The car, the economy and the environment

- Historical background and technological development
- The world car production
- Energy and environmental impact (energy consumption, CO_2 emissions, local emissions, noise)
- Electric cars and other vehicles: market and industrial issues
- Autonomous cars?

Introduction

The car changed our life, our landscape, our economy

The car is by far the most used short-to-medium distance means of transport

Tab. 7.5 - Traffico totale interno[1] di passeggeri per modo di trasporto - Anni 2005, 2007-2013

Milioni di passeggeri-km

Modalità di trasporto	2005	2007	2008	2009	2010	2011	2012	2013
Impianti fissi [2]	56.516	56.904	56.797	55.483	54.677	54.361	53.716	*54.417*
Su strada [3]	*827.488*	*822.861*	*824.268*	*864.026*	*842.090*	*810.692*	*721.924*	*763.655*
Vie d'acqua [4]	*3.725*	*4.059*	*4.186*	*4.321*	*4.088*	*3.904*	*3.731*	*3.841*
Navigazione aerea	*12.813*	*15.334*	*15.064*	*14.700*	*15.726*	*16.765*	*16.545*	*16.235*
Totale	**900.541**	**899.158**	**900.315**	**938.530**	**916.581**	**885.722**	**795.916**	**838.149**

In corsivo i dati stimati - Le somme possono non coincidere con i totali a causa degli arrotondamenti.

(1) Sono considerati gli spostamenti dei passeggeri realizzati mediante vettori nazionali con origine e destinazione interne al territorio italiano. Per il traffico ferroviario è compresa anche la quota dei traffici internazionali realizzata su territorio nazionale.

(2) Comprende i trasporti su ferrovia, tranvie, metropolitane, funicolari e funivie.

(3) Comprende i trasporti collettivi extraurbani, i trasporti su filovie ed autobus, e i trasporti privati.

(4) Comprende la navigazione marittima e quella per vie d'acqua interne.

Fonte: Ministero delle Infrastrutture e dei Trasporti, Fonti diverse.

Technological development

A car (or automobile) is a wheeled motor vehicle used for transportation. Most definitions of cars say that they run primarily on roads, seat one to eight people, have four wheels, and mainly transport people rather than goods.

Car, carriage, to carry
Vettura, autovettura

passenger car (*plural* **passenger cars**)

1. (*rail transport*) A railroad car that carries passengers.
2. (*vehicles*) A road vehicle that carries passengers; a motorcar or automobile.

A **passenger railroad car or passenger car** (United States), also called a passenger carriage, passenger coach (United Kingdom and International Union of Railways), or passenger bogie (India) is a **railroad car** that is designed to carry passengers. The term passenger car can also be associated with a sleeping car, a baggage car, a dining car, railway post office and prisoner transport cars.

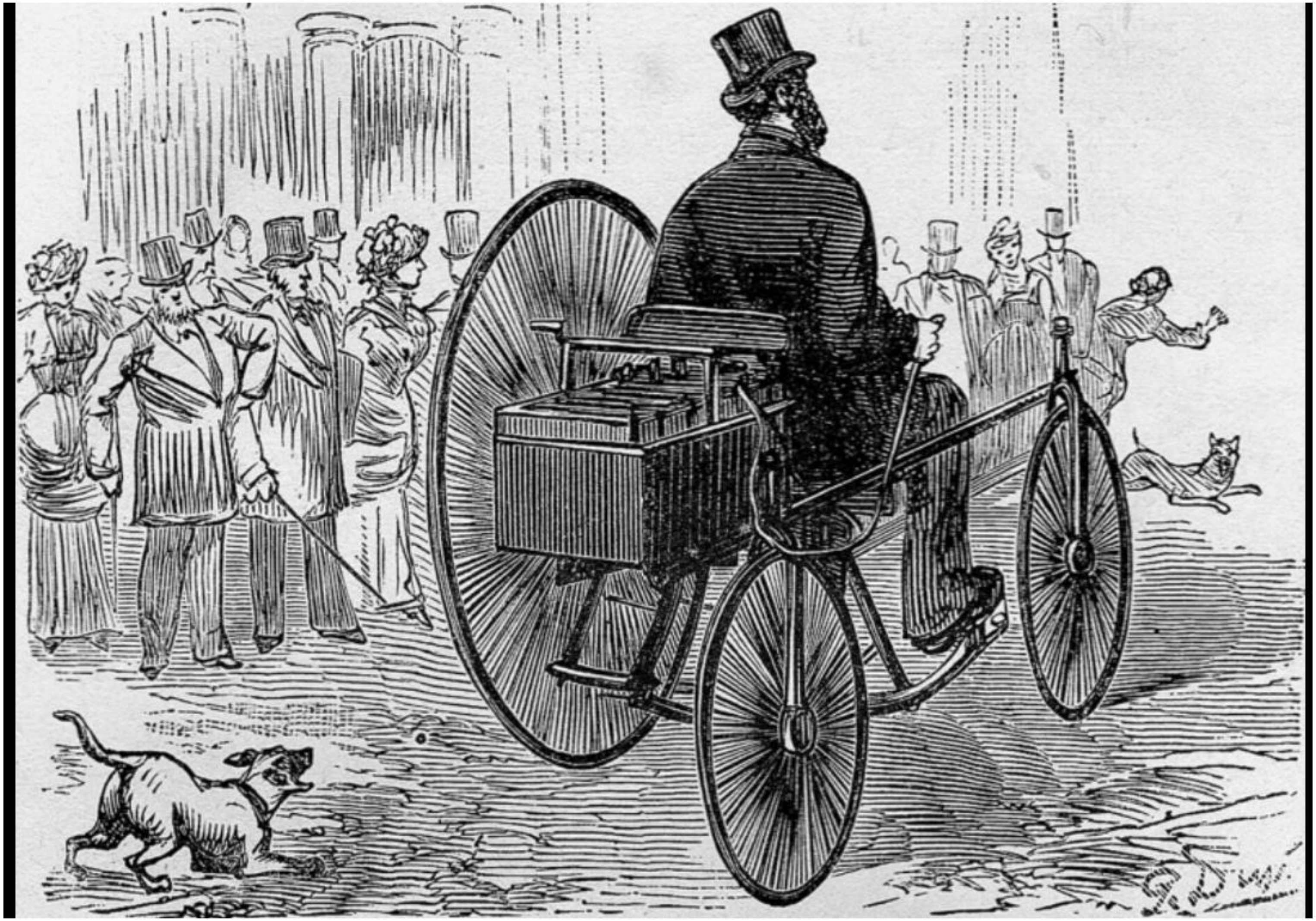
Electric vehicles

Early Electric Vehicles

ULLSTEIN BILD DTL. | GETTY IMAGES

We start in the 1830s, with Scotland's Robert Anderson, whose motorized carriage was built sometime between 1832 and '39. Batteries (galvanic cells) were not yet rechargeable, so it was more parlor trick ("Look! No horse nor ox, yet it moves!") than a transportation device. Another Scot, Robert Davidson of Aberdeen, built a prototype electric locomotive in 1837. A bigger, better version, demonstrated in 1841, could go 1.5 miles at 4 mph towing six tons. Then it needed new batteries. This impressive performance so alarmed railway workers (who saw it as a threat to their jobs tending steam engines) that they destroyed Davidson's devil machine, which he'd named Galvani.

https://www.caranddriver.com/features/g15378765/worth-the-watt-a-brief-history-of-the-electric-car-1830-to-present/



In November 1881, French inventor Gustave Trouvé demonstrated the first working (three-wheeled) **car powered by electricity** at the International Exposition of Electricity, Paris.

Benz Patent-Motorwagen Nr. 1

The Benz Patent-Motorwagen ("patent motorcar"), built in 1885 by the German Carl Benz, is widely regarded as the world's first production automobile; that is, a self-propelled vehicle for carrying people. It was patented and unveiled in 1886.

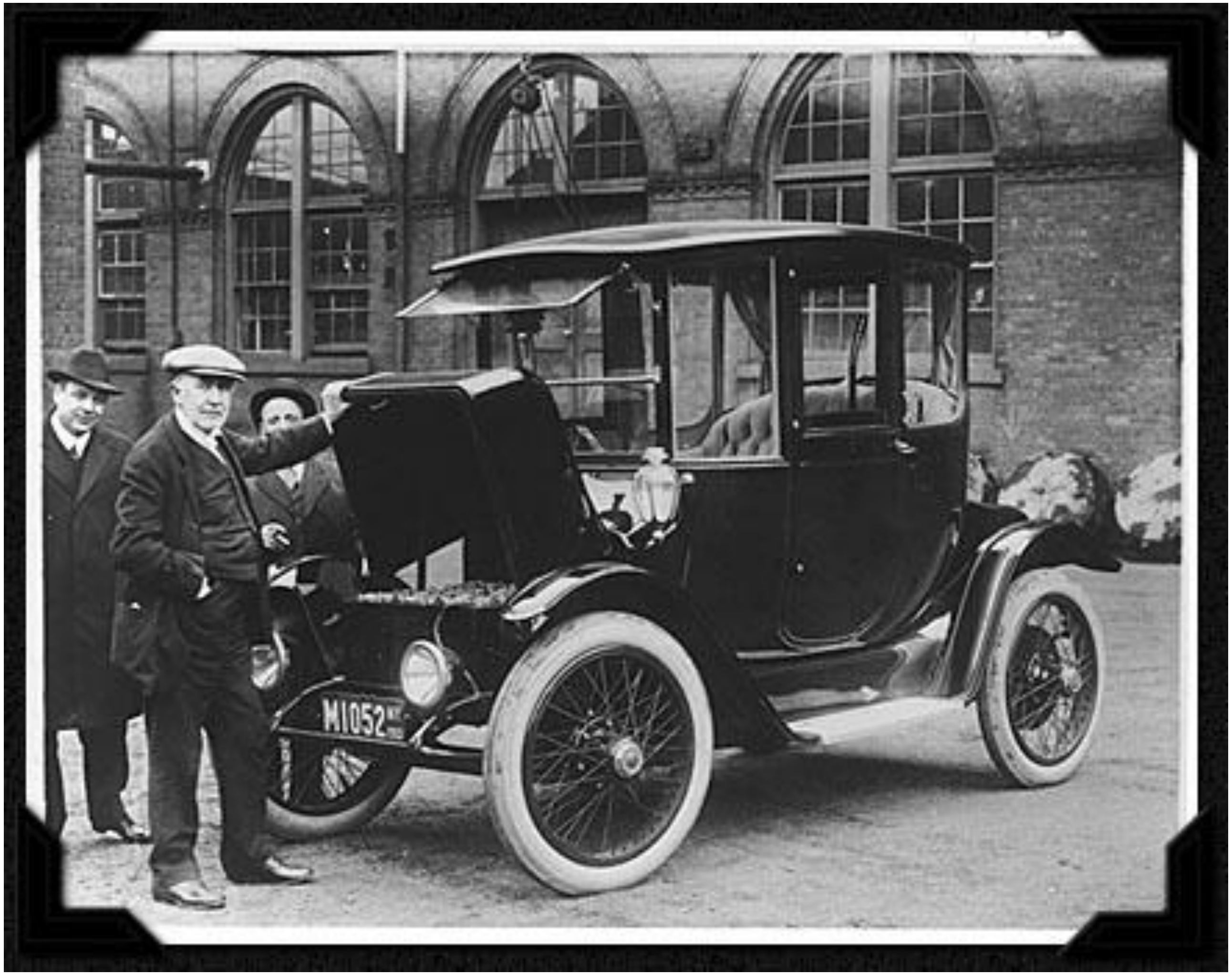
After developing a successful **gasoline-powered two-stroke piston engine** in 1873, Benz focused on developing a motorized vehicle **while maintaining a career as a designer and manufacturer of stationary engines** and their associated parts.

The first passenger cars were electric

German Flocken Elektrowagen of 1888, regarded as the first electric car of the world

German electric car, 1904

Detroit Electric car charging



Thomas Edison and a Detroit Electric car in 1913

It could **go 25 mph with a range of 80 miles**. electric cars maintained a market particularly in the cities where their silent operation and ease of use appealed to many. Often, the drivers were women who didn't want to hand-crank an engine to start it, so city shopping districts had charging stations to attract these affluent customers.

The ICE (internal combustion engine) cars

1910 Model T by FORD

Year	Production	Price for Runabout
1909	10,666	$825
1910	19,050	$900
1911	34,858	$680
1912	68,773	$590
1913	170,211	$525
1914	202,667	$440
1915	308,162	$390
1916	501,462	$345
1917	735,020	$500
1918	664,076	$500
1919	498,342	$500
1920	941,042	$395
1920	463,451	$395
1921	971,610	$325
1922	1,301,067	$319
1923	2,011,125	$364
1924	1,922,048	$265
1925	1,911,705	$260
1926	1,554,465	$360
1927	399,725	$360

The Model T was Ford's first automobile mass-produced on moving assembly lines with completely interchangeable parts, marketed to the middle class

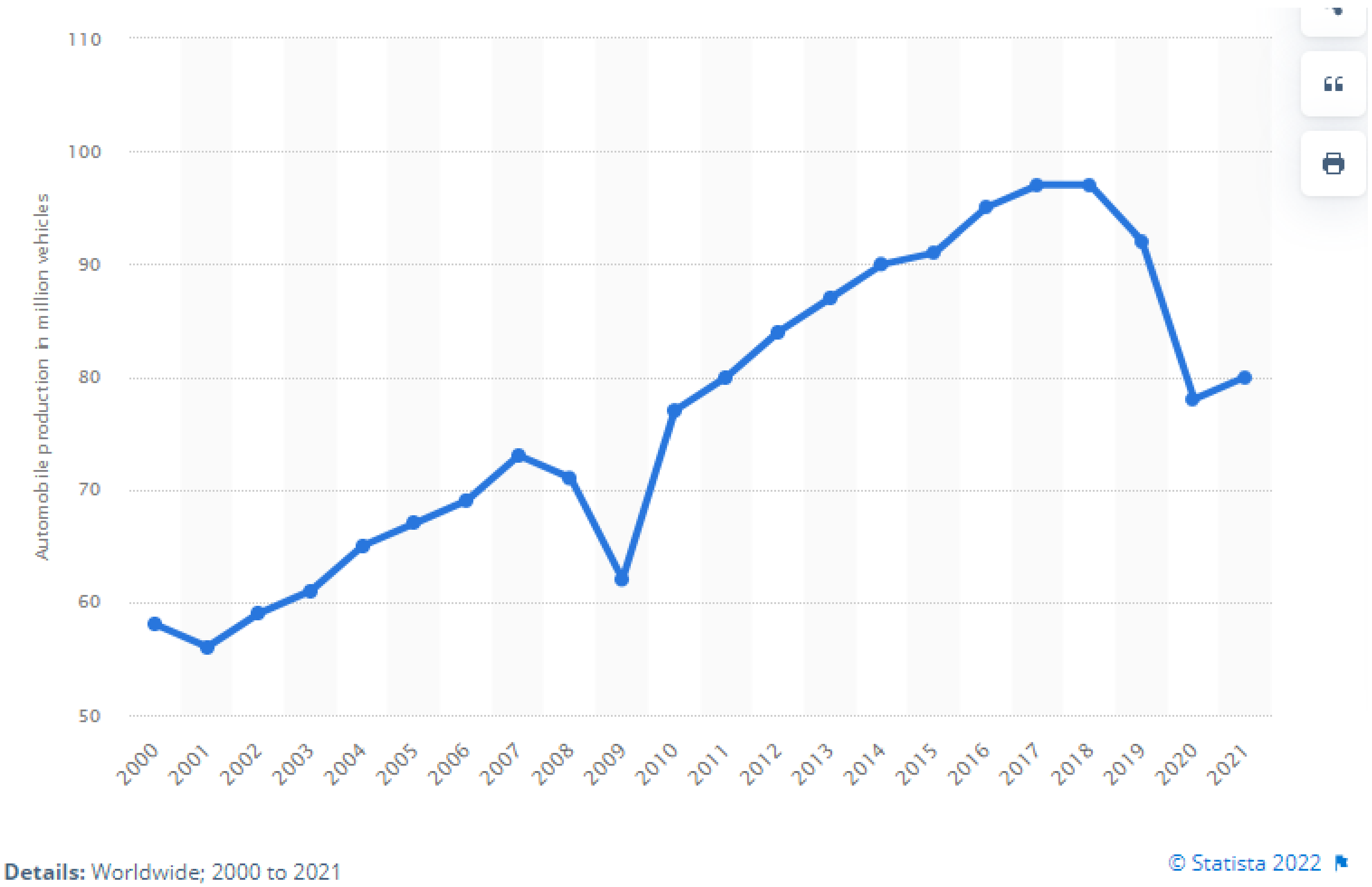
A rapid expansion of petrol infrastructure

Many fuel types

- Electric
- Gasoline\petrol
- Diesel
- Methane
- LPG
- Fuel cell (Hydrogen)
- Hybrid

Fiat 500 "Topolino" 1936

Estimated worldwide motor vehicle production from 2000 to 2021 (in million vehicles)

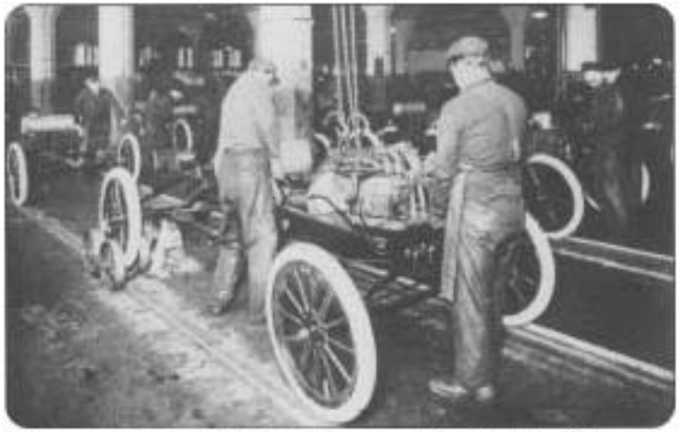


https://www.statista.com/statistics/262747/worldwide-automobile-production-since-2000/

Car manufacturing

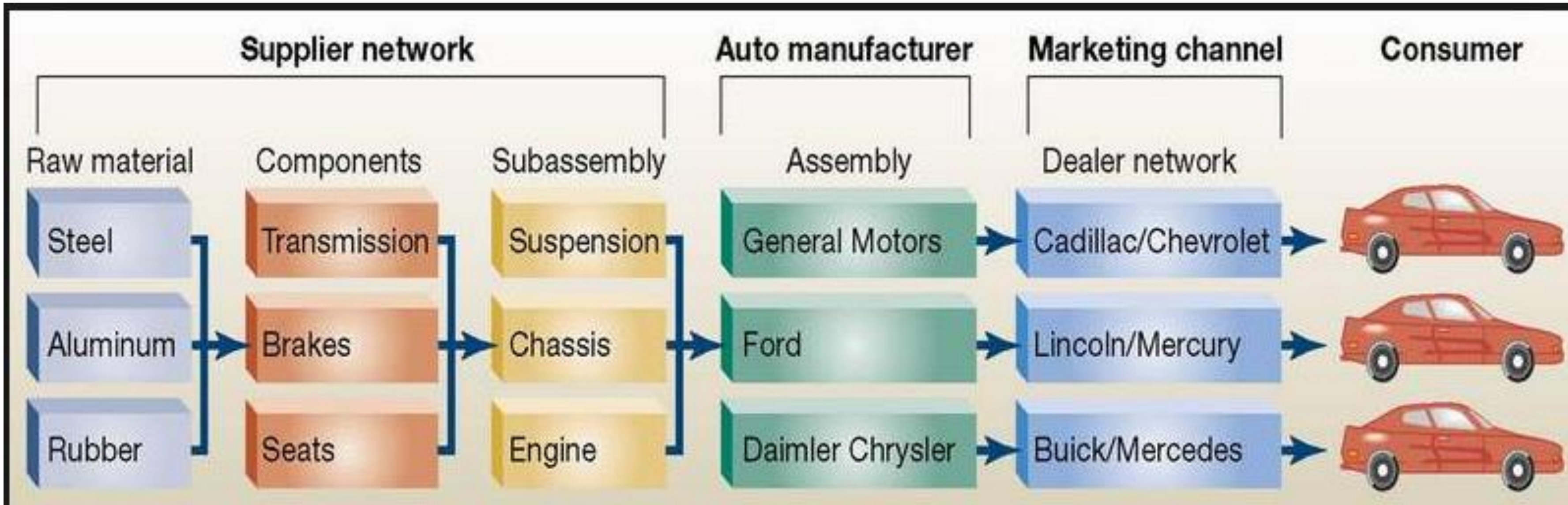
The automotive industry is a major industrial and economic force worldwide. It makes 60 million cars and trucks a year, and they are responsible for almost half the world's consumption of oil. The industry employs **4 million people** directly, and many more indirectly.

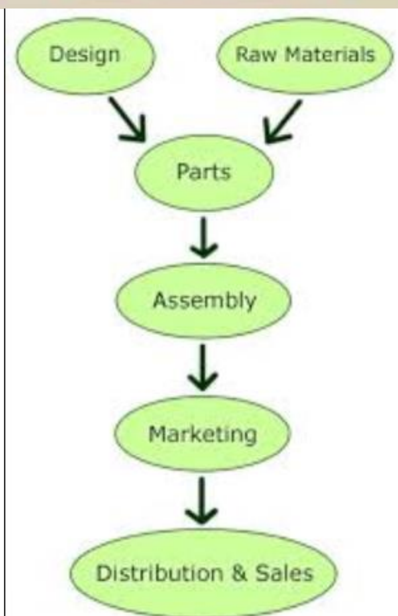
Despite the fact that many large companies have problems with overcapacity and low profitability, the automotive industry retains very strong influence and importance. **The industry also provides well-paying jobs with good benefits, has heavy linkages with supplier industries** (which gives it an oversized role in economic development)**, and has a strong political influence.**



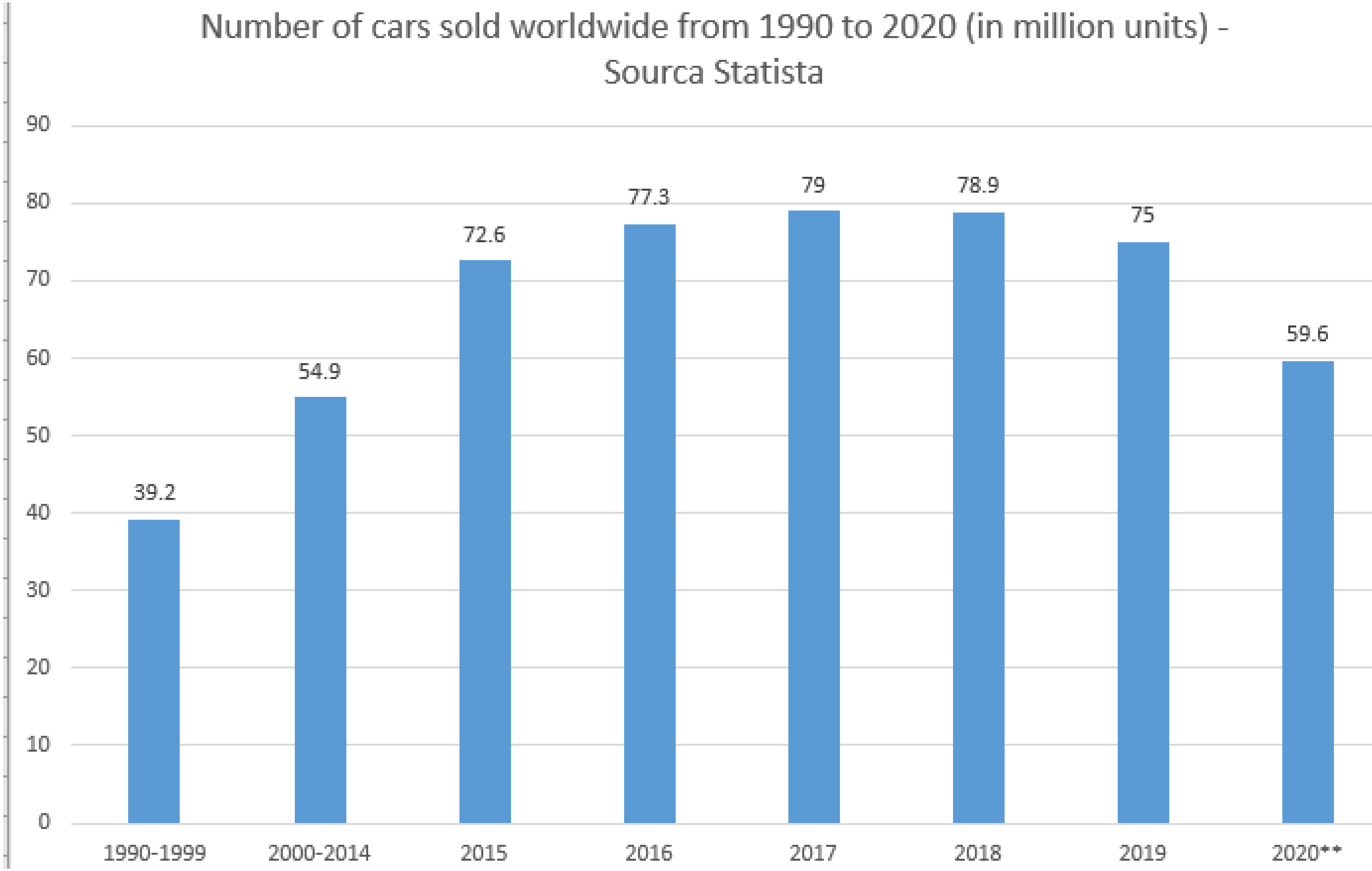
Workers install engines on Model Ts at a Ford Motor Company plant. The photo is from about 1917.

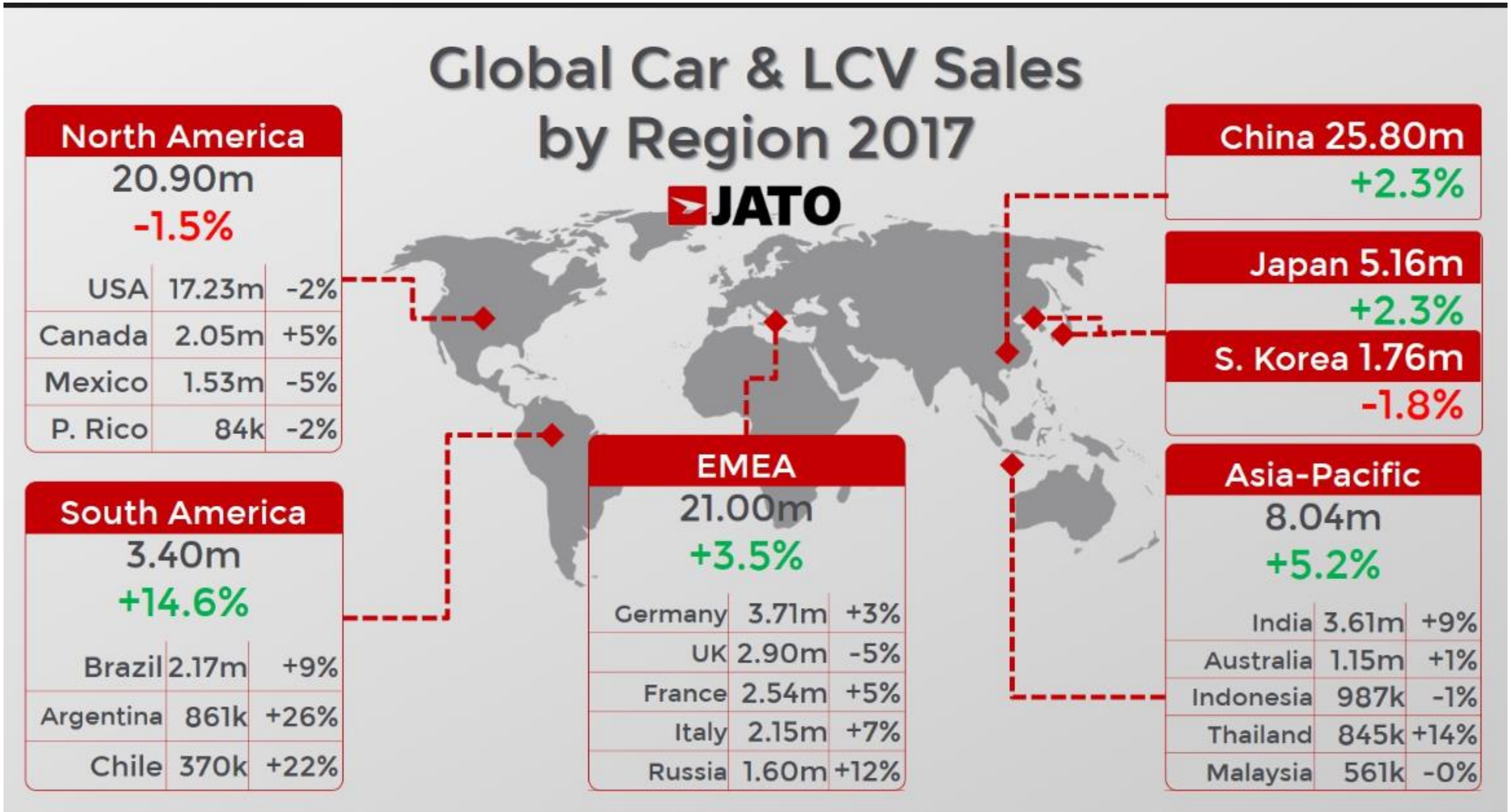
The value chain





Number of cars sold worldwide from 1990 to 2018 (in million units)



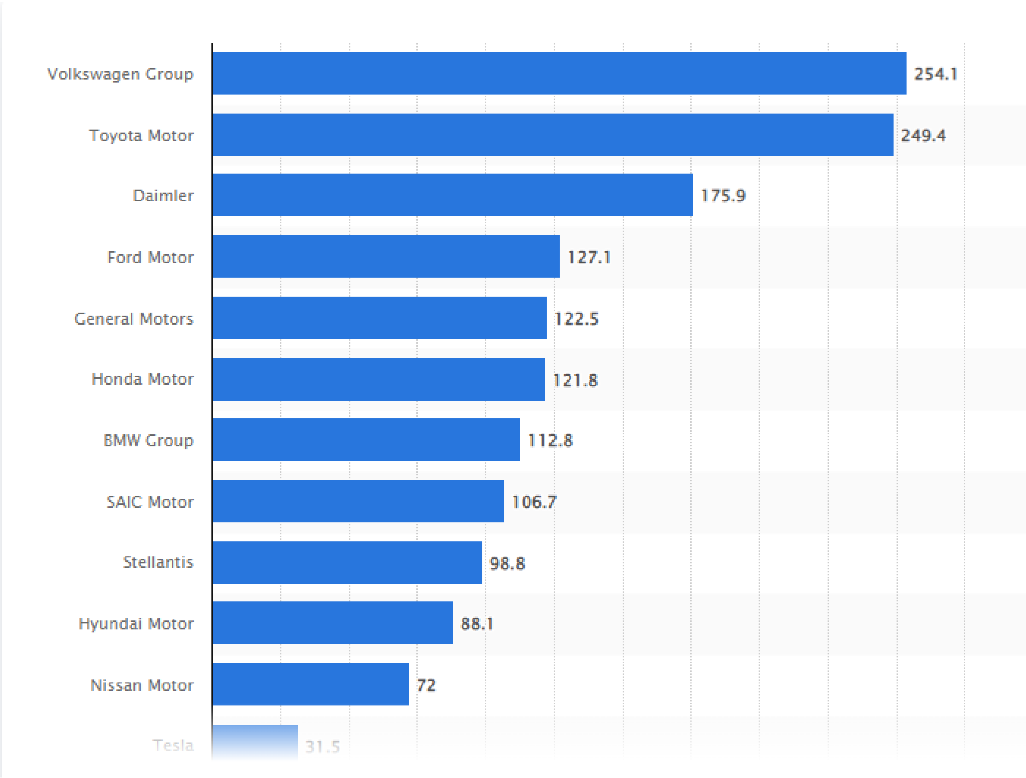


Number of road motor vehicles per 1,000 inhabitants

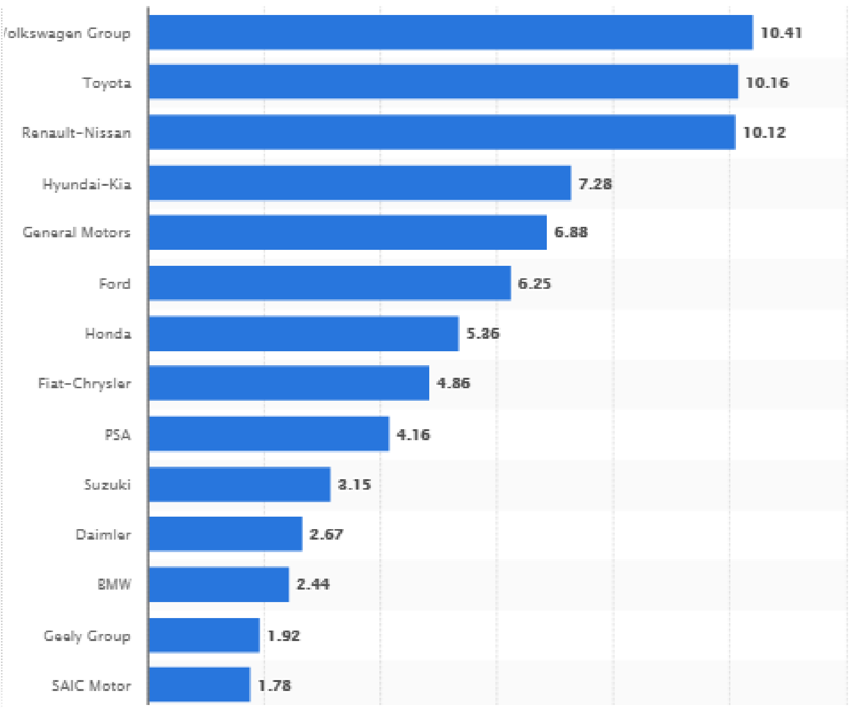
2	United States	910	255,009,283[2]	2017[2]
10	Italy	679		[1]
73	China	154	212,560,000	2016[32][33]
134	India	50	55,725,543[43]	2015

Leading automobile manufacturers

Revenue of leading automakers worldwide in 2020 (in billion U.S. dollars)



2017, based on vehicle sales (in million units)



https://www.statista.com/statistics/232958/revenue-of-the-leading-car-manufacturers-worldwide/

Energy and environmental impact

Energy

Local and global air pollution

Noise

The energy issue: more and more energy is needed

2010 474 exaJ = 15,000,000,000,000 Wh/y = 15 TW

2030 → 23 TW ; 2058 → 32 TW

(Souce: Fermeglia, 2017)

