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Energy research Centre of the Netherlands

State of affairs electric driving

Marcel Weeda, ECN Policy Studies

Hogeschool van Amsterdam, 15 November 2011

Energy Research Centre of the Netherlands

ECN's mission:

ECN develops high-level knowledge and technology for a sustainable energy system and transfers it to the market

- **Independent research organization**
- **Bridge between fundamental research and industrial products**

- **600 - 650 employees**
- **Annual turnover 70-75 M€**

- **Active in the field of:**
  - **Wind Energy**
  - **Solar Energy**
  - **Biomass, Coal and Environment**
  - **Efficiency & Infrastructure**
  - **Policy Studies**
  - **Engineering & Services**

Transport research at ECN Policy Studies

	wegverkeer	scheepvaart	vliegverkeer	trein

onderzoek & advies

- **Beleidsinstrumenten** — ontwerp en evaluatie
- **Sociaal-wetenschappelijk** — consumentengedrag
- **Kwantitatief** — modellen, projecties, monitoring
- **Technisch-economisch** — ketens, aandrijvingen, kosten

emissiereductie

energiebesparing

alternatieven voor olie

betere luchtkwaliteit

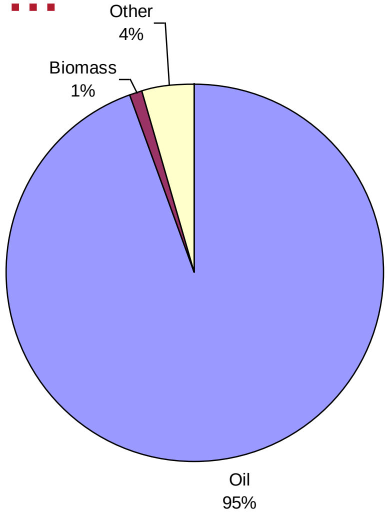
Combination of technical, economic and social expertise

Table of content

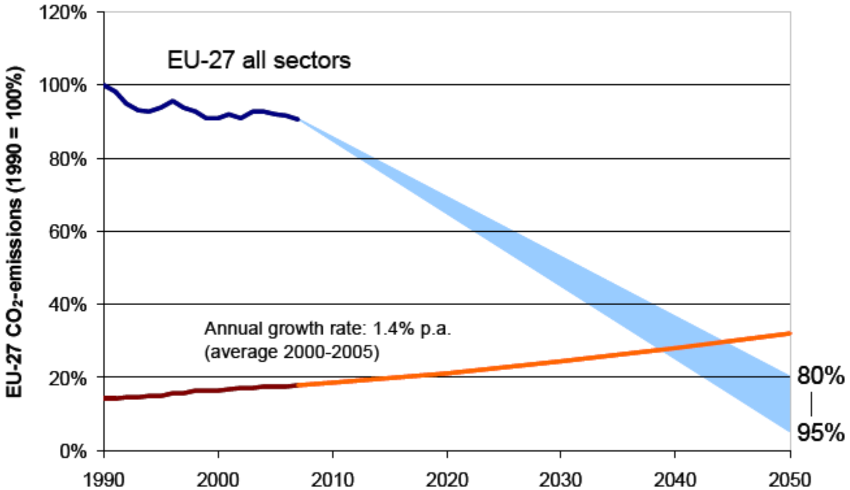
- General introduction
- Electric vehicles; types, characteristics, …
- CO_2 emissions of electric vehicles
- Main barriers to large scale adoption
- State of affairs electric cars and charging stations
- Policy
- Summary/Conclusions

Transport sector: we know why we have to act …

- Reduce dependency on oil
- Anticipation oil shortages
- Substantial GHG emission reduction needed to limit global warming



World energy consumption transport sector by energy source; IEA World Energy Outlook 2008



Source: European Environment Agency, 2009

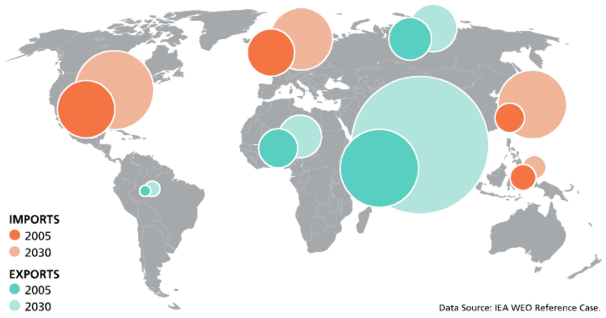


Figure ES-6. Net Regional Oil Imports and Exports

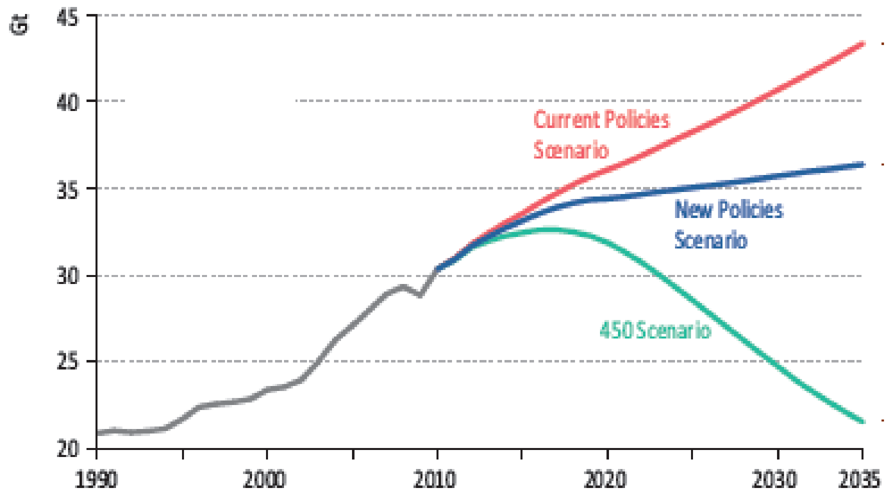
IEA World Energy Outlook 2011 (10 November 2011)

Jaarrapport van Internationaal Energie Agentschap

Verbruik van fossiele energie is rampzalig

Als de politiek niet snel de wereldwijde verslaving aan fossiele brandstoffen aanpakt, warmt het klimaat zozeer op dat grote gevaren dreigen voor de mens.

