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

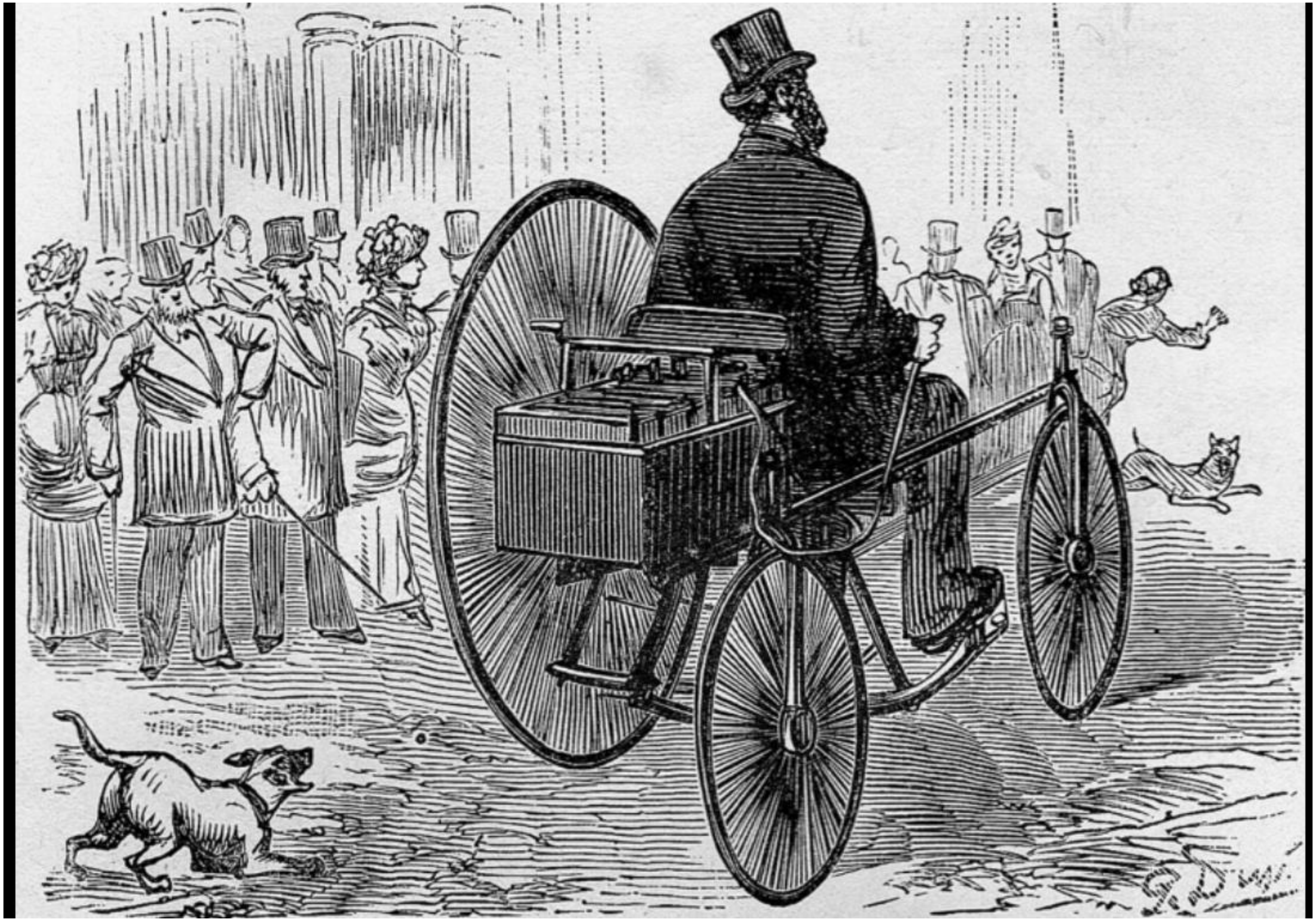
A car (or automobile) is a wheeled motor vehicle used for transportation. Most definitions of cars say that they run primarily on roads, seat one to eight people, have four wheels, and mainly transport people rather than goods.

Car, carriage, to carry
Vettura, autovettura

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

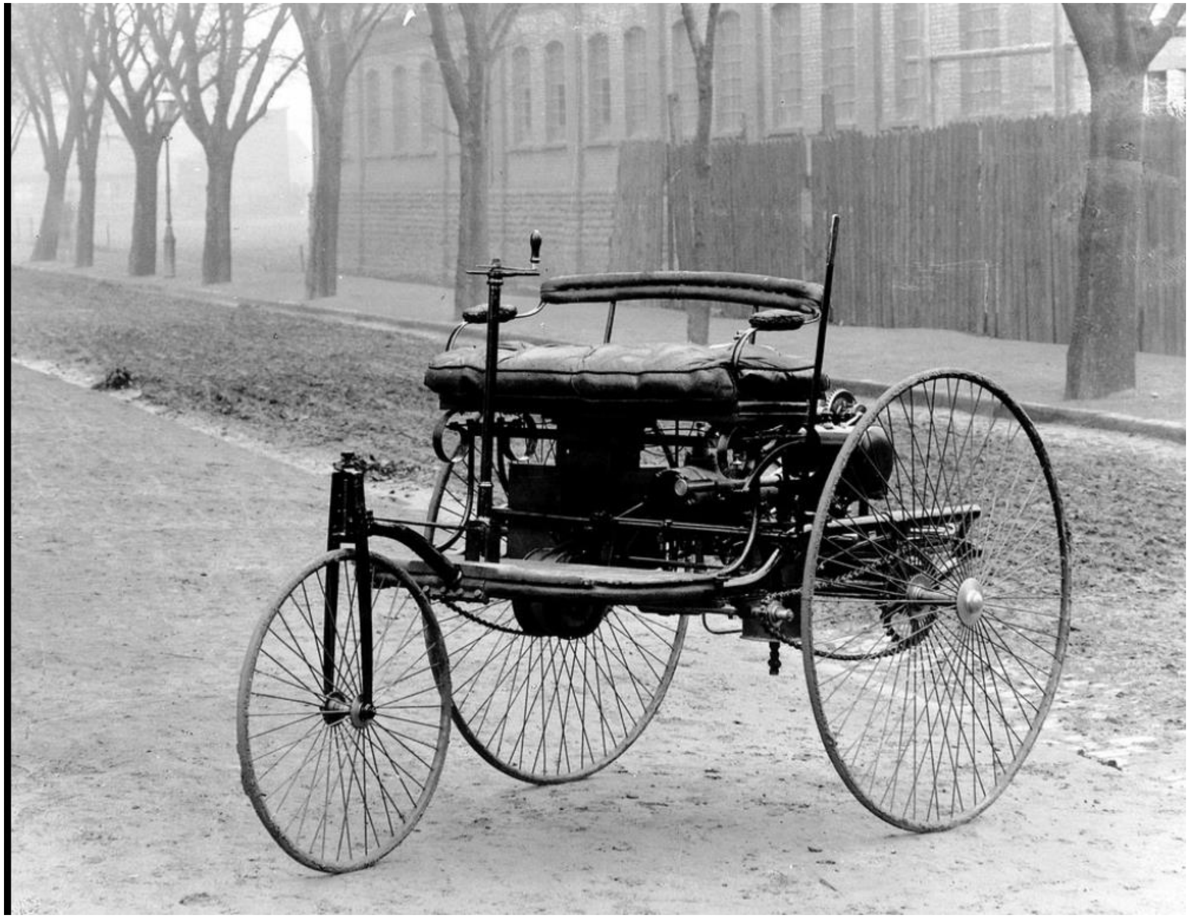
1. (*rail transport*) A railroad car that carries passengers.
2. (*vehicles*) A road vehicle that carries passengers; a motorcar or automobile.

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.



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.

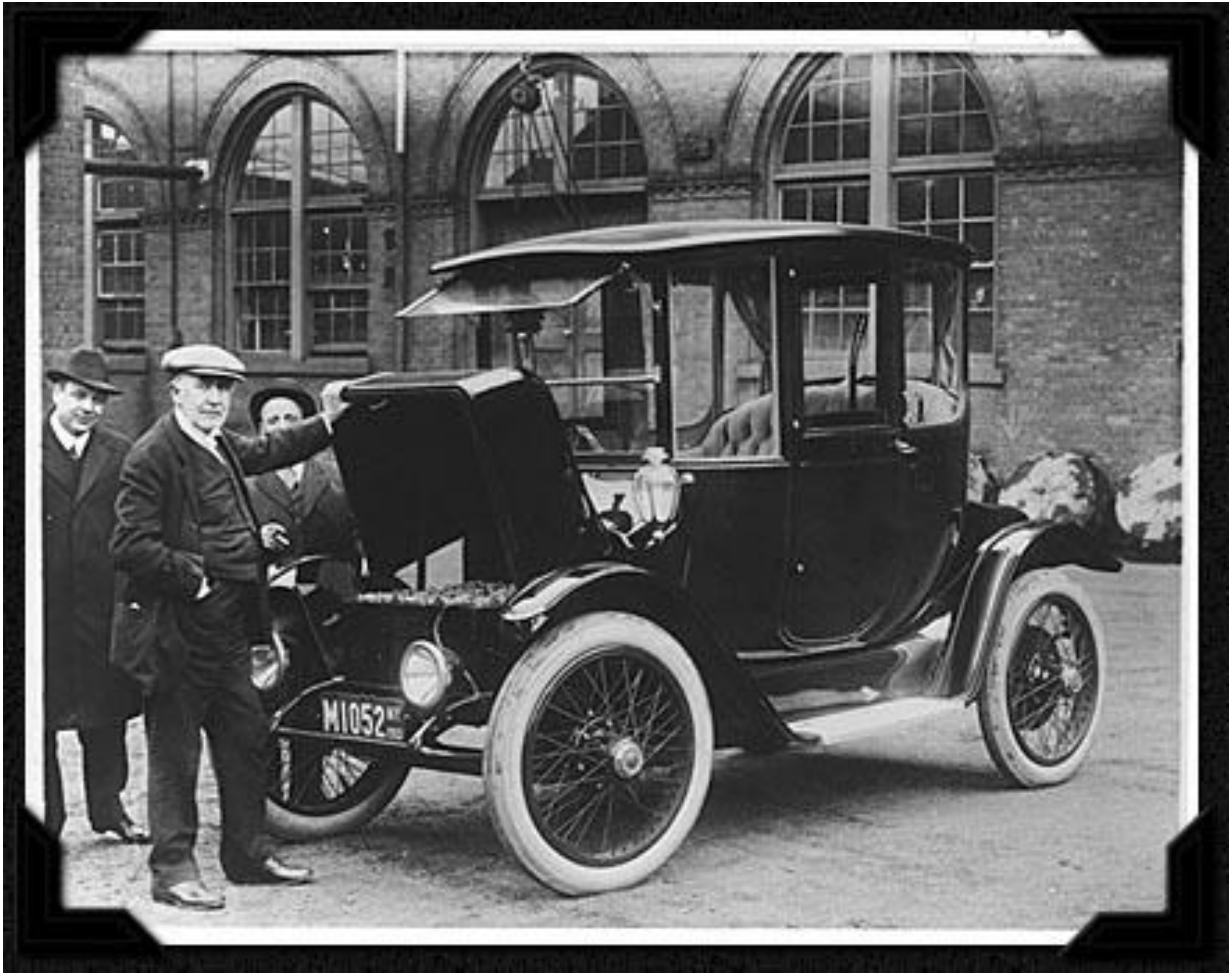
After developing a successful **gasoline-powered two-stroke piston engine** in 1873, Benz focused on developing a motorized vehicle **while maintaining a career as a designer and manufacturer of stationary engines** and their associated parts.

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

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

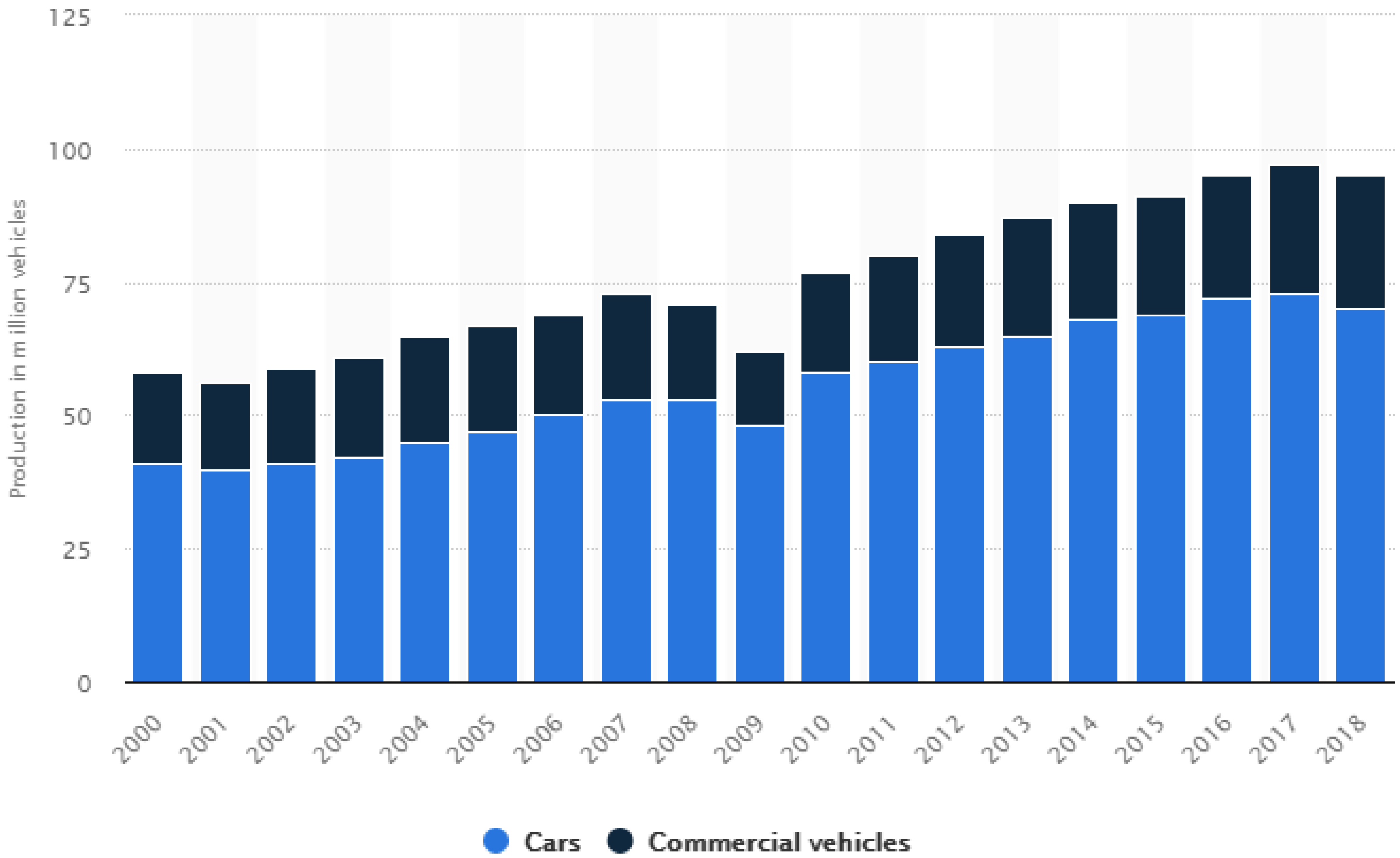
A rapid expansion of petrol infrastructure

Many fuel types

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

Fiat 500 "Topolino" 1936

Estimated worldwide automobile production from 2000 to 2018 (in million vehicles)

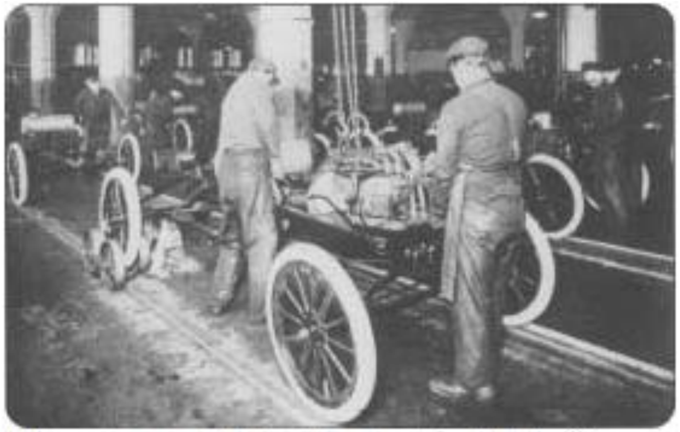


https://www.statista.com/statistics/262747/worldwide-automobile-production-since-2000/

Car manufacturing

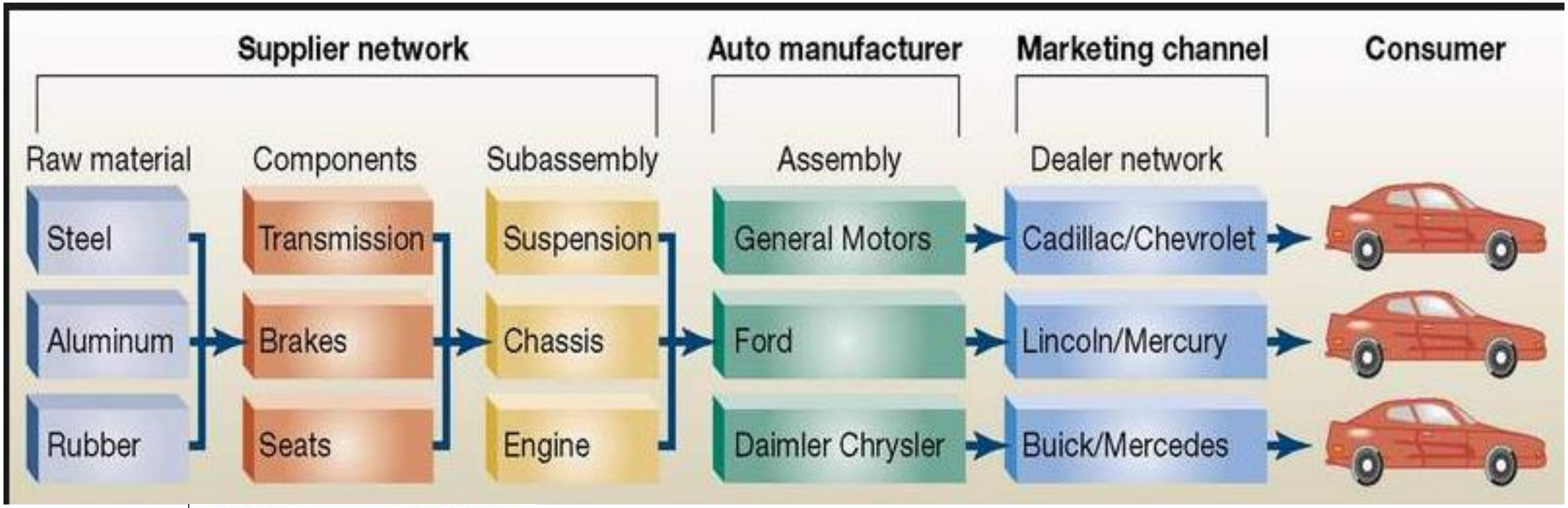
The automotive industry is a major industrial and economic force worldwide. It makes 60 million cars and trucks a year, and they are responsible for almost half the world's consumption of oil. The industry employs **4 million people** directly, and many more indirectly.

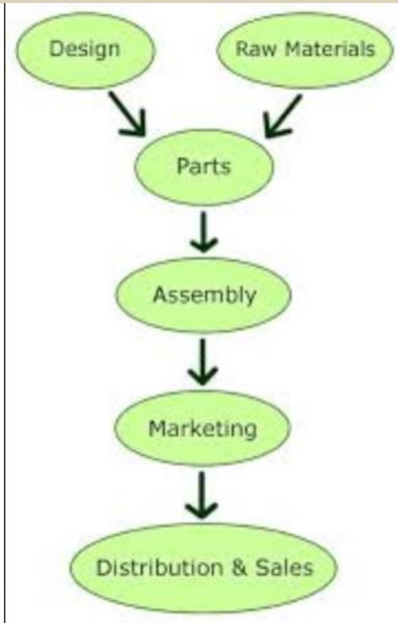
Despite the fact that many large companies have problems with overcapacity and low profitability, the automotive industry retains very strong influence and importance. **The industry also provides well-paying jobs with good benefits, has heavy linkages with supplier industries** (which gives it an oversized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



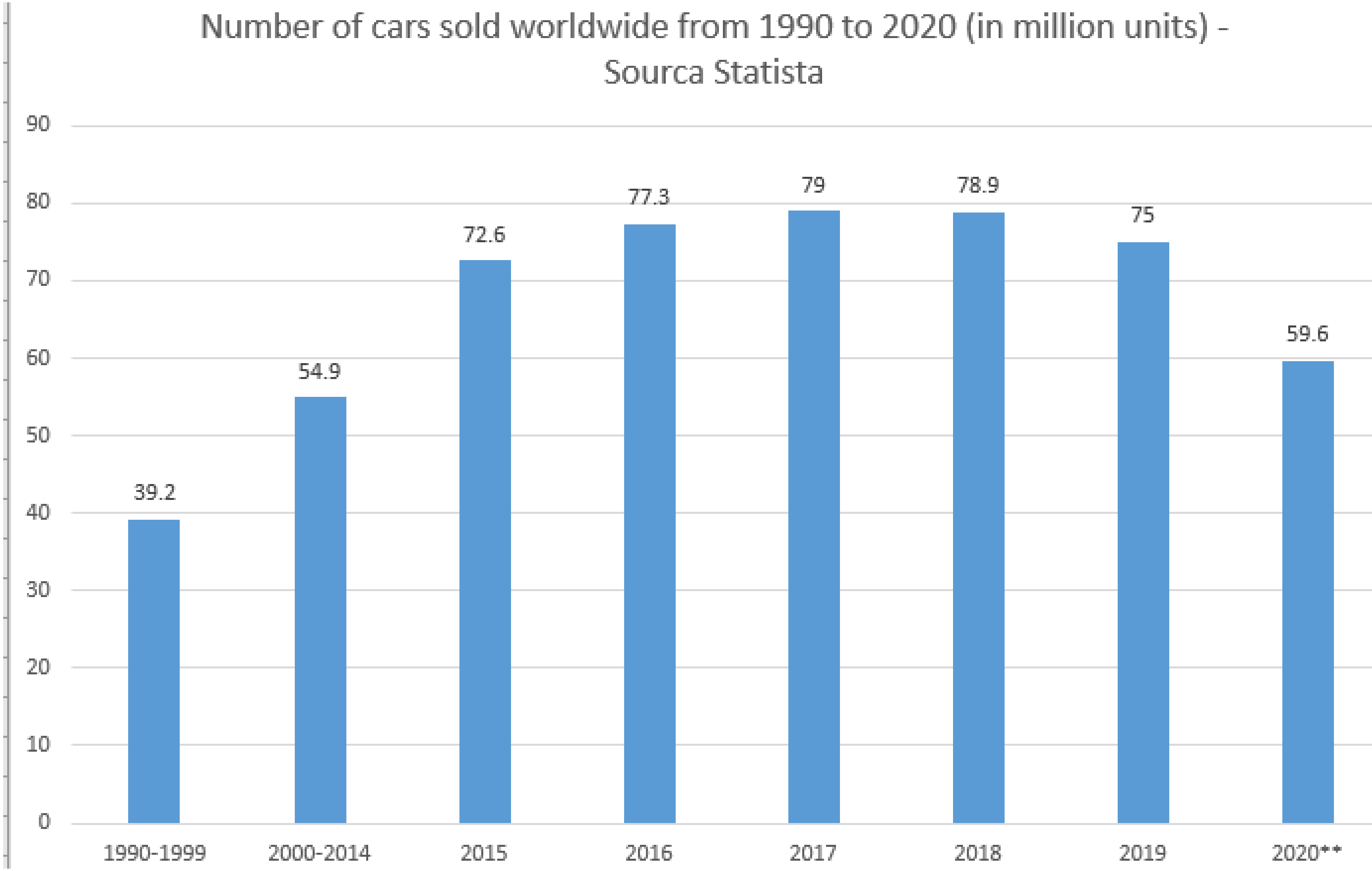
Workers install engines on Model Ts at a Ford Motor Company plant. The photo is from about 1917.

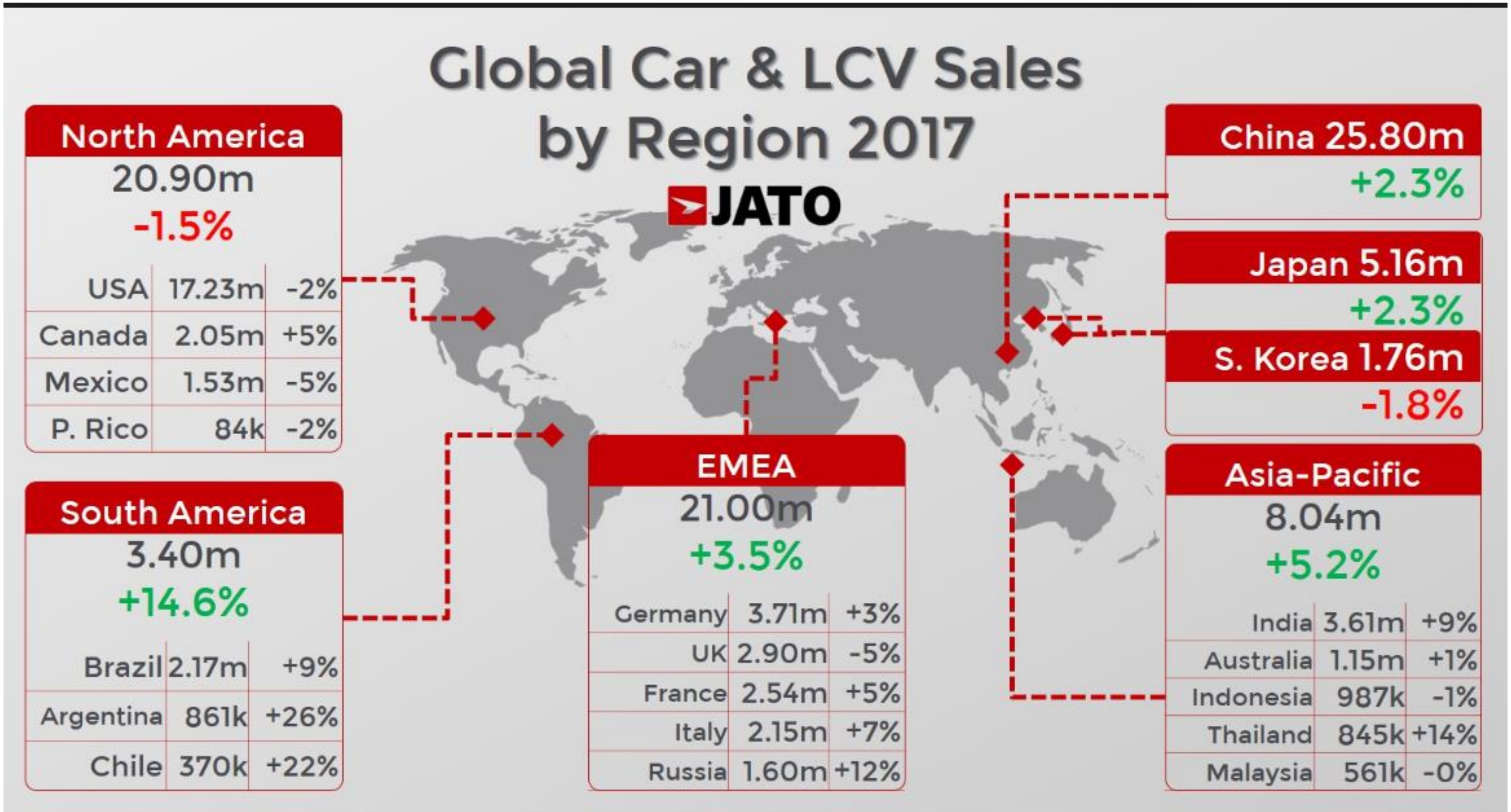
The value chain





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



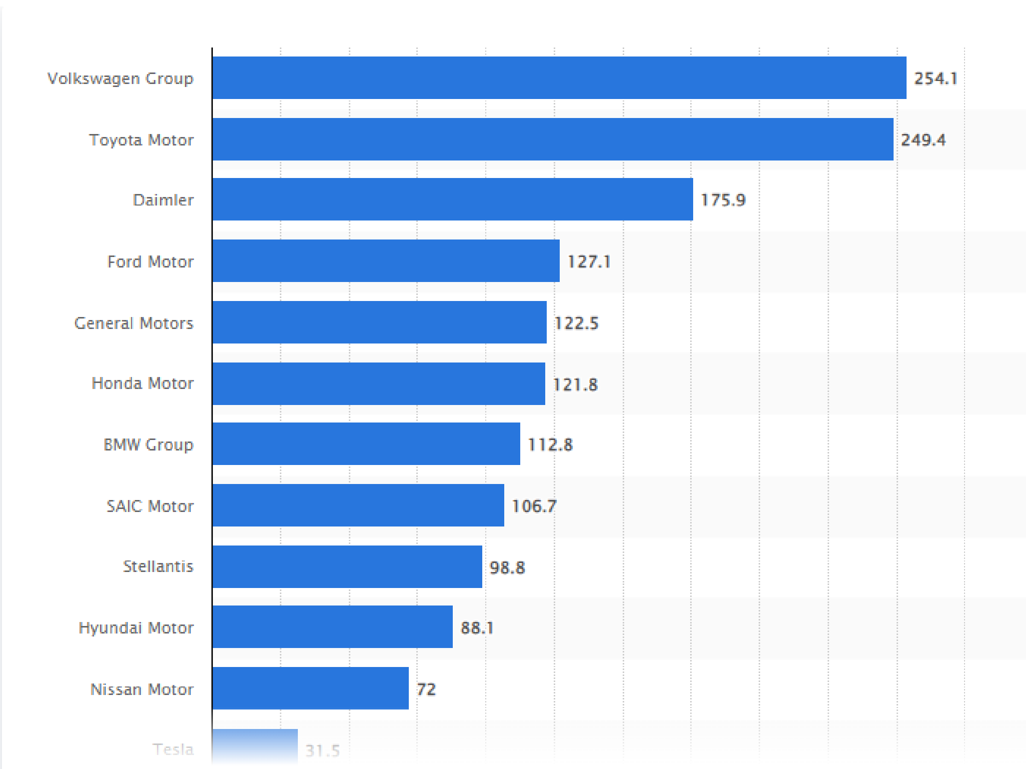


Number of road motor vehicles per 1,000 inhabitants

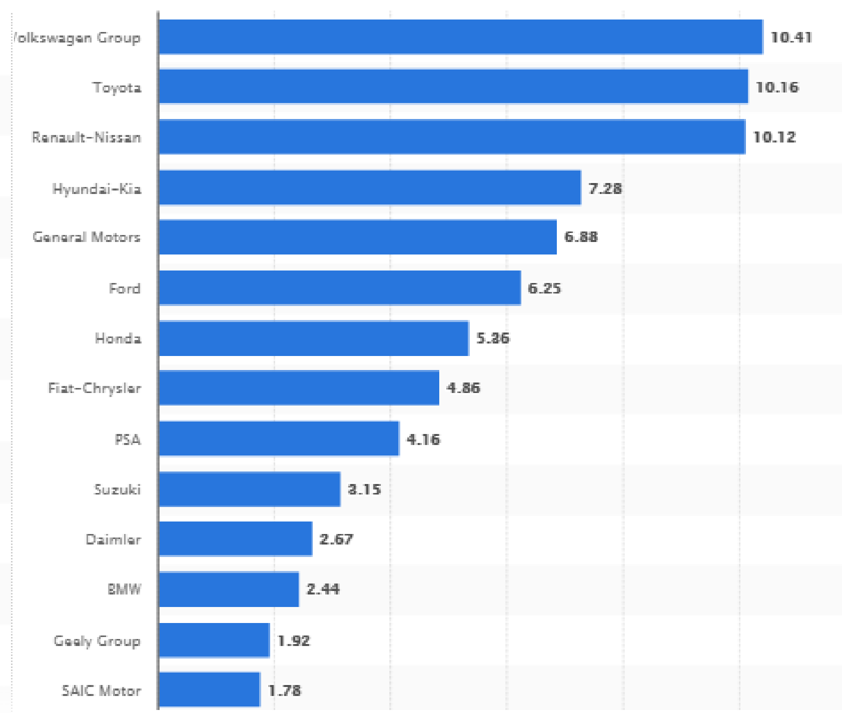
2	United States	910	255,009,283[2]	2017[2]
10	Italy	679		[1]
73	China	154	212,560,000	2016[32][33]
134	India	50	55,725,543[43]	2015

