E-mobility
Intelligent Transportation Systems

Rolland Vida

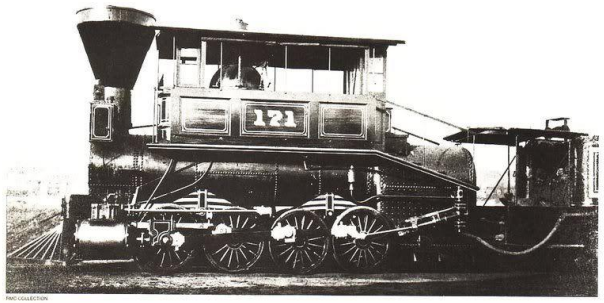

We will not stop until **every car on the road is electric**.
Elon Musk
(CEO, Tesla Motors)

BASICS

History of the Electric Car

1851

First electric rail car



1881

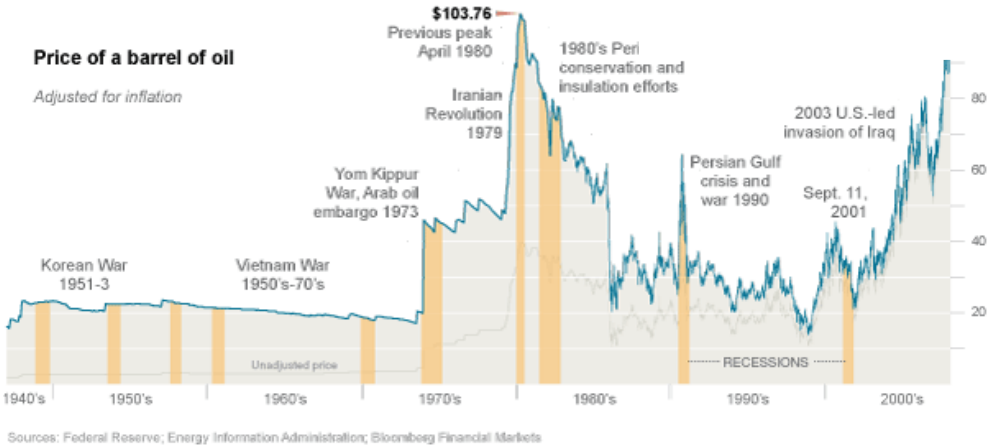
First electric car

Surge in production

1900

First hybrid vehicle

Preference for combustion engines



1990

Oil crisis leads to the renaissance of electric cars

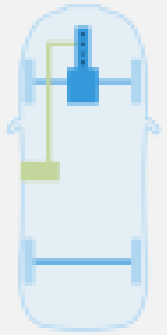
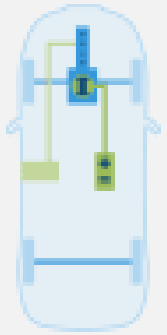
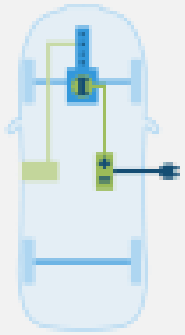
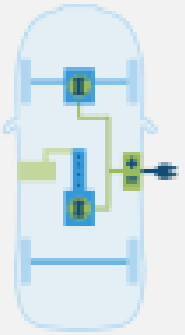
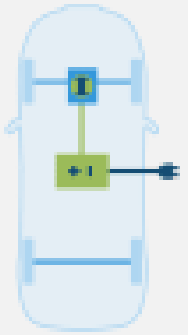
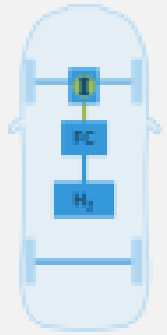
TODAY

A new trend begins: movement from combustion engine to electric drive

Upturn in electric car research and development

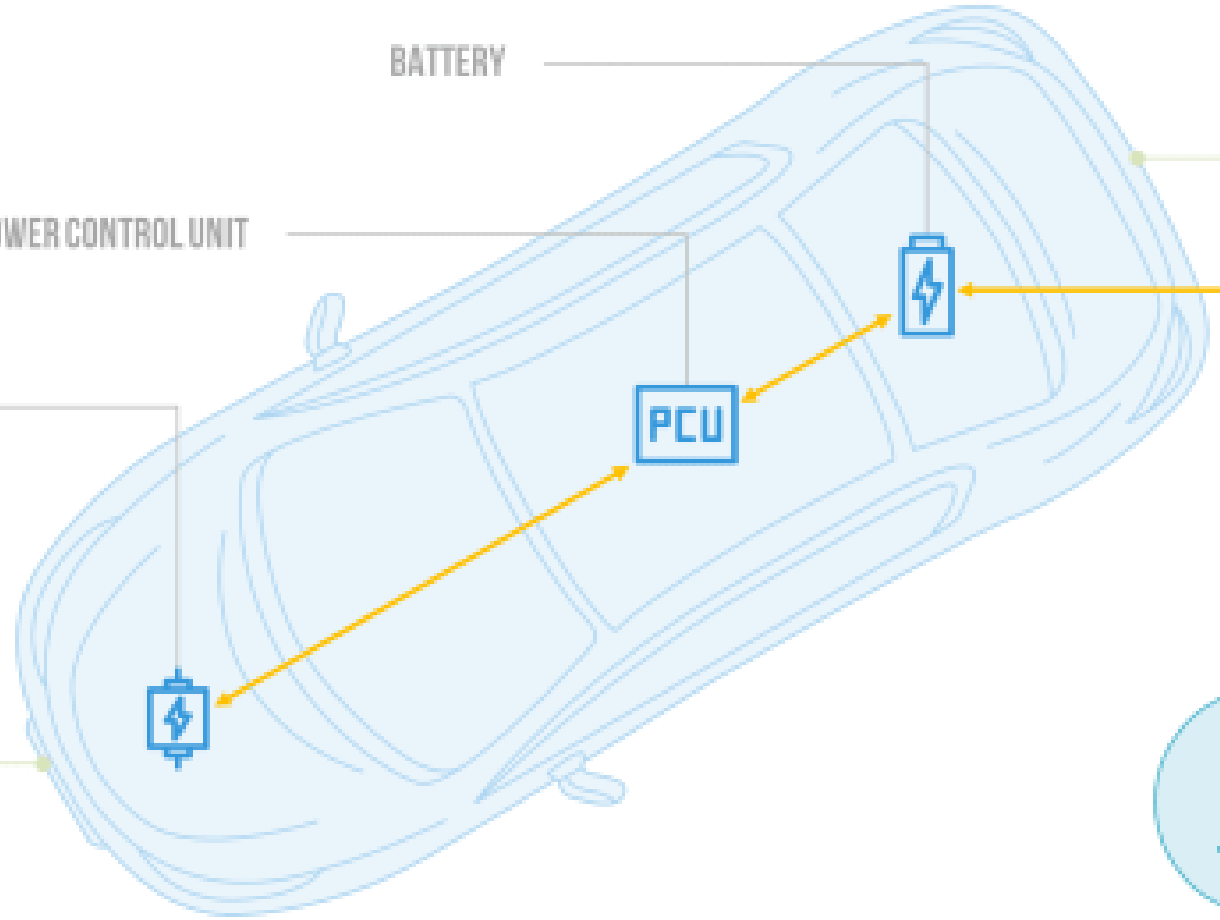
TECHNOLOGY

Comparison of Different Engines

					
CONVENTIONAL ENGINE	**PARALLEL HYBRID**	**PLUG IN HYBRID**	**SERIES HYBRID**	**ELECTRIC-VEHICLE BATTERY**	**FUEL CELL**
Powertrain is driven by a gas or diesel engine	Combustion engine and electric motor deliver parallel power	Battery can be recharged via onboard engine and plugging into a power grid	Combustion engine drives an electric generator which both charges a battery and powers an electric motor	Electric motor draws its energy from an accumulator, which can only be charged via a power grid	A hydrogen-powered fuel cell generates energy to power the on-board electric motor
Example: **Golf VII TSI**	Example: **Honda Civic Hybrid**	Example: **Chrysler Pacifica**	Example: **BMW i3**	Example: **Nissan Leaf**	Example: **Toyota Mirai**

TECHNOLOGY

Electric Vehicle



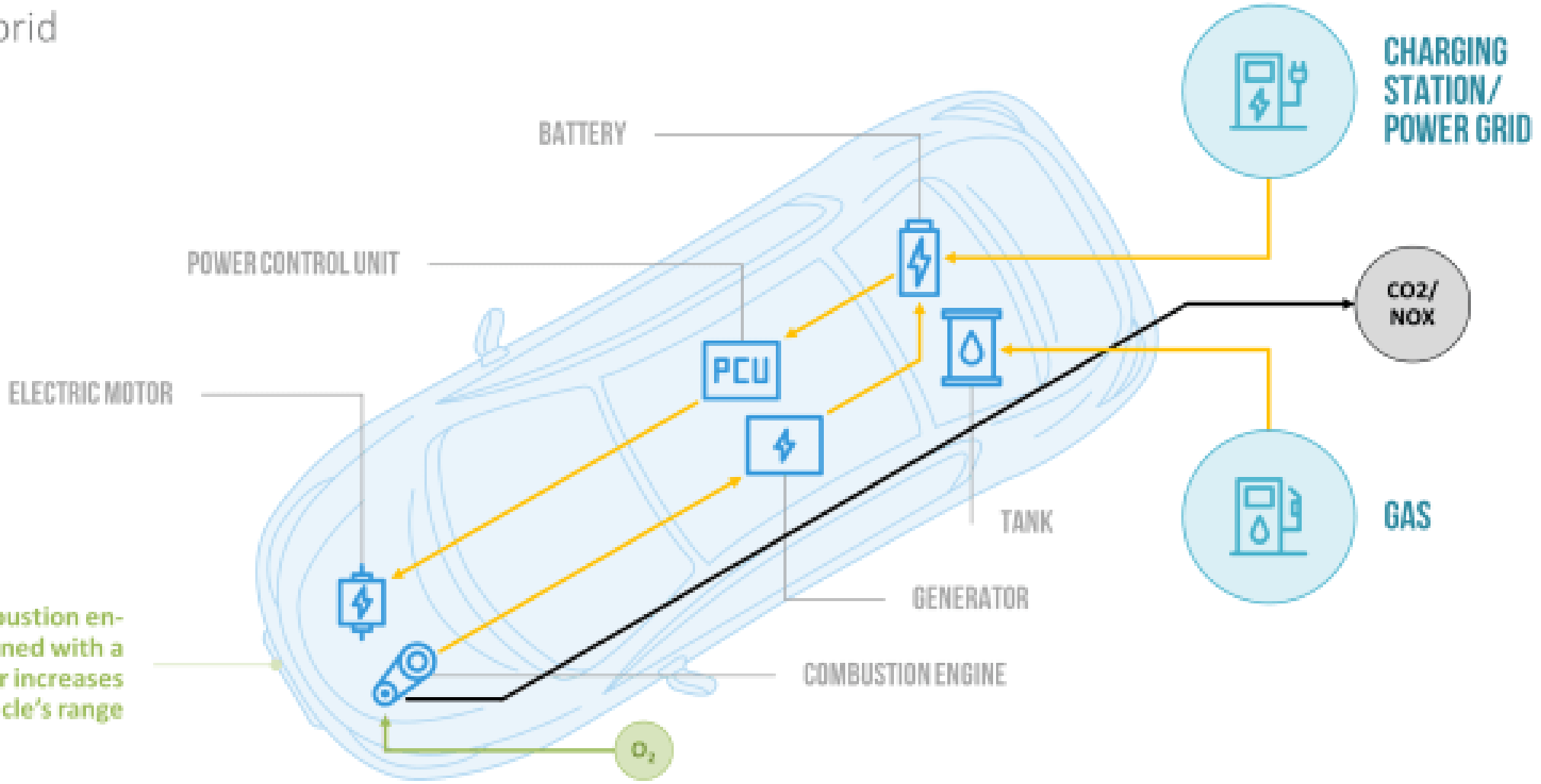
Energy is recuperated through regenerative braking and downhill driving