World energy-related CO2 emission by scenario

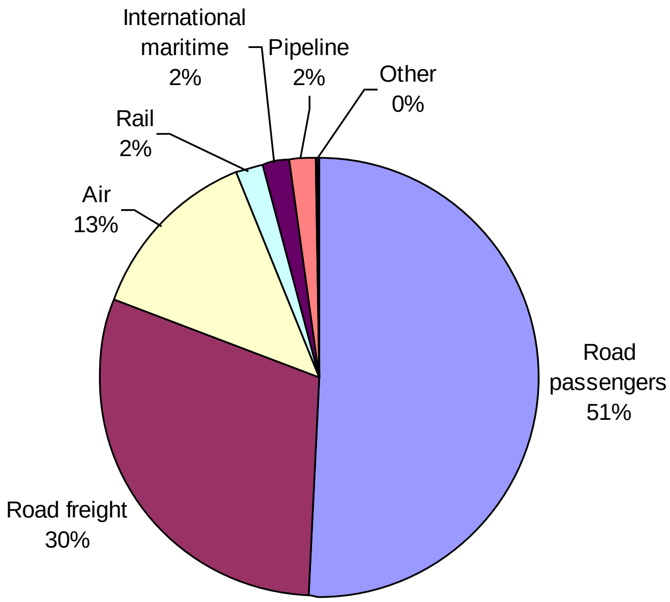


Source: IEA World Energy Outlook 2011

… and we have options on different levels

- Reduce transport demand
- Improve transport efficiency
- Improve driving behaviour
- Improve vehicle efficiency
- Use low carbon fuels

Focus on innovative drivetrains



World energy consumption transport sector by energy source; IEA World Energy Outlook 2008

Several innovative electric concepts available

- Electric car:
  - Car driven by an electric motor only
  - Supply of electricity is the challenge, not the electric motor
  - Storage and energy density are the key issues

PHEV:
Plug-in Hybrid Electric Vehicle

E-REV:
Electric – Range Extended Vehicle

BEV:
Battery Electric Vehicle

FCEV:
Fuel Cell Electric Vehicle

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Specific energy density car storage systems

Energy carrier	Energy density (kWh/kg)
Diesel	8.0 *)
Gasoline	8.0 *)
Lead-acid battery	0.04
Ni-MH battery (e.g. Prius)	0.07
Li-cobalt-ion battery (e.g. Tesla)	0.11
$LiFePO_4$-ion battery (State-of-the-art traction)	0.13
Li-ion batteries in portable electronics (target traction)	0.20
Hydrogen in on board storage system (State-of-the-art)	1.7 **)
Hydrogen in on board storage system (target)	3.0

*) Weight storage tank is 25% of mass including fuel

**) ~0.9 kWh/kg including fuel cell system

The power of a fuel dispenser

- Do you know what you are playing with when you are refuelling your car?

- Fuel consumption and fuel dispensing
  - 40 liter per minute
  - 1 liter for 15-20 km

  } 600-800 km range per minute

- Fuel dispensing and energy content
  - 40 liter per minute
  - 10 kWh/liter

  } 400 kWh per minute

- Energy content and power
  - 400 kWh per minute
  - 60 minutes per hour

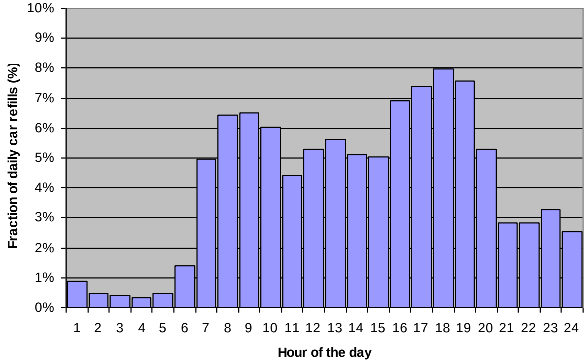
  } 24000 kW = 24 MW

Power required for fast charging

- Assume (single car):
  - Energy use 4x less: 6 MW
  - Range 25%: 1.5 MW
  - Charge in 30 min: 50 kW

- Assume (fleet):
  - 8 mln cars
  - 25% EV = 2 mln cars
  - 13,000 km/yr
  - 0.2 kWh/km
  - Average power 600 MW

  - 10% fast charging = 200,000 cars
  - Peak demand 8% of cars: 800 MW



- At present about 20,000 fuel dispenser

Overview of EVs on the market and in development



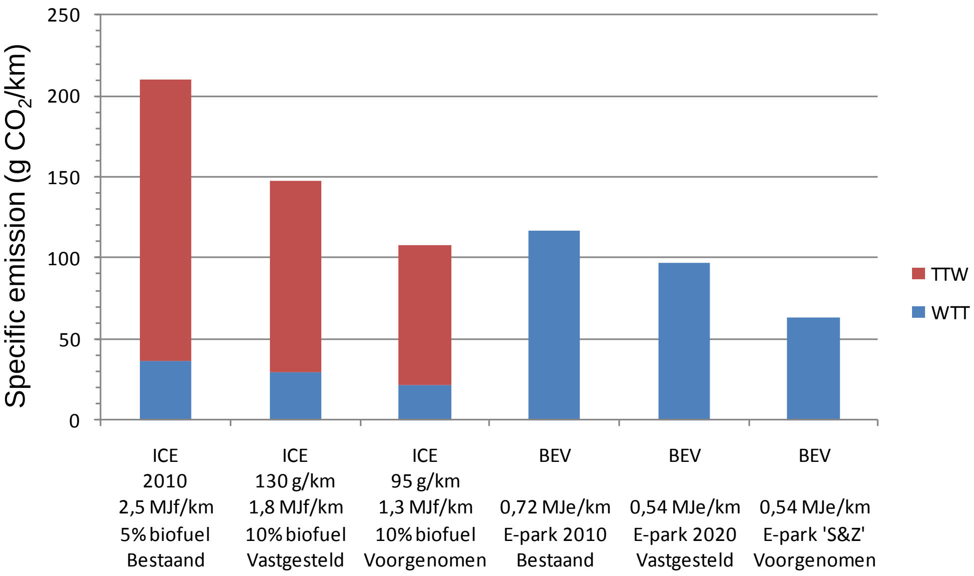


	Nissan Leaf	Mitsubishi i-MiEV	Citroën C-Zero	Peugeot iOn	Opel Ampera
	BEV	BEV	BEV	BEV	E-REV
Size: LxWxH (m)	4.45 x 1.77 x 1.55	3.47 x 1.48 x 1.60	3.47 x 1.48 x 1.60	3.47 x 1.48 x 1.60	4.50 x 1.80 x 1.44
Battery (kWh)	24	16	16	16	16
Range (km)	160	150	150	150	60 (+ < 440)
Top speed (km/hr)	140	135	135	130	161
Curb weight (kg)	1521	1085	1100	1100	1635
Price (€)	34,990	34,930	35,164	35,165	44,500

- Others: Tesla, Think, Tazzari, Electric Car Europe (ECE; conversion)
- Close or not yet available in NL: Toyota Prius Plug-in; Renault Fluence; Renault Kangoo; Smart; …
- Numerous prototypes, demo-series and announcements

What is the CO_2 emission of electric cars?