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

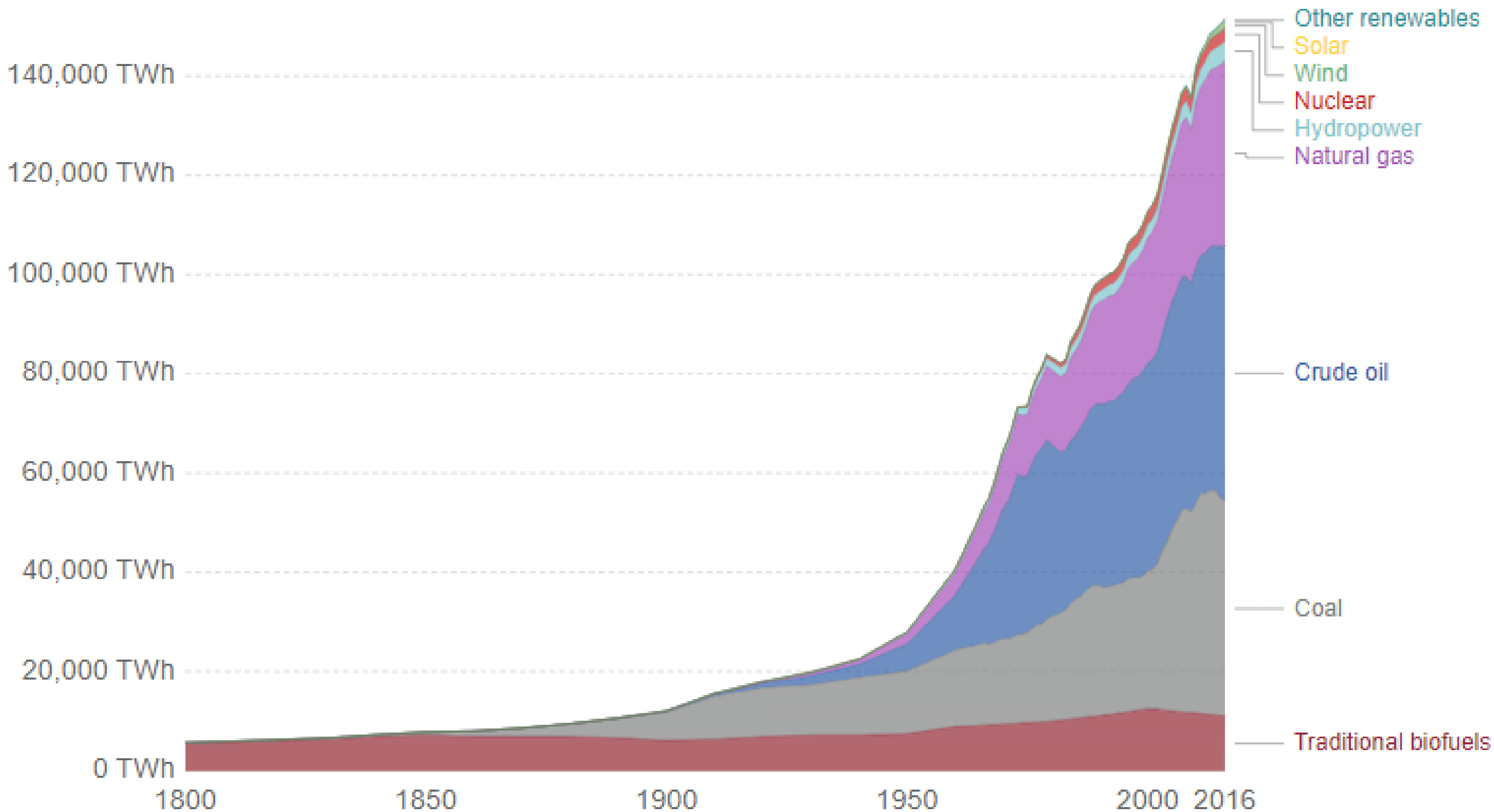
- **Nuclear energy**
- **Nuclear fusion**

Renewable resources

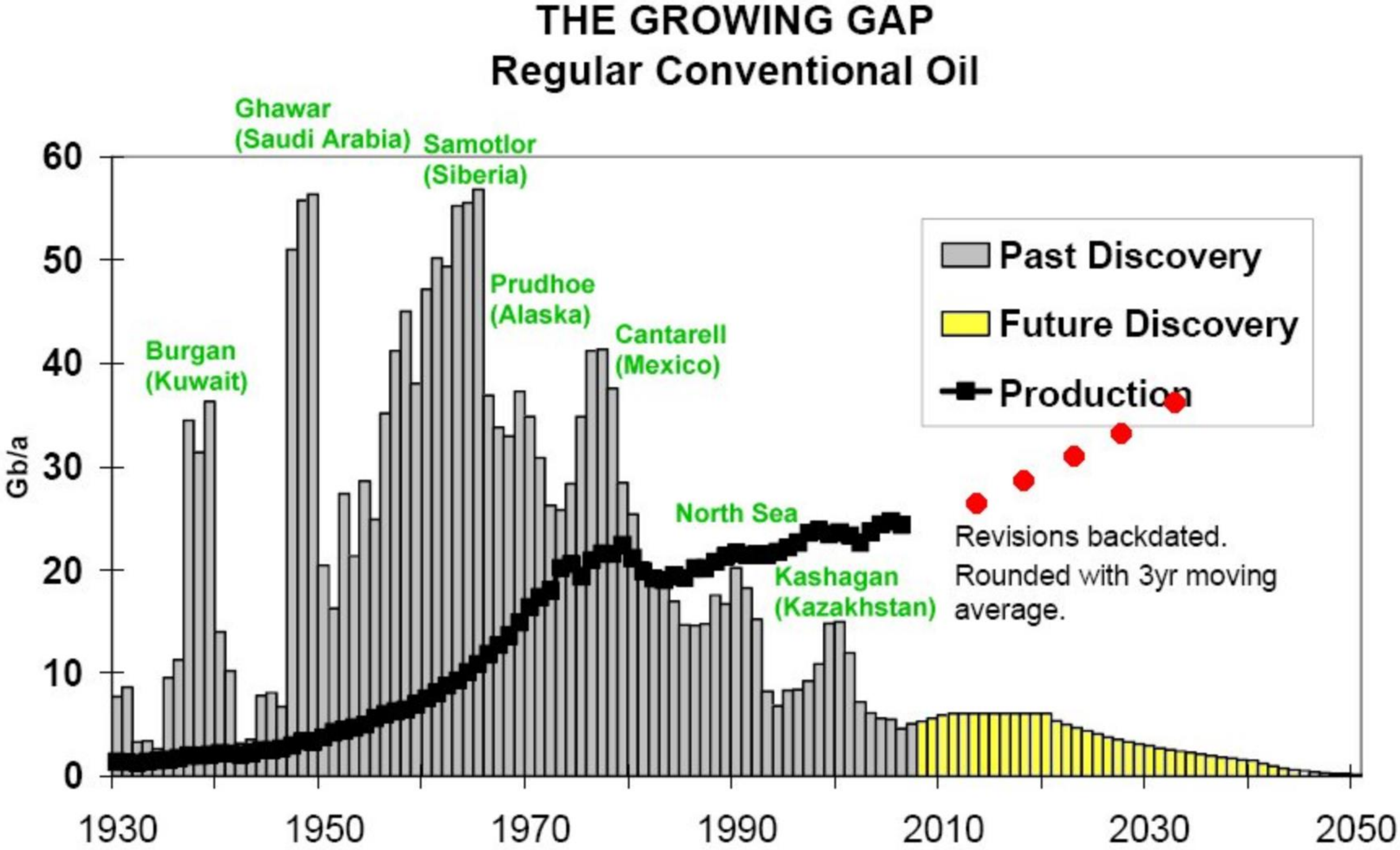
- **Solar energy**
- **Wind power**
- **Wave and tidal power**
- **Geothermal**
- **Biomass**
- **Hydropower**

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.

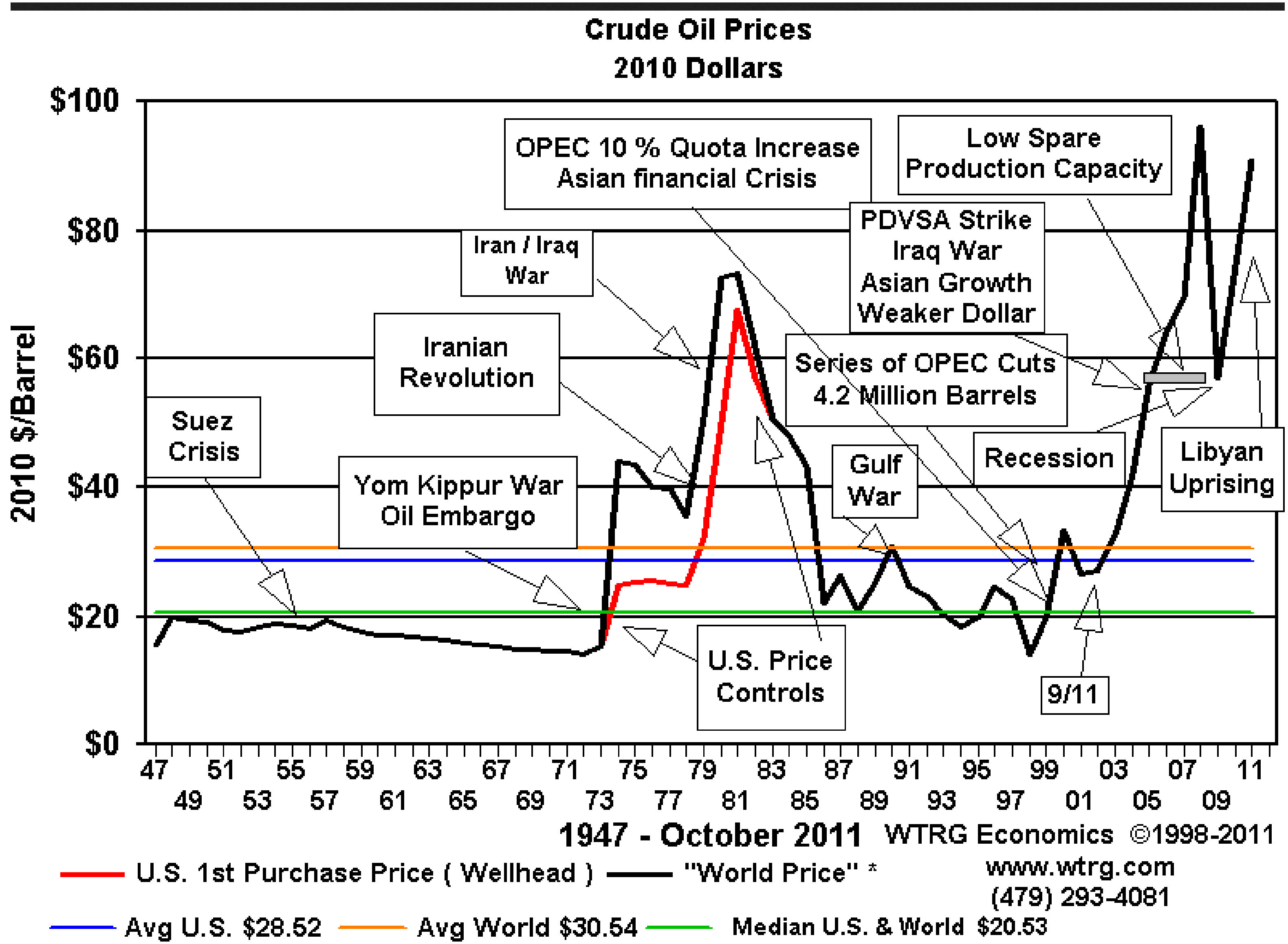


Source: Vaclav Smil (2017) and BP Statistical Review of World Energy ver the next few years we will find less and less deposits in front of one Increasing production: DROPS



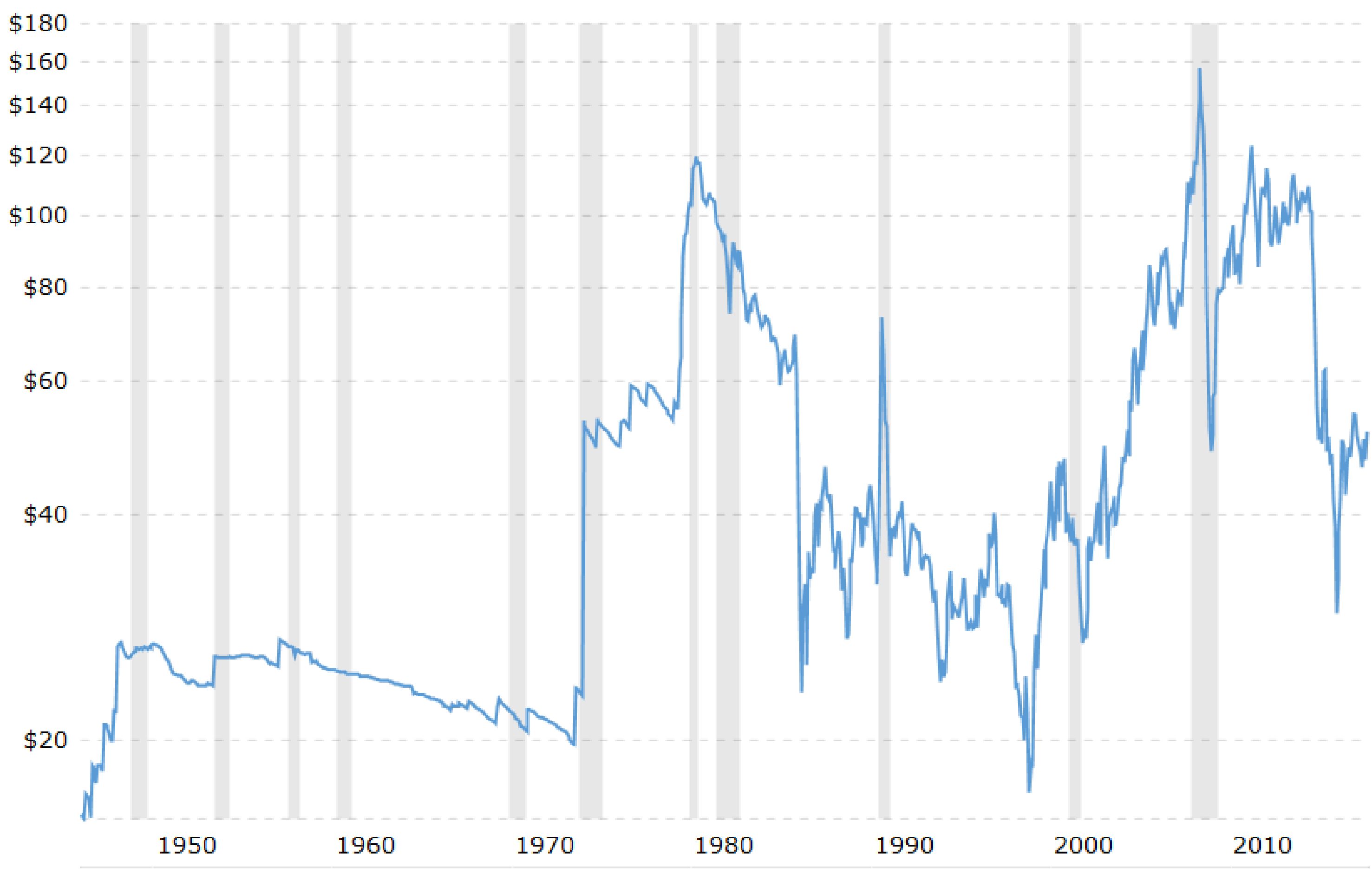
Over the next few years less and less new oil reserves will be available to satisfy an ever-increasing production. (Fermeglia, 2017)

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.

03:40 am CDT 01/12/2021 Technicals

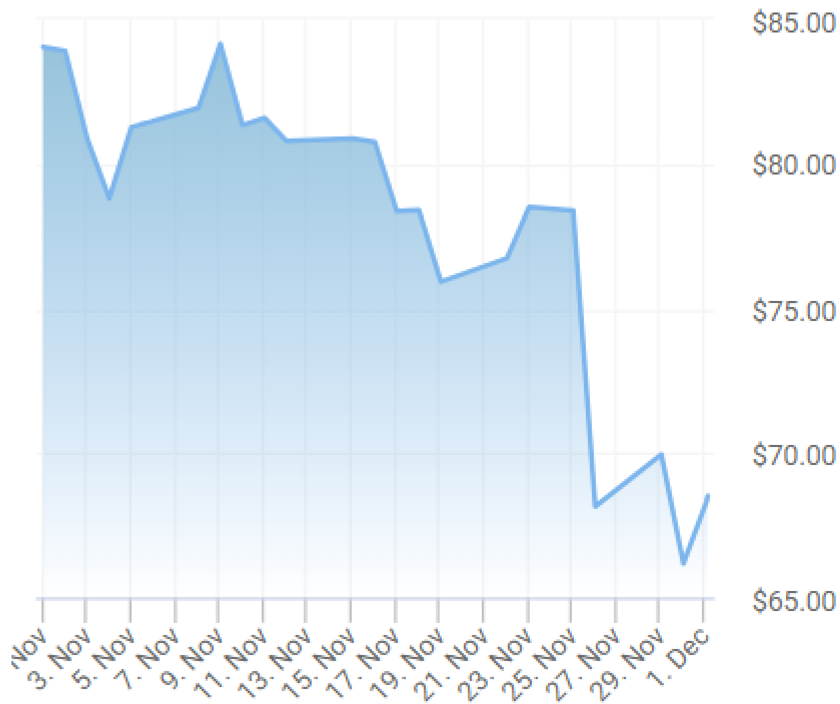
WTI Crude (January Contract)

68.56 +3.60%

03:39 am CDT 01/12/2021 Technicals

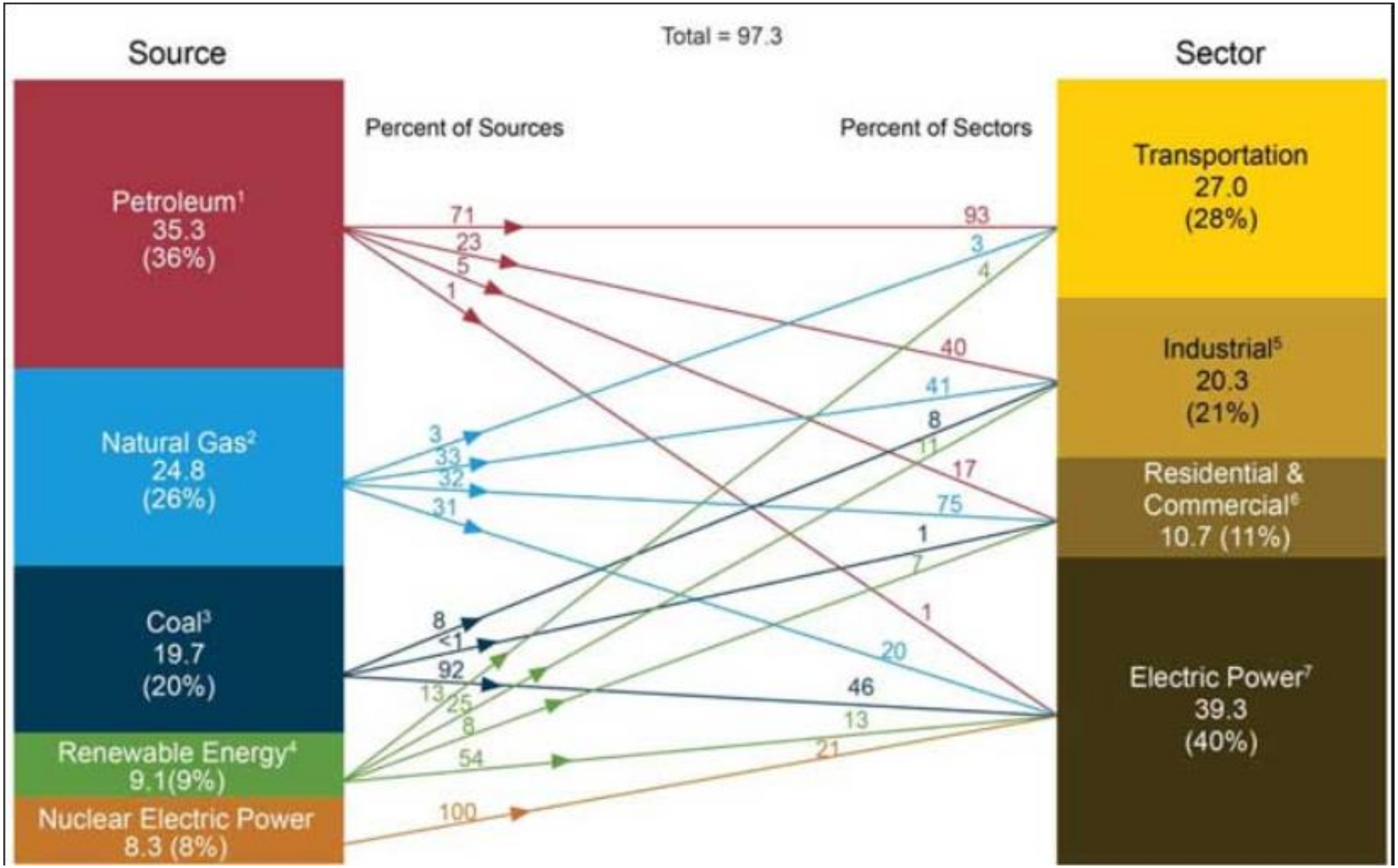
WTI Crude (January Contract)

68.51 +3.63%



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

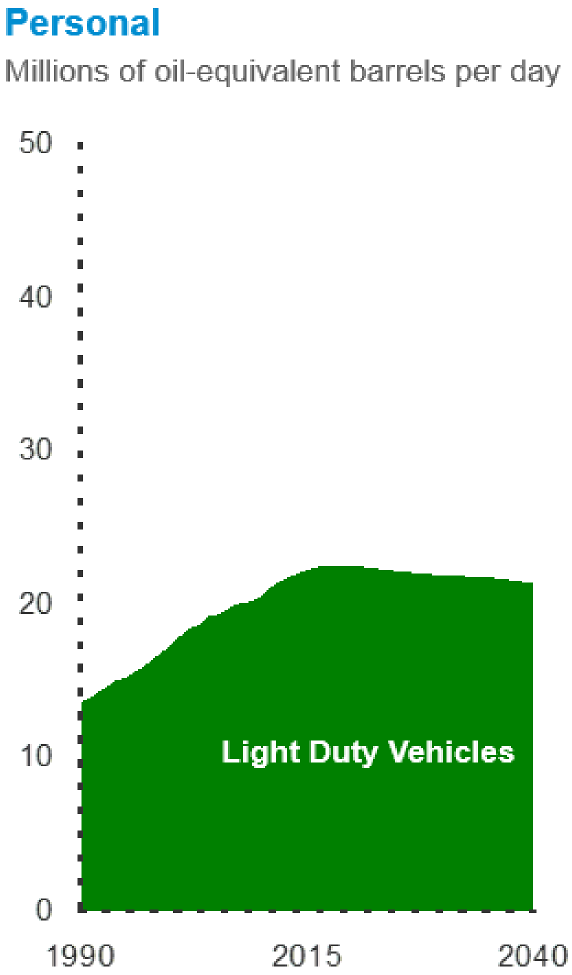
Trasport's share of energy consmption

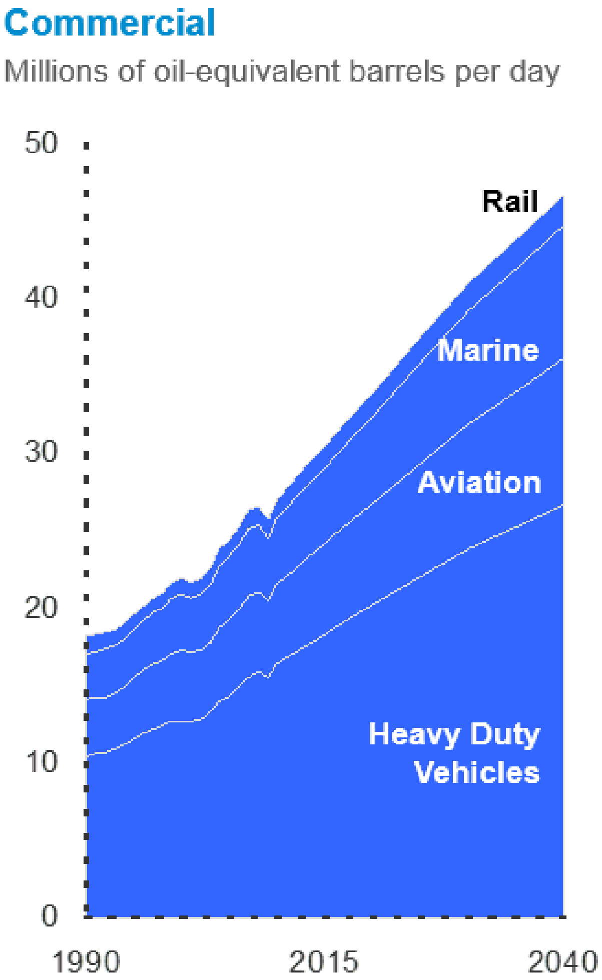


28% of total energy, 93% of which petroleum

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

Global energy demand for transportation





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.

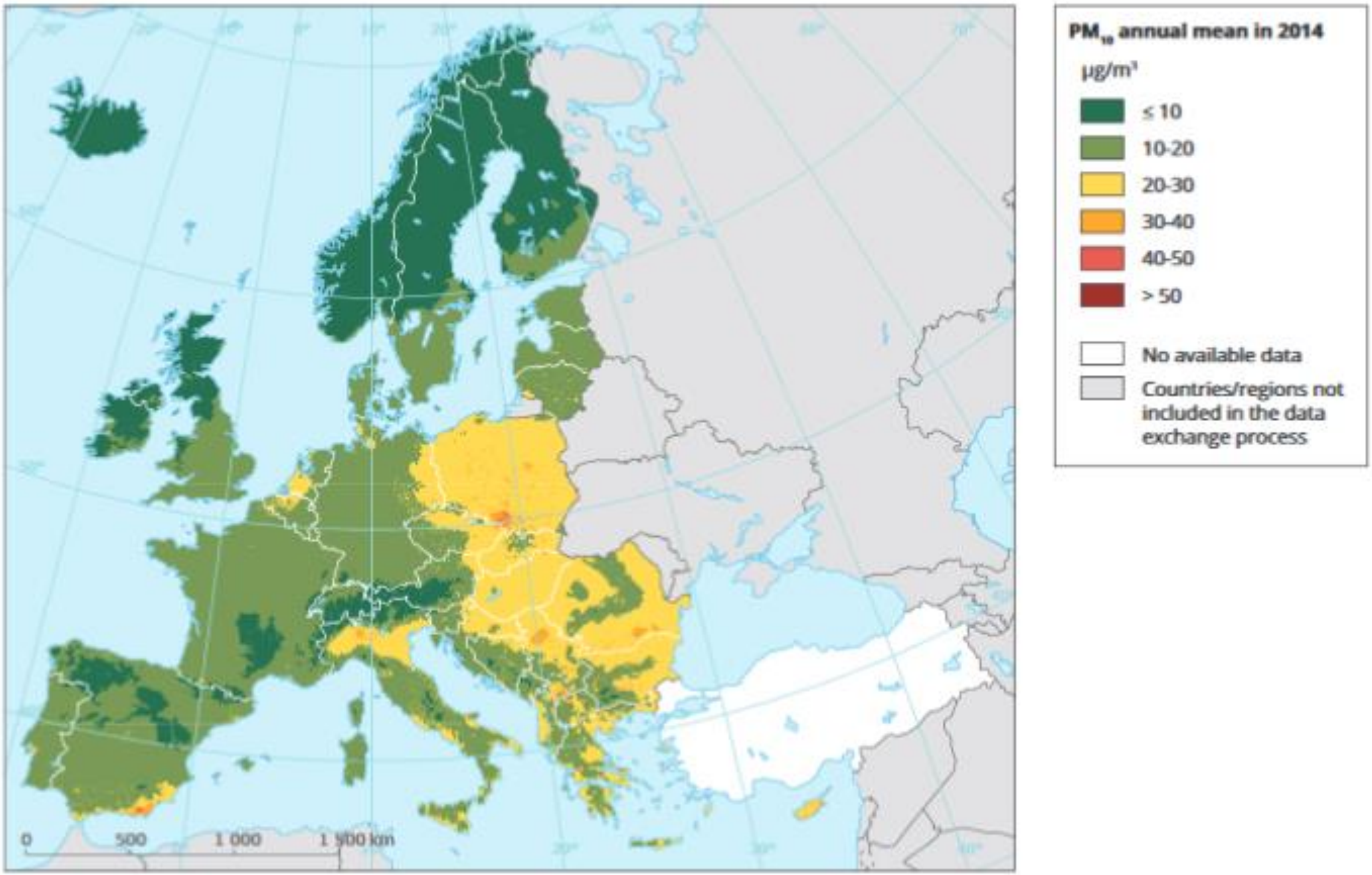
Table ES.1 Percentage of the urban population in the EU-28 exposed to air pollutant concentrations above certain EU and WHO reference concentrations (2012–2014)

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

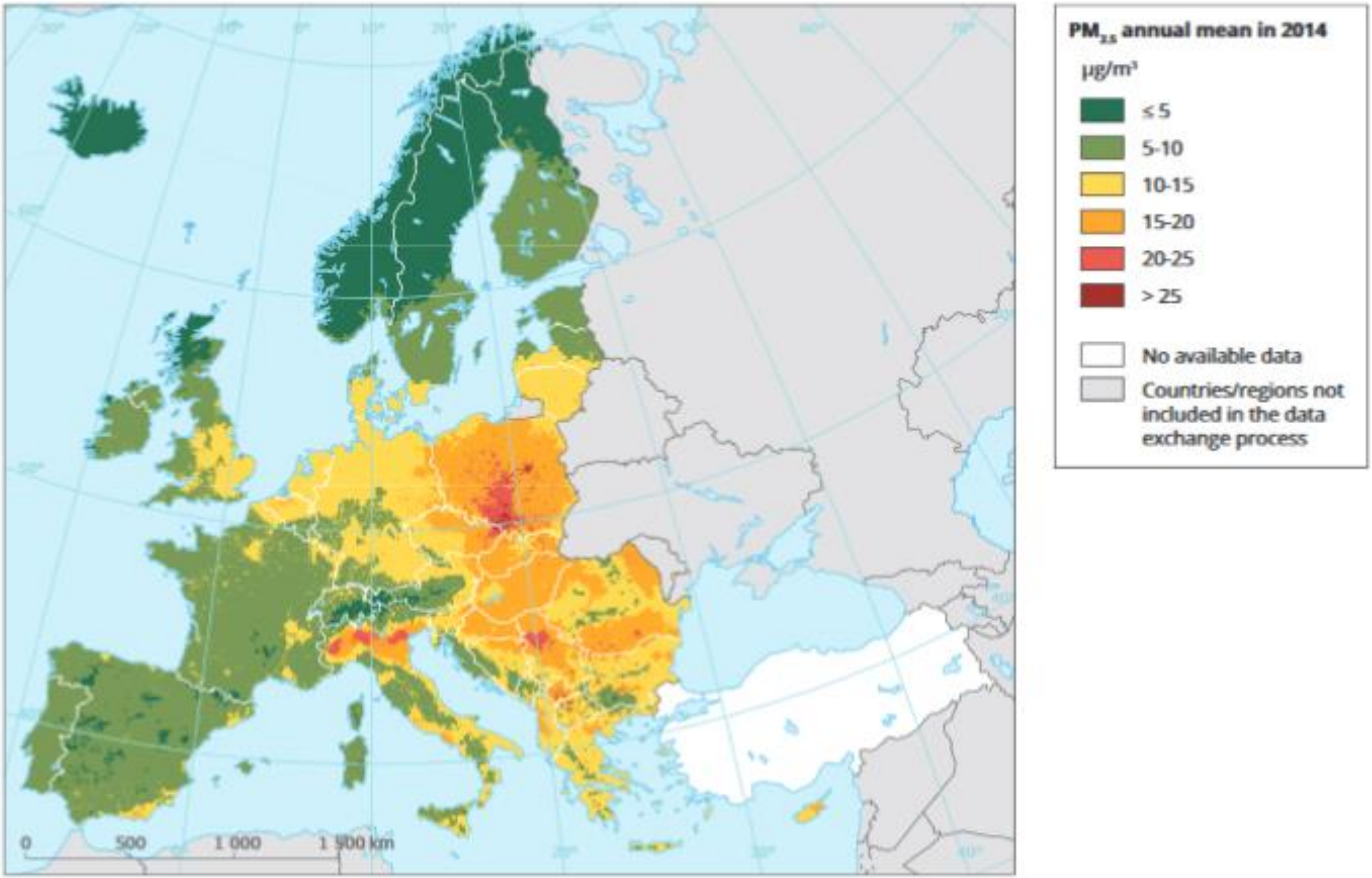
Air pollution: PM10

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

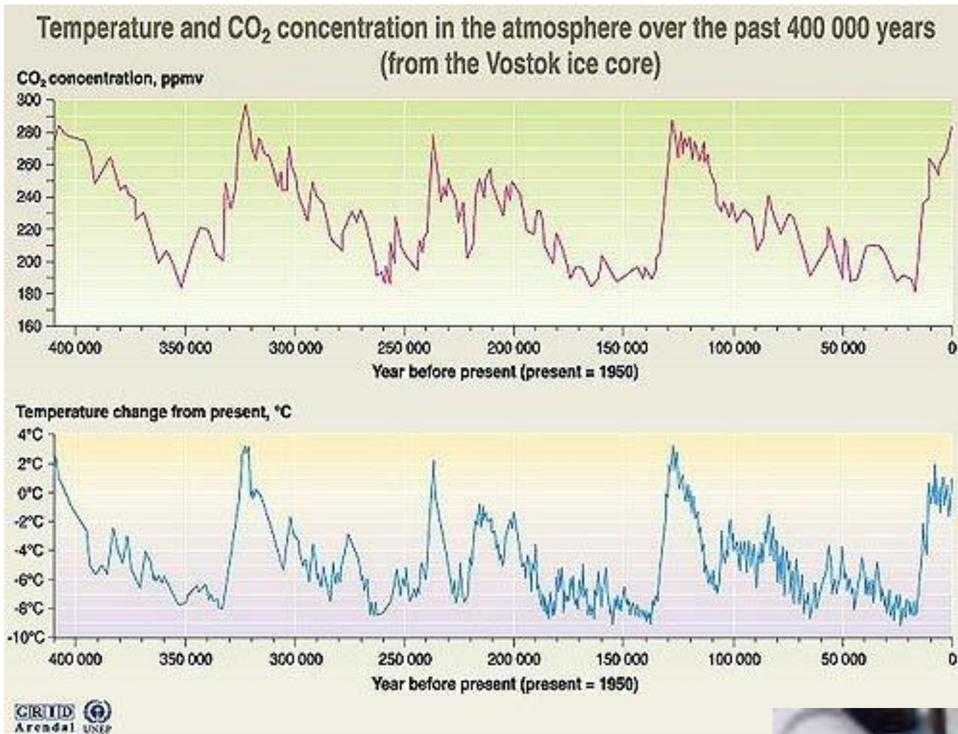
World Health Organization (WHO) estimates that about 40 % of the population in the EU is exposed to road traffic noise at levels exceeding 55 dB(A), and that more than 30 % is exposed to levels exceeding 55 dB(A) during the night.

