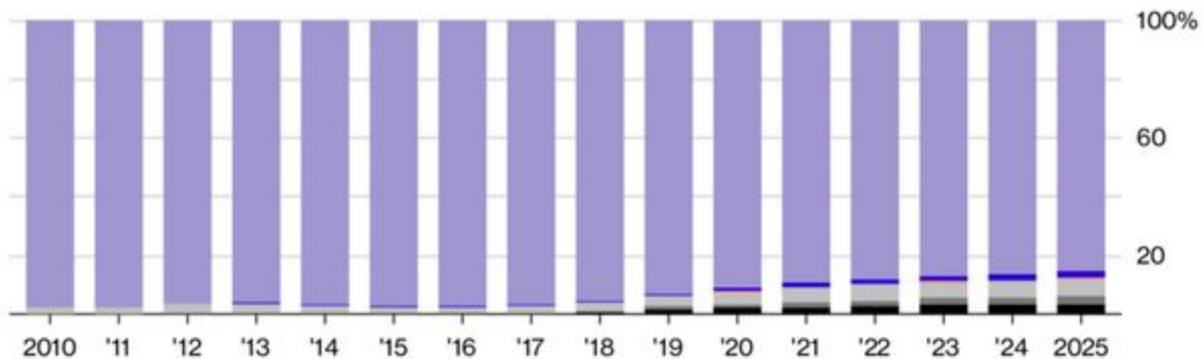
# Market Projections

- Audi, Jaguar, Tesla, Porsche, Nissan, Hyundai, GM, BMW, Mercedes etc. introducing EVs by 2020 (some already did)
- Bloomberg estimates 127 EV models in the next 5 years
- But analysts don't forecast consumers cashing in quickly
  - LMC Automotive forecast/Bloomberg predict EVs to be 3-6% of global sales by 2025
  - JPMorgan Chase forecasts upto 8% market share by 2025

## Gasoline's Staying Power

Internal combustion engines will still power 85 percent of new U.S. cars in 2025

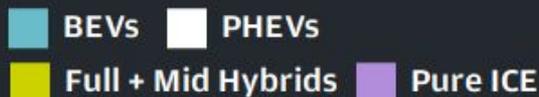
■ Mild hybrid (with 48V) ■ Plug-in hybrid ■ Full hybrid ■ Fuel cell ■ Battery electric vehicle  
■ Extended-range EV ■ Internal combustion engine



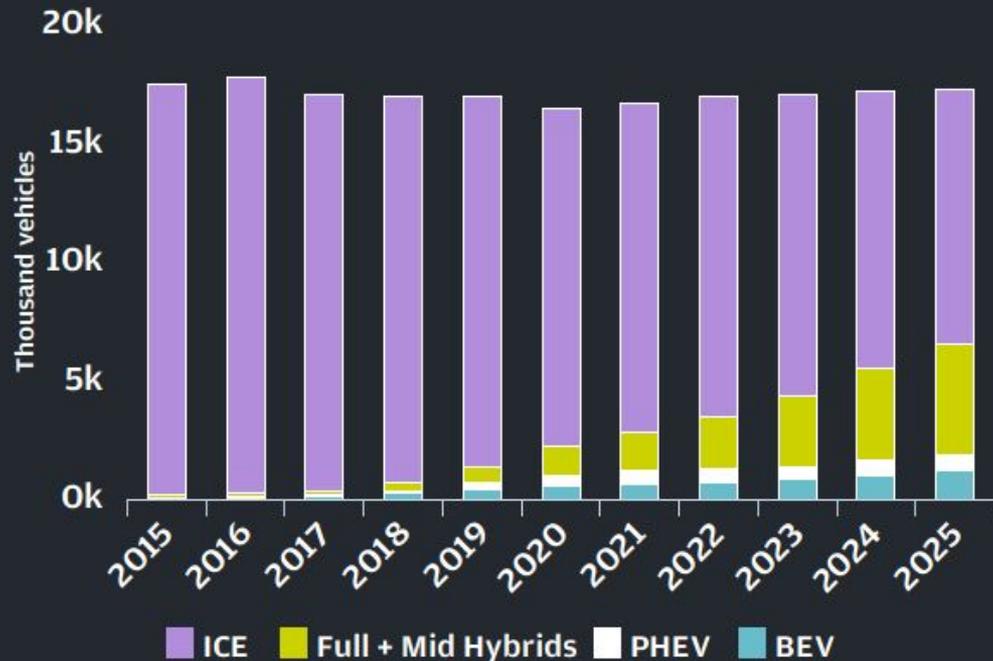
Source: LMC Automotive forecast

**Bloomberg**

## GLOBAL ELECTRIC VEHICLE FORECAST



## ESTIMATED NORTH AMERICAN LIGHT VEHICLE SALES BY POWER TYPE



Source: J.P. Morgan estimates

# Reasons for consumers' reluctance?

- ICE-EV price difference
- Range apprehension, waiting for charges on long drives
  - People prepare for worst-case long drives, not expected-case city drives
- Convenient ride-hailing and public transport ⇒ reduced incentive to own
- Increased financial instability, student debt

“Things move about 10 times the speed that they moved 25 years ago. As soon as the ball crests the hill and everyone thinks, ‘I’m comfortable with this,’ then the whole industry will flip.”