- Based on average electricity generation
- Based on power plant that start generating when we plug-in the car
- Emission Trading Scheme (ETS) approach:
  - Zero emission
- LCA approach:
  - 10-25 g/km higher than ICE-car
  - Main cause: battery production



Main barriers to large scale adoption of EVs

- Upfront cost of EV
- Technology uncertainty
- Range and range anxiety
- Availability of charging infrastructure

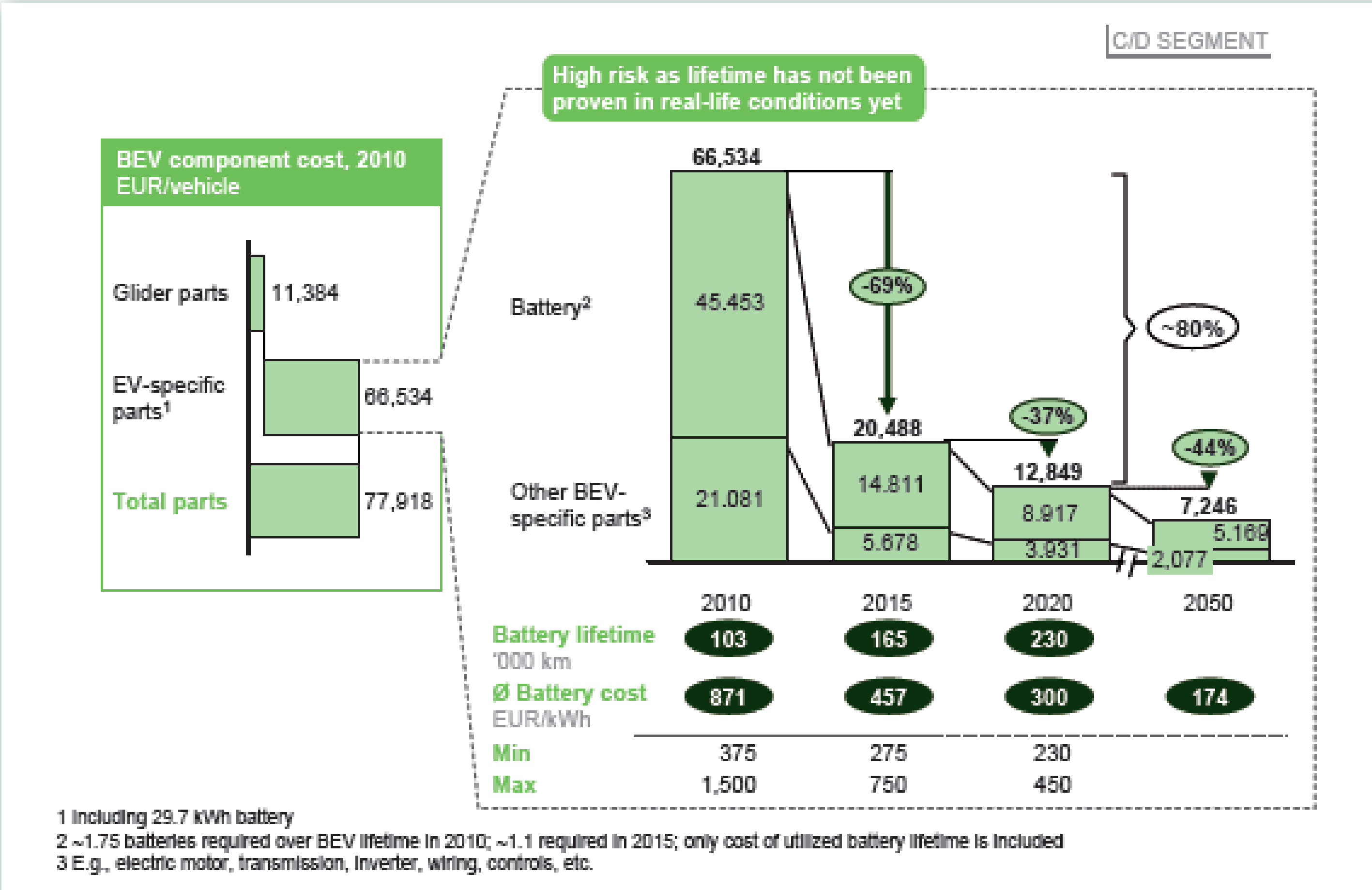
Consumers

Consumer characteristics

- Consumers are change-adverse
  - Only change if very urgent
- Most consumers do not enjoy thinking
  - As little time and effort for decision process as they can get away with
- Consumers are not good with numbers
  - Even bias in cost benefit-anaysis, e.g. more strongly averse by risk than motivated by possible gains
- Consumers are social beings
  - Listen to opinion of peers/role models, rather than to ‘objective’ information or to experts

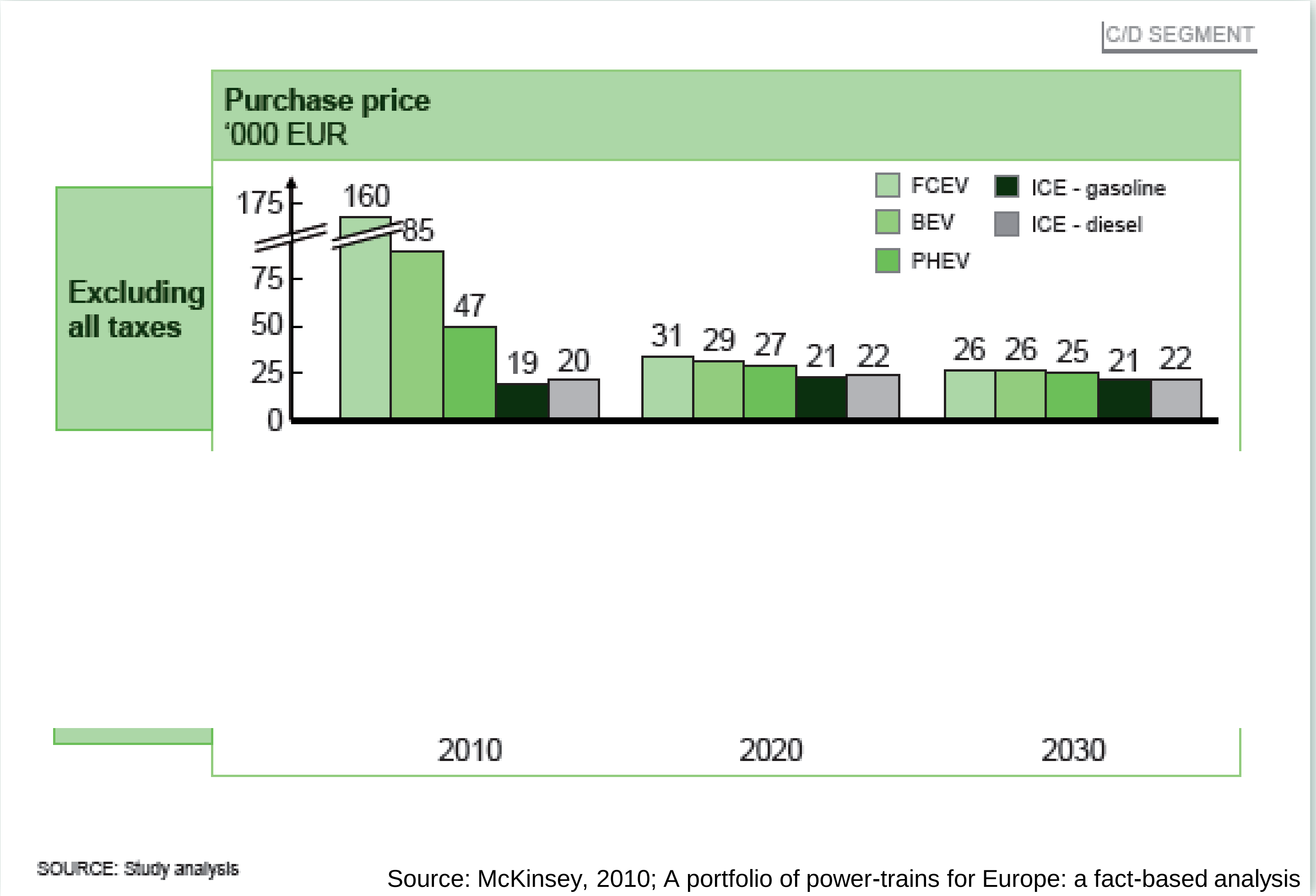
Average age buyers of a new car increases and is about 50 years!!