Global warming

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

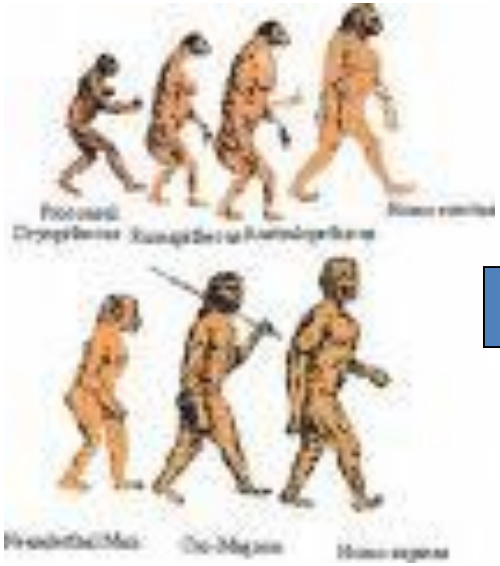
- **Is global warming happening?**
- **(If yes) Is global warming due to human activities?**

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

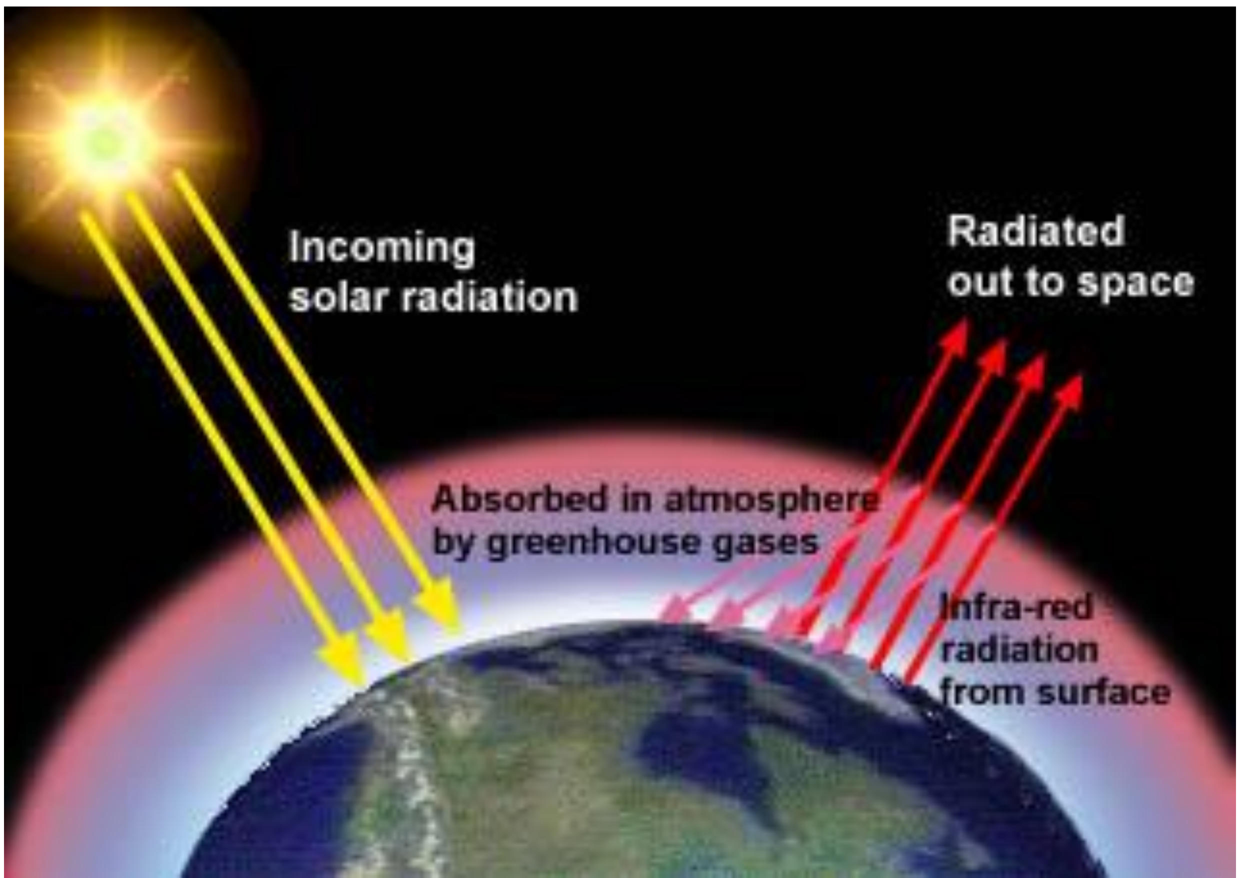
Since the beginning of the industrial era (“Anthropocene”) humans have injected into the atmosphere many types of pollutants

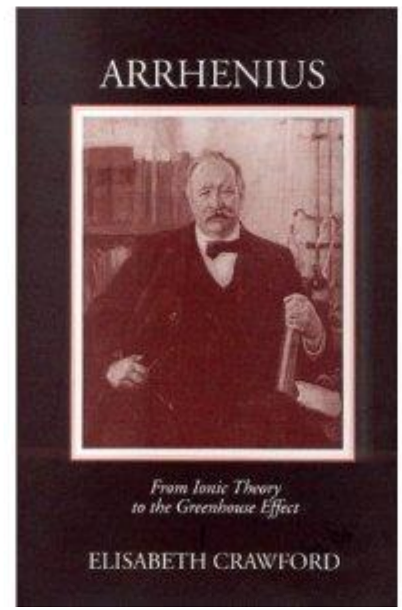


The Greenhouse Effect

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

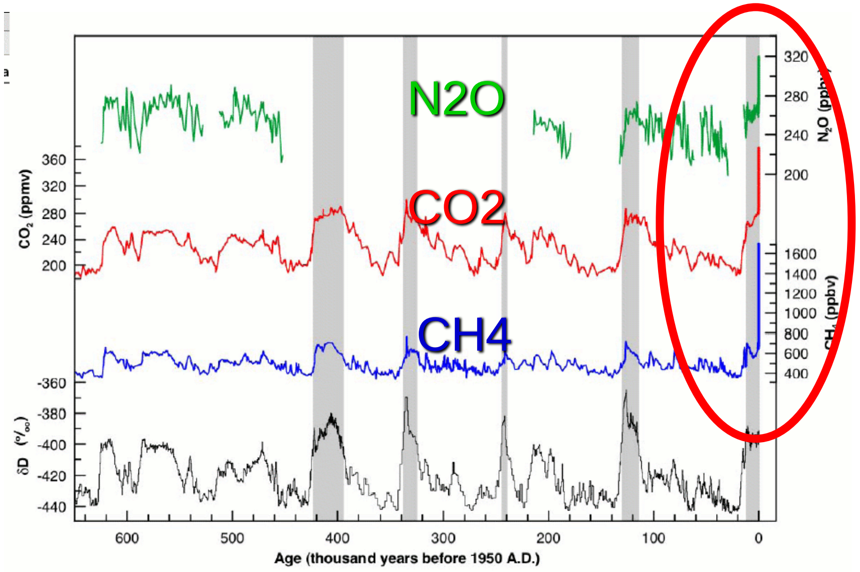
The main GHGs are H_2O, CO_2, O_3, CH_4, N_2O, CFCs

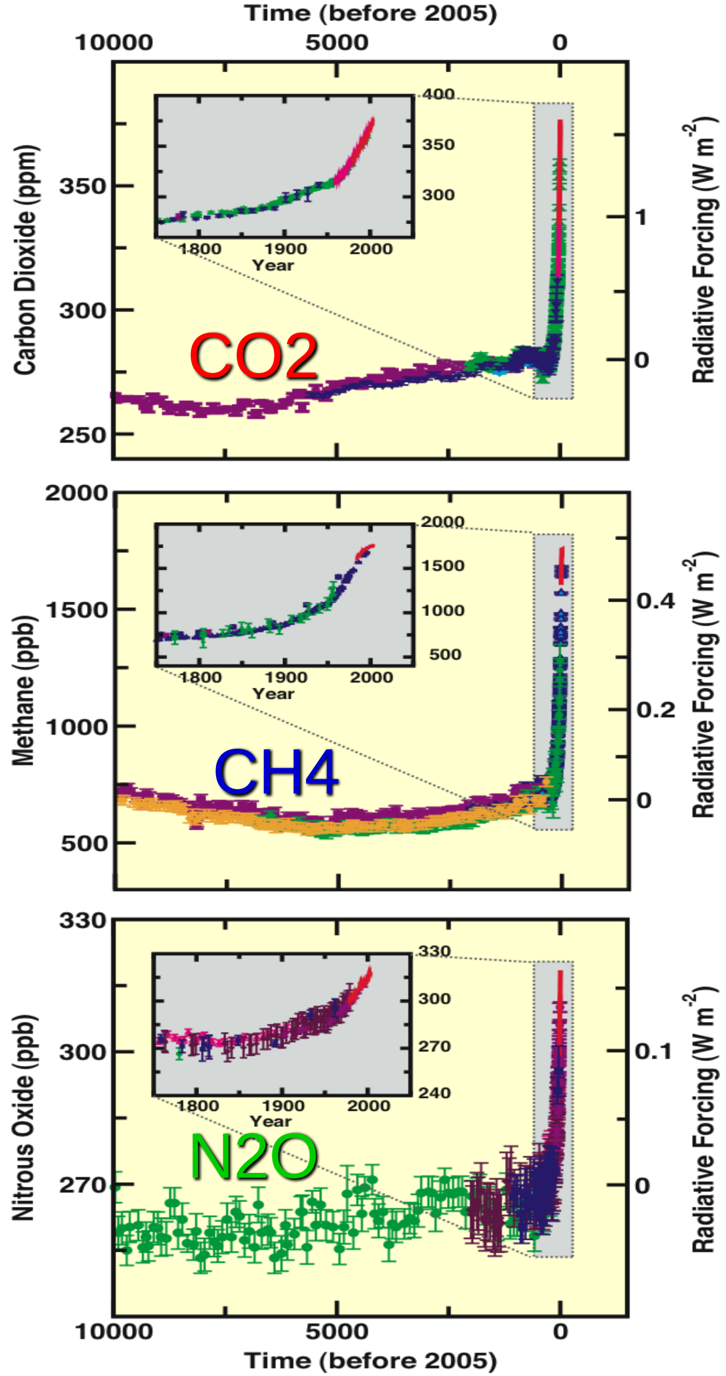




The greenhouse gas concentration in the atmosphere is sharply increasing

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

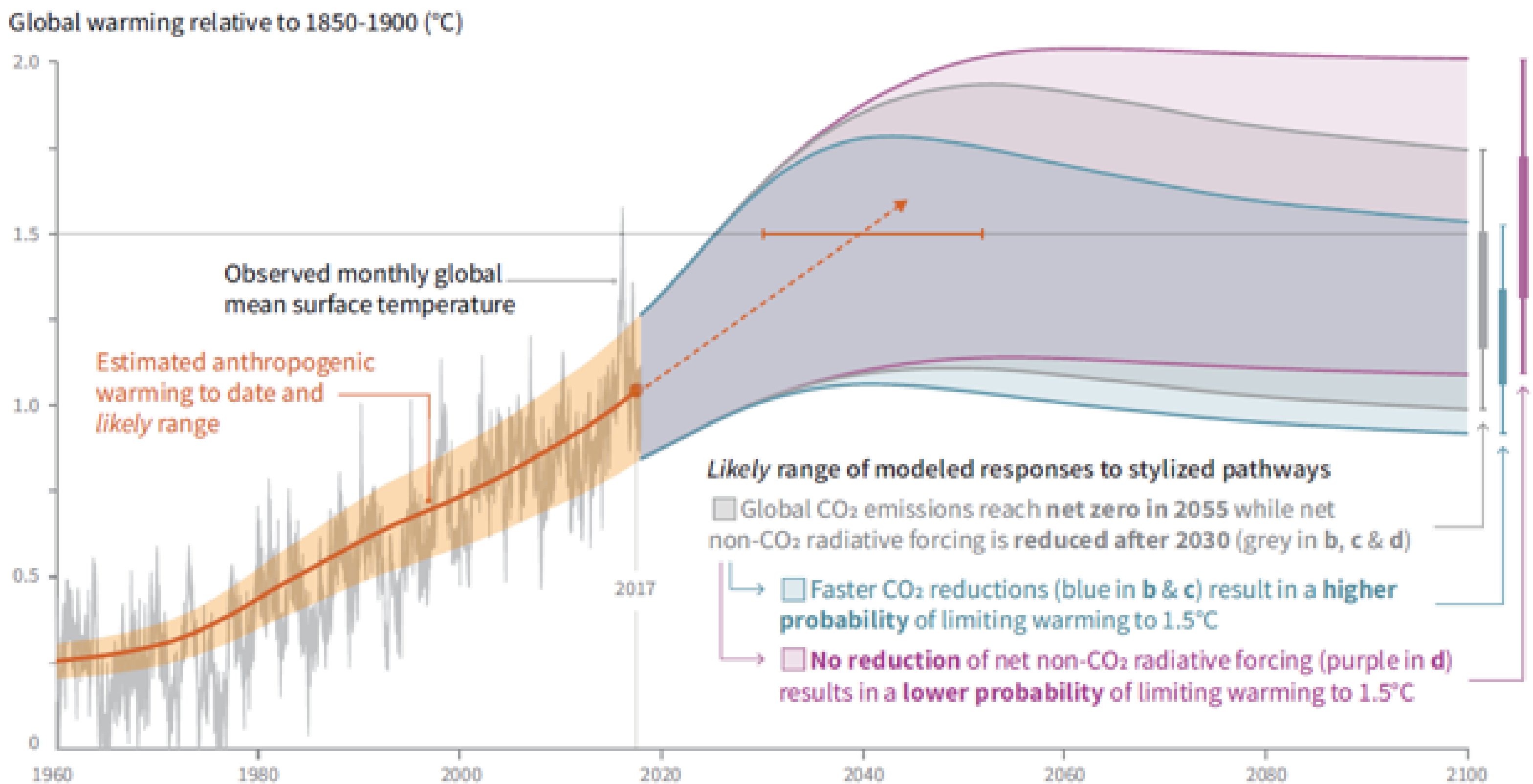
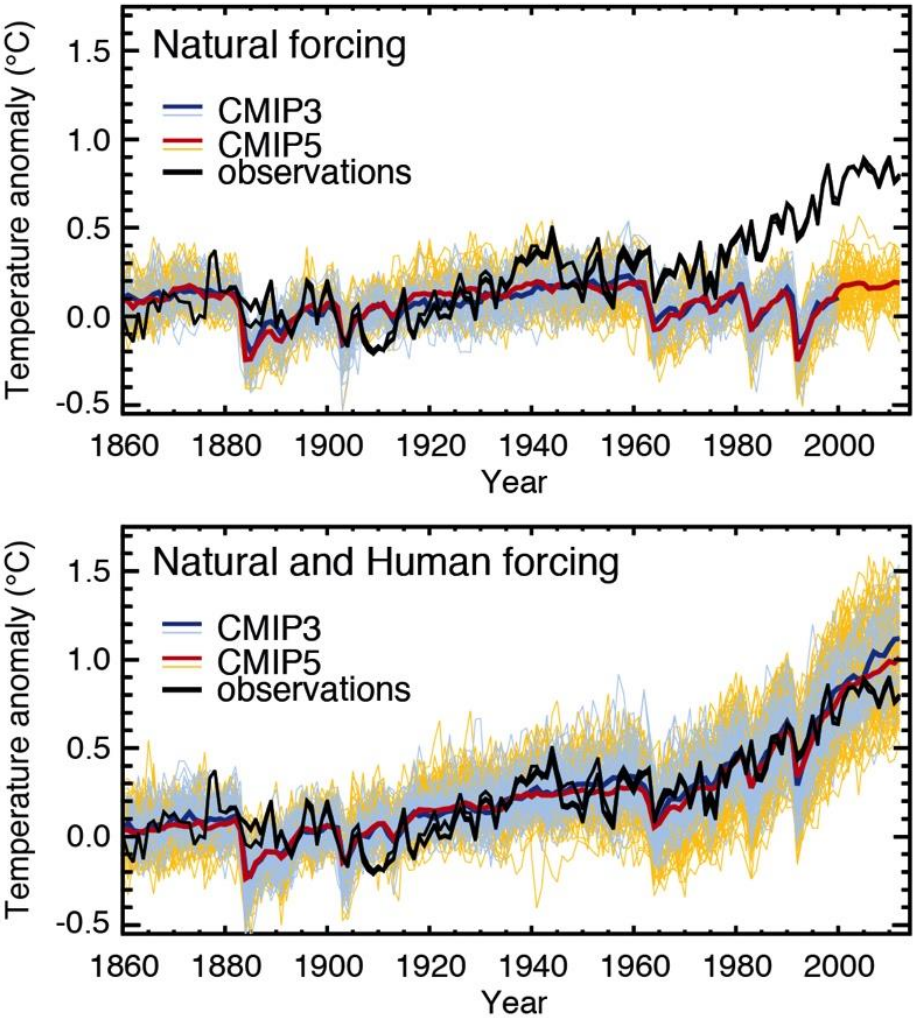
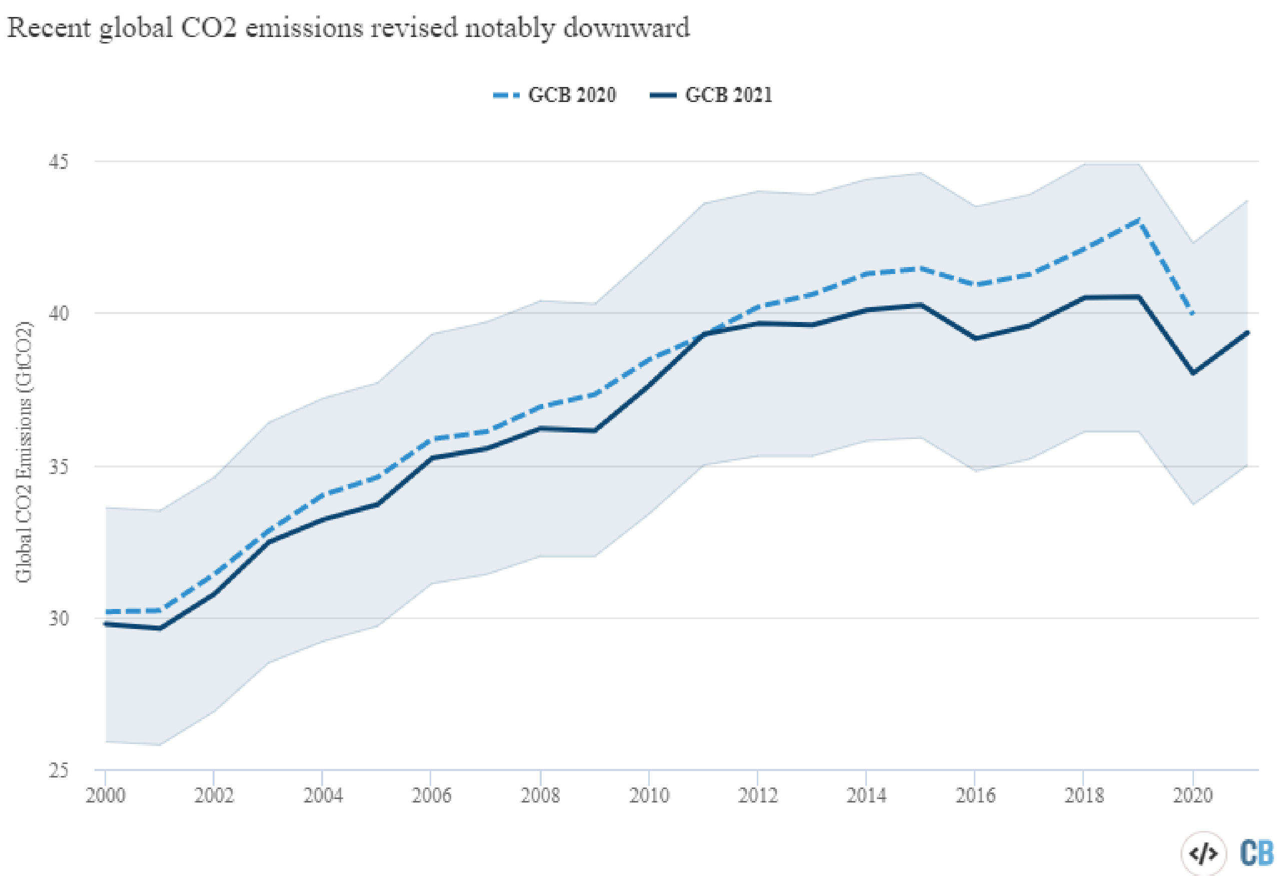


Figura 2 – Andamento della temperature media mondiale rispetto ai livelli pre-industriali. Fonte: IPCC – Summary for the policy makers https://www.ipcc.ch/sr15/

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)

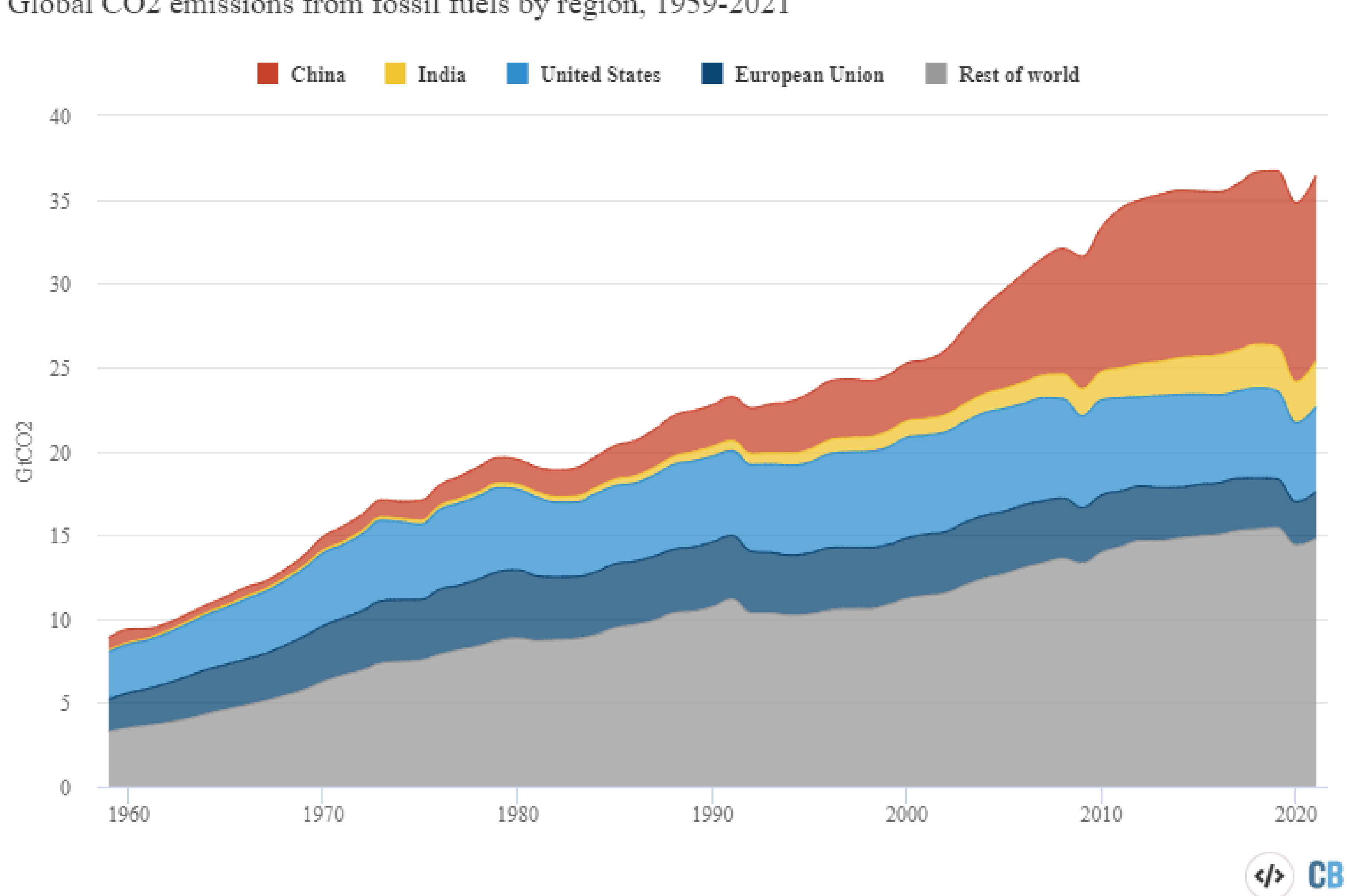


Recent evidence on annual CO2 emissions



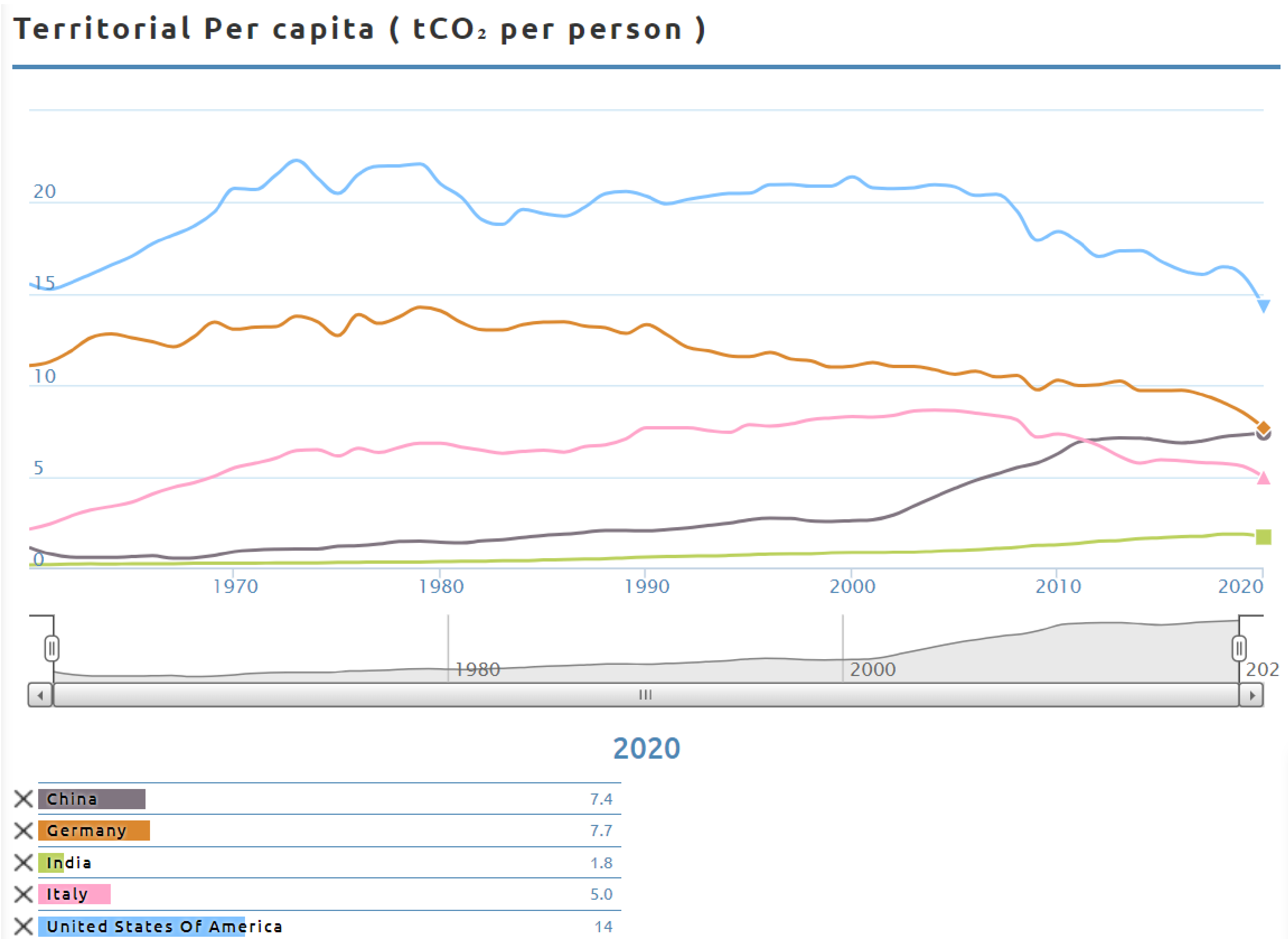
Annual total global CO2 emissions – from fossil and land-use change – between 2000 and 2021 for both the 2020 and 2021 versions of the Global Carbon Project's Global Carbon Budget. Shaded area shows the estimated one-sigma uncertainty for the 2021 budget. Data from the Global Carbon Project; chart by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

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



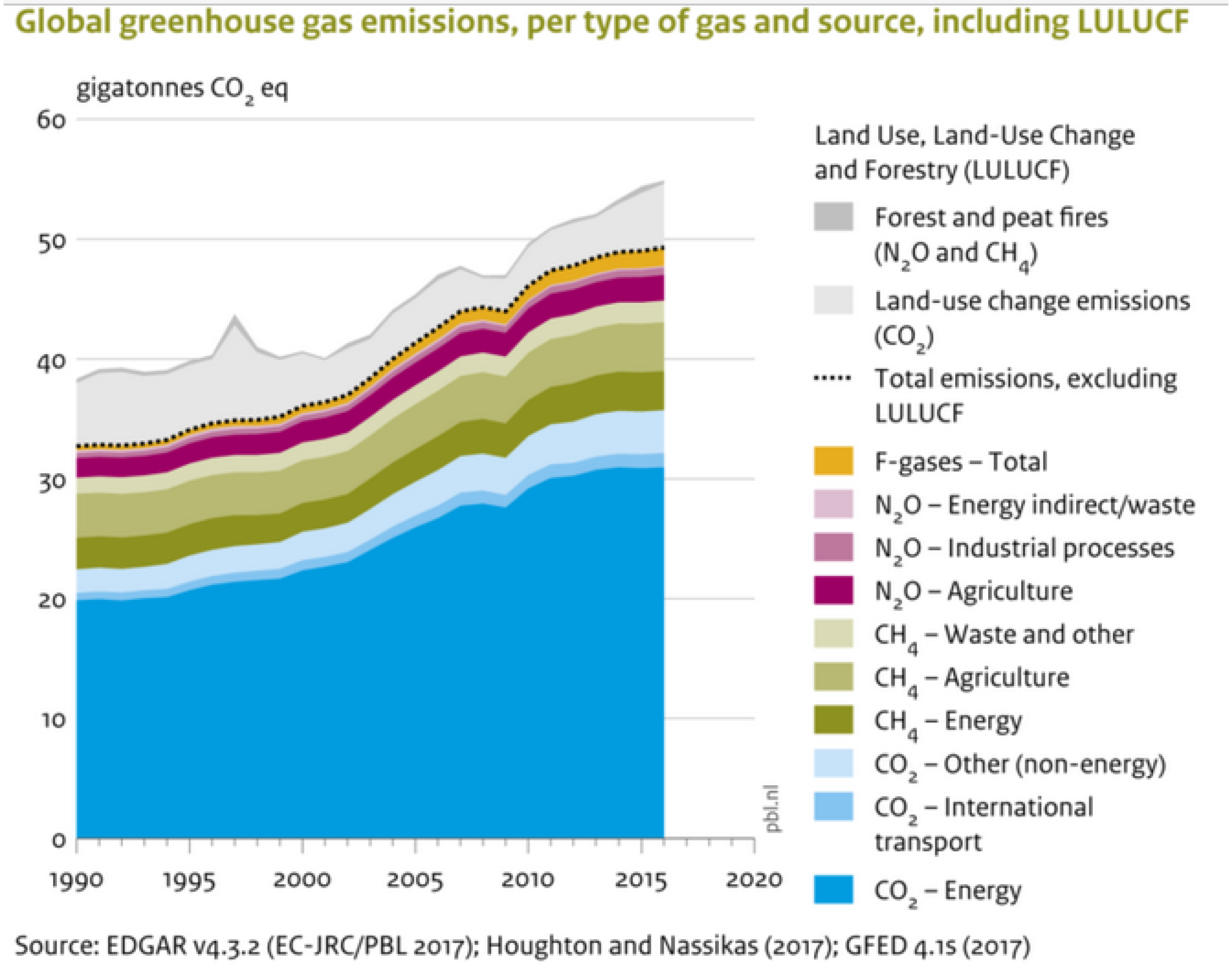
Annual fossil CO2 emissions by major country and rest of world from 1959-2021, in billions of tonnes of CO2 per year (GtCO2). Note that 2021 numbers are preliminary estimates. Data from the Global Carbon Project; chart by Carbon Brief using Highcharts.