World energy resources

Fossil fuels

- **Coal**
- **Natural gas**
- **Oil**

Nuclear fuels

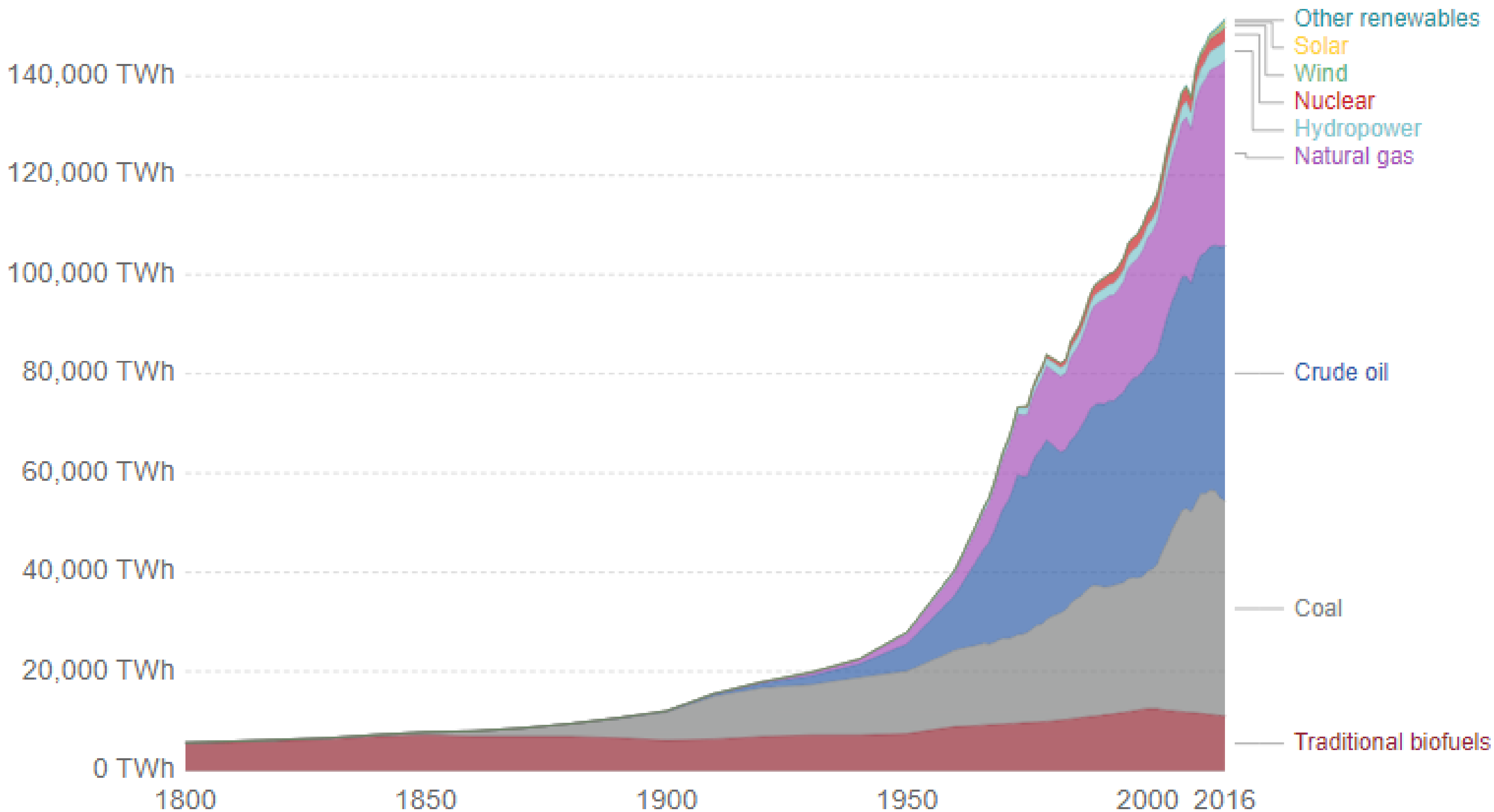
- **Nuclear energy**
- **Nuclear fusion**

Renewable resources

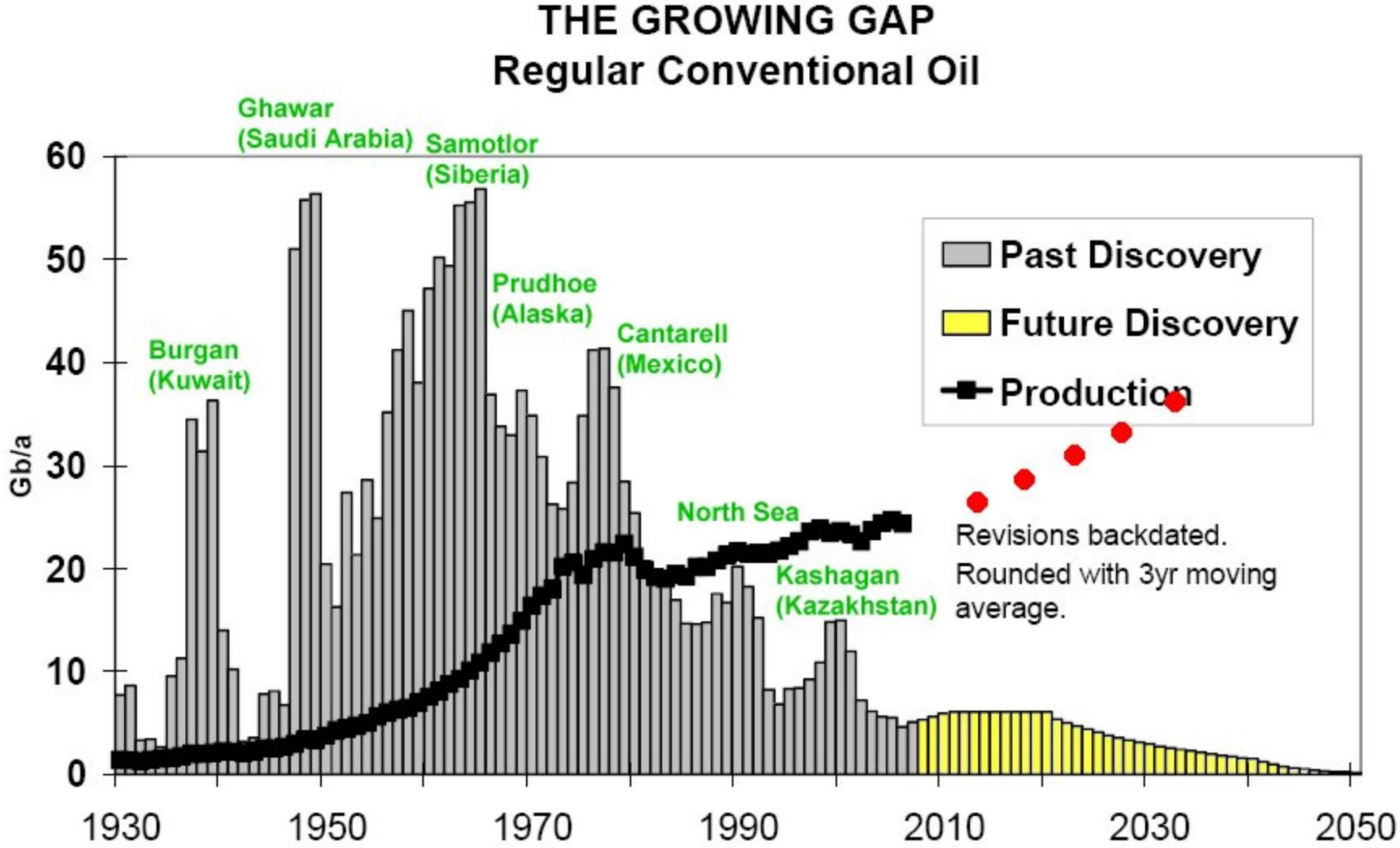
- **Solar energy**
- **Wind power**
- **Wave and tidal power**
- **Geothermal**
- **Biomass**
- **Hydropower**

Global Primary Energy Consumption, World

Global primary energy consumption, measured in terawatt-hours (TWh) per year. Here 'other renewables' are renewable technologies not including solar, wind, hydropower and traditional biofuels.

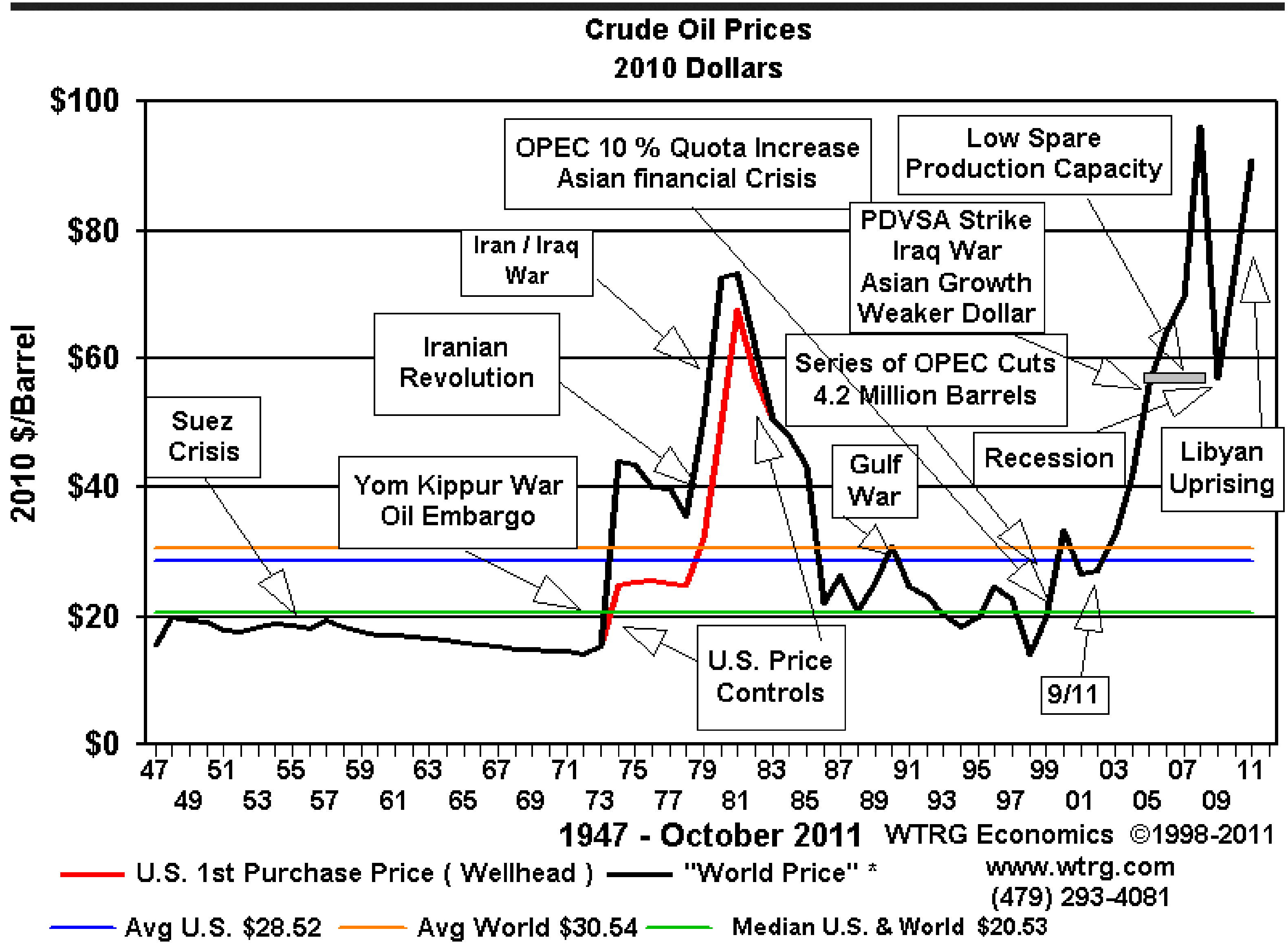


Source: Vaclav Smil (2017) and BP Statistical Review of World Energy ver the next few years we will find less and less deposits in front of one Increasing production: DROPS



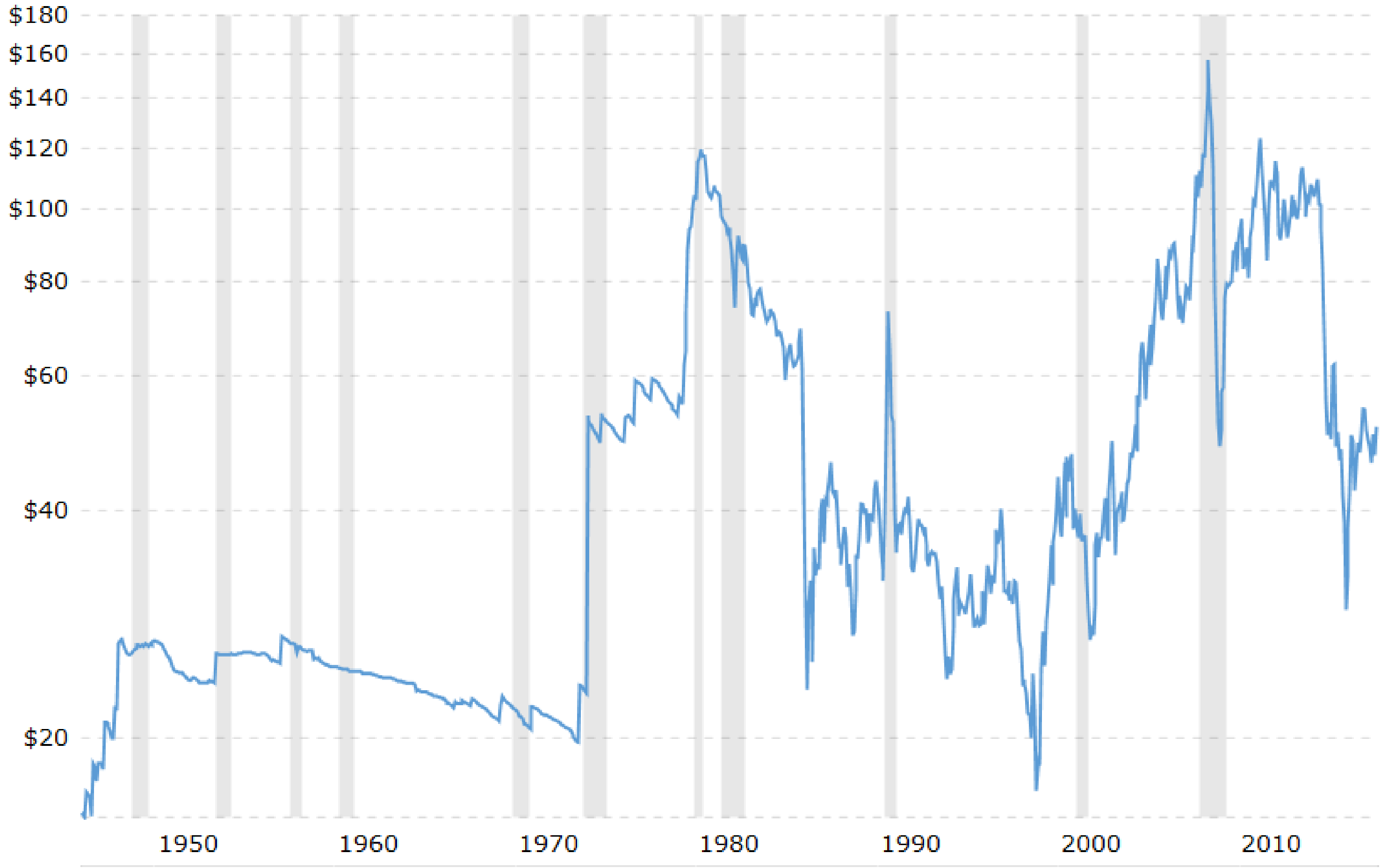
Over the next few years less and less new oil reserves will be available to satisfy an ever-increasing production. (Fermeglia, 2017)

The oil price

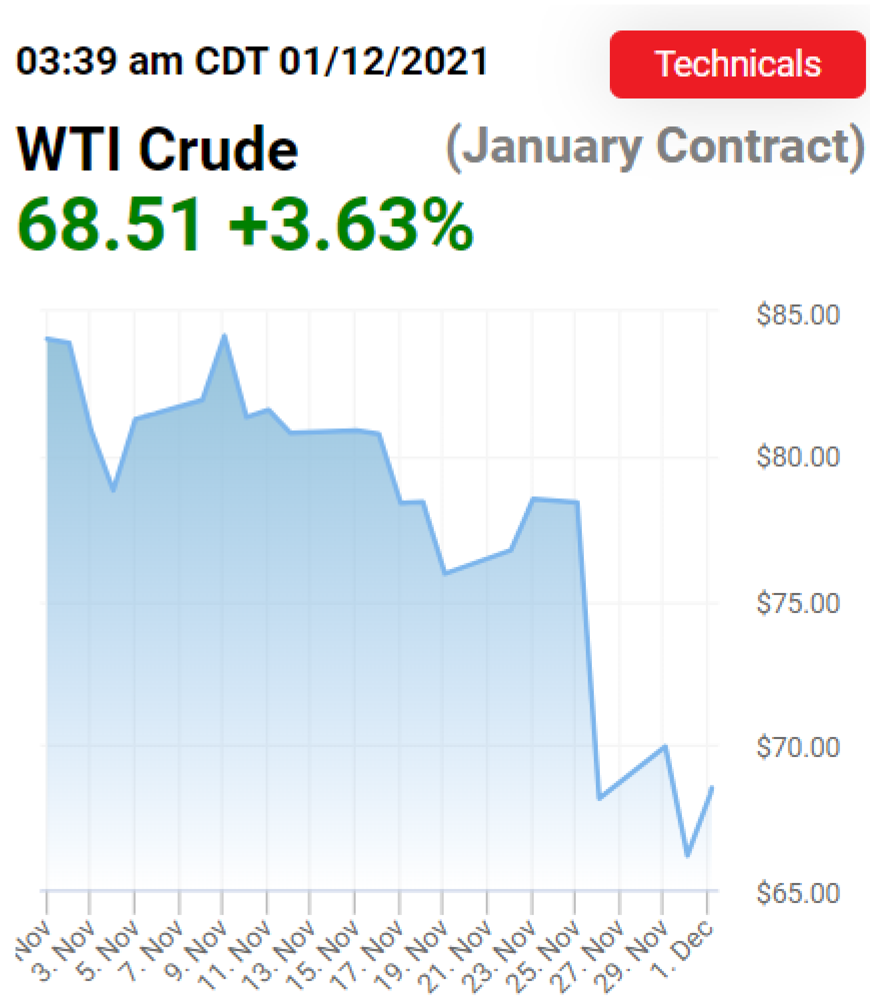


The oil price (1987-2015)

September 29, 2017 is **$51.49** per barrel.

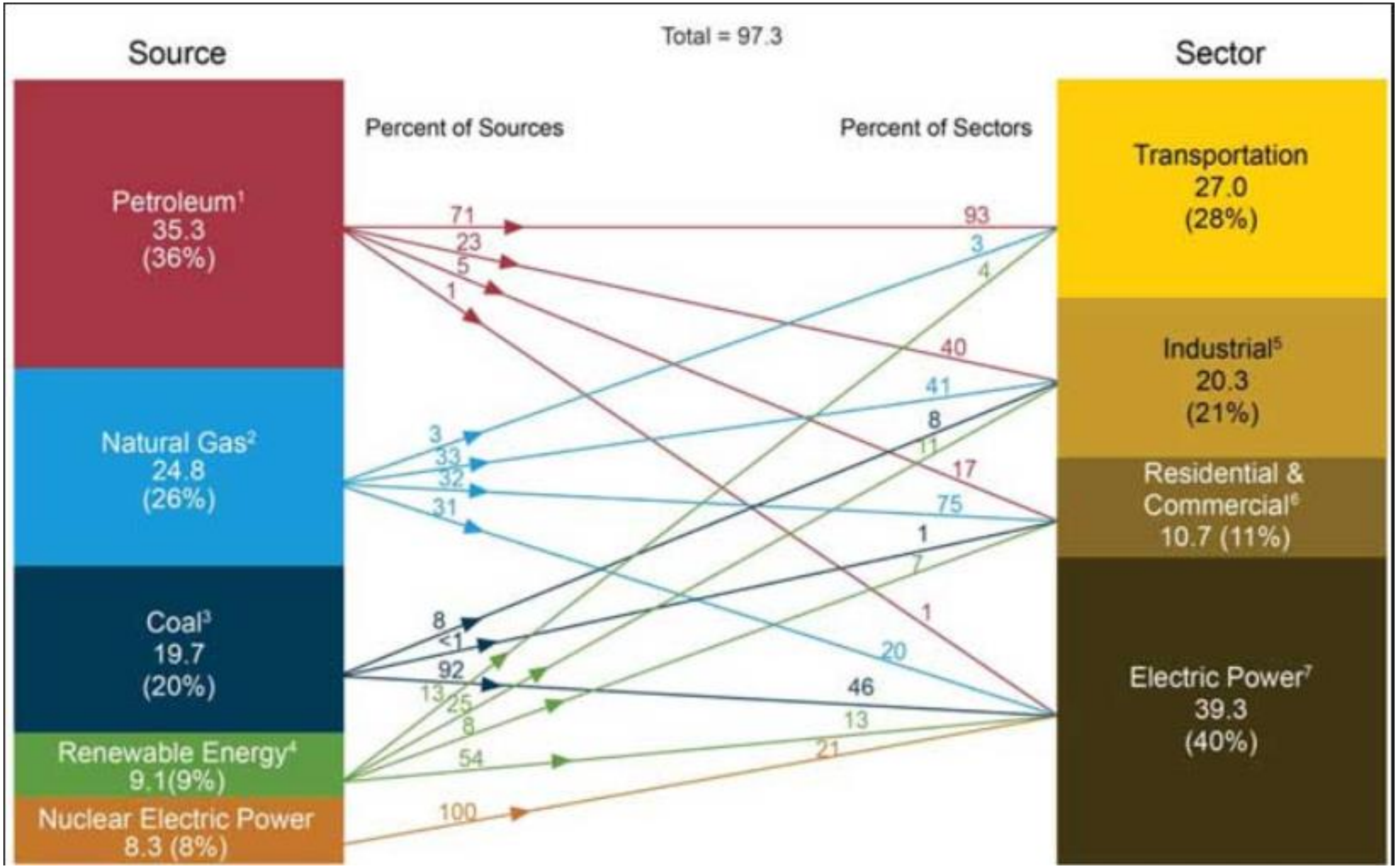


Brent barrel petroleum spot prices since May 1987. Due to exchange rate fluctuations, the real price line is only relevant to the United States and countries with a currency tied to the U.S. dollar at a constant rate throughout the period.



https://oilprice.com/oil-price-charts/

Trasport’s share of energy consmption



28% of total energy, 93% of which petroleum

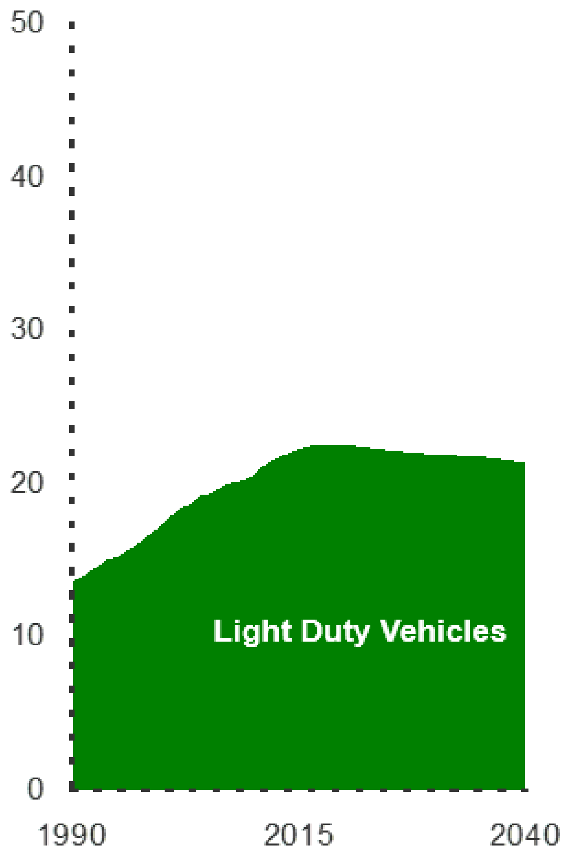
U.S. Energy Information Administration, Annual Energy Review 2011,

Global energy demand for transportation

UNIVERSITÀ DEGLI STUDI DI TRIESTE

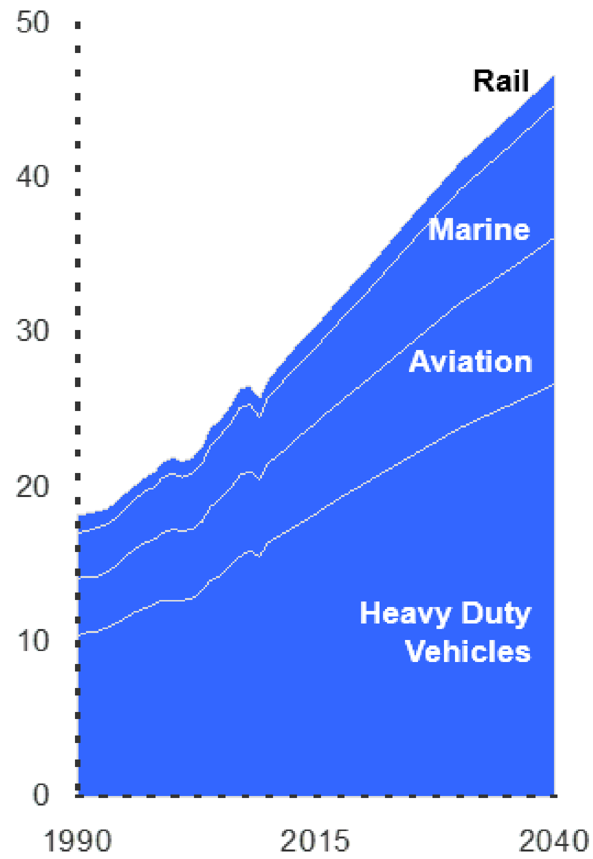
Personal

Millions of oil-equivalent barrels per day



Commercial

Millions of oil-equivalent barrels per day



Fonte: The Outlook for energy: a view of 2040, Exxon

Environmental impact: local pollutants, noise and CO_2 emissions

Local pollutants: CO, PM, NOx, O3

More than 80% of people living in urban areas that monitor air pollution are exposed to air quality levels that exceed WHO limits.

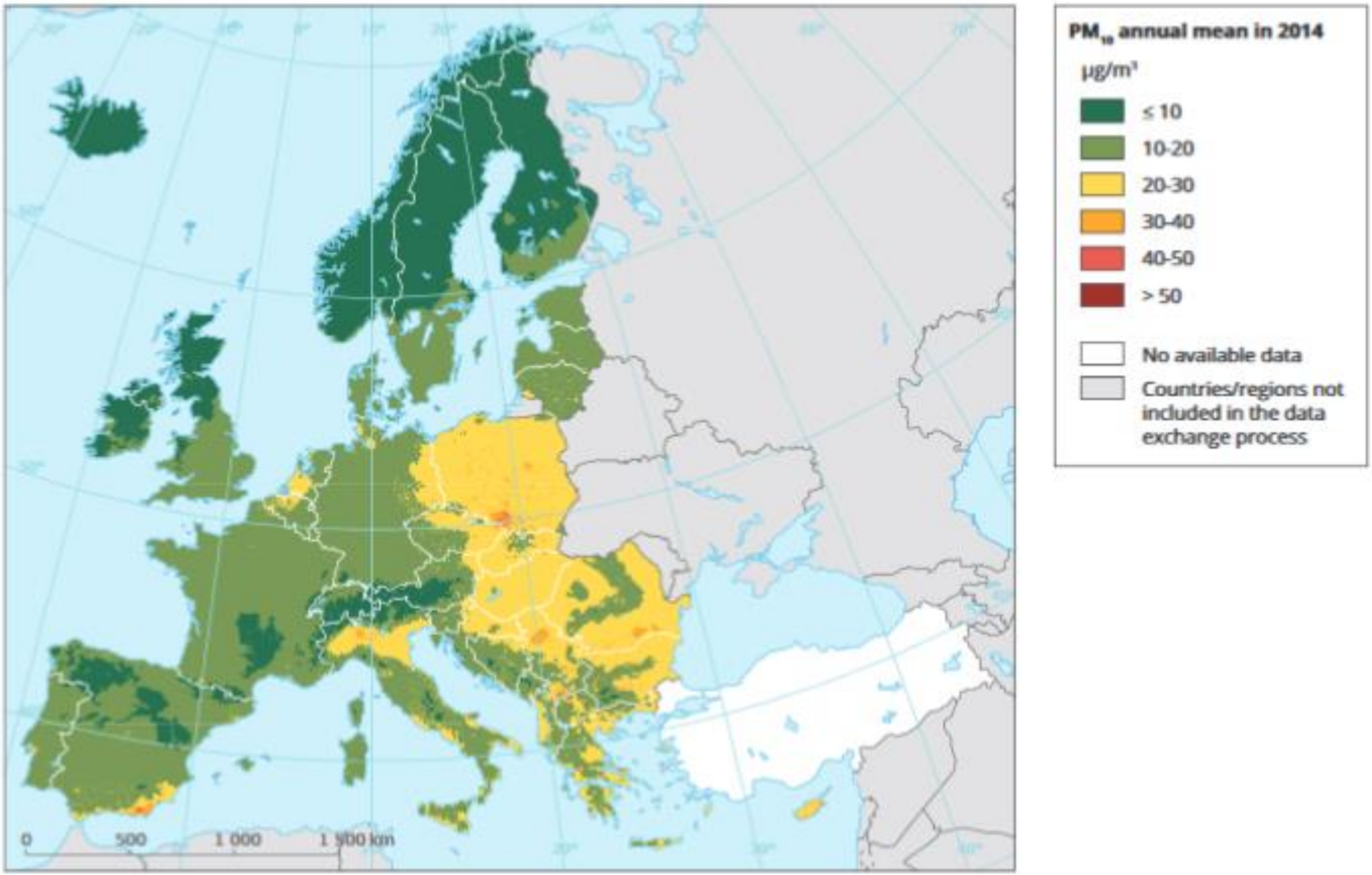
Table ES.1 Percentage of the urban population in the EU-28 exposed to air pollutant concentrations above certain EU and WHO reference concentrations (2012–2014)

Pollutant	EU reference value (a)	Exposure estimate (%)	WHO AQG (a)	Exposure estimate (%)
$PM_{2.5}$	Year (25)	8–12	Year (10)	85–91
PM_{10}	Day (50)	16–21	Year (20)	50–63
O_3	8-hour (120)	8–17	8-hour (100)	96–98
NO_2	Year (40)	7–9	Year (40)	7–9
BaP	Year (1)	20–24	Year (0.12) (RL)	88–91
SO_2	Day (125)	< 1	Day (20)	35–49

Air quality in Europe — 2016 report

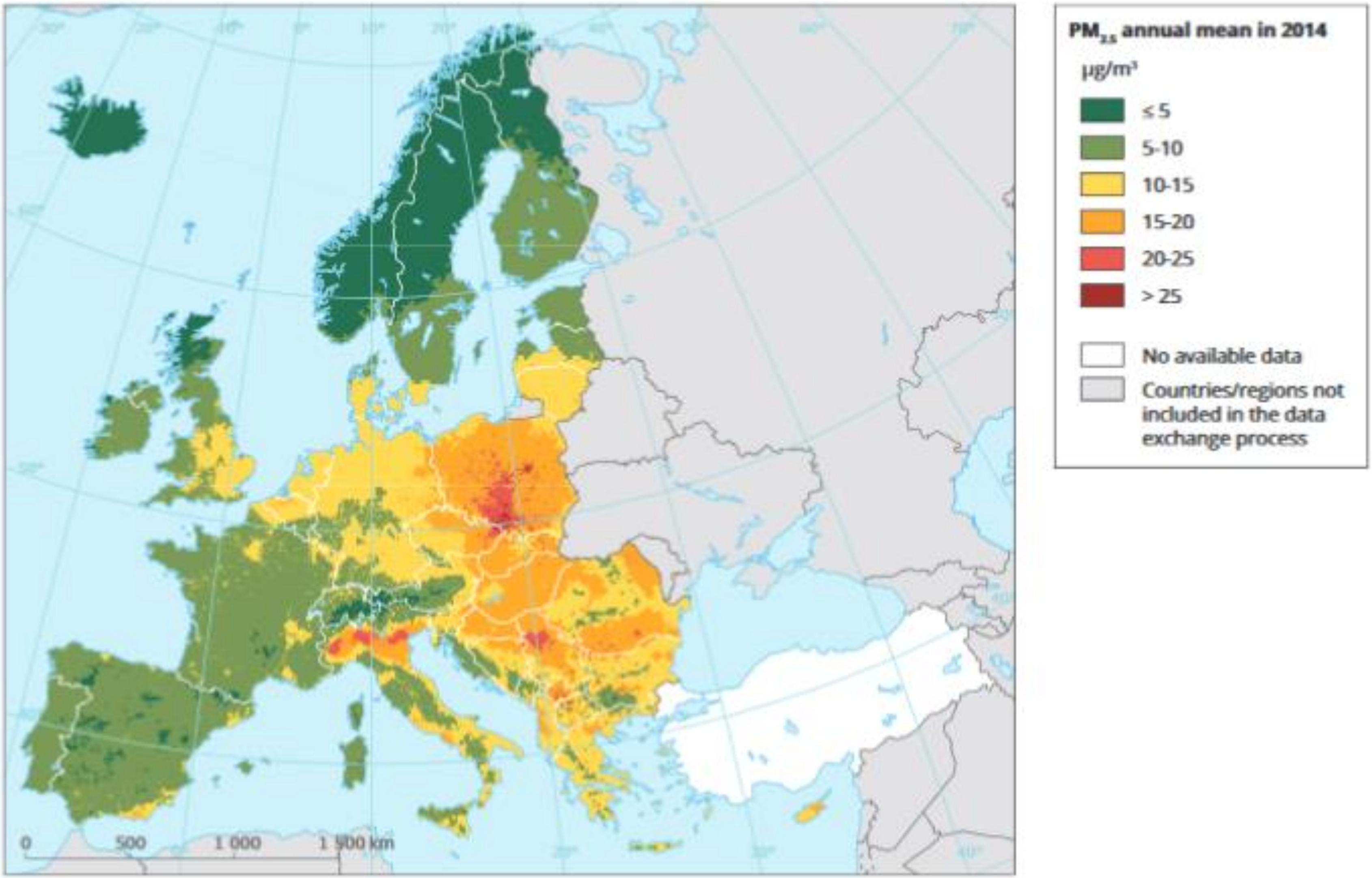
Air pollution: PM10

Figure 9.1 **Concentration interpolated maps of PM_{10} (annual mean, µg/m³), $PM_{2.5}$ (annual mean, µg/m³), NO_2 (annual mean, µg/m³), and O_3 (SOMO35, µg/m³ .days) for the year 2014**



https://www.eea.europa.eu/publications/air-quality-in-europe-2017

Air pollution : PM2.5



Noise

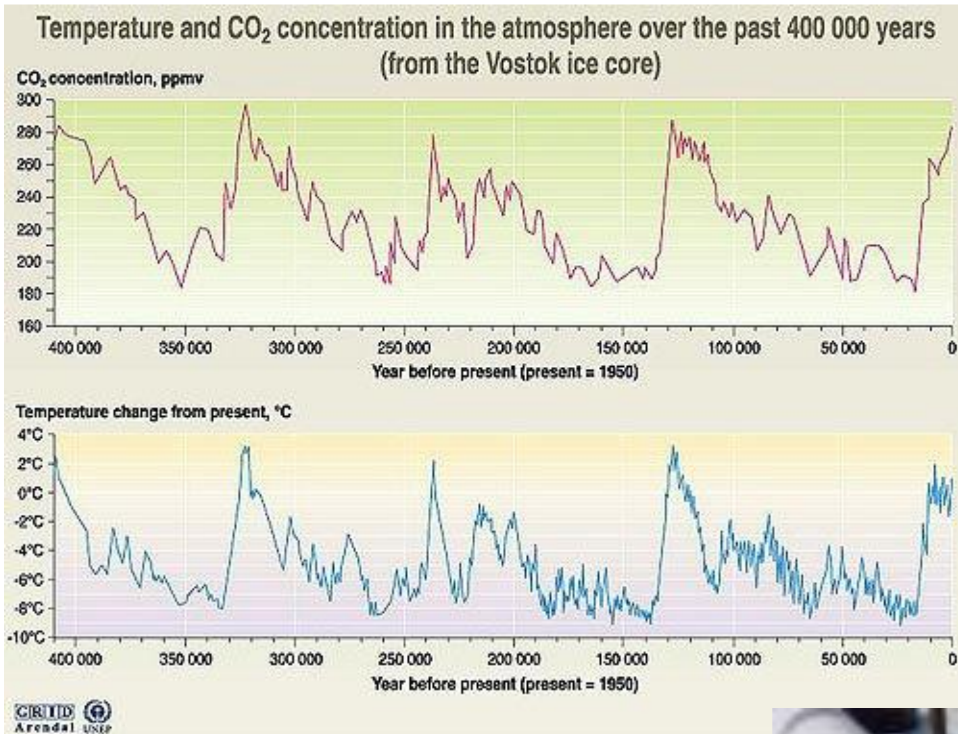
World Health Organization (WHO) estimates that about 40 % of the population in the EU is exposed to road traffic noise at levels exceeding 55 dB(A), and that more than 30 % is exposed to levels exceeding 55 dB(A) during the night.