--- Rick Haas  
Former Chief Engineer of Tesla Model S  
With Mahindra now

**When consumers not on-board, why are companies pushing hard?**

# Any hope?

## Maybe (on the bright side)

Stricter government regulations

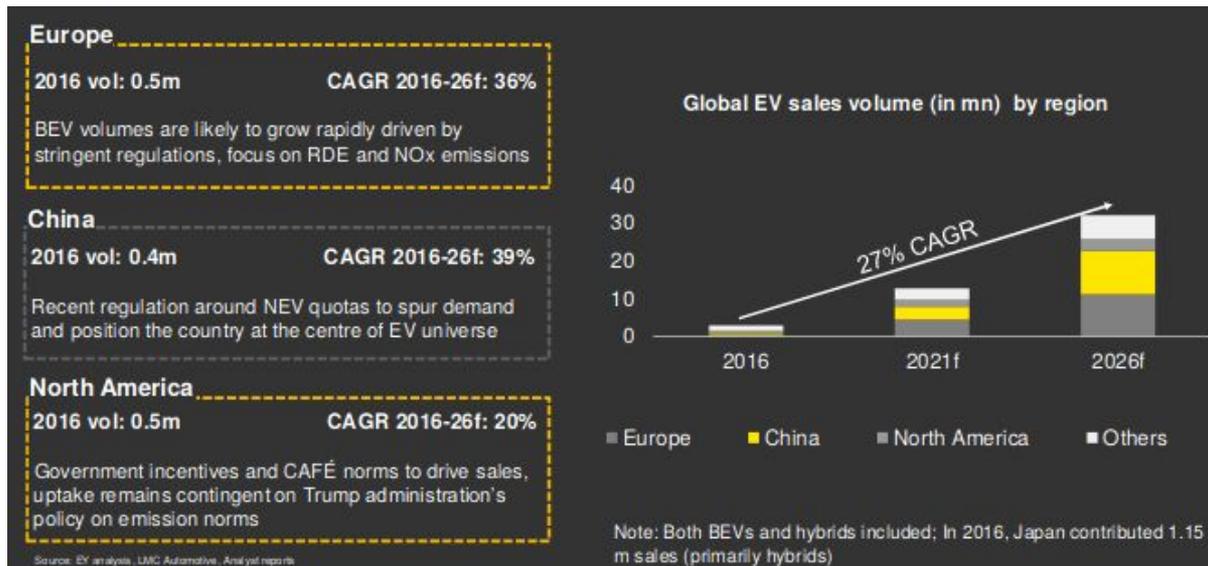
High gasoline prices

Cheaper Li-ion battery production:  
from \$273/kWh to \$73/kWh in 2030

Batteries' low degradation  $\Rightarrow$  cars  
last longer

Rapid charging network

Astronomical R&D investment



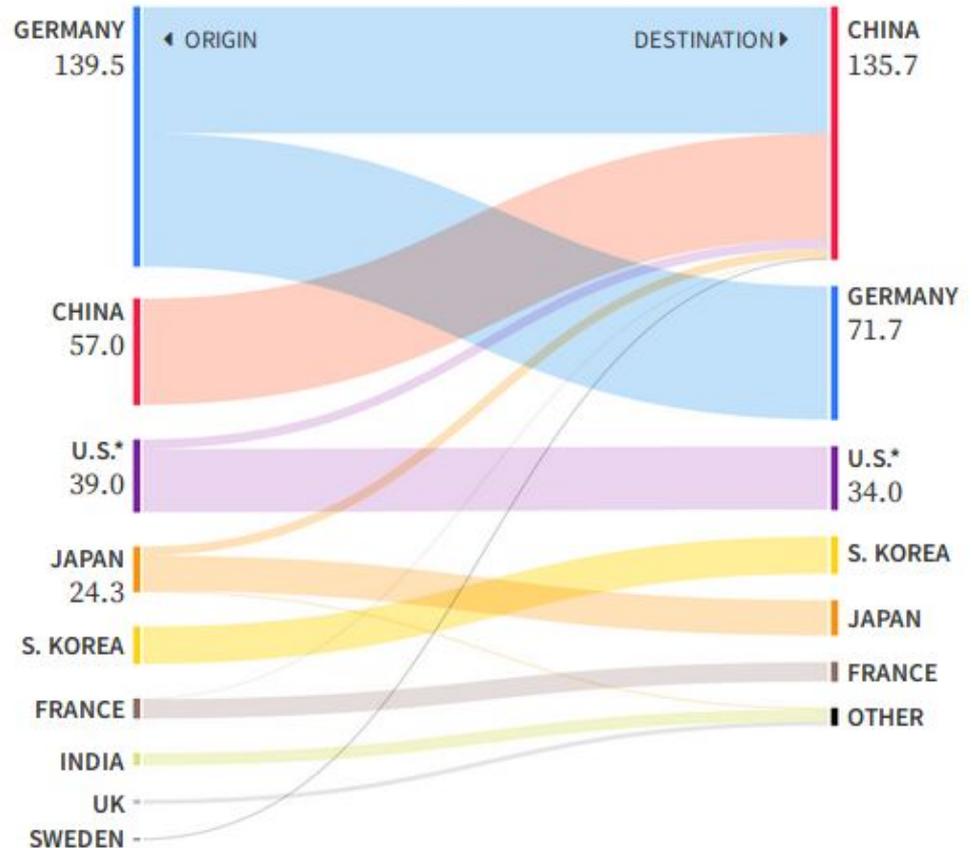
# Top Investors

(Jan 2019) Top 5 planned investors:

- Volkswagen: \$91 B
- Daimler: \$42 B
- Hyundai: \$20 B
- Changan: \$15 B
- Toyota: \$ 13.5 B
- Ford, Nissan, Renault, Tesla, GM, BMW follow closely

## EV INVESTMENT FLOWS BY COUNTRY OF ORIGIN OF AUTOMAKER

In billions of dollars



Source: Reuters Graphics \*U.S. includes Fiat Chrysler.

# Environmental Impact of EVs

# My initial reactions to EVs

Surely, EVs are zero-emissions and thus good for the environment, right?

Not so fast, consider emissions from:

- Mass production
- Mining for batteries' raw materials