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

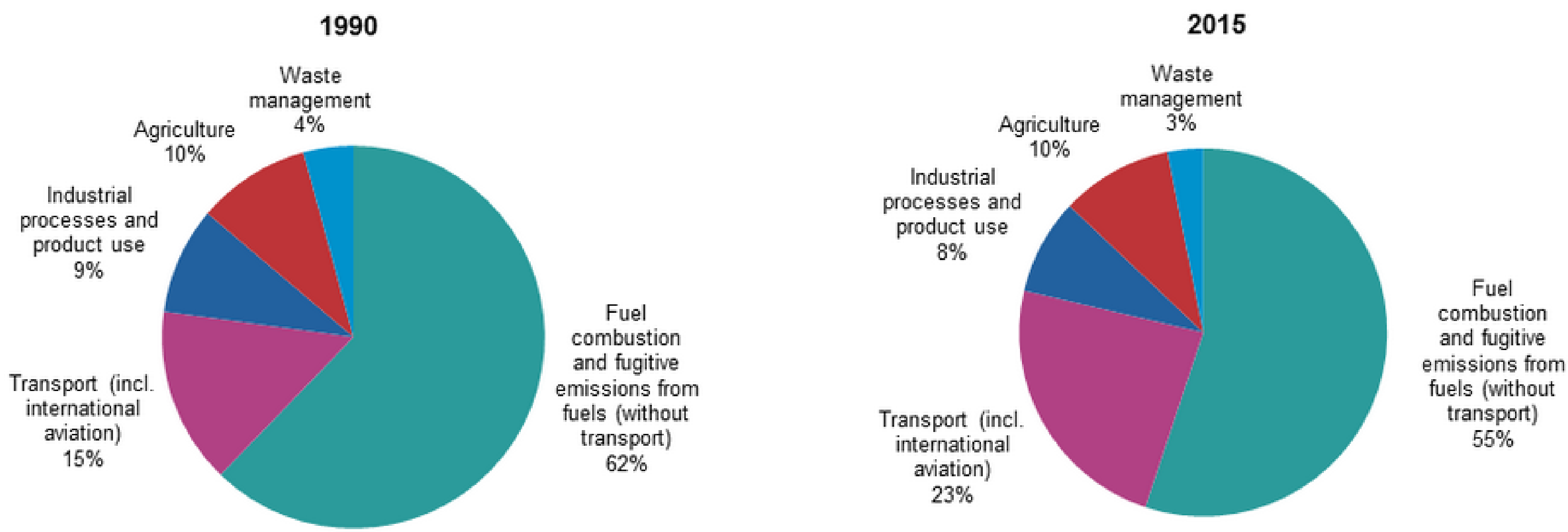


Transport activities account for 20% of the overall CO2 emissions

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

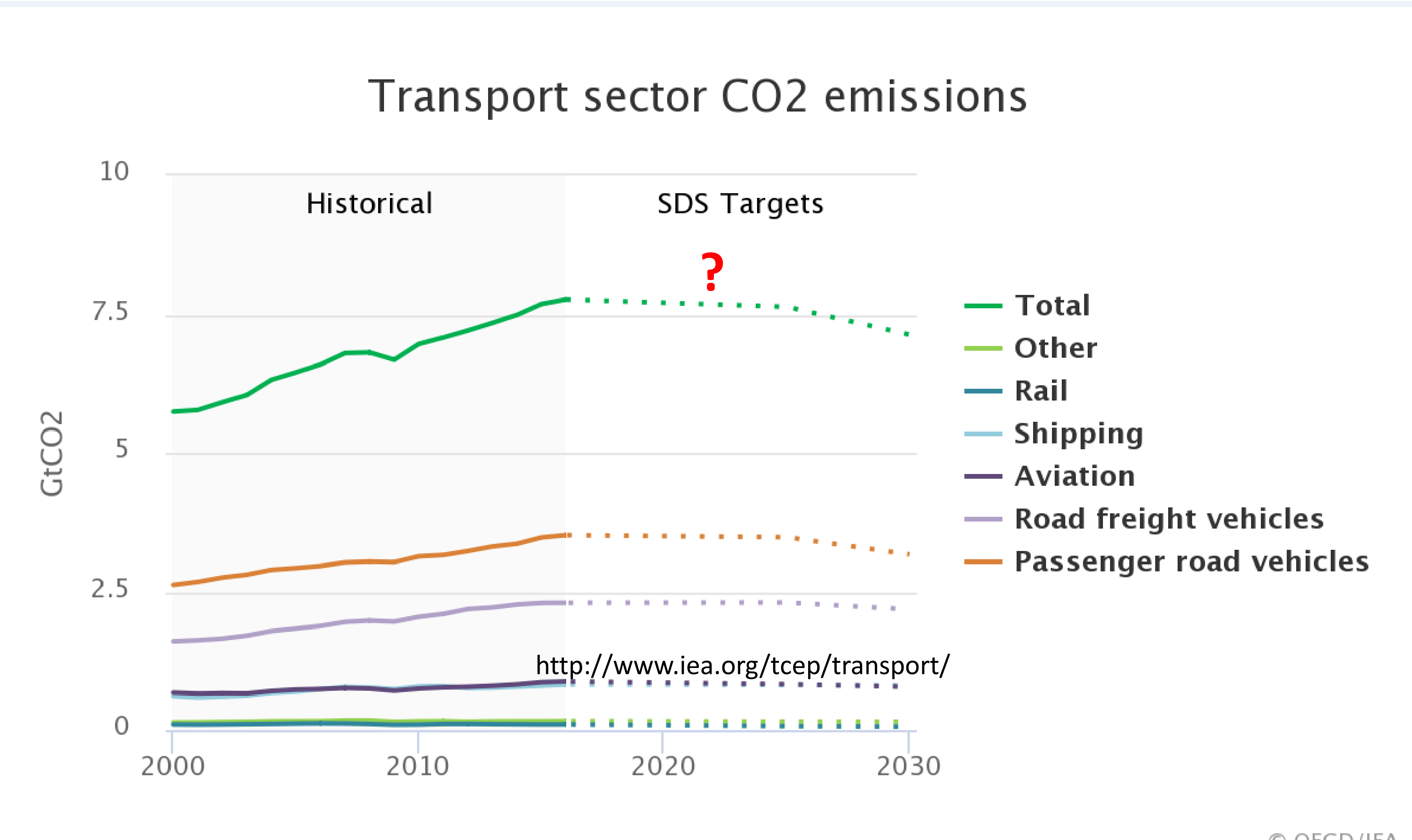


http://ec.europa.eu/eurostat/statistics-explained/index.php/Greenhouse_gas_emission_statistics

International Energy Agency, May 2018

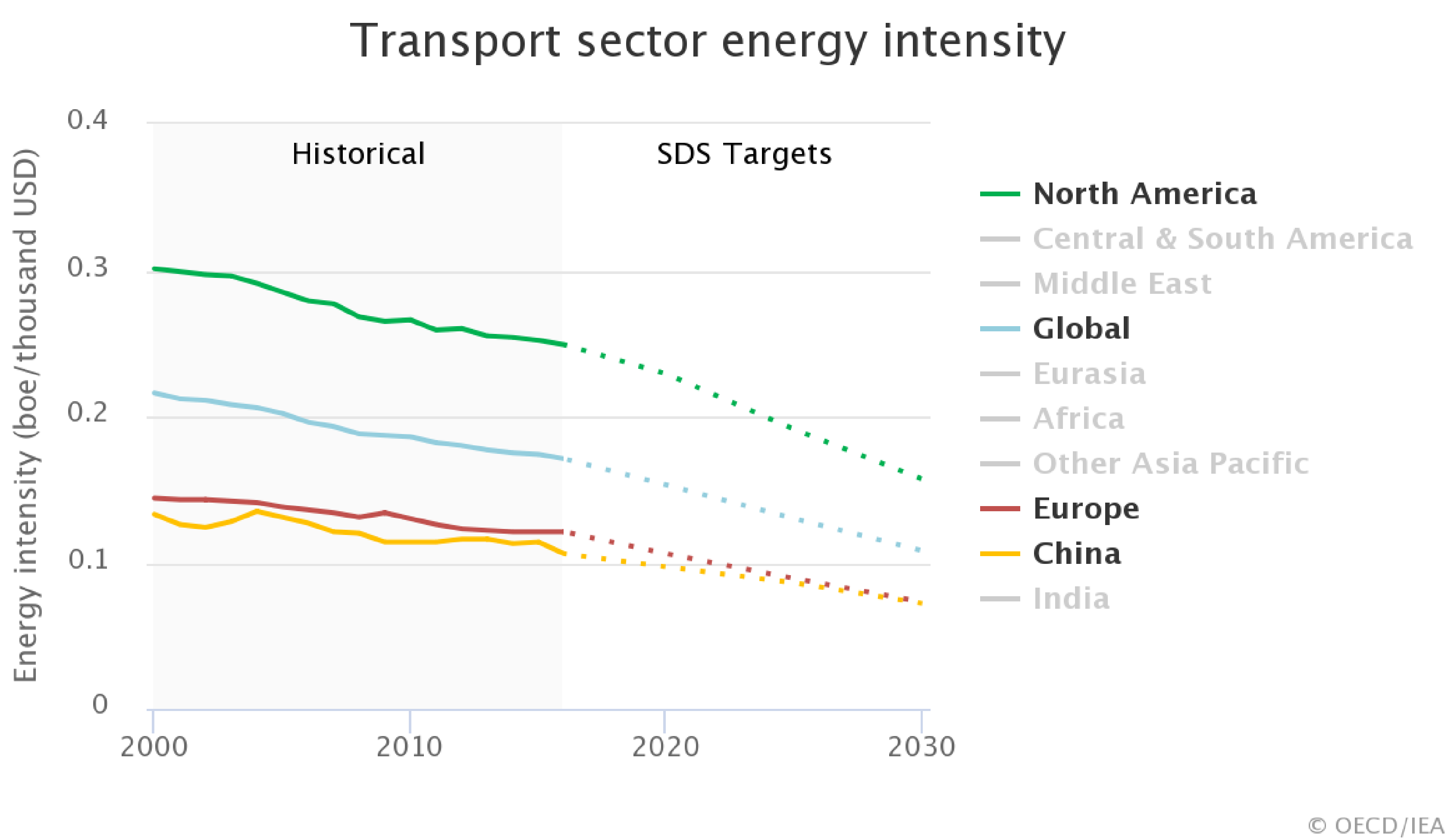
- Transportation was responsible for 24% of direct CO_2 emissions in 2017.
- Road vehicles – cars, trucks, buses and two-wheelers – accounted for 77% of both global final energy demand and CO_2 emissions attributable to the transport sector as a whole.
- Car buyers continue to choose bigger, heavier 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?



L'intensità energetica è diminuita.

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



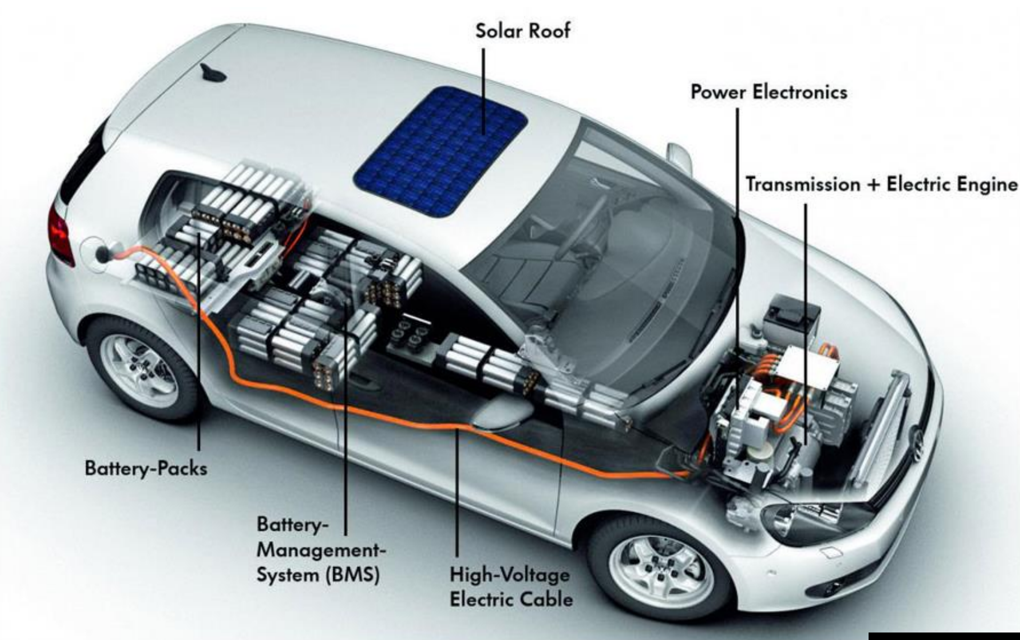
http://www.iea.org/tcep/transport/

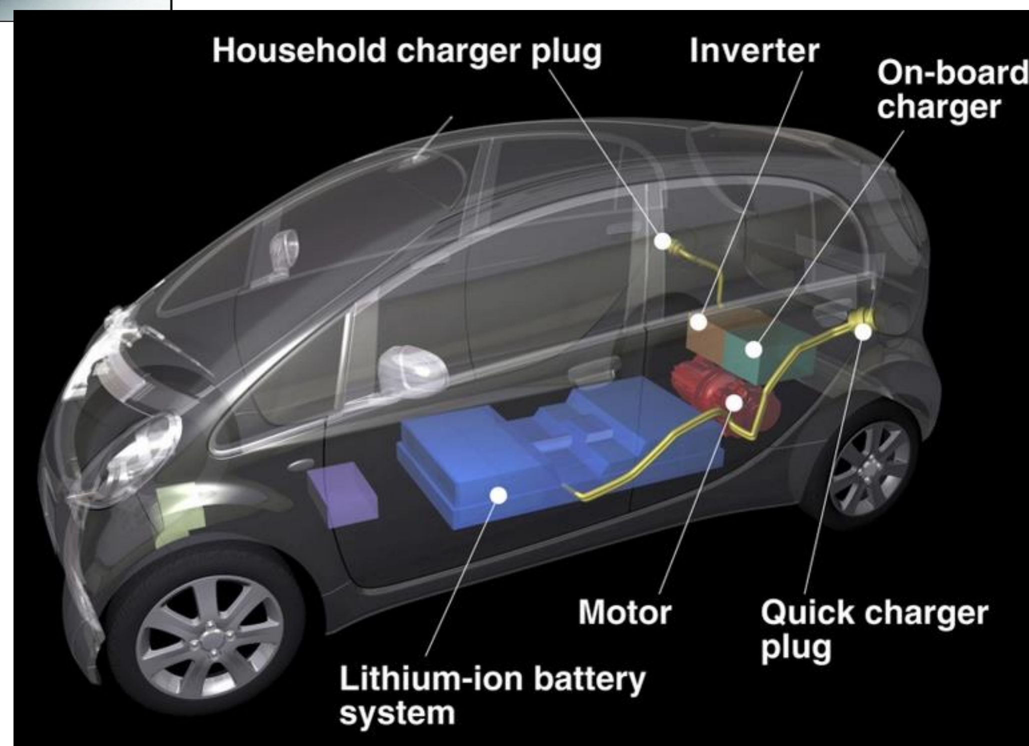
Decarbonising transport: electric vehicles and renewable energy sources

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



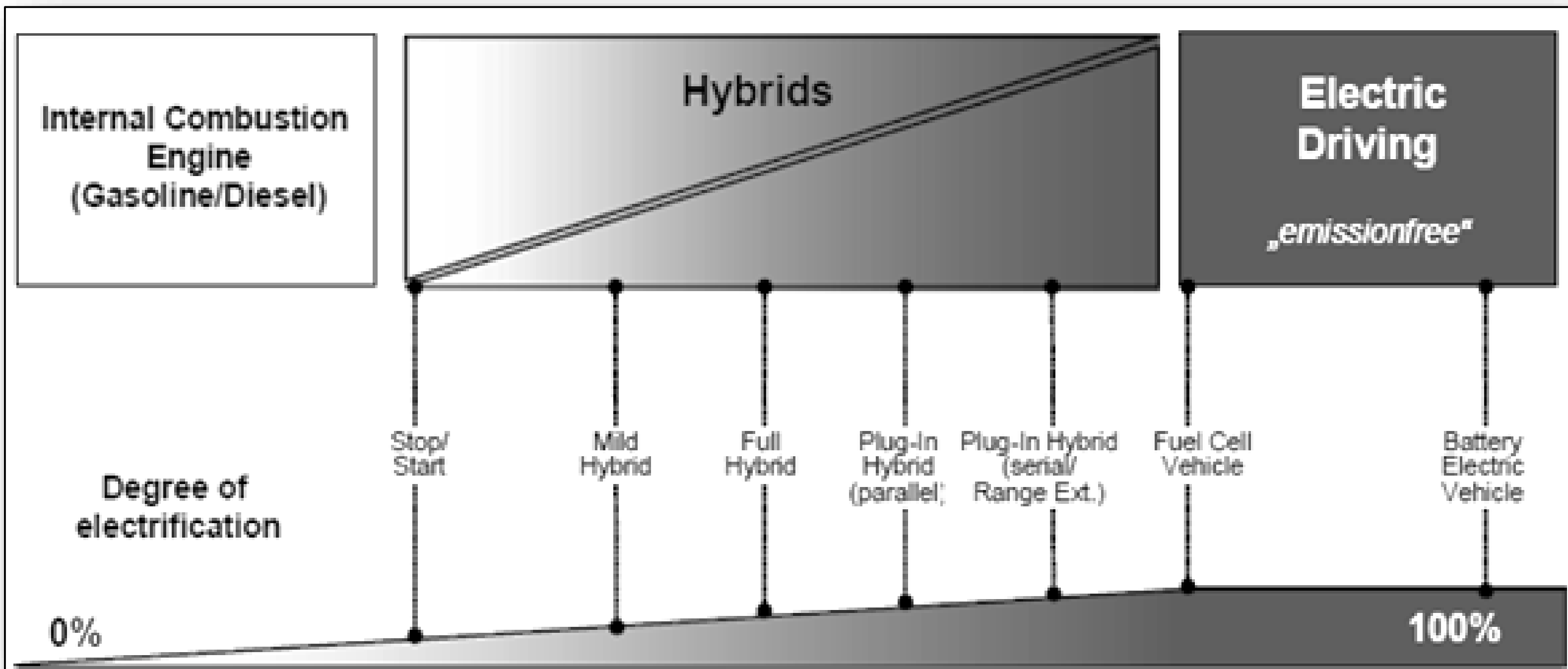
MiEV




THINKcity

FLUENCE

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



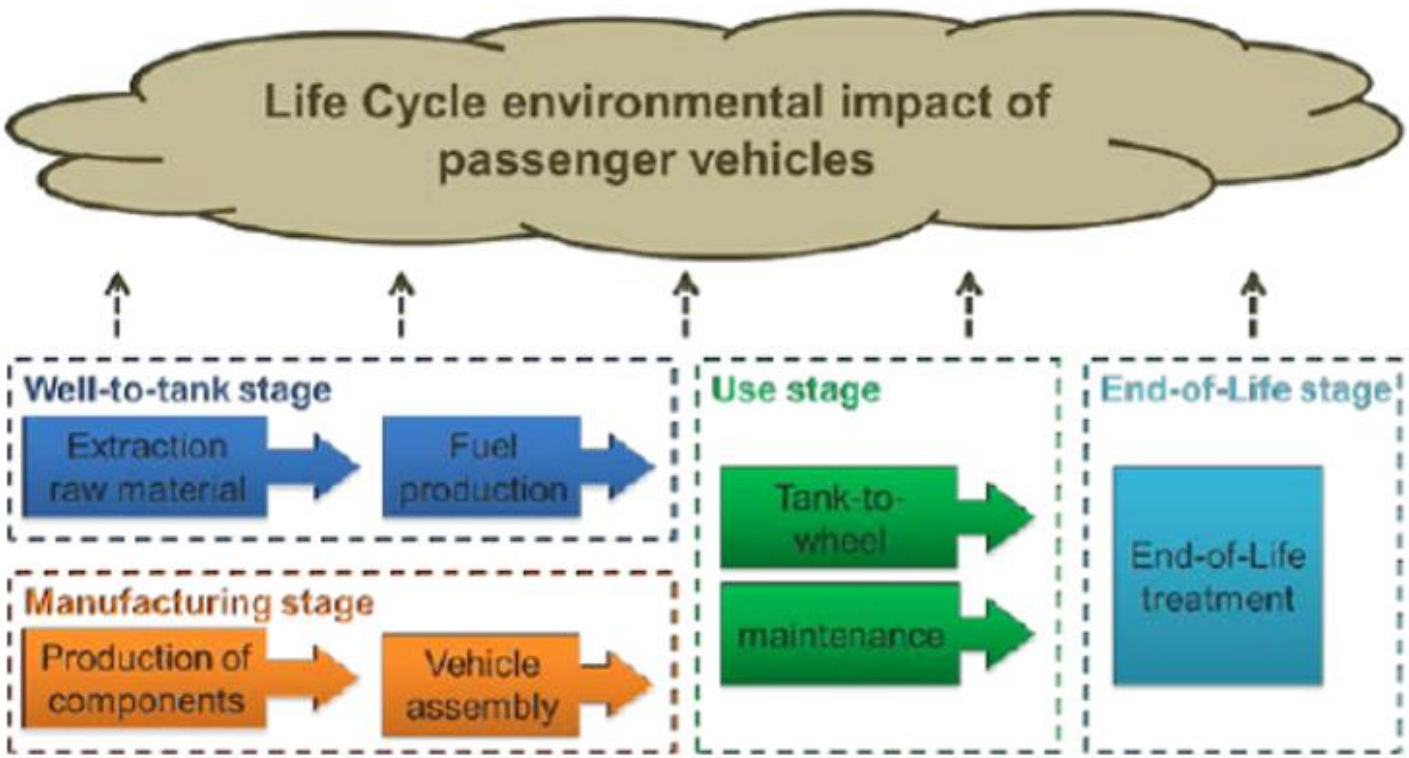
Q1: The electric car: a better balance between mobility and the enviornment?

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

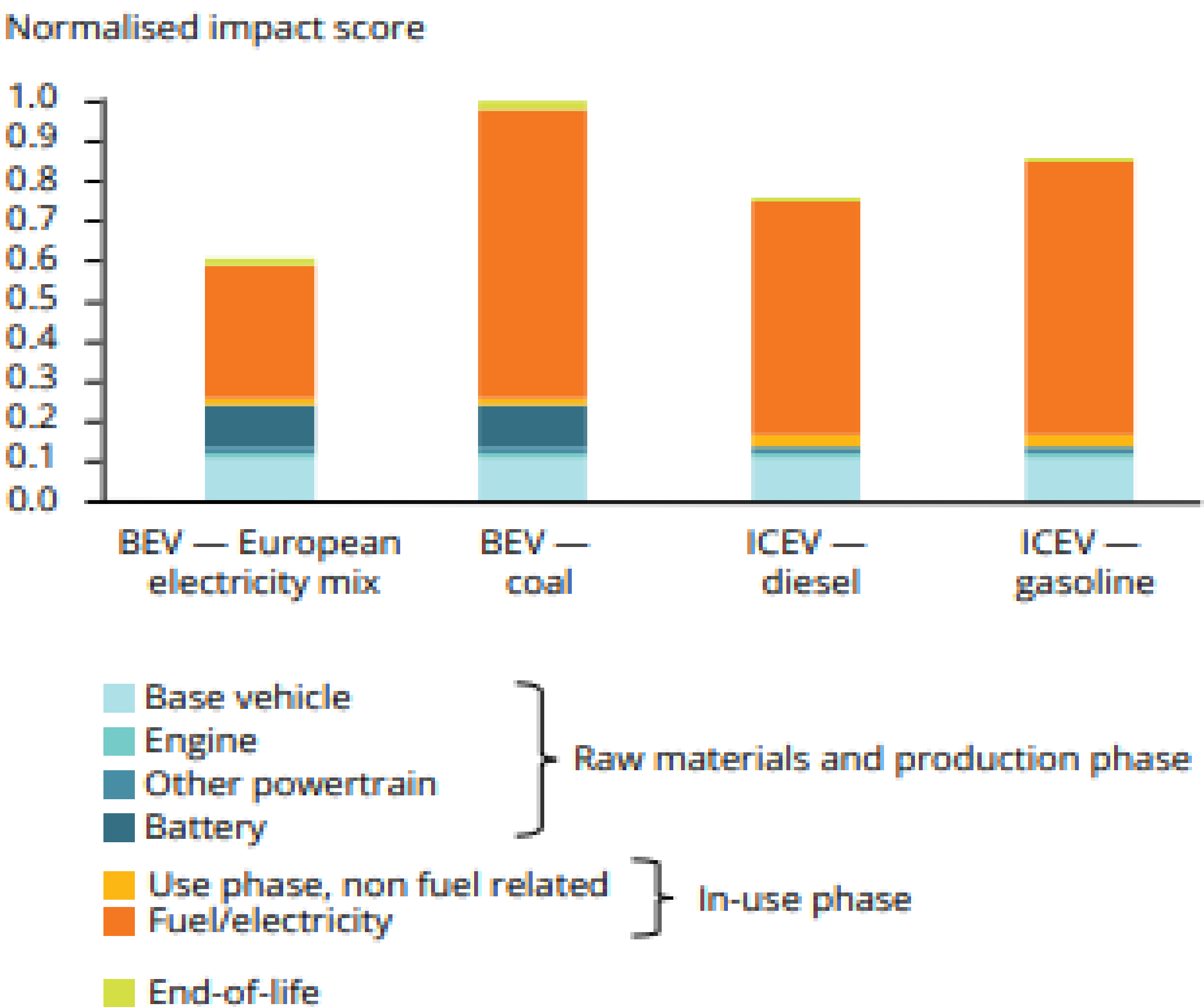
Figure 1. Schematic representation of the different life cycle stages of a vehicle.



Key determinants of energy and environemntal efficiency

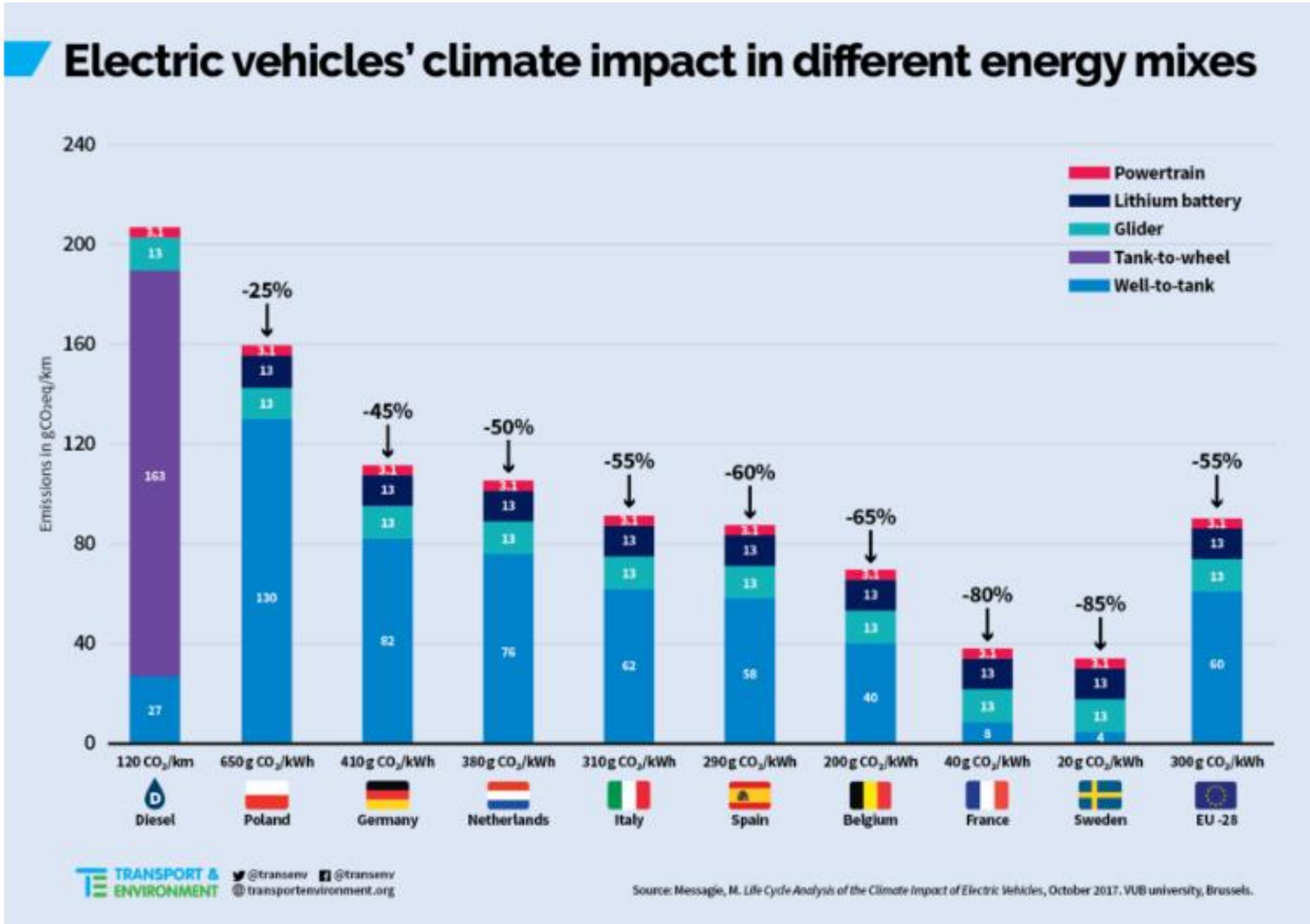
- **The efficiency of the vehicle**
- **The efficiency in electricity production**
- **The efficiency in gasoline production**
- **The drive cycles (urban, interurban)**

Evidence for Europe. It depends on the energy mix



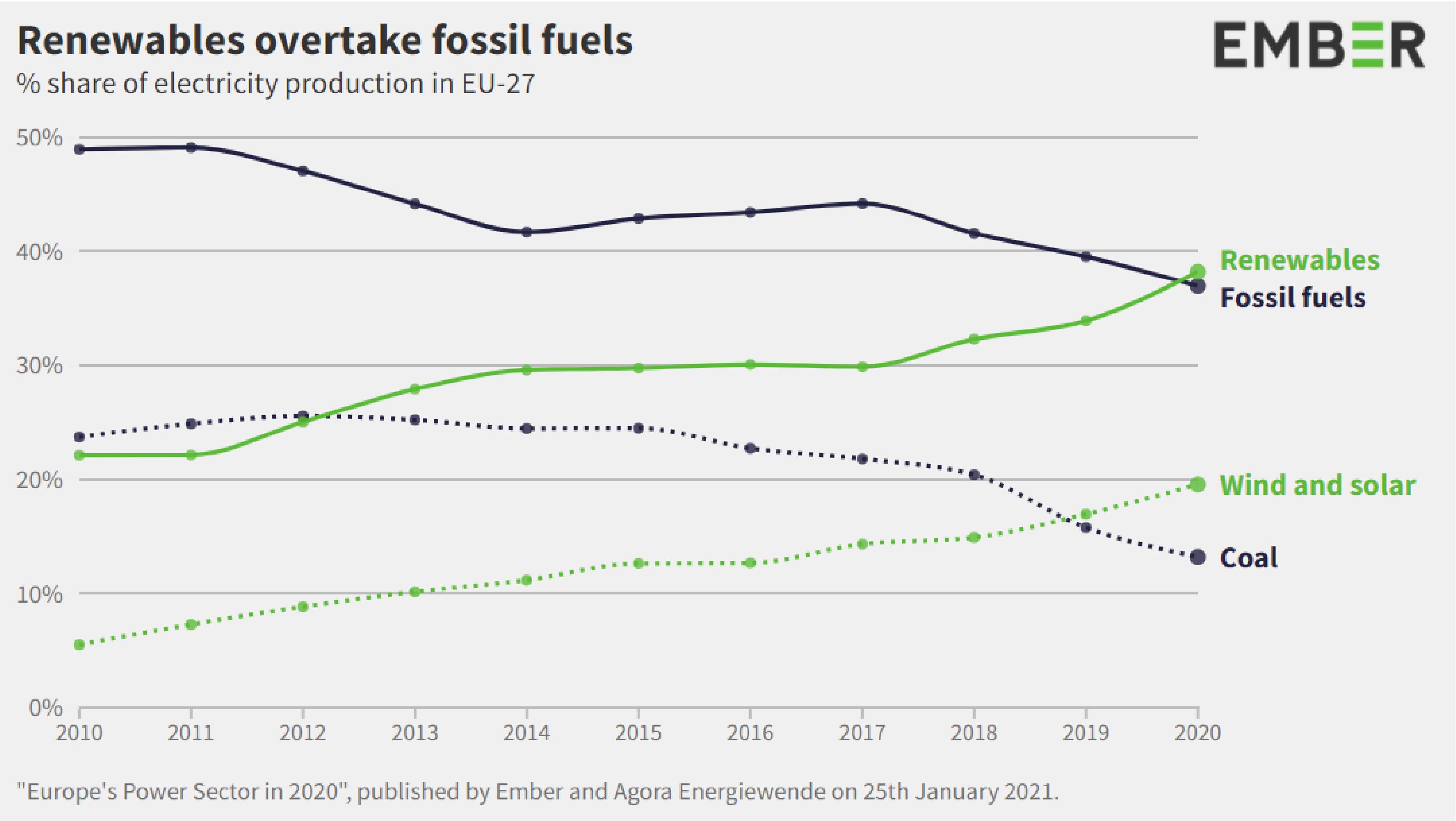
Source: European Environment Agency (2018), *Electric vehicles from life cycle and circular economy perspectives*, Transport and Environment Reporting Mechanism (TERM) report

Europe : it depends from the countries energy mix



Transport & Environment (T&E)- Electric cars emit less CO2 over their lifetime than diesels even when powered with dirtiest electricity (Italy, Europe -55%)