Global warming

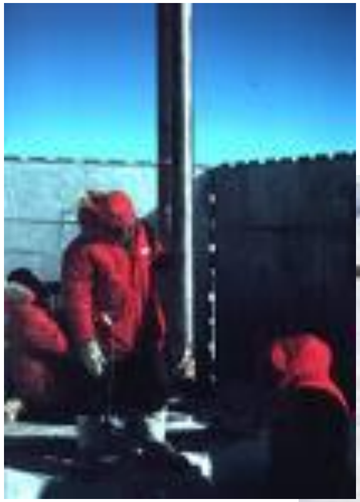
From the slides by Filippo Giorgi, Abdus Salam ICTP, Trieste, Ciamician School on Energy, Trieste, 2017

- **Is global warming happening?**
- **(If yes) Is global warming due to human activities?**

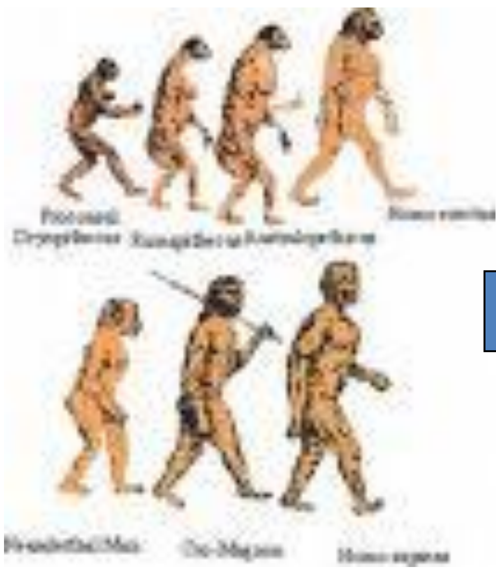
Glacial and interglacial periods have happened at regular intervals due to small variations of the Earth's orbit



Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3June), pp 429-436, 19



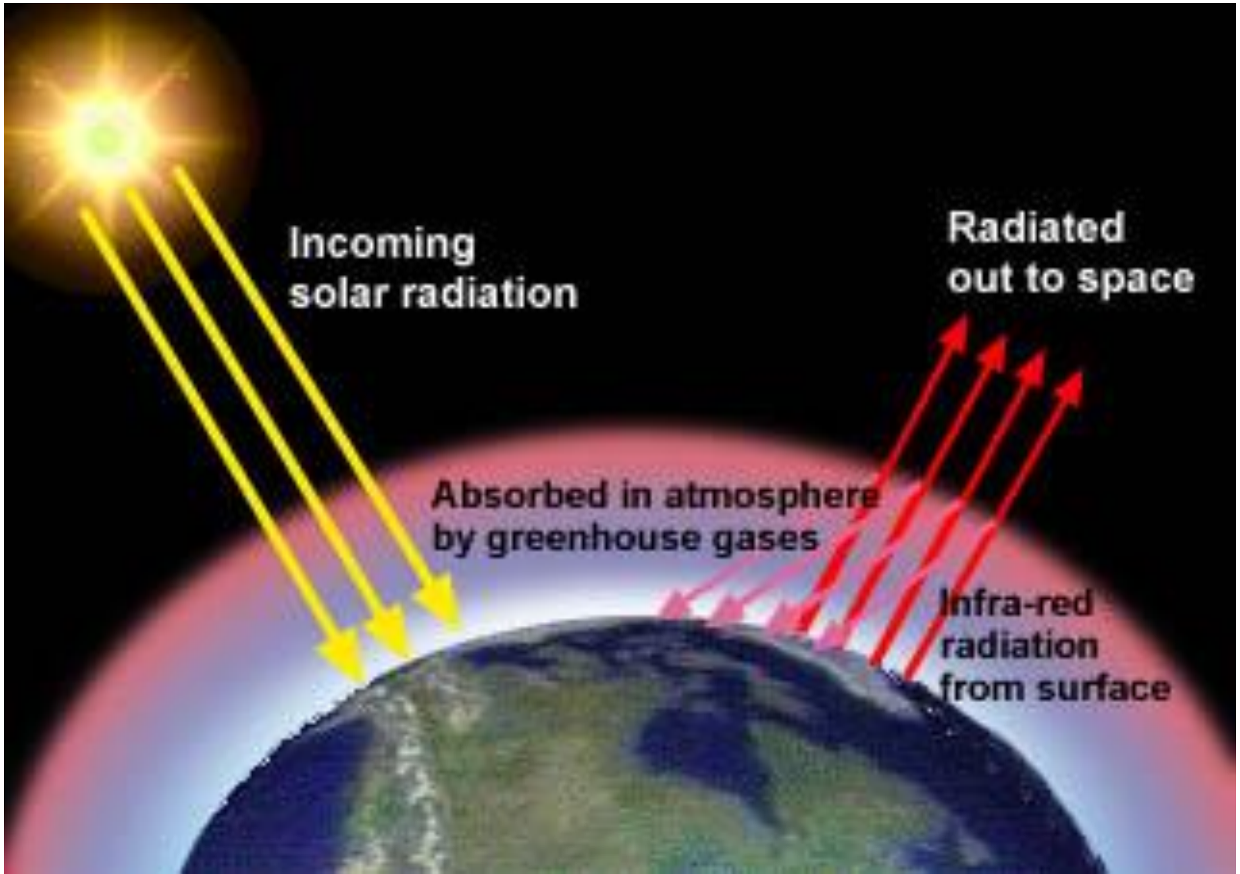
Since the beginning of the industrial era ("Anthropocene") humans have injected into the atmosphere many types of pollutants

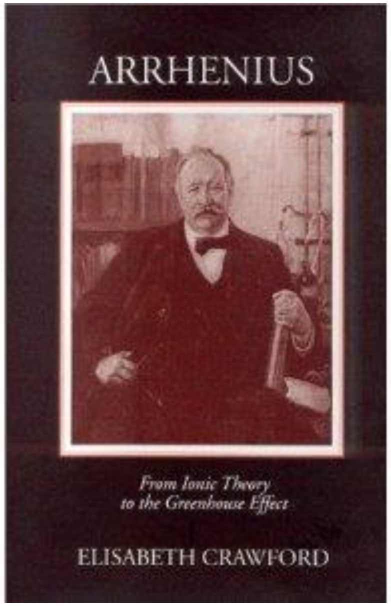


The Greenhouse Effect

Greenhouse gases (GHG) absorb the infrared radiation emitted by the surface of the Earth and re-emit it in all directions (including downwards) thereby warming the atmosphere and oceans

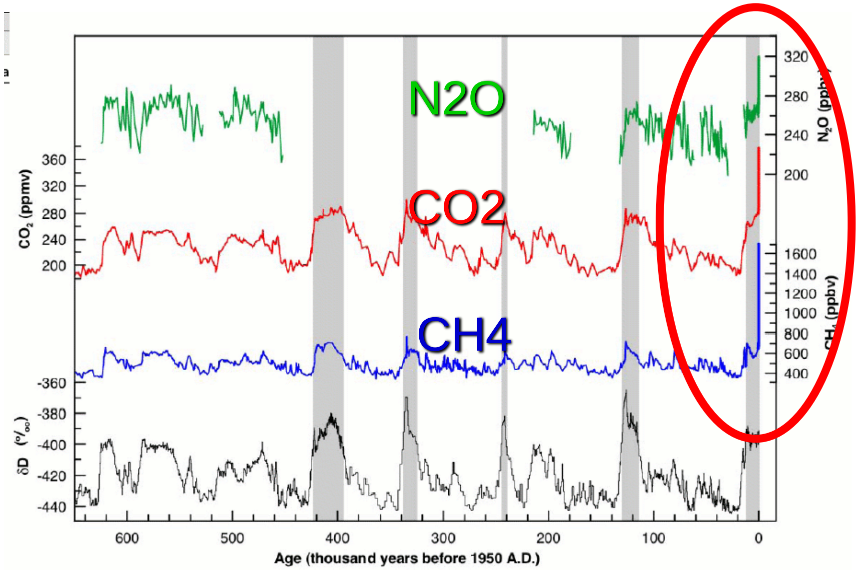
The main GHGs are H_2O, CO_2, O_3, CH_4, N_2O, CFCs

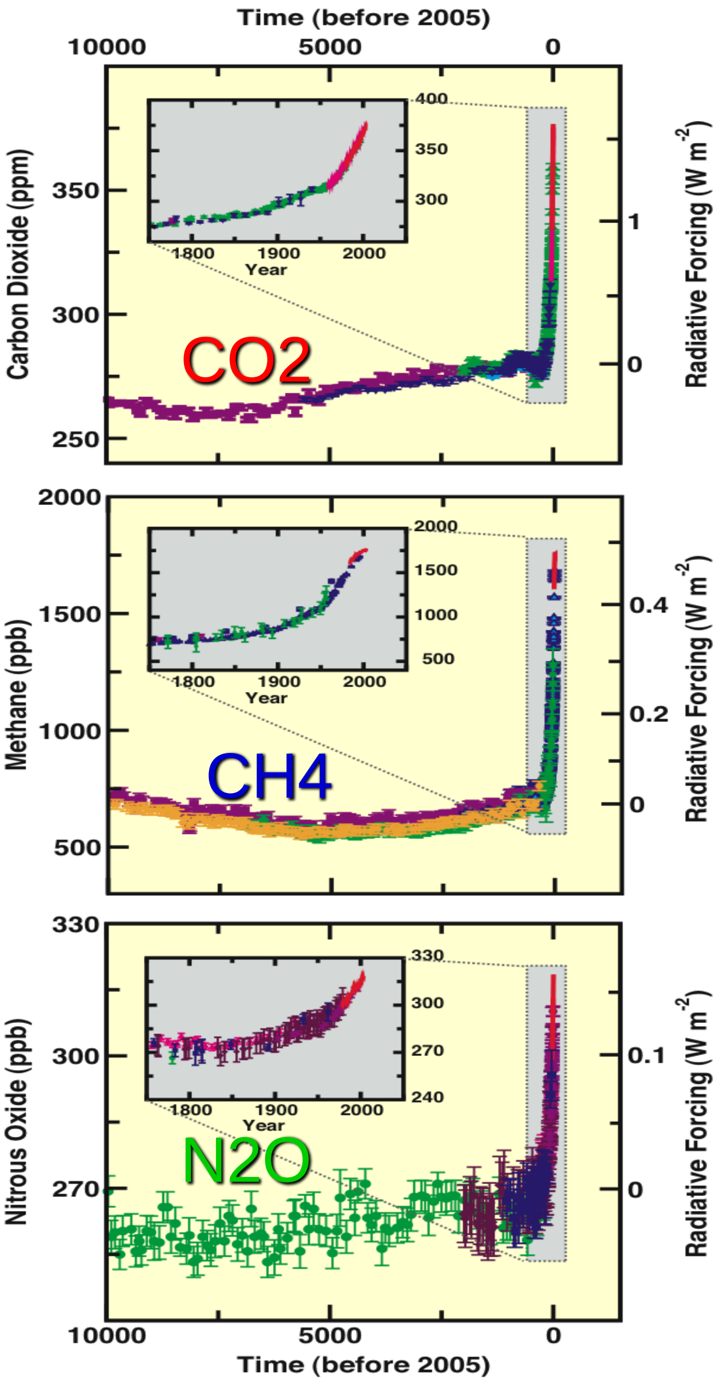




The greenhouse gas concentration in the atmosphere is sharply increasing

The isotopic composition of CO2 and the ratio of oxygen to nitrogen confirm that the increase in CO2 is mostly from fossil fuel burning





Question 1: Is global warming happening?

- Evidence 1: The global temperature of the Earth's surface has increased by about 0.9 degrees in the last 100 years
- Evidence 2: Melting of glaciers and snow
- Evidence 3: Melting of the arctic ice
- Evidence 4: Sea level rise
- Evidence 5: Heat absorption by the oceans

Answer to question 1 Global warming is unequivocal (IPCC 2007/13)

(If yes) Is global warming due to human activities?

The earth's climate can change because of anthropogenic or natural factors

Human factors

- Greenhouse gases
- Atmospheric aerosols
- Land-use change

Natural factors

- Volcanic activity
- Variations of solar radiations
- Natural variability (ENSO, NAO)

Recent evidence on average temperature

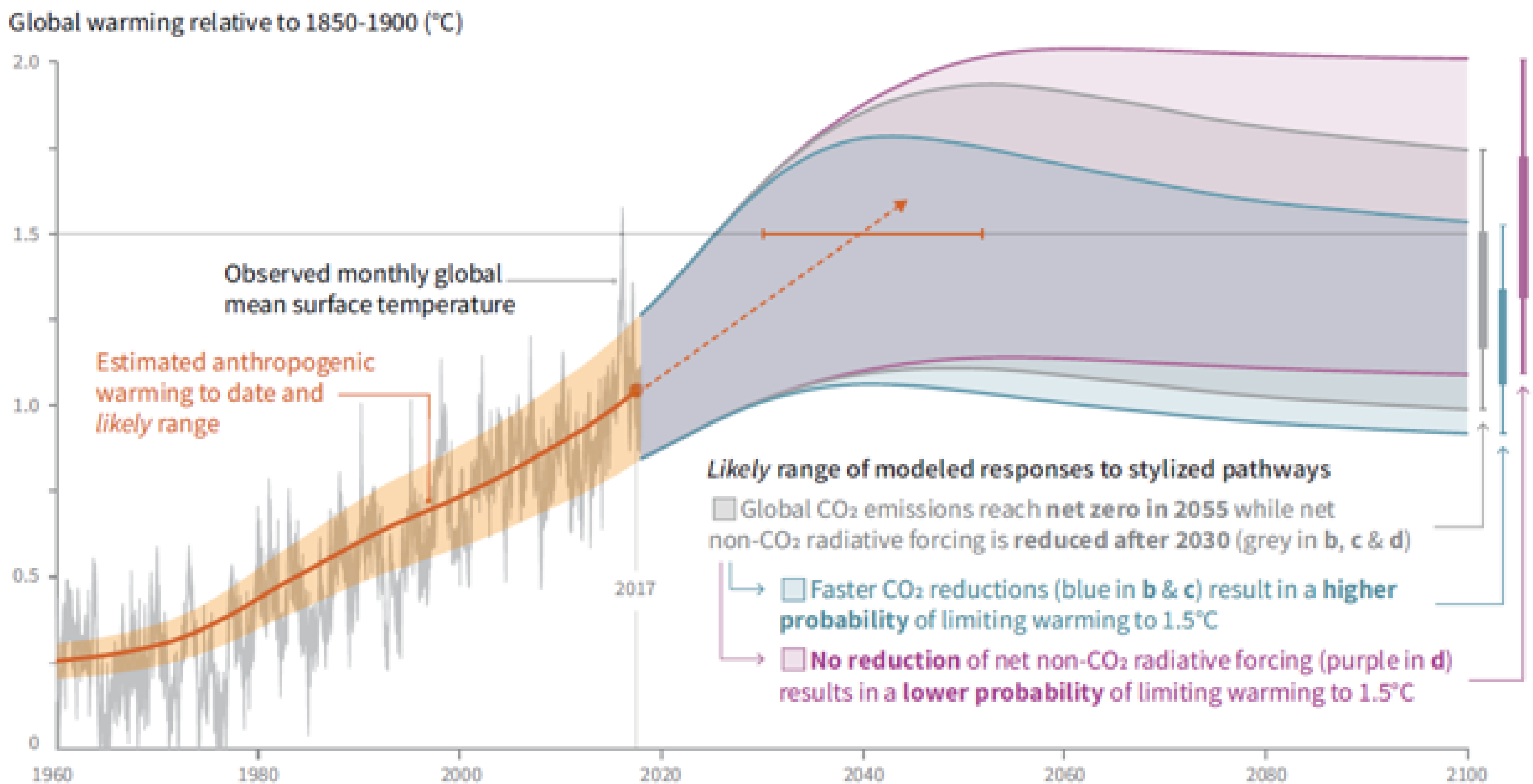
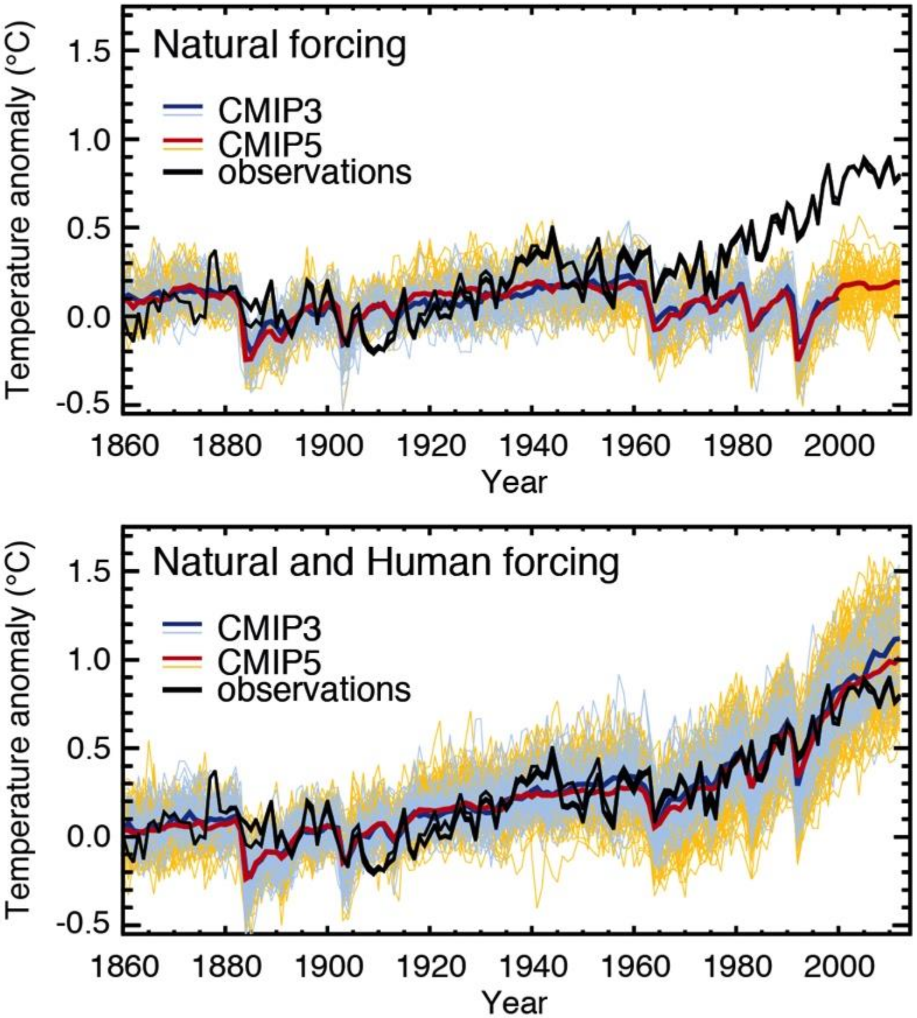
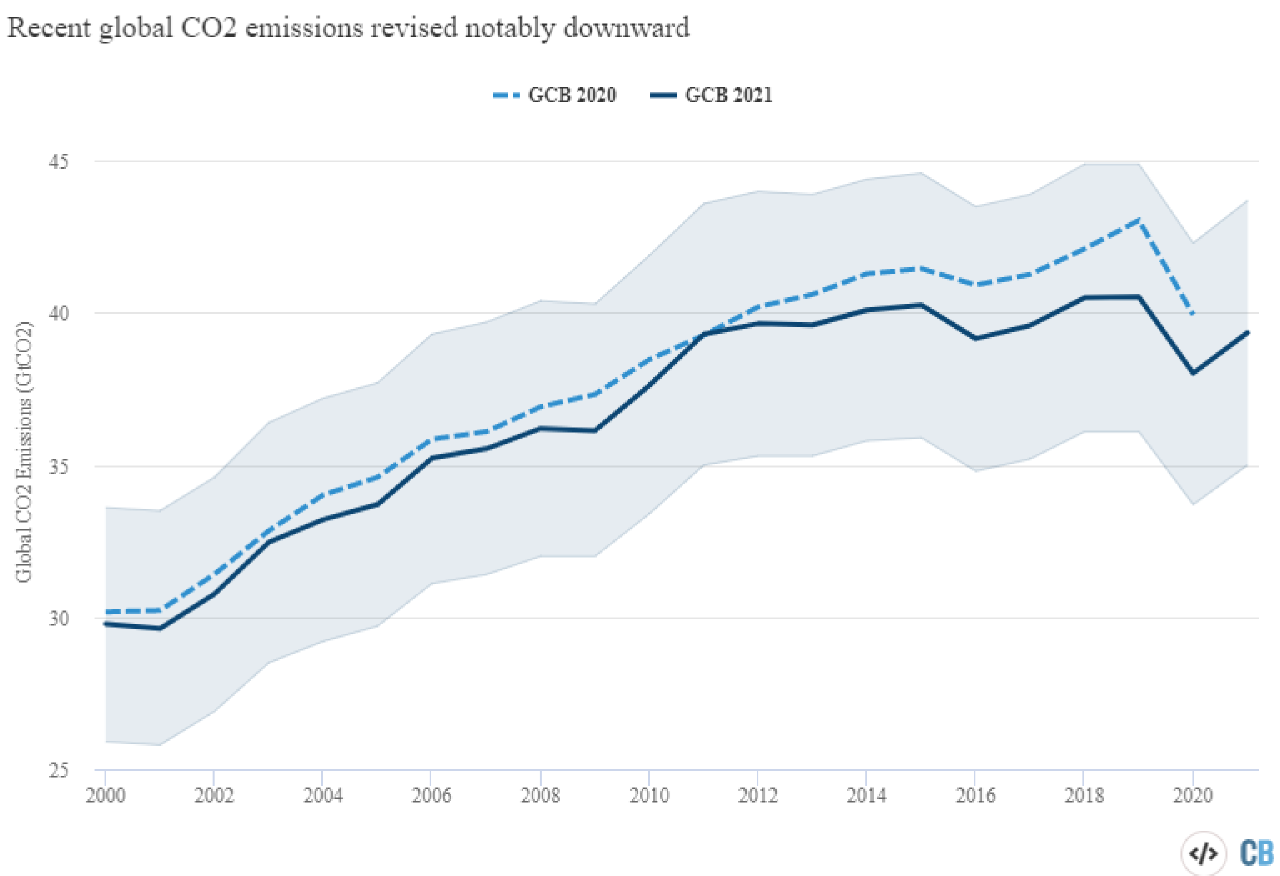


Figura 2 – Andamento della temperature media mondiale rispetto ai livelli pre-industriali. Fonte: IPCC – Summary for the policy makers https://www.ipcc.ch/sr15/

Many studies have shown that most of the warming since the mid 20th century is due to the increase in greenhouse gases of anthropogenic origin (>95%, IPCC 2013)



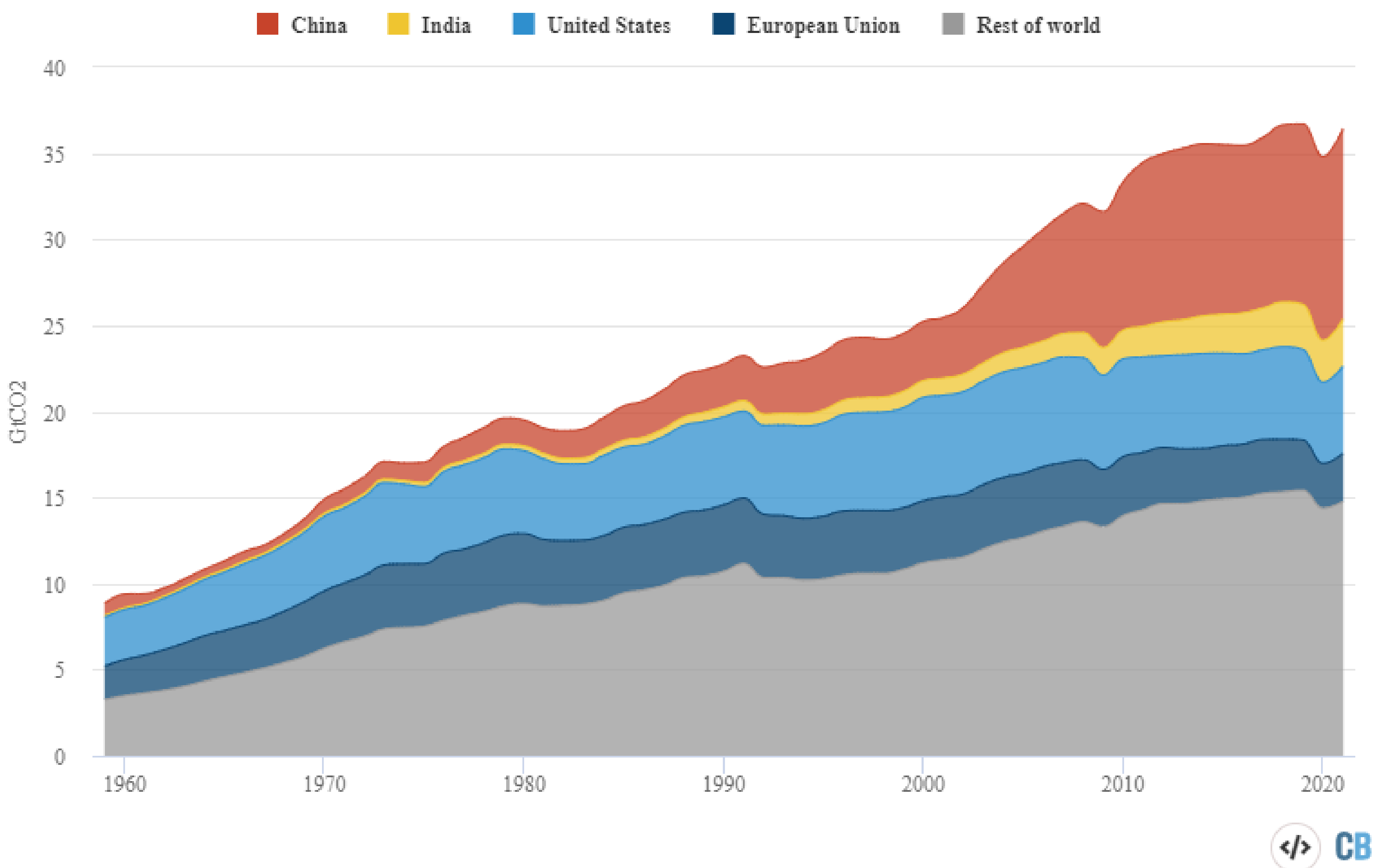
Recent evidence on annual CO2 emissions



Annual total global CO2 emissions – from fossil and land-use change – between 2000 and 2021 for both the 2020 and 2021 versions of the Global Carbon Project's Global Carbon Budget. Shaded area shows the estimated one-sigma uncertainty for the 2021 budget. Data from the Global Carbon Project; chart by Carbon Brief using Highcharts.

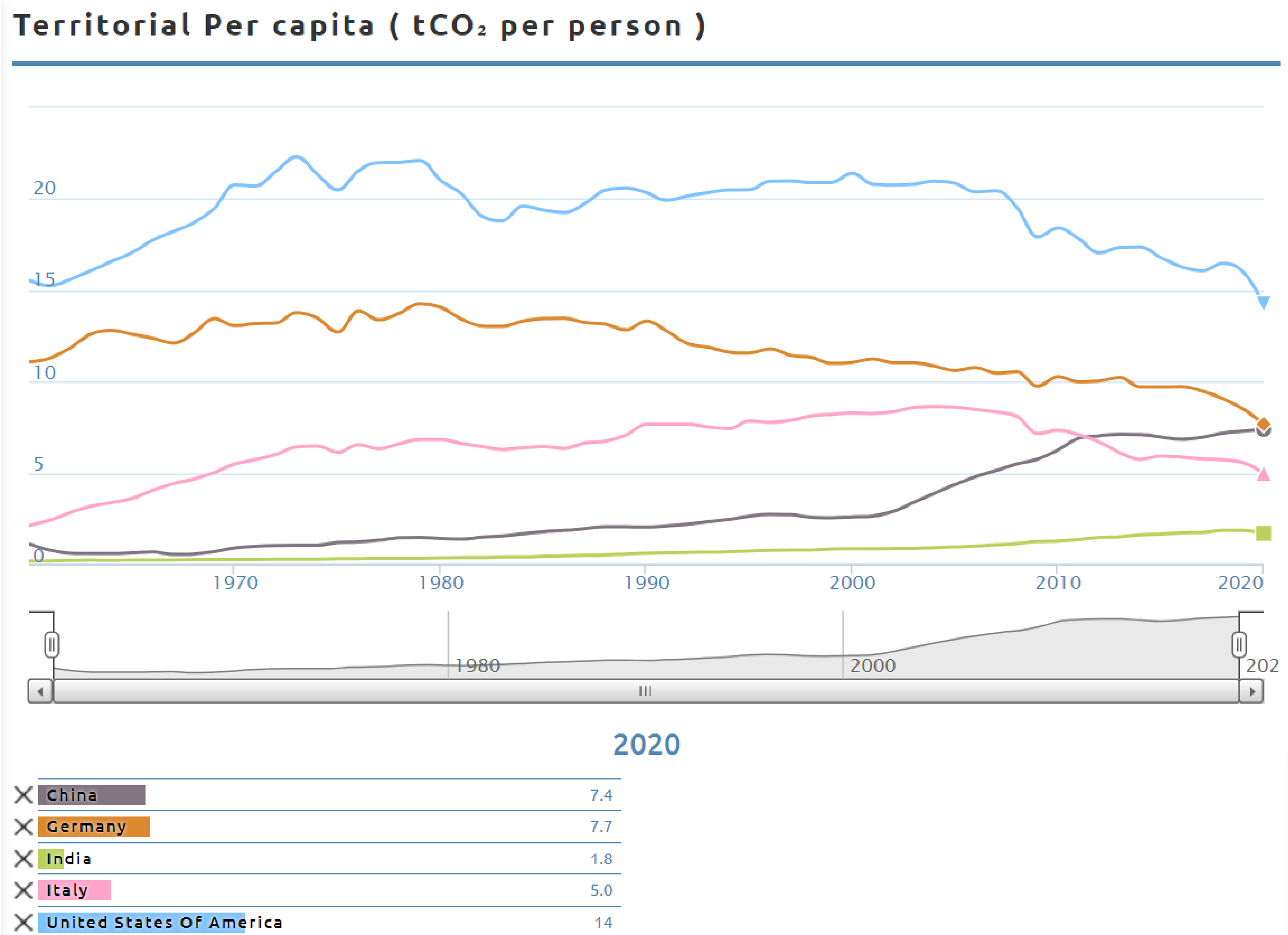
https://www.carbonbrief.org/global-co2-emissions-have-been-flat-for-a-decade-new-data-reveals

Global CO2 emissions from fossil fuels by region, 1959-2021



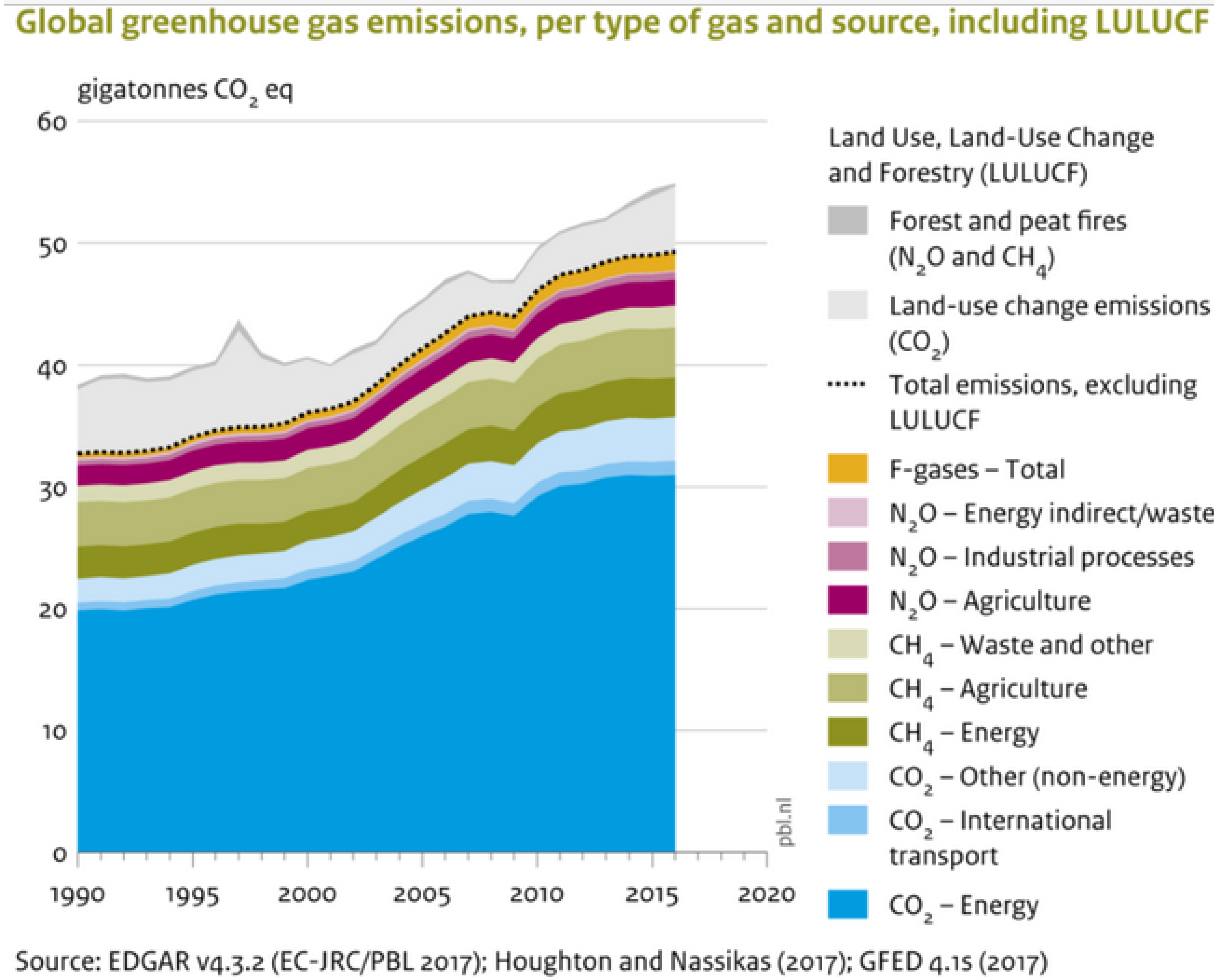
Annual fossil CO2 emissions by major country and rest of world from 1959-2021, in billions of tonnes of CO2 per year (GtCO2). Note that 2021 numbers are preliminary estimates. Data from the Global Carbon Project; chart by Carbon Brief using Highcharts.

https://www.carbonbrief.org/global-co2-emissions-have-been-flat-for-a-decade-new-data-reveals



http://www.globalcarbonatlas.org/en/CO2-emissions

Global Greenhouse Gas Emissions Levels

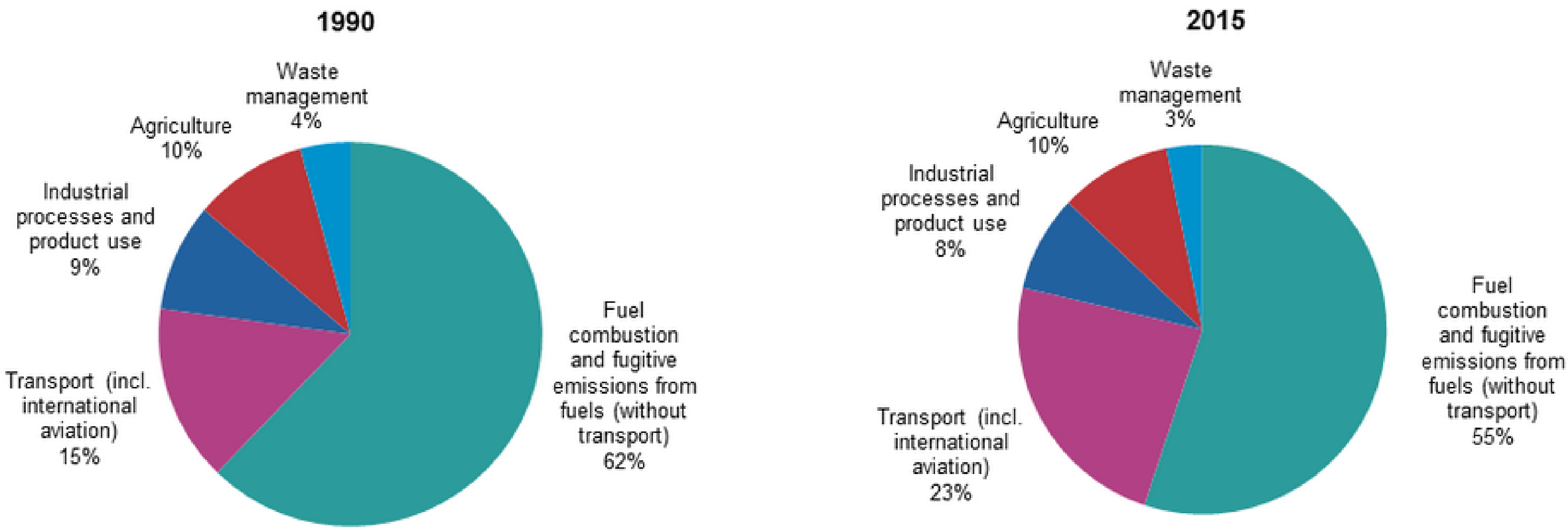


Transport activities account for 20% of the overall CO2 emissions

New figures from the PBL Netherlands Environmental Assessment Agency have confirmed global greenhouse gas emissions levels continued to increase in 2016, albeit at a relatively slow rate, reaching 49.3 Gigatonnes in CO_2 equivalent.