An electric motor only runs when the vehicle is moving

CHARGING STATION/ POWER GRID

TECHNOLOGY

Plug-in Hybrid



A combustion engine combined with a generator increases the vehicle's range

TECHNOLOGY

Range

I OFTEN EXPERIENCE RANGE ANXIETY

22% AGREE

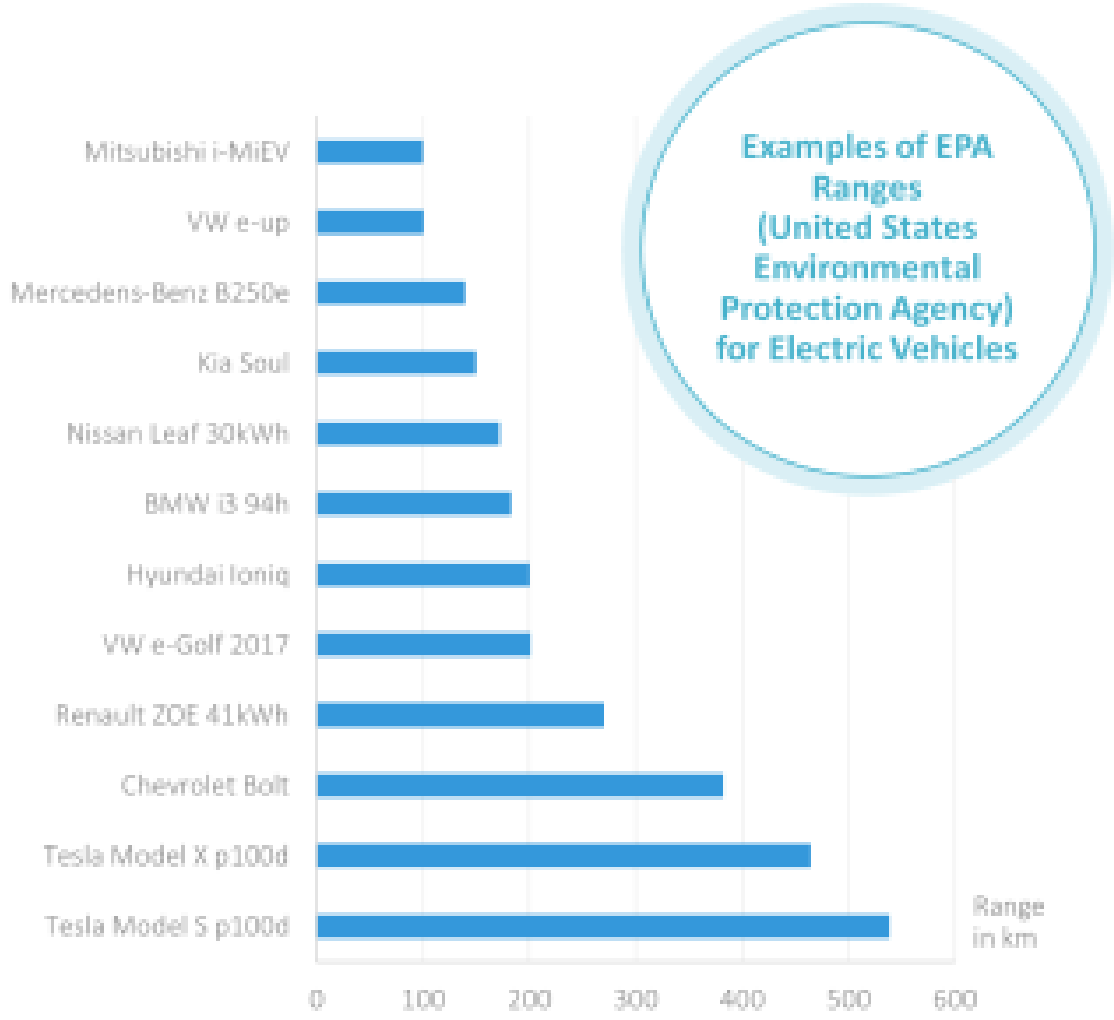
Range can vary greatly due to driving style and environmental influences, such as temperature.

Additional combustion engines (hybrid) or fuel cells can increase range.

Interchangeable battery systems are suited for use with forklifts and other similar industrial vehicles.

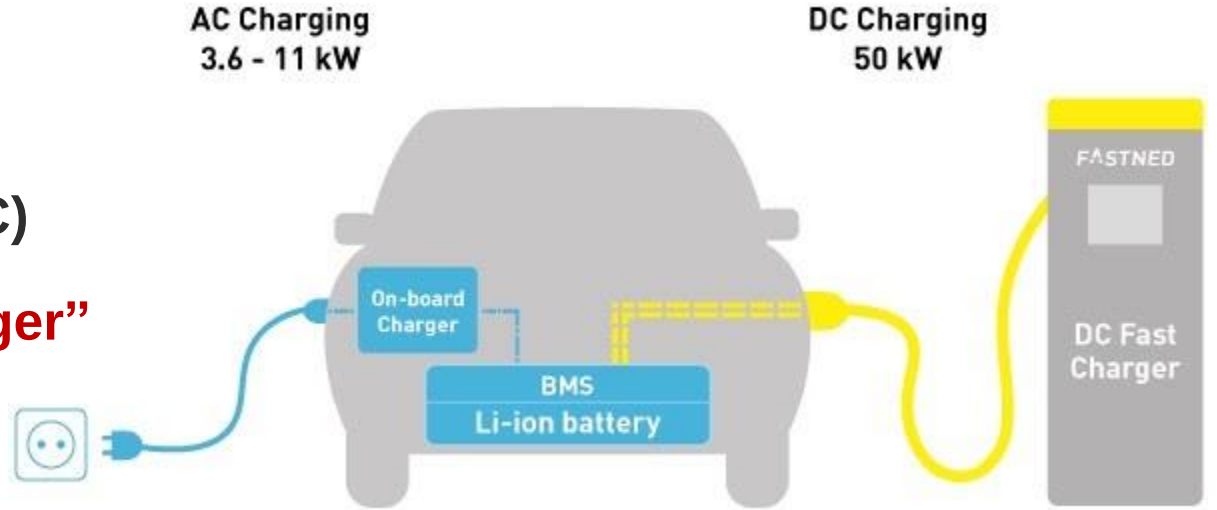
Interchangeable batteries for cars proved to be difficult to handle, as battery lifetimes vary much, and batteries are expensive

- Although 80% cheaper than 8-10 years ago



The charging problem

- Batteries need **Direct Current (DC)** for charging
- The electric grid delivers **Alternating Current (AC)**
- An **AC/DC converter** is needed – part of a **„charger”**



- **On board charger** integrated in the vehicles
  - Small, light, cheap, long lasting – but **slow (10-20 kW)**
  - Takes hours to charge at home or at work – but we have time
  - Charge points at home are no chargers, but smart sockets
- **External charger** does the AC/DC conversion
  - Heavier, larger, more complex, more expensive – but **much faster (350 kw)**
  - Takes 15-20 minutes to charge to 80%
  - Still much slower than refueling an ICEV (1-2 minutes)

INFRASTRUCTURE

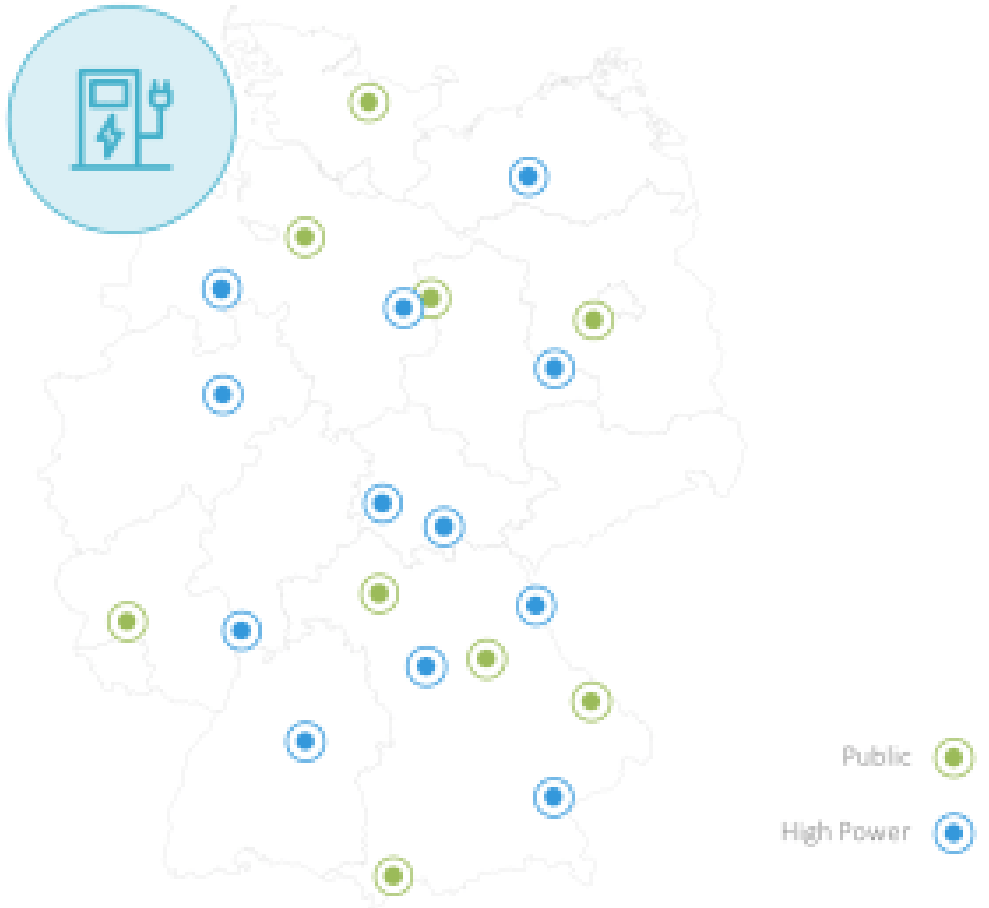
Charging Station Map

Charging station maps have become increasingly important for route planning. They provide EV drivers with information about ...