Upfront cost of EVs: expensive batteries



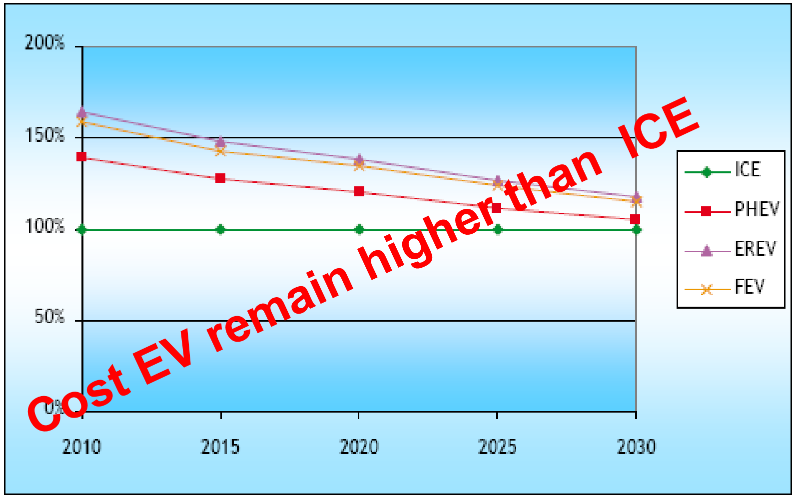
Source: McKinsey, 2010; A portfolio of power-trains for Europe: a fact-based analysis

Upfront cost of EVs

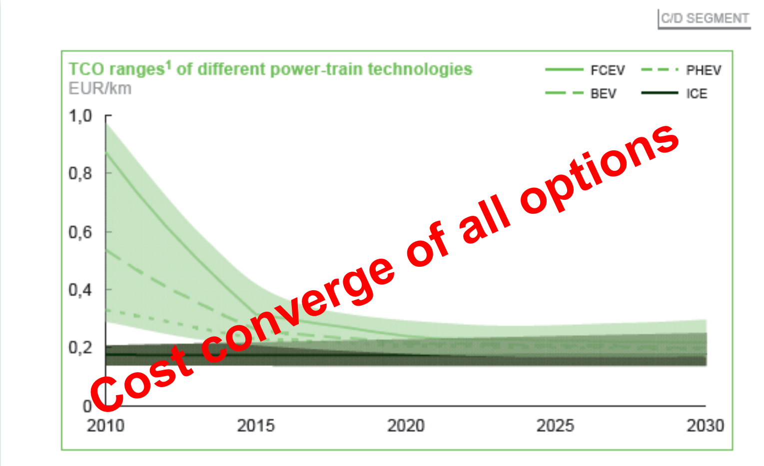


Source: McKinsey, 2010; A portfolio of power-trains for Europe: a fact-based analysis

TCO approach instead of upfront cost: all outcomes available

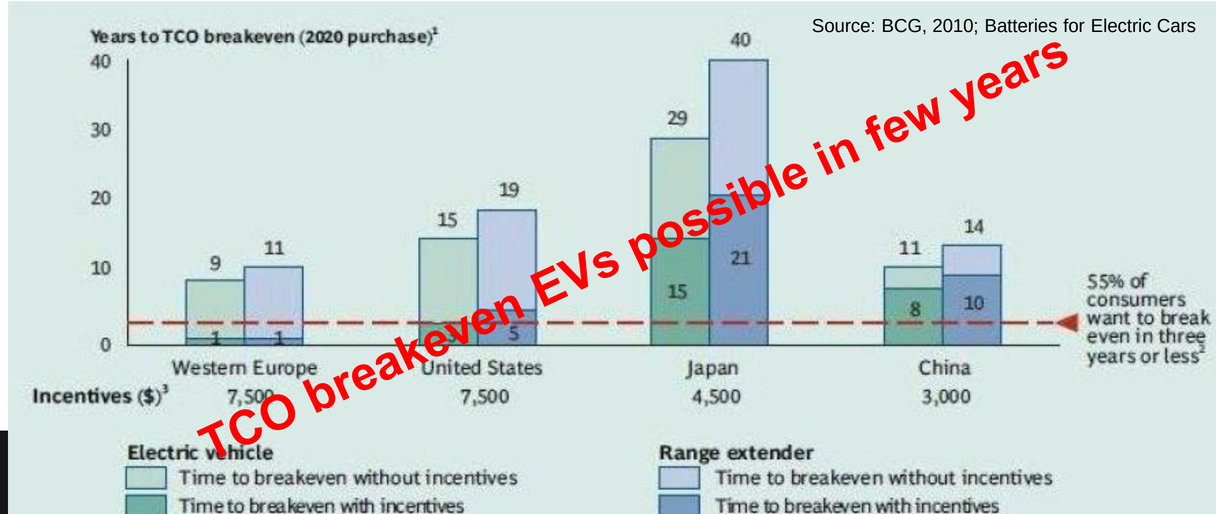


Source: CE, 2011; Impact of Electric Vehicles (Deliverable 4)



1 Ranges based on data variance and sensitivities (fossil fuel prices varied by +/- 50%; learning rates varied by +/- 50%)

Source: McKinsey, 2010; A portfolio of power-trains for Europe: a fact-based analysis



Source: BCG, 2010; Batteries for Electric Cars

Technology uncertainty EV

- Technology uncertainty EV related to batteries
  - Cycle life and calender life under all sorts of real-life conditions
- Nissan indications
  - (in general) “lifespan of 5 – 10 years under normal use”
  - Leaf’s battery is garantueed for eight years or 160,000 km
- Nissan recommends:
  - Avoid exposing a vehicle to ambient temperatures above 49°C for over 24 hours
  - Avoid storing a vehicle in temperatures below -25°C for over 7 days
  - Do not leave your vehicle for over 14 days where the Li-ion battery available charge gauge reaches a zero or near zero (state of charge)
  - Avoid exceeding 70 to 80% SoC when using frequent (more than one a week) public Fast Charge or Quick Charging
  - Allow the battery charge to be below at least 80% before charging
  - Allow the vehicle and Li-ion battery to cool down before charging
  - …