Transport is responsable for about 25% of CO2 emissions

Greenhouse gas emission statistics EU28: Fonte: Eurostat

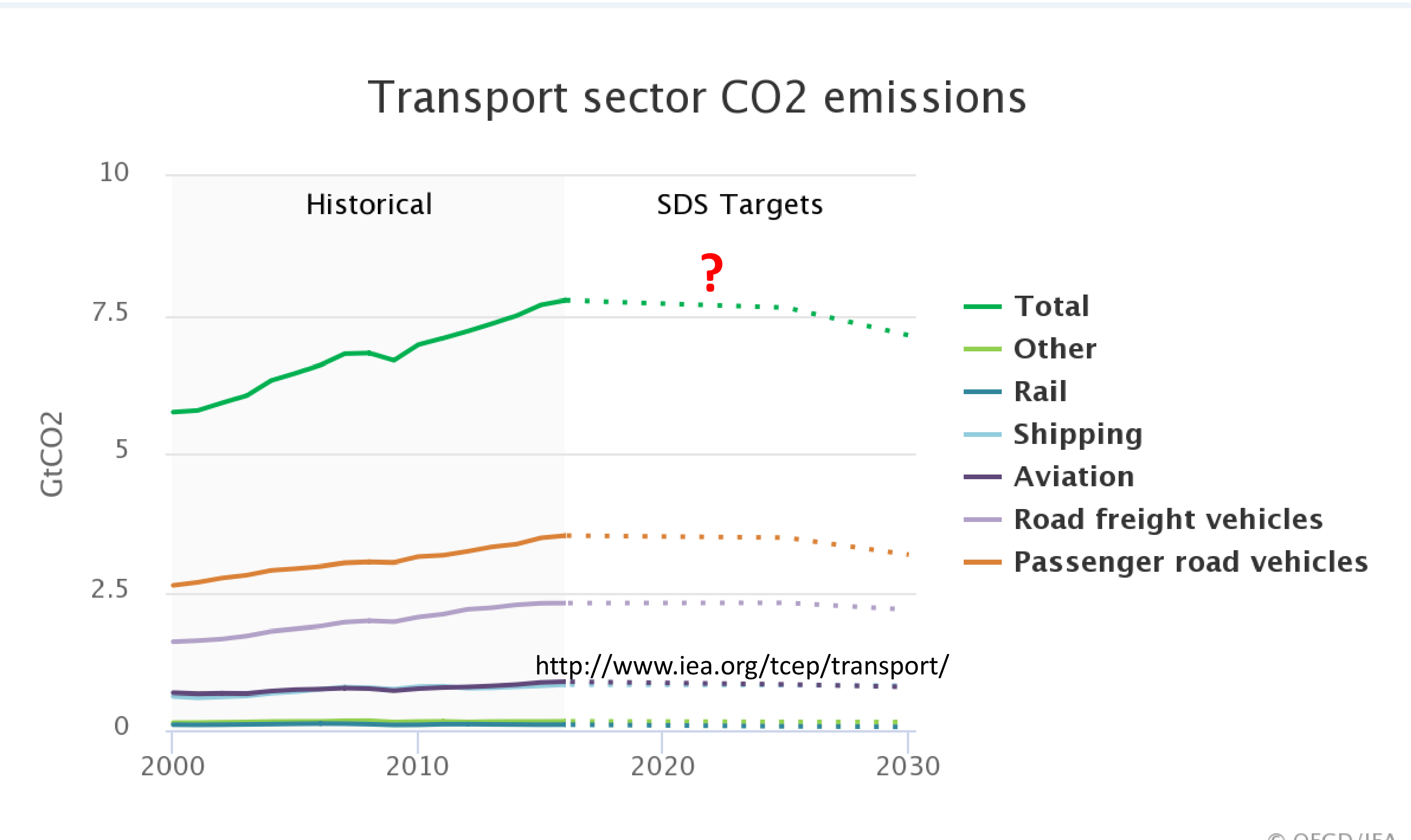


http://ec.europa.eu/eurostat/statistics-explained/index.php/Greenhouse_gas_emission_statistics

International Energy Agency, May 2018

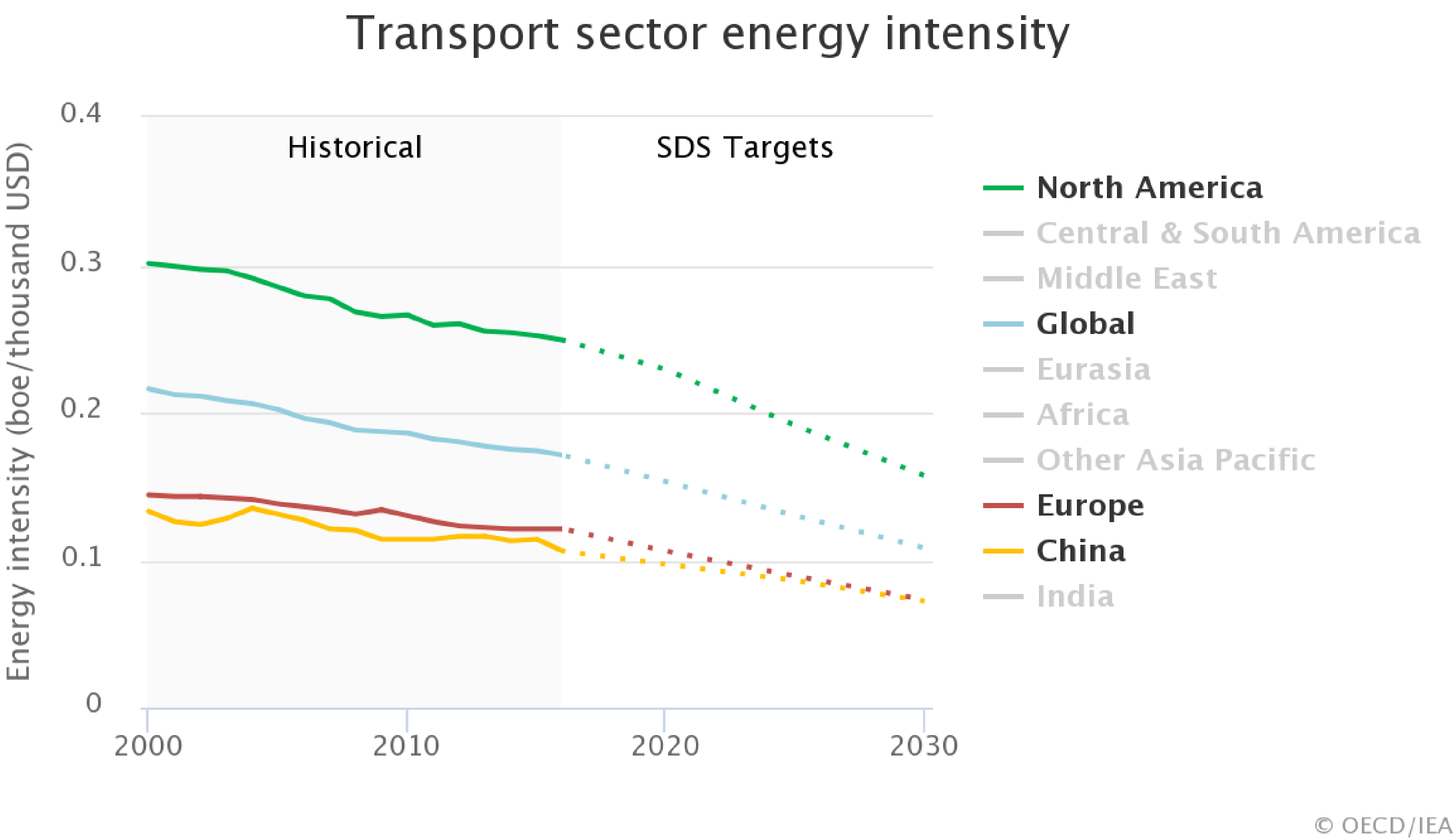
- Transportation was responsible for 24% of direct CO_2 emissions in 2017.
- Road vehicles – cars, trucks, buses and two-wheelers – accounted for 77% of both global final energy demand and CO_2 emissions attributable to the transport sector as a whole.
- Car buyers continue to choose bigger, heavier vehicles, not only in the United States but increasingly in Europe and Asia too.
- In Europe, this has led to a rise in the average new car CO_2 emissions in 2017.

Transport sector CO_2 emissions. Emissions from transport need to peak around 2020 to meet the Sustainable Development Strategy (SDS) goals. Will they?



The energy intensity has declined

Energy intensity will need to improve more than twice as fast as it has since the year 2000 to meet SDS goals by 2030.



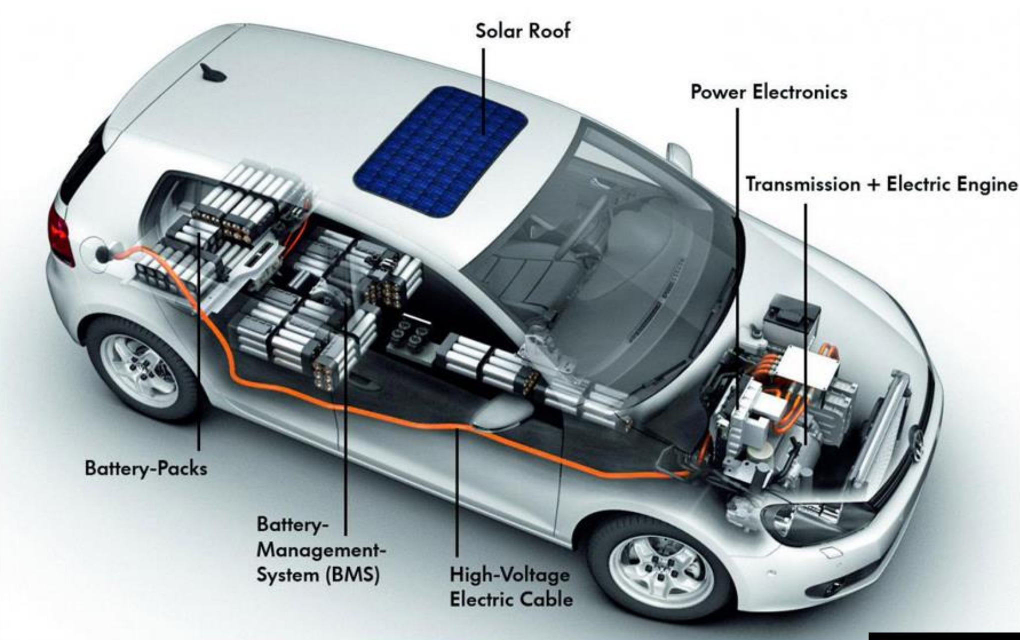
http://www.iea.org/tcep/transport/

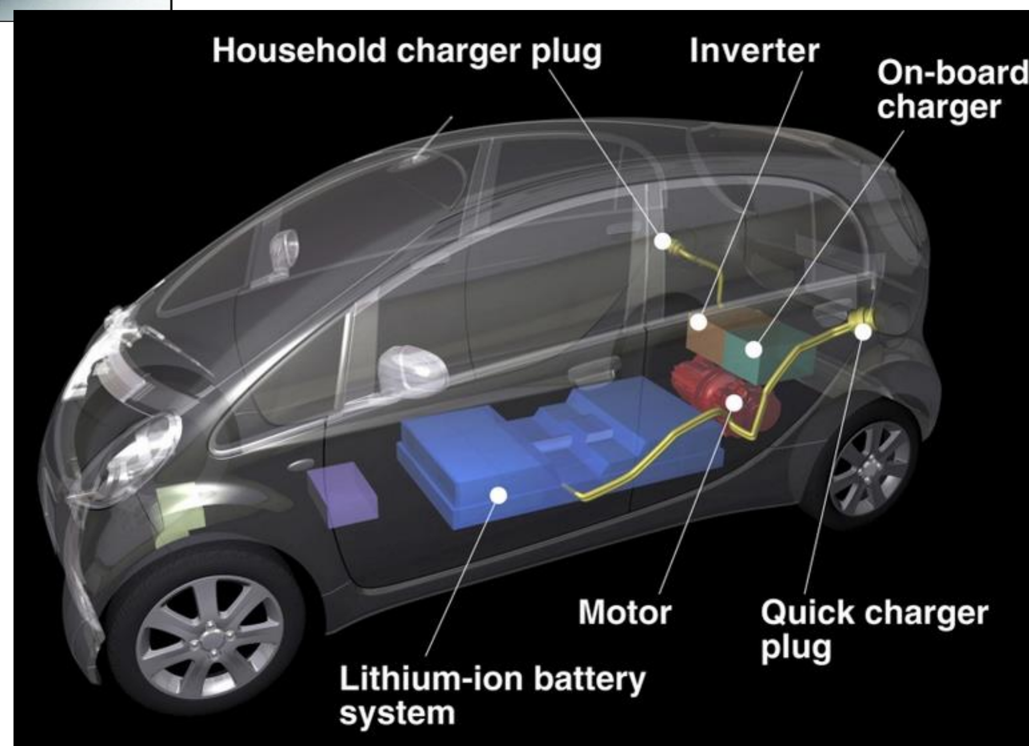
Decarbonising transport: electric vehicles and renewable energy sources

The electric car: 4 research questions

1. The electric car: a better balance between mobility and the environmental sustainability?
2. Is there the market for electric cars and how big is it? Will EVs substitute ICEVs? At which rate? Which EVs (BEVs or PhEVs or HEVs)?
3. What are the industrial implications? (new firms, new countries, new industries, new business models)
4. What are the main determinants? (technology, policies, consumers, science)

The Electric Car


Solar Roof
Power Electronics
Transmission + Electric Engine
Battery-Packs
Battery-
Management-
System (BMS)
High-Voltage
Electric Cable


Household charger plug
Inverter
On-board
charger
Motor
Quick charger
plug
Lithium-ion battery
system

The models

Renault

Tesla Motor and Smart


ZERO



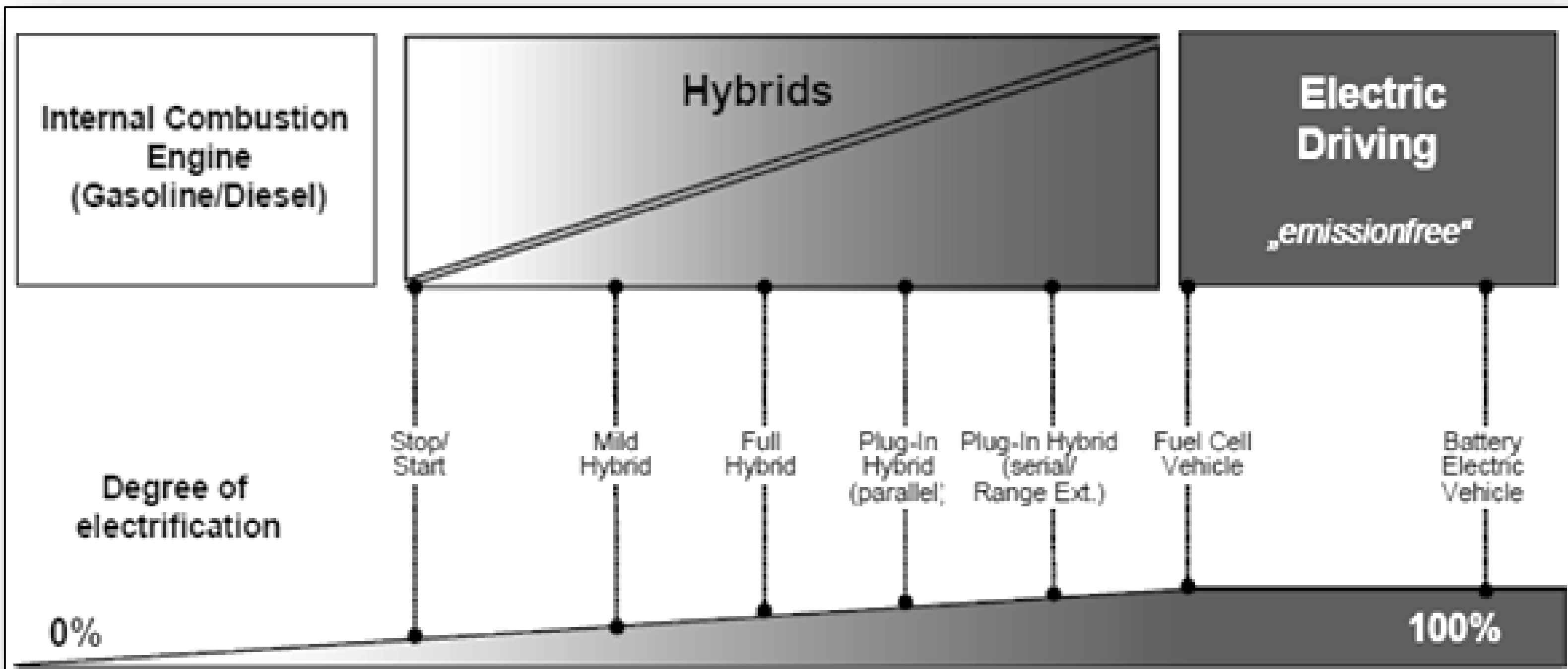
MiEV





FLUENCE

New vehicles: hybrids, plug-in hybrids, electric, hydrogen



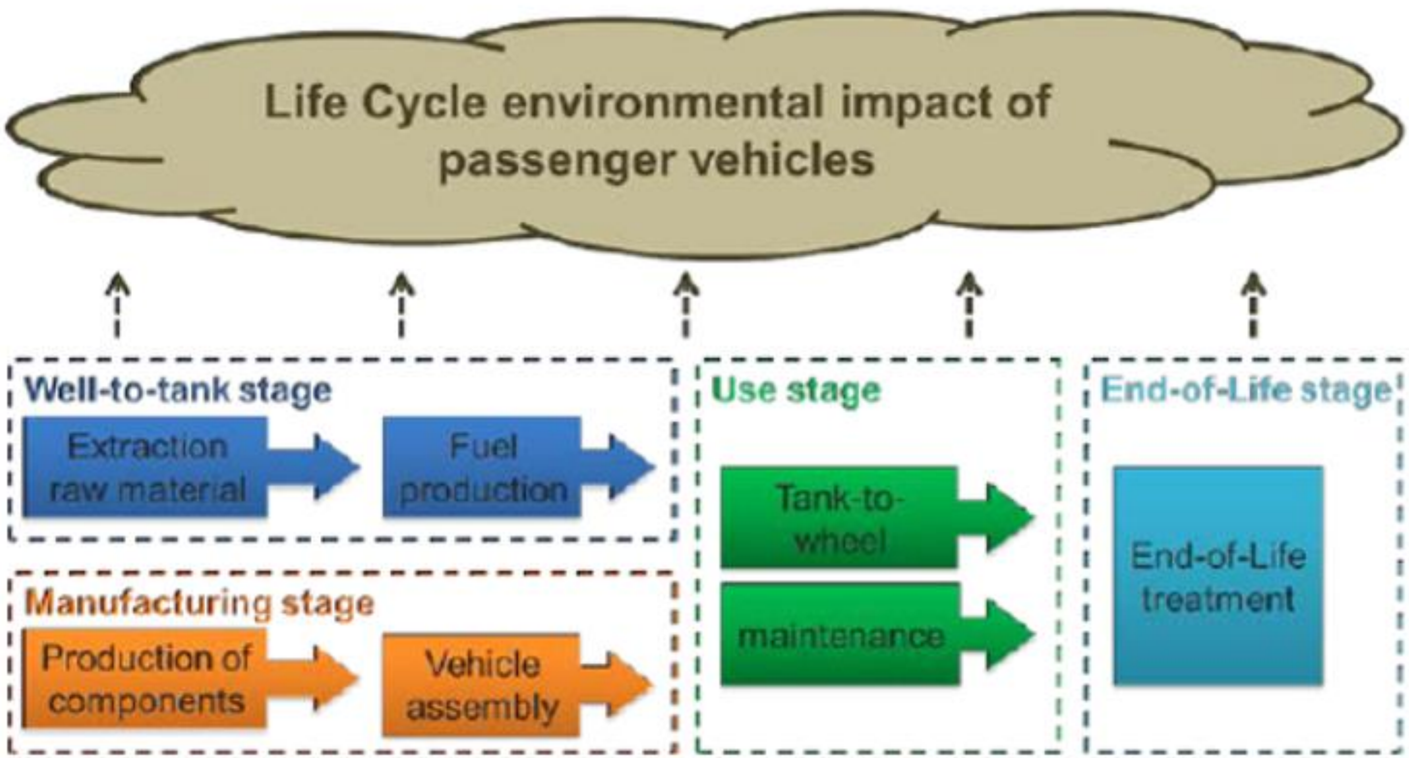
Q1: The electric car: a better balance between mobility and the enviornment?

Caveats:

- **Many models and sizes (citiy cars, sedans, SUVs, luxus cars,..).**
- **Many technologies (ICEV, HEV, PHEV, BEV, …LNG, Methane).**
- **Many electricity mixes (carbon, RES): average or region specific mix?**
- **Many climates (e.g., California, Norway)**
- **Many topologies and geographies (population density, location of electric plants)**

Life cyle analysis: consensus and caveats

Figure 1. Schematic representation of the different life cycle stages of a vehicle.



Key determinants of energy and environmental efficiency

- The efficiency of the vehicle
- The efficiency in electricity production
- The efficiency in gasoline production
- The drive cycles (urban, interurban)

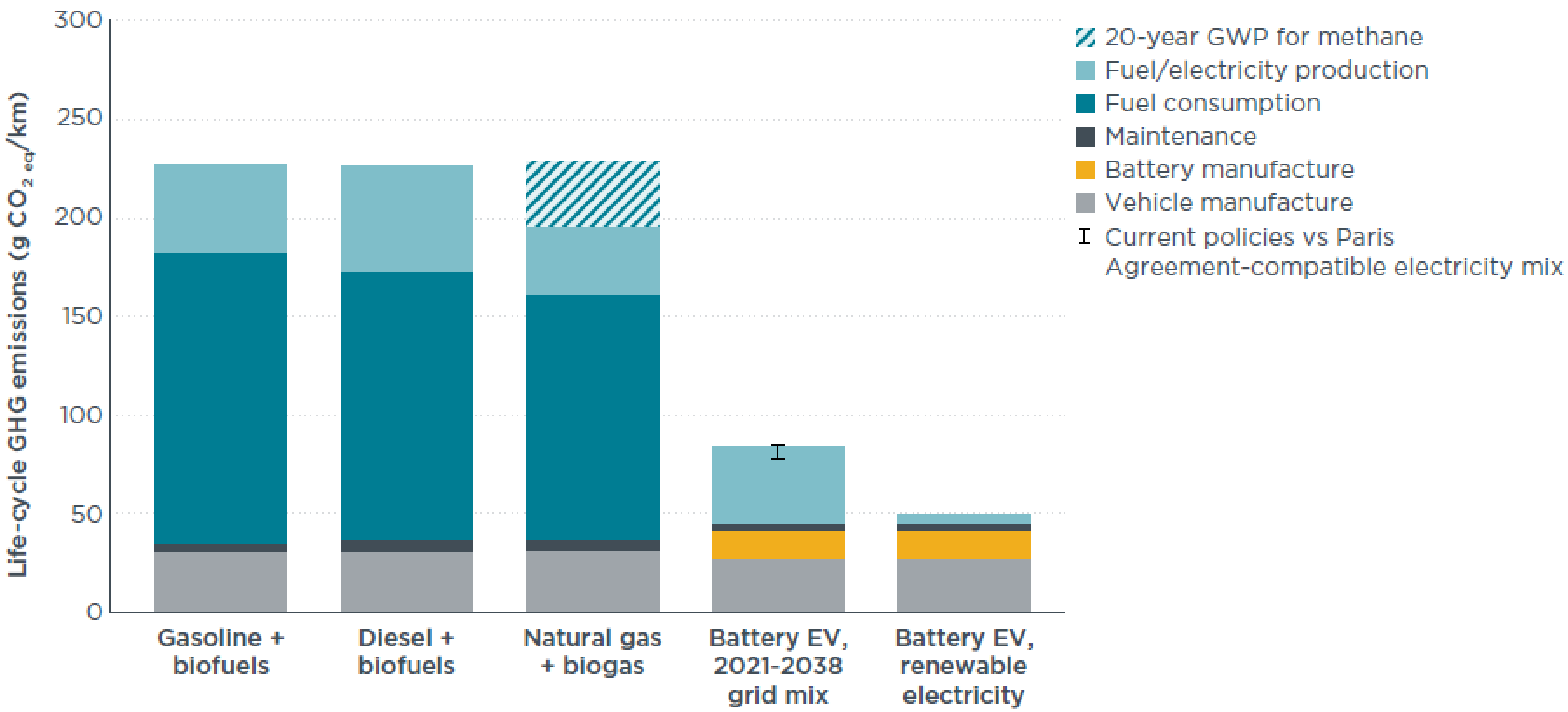


Figure 3.1. Life-cycle GHG emissions of small segment gasoline, diesel, and CNG ICEVs and BEVs registered in Europe in 2021.

BEVs have 63%–69% lower life-cycle GHG emissions than gasoline cars

The life-cycle GHG emissions of average BEVs registered in 2021 are estimated to be 77–84 g $CO_{2\,eq.}$/km for small, 76–83 g $CO_{2\,eq.}$/km for lower medium, and 82–90 g $CO_{2\,eq.}$/km for SUV segment cars, depending on whether the electricity mix is projected to develop according to the IEA's STEPS (upper values) or the SDS (lower values). These values correspond to 63%–69% lower life-cycle GHG emissions than average gasoline cars.

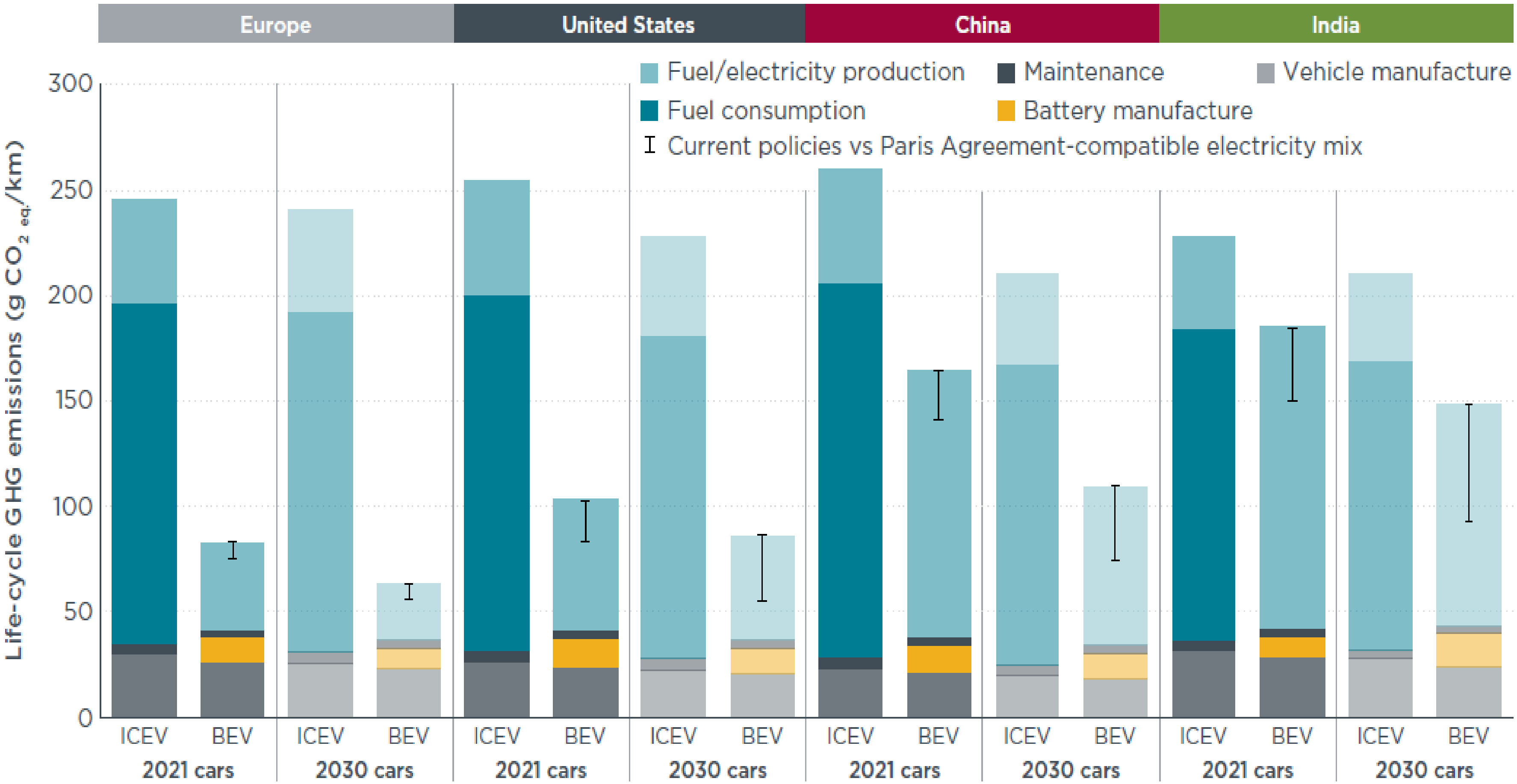


Figure ES.1. Life-cycle GHG emissions of average medium-size gasoline internal combustion engine (ICEVs) and battery electric vehicles (BEVs) registered in Europe, the United States, China, and India in 2021 and projected to be registered in 2030. The error bars indicate the difference between the development of the electricity mix according to stated policies (the higher values) and what is required to align with the Paris Agreement.

Fonte: ICCT – 2021 - A GLOBAL COMPARISON OF THE LIFE-CYCLE GREENHOUSE GAS EMISSIONS OF COMBUSTION ENGINE AND ELECTRIC PASSENGER CARS

Georg Bieker

ICCT – International Council on Clean Transportation Europe

Only battery electric and hydrogen fuel cell electric vehicles have the potential to achieve the magnitude of life-cycle GHG emissions reductions needed to meet Paris Agreement goals.

As shown for average new medium-size cars in Figure ES.1, the assessment finds that the life-cycle emissions over the lifetime of BEVs registered today **in Europe, the United States, China, and India are already lower than a comparable gasoline car by 66%–69% in Europe, 60%–68% in the United States, 37%–45% in China, and 19%–34% in India.**

For medium-size cars projected to be registered in 2030, as the electricity mix continues to decarbonize, the life-cycle emissions gap between BEVs and gasoline vehicles increases to 74%–77% in Europe, 62%–76% in the United States, 48%–64% in China, and 30%–56% in India.

As indicated in the figure, *a large uncertainty lies in how the future electricity mix develops in each region*; the high ends of the error bars reflect more emissions when only considering currently existing and announced policies, and the low ends reflect the implementation of policies the International Energy Agency projects would be required for the power sector to align with Paris Agreement targets.

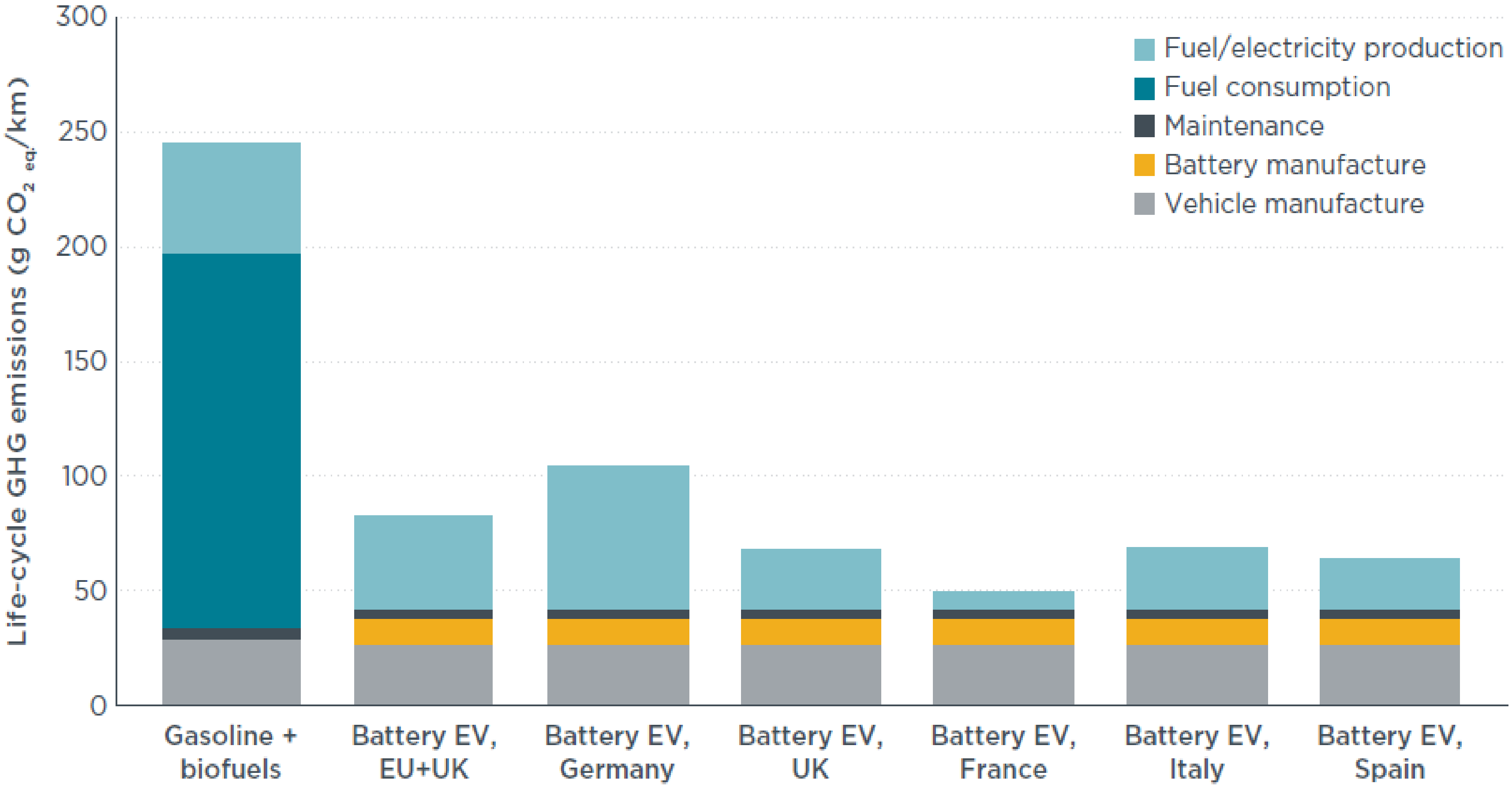
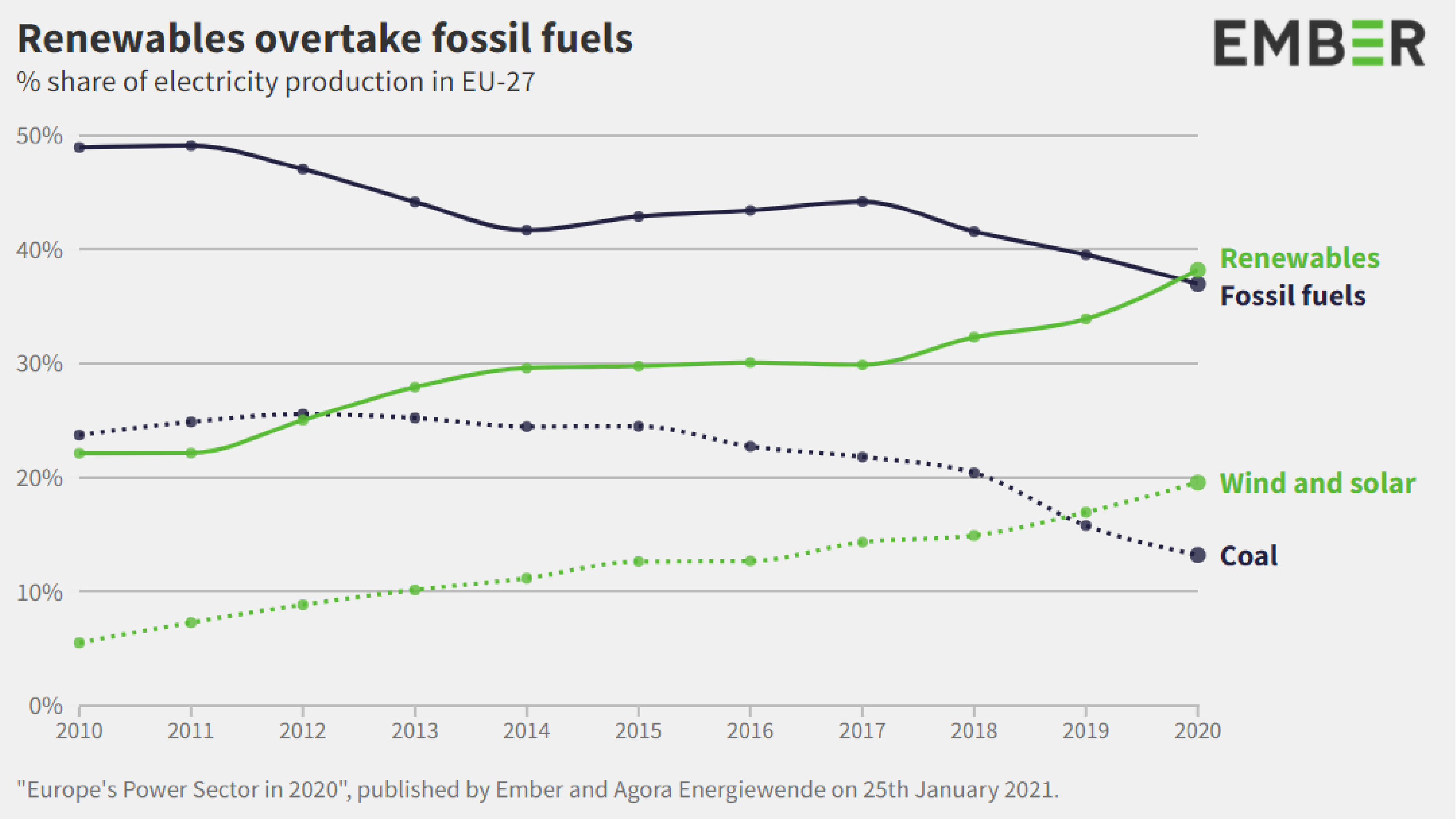


Figure 3.5. Life-cycle GHG emissions of lower medium segment BEVs registered in Europe in 2021, with the vehicle lifetime average electricity mix in the European Union and United Kingdom, Germany, United Kingdom, France, Italy and Spain, compared to gasoline ICEVs.