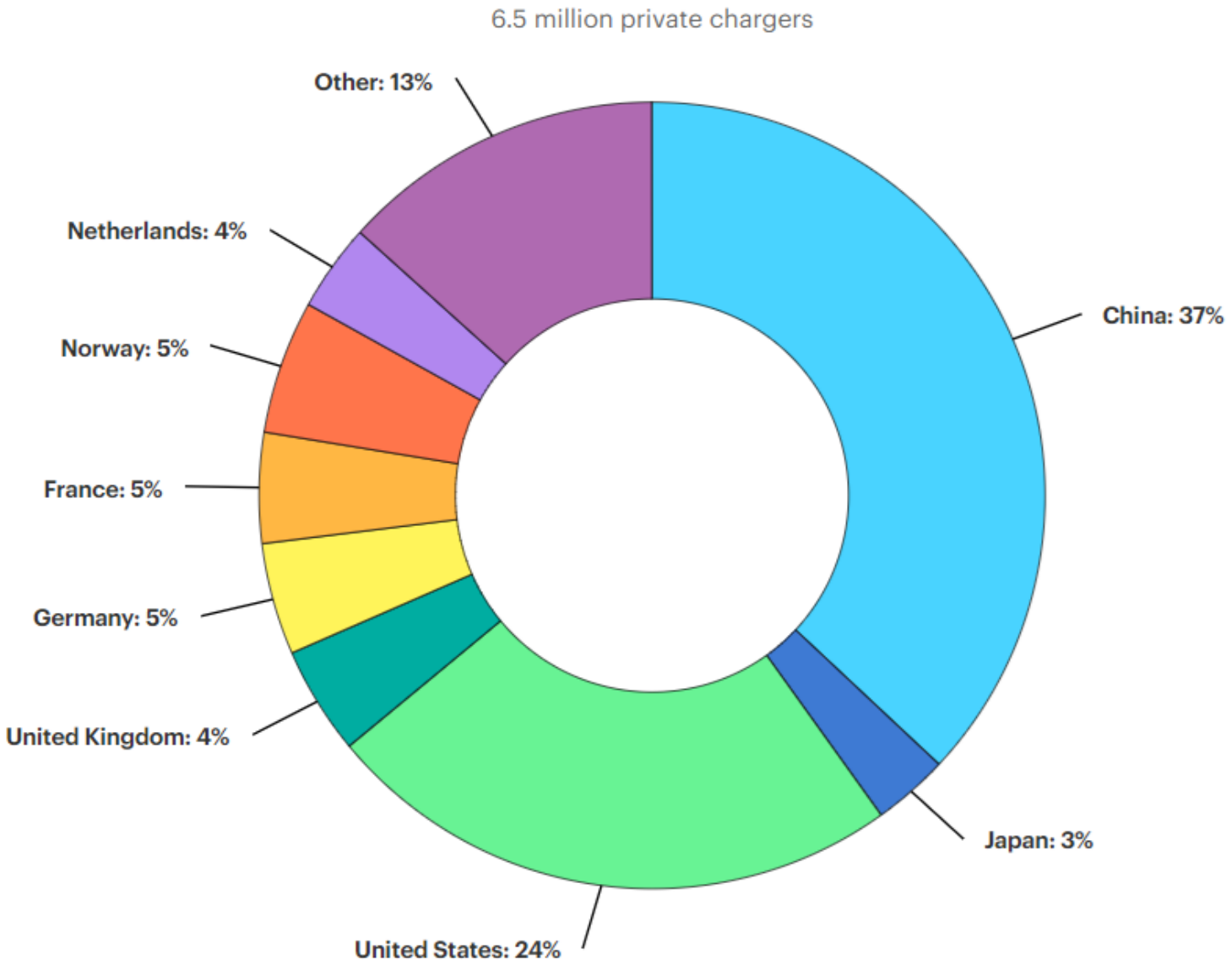
charging station locations.

operational status and number of stations.

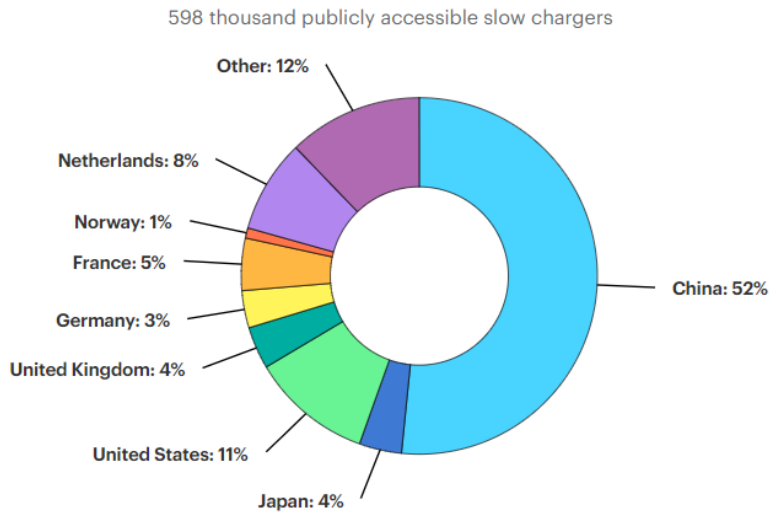
types of ports available at each location.



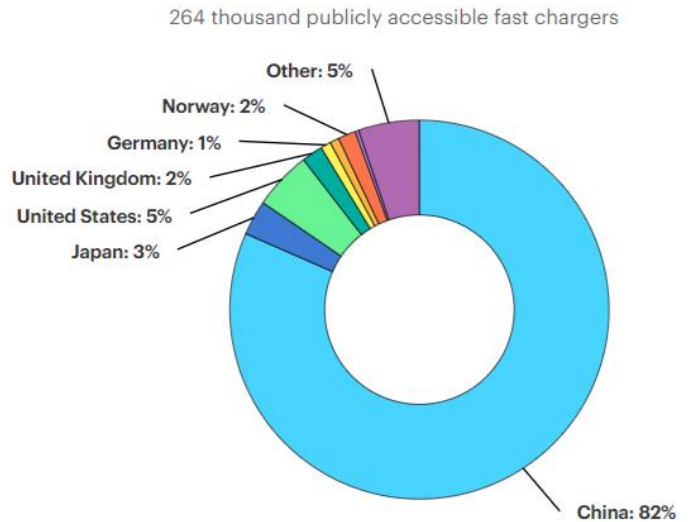
Private electric vehicle slow chargers by country, 2019



Publicly accessible electric vehicle slow chargers by country, 2019



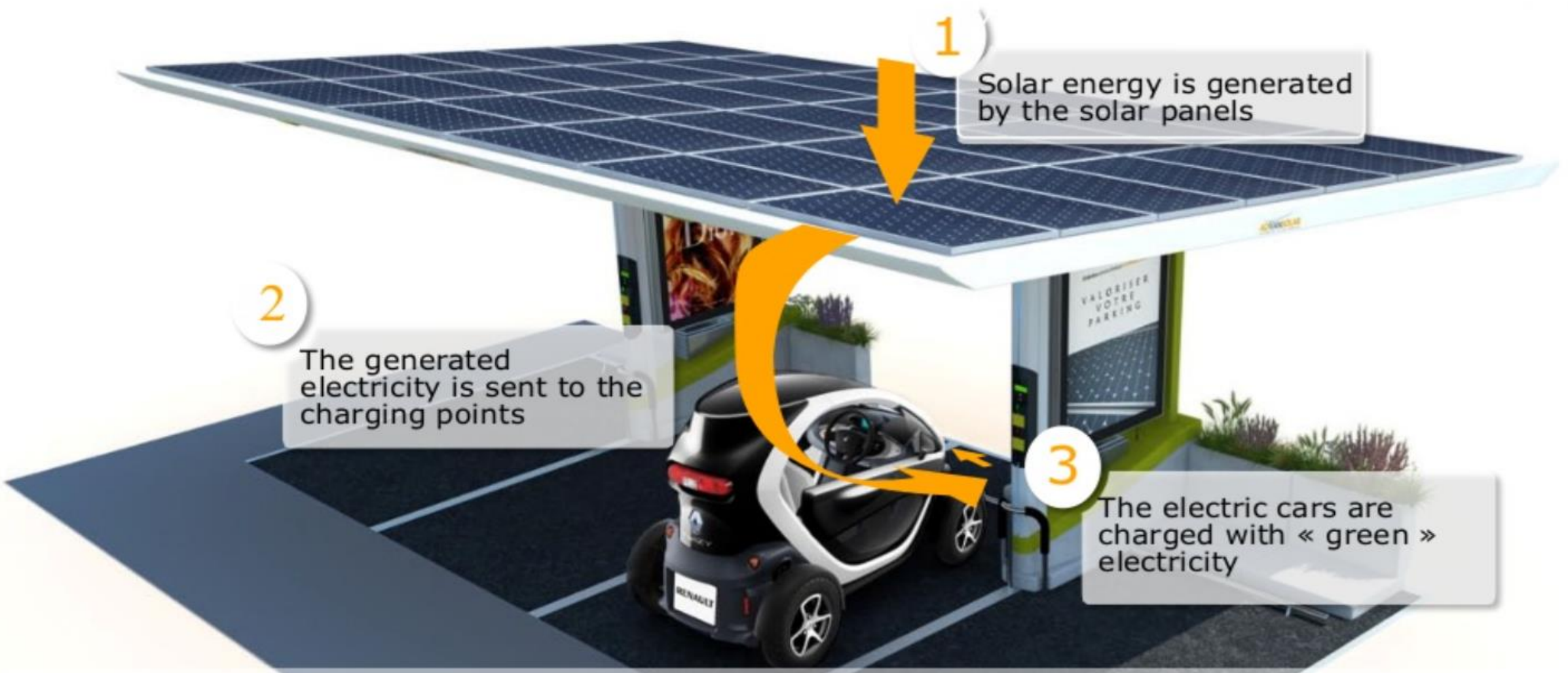
Publicly accessible electric vehicle fast chargers by country, 2019