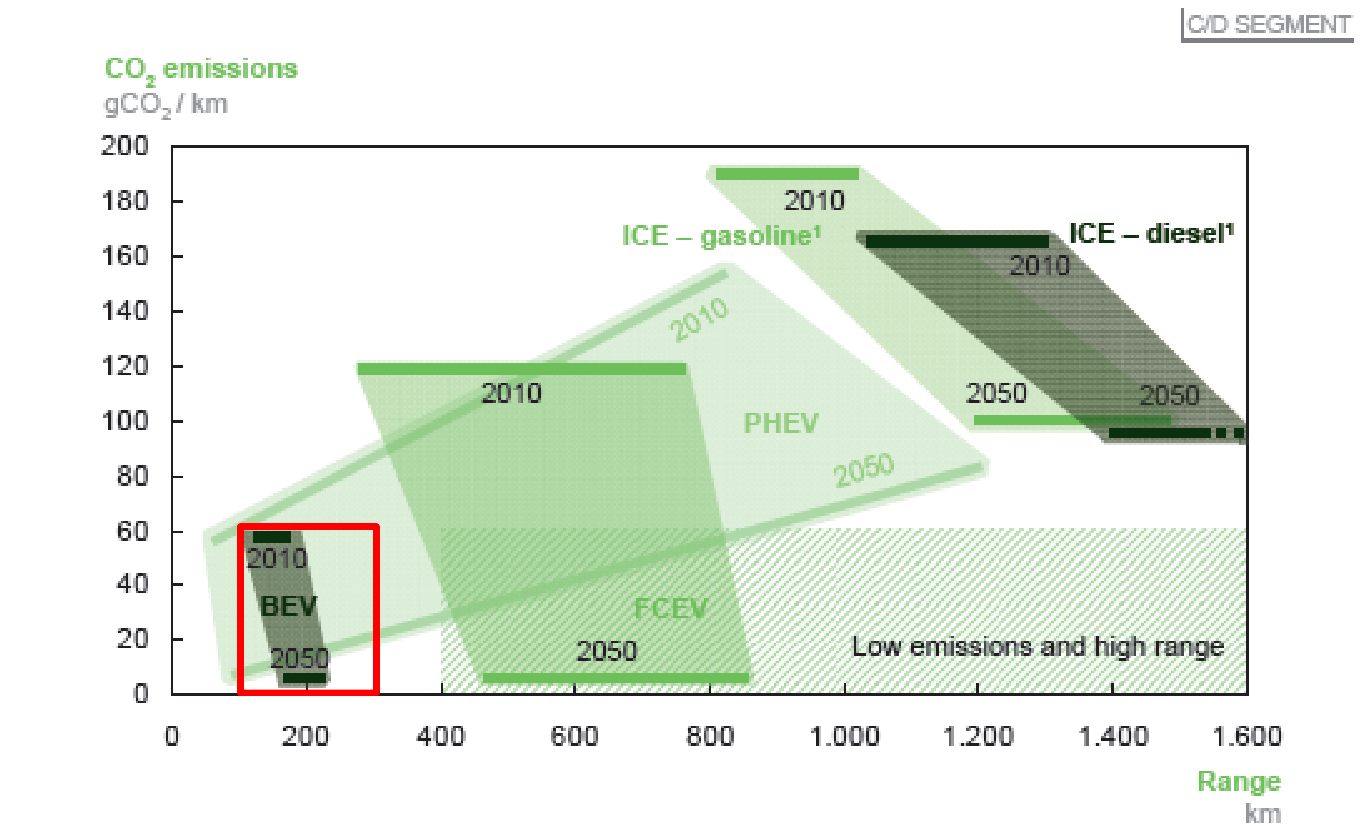
Range and range anxiety: range differs …

1 Bars represent range of performance across reference segments
2 Fast charging; implies higher infrastructure costs, reduced battery lifetime and lower battery load
3 The gas tank of a PHEV has the same refueling time as a conventional vehicle

SOURCE: Study analysis

Source: McKinsey, 2010; A portfolio of power-trains for Europe: a fact-based analysis

Range and range anxiety: … and remains relatively low



1 ICE range for 2050 based on fuel economy improvement and assuming tank size stays constant. Assuming 6% CO2 reduction due to biofuels by 2020; 24% by 2050

SOURCE: Study analysis

Source: McKinsey, 2010; A portfolio of power-trains for Europe: a fact-based analysis

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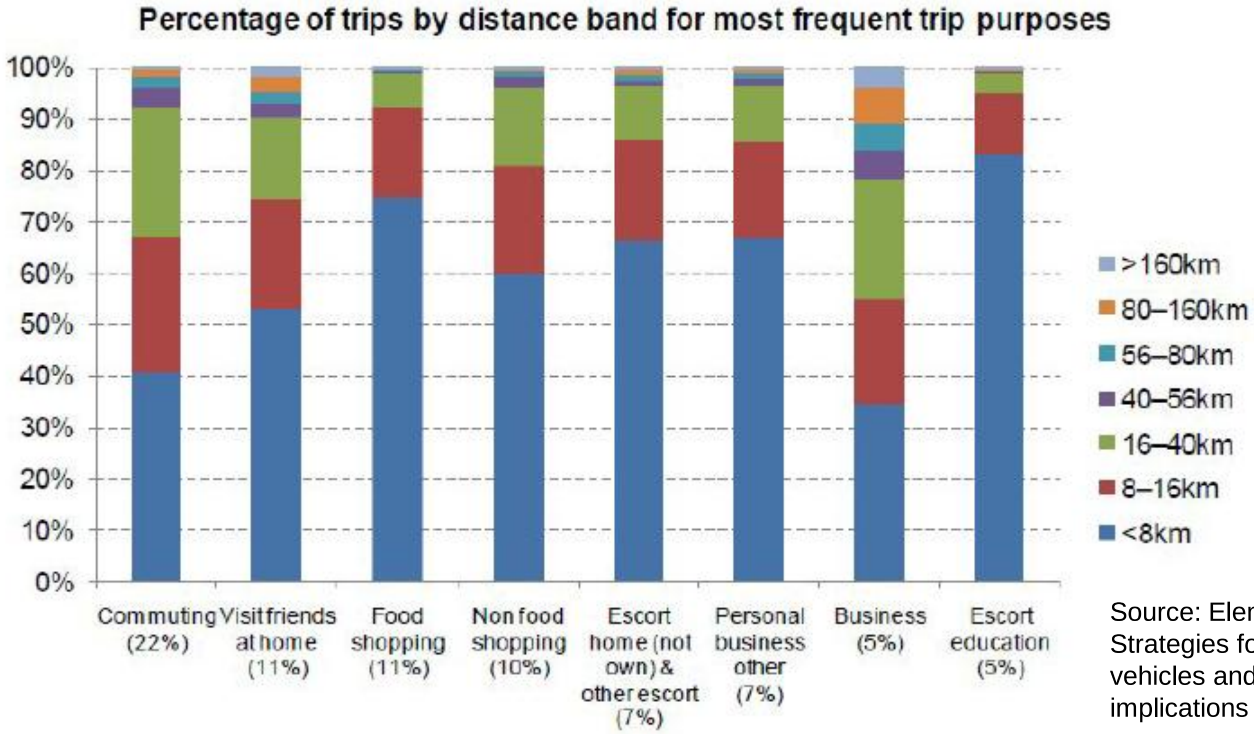
Range and range anxiety: range varies