Europe..and the grid is getting cleaner



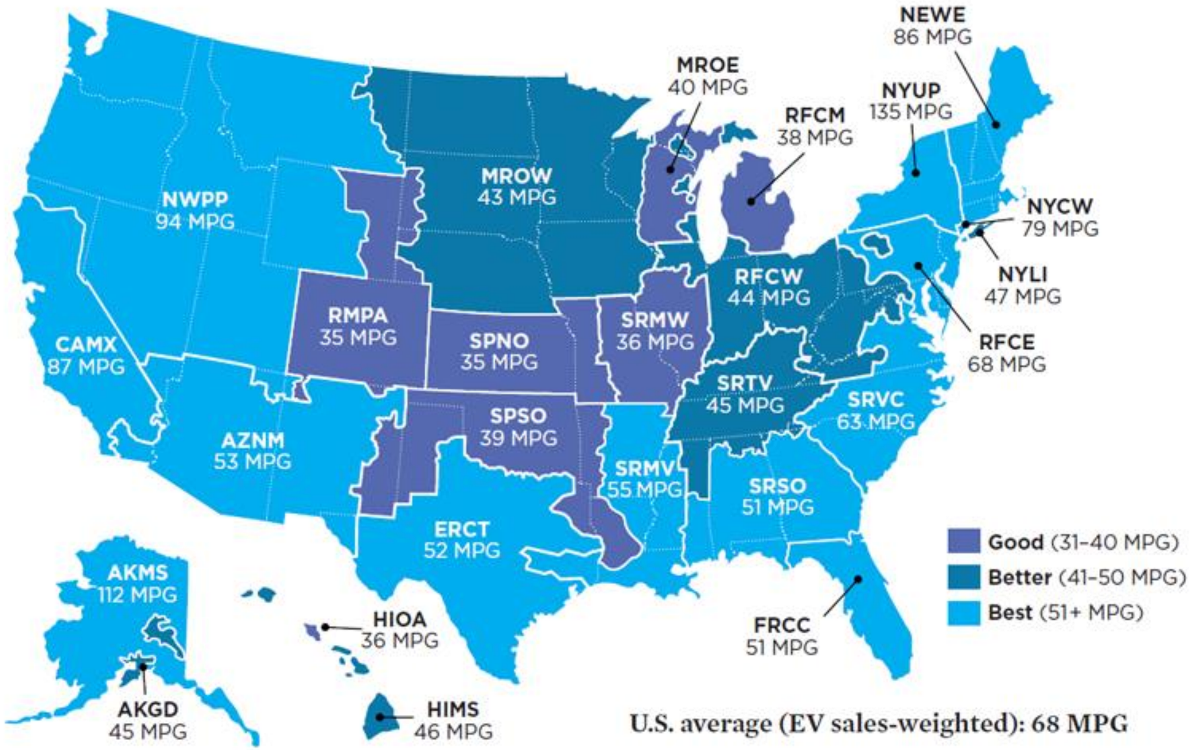
Renewables rose to generate 38% of Europe's electricity in 2020 (compared to 34.6% in 2019), for the first time overtaking fossil-fired generation, which fell to 37%. This is an important milestone in Europe's Clean Energy Transition. At a country level, Germany and Spain (and separately the UK) also 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

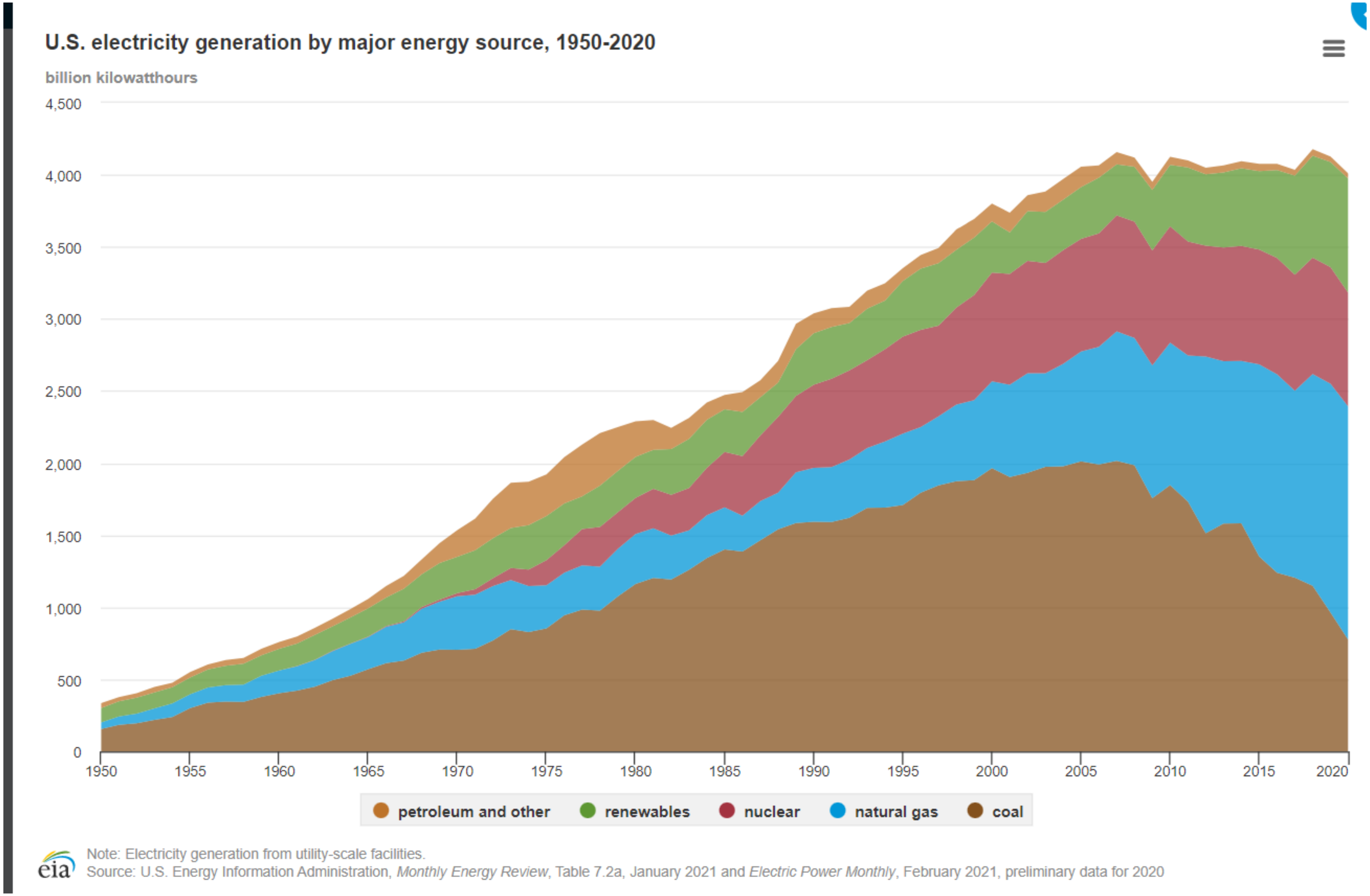


How many miles per gallon would a gas car have to achieve to produce global warming emissions equivalent to an EV? The answer depends on where you live. Numbers based on the EPA's eGRID 2015 database. Click to enlarge.

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

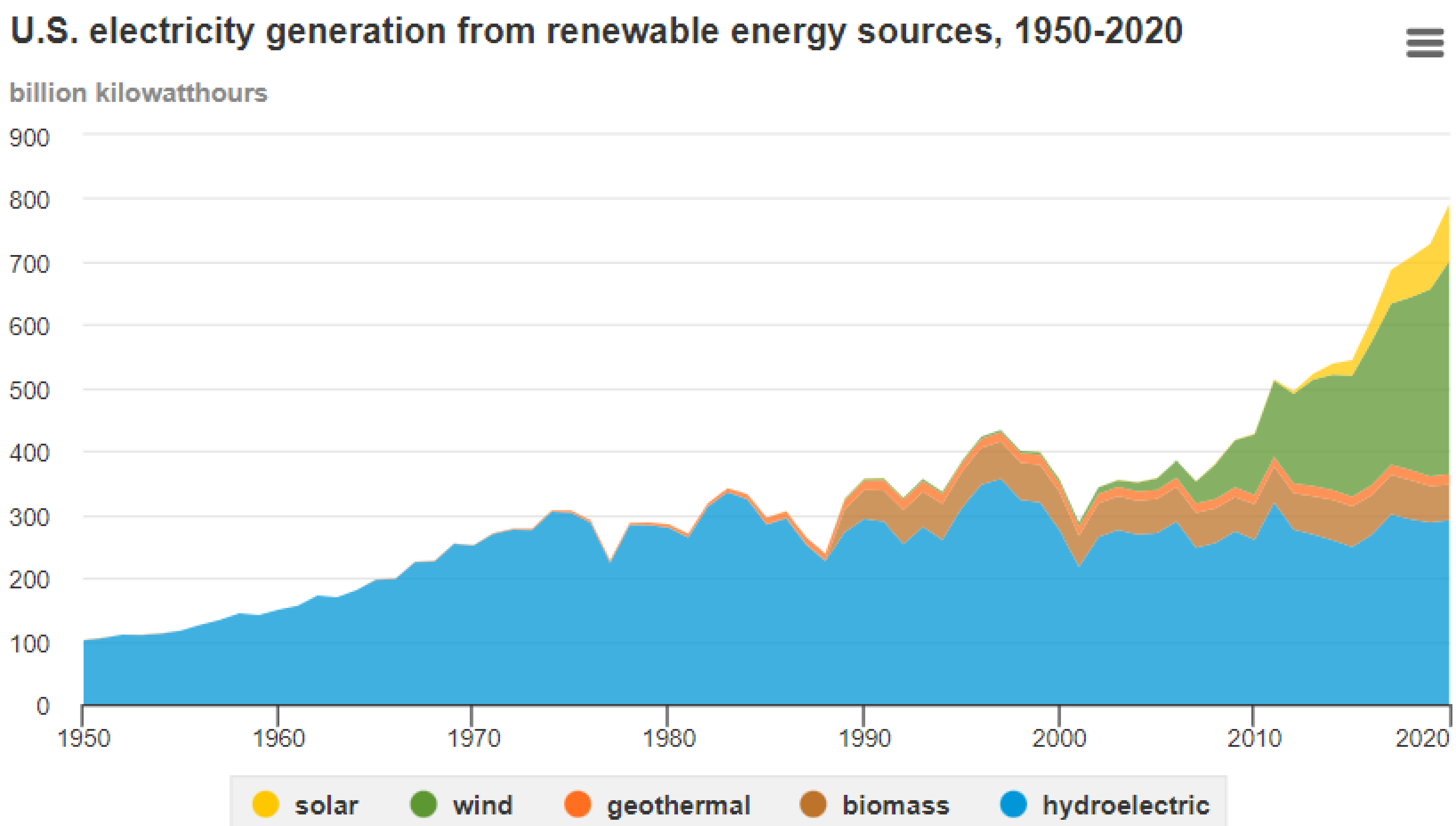
https://www.ucsusa.org/clean-vehicles/electric-vehicles/life-cycle-ev-emissions

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

My estimate for Italy (2016)

a) database VCA, August 2016; b) The 10 best selling cars in Italy in 2016; c) CO_2 emissions to produce electricity: ENEA estimates for the year 2013; d) best available estimates on CO_2 emissions in vehicle and battery production.

Tabella 10 – Una prima stima per l'Italia: Emissioni di CO_2 medie (g/km)

	BEV	ICEV - diesel	ICEV - benzina	HEV
Veicolo di base	34,0	34,0	34,0	34,0
Motore	2,7	4,0	4,0	4,0
Altre componenti	4,8	5,5	5,5	5,5
Batteria	31,0	0,6	0,6	0,6
Fase di uso, non legate al carburante	7,2	8,9	8,9	8,9
Carburante\elettricità	**51,0**	**108**	**111**	**92**
Smaltimento\riuso	4,7	3,4	3,4	3,4
Totale	135,4	164,4	167,4	148,4

Main conclusions:

1) **uncertainties emissions in the production and transport of conventional fuel and battery production, recycle and disposal;**
2) **Cars are highly differentiated by segment. Comparisons require homogeneity**
3) **The energy mix is crucial and rapidly changing**

Danielis, R. (2017) - Le emissioni di CO2 delle auto elettriche e delle auto con motore a combustione interna. Un confronto per l'Italia tramite l'analisi del ciclo di vita, WP SIET

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

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

Factors favoring EVs

CLEAN DISRUPTION OF ENERGY & TRANSPORTATION

1. Energy Storage
2. Electric Vehicles
3. Self-driving Cars
4. Solar

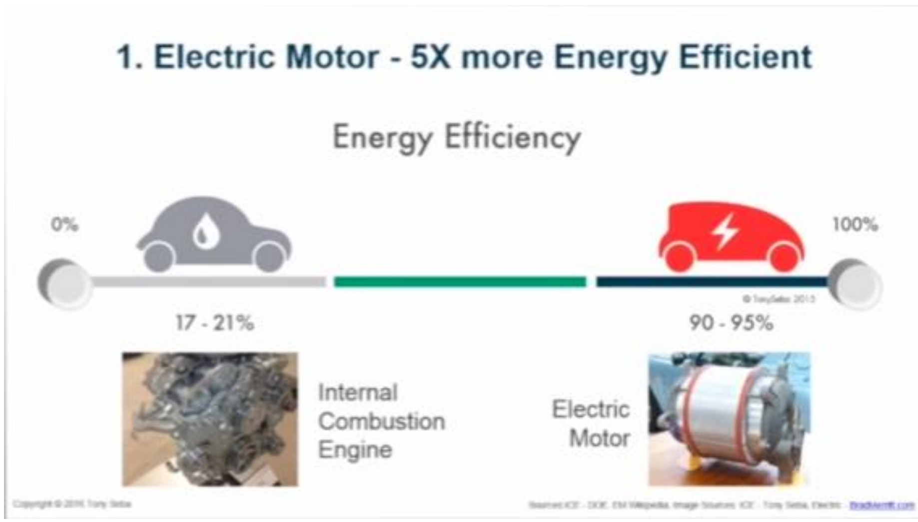
Li-on Battery costs dropping exponentially

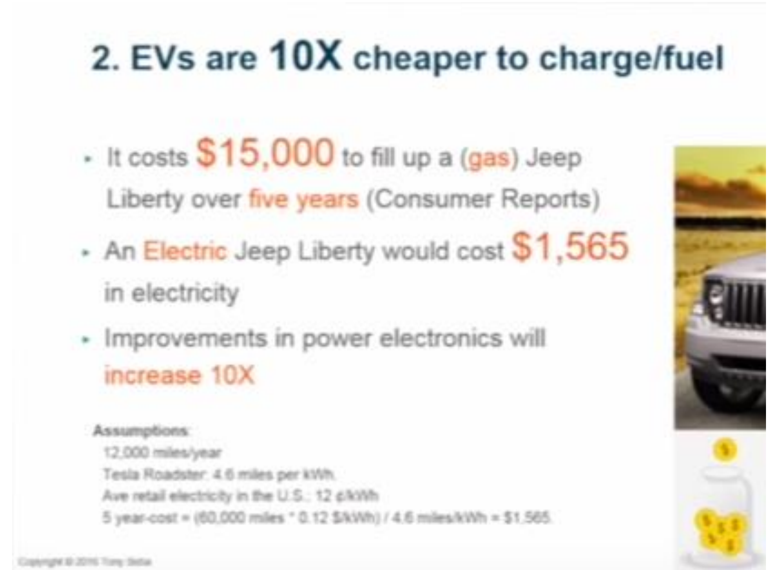
- **Laptop Li-on battery costs dropped ~14% per year over 15 years.** (1)
- Investments in battery tech increasing dramatically:
  - **3 multi-trillion $ industries investing:**
    1. **IT/ Electronics**
    2. **Automotive**
    3. **Energy**

Projected cost of Li-On Battery $/kWh

Assumption: 16% /year Technology Cost Curve

Factors favoring EVs

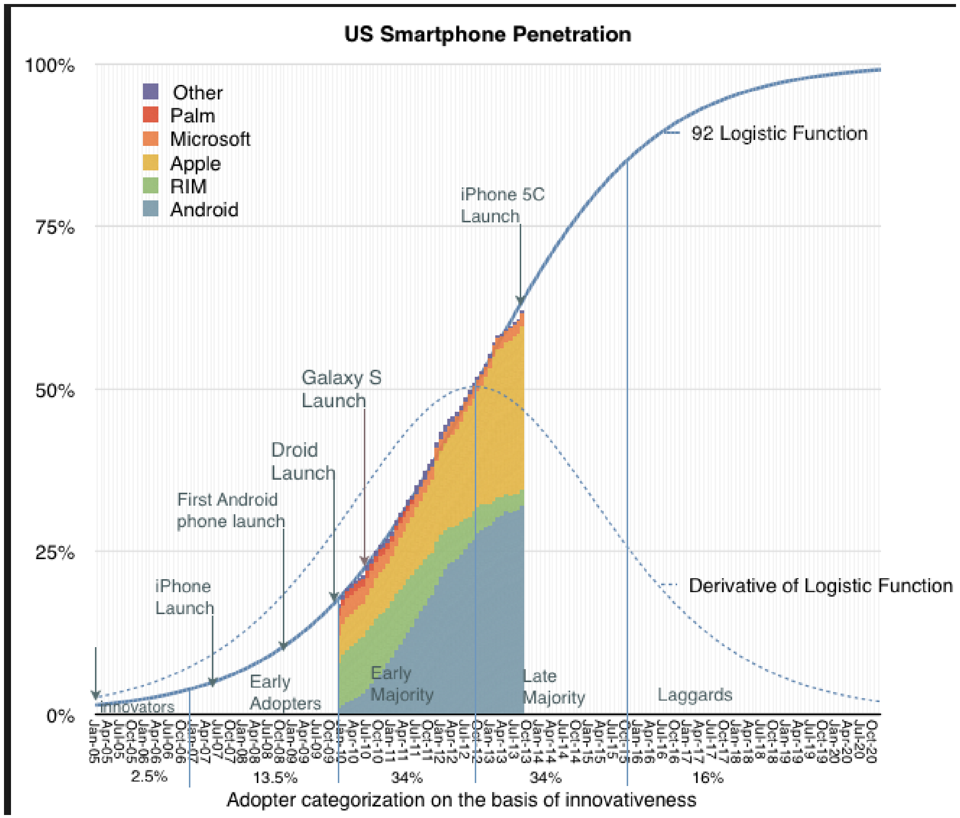


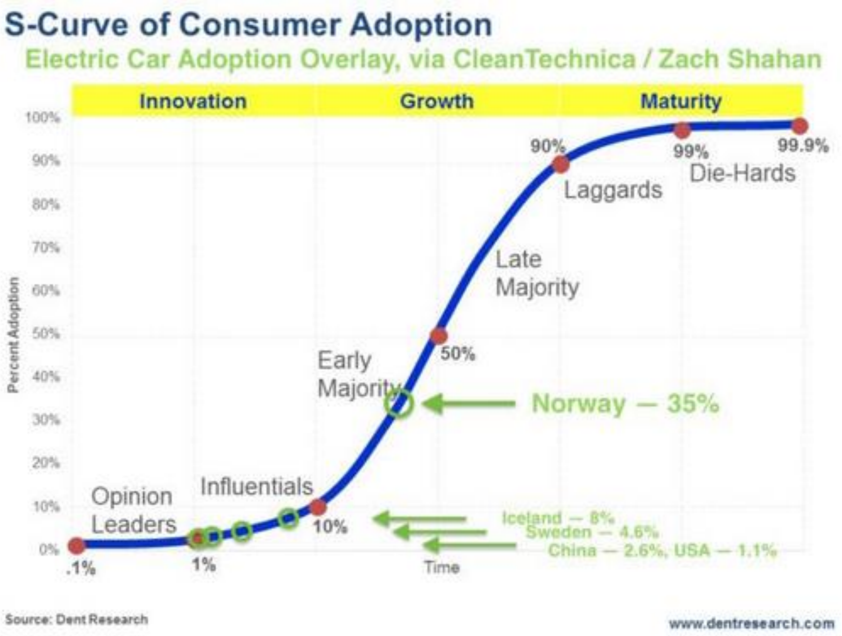


The Pessimist’s view: Takeshi Uchiyamada (Toyota Chairman)

- 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

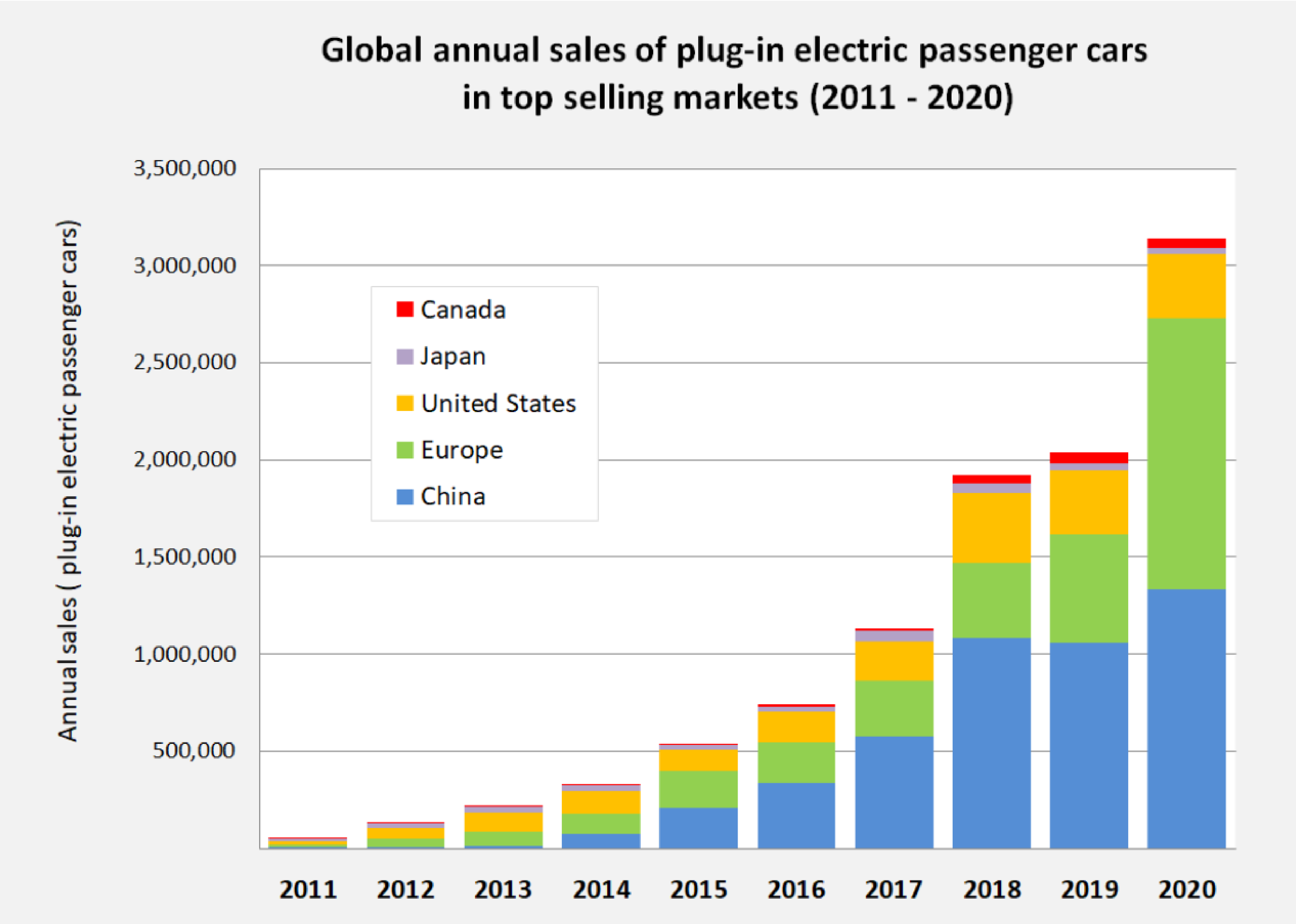




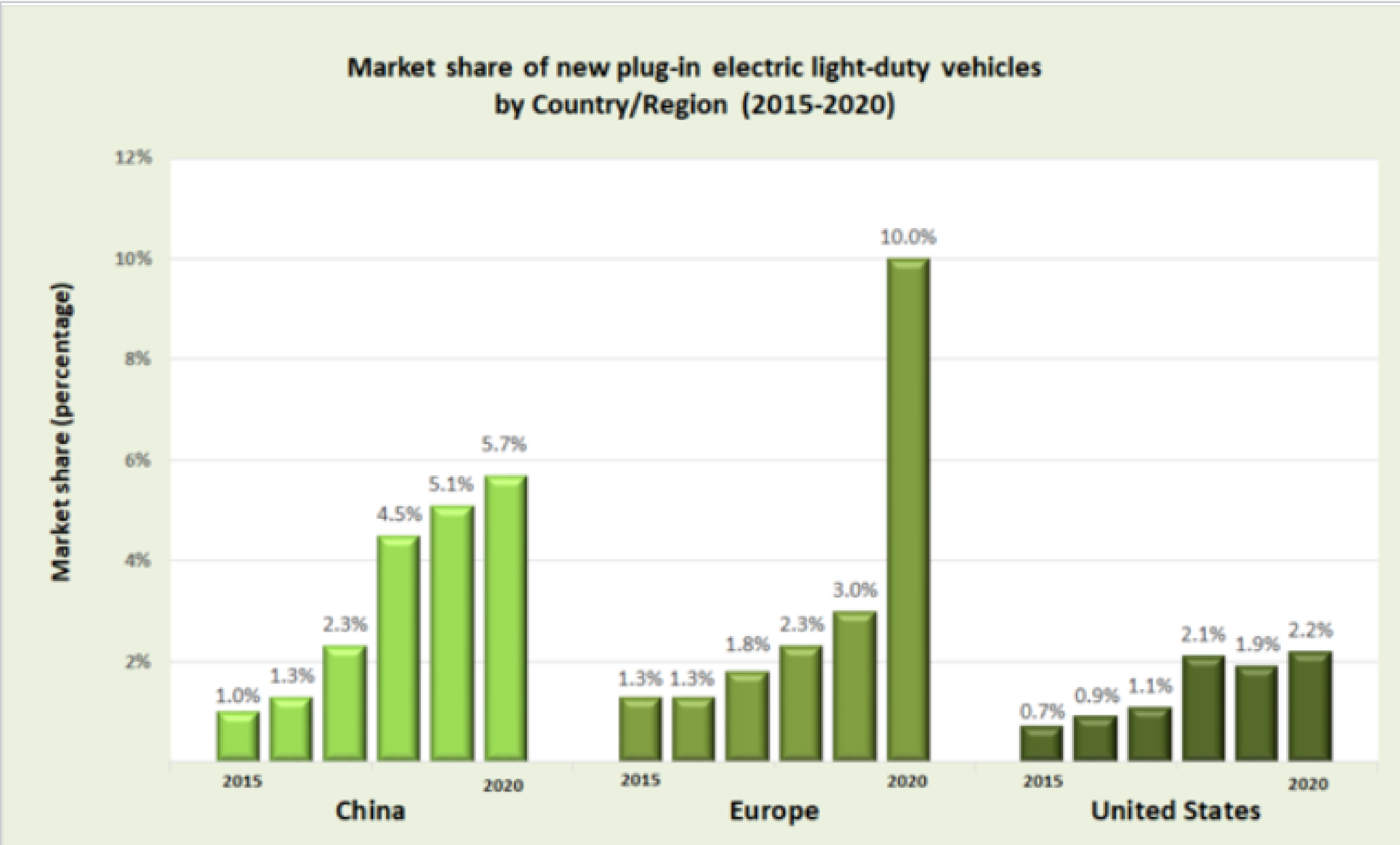
Q2: Is there the market for electric cars and how big is it? Will EVs substitute ICEVs? At which rate? Which EVs (BEVs or PHEVs or HEVs)

- Current market share
- Total cost of ownership
- Consumers’ choices

Current market



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



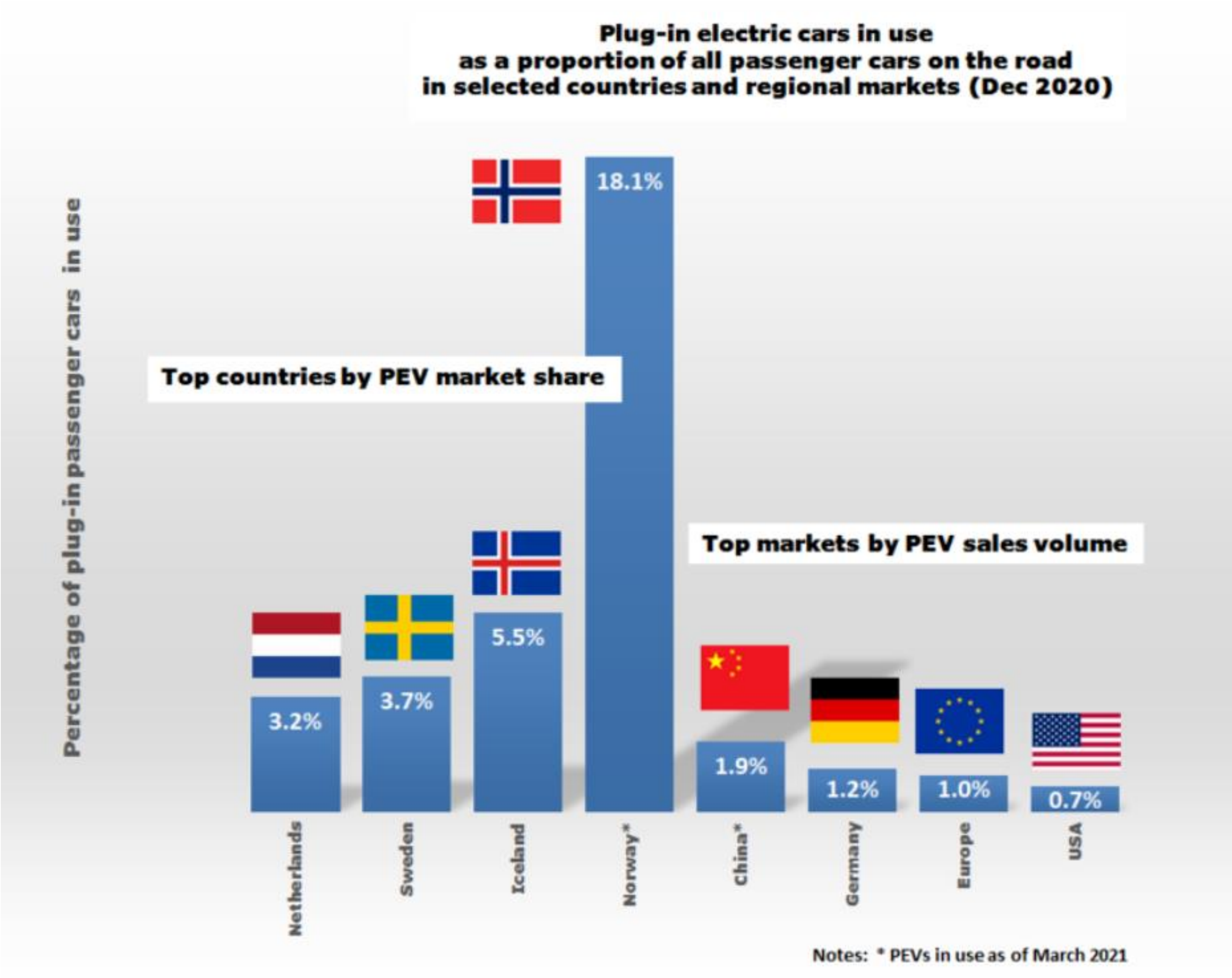
Market share of new plug-in electric light-duty vehicles
by Country/Region (2015-2020)
Market share (percentage)
12%
10%
8%
6%
4%
2%
1.0%
1.3%
2.3%
4.5%
5.1%
5.7%
1.3%
1.3%
1.8%
2.3%
3.0%
10.0%
0.7%
0.9%
1.1%
2.1%
1.9%
2.2%
2015
2020
China
2015
2020
Europe
2015
2020
United States

The growing market for electric cars

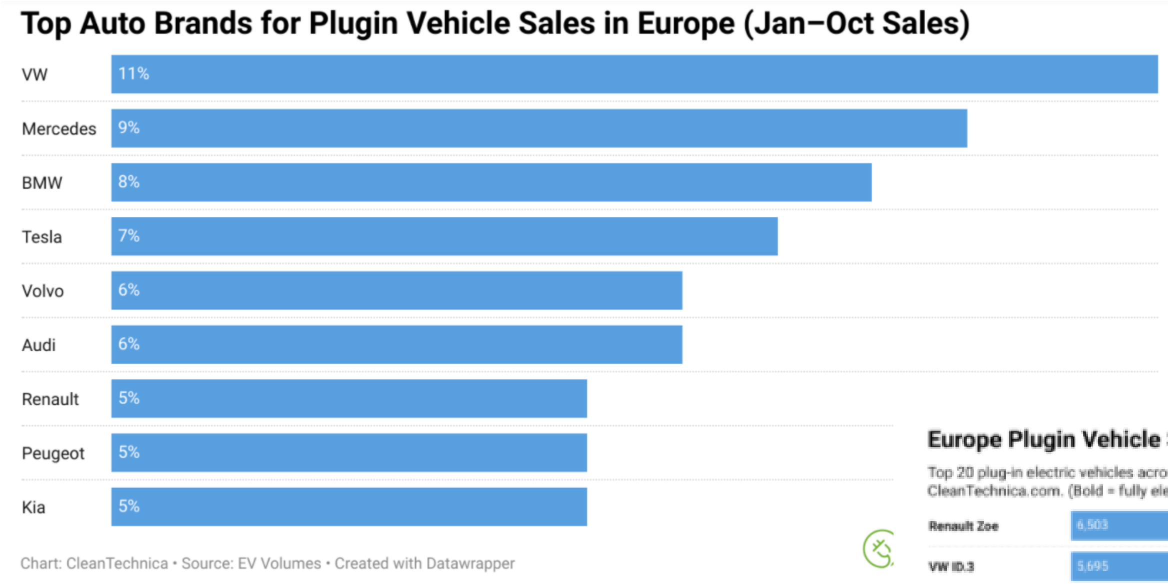
Market share [edit]

Passenger plug-in market share of total new car sales for selected countries and selected regional markets since 2013