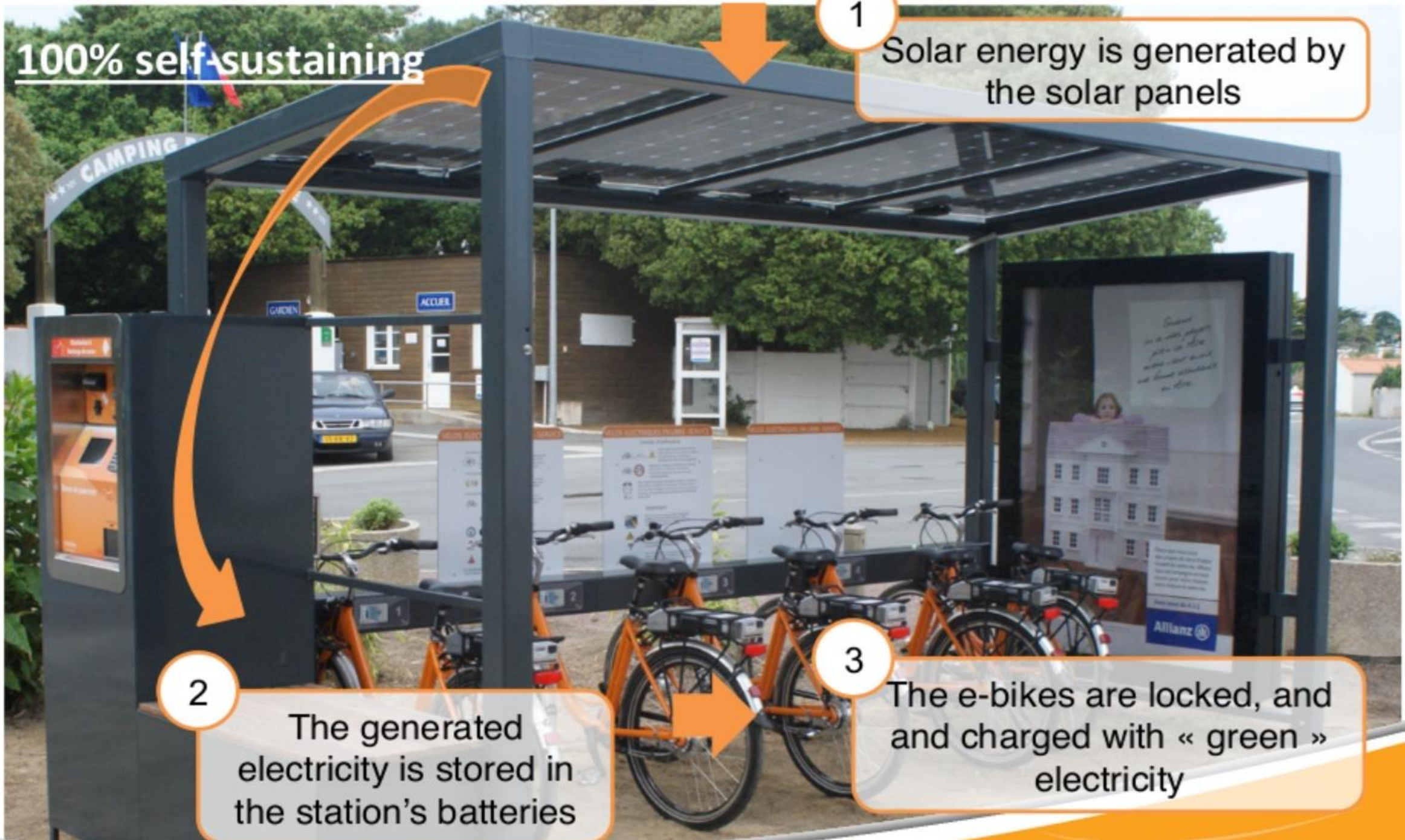
From hardly visibile electric charging stations

To clearly visible, solar powered charging stations

OKOS VÁROS @ BME TMIT



- The production of renewable energy **compensates** the energy need of the electric vehicles
- Charging infrastructures are made **clearly visible**, which strengthens their awareness among consumers
- The electric car becomes truy **« green »**
- The association with **solar power** - free, unlimited, renewable – further improves electric vehicles' **positive image**

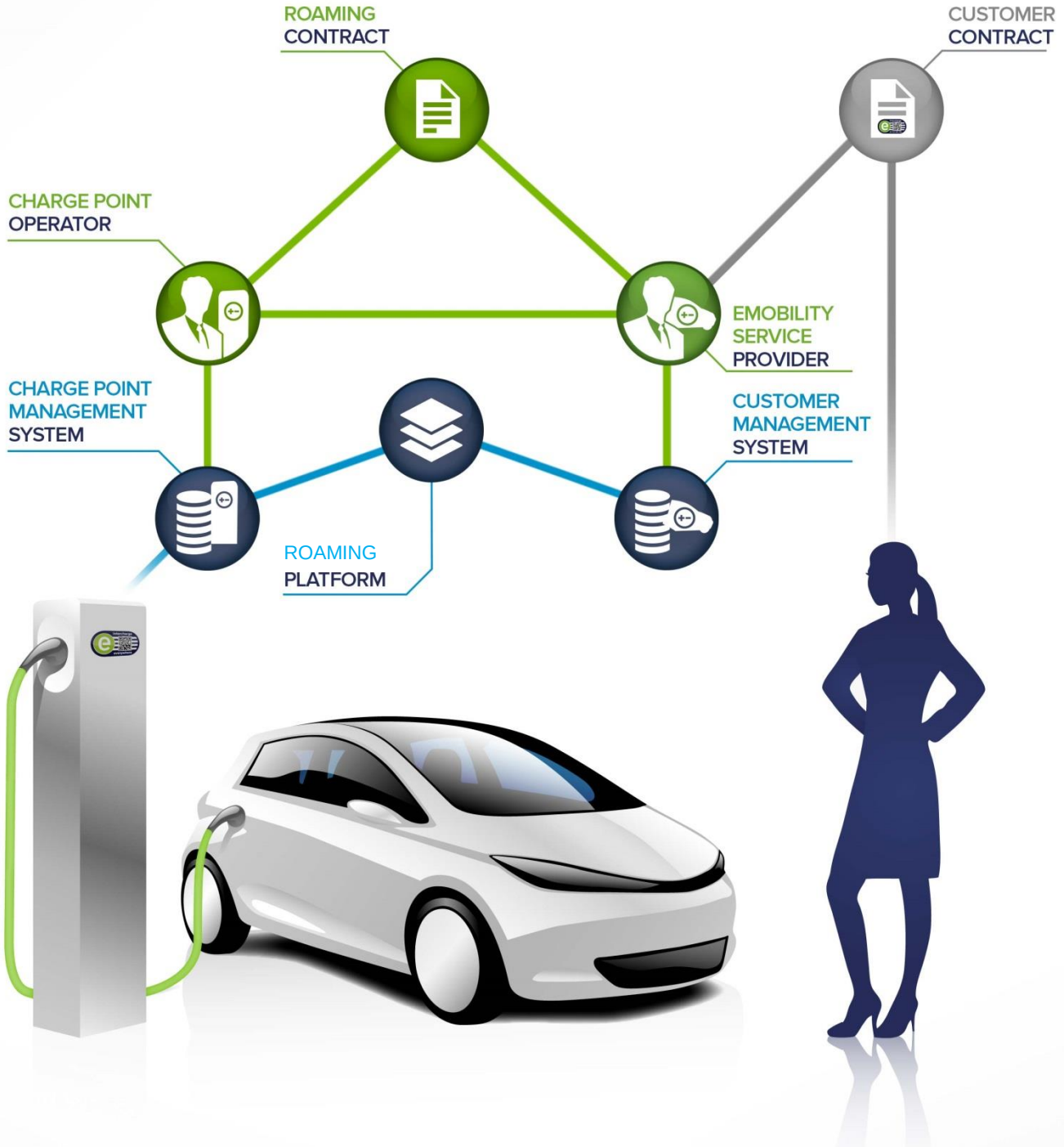

100% self-sustaining
1
Solar energy is generated by the solar panels
2
The generated electricity is stored in the station's batteries
3
The e-bikes are locked, and and charged with « green » electricity

INFRASTRUCTURE

Roaming Platform System

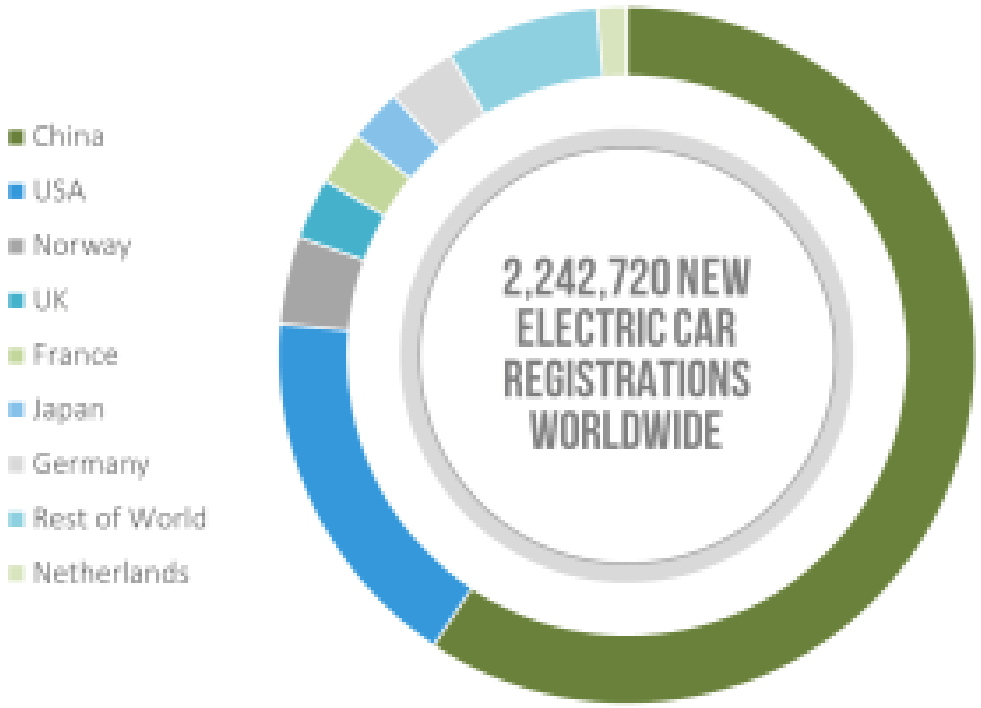
PAYMENT USING

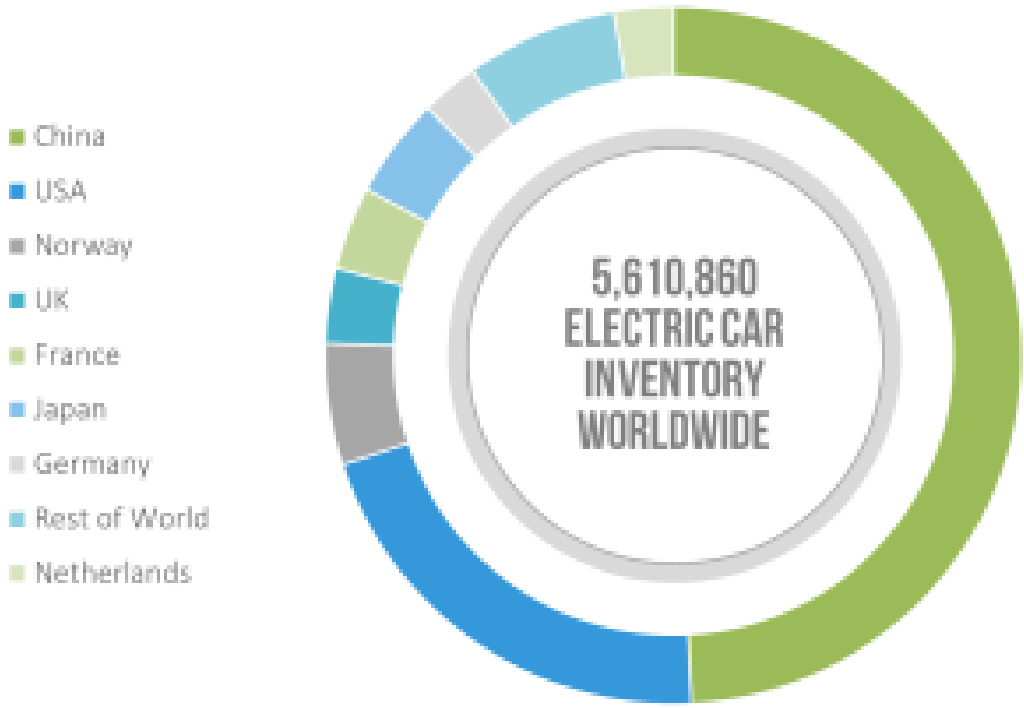
- ✓ an app
- ✓ a bank card
- ✓ standardized access and billing throughout Europe