- End-of-life disposal and recycling
- Emissions from electricity generation

# Emissions during EVs' lives

- Mass **production emissions unavoidable**; more than ICEs because building batteries emits more CO<sub>2</sub> than producing ICEs
- Mining a mediocre concern
  - Li-ion made of Li (5%), Co (20%), Ni (30%) (**mined in deserted ecosystems**)
  - Contrast to oil fields, which often are set up in grasslands
  - Mining is **water-intensive** however
  - **Limited resource**, will run out eventually
- Most metals in batteries can be **recycled efficiently**
  - Recycled batteries find use in non-EV-like battery packs (street lights etc.)
  - Recycling however is **water and energy intensive**

**Going forward: need efficiencies in production and recycling to improve**

# Emissions from generating electricity

Factoring in these emissions impacts carbon emissions from EVs

In coal-dependent countries, 1-15 years for EVs to break even with ICEs

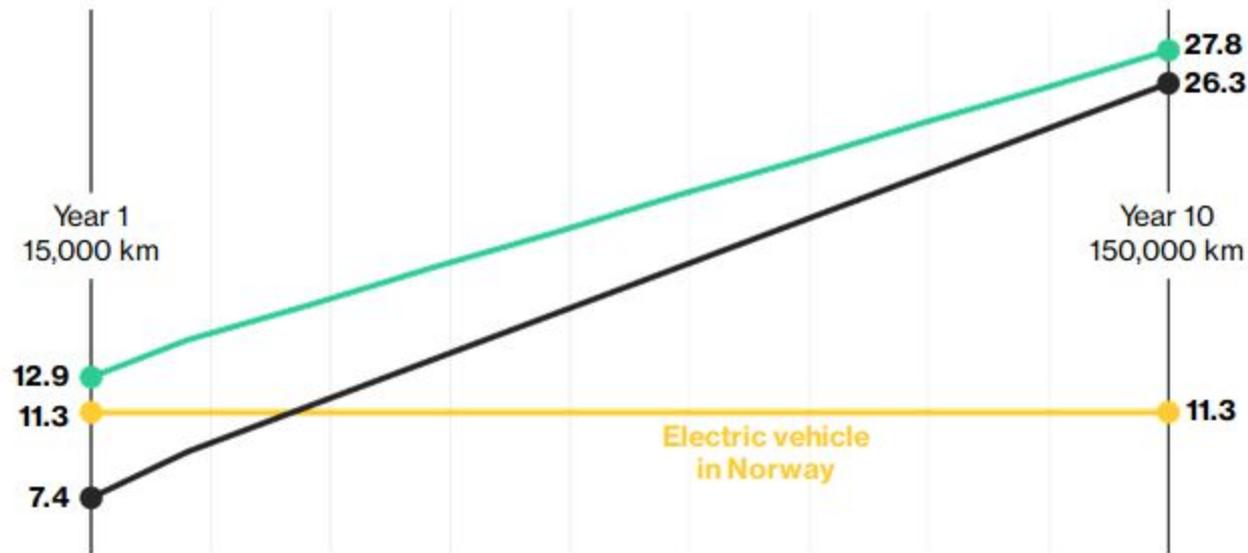
In countries with more renewable energy, EVs pollute less