Country	H1 2021[120]	2020	2019[121]	2018	2017	2016 [16][122]	2015 [123][124]	2014[125]	2013[126]
Norway[93][95][96][127]	82.7%	74.7%	55.9%	49.1%	39.2%	29.1%	22.4%	13.8%	6.1%
Iceland[128][129][130][131][132]	55.6%	45.0%	22.6%	19%	14.05%	4.6%	2.93%	2.71%	0.94%
Sweden[109][133][134][135]	39.9%	32.2%	11.4%	8.2%	5.2%	3.5%	2.62%	1.53%	0.71%
Netherlands[136][137][76]	19.7%	24.6%	14.9%	6.2%	2.2%	6.7%	9.9%	3.87%	5.55%
Finland[128][138][139][140]	28.3%	18.1%	6.9%	4.7%	2.57%	1.2%	—	—	—
Denmark[141][142][143][144]	26.8%	16.4%	4.2%	2%	0.4%	0.6%	2.29%	0.88%	0.29%
Switzerland[145][128][146][147]	18.2%	14.3%	5.5%	3.2%	2.55%	1.8%	1.98%	0.75%	0.44%
Germany[89][90][125][148][149][150]	22.1%	13.5%	3.0%	1.9%	1.58%	1.1%	0.73%	0.43%	0.25%
Luxembourg	18.3%	—	—	—	—	—	—	—	—
Portugal[145][151]	15.4%	13.5%	5.7%	3.6%	1.9%	—	—	—	—
France[i][99][100][152]	15.5%	11.2%	2.8%	2.11%	1.98%	1.4%	1.19%	0.70%	0.83%
UK[103][153][154][155]	14.9%	10.7%	2.9%	2.53%	1.86%	1.37%	1.07%	0.59%	0.16%
Belgium[145][128][156][157]	15.3%	10.7%	3.2%	2.5%	2.7%	1.8%	—	—	—
Austria[128][158][159][160]	17.2%	9.5%	3.5%	2.6%	2.06%	1.6%	0.90%	—	—
Ireland[161][162][163]	13.4%	7.4%	4.1%	1.57%	0.72%	0.48%	0.46%	0.27%	—
China[27][125][148][164][165][166][167]	12%	5.4%	4.9%	4.2%	2.1%	1.31%	0.84%	0.23%	0.08%

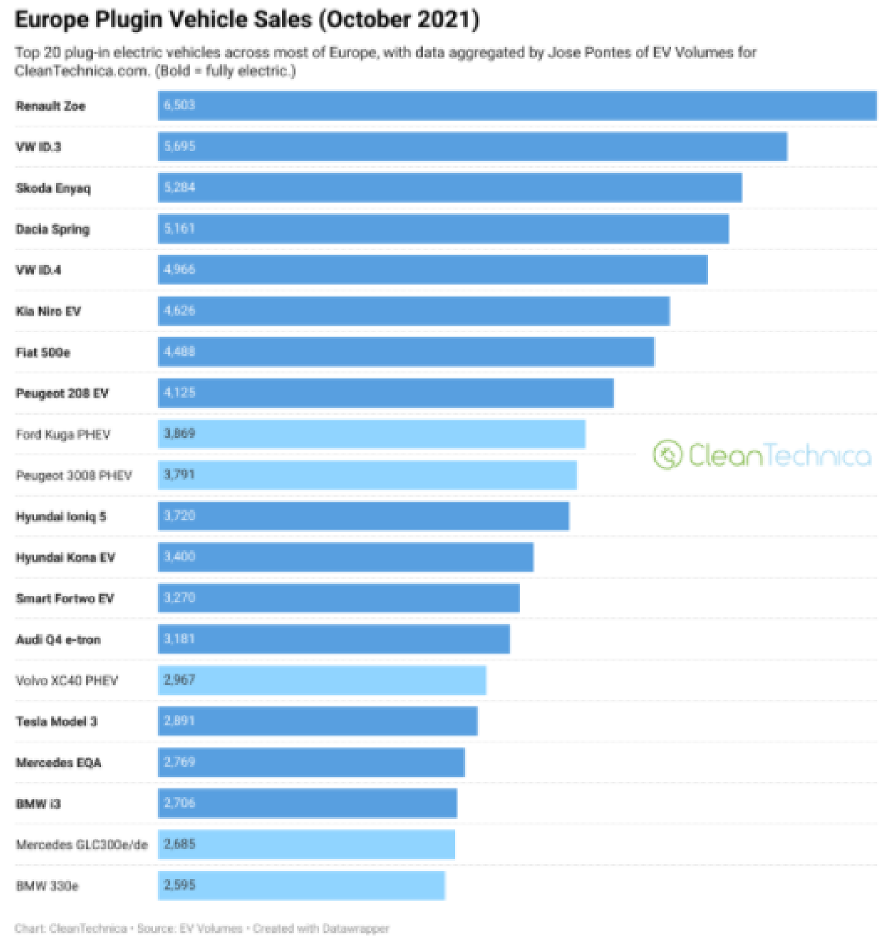


Plug-in electric cars in use
as a proportion of all passenger cars on the road
in selected countries and regional markets (Dec 2020)
Percentage of plug-in passenger cars in use
Top countries by PEV market share
Top markets by PEV sales volume
3.2%
3.7%
5.5%
18.1%
1.9%
1.2%
1.0%
0.7%
Netherlands
Sweden
Iceland
Norway*
China*
Germany
Europe
USA
Notes: * PEVs in use as of March 2021



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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ENERGY POLICY

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

Romeo Danielis*, Marco Giansoldati, Lucia Rotaris
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**

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

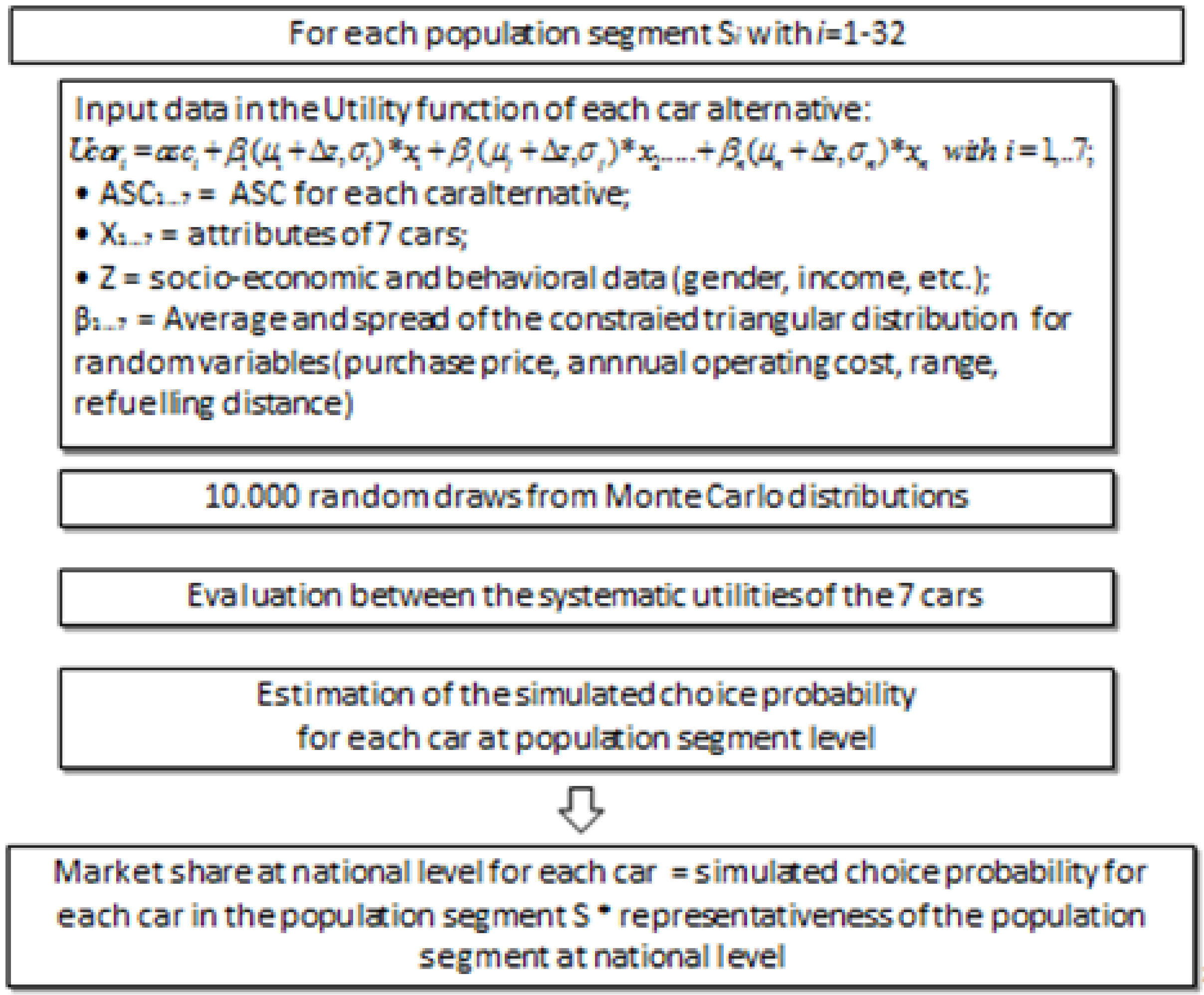
1. **Multinomial Logit model:**
   - to evaluate in a simple manner the monetary value of the nonmonetary attributes
2. **Mixed Multinomial Logit model:**
   - to take into account the random nature of the model coefficients;
   - to explore the role played by the socio-economic variables in determining 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)**

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**

Variety: vertical and horizontal differentiation





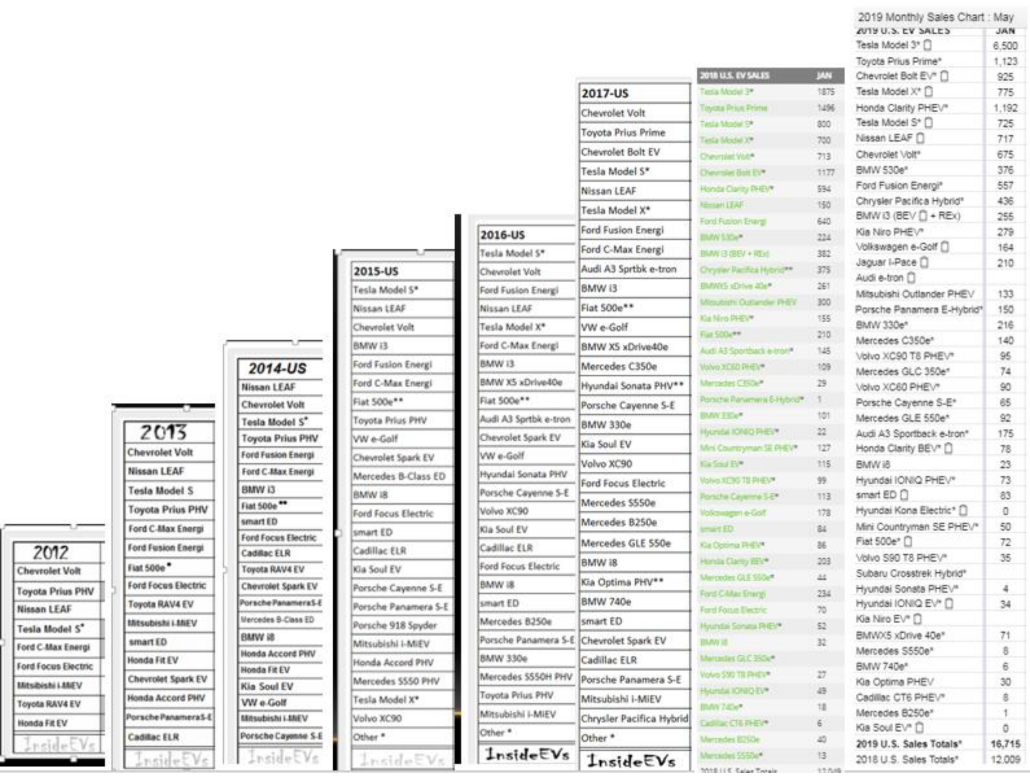



A product is mature when it is highly differentiated.
Differentiation:

- **satisfies consumer's needs (travel needs (out of town trips), speed, size (family, dog))**
- **meets different willingnesses to pay (income levels)**
- **It is one of the most important competitive strategy**

The car is one of the most highly differentiated products (level of maturity)

Variety is increasing: BEV, PHEV, EREV (no HEV) in the USA



Source: Insideevs.com
Jan. 2012: 9
Jan. 2013: 16
Jan. 2014: 22
Jan. 2015: 24
Jan. 2016: 26
Jan. 2017: 32
Jan. 2018: 42
May, 2019: 45
November 2020: 75; 33 BEV+ 42 PHEV

US 2020 - BEV

INSIDEEVs

All-Electric Car Comparisons - US

Estimated/Unofficial

Updated 2020-11-22

Brand	Model		Base Price (MSRP)	Dest. Charge	Tax Credit	Price After Tax Credit	Battery Size (kWh)	EPA Range (mi)	0-60 mph (sec)	Top Speed (mph)	Peak Power (kW)	EPA Energy consumption combined / city / highway (Wh/mi)		
Audi	e-tron (2021)	AWD	$ 65 900	$1 095	$7 500	$ 59 495	95	222	5.5	124	300	432	432	438
Audi	e-tron Sportback (2021)	AWD	$ 69 100	$1 045	$7 500	$ 62 645	95	218	5.5	124	300	438	443	432
BMW	i3 (2020)	RWD	$ 44 450	$ 995	$7 500	$ 37 945	42.2	153	7.2	93	125	298	272	330
BMW	i3s (2020)	RWD	$ 47 650	$ 995	$7 500	$ 41 145	42.2	153	6.8	100	135	298	272	330
Chevrolet	Bolt EV (2020)	FWD	$ 36 620	$ 875	N/A	$ 37 495	66	259	6.5	90	150	286	265	312
Ford	Mustang Mach-E Select SR RWD (2021)	RWD	$ 42 895	$1 100	$7 500	$ 36 495	75.7	230	5.8		198			
Ford	Mustang Mach-E Select SR AWD (2021)	AWD	$ 45 595	$1 100	$7 500	$ 39 195	75.7	210	5.2		198			
Ford	Mustang Mach-E Premium ER RWD (2021)	RWD	$ 52 000	$1 100	$7 500	$ 45 600	98.8	300	6.1		216			
Ford	Mustang Mach-E Premium ER AWD (2021)	AWD	$ 54 700	$1 100	$7 500	$ 48 300	98.8	270	4.8		258	374	351	401
Ford	Mustang Mach-E GT ER AWD (2021)	AWD	$ 60 500	$1 100	$7 500	$ 54 100	98.8	250	4.0					
Hyundai	IONIQ Electric (2020)	FWD	$ 33 045	$ 995	$7 500	$ 26 540	38.3	170	10.0	102	100	253	232	279
Hyundai	Kona Electric (2020)	FWD	$ 37 190	$1 175	$7 500	$ 30 865	64	258	7.6	104	150	281	255	312
Jaguar	I-PACE (2020)	AWD	$ 69 850	$1 025	$7 500	$ 63 375	90	234	4.5	124	294	443	421	468
Kia	Niro EV (e-Niro) (2020)	FWD	$ 39 090	$1 120	$7 500	$ 32 710	64	239	7.5	104	150	301	274	330
MINI	Cooper SE (2020)	FWD	$ 29 900	$ 850	$7 500	$ 23 250	32.6	110	6.9	93	135	312	293	337
Nissan	LEAF (40 kWh) (2020)	FWD	$ 31 600	$ 925	$7 500	$ 25 025	40	149	7.4	90	110	304	274	340
Nissan	LEAF e+ S (62 kWh) (2020)	FWD	$ 38 200	$ 925	$7 500	$ 31 625	62	226	6.5		160	312	286	347
Nissan	LEAF e+ SV/SL (62 kWh) (2020)	FWD	$ 39 750	$ 925	$7 500	$ 33 175	62	215	6.5		160	324	296	359
Polestar	2 (2021)	AWD	$ 59 900	$1 300	$7 500	$ 53 700	78	233	4.7		300	366	351	383
Porsche	Taycan 4S Perf Battery Plus (2020)	AWD	$ 103 800	$1 350	$7 500	$ 97 650	93.4	203	3.8	155	420	488	496	475
Porsche	Taycan Turbo (2020)	AWD	$ 150 900	$1 350	$7 500	$ 144 750	93.4	201	3.0	161	500	488	496	475
Porsche	Taycan Turbo S (2020)	AWD	$ 185 000	$1 350	$7 500	$ 178 850	93.4	192	2.6	161	560	496	503	496
Tesla	Model 3 Standard Range Plus (2021)	RWD	$ 37 990	$1 200	N/A	$ 39 190	50	263	5.3	140				
Tesla	Model 3 Long Range AWD (2021)	AWD	$ 46 990	$1 200	N/A	$ 48 190	75	353	4.2	145		251	239	265
Tesla	Model 3 Perf. LR AWD 20" (2021)	AWD	$ 54 990	$1 200	N/A	$ 56 190	75	315	3.1	162		298	286	315
Tesla	Model S Long Range Plus (2020)	AWD	$ 69 420	$1 200	N/A	$ 70 620	100	402	3.7	155		288	279	301
Tesla	Model S Perf. LM 19" (2021)	AWD	$ 91 990	$1 200	N/A	$ 93 190	100	387	2.3	163		306	296	318
Tesla	Model X Long Range Plus (2021)	AWD	$ 79 990	$1 200	N/A	$ 81 190	100	371	4.4	155		321	309	334
Tesla	Model X Perf. LM 20" (2021)	AWD	$ 99 990	$1 200	N/A	$ 101 190	100	341	2.6	163		347	337	355
Tesla	Model Y Long Range AWD 19" (2021)	AWD	$ 49 990	$1 200	N/A	$ 51 190	75	326	4.8	135		270	257	288
Tesla	Model Y Perf. LR AWD 21" (2021)	AWD	$ 59 990	$1 200	N/A	$ 61 190	75	303	3.5	155		304	293	318
Volvo	XC40 Recharge (2021)	AWD	$ 53 990	$ 995	$7 500	$ 47 485	78	208	4.7		300	427	396	468
Volkswagen	ID.4 Pro (2021)	RWD	$ 39 995	$ 920	$7 500	$ 33 415	82	250						

https://insideevs.com/reviews/344001/compare-evs/

US 2020 - PHEV

Updated 2020.11.22

Brand	Model		Base Price (MSRP)	Dest. Charge	Tax Credit	Price After Tax Credit	Battery Size (kWh)	EPA EV Range (mi)	Total Range (mi)	0-60 mph (sec)	Top Speed (mph)	Peak System Output Total (kW)	EV	ICE
Audi	A7 55 TFSI e quattro (2021)	AWD	$ 74 900	$1 045	$6 712	$ 69 233	**14.1**	24	440	5.7		270	105	185
Audi	A8 L 60 TFSI e quattro (2021)	AWD	$ 95 900	$1 045	$6 712	$ 90 233	**14.1**	18	420	4.9	130	330	100	250
Audi	Q5 55 TFSI e quattro (2021)	AWD	$ 51 900	$1 095	$6 712	$ 46 283	**14.1**	19	400	5.0	130	270	105	185
BMW	330e (2021)	RWD	$ 44 550	$ 995	$5 836	$ 39 709	**12.0**	22	320	5.6	130	215	83	135
BMW	330e xDrive (2021)	AWD	$ 46 550	$ 995	$5 836	$ 41 709	**12.0**	20	290	5.7	130	215	83	135
BMW	530e (2021)	RWD	$ 57 200	$ 995	$5 836	$ 52 359	**12.0**	20	350	5.9	146	185	83	135
BMW	530e xDrive (2021)	AWD	$ 59 500	$ 995	$5 836	$ 54 659	**12.0**	18	330	5.9	146	185	83	135
BMW	745e xDrive (2021)	AWD	$ 95 900	$ 995	$5 836	$ 91 059	**12.0**	16	290	4.9	155	290	83	210
BMW	i3 REx (2020)	RWD	$ 48 300	$ 995	$7 500	$ 41 795	**42.2**	126	200	8.0	93	125	125	34
BMW	i3s REx (2020)	RWD	$ 51 500	$ 995	$7 500	$ 44 995	**42.2**	126	200	7.6	100	135	135	34
BMW	X3 xDrive30e (2021)	AWD	$ 49 600	$ 995	$5 836	$ 44 759	**12.0**	17	340	5.9	130	215	80	135
BMW	X5 xDrive45e (2021)	AWD	$ 65 400	$ 995	$7 500	$ 58 895	**21.6**	31	400	5.3	146	290	83	210
Chrysler	Pacifica Hybrid (2021)	FWD	$ 39 995	$1 495	$7 500	$ 33 990	**16.0**	32	520			194	89	
Ferrari	SF90 Stradale (2021)	AWD			$3 501		**7.9**	8	330	2.5	211	735	162	574
Ford	Escape PHEV (2020)	FWD	$ 33 040	$1 245	$6 843	$ 27 442	**14.4**	37	530			165	88	
Ford	Fusion Energi - Titanium (2020)	FWD	$ 35 000	$1 195	$4 609	$ 31 586	**9.0**	26	610			143	35	103
Honda	Clarity Plug-in Hybrid (2020)	FWD	$ 33 400	$ 955	$7 500	$ 26 855	**17.0**	47	340			156	135	76
Hyundai	IONIQ Plug-in Hybrid (2020)	FWD	$ 26 500	$ 995	$4 543	$ 22 952	**8.9**	29	630			102	45	76
Hyundai	Sonata PHEV (2019)	FWD	$ 33 400	$ 955	$4 919	$ 29 436	**9.8**	28	600		75	148	50	113
Karma	Revero GT 21" (2021)	RWD	$ 144 800	$1 800	$7 500	$ 139 100	**28.0**	61	330	4.5	125	400	400	125
Kia	Niro PHEV (2020)	FWD	$ 29 490	$1 120	$4 543	$ 26 067	**8.9**	26	560				45	76
Land Rover	Range Rover P400e (2021)	AWD	$ 97 000	$1 350	$6 295	$ 92 055	**13.1**	19	480	6.4	137	297	105	221
Land Rover	Range Rover Sport P400e (2021)	AWD	$ 83 000	$1 350	$6 295	$ 78 055	**13.1**	19	480	6.3	137	297	105	221
Lincoln	Aviator Grand Touring (2021)	AWD	$ 68 900	$1 095	$6 534	$ 63 461	**13.6**	21	460			363	75	294
Mercedes	GLC 350e 4MATIC (2020)	AWD	$ 51 900	$ 995	$6 462	$ 46 433	**13.5**	22	360	5.6		232	90	153
MINI	Cooper S E Countryman ALL4 (2021)	AWD	$ 41 500	$ 850	$5 002	$ 37 348	**10.0**	17	300	6.7	78	165	65	100
Mitsubishi	Outlander PHEV (2020)	AWD	$ 36 295	$1 195	$5 836	$ 31 654	**12.0**	22	310				120	86
Polestar	1 (2021)	AWD	$ 155 000		$7 500	$ 147 500	**34.0**	52	470	4.2		455	170	240
Porsche	Cayenne E-Hybrid (2020)	AWD	$ 81 800	$1 350	$6 712	$ 76 438	**14.1**	14	420	4.7	157	339	100	264
Porsche	Cayenne E-Hybrid Coupe (2020)	AWD	$ 87 600	$1 350	$6 712	$ 82 238	**14.1**	14	420	4.8	157	339	100	264
Porsche	Cayenne Turbo S E-Hybrid (2020)	AWD	$ 163 200	$1 350	$6 712	$ 157 838	**14.1**	12	360	3.6	183	500	100	403
Porsche	Cayenne Turbo S E-Hybrid Coupe ('20) (2020)	AWD	$ 166 200	$1 350	$6 712	$ 160 838	**14.1**	12	360	3.6	183	500	100	403
Porsche	Panamera 4 E-Hybrid (2020)	AWD	$ 103 800	$1 350	$6 712	$ 98 438	**14.1**	14	490	4.4	172	340	100	246
Porsche	Panamera Turbo S E-Hybrid (2020)	AWD	$ 187 700	$1 350	$6 712	$ 182 338	**14.1**	14	450	3.2	192	504	100	410
Subaru	Crosstrek Hybrid (2020)	AWD	$ 35 145	$1 010	$4 502	$ 31 653	**8.8**	17	480				86	100
Toyota	Prius Prime (2021)	FWD	$ 28 220	$ 955	$4 502	$ 24 673	**8.8**	25	640			90	68	71
Toyota	RAV4 Prime (2021)	AWD	$ 38 100	$1 175	$7 500	$ 31 775	**18.1**	42	600	5.7		225	174	130
Volvo	S60 T8 Twin Engine (2021)	AWD	$ 47 650	$ 995	$5 419	$ 43 226	**11.6**	22	510	4.3		294	64	230
Volvo	S90 T8 Twin Engine (2020)	AWD	$ 60 050	$ 995	$5 419	$ 55 626	**11.6**	21	490	4.8		294	64	230
Volvo	V60 T8 Twin Engine Polestar (2020)	AWD	$ 67 300	$ 995	$5 419	$ 62 876	**11.6**	22	510	4.3		305	64	230
Volvo	XC60 T8 Twin Engine (2021)	AWD	$ 53 500	$ 995	$5 419	$ 49 076	**11.6**	18	520			294	64	230
Volvo	XC90 T8 Twin Engine (2020)	AWD	$ 63 450	$ 995	$5 419	$ 59 026	**11.6**	18	520			294	64	230

https://insideevs.com/reviews/344001/compare-evs/

Recent models

- VW: Volkswagen ID.3, ID.4, ID.5 Volkswagen ID Crozz, Volkswagen ID Buzz and Cargo Concept
- Audi e-tron SUV, Audi e-Tron GT, Porsche Taycan
- Skoda Citigo, Seat El-Born, Seat Mii electric

VW group

- BMW: Mini Cooper SE, BMW i4
- Peugeot e-208, Fiat e500
- Tesla Model Y, Tesla semi, Tesla pick up
- Rivian electric SUVs and pick-ups
- Chinese related: Byton EV SUV, Faraday Future FF-91, Polestar 2, Vauxhall Corsa-e
- Honda e

- And Toyota???

New Firms: Tesla Motors, (Apple)

- **Barriers to entry: The automotive sector was commonly thought as having high barriers to entry (highly concentrated)**
- **Economies of scale: Telsa – 250,000 – Toyota, VW, Ford: about 9,000,000**
- **Competition: Nissan Leaf, Renault Zoe, GM Chevrolet Bolt, BMW i3, BMW i8, eGolf, BYD…**
- **Profitability: EVs are less profitable than ICEVs.**

Industrial issues

Saving the planet

- **Elon Musk presented the Model 3 with the motivation to stop climate change. Rhetoric or real motivation?**
- **CEO only rarely put forward ideological motivations. Usual motivations: market share, value for the shareholders (profits), being competitive**
- **A real energy balance has not being presented. Elon Musk (Tesla) and Carlos Goshn (Nissan-Renault) speak of zero-emission cars..**

Financial indicators

	Tesla Motors	General Motors
Enterprise Value (Nov 20th, 2019):	**72.54B**	**138.71B**
Revenue (ttm):	**24.42B**	**144.81B**
Profit Margin (ttm):	**-3.39%**	**6.19%**
Operating Margin (ttm)	**0.62%**	**4.92%**
Enterprise Value/Revenue (ttm):	**3.09**	**0.96**

ttm = Trailing Twelve Months (as of Nov 20th, 2019)

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://ca.finance.yahoo.com/quote/TSLA/key-statistics?p=TSLA&guccounter=1

Old firms (incumbunts)

Big players' reaction

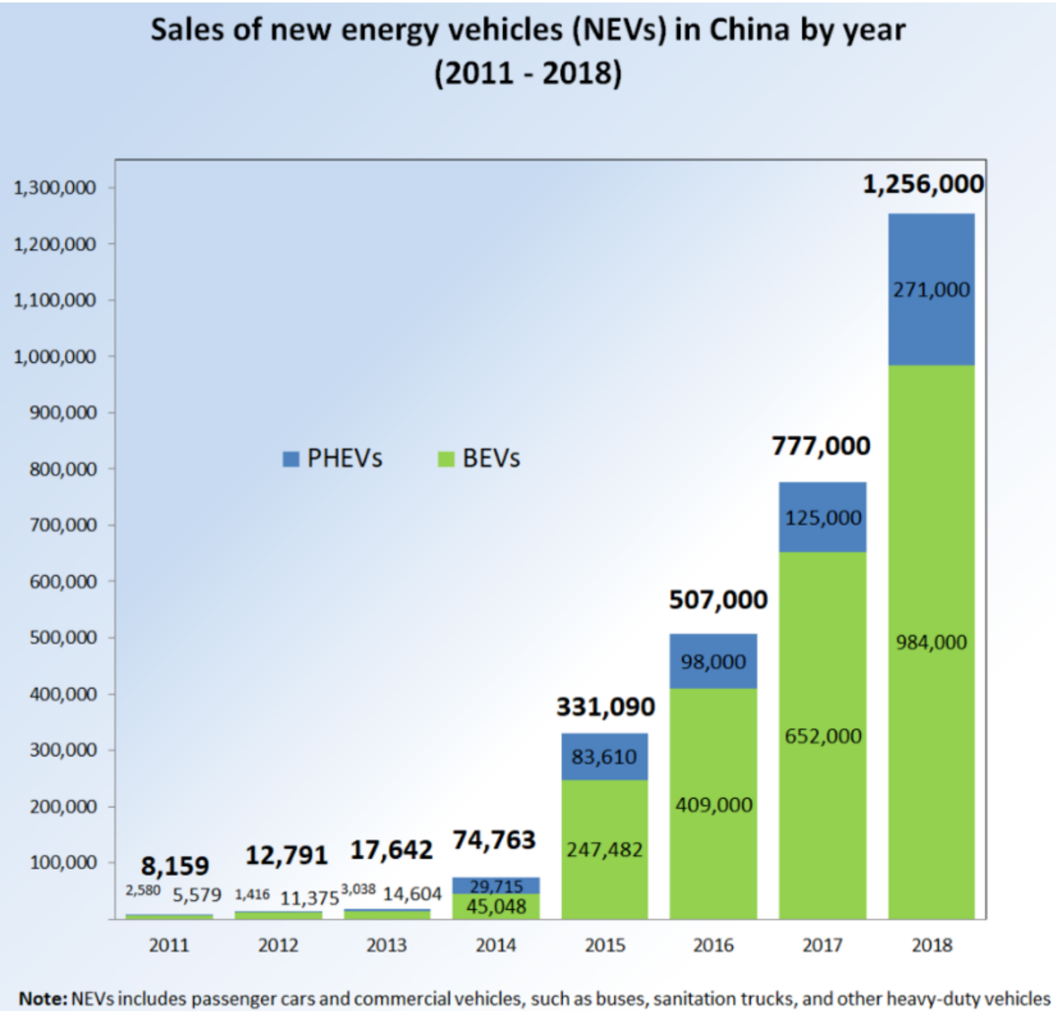
- **Volkswagen's CEO Herbert Diess said that the company will help electric cars go mainstream using its new MEB platform, which is developed for the mass market. Currently, Volkswagen is at #8 among automotive groups, at a volume 2.5-times lower than Tesla in regards to plug-in electric vehicle production, but Diess believes that will change.**
- **The new MEB platform is expected to lower the price of EVs by 40%, while at the same time doubling the range and increasing interior space.**
- **Another strong point for VW is that they are big in China, which accounts for about half of the global plug-in car market. With several mainstream brands around the world and production plants all over the globe, as well as placed orders for batteries from CATL, LG Chem and Samsung SDI, Volkswagen feels confident that it will be the automaker to take electric vehicles mainstream.**

INSIDEEVS.COM 13/9/2017

Frank Lindenberg, Vice President of Finance and Controlling at Mercedes-Benz Cars

- ***"In the beginning of the cycle we believe that we will have to face a significantly lower margin. For some vehicles half of the margin of the vehicles they replace." "We are still aiming for a 10 percent return on sales, but have to be prepared for a kind of transition, with a corridor of 8 to 10 percent,"***

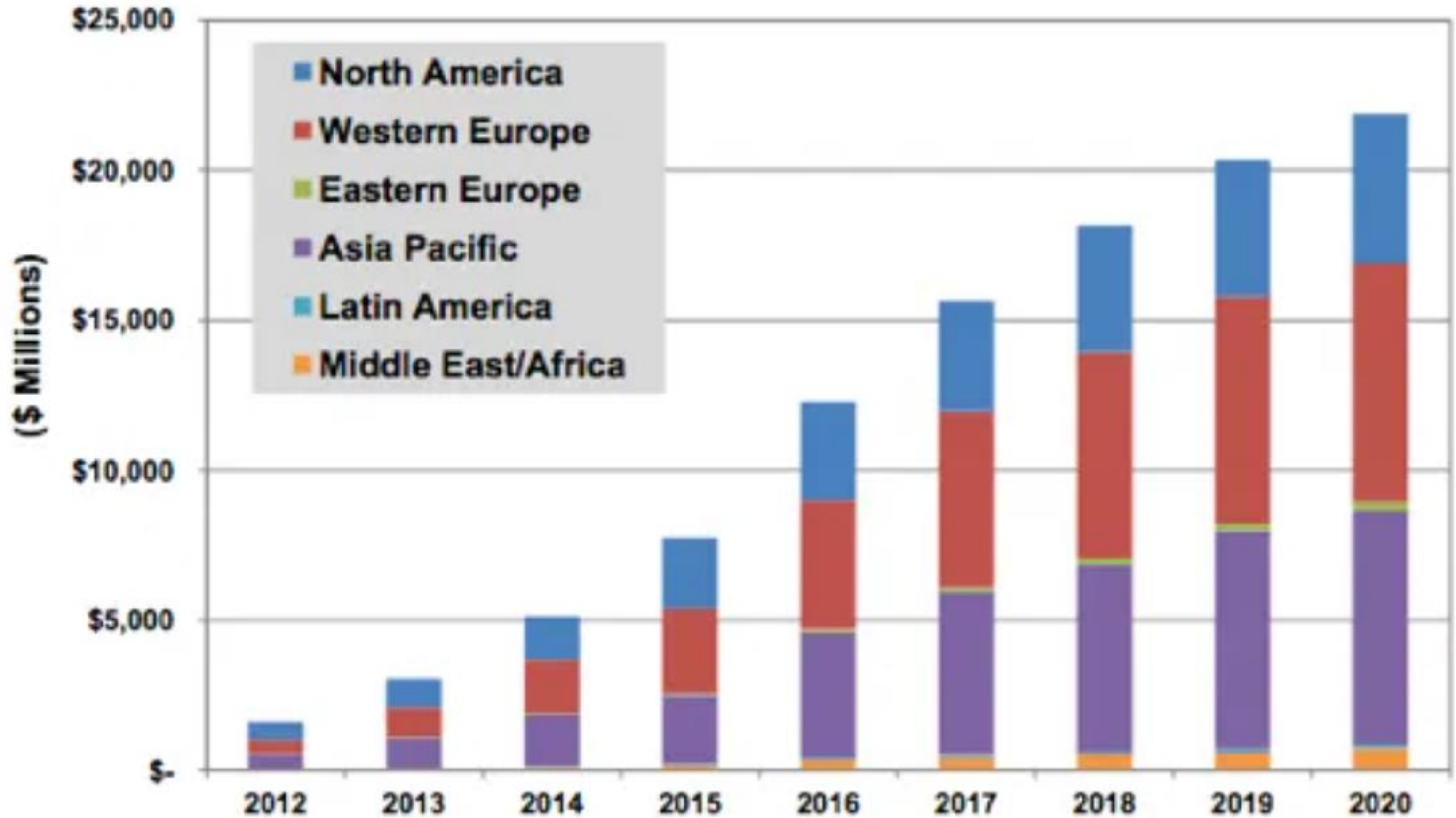
New Countries: China, India



Pl	China	October	2018	%
1	BAIC EC-Series	20648	68025	9
2	BYD Qin PHEV	3889	38859	5
3	JAC iEV S/E	4790	35261	5
4	BYD e5	4460	32406	4
5	BYD Song PHEV	3160	31699	4
6	Chery eQ	5547	30650	4
7	SAIC Roewe Ei6 PHEV	3081	29185	4
8	Hawtai EV160	5736	27068	4
9	BAIC EX-Series	3091	24805	3
10	Geely Emgrand EV	2471	24110	3
11	BYD Tang PHEV *(Gen. I & II)*	6037	23934	3
12	JMC E200	4195	23532	3
13	BAIC EU-Series	4075	21841	3
14	SAIC Roewe Ei5 EV	2337	21564	3
15	BYD Yuan EV	5803	21490	3
16	SAIC Roewe eRX5 PHEV	1196	21115	3
17	SAIC Baojun E100	3126	16041	2
18	Zotye E200	2050	14668	2
19	Zhidou D2 EV	63	13198	2
20	Hawtai xEV	2245	12641	2
	Others	31401	218845	29
	TOTAL	119401	750937	100

Batteries: a new market

Chart 1.1 *Total Lithium Ion Transportation Battery Revenue by Region, World Markets: 2012-2020*



(Source: Pike Research)

New business models

- **Business models 1: direct sales (Tesla) vs. dealership. Control margins and sales (Apple)**
- **Business models 2: Flat energy costs (included in the price) with a proprietary charging stations infrastructure (Superchargers). Too huge investments?**
- **Integration:**
  - **Vertical: Gigafactory (with Panasonic): do not rely on external providers, control of the supply chain**
  - **Transport and Energy: Solar City (Cars, superchargers, batteries, storage systems, PV)**

Q4; What are the main determinants?