ECONOMY

New Registrations & Inventory 2018





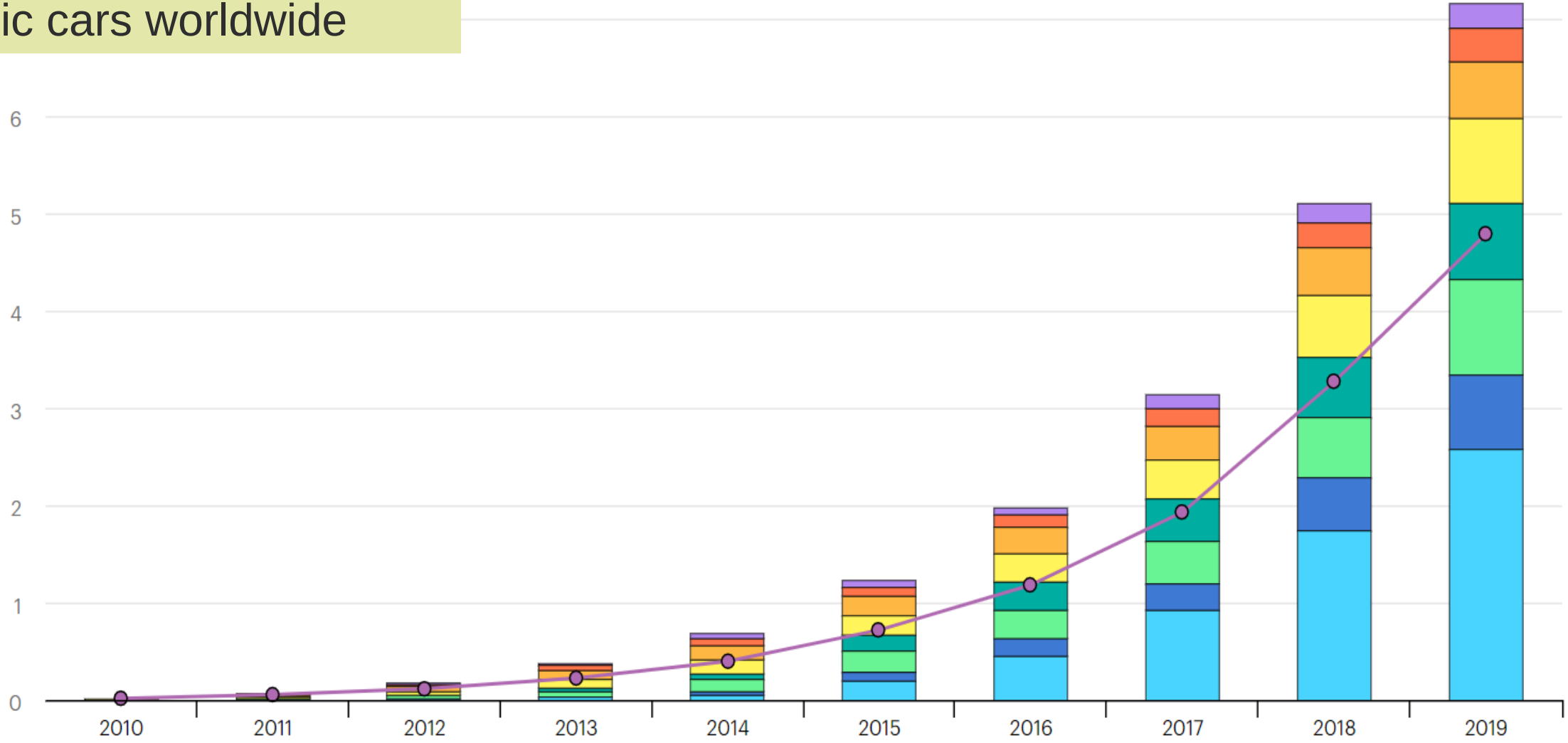
Source: ZSW, 2018

Total cars worldwide: ~ 800 million (2019) – doubling every 20 years

Percentage of electric cars: ~ 1% (2019)

- Only 17.000 electric cars worldwide in 2010.

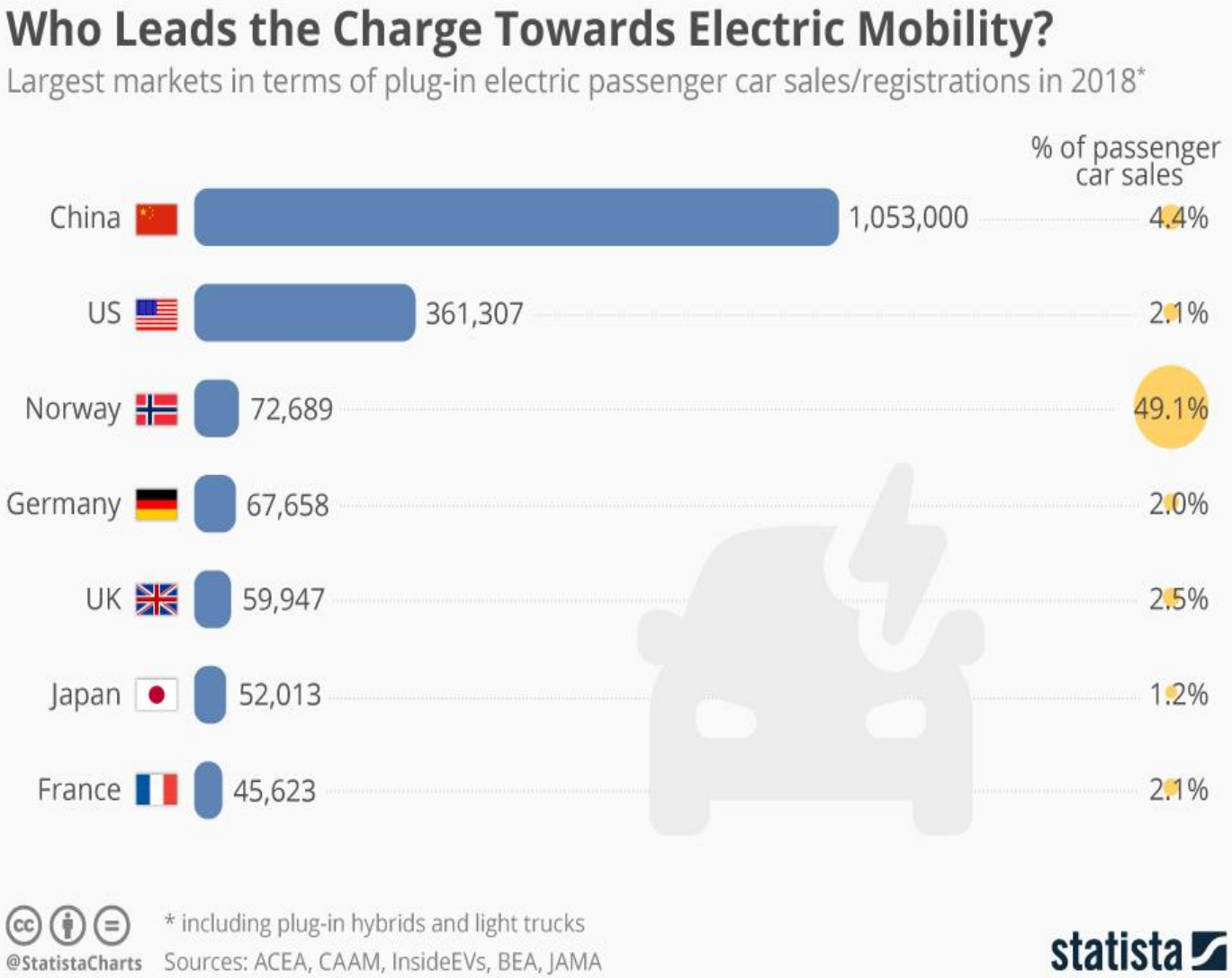
Electric cars worldwide

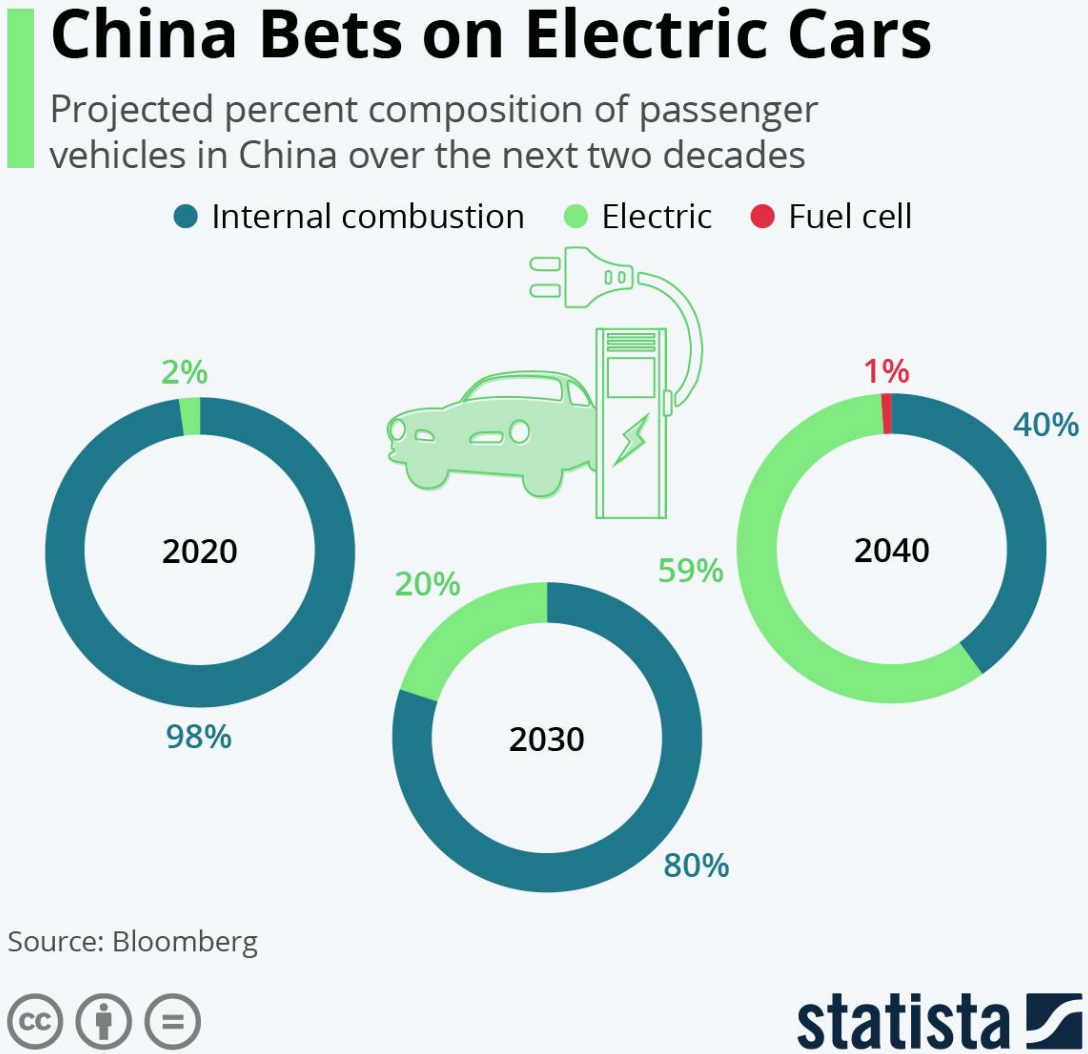


BEV (Battery Electric Vehicle)
PHEV (Plug-in Hybrid Electric Vehicle
ICEV (Internal Combustion Engine Vehicle)