**A comprehensive analysis: <https://youtu.be/6RhtiPefVzM>**

## Not So Green?

An **electric vehicle in Germany** would take more than 10 years to break even with an **efficient combustion engine's** emissions

Tons of CO2 emitted from cars driven 15,000km/year



Year 1 includes manufacturing-stage emissions. Predictions based on carbon tailpipe emissions and energy mix in 2017.

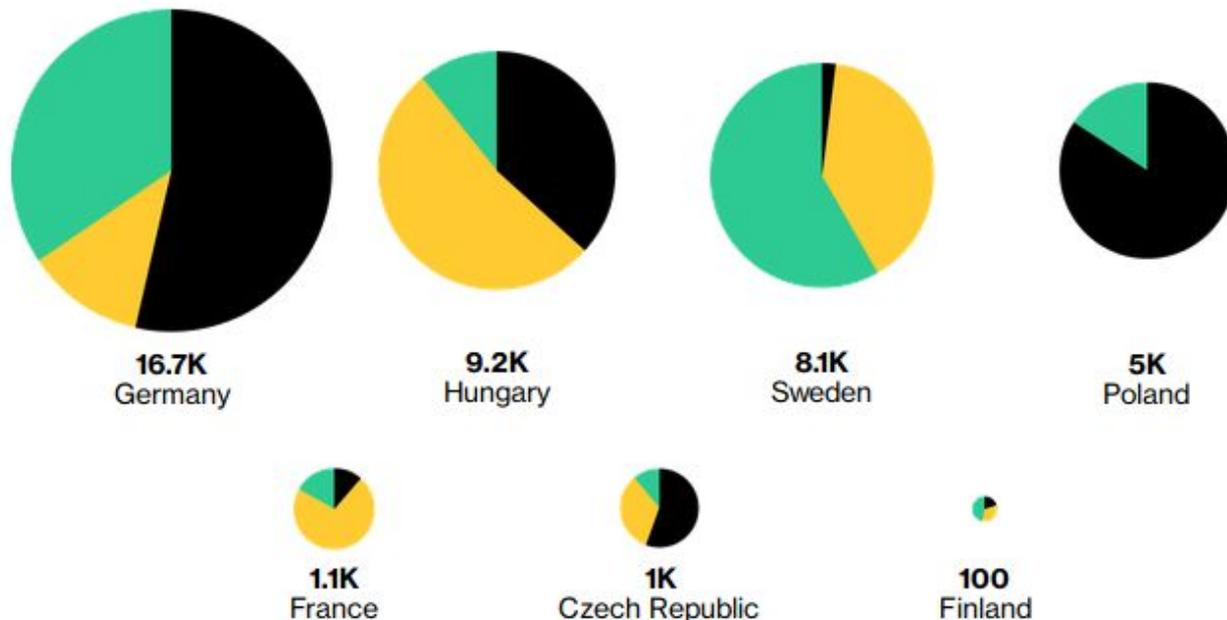
Source: Berylls Strategy Advisors

## The Dirt on Electric Car Batteries

Battery makers plan factories in Germany, Poland, where coal is still king

### Battery capacity, in megawatt hours

Energy mix ■ Renewable ■ Nuclear ■ Non-renewable



Capacity includes plants announced and under construction. Actual energy generation in 2017.

Sources: Bloomberg New Energy Finance, European Network of Transmission System Operators for Electricity

Motorsports

# Motorsports?

## Formula 1, 2, ...

- Premier cars by racing in the premier world championships
- Competed for by premier companies (Mercedes, Ferrari etc. this season)

## Formula E

- New all-electric cars, gaining fan support quickly



# Impacts on the Automobile industry

Transmission control, traction control, car build, regen braking, heat reuse etc. developed in Formula N championships (N = 1, 2, ...)

Formula E: test-bed for electric vehicles, especially for range, reliability, efficiency, and performance

- Most supercars have turbocharged hybrid ICEs ← refined by Formula N
  - ICEs are efficient and powerful in combination with electric motors (remember instant torque?)
- Porsche, Audi, Mahindra, BMW etc. compete in Formula E to develop roadcars

# Formula E propaganda video



Formula 1 sounds that I make





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