1. Technological: battery
2. Political: charging infrastructure, monetary and non-monetary policies
3. Automotive industry
4. Consumers choices
5. Scientific

Factor n° 1: The EV battery

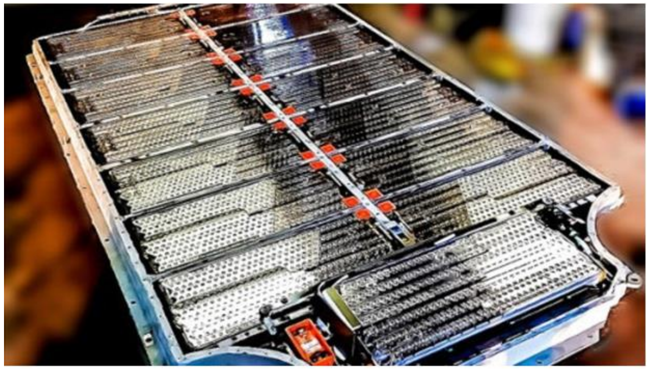
- Chemistries, , power-to-weight ratio (per unit weight), energy to weight ratio (specific energy is energy per unit mass) and energy density (per unit volume), cycles (before degradation), recharging time, disposal
- In 2015 the most used battery type for electric vehicles is Lithium-ion battery. For example: cars Nissan Leaf, Tesla Model S, Renault Zoe, BMW i3, BYD e6, Tesla Model X and more; battery electric bus: BYD ebus

Lithium batteries technology

- Lithium batteries were proposed by M. S. Whittingham, now at Binghamton University, while working for Exxon in the 1970s.
- *1991* – Sony and Asahi Kasei released the first commercial lithium-ion battery. It combined the lithium cobalt oxide cathode of a German-American, John B. Goodenough, with a carbon anode to create the world's first commercial rechargeable lithium ion battery.
- *2004* – Chiang again increased performance by utilizing iron(III) phosphate particles of less than 100 nanometers in diameter. This decreased particle density almost one hundredfold, increased the positive electrode's surface area and improved capacity and performance. Commercialization led to a rapid growth in the market for higher capacity LIBs, as well as a patent infringement battle between Chiang and John Goodenough.
- *2012* – John Goodenough, Rachid Yazami and Akira Yoshino received the 2012 IEEE Medal for Environmental and Safety Technologies for developing the lithium ion battery.

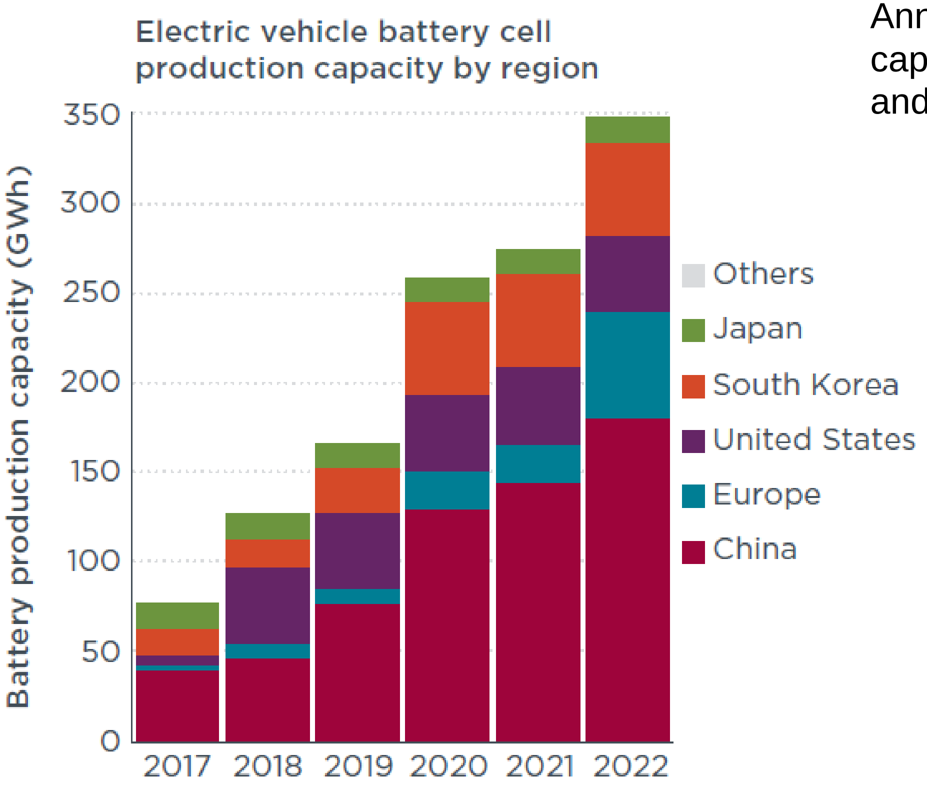
battery

Battery pack



Giga-factory

Battery production increases (China, South Corea, Japan, USA)



Announced electric vehicle battery pack production capacity for 2017–2022, by company and region.

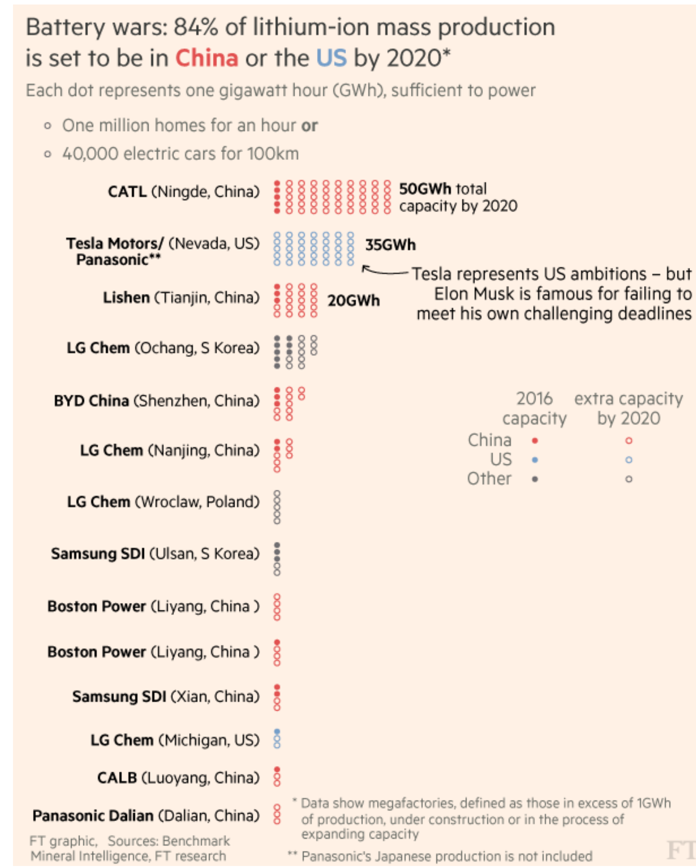
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

New industries: Battery and storage

- **Batteries: a new industry**
  - **Panasonic (Japan)**
  - **BYD’s substantial electric bus battery (China)**
  - ***AESC, the joint venture between NEC (Nippon Electric Company) and Nissan***
  - **LG Chem (South Corea) is the supplier for the Chevy Volt**
  - ***Lithium Energy Japan (GS Yuasa / Mitsubishi)***
  - ***Samsung* (South Corea) *has a partnership with BMW and FIAT***
  - ***Epower is the first of a series of small Chinese battery makers***
  - **Tesla/Panasonic Gigafactory (opening 2016)**

No European big producer: VW?

Solar city (cars, battery, storage, PV)

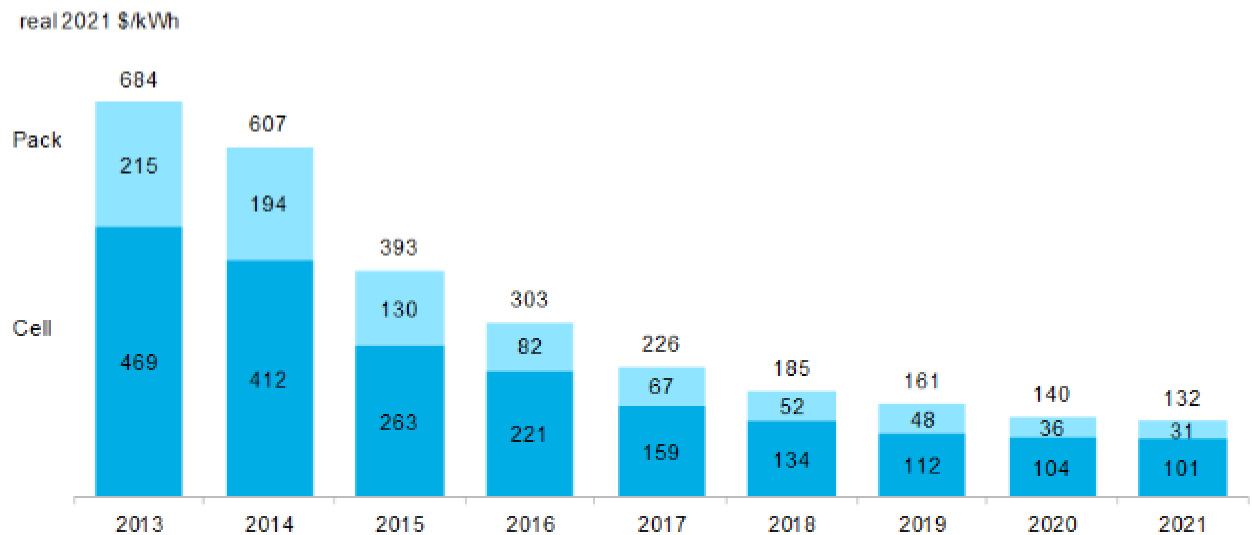


The cost per kWh

- How to decrease the cost per kWh?
  - Cost of materials (battery packs)
  - Cost of manufacturing (scale, engineering)
  - Increase performance: new batteries (chemistry, solid state)
- Gradual vs. disruptive reduction?
- Range parity, cost parity

https://about.bnef.com/blog/battery-pack-prices-fall-to-an-average-of-132-kwh-but-rising-commodity-prices-start-to-bite/

Figure 1: Volume-weighted average pack and cell price split



Source: BloombergNEF.

Energy & Environmental Science

ANALYSIS

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Determinants of lithium-ion battery technology cost decline†

Micah S. Ziegler,[a] Juhyun Song[a] and Jessika E. Trancik*[ab]

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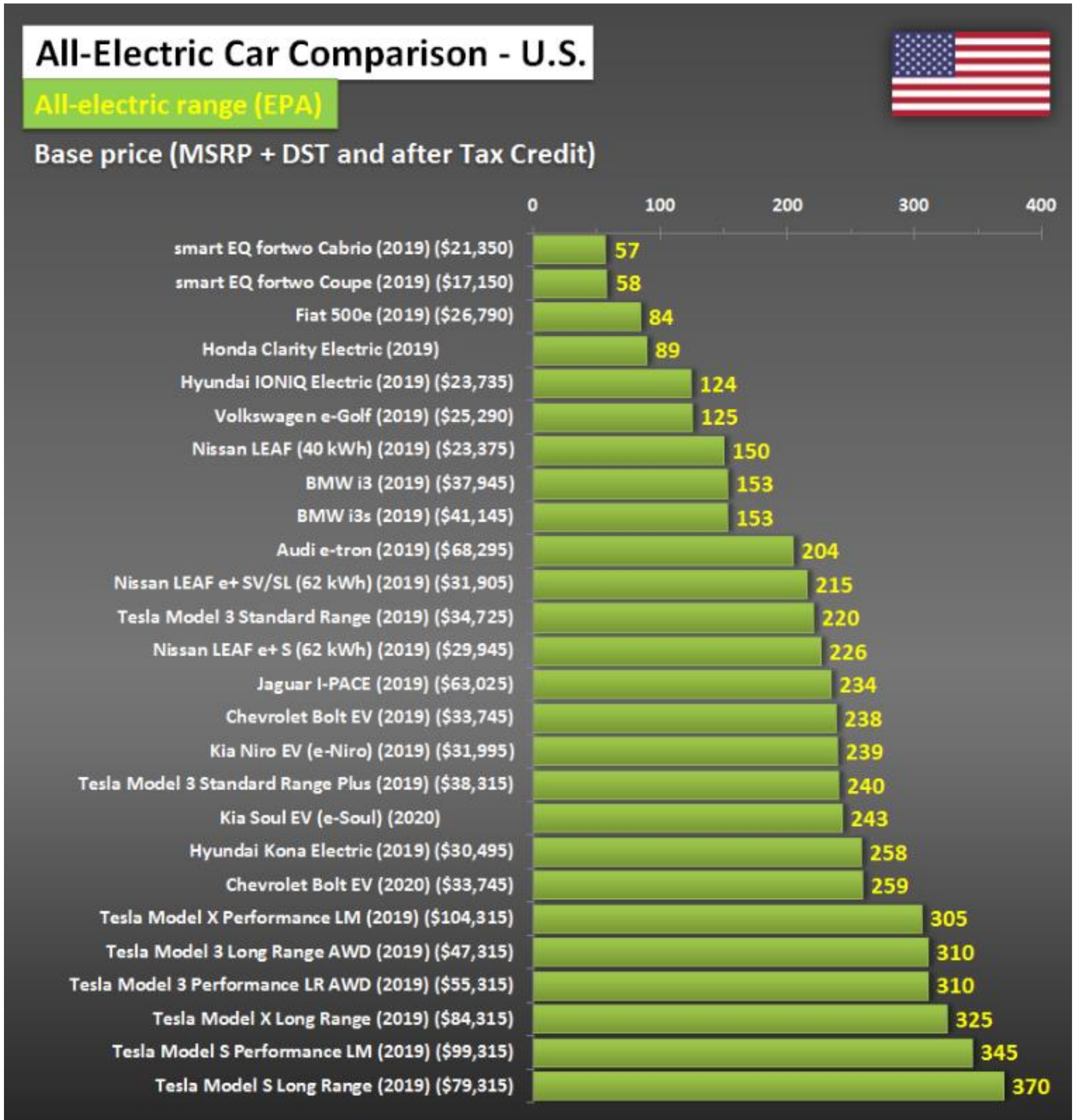
rsc.li/ees

Prices of lithium-ion battery technologies have fallen rapidly and substantially, by about 97%, since their commercialization three decades ago. Many efforts have contributed to the cost reduction underlying the observed price decline, but the contributions of these efforts and their relative importance remain unclear. Here we address this gap by developing a set of cost change models to disentangle these efforts and estimate their individual contributions to the cost decline of lithium-ion cells. We collect data on lithium-ion cell components and their prices, develop a cost equation and cost change equations for these cells, and estimate the contributions of different low-level mechanisms of cost reduction, such as the impacts of changes in energy capacity characteristics, reductions in material prices, and changes in non-material costs. We find that between the late 1990s and early 2010s, about 38% of the observed cost decline resulted from efforts to increase cell charge density. Meanwhile, reductions in cathode materials prices contributed 18% of the cost reduction, and changes in non-material costs accounted for 14% of the cost decline. We also consider the contributions of high-level mechanisms, including research and development (R&D), learning-by-doing, and economies of scale. We find that the largest share of cost change was driven by public and private research and development, which we estimate contributed a majority of the observed cost reduction, with a lower contribution from economies of scale. Moreover, we find that the majority of the R&D contribution can be attributed to advancements in chemistry and materials science. Looking to the future, these results suggest that the nature of electrochemical battery technology, which often allows for many different combinations of electrode materials and electrolyte chemistries, presents further opportunities for new approaches and cost decline in batteries. However, public policy may be needed to help avoid premature lock-in, which can result from market forces favoring incumbent technologies.

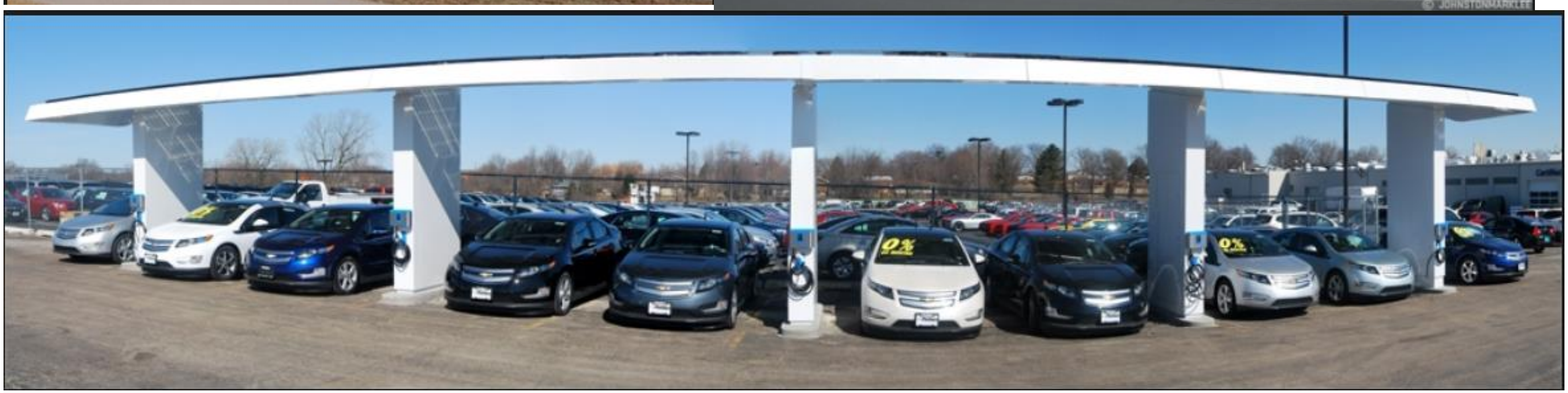
Range anxiety? The crucial factor: the cost of the battery!



Factor n° 2: the charging infrastructure

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

Charging station powered with solar panels



How important is the charging infrastructure for EVs uptake?

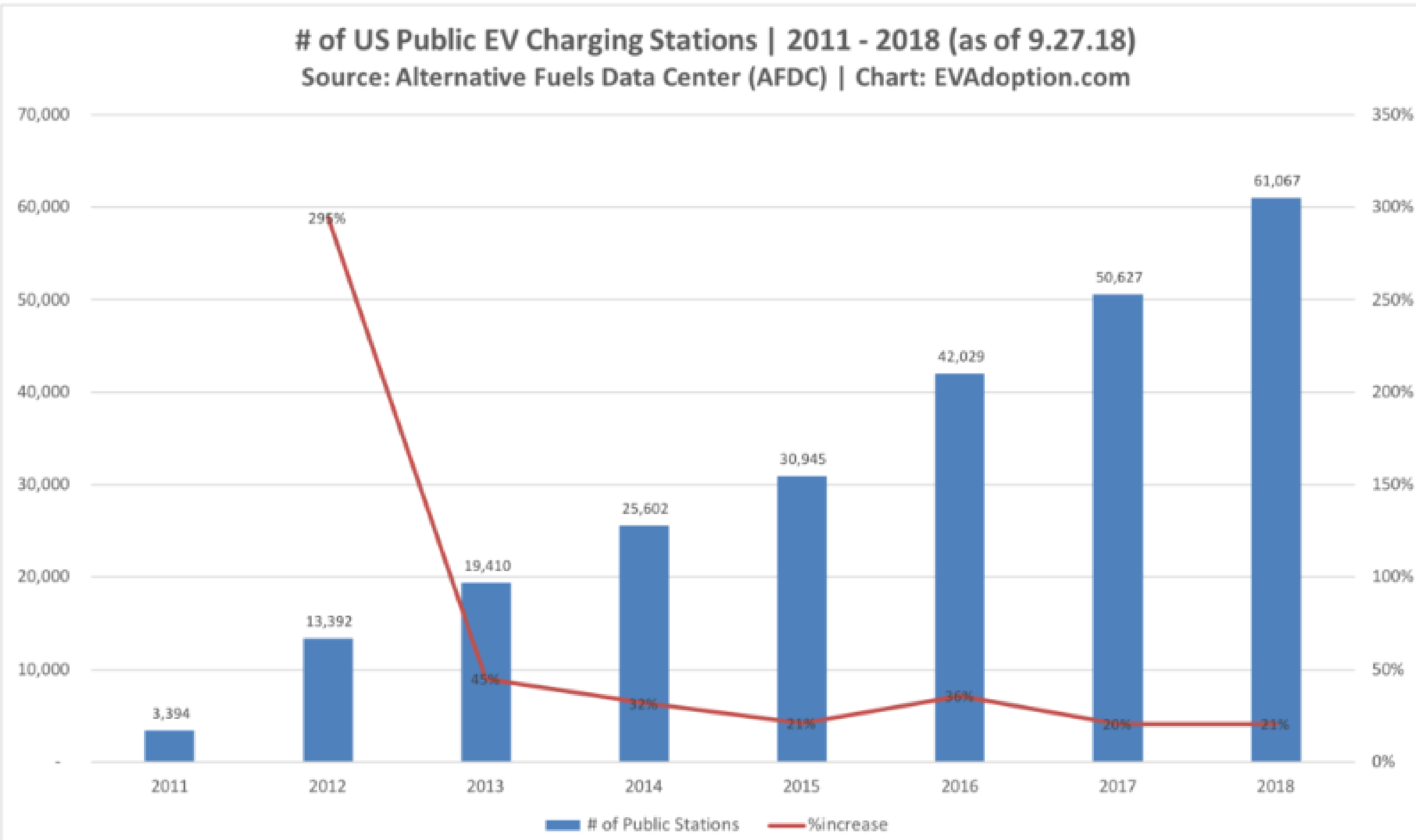
- **A ‘chicken or the egg’ dilemma: without the massive deployment of EVs, there is no need for charging infrastructures; but without charging infrastructures, the sales of EVs are hindered by the lack of charging solutions and the limited range of EV’s.**
- **Real importance: many trips are commuting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

Is public intervention necessary? Is it sufficient?

- **The proprietary private model: Tesla - 616 Supercharger-Stations with 3,644 charging places (April 2016); 934 Supercharger-Stations with 6,372 charging places (September 2017);**
- **New business model: Flat (zero) energy costs. Included in the price of the car for high end EVs**
  - **Zero variable cost? incentive to travel; marketing trick (not extended to the Model 3)**
  - **How much has it costed to Tesla? Is it sustainable? Should it be opened to other users?**
- **Who is going to build the unprofitable chargers (low usage highways and roads)? the lower the battery density the more dense should the charging network be**

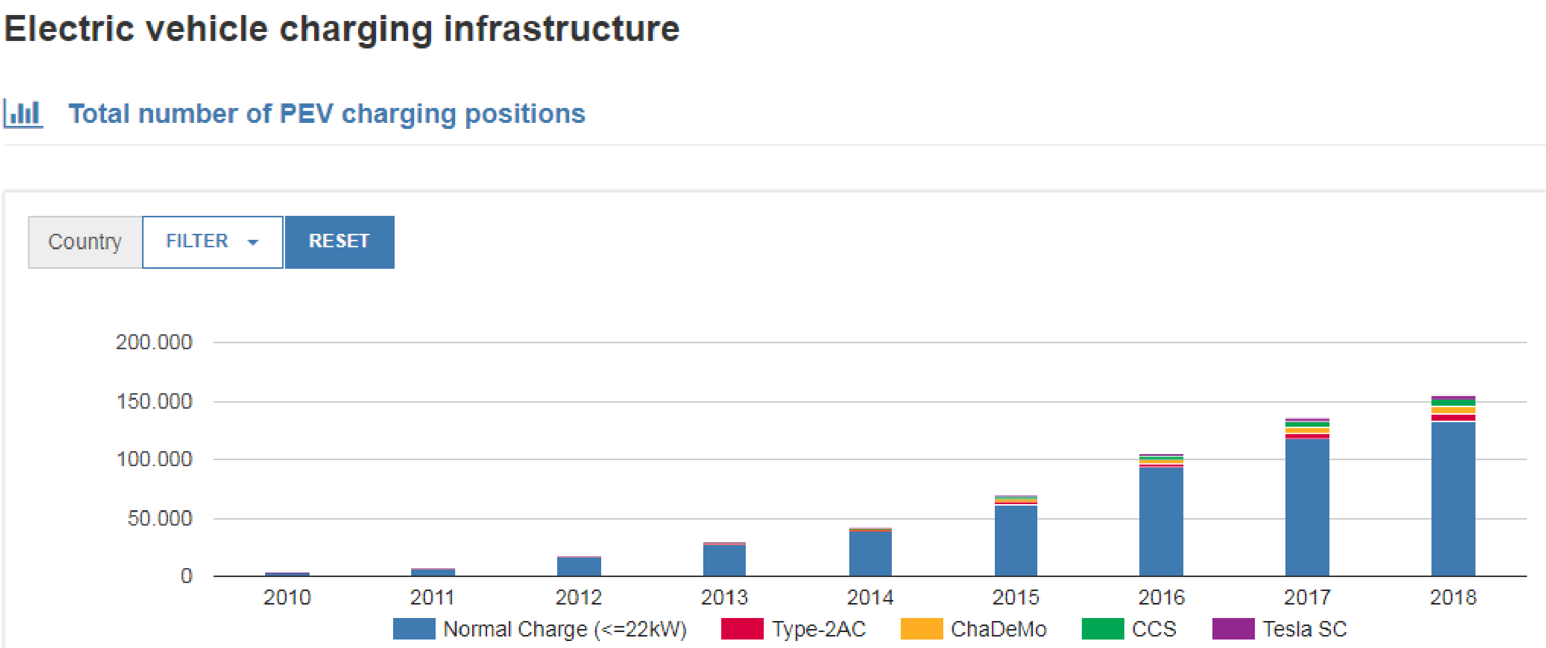
Charging stations development

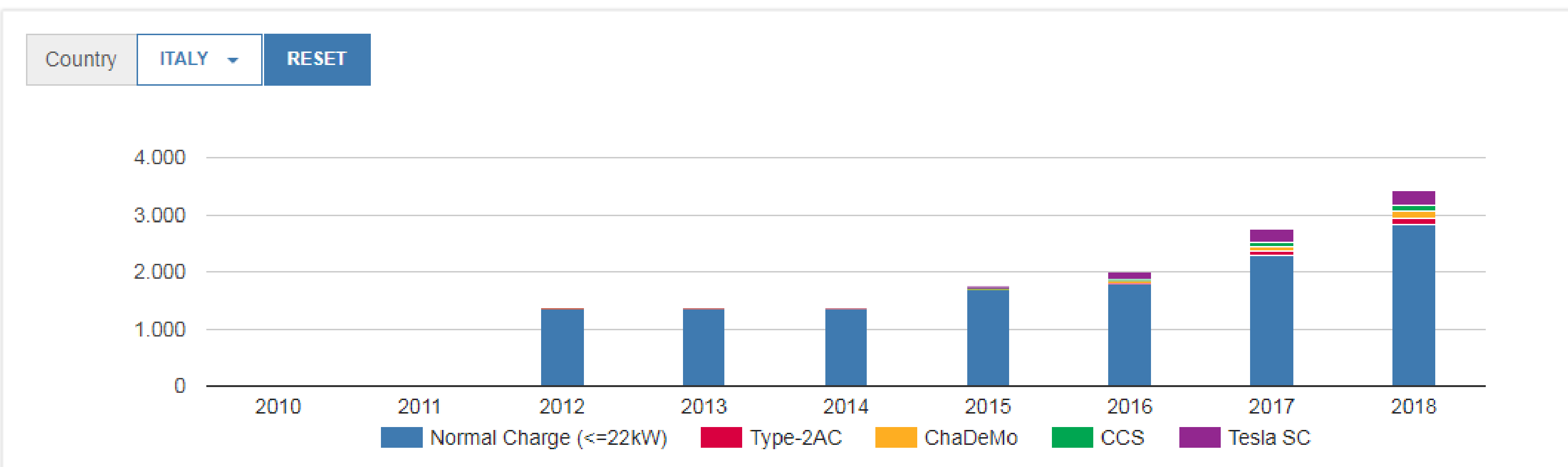
Number of Public Charging Stations (Outlets) in the US – 2011-2018



https://evadoption.com/ev-charging-stations-statistics/

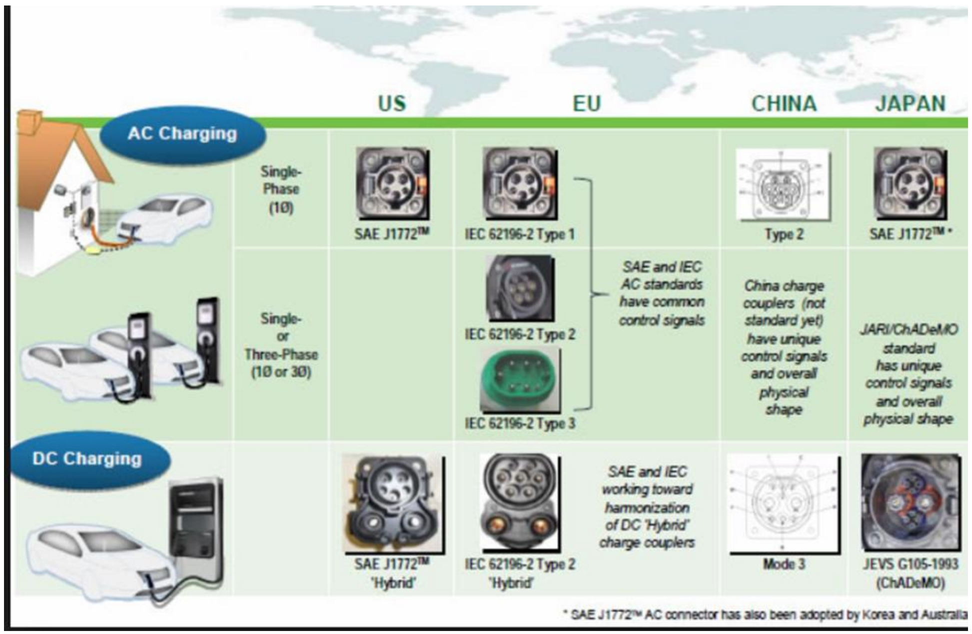
Europe and Italy

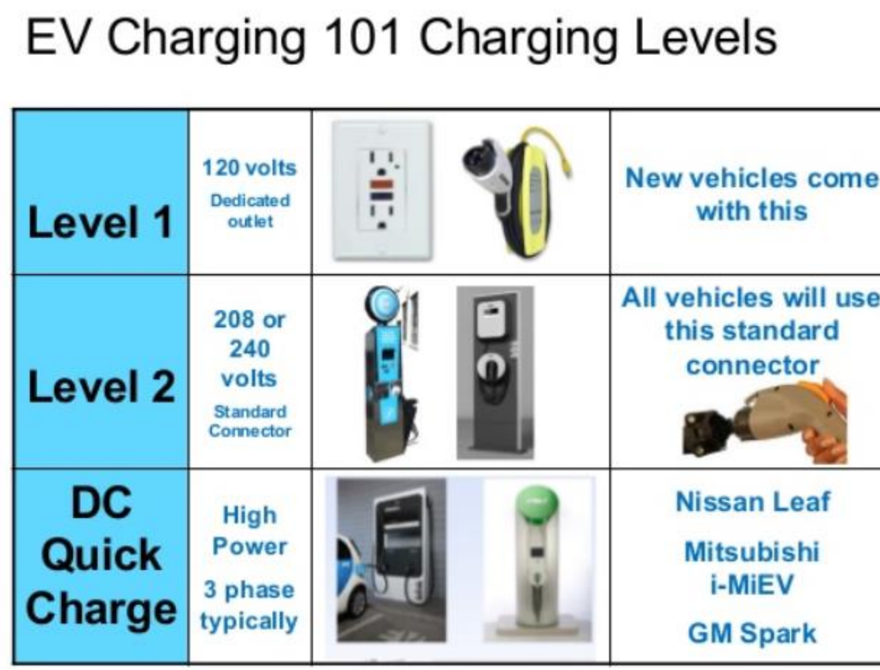




https://www.eafo.eu/electric-vehicle-charging-infrastructure

The charging equipment: the battle for the standards





EV Charging 101 Charging Levels

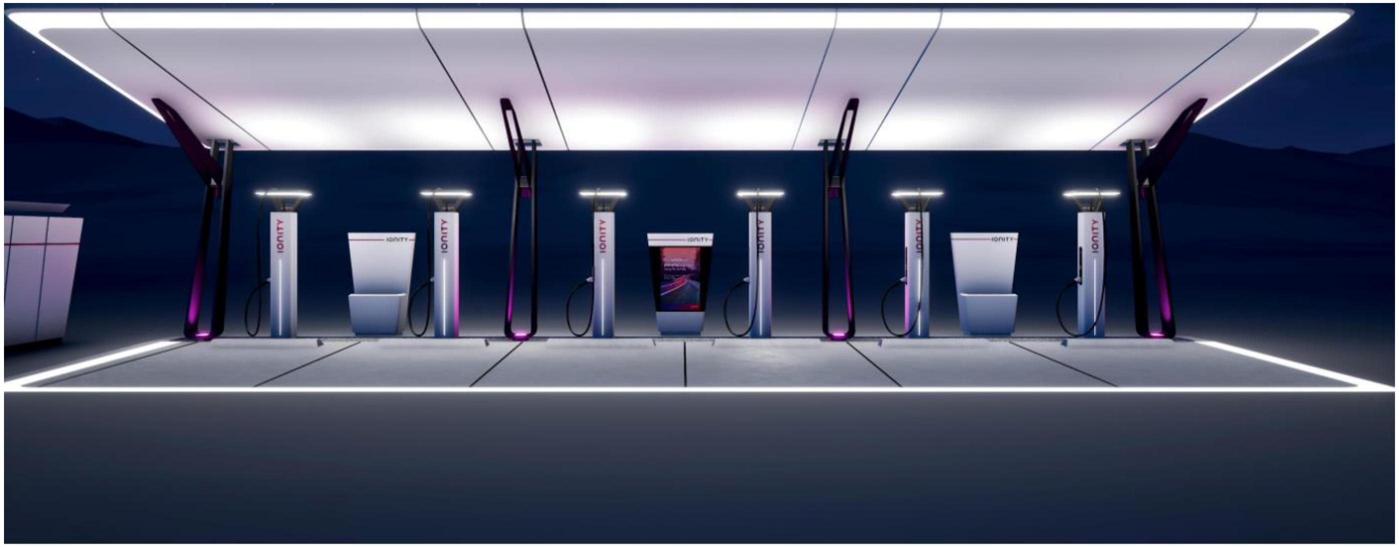
Level 1	120 volts Dedicated outlet		New vehicles come with this
Level 2	208 or 240 volts Standard Connector		All vehicles will use this standard connector
DC Quick Charge	High Power 3 phase typically		Nissan Leaf Mitsubishi i-MiEV GM Spark