Europe..and the grid is getting cleaner



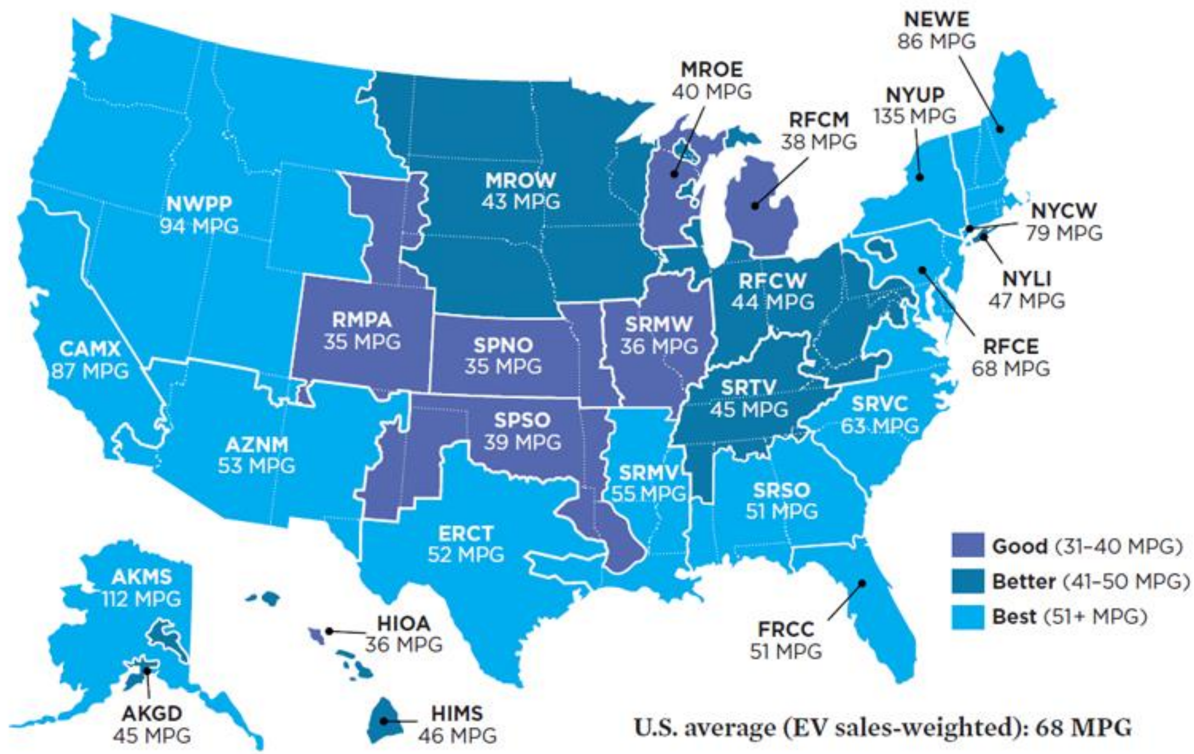
Renewables rose to generate 38% of Europe's electricity in 2020 (compared to 34.6% in 2019), for the first time overtaking fossil-fired generation, which fell to 37%. This is an important milestone in Europe's Clean Energy Transition. At a country level, Germany and Spain (and separately the UK) also achieved this milestone for the first time. The transition from coal to clean is, however, still too slow for reaching 55% greenhouse gas reductions by 2030 and climate neutrality by 2050.

https://ember-climate.org/project/eu-power-sector-2020/

USA: Life Cycle Electric Vehicle Emissions (2015) Union of Concerned Scientist

global warming emissions of electric cars on a *life cycle* basis—from the manufacturing of the vehicle's body and battery to its ultimate disposal and reuse

Electric Vehicle Global Warming Pollution Ratings and Gasoline Vehicle Emissions Equivalents by Region

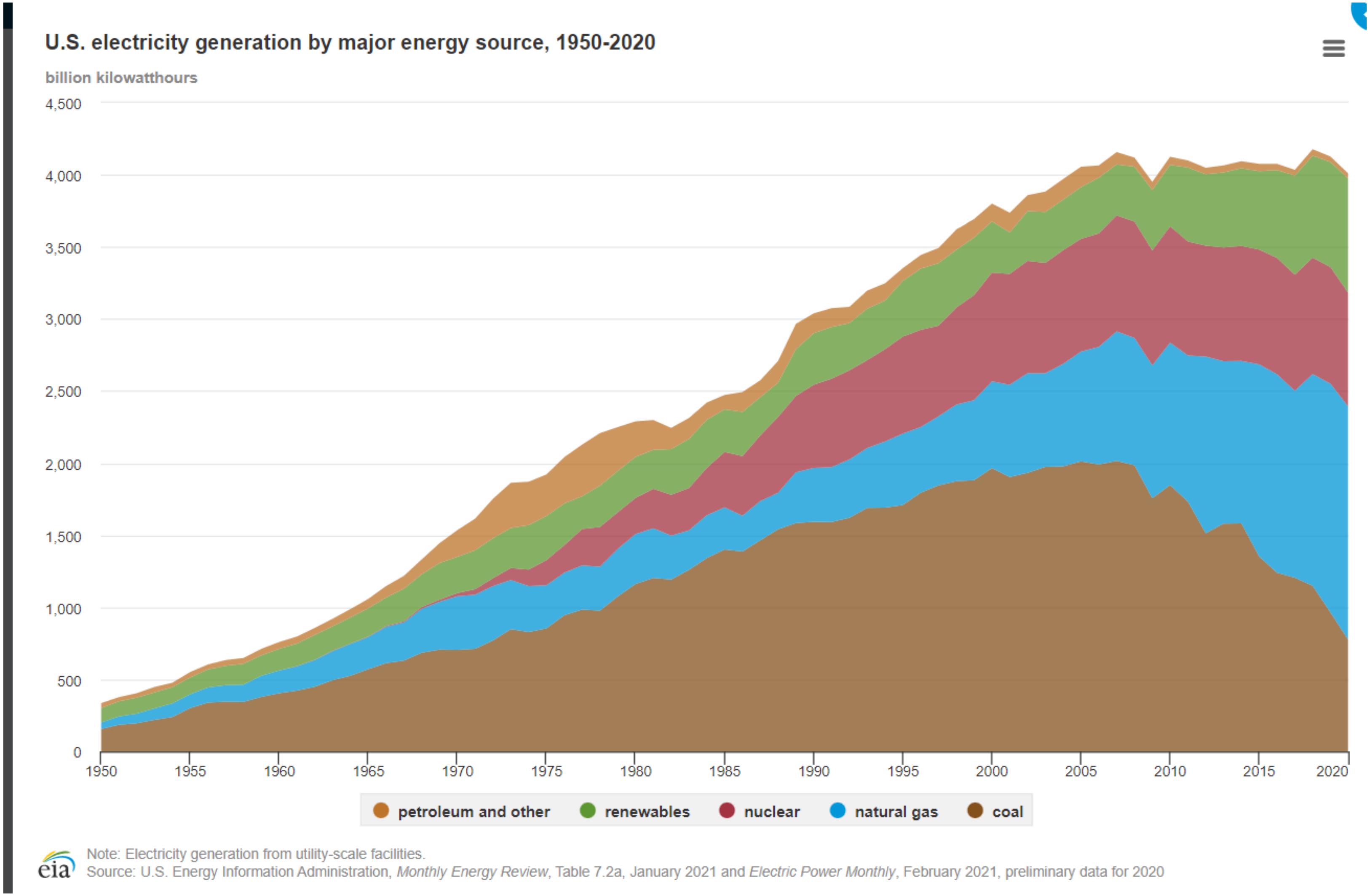


How many miles per gallon would a gas car have to achieve to produce global warming emissions equivalent to an EV? The answer depends on where you live. Numbers based on the EPA's eGRID 2015 database. Click to enlarge.

The fuel economy of new U.S. cars and trucks hit a record 24.7 miles per gallon in the 2016 model year, a government report said

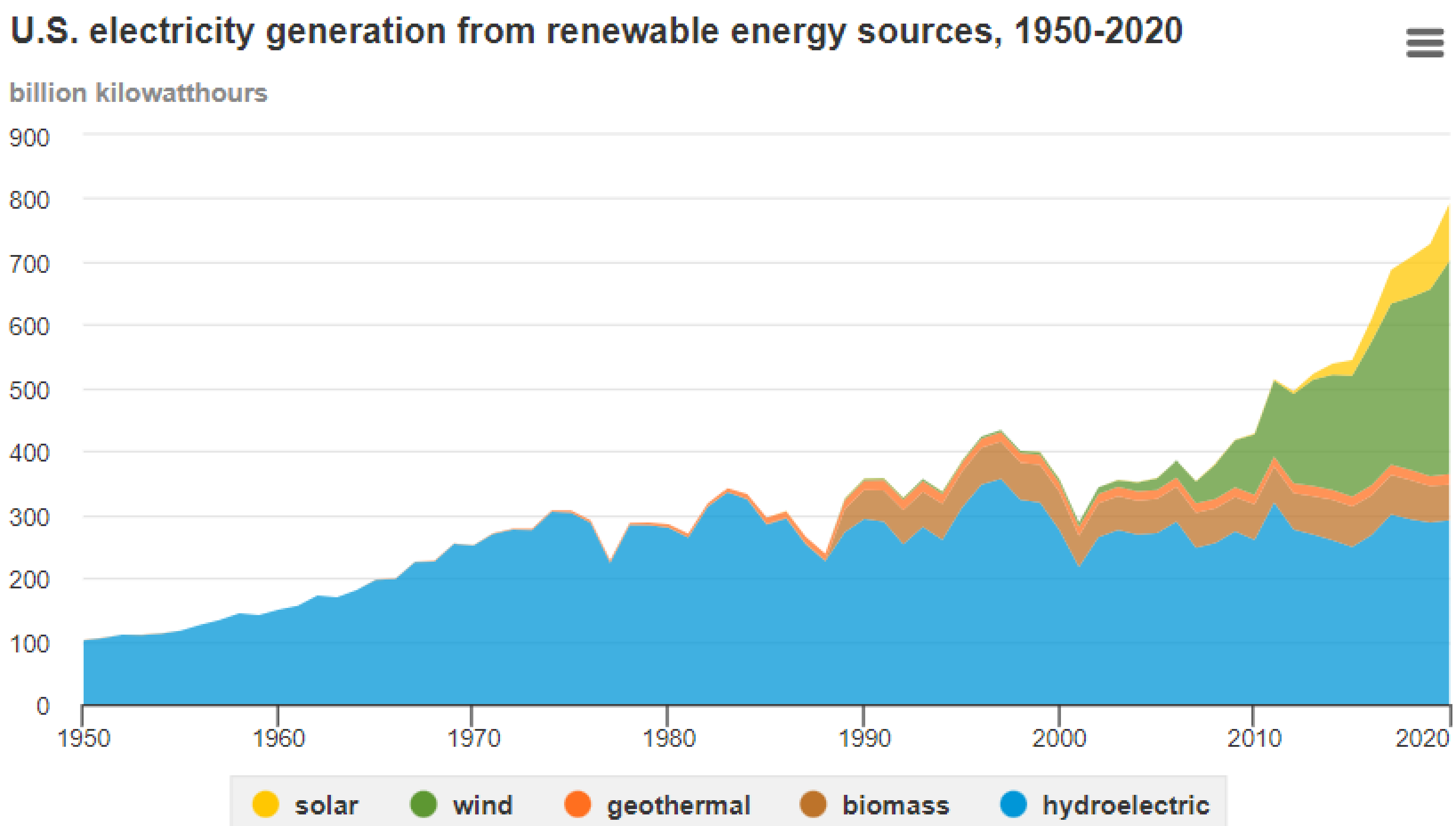
https://www.ucsusa.org/clean-vehicles/electric-vehicles/life-cycle-ev-emissions

USA …and the grid is getting cleaner



https://www.eia.gov/energyexplained/electricity/electricity-in-the-us.php

Especiallly wind..



Note: Electricity generation from utility-scale facilities. Hydroelectric is conventional hydropower.
Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 7.2a, January 2021 and *Electric Power Monthly*, February 2021, preliminary data for 2020

Personal conclusions

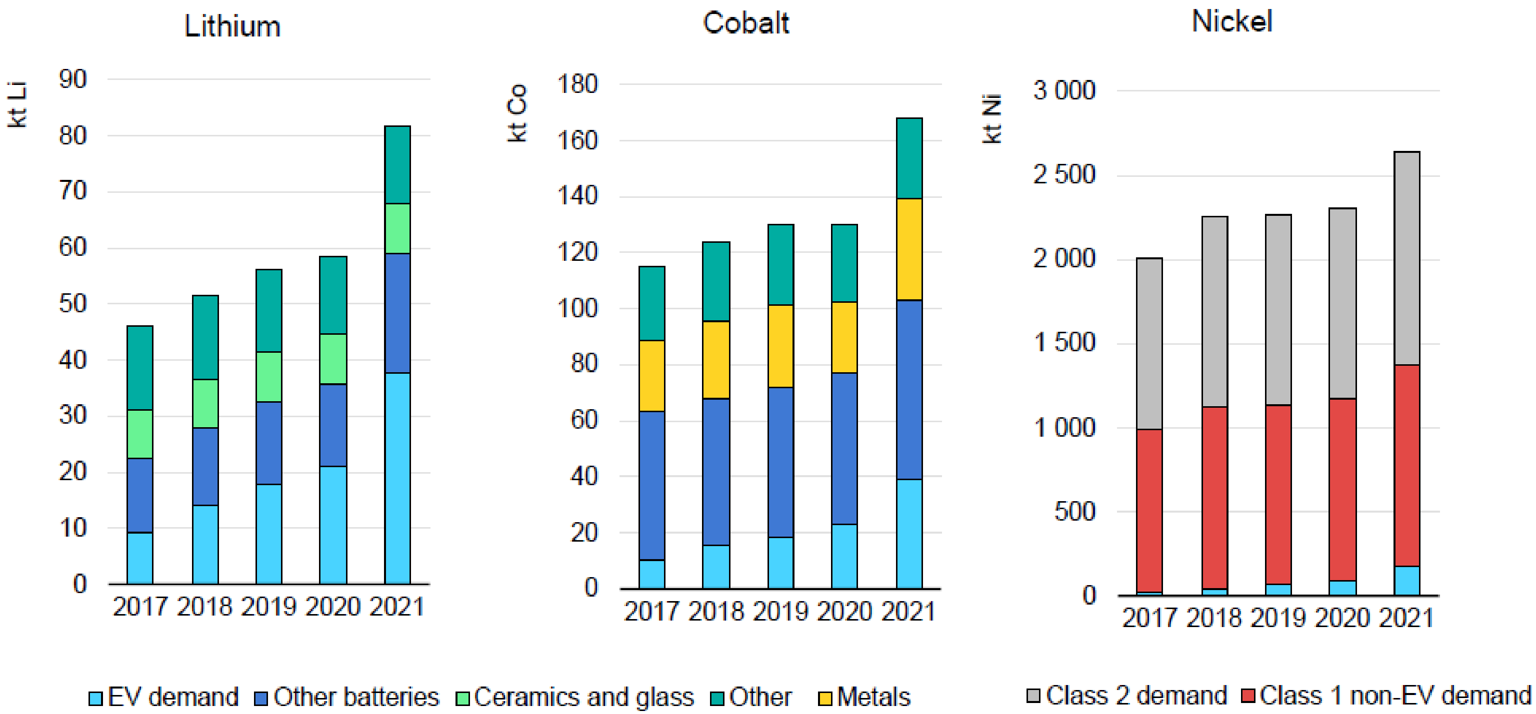
- EVs are better than ICEVs in terms of GHG if coupled with RES-based electricity production
  - The electricity mix is getting greener (USA, China)
- EVs transfer air pollution out of the urban areas
- EVs are less noisy
- Batteries should be re-used or recycled

What about cobalt mining by children?

- *Source: IEA – Global electric vehicle outlook - 2022*
- Cobalt
- Cobalt demand was 170 kt in 2021, of which the EV battery share was 24%, up from 18% in 2020. Cobalt is also used in superalloys, hard metals and catalysts. The cobalt intensity of Li-ion batteries has decreased significantly over recent years as battery makers moved
- to higher nickel content chemistries to achieve higher energy densities and lower costs (cobalt is the most expensive constituent per kg of Li-ion battery metal). The additional concerns of human rights abuses and child labour related to cobalt mining in the Democratic Republic of Congo (DRC) have also motivated battery makers to move away from cobalt-intensive chemistries.

EV batteries are the main demand driver for lithium demand, but their importance is also rapidly rising for cobalt and nickel

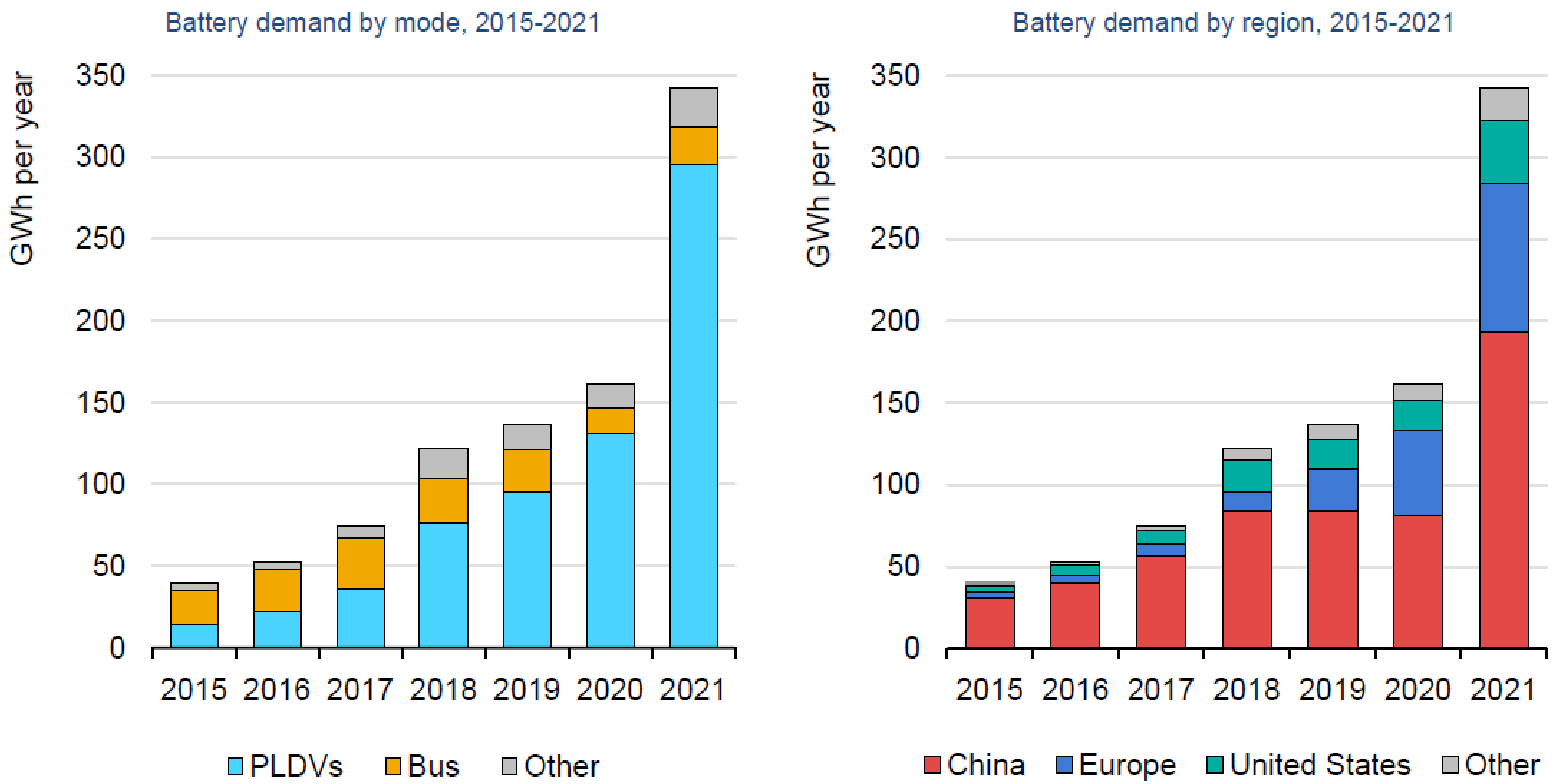
Battery metals demand, 2017 - 2021



Notes: Class 1 nickel (>99.8%) is suitable for use in batteries and Class 2 nickel (<99.8%) is not applicable for use in batteries without significant further processing. Other batteries includes: batteries for stationary storage and consumer electronics.

Sources: IEA analysis based on EV Volumes and S&P Global.

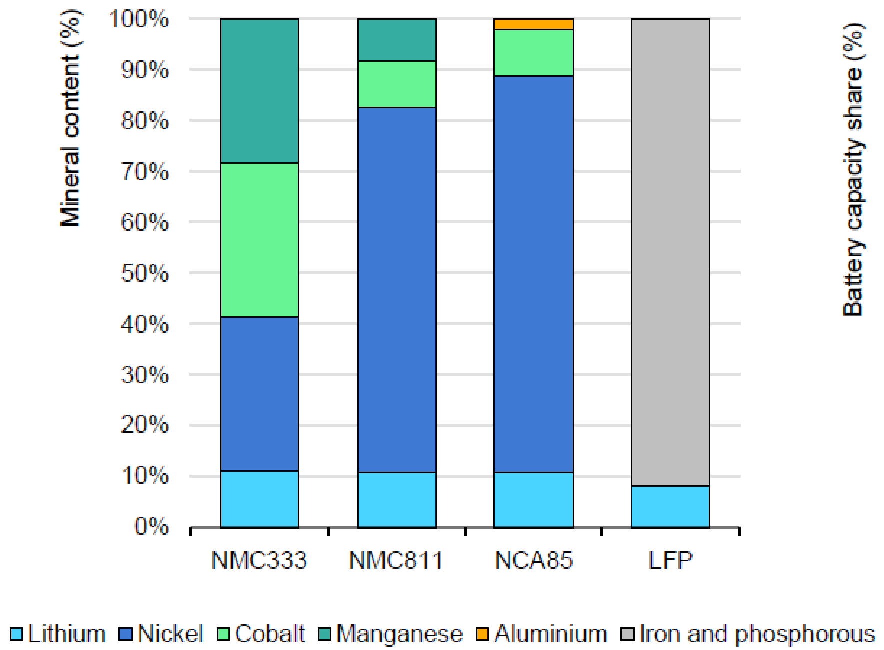
Global battery demand doubled in 2021, driven by electric car sales in China



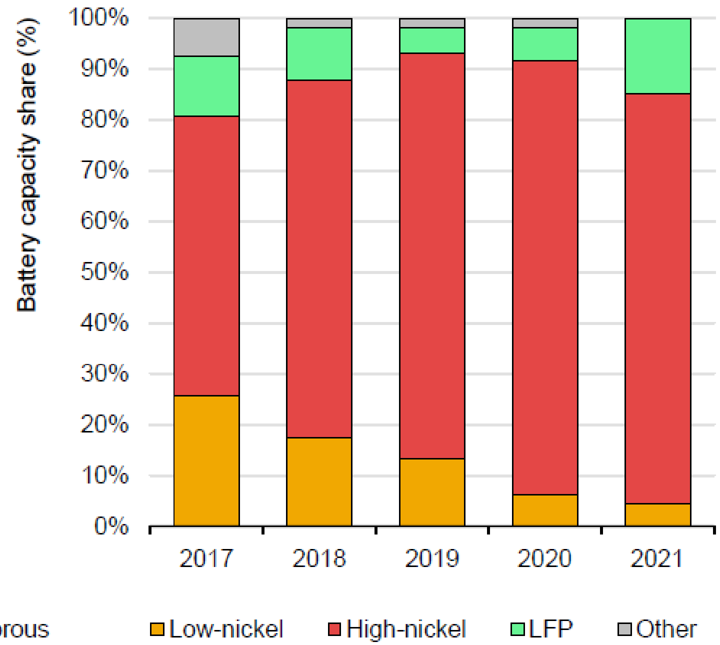
Notes: GWh = gigawatt-hours; PLDVs = passenger light-duty vehicles; other includes medium- and heavy-duty trucks and two/three-wheelers. This analysis does not include conventional hybrid vehicles.
Sources: IEA analysis based on EV Volumes.

High-nickel cathode battery chemistries remain dominant though lithium iron phosphate is making a comeback

Mineral composition of different battery cathodes



LDV EV cathode sales share, 2017-2021



Notes: LDV = light-duty vehicle; LFP = lithium iron phosphate; NMC = lithium nickel manganese cobalt oxide; NCA = lithium nickel cobalt aluminium oxide. Low-nickel includes: NMC333. High-nickel includes: NMC532, NMC622, NMC721, NMC811, NCA and NMCA. Cathode sales share is based on capacity.
Sources: IEA analysis based on EV Volumes.

Resurgence of LFP

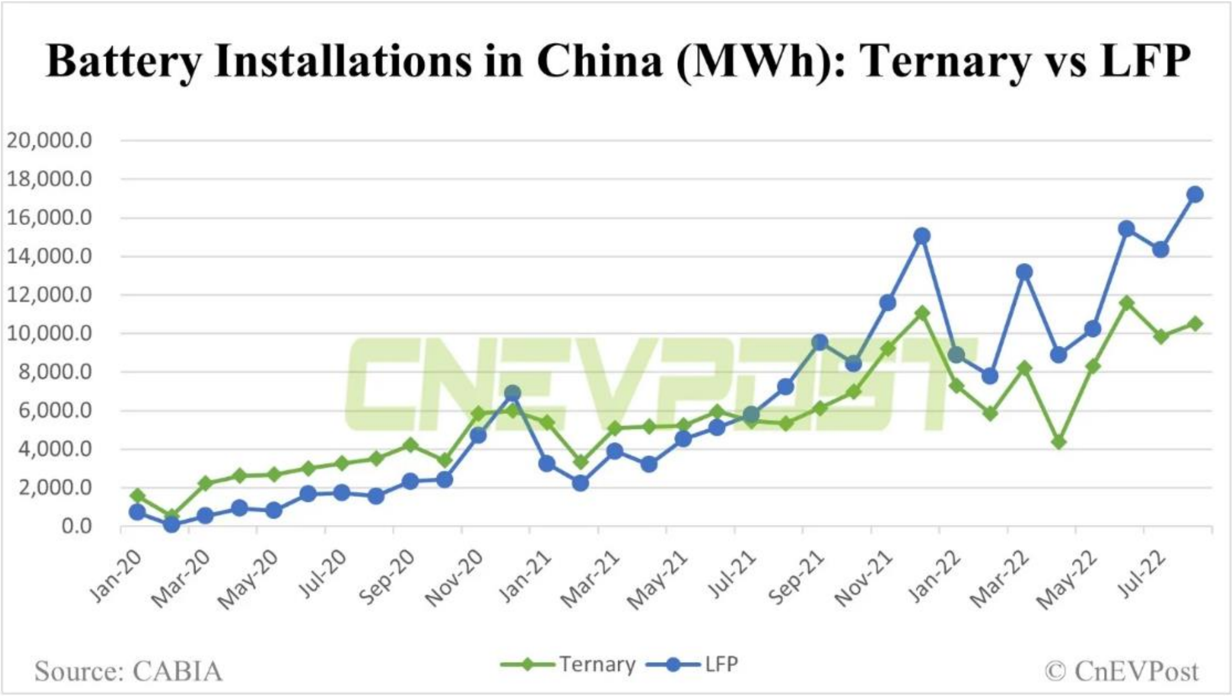
Nickel-based chemistries retained dominance of the market in 2021 with 85% of EV battery demand. However, there has been a major resurgence of LFP battery chemistries over the last two years with 15% of EV battery demand in 2021, doubling from 7% in 2020, primarily driven by increasing uptake of LFP in electric cars in China. LFP demand share in LDVs in China more than doubled from 11% in 2020 to 25% in 2021, despite the lower energy density of LFP than high-nickel chemistries. Given high battery metal prices, LFP has become more attractive as it contains no cobalt or nickel, instead using low cost iron and phosphorous (though remaining exposed to rising lithium prices). LFP relies on lithium carbonate rather than hydroxide used for nickel-rich chemistries.

The cost advantages of LFP in a high commodity price market are one reason for the resurgence. Another is the recent innovation of cell-to-pack (CTP) technology, eliminating the need for modules to house cells in the battery pack, thereby reducing the dead weight in the pack and improving the energy density of LFP batteries. CTP technology was pioneered by BYD with the Blade battery and it continues to be improved. CATL released their third-generation CTP battery increasing the LFP pack energy density to around 85% of a conventional NMC811 battery. CTP is also being applied to high-nickel chemistries to further improve their energy density.

LFP production is mostly limited to China – the traditional main hub – for the LFP battery chemistry. One reason for this is LFP patents; the research consortium owning the patents formed an agreement with battery makers in China in which they would not be charged a licence fee for using LFP if only used in China. These patents and licence fees are set to expire in 2022 making production and sales abroad more attractive. Another key reason is the early subsidies in the LFP supply chain in China.

LFP is now set to surge globally. Recently, major non-Chinese EV manufacturers, such as Tesla and Volkswagen, announced moves to LFP chemistries for entry-level high volume EV models. Almost half of all Tesla EVs produced in the first-quarter of 2022 used LFP. LFP battery production is now planned in Europe and the United States to meet anticipated LFP demand for EVs in these regions.

A surge in LFP poses a challenge for battery recycling as it is difficult to make a profit recovering iron and phosphorous. Without valuable metals such as nickel and cobalt, the value that can be recovered from LFP batteries drops considerably from conventional recycling methods and its economic viability is a concern. LFP appears to require direct recycling to be profitable or will require regulatory intervention, frameworks or alternative business models.



https://cnevpost.com/2022/09/23/byd-chairman-believes-lfp-batteries-right-choice-for-china/

At present, power batteries mainly include LFP batteries (lithium iron phosphate) and ternary lithium batteries, the difference between the two mainly lies in the fact that the former does not need to use cobalt and nickel like the latter.