- Nissan Leaf (EPA-city cycle): 160 km
- US EPA five cycle tests: 117 km
- US Federal Trade Commission: 154 – 180km
- New European Drive Cycle (NEDC): 175 km
- Nissan real life tests: 76 – 222km
- US consumer reports (commute, cold weather) avg. 105 km (-7 / -1°C)

Summary of the Nissan's results using EPA L4 test cycle operating the Leaf under different real-world scenarios

Driving condition	km/h	°C	Total Drive Duration	km	Air conditioner
Cruising (ideal condition)	61	20	3 hr 38 min	222	Off
City traffic	39	25	4 hr 23 min	169	Off
Highway	89	35	1 hr 16 min	110	In use
Winter, stop-and-go traffic	24	−10	4 hr 08 min	100	Heater on
Heavy stop-and-go traffic	10	30	7 hr 50 min	76	In use
EPA five-cycle tests		n.a.		117	Varying

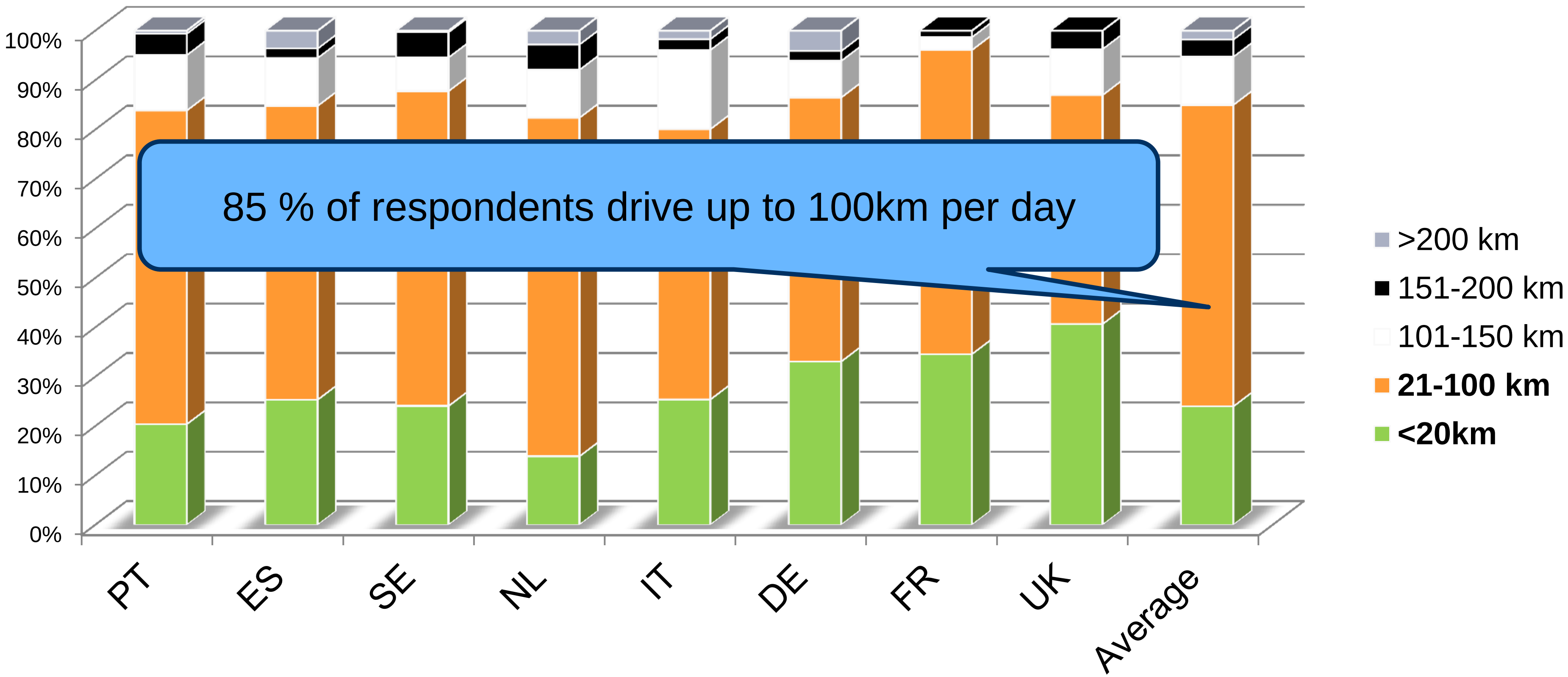
Range and range anxiety: range adequate on average



Source: Element Energy, Oct 2009; Strategies for the uptake of electric vehicles and associated infrastructure implications

- Based on real-life data of Nissan Leafs on the road in US and Japan:
  - Most owners: <100 km/day; average owners charge 2 hours/night
  - US (7500 Leafs): average 60 km/day and average trip length 11 km.

Survey results: current daily kilometers



BUT: required battery capacity to be interested in buying EV: 308km (NL 389km)!

People take into account the occasional longer trip

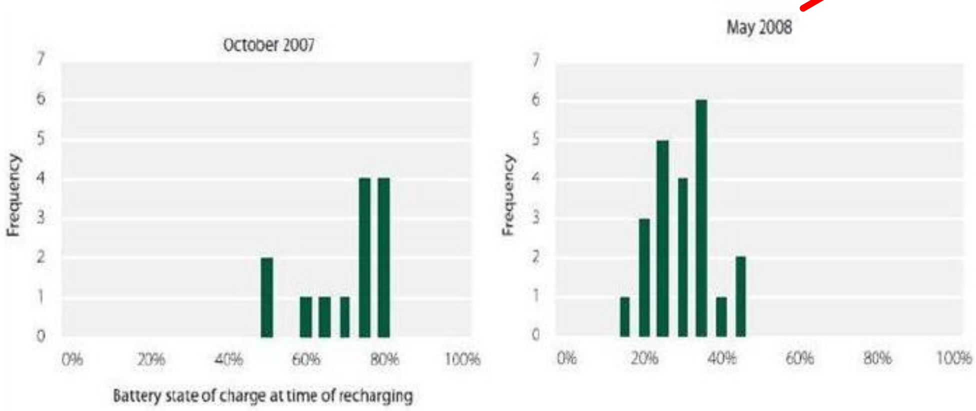
Availability of charging infrastructure: what kind?

- How fast?
  - Level 1: slow charging; 120-230 V AC/16 A; 7-8 hours
  - Level 2: slow? charging; 230-400 V AC/16-32A; 2-4 hours
  - Level 3: fast charging; up to 600V DC/550A; ≤ 30 min
- How safe?
  - Mode 1: Domestic socket and extension cord
  - Mode 2: Domestic socket and a cable with a protective device
  - Mode 3: Specific socket on a dedicated circuit
  - Mode 4: Direct current connection for fast recharging
- Where?
  - Home charging
  - Charging at public areas and at work
  - Charging at station like locations (incl. battery swap)
- Conductive (via cable) or inductive (wireless)?