China BEV · China PHEV · Europe BEV · Europe PHEV · United States BEV · United States PHEV · Other BEV · Other PHEV · World BEV

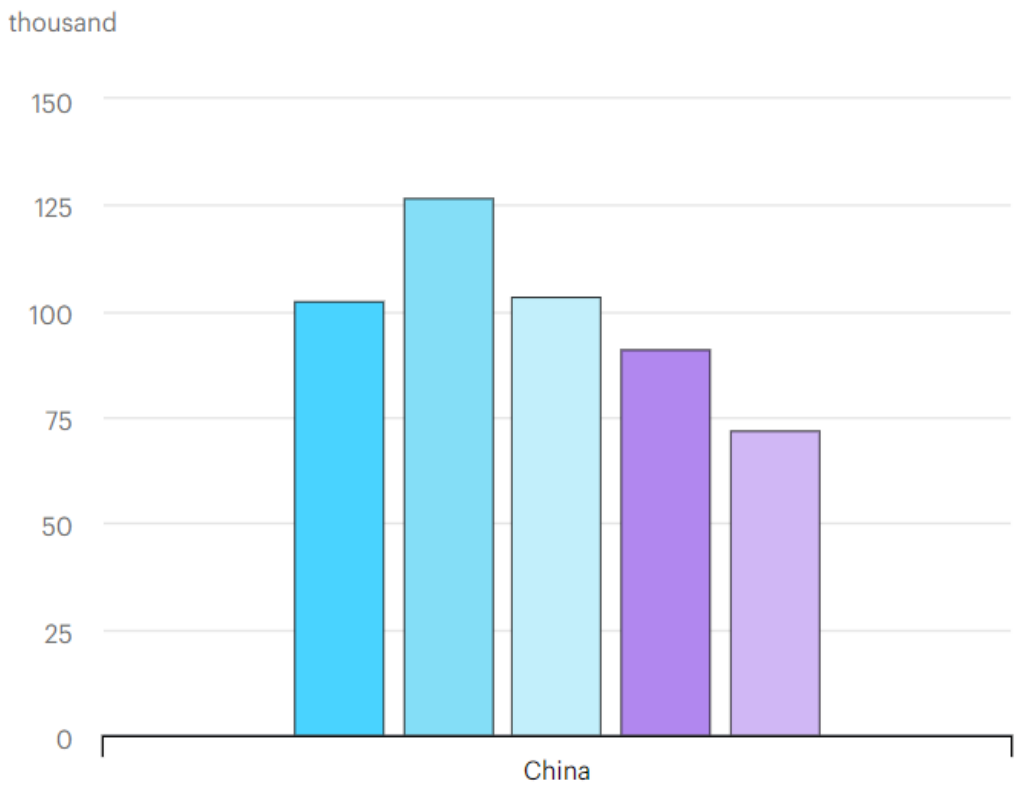
Share of electric cars





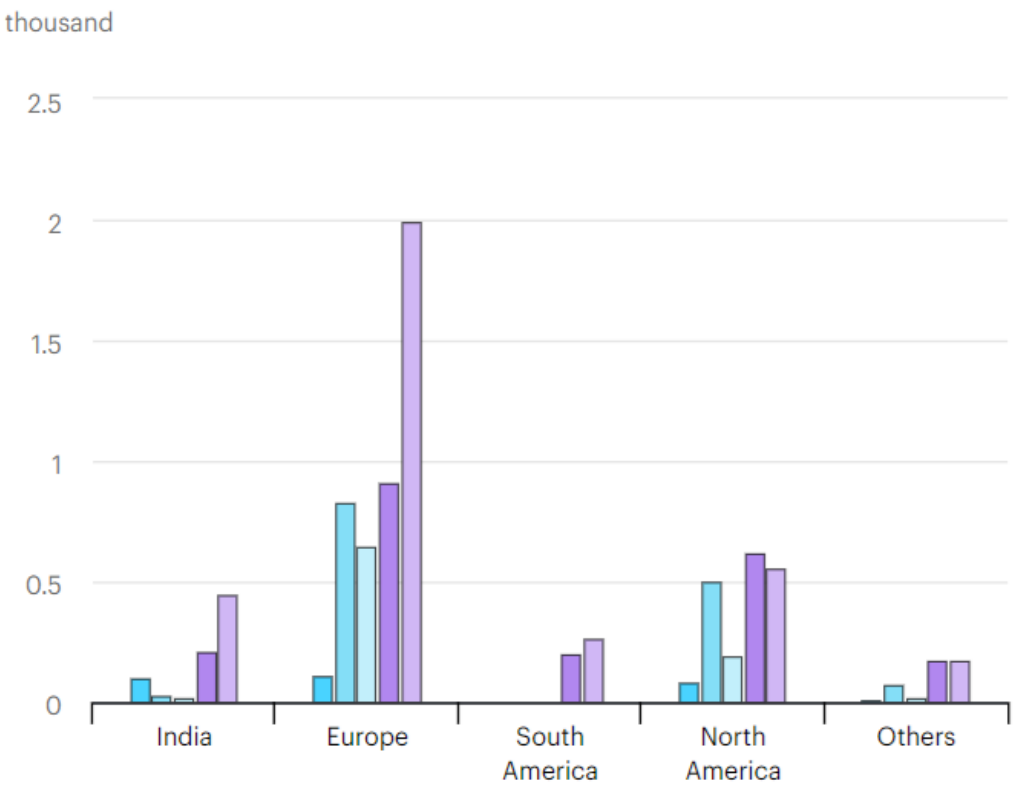
Electric buses worldwide

New electric bus registrations in China, 2015-2019



2015 2016 2017 2018 2019

New electric bus registrations by country/region, 2015-2019



2015 2016 2017 2018 2019

Electric buses: Helsinki (Finland) vs. Shenzhen (China)

Helsinki

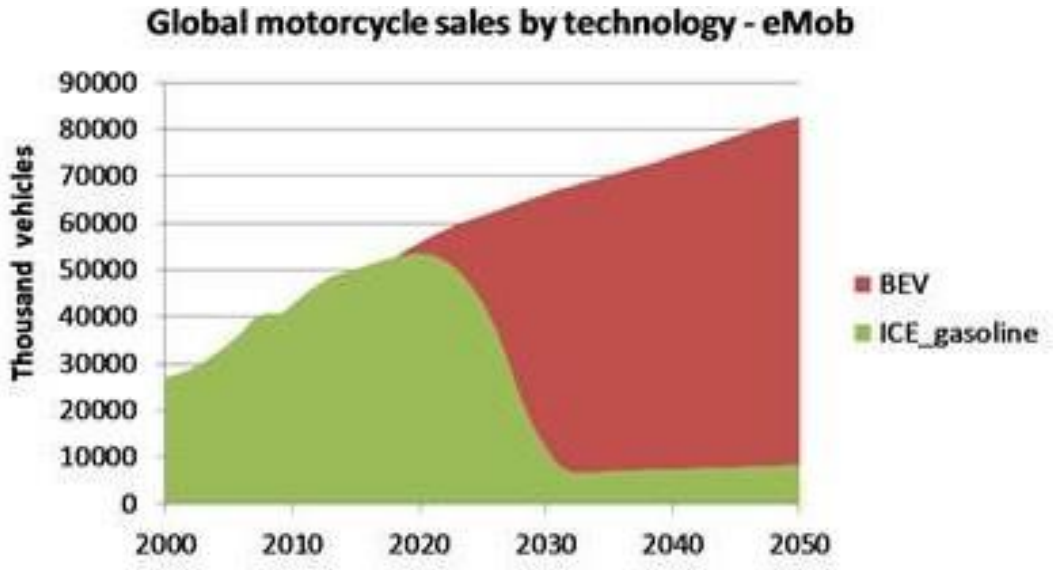
- Population: 1.5 million (Helsinki region)
- Electric buses %: 3.4 (in 2020)
  - To be extended to 30% by 2025
- Electric buses #: 48
- Charging: 33 terminals at 2 stations

Schenzen

- Population: 12 million
- Electric buses %: 100 (by 2017 already)
- Electric buses #: 17,000
- Charging: 1700 terminals at 104 stations

Electric bikes/scooters

- 350 million electric two/three-wheelers
  - 25% of two/three wheelers worldwide (as opposed to 1% for cars)
  - Most of them in China – ban on ICE scooters in many Chinese cities



Toyota iRoad

ECONOMY

Costs

Energy Costs

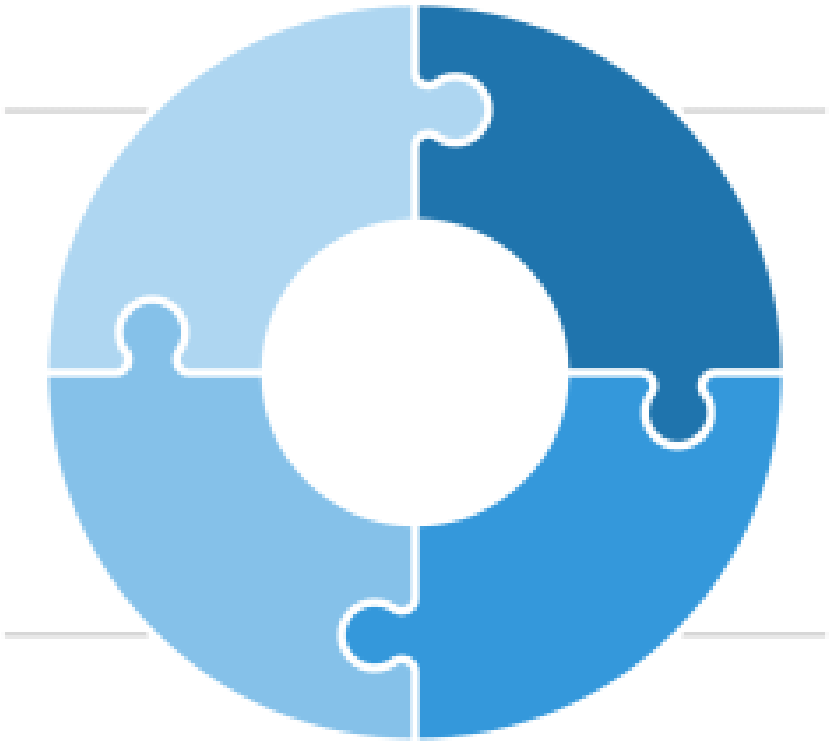
The cost per kilometer driven with an electric car is significantly lower than with a combustion engine car

