Energy Transition in Transport
Role of Electric Vehicles

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Amount of transport services per capita based on non-commercial renewable energy

- Horse power
- Sailing ship
- Steam machine, steam railway
- Electricity, combustion engine

Based on commercial energy
Transport sector

- oil products
- least-diversified
- energy import dependency
Electric vehicles

Paris Declaration on Electro-Mobility and Climate Change & Call to Action:

• more than 100 million EVs

• 400 million two and three-wheelers
Electric vehicles

1830 1900

Henry Ford started mass production of ICE Ford T

1912: Global BEVs stock was approx. 30,000.

1920

Large availability of cheap oil and predominance of ICE vehicles

Legislation in 1990 in California to reduce pollution and introduce 2% of EVs by 1998

First oil shock → need for alternative to fossil fuels arise

Multiple trials for EVs in EU and USA, but with no success. Investment in fuel cell research.

Toyota begins sales of Prius, world’s first commercial hybrid car.

2012: Global BEVs stock was approx. 180,000.


EVs enter the market and find broad appeal.

EVs reach historical production.

1930-1973: EV disappeared

High oil prices and pollution cause renewed interest in EVs.

Public and private sectors recommit to vehicle electrification.

Period of increasing popularity

Period of declining popularity

Attempts of reviving popularity
Total final electricity consumption by sector (Mtoe)

IEA, 2019
Electric vehicles
Electric vehicles

Development of the global stock of rechargeable EVs

China 45%
USA 22%
Europe 24%

Evolution of EVs stock by country (thousands of vehicles)
Electric vehicles

Advantages

- Energy efficiency
- Energy security
- Air pollution
- Noise reduction

Disadvantages

- Costs
- Driving range
- Charging time
- Charging infrastructure
Km per day in cities
Battery capacity for different types of EVs

- HEV
- PHEV
- BEV
Economic assessment

The costs per km driven $C_{km}$ are calculated as:

$$C_{km} = \frac{IC \cdot \alpha}{skm} + P_f \cdot FI + \frac{C_{O&M}}{skm}$$

[€/100 km driven]

IC......investment costs [€/car]
α.......capital recovery factor
skm.....specific km driven per car per year [km/(car.yr)]
Pf.......fuel price incl. taxes [€/litre]
C_{O&M}....operating and maintenance costs
FI........fuel/energy intensity [litre/100 km; kWh/100 km]

A capital recovery factor ($\alpha$) is the ratio of a constant annuity to the present value of receiving that annuity for a given length of time. Using an interest rate ($z$), the capital recovery factor is:

$$\alpha = \frac{z(1+z)^n}{(1+z)^n - 1}$$

n.....the number of annuities received.
**Economic aspects**

Total costs of service mobility of various types of EV in comparison to ICE cars.
Battery pack price ($/kWh)

2010: 1200
2011: 1000
2012: 800
2013: 600
2014: 400
2015: 200
2016: 100
2017: 50
2018: 25
Scenario for development of investment costs

(Power: 80 kW)

- FCV
- BEV

EUR/car

2010  2015  2020  2025  2030  2035  2040  2045  2050

- Gasoline
- Diesel
- Gasoline-Hybrid
- Diesel-Hybrid
- Electric vehicles
- Fuel cell vehicles
Electric vehicles

**Monetary measures**
- road taxes
- annual circulation tax
- company car tax
- registration tax
- fuel consumption tax
- congestion charges

**Non-monetary measures**
- free parking spaces
- possibility for EVs drivers to use bus lanes
- wide availability of charging stations
- permission for EVs to enter city centers and zero emission zones
Environmental assessment

Well-to-Wheel (WTW)

Primary energy source

Fuel

Mobility

Well-to-Tank (WTT)

Tank-to-Wheel (TTW)

TTW_car

TTW_fuel
Environmental assessment

CO₂ emissions per km driven for various types of EV in comparison to conventional cars (power of car: 80kW)
The carbon intensity of electricity mix

CO2 per kWh electricity generated in different European countries
Environmental assessment

CO₂ emissions per km driven for BEVs powered by grid electricity in different countries
Oil and lithium reserves

Countries with the largest conventional oil reserves:
- Saudi Arabia: 26%
- Iran: 15%
- Iraq: 14%
- Kuwait: 10%
- Libya: 4%
- Nigeria: 3%
- United States: 5%
- Russia: 9%
- United Arab Emirates: 9%

World lithium reserves by country:
- Chile: 52%
- China: 22%
- Argentina: 14%
- Australia: 11%
- Brazil: 0%
- Zimbabwe: 0%
- Portugal: 1%
- United States: 0%
Car-oriented mobility

More cars → More roads → Congestion → More cars

More roads → Congestion → More cars → More roads

Congestion → More roads → Congestion → More cars

More cars → More roads → Congestion → More cars
Mobility

Car-oriented transport development
Towards Sustainable Mobility

- **Avoid**
  - ...unnecessary travel and reduce trip distances

- **Shift**
  - ...towards more sustainable modes

- **Improve**
  - ...transport practices and technologies
Conclusions

- EVs …part of the solution…cost reductions, improvement of battery characteristics, as well as development of infrastructure

- Most of the policies implemented will be abolished with the increasing number of EVs

- Future policy design should ensure high environmental benefits of EVs.

- Full environmental benefit – only if EVs are powered by electricity generated from renewable energy source

- New mobility behavior
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Electric vehicles

Fuel cell electric passenger car stock: 11,200
Main battery cell manufactures

- Japan: 29%
- US: 23%
- Europe: 15%
- South Korea: 15%
- China: 18%

Japan and the US together make up more than 65% of the battery cell manufacturing market.