Availability of charging infrastructure: how much?

- Consumers generally welcome the idea of home recharging
- Still public charging will be required:
  - No private parking available; especially cities; also NL relatively little
  - Consumers also want/need to recharge in public places
  - Means of addressing range anxiety

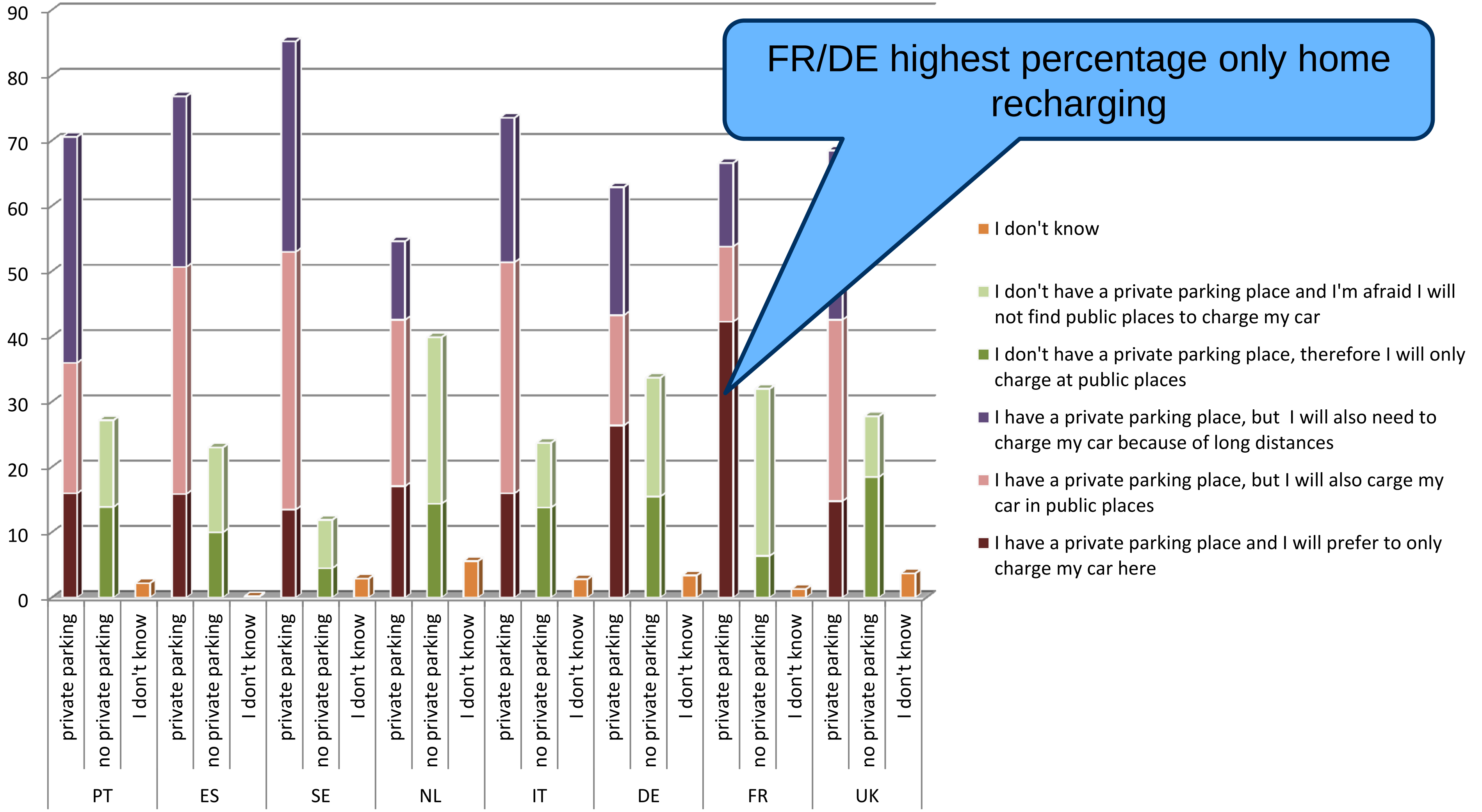
Addition of a second fast charger



More experience and increased confidence?

Source: TEPCO; Development of the most suitable infrastructure for commuter electric vehicles

Prefered charging location



Survey results: preferred charging location

G4V Grid for Vehicles

- 70% respondents has private parking place
  - 1/3 prefers to only charge at home/work
  - 1/3 also wants to charge at public places
  - 1/3 also needs to charge at public places because of long distances

30% without private parking place

Of these: 12% is afraid they will not find a place to charge

25% of these only want to charge at home with price incentive (!)

With price incentive (€ 5 vs 3)
53% will only charge at home or work

SEVENTH FRAMEWORK PROGRAMME

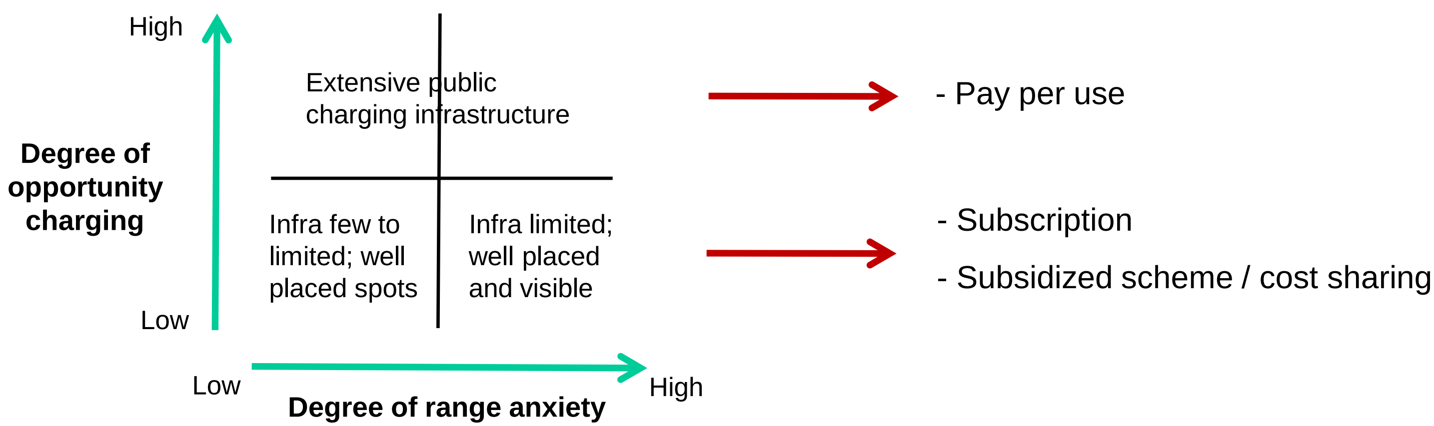
Availability of charging infrastructure: how much of what?

in US $	Level II: Private home/garage	Level II: Commercial garage/ public street	Level III	Battery swap
PlanNYC/ McKinsey	1,500-2,500	2,000-7,500 dependent on location	more than 40,000	-
BCG, Element Energy and other studies	500-2,000	3,000 -8,000 dependent on location	more than 50,000	-
Interviews and author's estimates	500-1,000	3,000 –7,000	40,000 – 75,000	+1,500,000

Source: CCI, 2010; Policy options for electric vehicle charging infrastructure in C40 cities

- Nissan developed its own 500 V DC fast charger (level 3) that went on sale in Japan for around $ 16,800 in May 2010

Availability of charging infrastructure: business models?