~20-25 Ft/km for an ICEV
~6 Ft/km for an EV

Purchase Costs

Electric cars are significantly more expensive to buy

Reasons: Low production volume and expensive accumulator production



Repair and Maintenance Costs

Thanks to a simpler design and fewer wearing parts, the repair and maintenance costs for an electric car are significantly lower

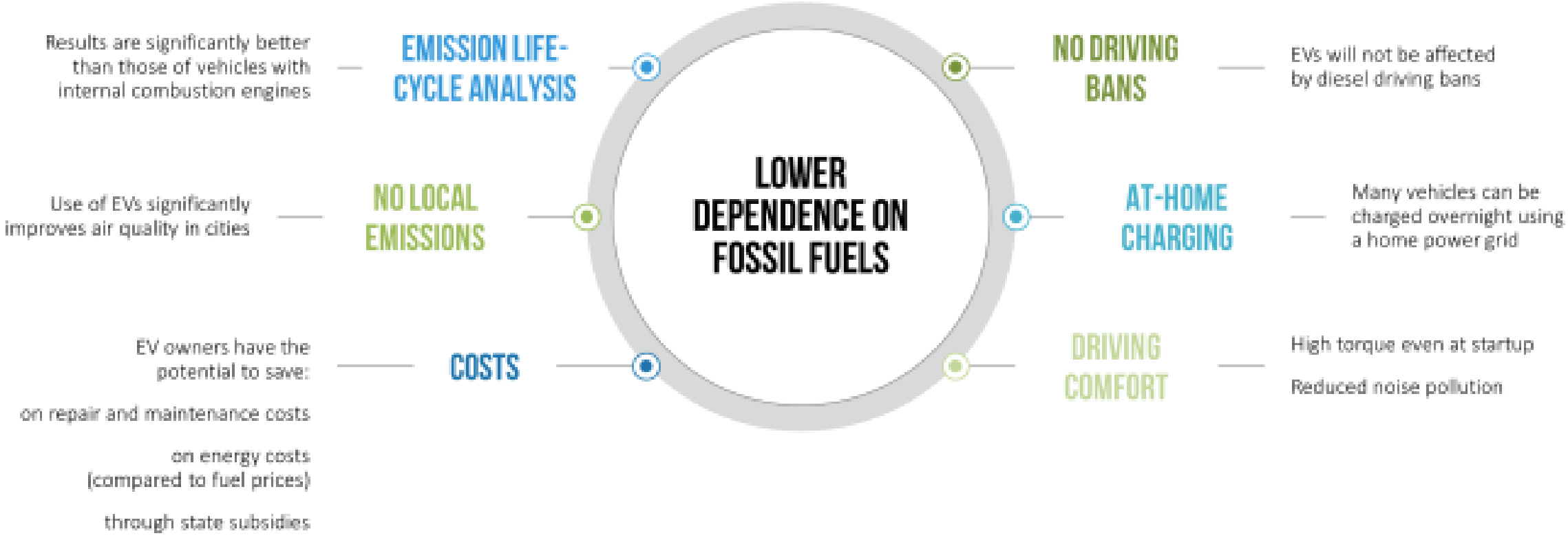
Total Costs

In terms of total costs, many of the electric cars available on the market are cheaper than conventional vehicles