Q2: Is there the market for electric cars and how big is it? Will EVs substitute ICEVs? At which rate? Which EVs (BEVs or PHEVs or HEVs)

Optimist's view: Futurologist Tony Seba: The Electric Vehicle Disruption - End of Oil by 2030 – All cars will be electric by 2025

2016: Key Exponential Technologies

1. Sensors / Internet of Things
2. Artificial Intelligence / Machine Learning
3. Robotics
4. Solar PV
5. Energy Storage
6. 3D Printing
7. 3D Visualization
8. Mobile Internet & Cloud
9. Big Data / Open Data
10. Unnamed Aerial Vehicles / Nano Satellites
11. eMoney / eFinance

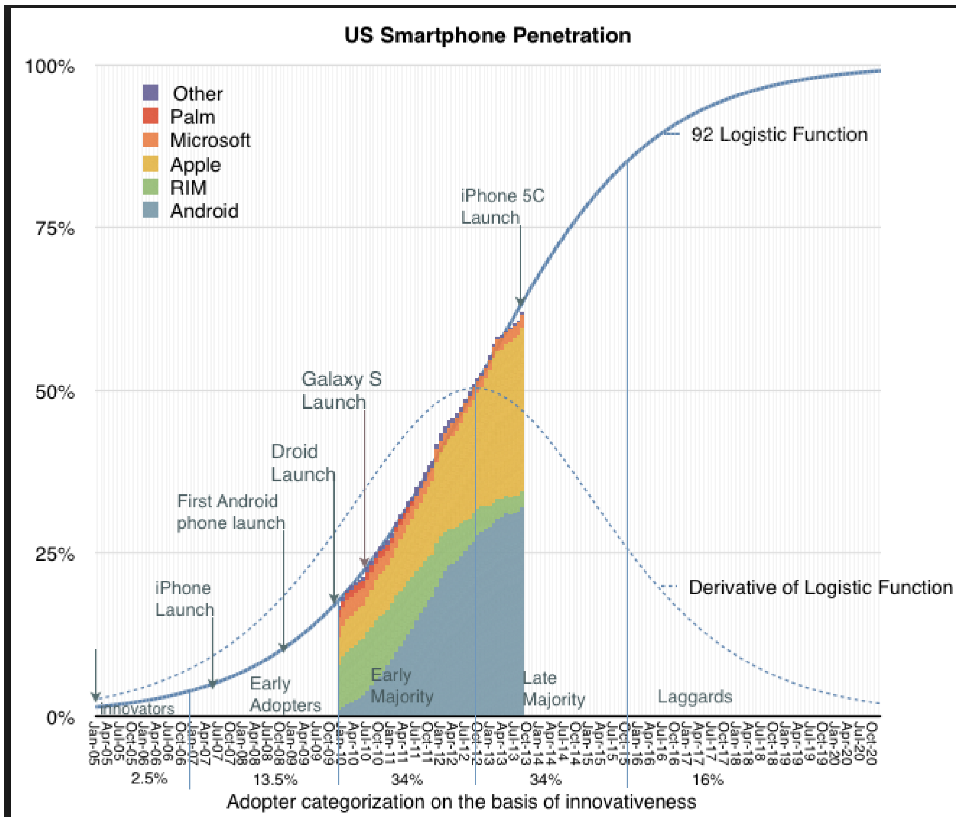
BEV are a technology-based disruption (exponential growth)

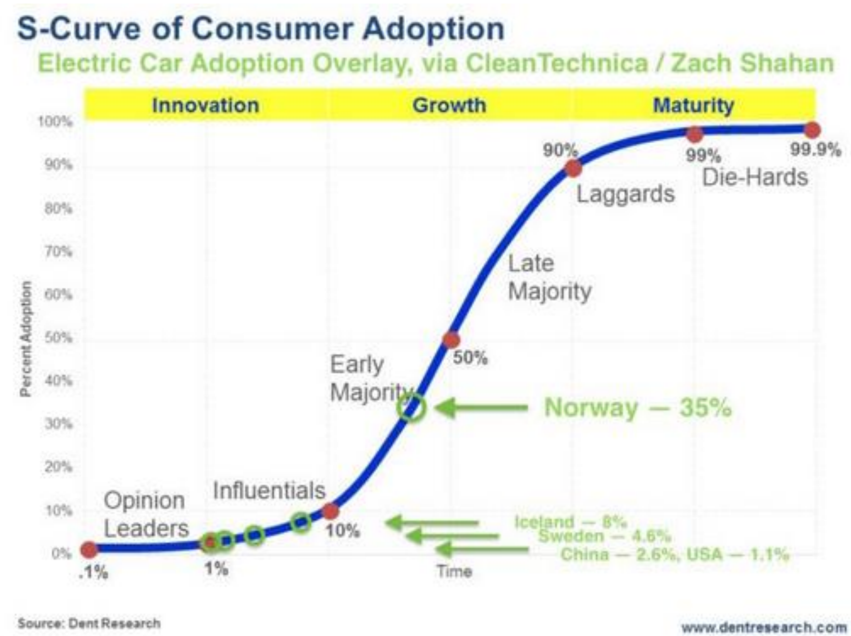
– **1900: NY all horses, 1 car; 1913 NY: all cars, 1 horse**

The Pessimist's view: Takeshi Uchiyamada (Toyota Chairman)

- **Toyota Takeshi Uchiyamada doesn't expect any rapid shift to fully-electric cars, as there are apparently still yet two or three more technological breakthroughs needed.**
  - **"I must say up front that we're not against electric vehicles. But in order for electric vehicles to cover long distances, they currently need to be loaded with a lot of batteries that take a considerable amount of time to charge. There's also the issue of battery life,"**
  - **"But as laws and regulations (that encourage the development of electric vehicles) come into effect in places like China and the U.S., car makers will have no choice but to roll out electric vehicles or risk going out of business," he said. "Toyota is no exception, but we're skeptical there would be a rapid shift to pure electric vehicles, given questions over user convenience."**
- **Toyota: Prius (HEV), Prime (PHEV)**

An intermediate point of view: The Logistic Curve Model



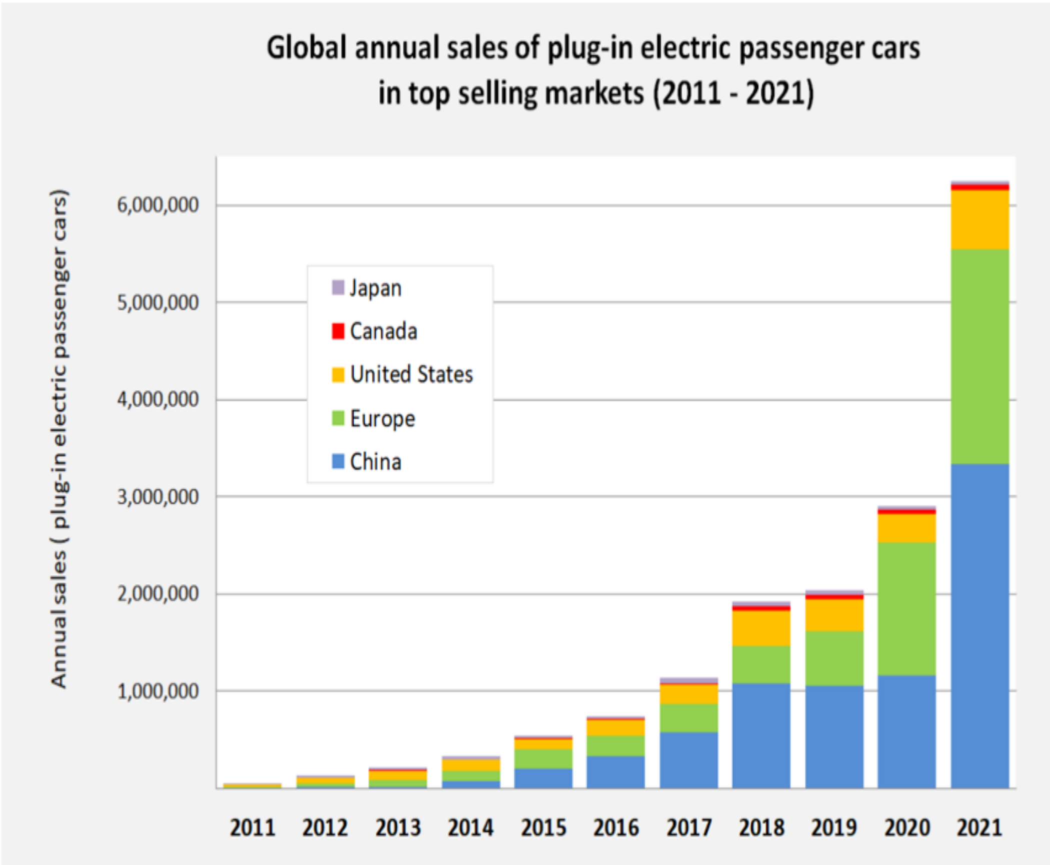


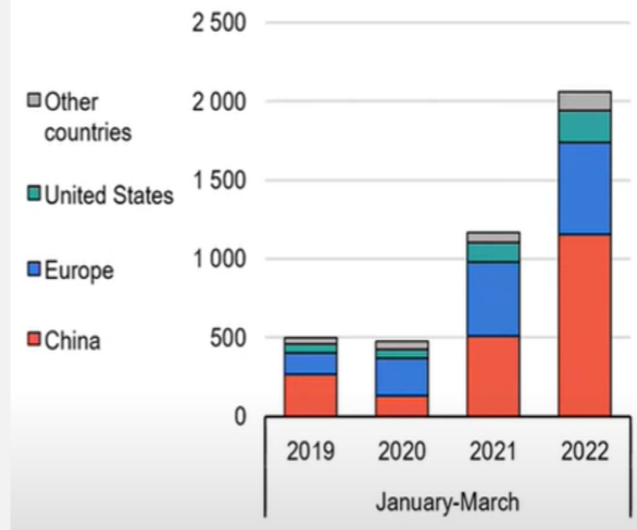
Q2: Is there the market for electric cars and how big is it? Will EVs substitute ICEVs? At which rate? Which EVs (BEVs or PHEVs or HEVs)

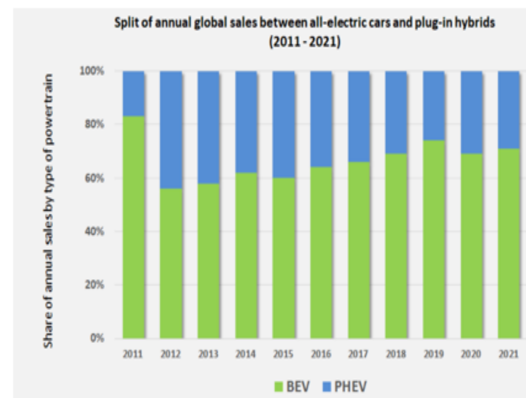
- Current market share
- Total cost of ownership
- Net purchase cost (including registration costs)
- Consumers' choices

Current market

Current EV market: nearly 10% at world level







https://en.wikipedia.org/wiki/Electric_car_use_by_country

Highly differentiated by country

PEV (BEV+PHEV): Sales, market, and usage share

Country or Region	PEV stock/ cumulative sales (2021	Annual sales (2021)	Market share (2021)	% of cars in use (2021)
China	7.84 million	3,334,000	15%	2.6%
Europe	≈5.67 million	2,332,798	19%	1.1%(2020)
United States	2,322,291	607,567	4%	0.7% (2020)
Germany	≈1.38 million	681,410	26.0%	2.5%
California	1,072,136	237,618	12.8%	2.27% (2020)
France	786,274	315,978	18.3%	1.29% (2020)
United Kingdom	745,000	305,281	18.6%	2.1%
Norway	647,000	167,949	86.2%	22.1%
Netherlands	390,454	95,464	29.8%	4.3%
Sweden	355,737	138,033	45.0%	4% (2020)
Japan	341,000	43,900	1%	0.5% (2020)
Canada	188,100 (2020)	47,000 (2020)	3.0% (2019) (2020)	0.73%
Global total	17.5 million	6,754,000	9%	1.0% (2020)

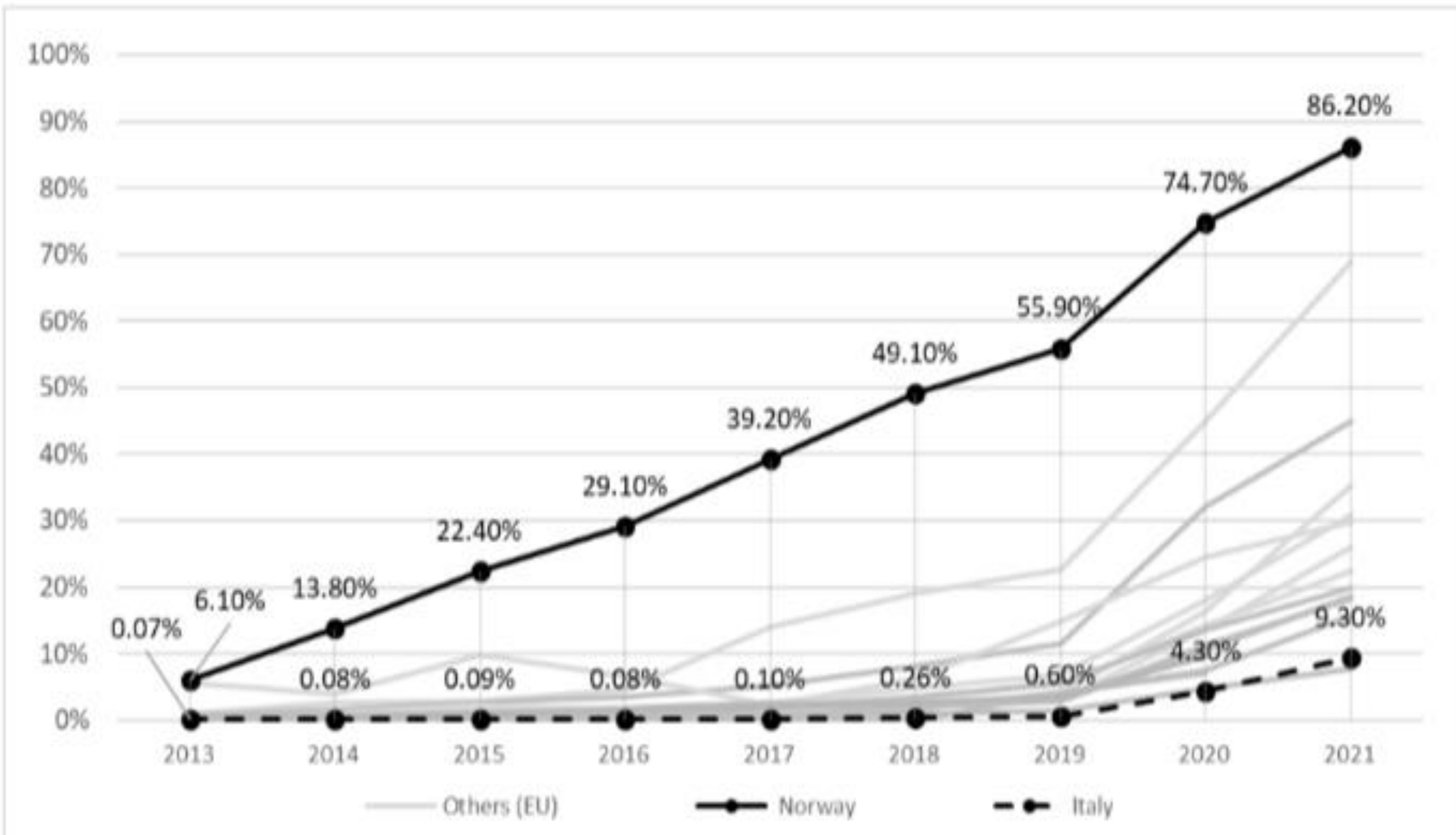
Sales do not reflect demand.
Waiting times of about 5-12 months.
Sales are supply-constraint

Light-duty plug-in electric vehicle stock, market penetration, annual sales, and market share in the top selling countries and regional markets for latest available year

https://en.wikipedia.org/wiki/Electric_car_use_by_country

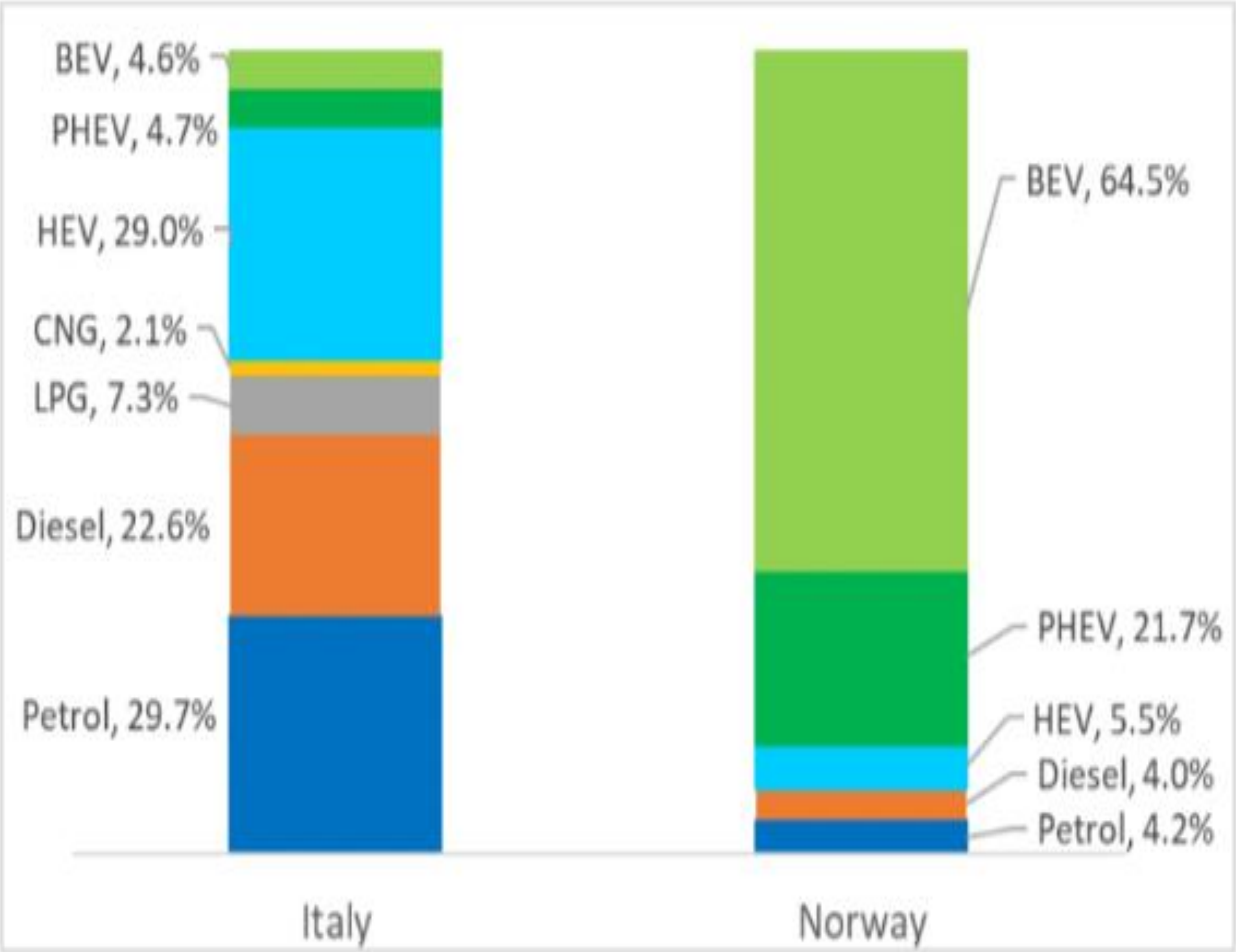
In Italy

Figure 3: Passenger EV market share of total new car sales for selected countries since 2013

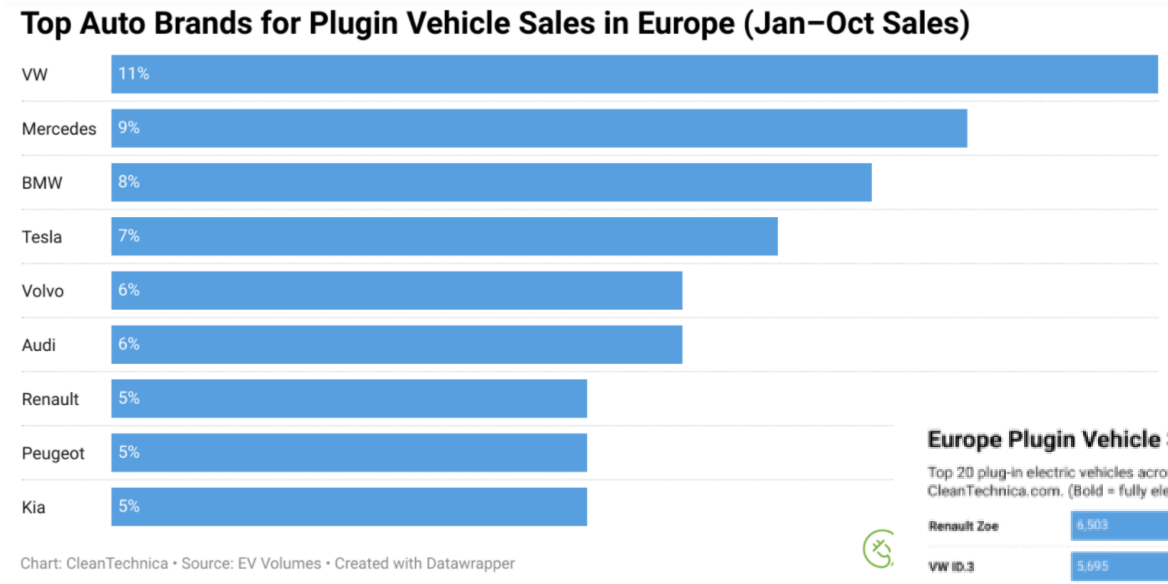


Source: Statistics Norway (2022), UNRAE (2022), ACI (2022)

Figure 1: New registrations by powertrain in Italy and Norway in 2021

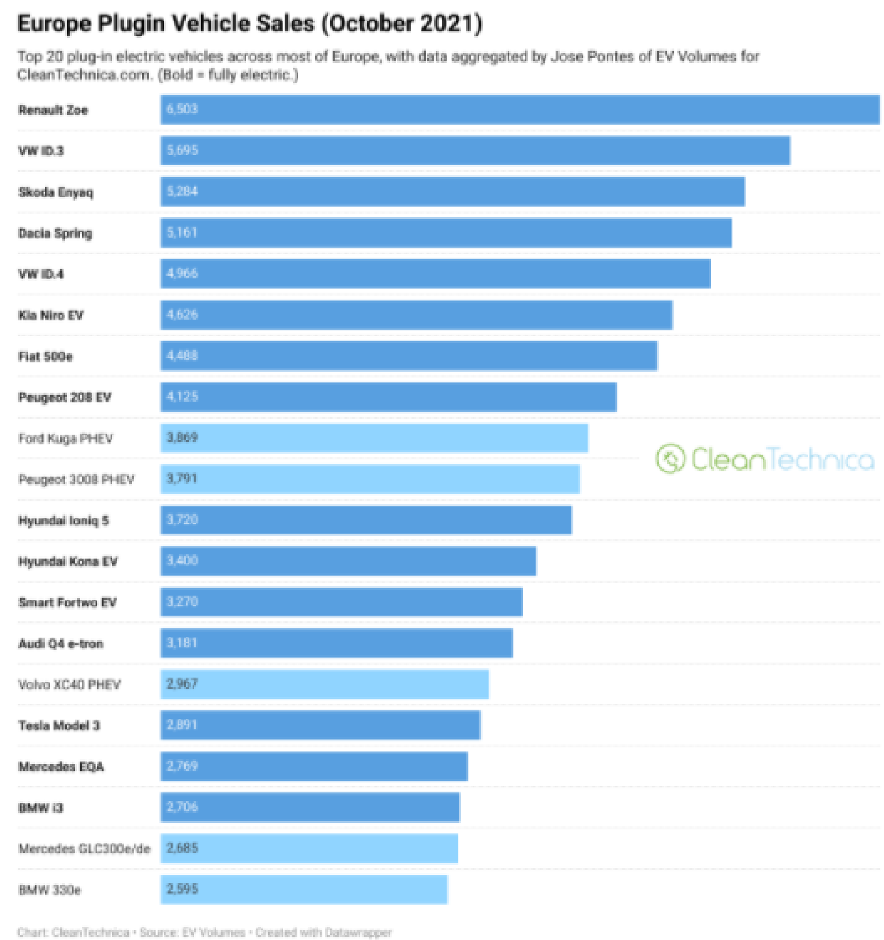


Source: Statistics Norway (2022), UNRAE (2022), ACI (2022)



CARS

13% Of Auto Sales In Europe Were Fully Electric Vehicles In October



Total cost of ownership (TCO)

It includes all the monetary costs you are facing in order to have and use a car for a number of years for a given number of kilometers.

PRIVATE COSTS comprise fixed costs and variable costs. The variability refers to the yearly distance travelled.

- **Initial fixed costs: purchase cost and registration fee;**
- **Annual fixed costs: insurance, circulation tax, routine maintenance**
- **Variable costs: fuel consumption and oil consumption**
- **fixed and a variable cost: non-routine maintenance, tire changes, the starter battery**

Tolls and parking charges might be differentiated by fuel type

SOCIAL COSTS: costs caused by emissions of local and global atmospheric pollutants and noise.

The TCO does not include time costs, particularly relevant for charging electric cars on public chargers, and costs resulting from the limited range of electric vehicles.

TCO\km: total cost of ownership of the 10 best-selling car in Italy for each propulsion system

Table 3
Average TCO/km for different AKT assumptions.

	P-ICEVs	D-ICEVs	HEVs	BEVs
MSRP (€)	13,717	20,227	25,744	33,440
AKT: 5,000 km	0.77	0.96	1.19	1.32
AKT: 10,000 km	0.46	0.55	0.68	0.70
AKT: 15,000 km	0.36	0.41	0.51	0.49

petrol-fueled ICEVs (P-ICEV), diesel-fueled ICEVs (D-ICEV), petrol-fueled hybrid electric vehicles (HEVs), and BEVs.
MSRP: manufacturers' suggested retail price
AKT: annual kilometers travelled

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journal homepage: www.elsevier.com/locate/enpol
ELSEVIER

A probabilistic total cost of ownership model to evaluate the current and future prospects of electric cars uptake in Italy

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Dipartimento di Scienze Economiche, Aziendali, Matematiche e Statistiche "Bruno de Finetti" Università degli Studi di Trieste, Via dell'Università, 1, 34123 Trieste, Italy

Total cost of ownership (TCO)

- In Italy, BEVs have much higher TCO than gasoline and diesel cars
  - Notwithstanding the lower variable costs (electricity cost per km vs petrol costs)
  - Even when the social costs (air pollution and noise) are internalized
- Crucial cost: battery cost
- In Norway, BEVs have the lower

Net purchase cost (including registration costs): Italy vs Norway

Table 9 – Net Purchase Price in Italy under base line Scenario S.0 "Status quo" - 10 best-selling cars

	MSRP (incl. VAT)	RT (fixed)	RT (variable)	Subsidy*	NPP 2021	NPP2021/MSRP
PV	19,265	151	259	1,295	18,380	95%
DV	29,641	151	345	1,393	28,744	97%
HEV	19,238	151	235	1,673	17,952	93%
PHEV	43,037	151	527	4,500	39,215	91%
BEV	30,574	151	403	6,500	24,628	81%

*Without scrapping

Table 10 – Car's Net Purchase Price in Norway under base line Scenario S.0 "Status quo"

	MSRP (€)	MSRP (incl. VAT)	Tare weight tax	CO_2 tax	NOx tax	Scrap tax	Tot RT	NPP	NPP/ MSRP
PV	40,017	50,021	2083	3286	469	240	6078	56,100	140%
DV	52,185	65,273	5052	6710	625	240	12,627	77,900	149%
HEV	35,950	44,938	9182	1972	469	240	11,862	56,800	158%
PHEV	33,020	41,275	10,267	-5815	33	240	4725	46,000	139%
BEV	43,153					240	240	43,393	101%

petrol-fueled ICEVs (P-ICEV), diesel-fueled ICEVs (D-ICEV), petrol-fueled hybrid electric vehicles (HEVs), and BEVs.

MSRP: manufacturers' suggested retail price

Let us consider 5 cars with different powertrains

VW Golf Life 1.0 110 hk eTSI
7-trinns DSG –

Benzina

Toyota RAV4 PHEV

Plug-in ibrida

VW T-ROC 2,0 150 HK TDI
SCR DSG 4MOTION

Diesel

Tesla Model 3

Solo elettrica

Toyota RAV4 HEV

Ibrida

In Norvegia....

Technical data	VW Golf Life 1,0 110 hk eTSI 7-trinns DSG	VW T-ROC 2,0 150 HK TDI SCR DSG	Toyota RAV4 HEV	Toyota RAV4 PHEV	Tesla Model 3
Tare weight	1,227	1,485	1,655	1,910	1,655
CV	110	150	178	306	351
KW	81	110	131	225	258
CO2/km	117	145	105	22	-
Nox/km	35	29	60	4	-

VW Golf Life 1.0 110 hk eTSI
7-trinns DSG –
Benzina

€: 30,625

Toyota RAV4 PHEV
Plug-in ibrida

€: 45,090

VW T-ROC 2,0 150 HK TDI
SCR DSG 4MOTION
Diesel

€: 38,823

Prezzo netto teorico ITA: prezzo listino + IPT + Ecobonus

Toyota RAV4 HEV
Ibrida

€: 37,094

Il prezzo finale dipende:
- dal concessionario
- dagli accessori (ruote, Adas)
- dalla configurazione
- dalla eventuale rottamazione
- dal mezzo di pagamento
- ecc..

Tesla Model 3
Solo elettrica

€: 50,220

VW Golf Life 1.0 110 hk eTSI
7-trinns DSG –
Benzina

€: 30,625

NOK: 501,783

VW T-ROC 2,0 150 HK TDI
SCR DSG 4MOTION
Diesel

€: 38,823

NOK: 739,394

Toyota RAV4 HEV
Ibrida

€: 37,094

NOK: 468,871

Toyota RAV4 PHEV
Plug-in ibrida

€: 45,090

NOK: 460.464

Tesla Model 3
Solo elettrica

€: 50,220

NOK: 412,390

Prezzo teorico ITA: prezzo listino + IVA+ IPT + Ecobonus
Prezzo teorico NOR: prezzo listino + IVA + Imposte

In Italia..

27	Costo emolumenti ACI
32	Costo bollo iscrizione al PRA
10.2	Costo diritti DT
32	Costo dell'imposta per rilascio della carta di circolazione
41.78	Targa
142.98	
180.97	IPT fino a 53 kW
4.21	ogni KW in più

ITALY	VW Golf Life 1,0 110 hk eTSI 7-trinns DSG	VW T-ROC 2,0 150 HK TDI SCR DSG 4MOTION	Toyota RAV4 HEV	Toyota RAV4 PHEV	Tesla Model 3
Powertrain	Petrol	Diesel	HEV	PHEV	BEV
MSRP without VAT	**24,426**	**30,943**	**29,836**	**39,754**	**45,074**
VAT 22%	5,374	6,807	6,564	8,746	9,916
MSRP+VAT	29,800	37,750	36,400	48,500	54,990
Subsidy without scrapping (2021)	-	-	-	4,500	6,000
IPT (imposta provinciale di trascrizione)	341	465	552	947	1,087
Fixed registration cost	143	143	143	143	143
Total Registration Tax	484	608	694	1,090	1,230
Total Net Tax	483.99	608	694	-3410	-4770
Net Purchase Price	**30,625**	**38,823**	**37,094**	**45,090**	**50,220**
Net Purchase Price/MSRP before VAT	**1.25**	**1.25**	**1.24**	**1.13**	**1.11**
Ind BEV=100 before tax	54	69	66	88	100
Ind BEV=100 after tax	61	77	74	90	100

Imposte nette: da 11% a 25%

BEV: + cara prima e dopo imposte

In Norvegia….

NORWAY	VW Golf Life 1,0 110 hk eTSI 7-trinns DSG	VW T-ROC 2,0 150 HK TDI SCR DSG	Toyota RAV4 HEV	Toyota RAV4 PHEV	Tesla Model 3
MSRP without VAT	**352,800**	**490,500**	**280,200**	**331,360**	**409,990**
VAT 25%	88,200	122,625	70,050	82,840	-
MSRP+VAT	441,000	613,125	350,250	414,200	409,990
Registration tax	58,383	123,869	116,221	43,864	-
-Tare weight tax	20,832	50,518	91,815	101,684	-
- NOx tax	4,688	6,251	4,688	328	-
- CO2 Tax	32,862	67,100	19,717	- 58,148	-
Scrap deposit tax	2,400	2,400	2,400	2,400	2,400
Total Net Tax	60,783	126,269	118,621	46,264	2,400
Net Purchase Price	**501,783**	**739,394**	**468,871**	**460,464**	**412,390**
Net Purchase Price/MSRP before VAT	**1.42**	**1.51**	**1.67**	**1.39**	**1.01**
Ind BEV=100 before tax	86	120	68	81	100
Ind BEV=100 after tax	122	179	114	112	100

Imposte nette: da 1% a 67%

BEV: - cara dopo imposte

«the polluter pays principle»

In Norvegia....

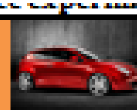
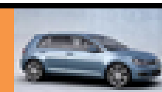
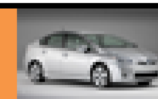
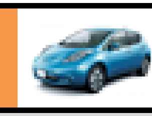
Technical data	VW Golf Life 1,0 110 hk eTSI 7-trinns DSG	VW T-ROC 2,0 150 HK TDI SCR DSG	Toyota RAV4 HEV	Toyota RAV4 PHEV	Tesla Model 3
Tare weight	1,227	1,485	1,655	1,910	1,655
CV	110	150	178	306	351
KW	81	110	131	225	258
CO2/km	117	145	105	22	-
Nox/km	35	29	60	4	-

Consumers' choices

- Consumers' decisions are not based only on costs!
- Driving pleasure (acceleration, silence)
- Status
  - Early adopters
    - Technology lovers, Environmentally-concerned drivers
  - Followers
    - Friends, Advertising campaign
- Charging infrastructure: range and charging times
- Monetary and non monetary incentives

Modelling individual's choices and simulating EV penetration

Example of a SP choice experiment

Car features							
	Ford Fiesta *(diesel)*	**VW Polo** *(gasoline)*	**Fiat Punto Evo** *(bi-fuel - CNG)*	**Alfa Romeo Mito** *(bi-fuel - LPG)*	**Toyota Yaris** *(hybrid - gasoline)*	**Peugeot iOn** *(BEV – own battery)*	**Renault Zoe** *(BEV – leased battery)*
Purchase price (€)	14,000	11,900	15,425	20,600	18,650	30,369	21,650
Range (km)	980	900	800	1200	1,000	150	210
Acceleration (0-100 in sec.)	15	13	15	15	13	12	12
Annual operating cost (€)	1,894	2,081	1,757	1,784	1,920	1,681	2,553
Refuelling (km)	1	1	5	5	1	0	0
Which car would you buy?							

Eva Valeri, Romeo Danielis, Simulating the market penetration of cars with alternative fuel\powertrain technologies in Italy, Transport Policy 37 (2015) 44–56

Econometric models

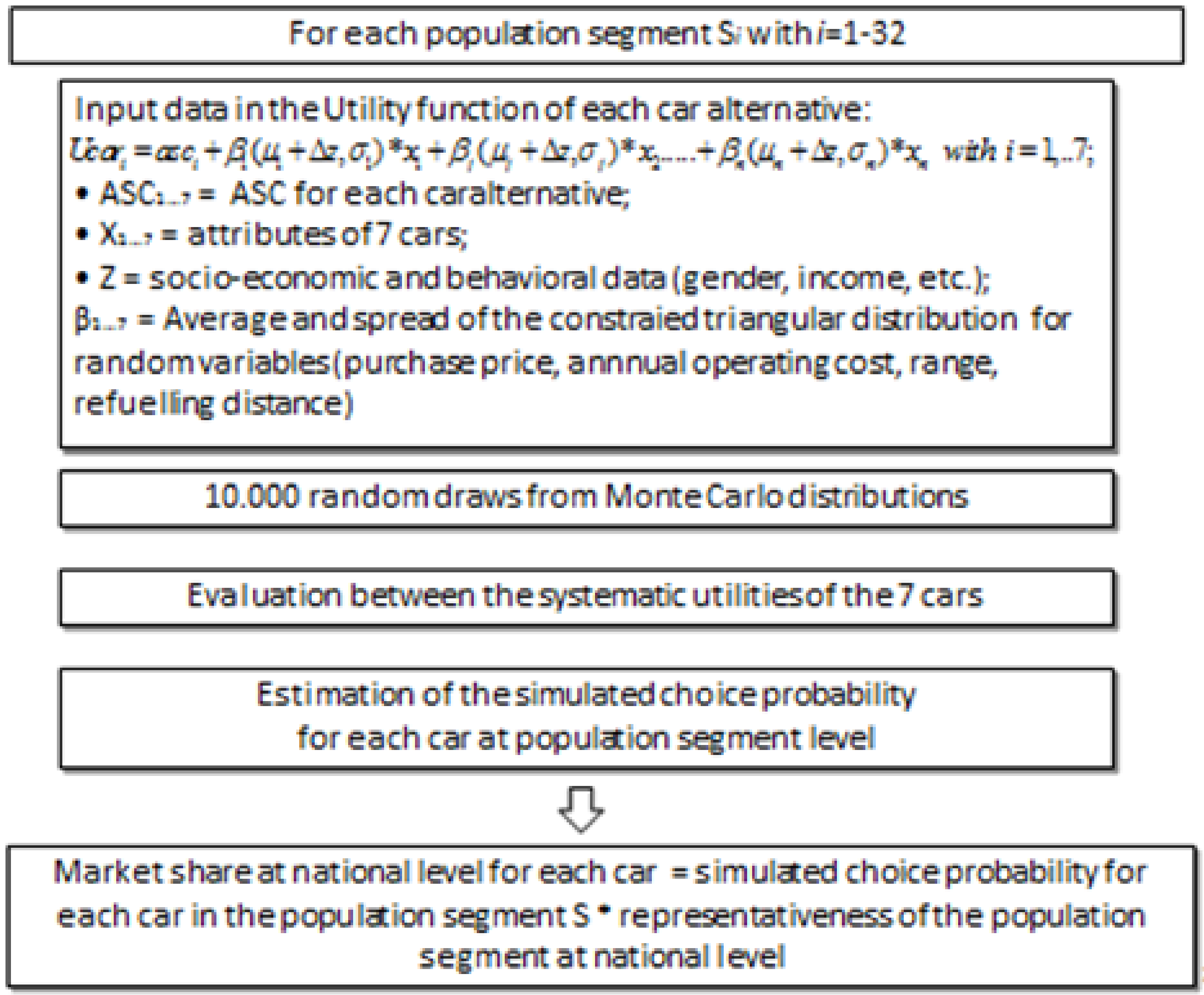
1. **Multinomial Logit model:**
   - to evaluate in a simple manner the monetary value of the nonmonetary attributes
2. **Mixed Multinomial Logit model:**
   - to take into account the random nature of the model coefficients;
   - to explore the role played by the socio-economic variables in determining the model coefficients, and;
   - to account for the correlation among alternatives and the panel features of the data set.