Inductive charging (wireless charging)

Charging power and connectors

Level	Original definition[227]	Coulomb Technologies' definition[228]	Connectors
AC Level 1	AC energy to the vehicle's on-board charger; from the most common U.S. grounded household receptacle, commonly referred to as a 120 volt outlet.	120 V AC; 16 A (= 1.92 kW)	SAE J1772 (16.8 kW), NEMA 5-15
AC Level 2	AC energy to the vehicle's on-board charger; 208 - 240 V, single phase. The maximum current specified is 32 A (continuous) with a branch circuit breaker rated at 40 A. Maximum continuous input power is specified as 7.68 kW (= 240 V × 32 A*).	208-240 V AC; 12 A - 80 A (= 2.5 – 19.2 kW)	SAE J1772 (16.8 kW), IEC 62196 (44 kW), Magne Charge (Obsolete), Avcon, IEC 60309 16 A (3.8 kW) IEC 62198-2 Type 2 same as VDE-AR-E 2623-2-2, colloquially known as the "Mennekes connector" (43.5 kW) IEC 62198-2 Type 3 colloquially known as "Scame"
AC Level 3	AC energy to the vehicle's on-board charger; 208 - 240 V, single phase. The maximum power of 96 kW (continuous).	208-240 V AC; 11.6 to 96 kW	SAE J1772 standard pending
Combo Charging System (CCS)	DC energy from an off-board charger; with additional pins to accommodate fast DC charging at 200–450 Volts DC and up to 90 kW. This will also use Power Line Carrier technology to communicate between the vehicle, off-board charger, and smart grid.	200–450 Volts DC and up to 90 kW	SAE J1772 Combo Coupler

Latest news: Ionity network



THE POWER OF 350 KW

The power of charging at 350 kW is the power to stop, drink a coffee, and go. At maximum speed, you can be on your way within minutes. Competing networks provide less power, and charge points in cities are even slower. So the first time you use an IONITY charging point, try not to be surprised how quickly… it's over.

October 31, 2018

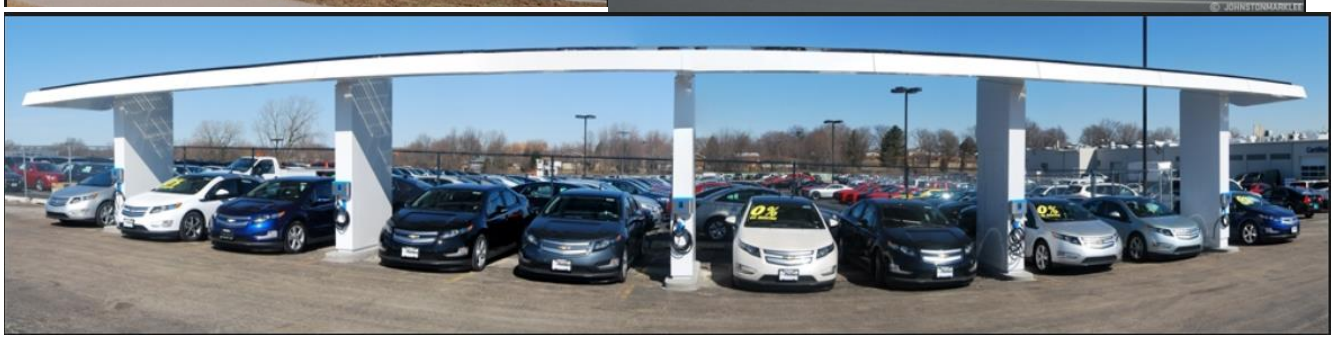
pdf

IONITY TEAMS UP WITH ENI AND ENEL X TO BUILD THE FIRST NETWORK OF HIGH-POWER-CHARGING STATIONS IN ITALY

IONITY, the joint venture of BMW, Daimler, Ford and Volkswagen Group with Audi and Porsche, has signed a framework agreement with Eni to build up to 30 High Power Charging stations in Italy from 2019, initiating a new era in Italian e-mobility.

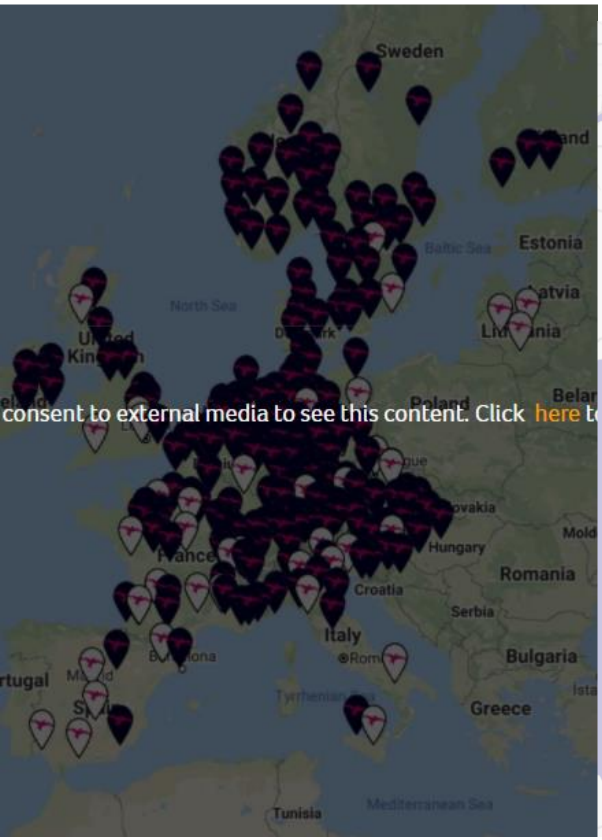
This new partnership complements the cooperation agreement IONITY has already signed with Enel, or more specifically its advanced energy services division Enel X, to install up to 20 IONITY high power charging stations by the end of 2019.

Charging station powered with solar panels: energy and transport integration



Competition among charging network

Ionity network



enel x

52481: punti di ricarica (ott. 2020)

T E S L A

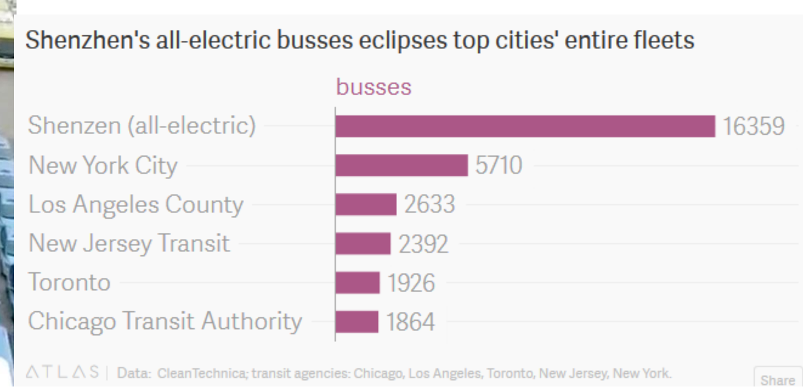
1,971 Supercharger Stations with 17,467 Superchargers

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 CO_2 emissions in Germany)

Tragic Siemens Magnus eFusion Prototype Accident

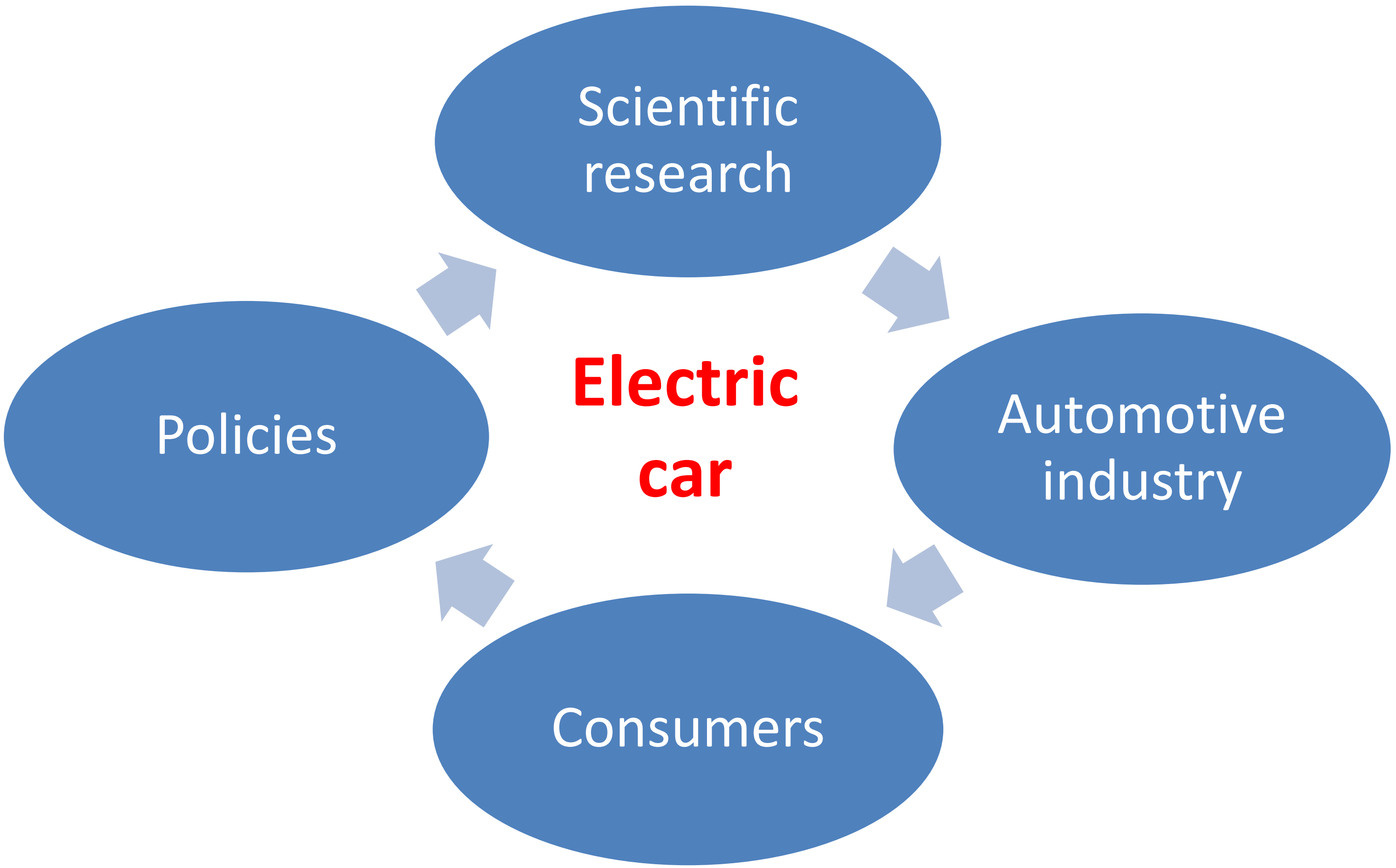
According to FlyingMag, the Magnus eFusion two-seat prototype crashed near Budapest, Hungary, after it was spotted catching on fire. The cause has yet to be officially determined. So far, the Siemens electric motor doesn't seem to be at fault and the culprit seems to lie with the batteries. We are waiting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

Economic policy issues

A. **The role of the public authorities: R&D, setting the stage, policies**
B. **The role of the customer**
C. **The role of the scientific community**

International shipping?

Decarbonising tranport: is it possible? The players



Decarbonising tranport: is it possible?

Avoid, Shift, Improve strategy

- Avoid
  - Reduce unecessary trips (land-use, urban planning, teleconferences)
- Shift to less carbon intensive modes of transport
- Improve: technology mandate
  - Electric vehicles (car, scooters, buses, trains, vans) using electriciy from renweable souces
  - Hydrogen fueled vehicles (coaches, trucks, boats) using electriciy from renweable souces
  - International aviation and shipping?

Effective and efficient policies to decarbonise transport

The role of the public authorities

1. Research & Development
   – Batteries
   – Engine
   – Smart grids

Government policy and the development of electric vehicles in Japan

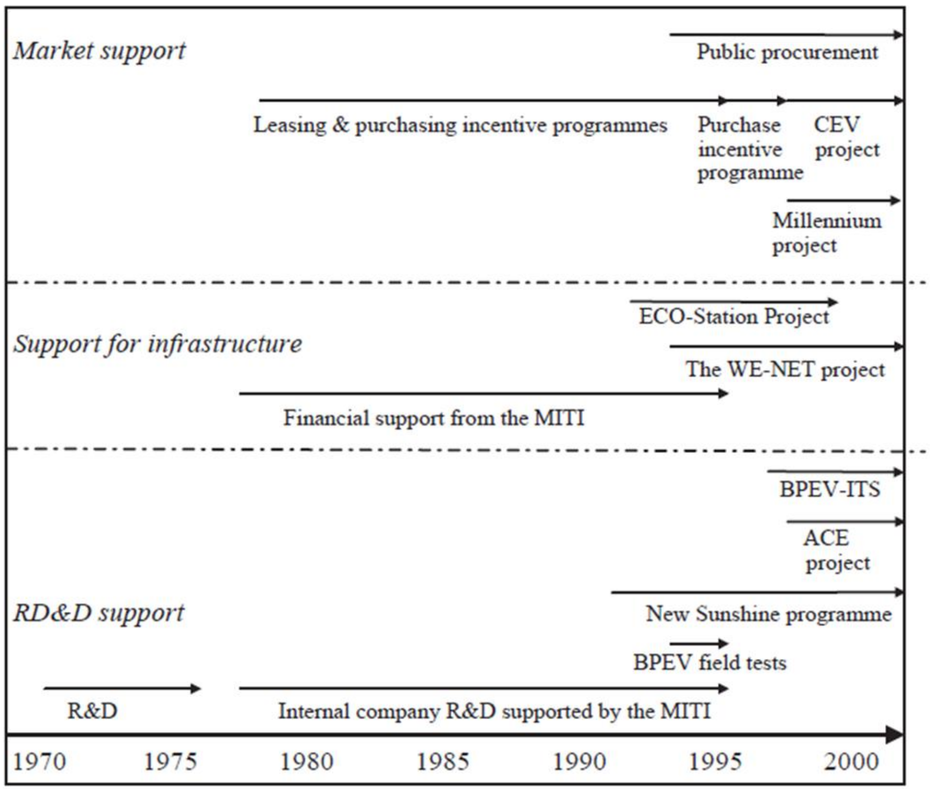


Fig. 1. Basic outline of Japanese Government programmes supporting BPEVs, HEVs and FCEVs.

Under the New Sunshine Programme,' R&D on polymer electrolyte fuel cells (PEMFC) has been undertaken since 1992. Research is also conducted under the same programme on lithium batteries (through the organisation LIBES) since 1992. The aim was to develop both stationary and vehicle applications of the next generation of batteries based on lithium.

In 1997 the MITI initiated the Advanced Clean Energy (ACE) vehicle programme. This is an R&D programme extending from 1997 to 2003 with the objective of developing different high-energy efficient hybrid vehicles.

Åhman, Max (2006). Government policy and the development of electric vehicles in Japan. *Energy Policy,* 34 (4): 433-443.

Policy taxonomy

- Taxonomy 1
  - Avoid: unnecessary trips, reduce mobility needs, shorten trips (techology, spatial planning)
  - Shift: to less CO2 intensive modes
  - Improve:
    - Traffic managment: reduced congestion
    - fuel efficiency, new propulson systems
- Taxonomy 2
  - Pricing: carbon tax, registration tax, congestion tax, subsidies, emission permits (ETS)
  - Regulation: standards, access restrictions, innovation enforcement (safety, emissions, noise)

The role of the public authorities

2. **Setting the stage: energy and environmental goals**
   - **Standards**
   - **Cafe regulation**
   - **COP21**
   - **Air quality regulation**
   - **Banning ICEVs or making them more costly (Netherlands, Norway)**

- **The myth of the level playing field: private and collective choices!**
    - **Huge German subsidies on diesel cars**
    - **Unrealistic EURO standards testing procedures**
- **Carlos Goshn: «the automotive industry is lead by the regulator»**

European Standards

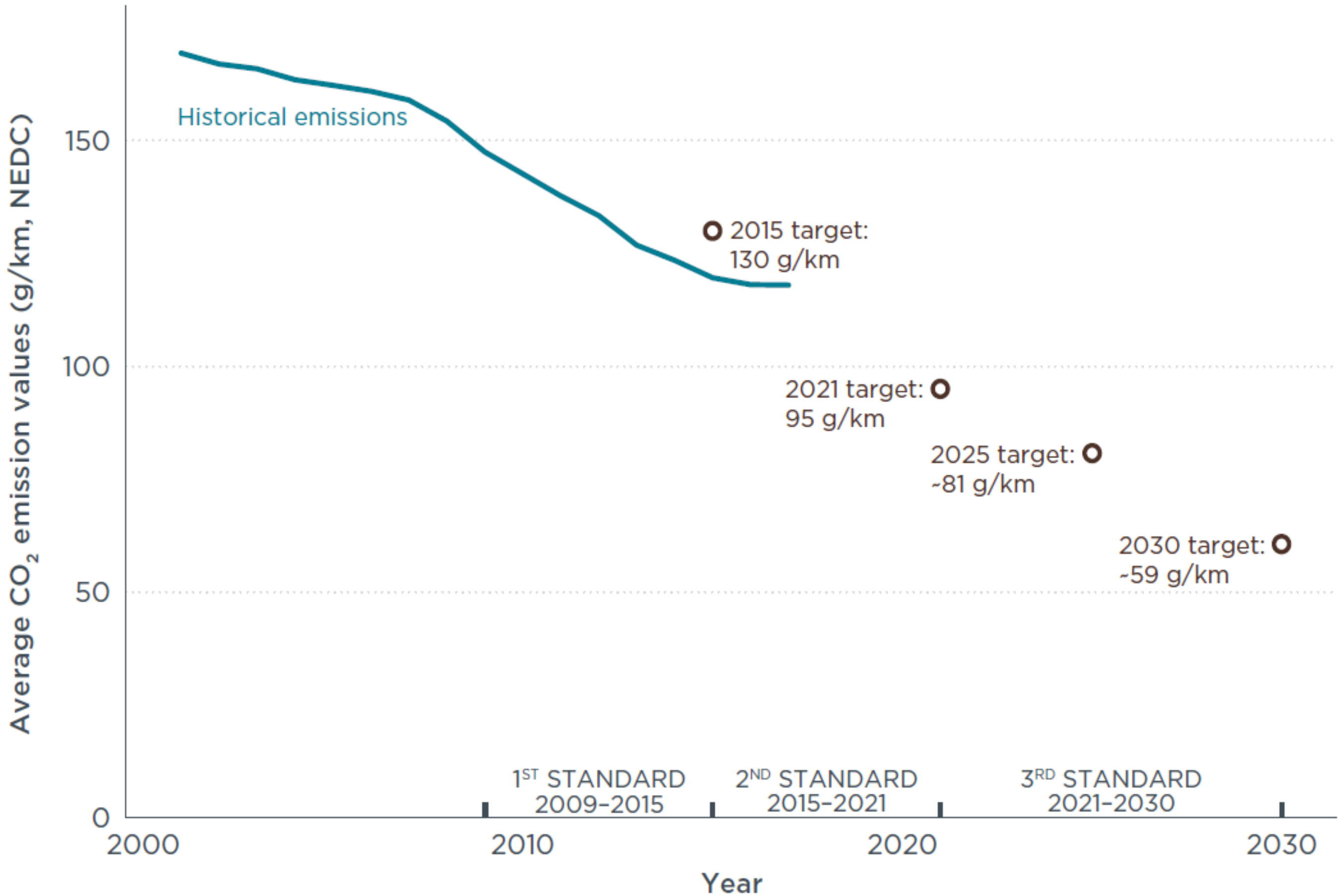


Figure 1. Average historical CO_2 emission values and adopted CO_2 standards for new passenger cars in the EU. All CO_2 values refer to New European Driving Cycle (NEDC) measurements.

Fonte: ICCT (2019)

Current values: cars

Tavola 9 – Automobili

Gruppo	EU quota di marcato 2017	Peso medio (kg) 2017	CO_2 media (g/km) 2017	CO_2 obiettivo (g/km) 2015	CO_2 obiettivo (g/km) 2021	% di veicoli elettrici 2017
Toyota	5%	1,359	103	127	94	0.3%
PSA	16%	1,273	112	125	91	0.1%
Renault-Nissan	15%	1,310	112	126	93	2.5%
FCA	6%	1,259	120	124	91	0.0%
Ford	7%	1,393	121	128	95	0.0%
BMW	7%	1,570	122	139	101	5.0%
Hyundai	6%	1,348	122	129	94	1.4%
Volkswagen	23%	1,420	122	132	96	1.2%
Daimler	6%	1,607	127	139	103	2.6%
Media		1,390	119	130	95	1.4%

Fonte: ICCT (2019)

Current values: vans

Tavola 10 – Furgoni

Gruppo	EU quota di marcato 2017	Peso medio (kg) 2017	CO_2 media (g/km) 2017	CO_2 obiettivo (g/km) 2015	CO_2 obiettivo (g/km) 2021	% di veicoli elettrici 2017
Peugeot	0.11	1659	129	171	137	0.6%
Citroën	0.1	1647	129	170	136	0.5%
Renault	0.15	1675	145	172	138	1.7%
Fiat	0.09	1707	152	175	141	0.0%
VW	0.11	1842	160	188	154	0.1%
Opel	0.03	1738	163	178	144	0.0%
Ford	0.16	1949	166	198	165	0.0%
Nissan	0.03	1883	167	191	158	4.9%
Mercedes-Benz	0.09	2004	191	203	170	0.0%
Iveco	0.03	2255	209	226	194	0.0%
Media		1798	156	175	147	0.8%

Fonte: ICCT (2019)

International comparison of standards

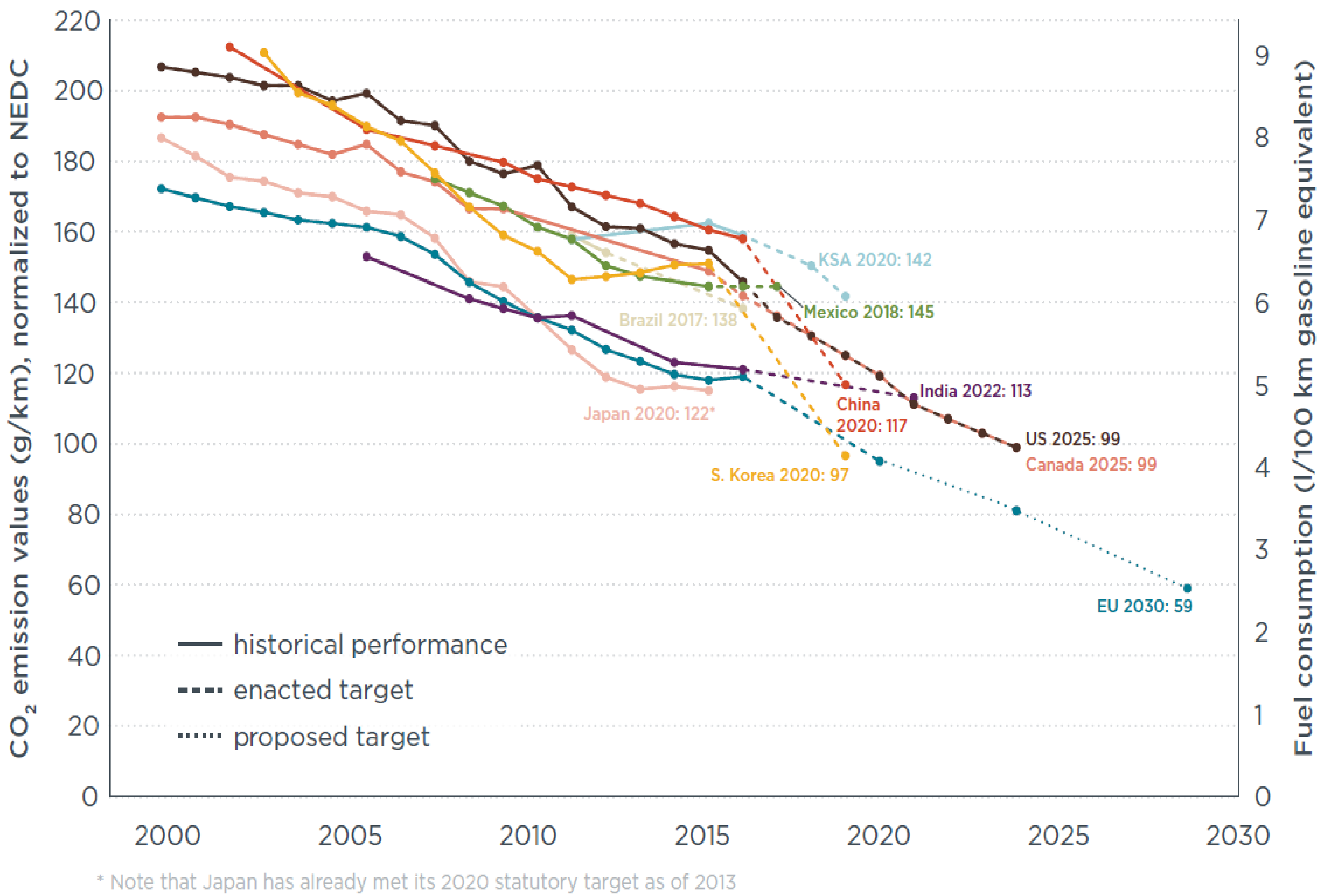


Figure 6. Comparison of global CO_2 regulations for new passenger cars.[17]

ICCT (2019)

The role of the public authorities

- 3. Policies
  - Investments in charging infrastructure
  - Monetary incentives
    - Direct subsidies (differentiate per purchasing price)
    - Reduced taxes (matriculation tax, property tax)
    - Reduced parking fees
  - Non-monetary
    - Access to zero-emission areas
    - Access to restrict areas (city center) or in restricted days
    - Exclusion from lottery (China)

Carbon tax vs. Emission trade schemes

- From the business point of view, the carbon tax provides price certainty, as the companies subject to the tax know how much they will have to pay per tonne of CO_2 emitted. From the regulator's point of view, the definition of the carbon tax does not guarantee a certain level of reduction of emissions, since it is not known a priori if companies will decide to pay the tax or to reduce emissions.
- ETS, by setting a ceiling on emissions, provide the regulator with quantitative certainty about emissions. From a business perspective, however, price fluctuations within the structure of the trading market do not allow for a solid basis for business planning.
- In the face of these problems, hybrid solutions have been proposed and implemented. For example, minimum and maximum price limits to prevent prices from being "too low" or "too high". Similarly, the carbon tax can be equipped with automatic adjustment mechanisms connected to the overall amount of emissions.

Emission trade schemes in practice

- Adopted in Europe since 2005 (**green certificates**), thanks to the agreements linked to the Kyoto protocol. Discussed in Germany. Supported by the EU.
- applied to the energy, iron and steel, mineral products, ceramics, paper and **civil aviation sectors**. They apply to over 12,000 power plants and companies in the 28 EU member states, as well as Iceland, Liechtenstein and Norway, covering around 45% of the EU's greenhouse gas emissions.
- do **not apply to the remaining modes of transport,** agriculture and building heating.
- From an initial market price of 30 €/ton CO2 equivalent in 2006, the market price of emission permits fell in 2016 to 5 € / ton CO2 eq., Euro), probably due to the economic and structural crisis excessive generosity in the allocation of quotas.

Carbon tax in practice

- Applied in Canada and in several European countries such as Finland (the first to adopt it in 1990), Denmark, the Netherlands, Norway, Switzerland and Ireland.
- In Italy Lepratti et al., 2017 write that "after an ephemeral transition in the late nineties (the tax in 1998, had been introduced with art. 8 of law no. 448 of 23 December 1998, in line with the conclusions of the Kyoto conference in 1997), in April 2012, the Council of Ministers approved the bill on tax delegation, divided into three different sectors. One of these sectors was dedicated to the reorganization of environmental taxation, in order to promote the growth and internalisation of environmental costs in production costs; among the intentions of the Ministry of the Environment there was that of allocating the tax revenues obtained from the introduction of the Carbon Tax to the financing system for renewable sources. **To date, the measure has not been implemented** ".

Political acceptance

- Some point out that the **carbon tax option has a greater chance of rapid implementation from an administrative point of view** than the creation of a separate emissions trading scheme.
- any type of carbon pricing system will require measures to **alleviate the burden of costs for consumers**, especially those with limited financial means. This could be done by reducing taxes on other energies (e.g. electricity) or by using part of the revenue from the pricing system to offer reimbursements to households. The new funds could also be used to **encourage the development of renewable energies**, thermal insulation programs or renovations of the heating system.

effectiveness

- How much these policies would change people's behavior? Probably not much in the short term, and more in the long term. Economists verify these impacts by estimating the elasticity of demand.
- The empirical evidence that we presented above makes us doubt that behavior and modal choices can change, both in terms of size and speed of adaptation, so as to obtain a significant reduction in CO_2 emissions from transport, unless to intervene very heavily, but politically unacceptable.
- Evidence from California.
  - California has set a price for transportation-generated carbon emissions, including both gasoline and diesel vehicles since 2015. Suppliers purchase emission permits for each ton of fuel. This increases fuel costs for drivers. At the current price of around $ 15 per tonne, the program adds around half a dollar, 49 cents, to the cost of a liter of gasoline. It has been observed that this value is completely irrelevant, being lower than the price difference between the petrol pumps within the city of Los Angeles. However, thanks to this program, California has raised over $ 9 billion in permit sales since the beginning of the program. This sum made it possible to finance renewable energies, public transport and low-emission vehicles. To help alleviate costs for the less well-off classes, a third of the funds raised are intended to improve public transport in the less well-off communities. Nonetheless, the effect of these carbon pricing measures on California's CO_2 emissions has been nil. After the decreases between 2007 and 2013, vehicle greenhouse gases increased every year.
- **Pricing and regulation should be jointly used!**

A challenge for transport economists!

- Which policies are more:
  - Effective
  - Efficient (private, social)

- Which policies for which country (city)

The role of the automotive industry

They decide how to invest:

- The Nissan-Renault Alliance (Carlos Goshn): Nissan Leaf, Renault Zoe
- Tesla Motors (Elon Musk), (Daimler)
- BMW (i3)
- GM Chevrolet Bolt
- Volkswagen: from Dieselgate to EVs

The role of the customer

- **The consumer chooses which car to buy**

The role of the scientific community

- The researchers choose what to do research on

Thank you for your attention!