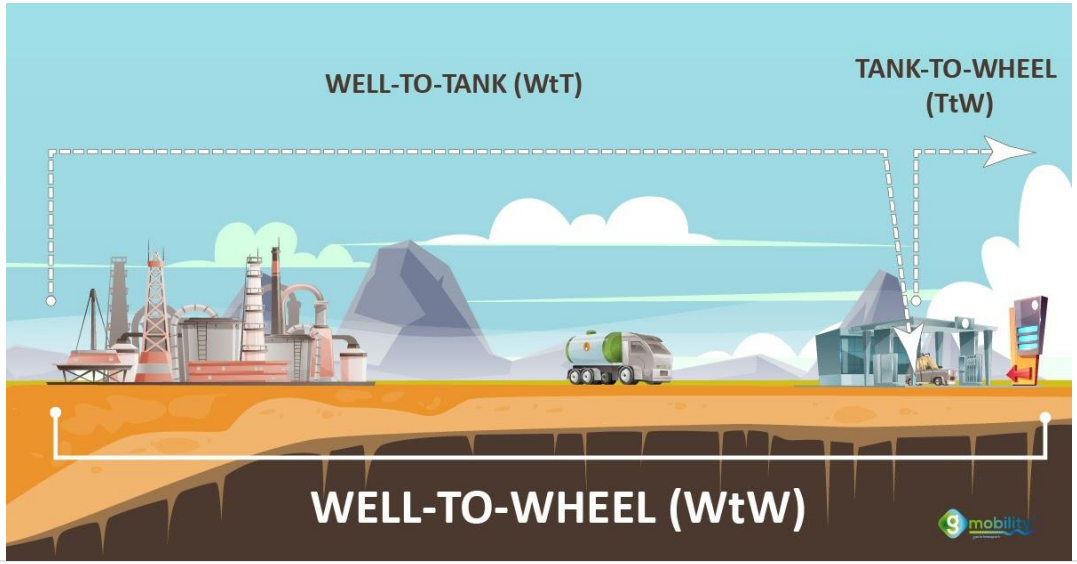
- If driven 15-20,000 km/year

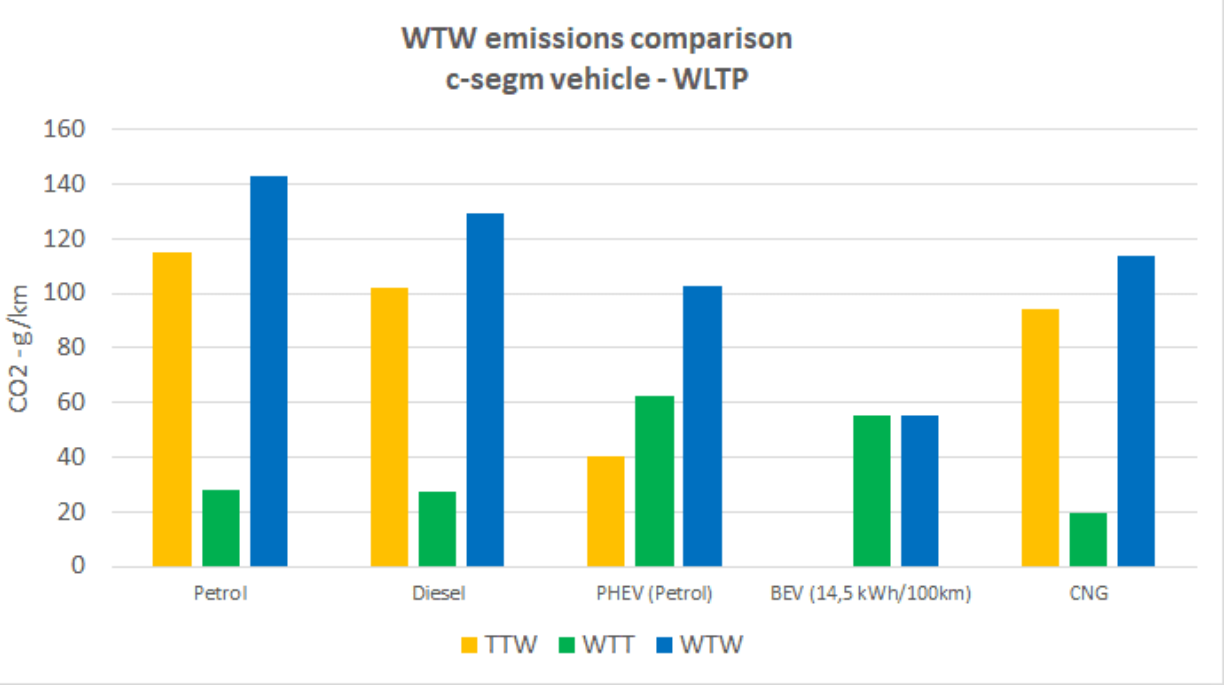
ADVANTAGES AND ISSUES

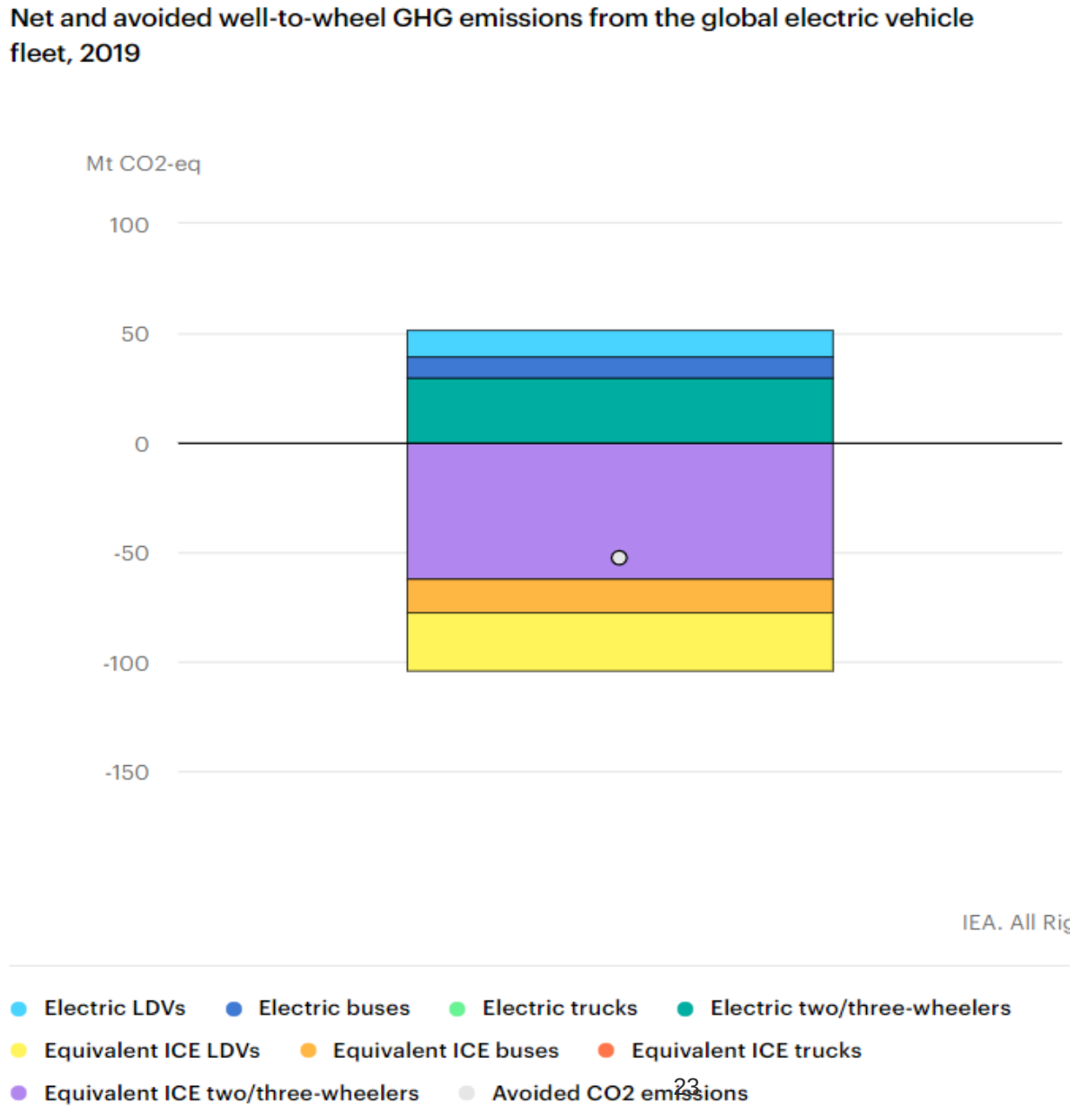
E-Mobility Advantages



GreenHouse Gas (GHG) emission comparison

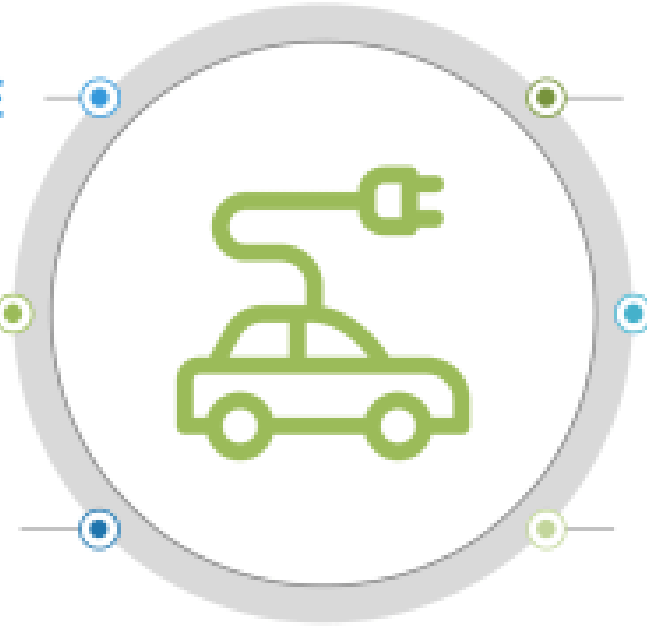






ADVANTAGES AND ISSUES

E-Mobility Issues



ENERGY STORAGE
An accumulator's lifetime and capacity depends on many factors

RANGE
An EV cannot yet match the mileage of a gas-powered or diesel vehicle

VARIETY OF OPTIONS
It is difficult for the consumer to determine the best option for his/her needs.

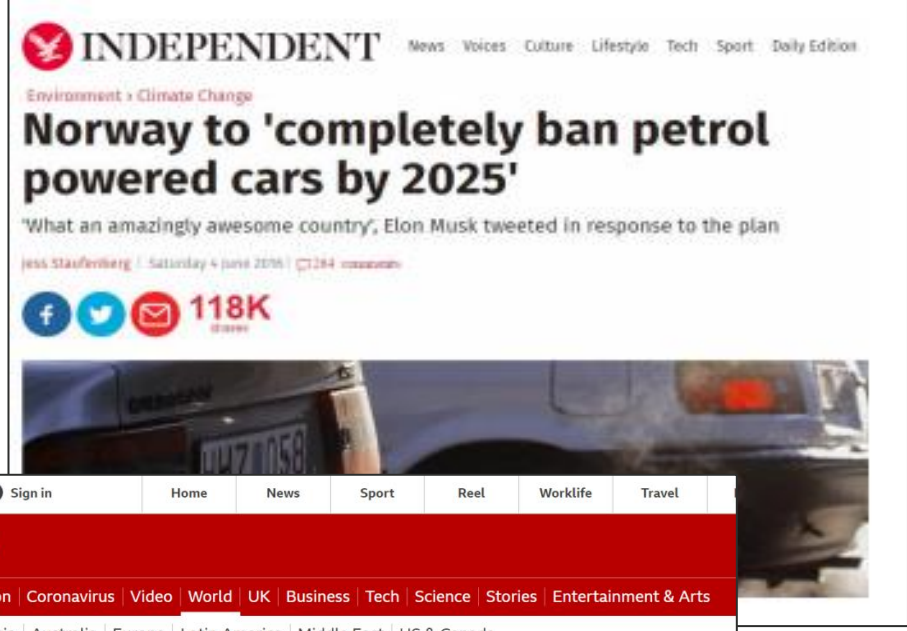
CHARGING STATIONS
The network of charging points is not yet large enough to meet demand

CHARGING TIMES
The charging time for accumulators does not yet match refueling time

HIGH UPFRONT COSTS
Low quantities and the costly production of accumulators ensure a high purchase price

Electric cars in smart cities

- **Incentives to support the spread of electric cars**
  - Lower registration fees and taxes
  - No drive-in restrictions (e.g., London downtown, Germany)
  - Free parking (e.g., in Budapest)
  - Free charging (just as a temporary measure)
  - Free use of HOV lanes
- **Bans on traditional cars (ICEVs)**
  - No ICEVs sold in Norway after 2025
  - No ICEVs sold in California after 2035



OUTLOOK

Vehicle-to-Grid (V2G)

ADVANTAGES:

car owner becomes an energy trader

decarbonization of the transport sector

performs load control tasks

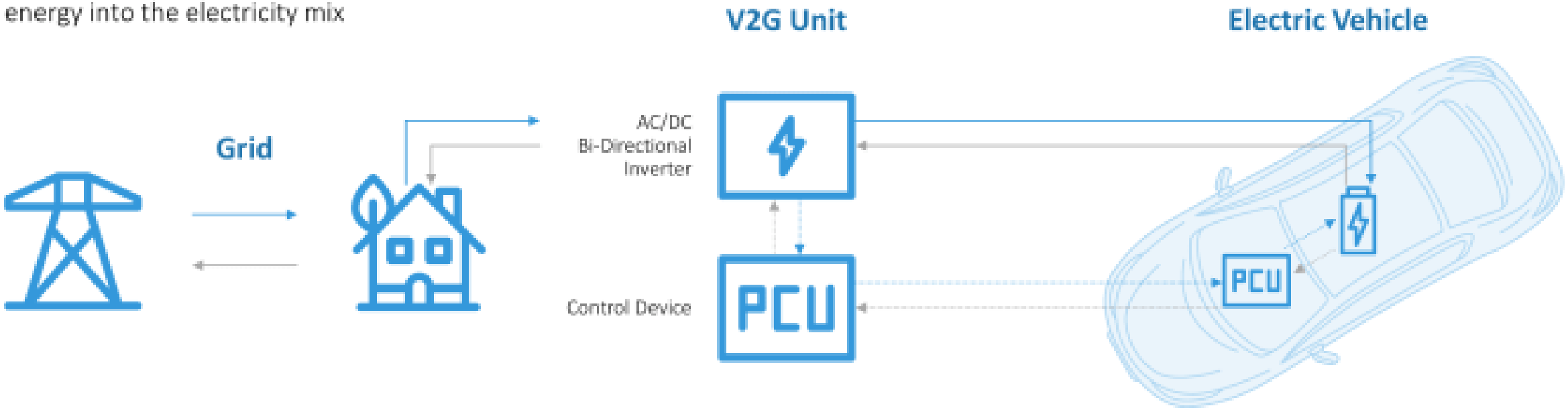
improved integration of wind energy into the electricity mix

IDEA:

Electric cars function as part of an intelligent energy system by feeding electricity back into the grid when the grid load is high

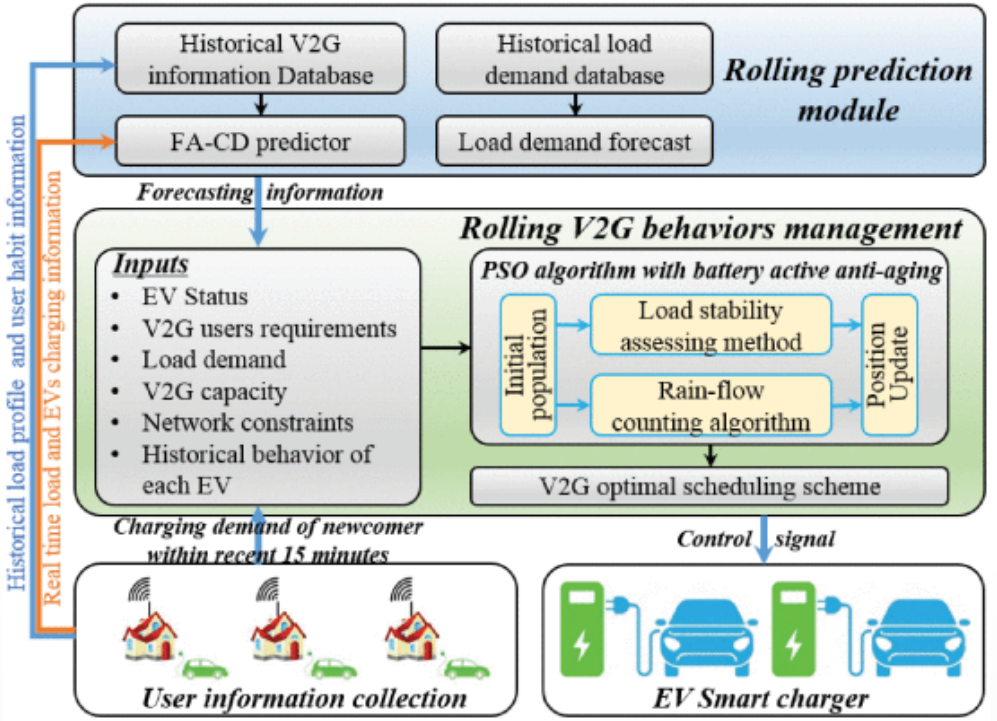
PROBLEM:

The lifespan of most batteries depends on charging cycles. V2G has a negative impact on battery longevity



Electric cars in smart cities – research issues

- **Intelligent route planning, charger reservation**
  - Dynamically changing traffic data
  - Dynamically changing charger avaiability
  - Dynamically changing demand
- **Optimization of EV car sharing fleets**
  - Allocation of cars taking into account charge levels
  - Gathering cars with depleted batteries
  - Placement of charging stations
- **Vehicle-to-grid optimization**
  - Discharge energy from EV battery to the grid, to lower peak demand
  - Transform night-time energy from the suburbs into day-time energy in the city
  - Take into account mobility, battery-degradation, grid power fluctuation level
  - V2G scheduling a large-scale, multi objective optimization problem – hard to find a global optimum



OUTLOOK

City of the Future