Econometric estimates

Table 7 – MNL model's estimates

Variables	Estim.Coeff.	Std.Err.	t-ratio	P-value
Alternative Specific Constants:				
ASC DV(Ford Fiesta) (β_D)	0.124	0.129	0.964	0.335
ASC CNGV (Fiat Punto Evo NP) (β_{CNG})	0.337	0.180	1.871	0.061
ASC LPGV (Alfa Romeo Mito) (β_{LPG})	0.385	0.194	1.979	0.048
ASC HEV (Toyota Yaris) (β_H)	-0.151	0.117	-1.292	0.196
ASC BEV-owned battery (Peugeot iOn) (β_{E-ob})	-0.465	1.041	-0.447	0.655
ASC BEV-leased battery (Renault Zoe) (β_{E-lb})	-1.526	0.927	-1.646	0.100
Generic attributes:				
Purchase Price (€1.000) (β_{pp})	-0.208	0.010	-20.575	0.000
non-BEV Range (1.000km) (β_R)	1.554	0.241	6.448	0.000
non-BEV Acceleration (β_A)	0.005	0.024	0.192	0.848
Annual operating cost (€1.000) (β_{AOC})	-1.287	0.079	-16.326	0.000
Refuelling distance (β_{RD})	0.013	0.010	1.317	0.188

Figure 1 – Framework of the simulation model



Frontline risk solver software

Scenario analysis

Table 15 – Market share variations relative to the base case scenario

Type of cars:	*Scenario 1: subsidy*	*Scenario 2: threefold range increase for electric cars*	*Scenario 3: 20% fossil-based fuel price increase*	*Scenario 4: €5.000 price reduction for the BEVs*	*Scenario 5: scenario 1 to 4 considered jointly*
VW Polo (gasoline)	-18.4	-0.3	-3.4	-0.1	-24.5
Ford Fiesta (diesel)	20.8	-0.4	0.5	-0.1	11.4
Fiat Punto Evo (bi-fuel - CNG)	-6.2	-0.4	1.9	-0.2	-7.9
Natural Power Alfa Romeo Mito (bi-fuel - LPG)	-2	-0.5	0.2	-0.1	-3.4
Toyota Yaris (hybrid - gasoline)	5.3	-0.3	-0.3	-0.1	3.2
Peugeot iOn (BEV – owned battery)	0.19	0.91	0.86	0.21	6.3
Renault Zoe (BEV – leased battery)	0.16	0.9	0.14	0.25	14.86

Conclusions on consumers' preferences

In order for the BEVs to gain significant market share all these conditions need to be <u>jointly</u> met:

- **Subsidy**
- **Increase in driving range (battery improvements)**
- **Purchasing price cuts (decrease in battery costs)**

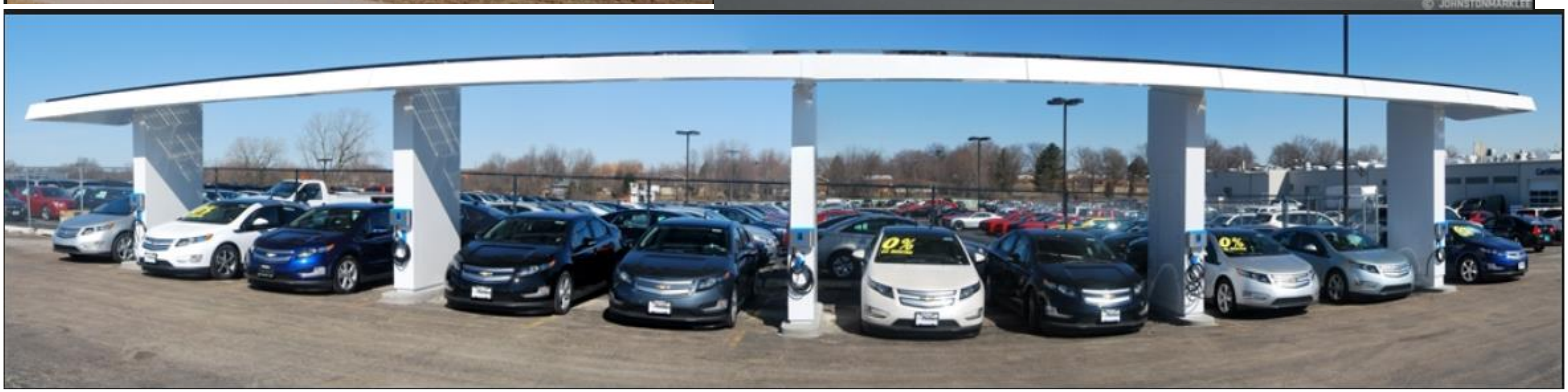
Where do I charge an EV?

How important is the charging infrastructure for EVs uptake?

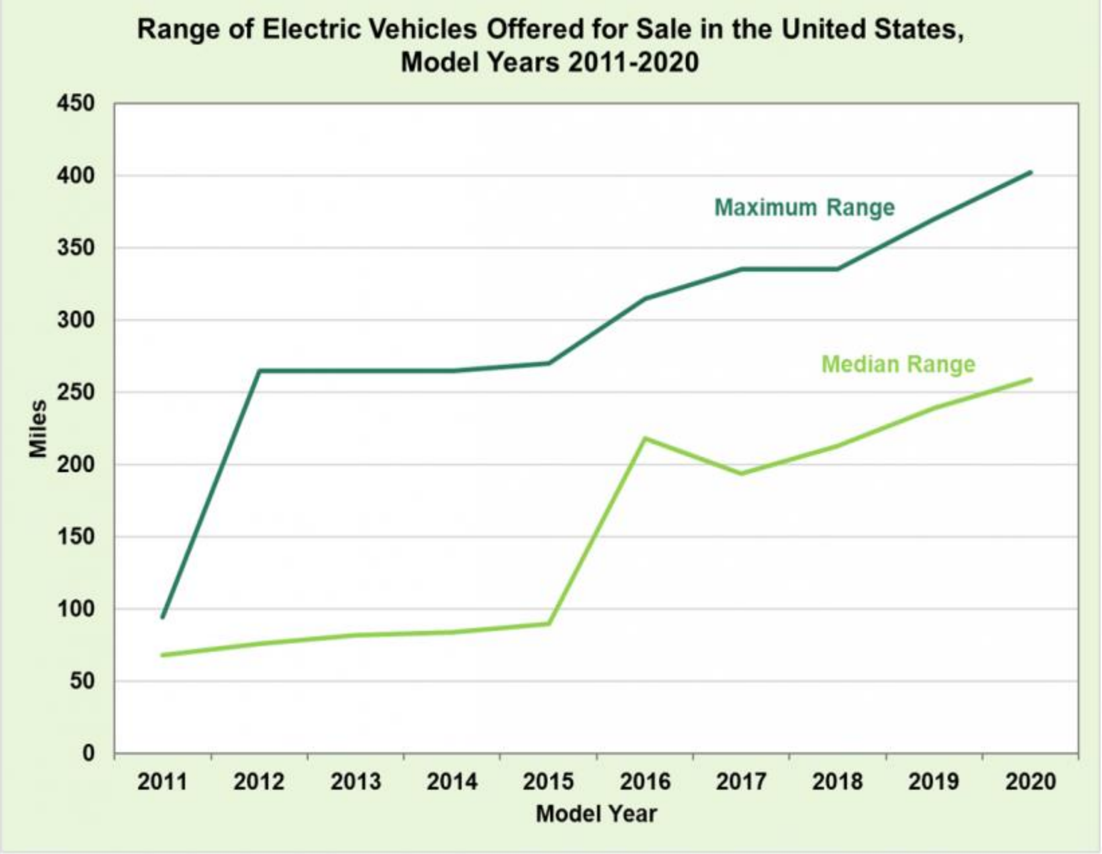
- A 'chicken or the egg' dilemma: without the massive deployment of EVs, there is no need for charging infrastructures; but without charging infrastructures, the sales of EVs are hindered by the lack of charging solutions and the limited range of EV's.
- Real importance: many trips are commuting trips taking place within the available range; Monte and Danielis, estimates from Census data, about 95%)
- Psychological importance: range anxiety

Charging infrastructure: up to 150 kW (350 kW) power

Charging station powered with solar panels



Drving range is increasing

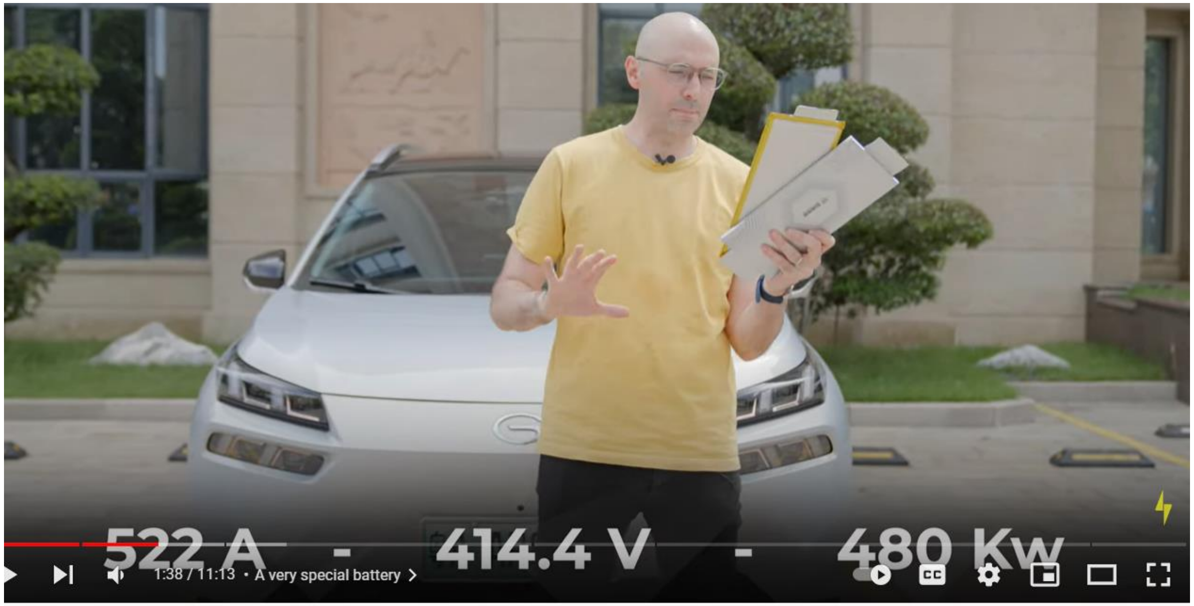


Source: U.S. Department of Energy and U.S. Environmental Protection Agency, Fuel Economy website. Data accessed October 30, 2020.

https://www.energy.gov/eere/vehicles/articles/fotw-1167-january-4-2021-median-driving-range-all-electric-vehicles-tops-250

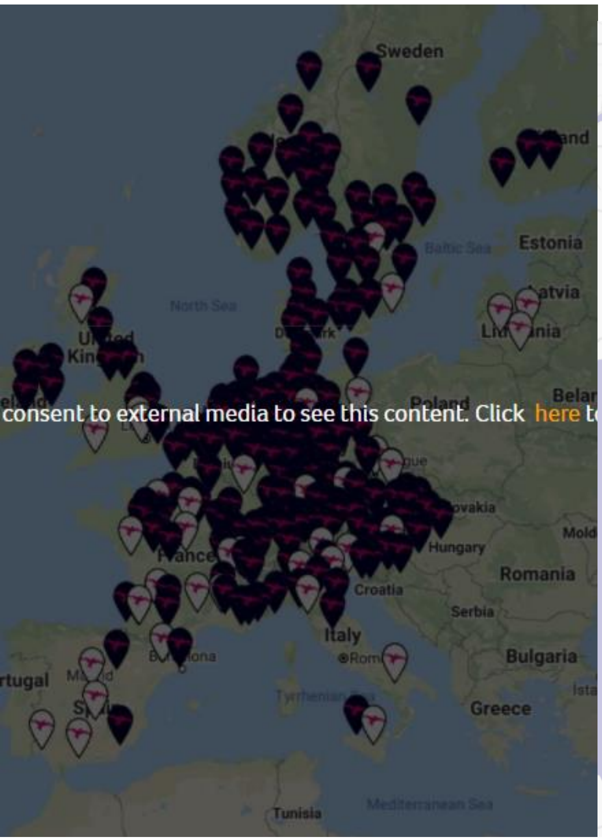
Charging is getting faster

https://www.youtube.com/watch?v=taehg2rZBpY
Testing The World's FASTEST Electric Car Charger!!



Competition among charging network

Ionity network



enel x

52481: punti di ricarica (ott. 2020)

T Ξ S L A

1,971 Supercharger Stations with 17,467 Superchargers

An alternative to charging: battery swapping

Nio reaches 10 million battery swaps and opens 1,000 swap stations

Q3: What the industrial implications?

- **Variety**
- **New firms: Tesla, (Apple)**
- **New countries: China, India**
- **New industries: Battery and storage, Solar city (cars, battery, storage, PV)**
- **New business models**

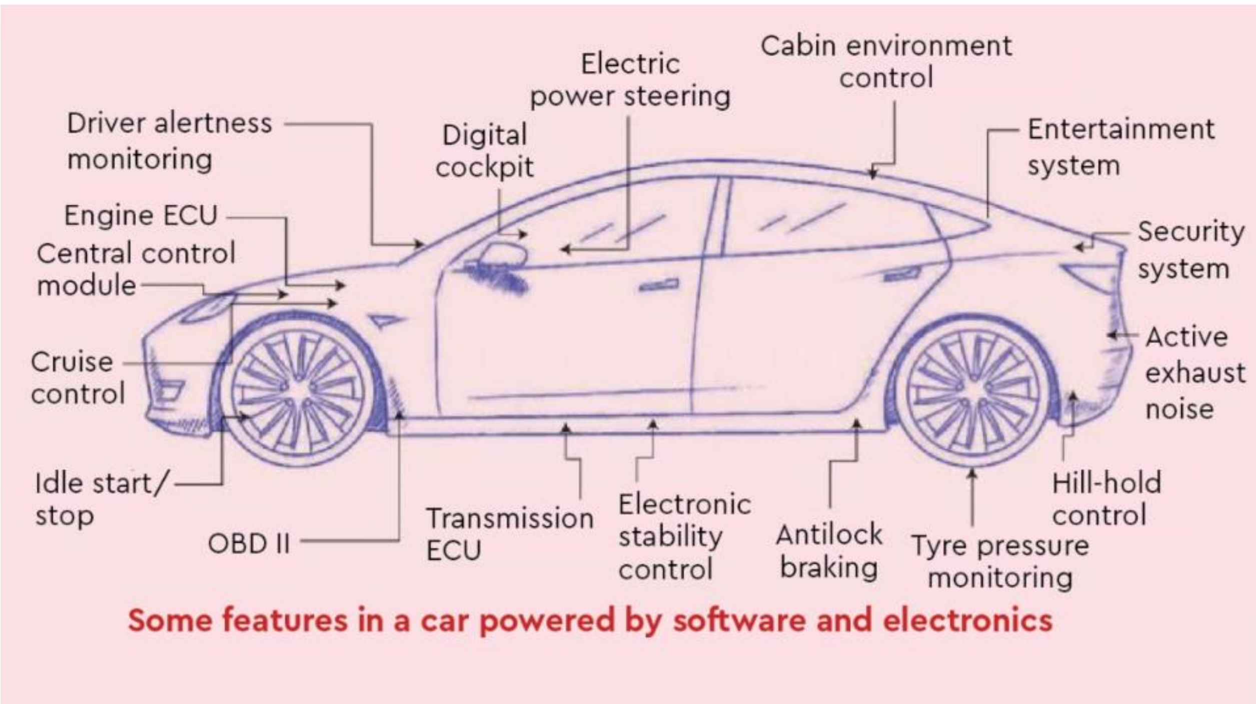
Which industrial implications? How do car manufacturers react?

Challenges for the automotive sector:

- Technical challenge: EVs are computer and battery on wheels, enabling factor for autonomous driving and connectivity
- Economic challenge: How to make profits out of EVs (cars, trucks and buses)
- Competition challenge: the Chinese (Asian) competition
- Industrial challenge: what is the best business model?
- Critical materials challenge (lithium, cobalt, nickel, rare minerals)
- Circular economy challenge

Technical challenge: EVs are computer and battery on wheels

EVs as computer and batteries on wheels

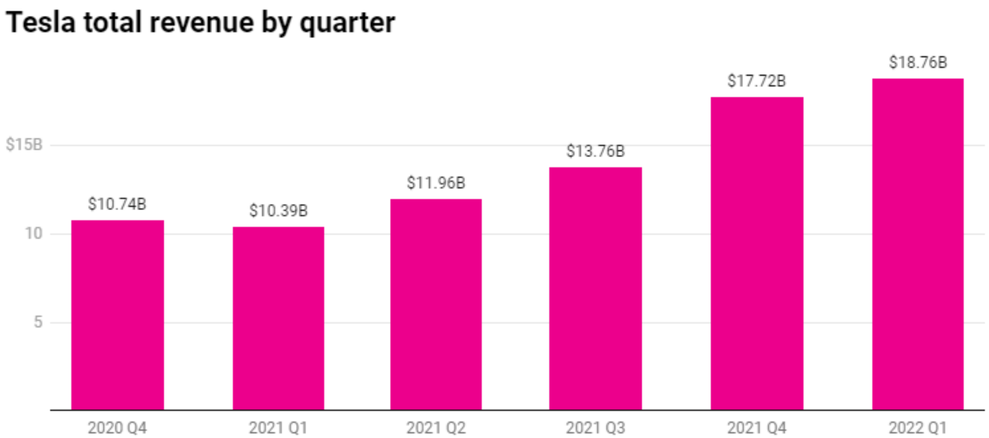


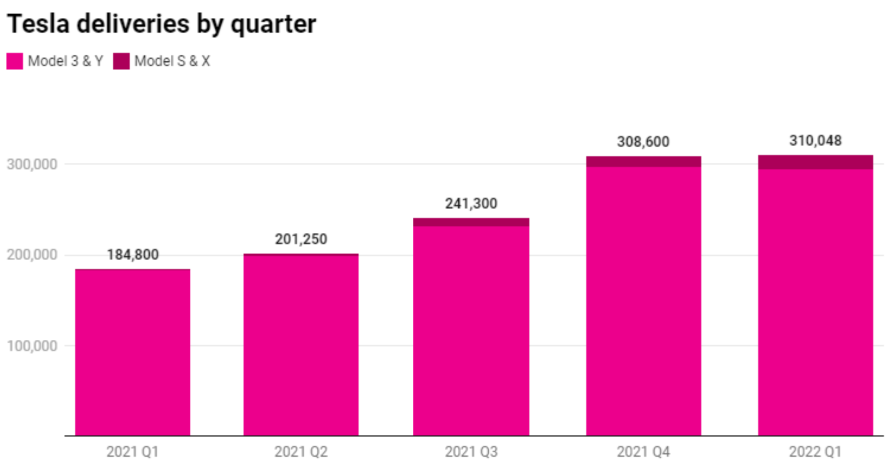
https://www.financialexpress.com/auto/car-news/semiconductors-your-car-is-a-computer-on-wheels/2458677/

- cars as **data generating computer centers** on wheels.
- EVs as **enabling factor for autonomous driving and connectivity** (Giovanni Pulice, CEO di e-shock, e-novia with JRC)

Economic challenge:
how to make profits out of EVs
(cars, trucks and buses)

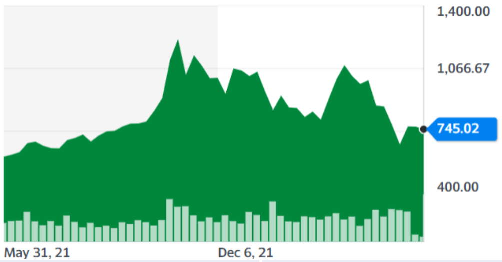
The case of Tesla





Amid supply chain constraints and production delays in China, Tesla reported that **it earned a $3.3 billion profit in the first quarter of 2022.** Tesla turned that profit on just over $18.7 billion in revenue, the company announced. That represents an 81 percent increase year over year, compared to $10.4 billion in revenue in Q1 2021.

The stock market rewards EV producers (equity finance)



	Tesla Motors	General Motors	Volkswagen AG	Rivian
Enterprise Value (Jun 1st, 2022):	678B	135B	212B	26B
Revenue (ttm):	62B	130B	250B	150M
Profit Margin (ttm):	13.50%	7.61%	7,64%	0%
Operating Margin (ttm)	15.49%	8.60%	9,43%	-3,592%
Enterprise Value/Revenue (ttm):	10.88	1.04	3.98	74.83

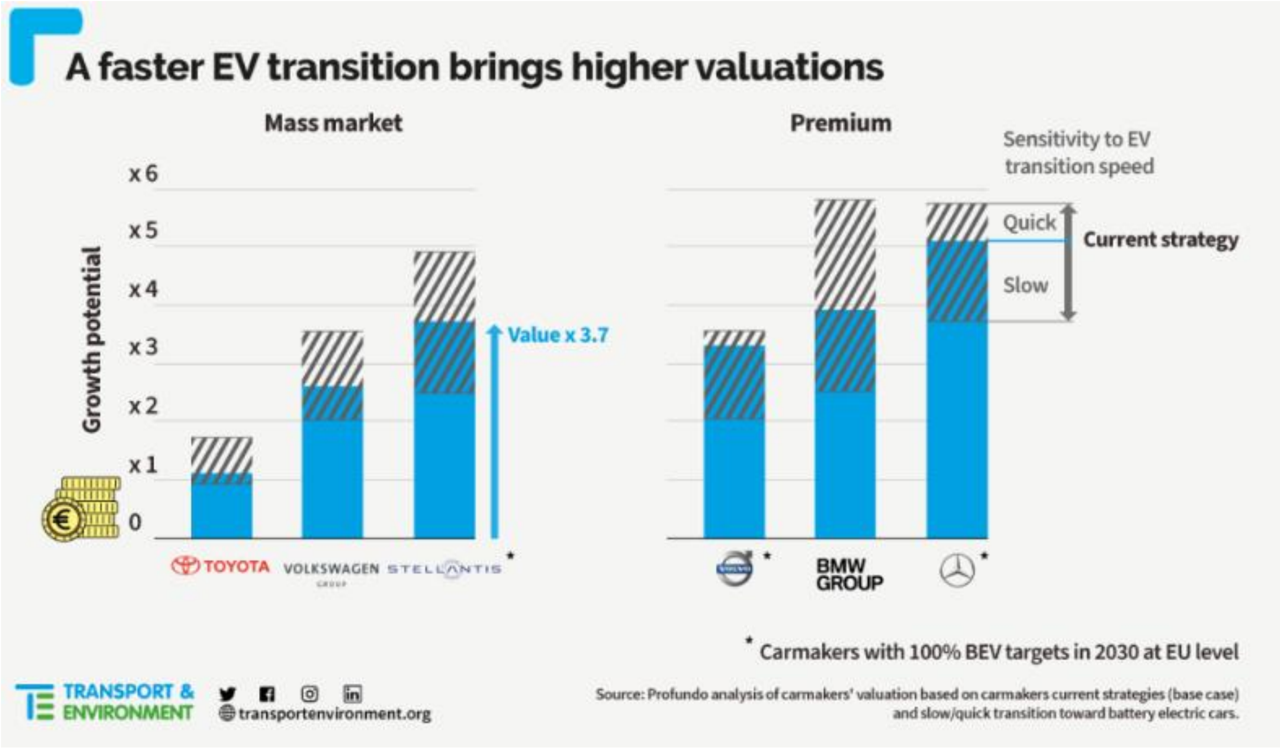
ttm = Trailing Twelve Months (as of June 1th, 2022)

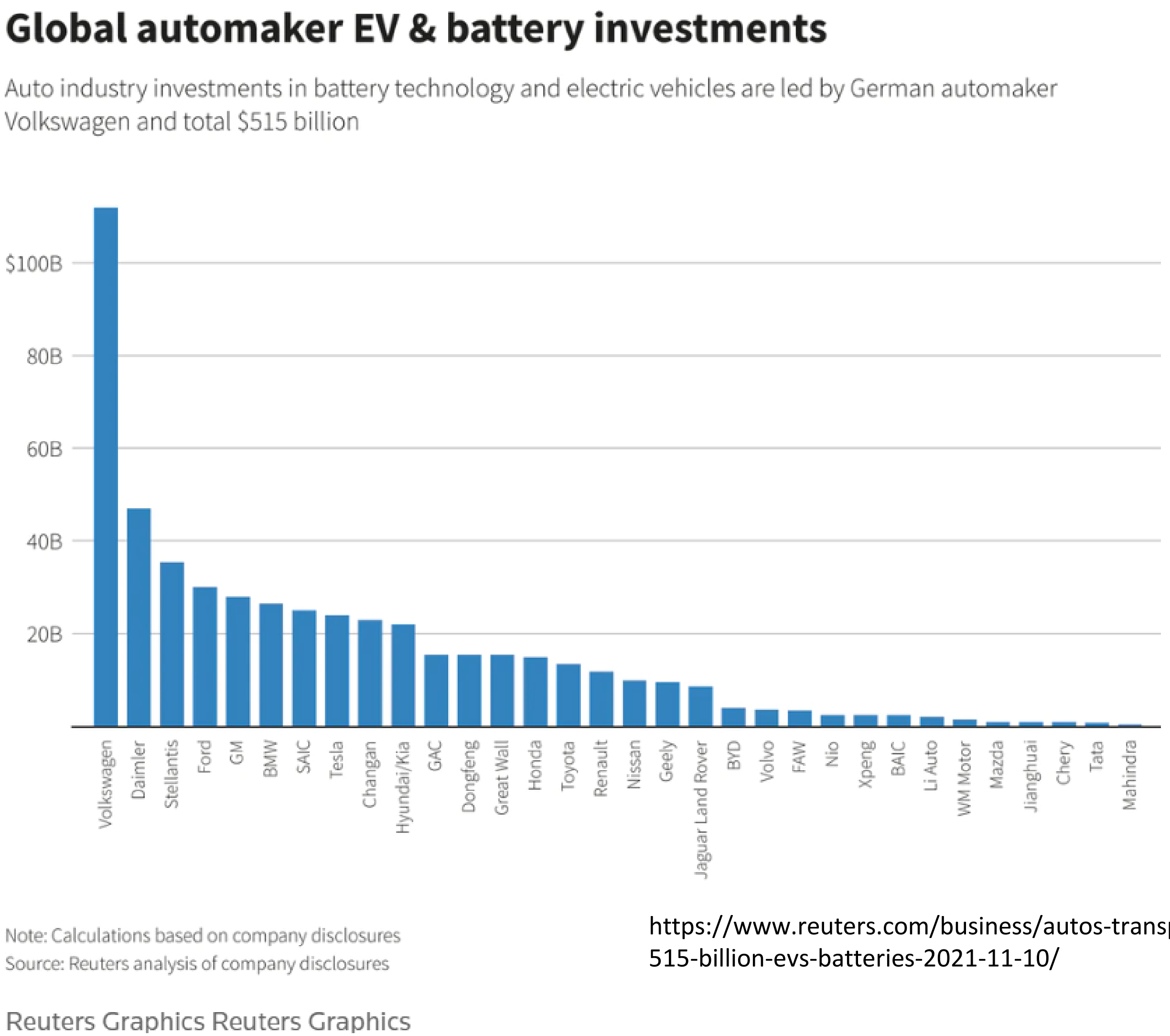
Enterprise Value is a measure of a company's total value, often used as a more comprehensive alternative to equity market capitalization. The market capitalization of a company is simply **its share price multiplied by the number of shares** a company has outstanding. Enterprise value is calculated as the **market capitalization plus debt, minority interest and preferred shares, minus total cash and cash equivalents.**

https://finance.yahoo.com/

Transport&Environment's claim: Phasing out combustion engines sales sooner is better for Europe's car industry and auto jobs

Profundo, using standard Sum Of The Parts (SOTP) analysis and Discounted Cash-Flows (DCF), shows that a quick EV transition by the six legacy car manufacturers could bring a **EUR 800 billion equity value enhancement compared to a slow switch to EVs**. Quicker rather than slower EV transition strategies in the 2020s are projected to generate higher margins, triggering higher equity value for shareholders as well as better access to capital.





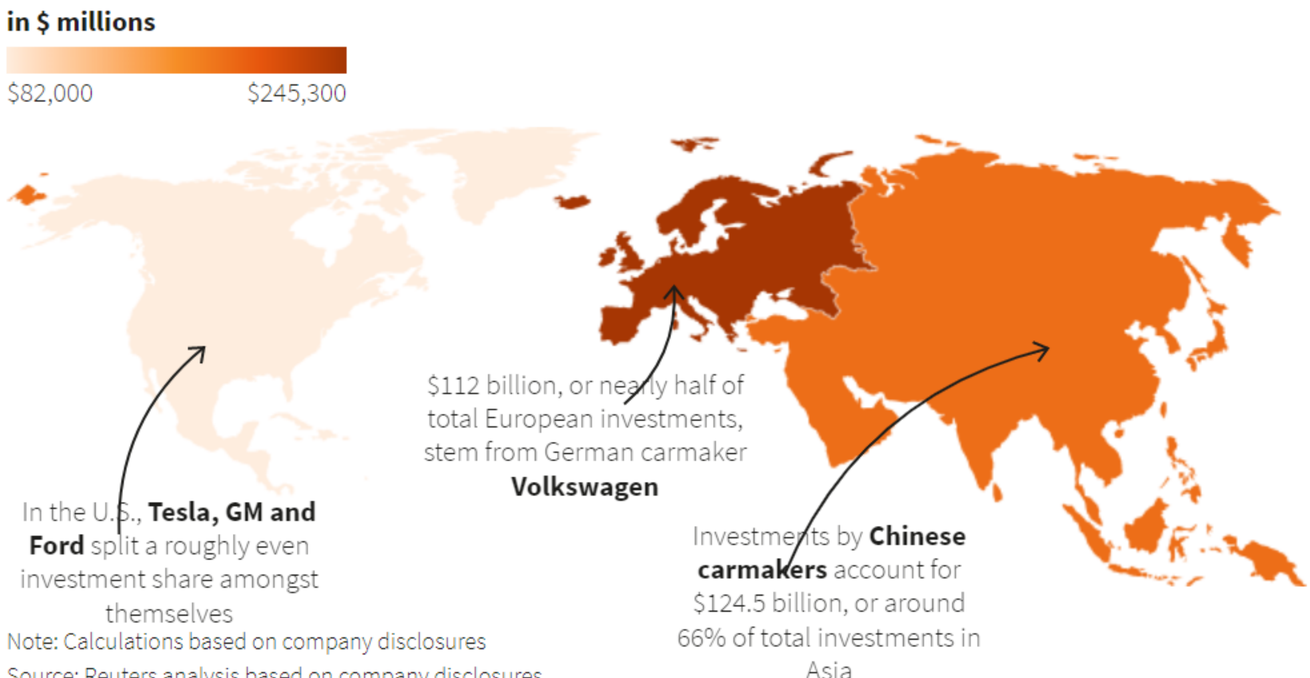
- German OEMs believe in EVs
- Nissan and Renault slowed down investments
- Ford and GM are catching up
- Chinese OEMs are investing
- Toyota, the largest OEM, does not

https://www.reuters.com/business/autos-transportation/exclusive-global-carmakers-now-target-515-billion-evs-batteries-2021-11-10/

Automaker EV & battery investments around the world

November 10, 2021

European automakers lead electric vehicle and battery investments in total dollar amounts. Asian and European automakers have jointly invested more than five times as much as their North American competitors.



Note: Calculations based on company disclosures

Source: Reuters analysis based on company disclosures

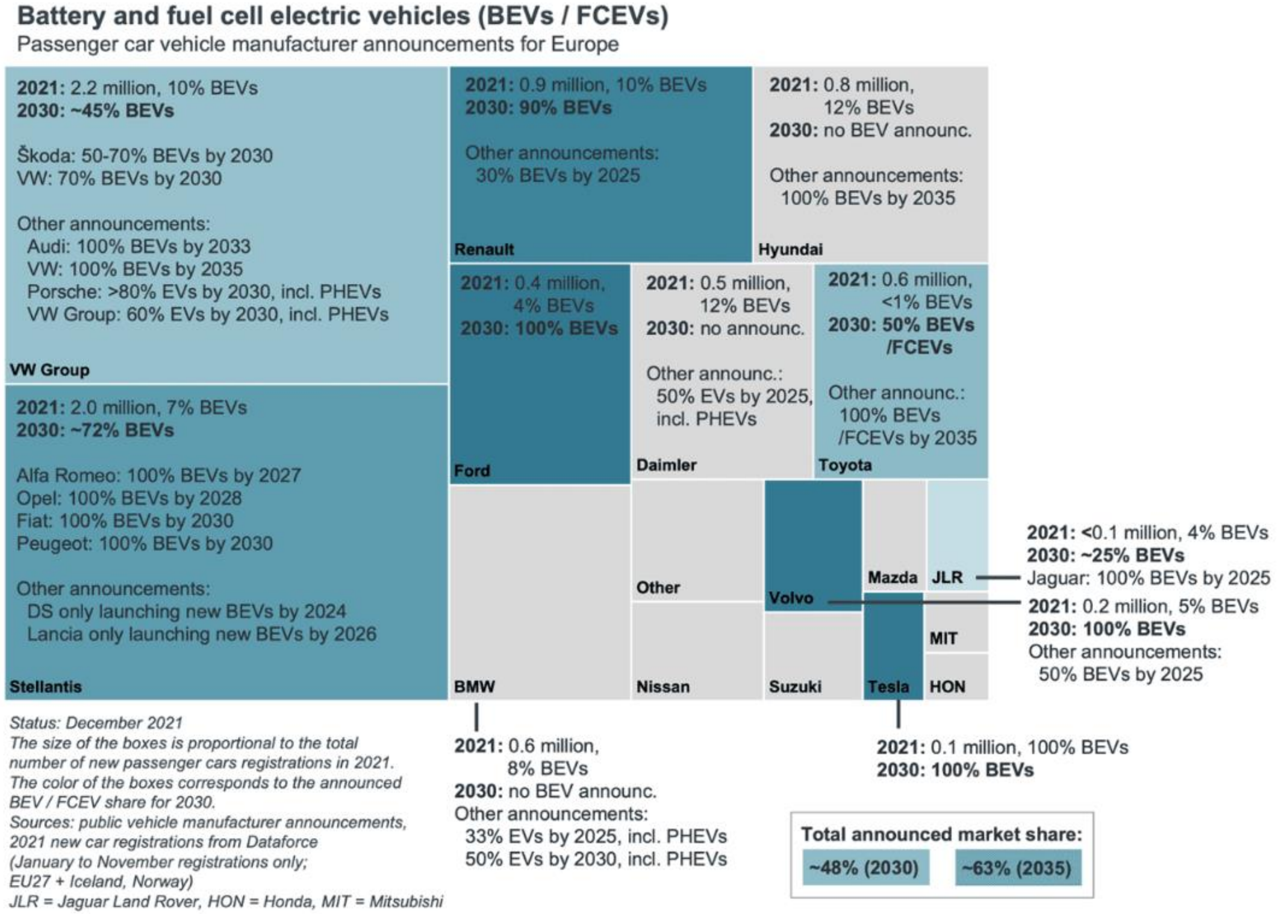
Most of the investments so far in China and Europe

https://graphics.reuters.com/CLIMATE-UN/AUTOS-EV/dwpkreagjvm/index.html

Take away

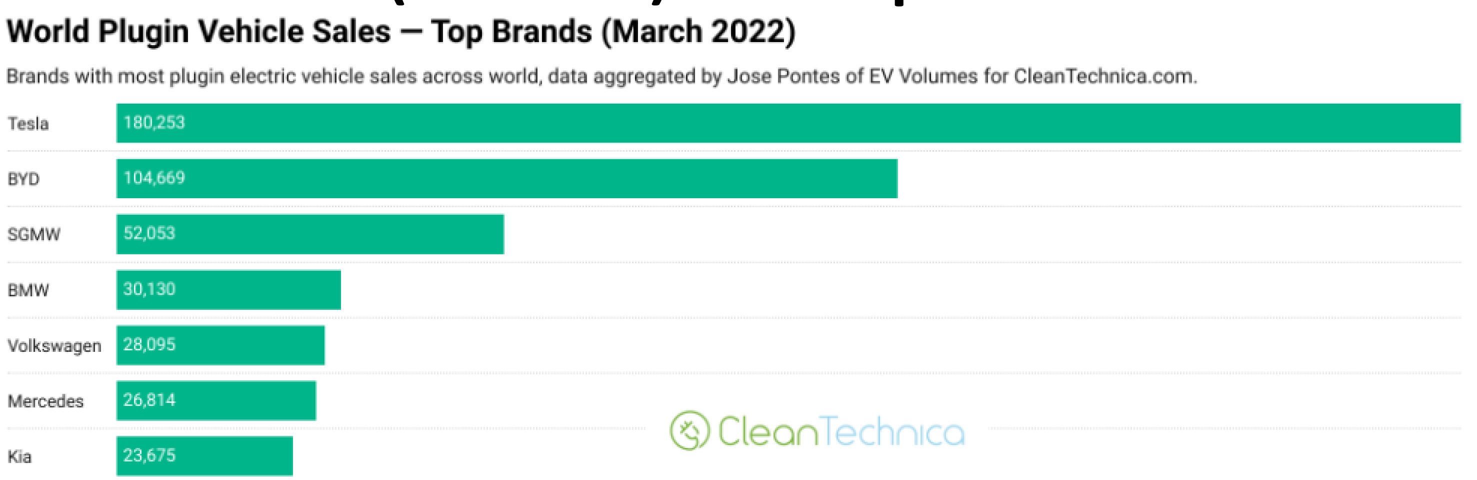
- OEMs start making profits on EVs
- Financial investors rewards OEMs who bet on EVs

Phase-out announcements by OEMs



https://theicct.org/fr-ita-manufacturer-ev-targets-jan22/

Competition challenge: the Chinese (Asian) competition



VinFast has great ambitions. My models VF 8 and VF 9 (previously called VF e35 and VF e36), made thanks to the collaboration with Pininfarina, sold in a chain of 50 stores in Europe by the end of 2022.

Gogoro and **Ola** (India): electric scooters

- Chinese carmakers were **nearly absent** on the European market in **2018**, but reached **2.8% of the BEV market in 2020**. Despite the fact that European customers were largely unfamiliar with Chinese brands and had preconceived ideas related to quality and safety. It is a sign of a supply gap in the market, as EU OEMs are slow to ramp up the supply to match the demand for EVs.
- First **Wuling-branded global NEV model** to hit market in second half of 2022: Best selling car – 30-40 thousand per month

SAIC-GM-Wuling (“SGMW”),

Wuling - Hong Guang MINI EV

- **Dimensioni:** 2,92 x 1,49 x 1,62 metri
- **Passo:** 1,94 metri
- **Batteria:** 9,3 kWh o 13,9 kWh
- **Autonomia:** 120 km o 170 km
- **Potenza max:** 27,2 CV
- **Coppia max:** 85 Nm
- **Velocità max:** 100 km/h

28.800 yuan,
about 4.000 euro

Industrial challenge: what business model?

- Integration: backward and forward
- Joint-ventures

Integration

Tesla:

- Wide range of products: mining, batteries, cars, software (AI), charging network (Supercargers), accumulators (Powerwall), solar home, finance, insurance,
- Direct sales: no car dealership
- No marketing expenses

Toyota

- **Toyota unveils 8.7 kWh battery for residential applications**

Gogoro:

- Products: motorcycles, swapping stations

Vertical integration: pros and cons

Advantages

- **Control over the supply chain**. Reduced disruptions and quality problems from suppliers
- Backward integration (**control of raw materials**) perhaps at the expense of rivals
- Forward integration (**control of the distribution process** and sale of its finished products.), potentially reducing distribution costs (dealers)
- **Improved planning**
- **Economies of scope**
- **Reduced transaction costs**
- **Reduce time-to-market**
- **Higher market intelligence**

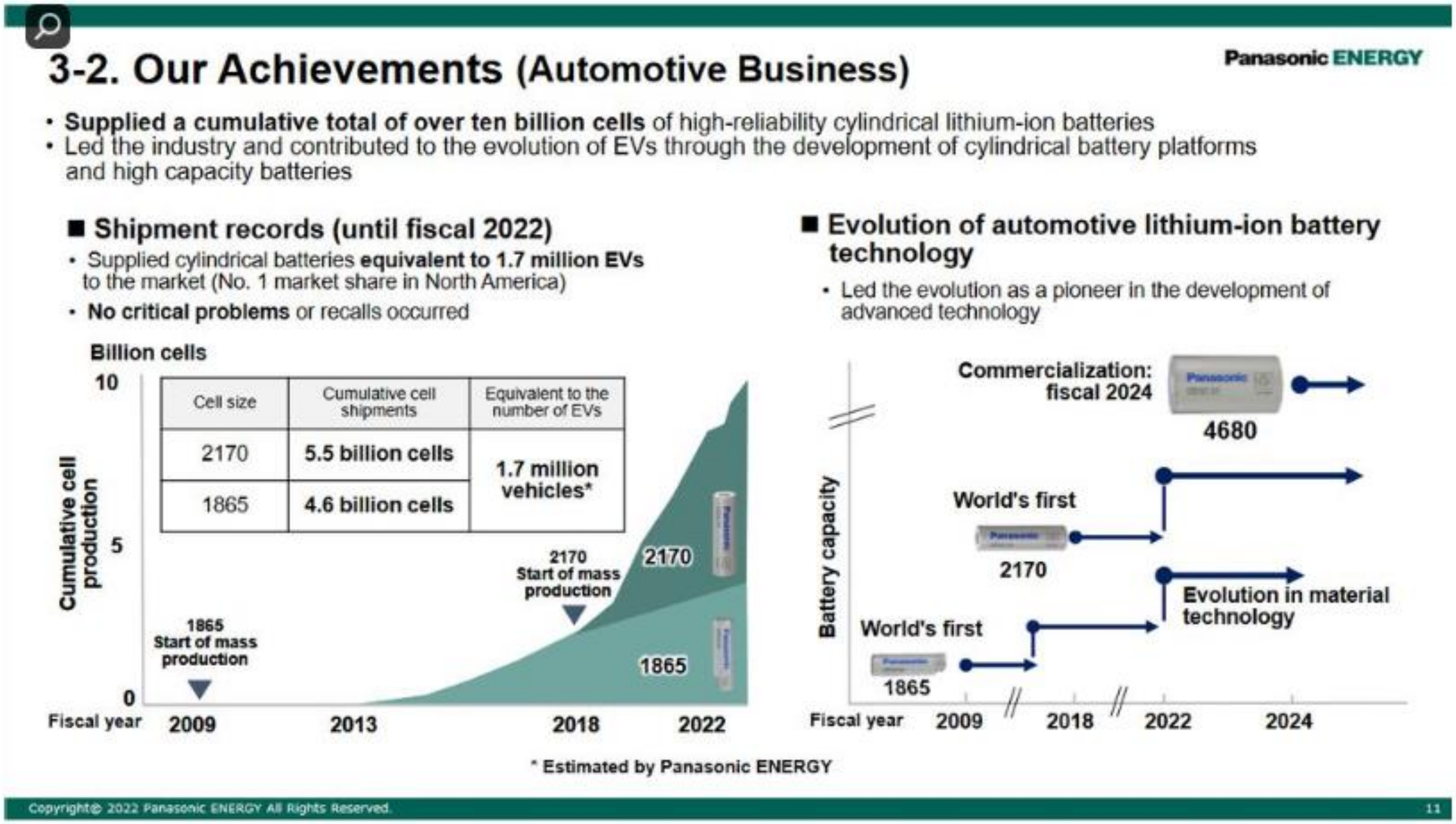
Disadvantages

- The **initial costs are significant**
- **Organizational complexity**
- **Coordination challenges**
- **Outsourcing to a company with superior expertise**
- **Lower economies of scale**
- **Reduced flexibility**
- **Loss of focus**

Joint ventures

- **Panasonic** ships 4680-type battery cell samples to **Tesla**
- **Samsung SDI** & **Stellantis** build battery factory: the previously announced plant is to be built in Kokomo, Indiana, with construction beginning this year
- **General Motors** and **Posco Chemical** have completed the formation of their announced cathode materials joint venture.
- **Renault Group** and **Managem Group** sign an agreement for a sustainable supply of **Moroccan Cobalt**
- **Nano One** (clean technology innovator in battery materials) and **Rio Tinto** (a leading global mining and metals group) announce strategic partnership

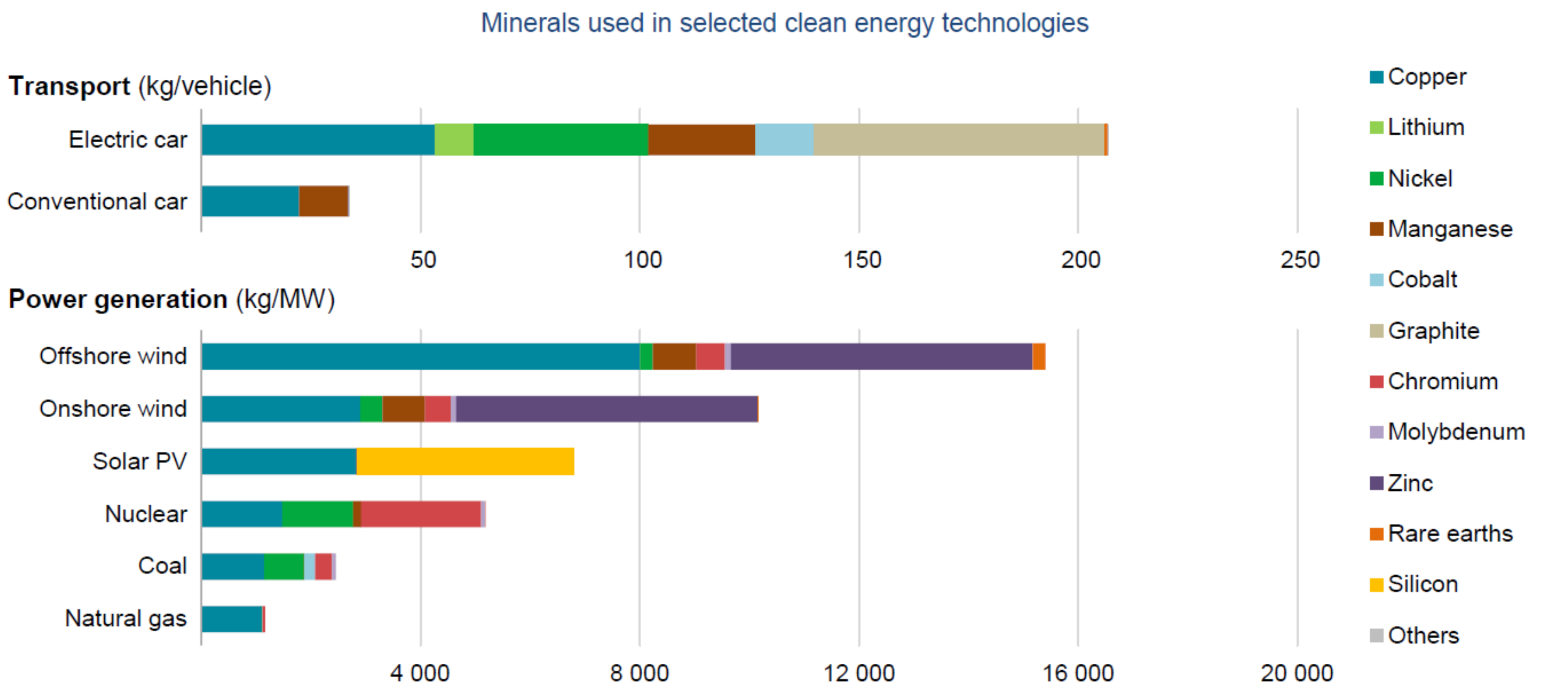
Panasonic Ships 4680-Type Battery Cell Samples To Tesla



https://insideevs.com/news/589715/panasonic-4680-battery-samples-tesla/

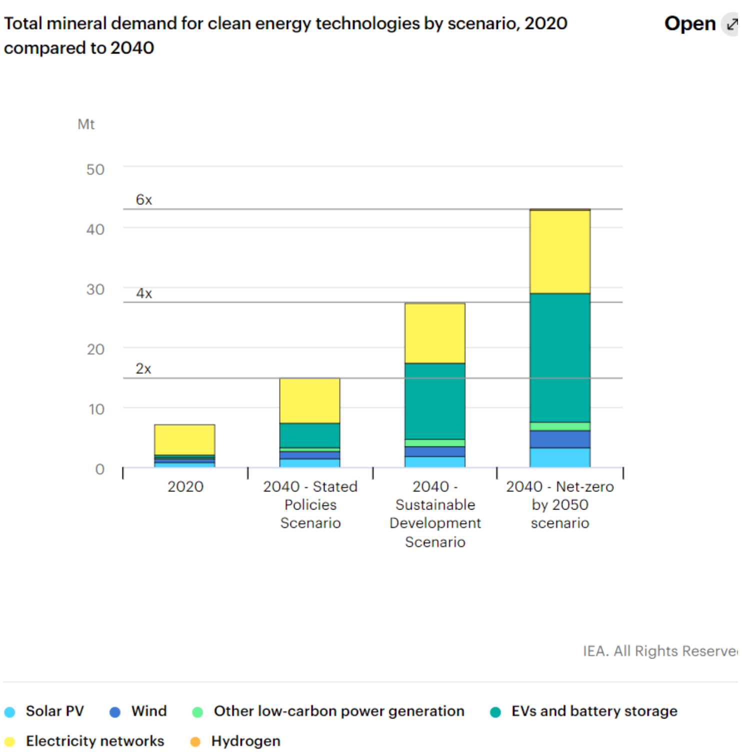
Critical materials challenge: lithium, cobalt, nickel, rare minerals, …

Clean energy technologies imply a significant increase in demand for minerals

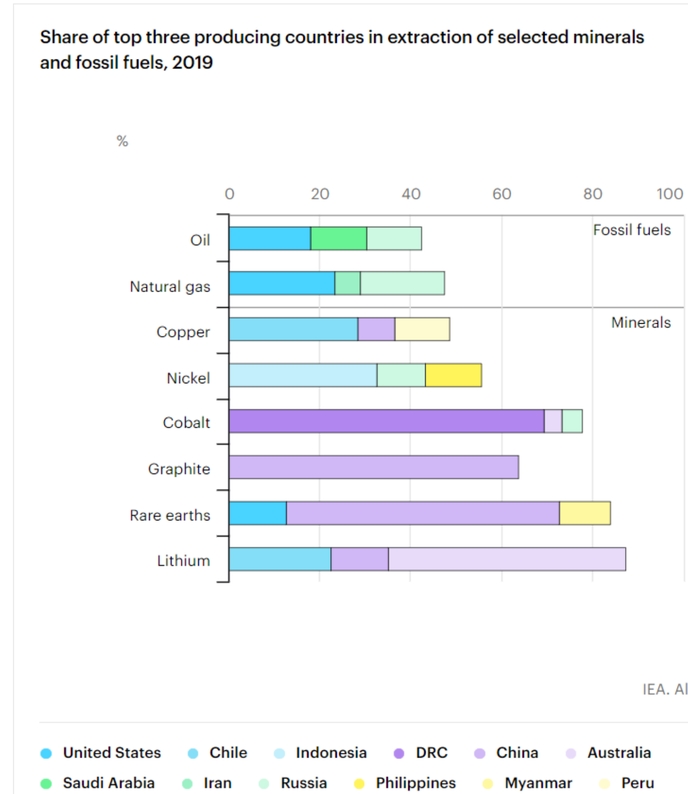


Notes: kg = kilogramme; MW = megawatt. Steel and aluminium not included. See Chapter 1 and Annex for details on the assumptions and methodologies.

Critical materials: increasing price volatility and availability issues

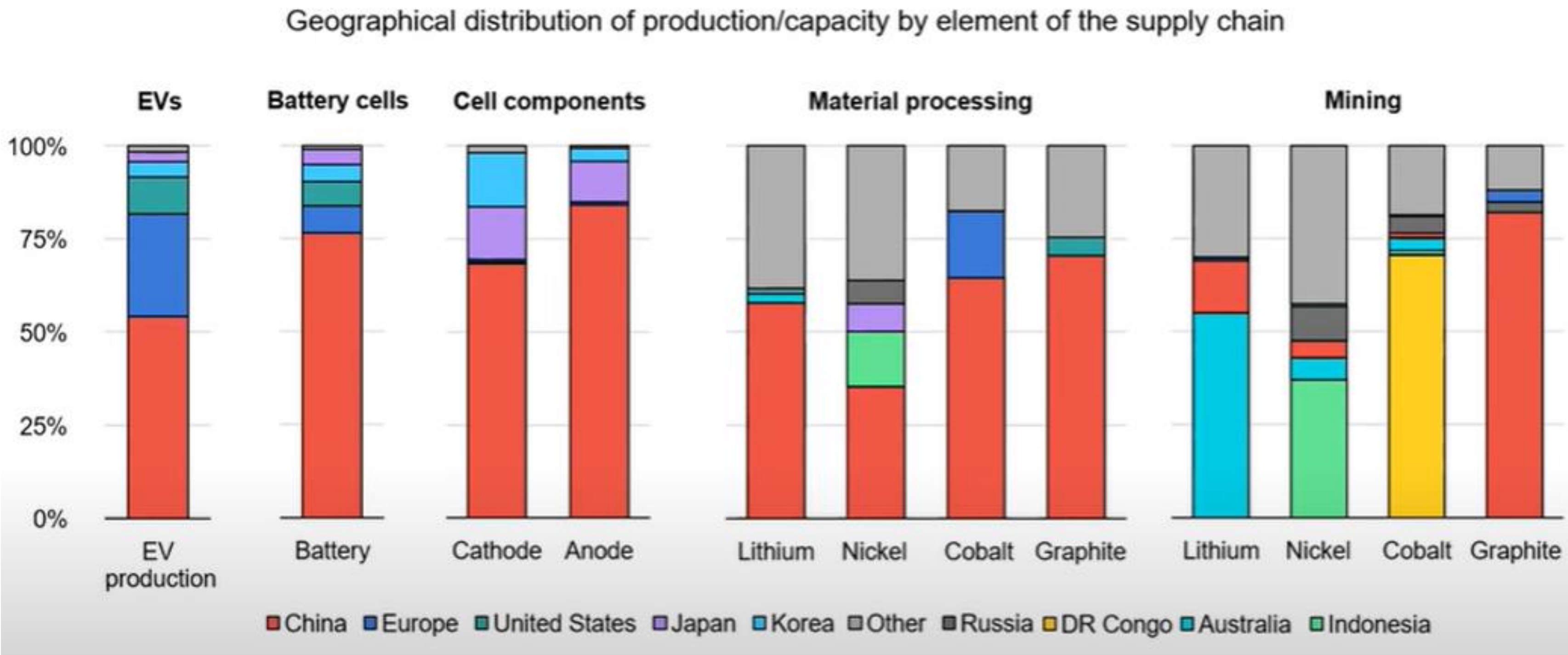


The prices of lithium and cobalt more than doubled in 2021, and those for copper, nickel and aluminum all rose by around 25% to 40%.



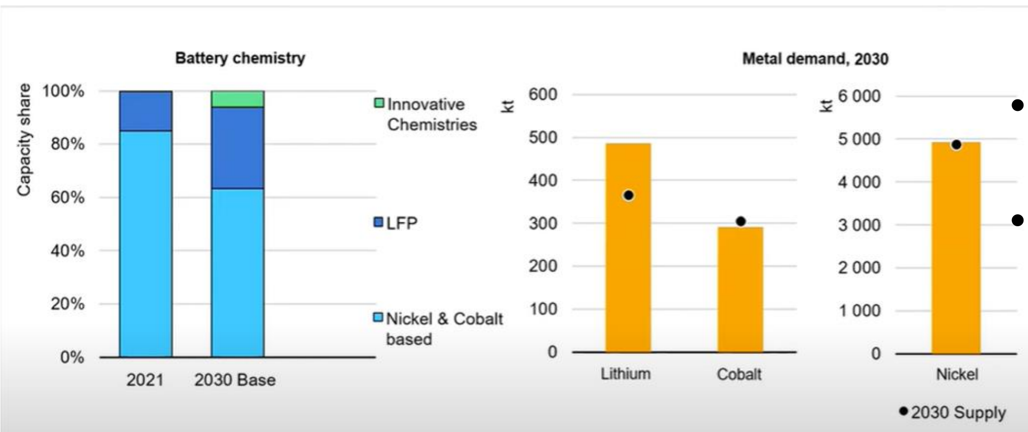
Increasing demand + concentrated supply = increasing prices

Today's EV value chain: concentration levels in the higher levels of the supply chain



China is home to most of global lithium-ion battery production capacity and that of its key components.
Over half of lithium, cobalt and graphite processing&refining capacity is in China

The challenge: anticipating bottleneck to meet future battery demand



Source: IEA

IEA to do list

- policy makers should provide **clear signals** about their climate ambitions and how their targets will be turned into action.
- provide the **confidence** investors need to commit to new projects.
- Efforts to **scale up investment** should go hand-in-hand with a broad strategy that encompasses **technology innovation, recycling, supply chain resilience and sustainability standards**.
- no shortage of resources worldwide
- there are **sizeable opportunities** for those who can produce minerals in a sustainable and responsible manner.
- no single country will be able to solve these issues alone, strengthened **international cooperation** is

Circular economy challenge

“Recycling end-of-life batteries is a **cornerstone to ensuring the electric vehicle transition** is a true success from an environmental perspective” says Emma Nehrenheim, Chief Environmental Officer of Northvolt.

Closing the circle: circular economy

BMW Group partnership with **Zhejiang Huayou Recycling** Technology Co., Ltd. to co-develop innovative cooperation model on closed-loop recycling and cascade utilization of power battery raw materials.

- Huayou Recycling's advanced green metallurgical technology **reduce the carbon emissions** generated in the mining process **by 70%**
- Huayou Recycling is a wholly-owned subsidiary of Zhejiang Huayou Cobalt Co., Ltd. ("Huayou Cobalt"), a Chinese leading supplier of lithium-ion battery materials and cobalt materials.

Hydrovolt, a battery recycling joint venture between **Northvolt** (European supplier of battery cells, founded 2016, 3,000 people)and Hydro (31,000 employees in more than 140 locations and 40 countries), has started commercial recycling operations at its plant in Fredrikstad, Norway.

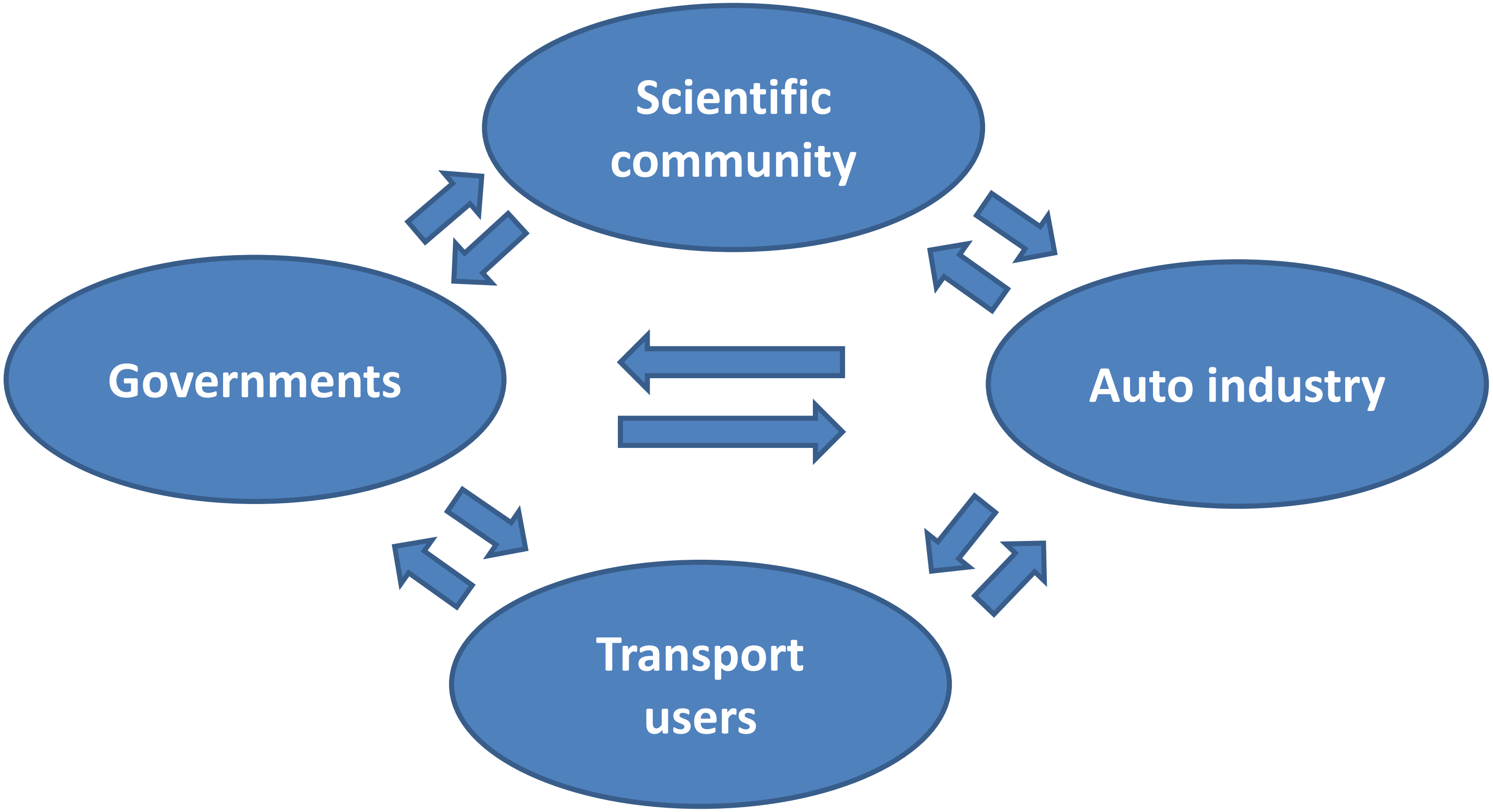
- The fully automated recycling process at Hydrovolt enables up to 95% of battery metals to be recovered from batteries, including plastics, copper, aluminium and black mass, a powder containing metals of nickel, manganese, cobalt and lithium, which will be supplied to Northvolt for further recycling.

Heritage Battery Recycling with **Retriev Technologies** and **KBI**

- **Retriev Technologies** the largest and most diverse lithium-ion battery processor in North America, with over 30 years in operation.

Redwood Materials, Inc, founded by J.B. Straubel, partnered with Panasonic, Ford Motor Company, and Amazon

Decarbonizing transport: the main players



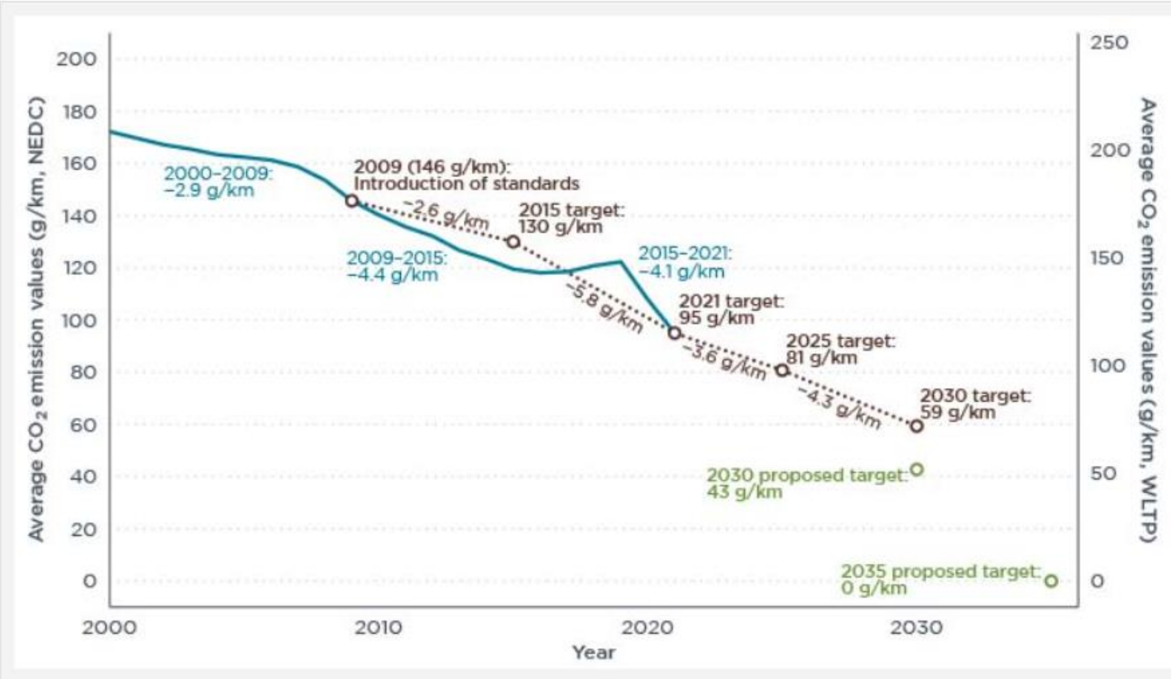
Decarbonising policies

- **Regulatory – Command and control – Standards**:
  - Mandate what to produce\sell
- **Fiscal**:
  - influence consumer's decisions by altering the relative prices\costs
- **Information**: eco-labeling
  - Influencing decisions by informing customers

Regulatory – Command and control - Standards

- **Zero emission vehicle (ZEV) mandates**: require auto manufacturers to sell a minimum amount of ZEVs each year. (USA, Canada, China)
- **Corporate Average Fuel Economy (CAFE) regulation**: require that passenger cars and light trucks produced for sale reach, on average, a certain minimal fuel economy standards. (US)
- The European Union since 2009, it introduced **obligatory corporate average CO2 emission limits** on new passenger cars and light commercial vehicles registered in the European Union and EEA member states. Carmakers who fail to comply are required to pay a premium for each vehicle registered depending on the amount of CO2 g/km exceeded. (EU)
- **Vehicle emissions standards, fuel content regulation**
- **ICEV phase-out legislation:** EU in 2035, Norway in 2025

UE mandatory corporate average CO2 emission limits



Average CO2 values and fleet targets

- Dispute on next standards
- Gap between what carmakers certify in tests and what cars emit on the road

https://theicct.org/eu-co2-standards-nothing-to-fear-feb22/

Command and control: pros and cons

Advantages

- **Highly effective** in reducing the average fuel and CO_2 intensity of a car fleet
- **Enacted at international level**, while fiscal policies are usually set at national level: avoid strategic behaviors
- **Do not require public funds**
- **Allow flexibility on single models**

Disadvantages

- **Inefficient**: do not equate marginal costs among OEMs
- **No incentive to improve over the mandate**
- **Rebound effect**: fuel efficiency increases lead to more travel

Fiscal policies

- **Upfront costs**:
  - Value added taxes,
  - registration taxes,
  - bonus-malus systems
  - company car taxes
- **Operational costs**:
  - Fuel taxes,
  - circulation taxes,
  - parking taxes

Fiscal policies: pros and cons

Advantages

Generate tax revenue to finance transport infrastructure

Registration taxes

- Highly impact on car choice

Fuel taxes

- efficient
- Encourage to buy cars with higher energy efficiency
- reduce car use
- Encourage use of other transport modes
- No rebound effect

Disadvantages

- Political acceptability
- Equity issues
- Difficult to find\set optimal levels
- Strategic behavior at national level

Fuel taxes

- Not very effective on car choice

Fiscal policies differ among countries

Taxes are set at national level and are very different across the EU due to different national goals (reflect environmental factors, to increase government revenues, to stop fuel tourism, to increase competitiveness of national road hauliers, to reflect road damage costs, to promote alternative fuel suppliers and to encourage or discourage particular types of vehicles)

Criteria for taxes on car acquisition and ownership (data source: ACEA, 2014) Status: 1 January 2014 – Ajanovic et al. (2016)

Registration tax based on:	
CO_2 emissions	Austria, Cyprus, Spain, France, Ireland, Lithuania, Malta
Car price + CO_2 emissions	Finland, Hungary, Croatia, Netherlands, Slovenia
Cylinder capacity	Belgium, Greece, Hungary, Poland, Portugal, Romania
Kilowatt/weight/seats	Italy, Slovakia
None	Bulgaria, Czech Republic, Germany, Estonia, Luxembourg, Sweden, United Kingdom
Ownership tax based on:	
Fuel consumption	Denmark
Weight	Lithuania, Denmark, Sweden
CO_2 emissions	Cyprus, Germany, Italy, Croatia, Ireland, Luxemburg, Sweden, United Kingdom
Power (horsepower; kilowatt)	Spain; Austria, Bulgaria, Italy, Hungary
Cylinder capacity	Belgium, Malta, Romania, Slovenia, United Kingdom
None	Czech Republic, Estonia, France, Lithuania, Poland, Slovakia

To summarize

Policies influence market outcomes

- Decarbonization policies: regulatory and fiscal policies

The automotive sector reacts to policies by re-organizing its structure and supply chain

Challenges for the automotive sector:

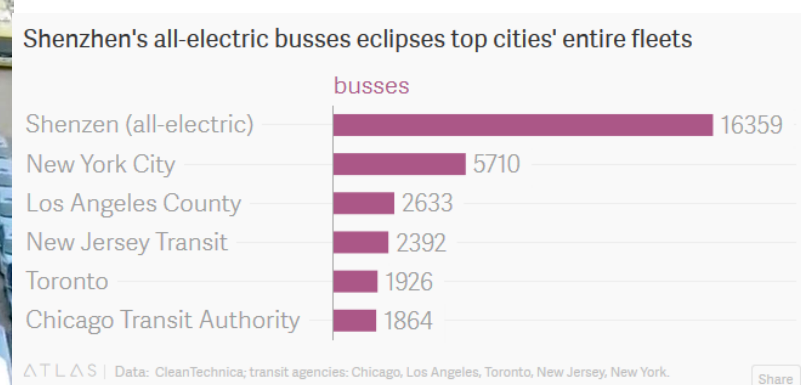
- Technical challenge: EVs are computer and battery on wheels, enabling factor for autonomous driving and connectivity
- Economic challenge: How to make profits out of EVs (cars, trucks and buses)
- Competition challenge: the Chinese (Asian) competition
- Industrial challenge: what business model?
- Critical materials challenge (lithium, cobalt, nickel, rare minerals)
- Circular economy challenge

Not only cars

Scooters and motorcyles

Electric Bus

Shenzhen’s transport commission said on Dec. 27 2017 that it had transitioned its 16,359 buses to all-electric models. The city’s 17,000 taxis are next (63% of them are already electric).



Apr 11, 2018 **Flixbus launches first long-distance electric bus route in France**

Urban goods distribution

This was a privately organized research initiative at the RWTH Aachen University which later became an independent company in Aachen
In April 2016, Deutsche Post DHL Group announced that StreetScooter GmbH would be scaling up to manufacture approximately 10,000 of the Work vehicles annually, starting in 2017.

Die London Electric Vehicle Company (LEVC) zeigt ein erstes Foto ihres elektrifizierten Transporters, der Ende 2019 in den Handel kommen soll.

Long distance trucks

The Tesla Semi is an all-electric battery-powered Class 8 semi-trailer truck prototype which was unveiled on November 16, 2017 and planned for production in 2019. The company initially announced that the truck would have a 500 miles (805 km) range on a full charge and with its new batteries it would be able to run for 400 miles (640 km) after an 80% charge in 30 minutes using a solar-powered "Tesla Megacharger" charging station.

Bundesverkehrsministerium fördert umweltfreundliche Lkw
Die Höhe der Zuschüsse beträgt 12.000 Euro für E-Lkw bis 12 Tonnen und 40.000 für E-Lkw über 12 Tonnen.

Special transport vehicles… in Bern

At the airport..

Maritime Transport

In Norwegen geht in diesem Monat die „Future of the Fjords” in Betrieb. Die 42 Meter lange und 15 Meter breite Elektro-Fähre mit einem Rumpf aus Kohlenstofffasern bietet Platz für nicht weniger als 400 Passagiere.

Air Transport?

(15% of CO2 emissions in Germany)

Tragic Siemens Magnus eFusion Prototype Accident

According to FlyingMag, the Magnus eFusion two-seat prototype crashed near Budapest, Hungary, after it was spotted catching on fire. The cause has yet to be officially determined. So far, the Siemens electric motor doesn't seem to be at fault and the culprit seems to lie with the batteries. We are waiting for the official report.

International shipping?

Thank you for your attention!