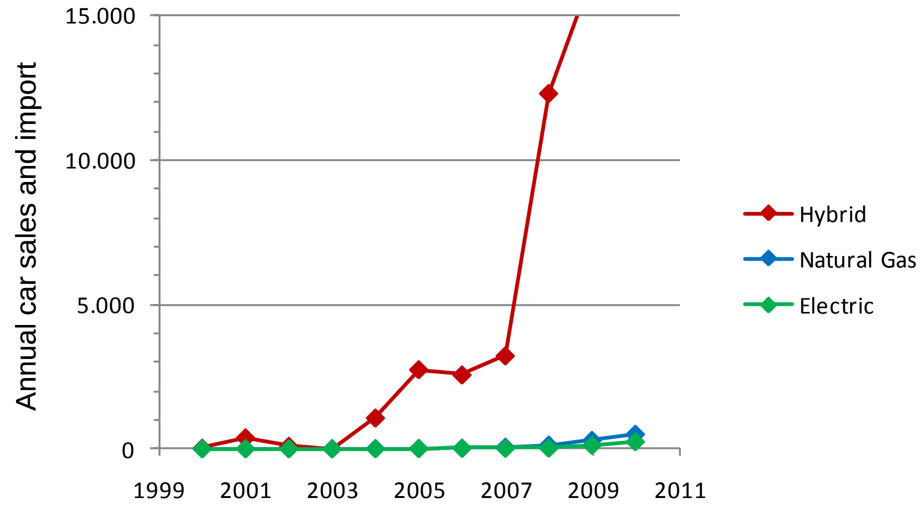


- Determining factors:
  - Number and development EVs
  - Annual mileage (km/yr)
  - Specific energy use (kWh/km)
  - Degree of convenience/opportunity charging
  - Characteristics charging station: lifetime, costs
    - Investment and financing
    - Maintenance
    - Sales and operations
    - Rental cost parking space/location
    - Margin
  - Number of charging stations

Barriers to large scale deployment EV charging infra

- Economic barriers
  - Uncertainty regarding demand
  - Number and type of charging infra required
- Regulatory barriers
  - Finalization of standards by international standard setting bodies
  - Policy uncertainty
    - Interoperability
    - Regulation over sale of electricity
    - Regulation regarding investment in infrastructure
  - Permitting
- Technology barriers
  - Uncertainty regarding charging technology and smart grid applications

State of affairs: cars



- End of 2010 about 400 Electric cars in the Netherlands
- First half year 269 electric cars
- Nissan Leaf 259 through October 2011
- UK through September 787, but quarterly sales decrease despite £5000 support: Q1 465, Q2 216, Q3 106.

- Car2go starts in Amsterdam with 300 electric cars on 24th of November 2011

State of affairs: charging stations

- As of November 2011 about 2250 charging points (www.oplaadpalen.nl).
- First European fast charging station in Leeuwarden, May 2011
- 25 fast charging points planned in 2011 (15 installed) and about 60 expected end of 2012

Opening Leeuwarden

Fast charger in Amsterdam

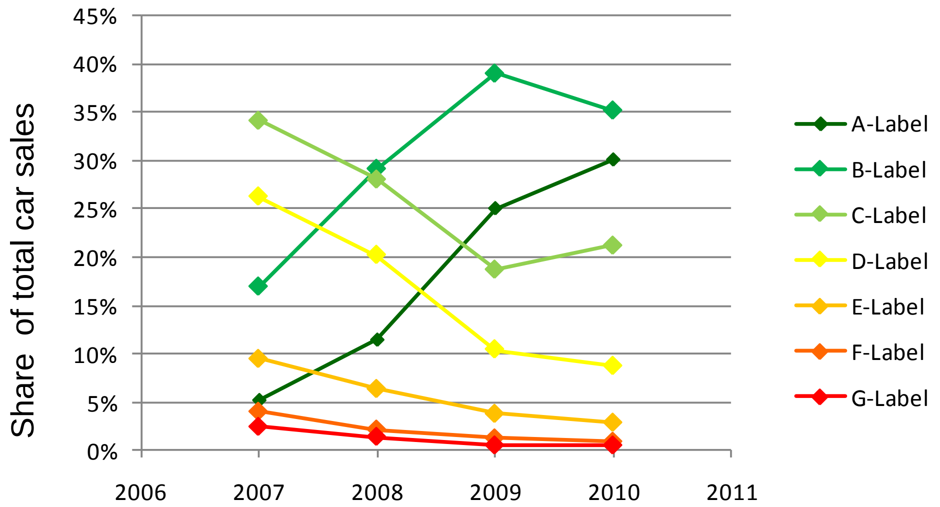
- Mennekes plug adopted as standard in NL:
  - Most likely final standard
  - Allows use of high power
  - Favourable safety aspects

Dutch policy electric cars

- Specific policy: “Elektrisch rijden in de versnelling” Plan 2011-2015
  - Main support to focal areas
  - Focus on promising market segments (best perspectives for business case)
  - Promote earning potential of electric mobility

- General policy: new taxation scheme for cars - “Autobrief”
  - Swapping of current purchase tax (BPM) to one based on car CO_2 emission
  - Exemption purchase tax (CO_2 basis) to 2015
  - No addition to taxable income of lease EVs to 2015
  - No road tax to 2015

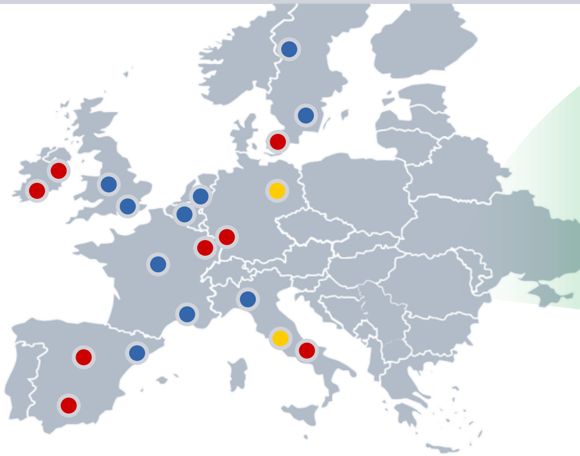
- Targets and ambitions
  - 20,000 EVs in 2015
  - 200,000 in 2020 and 1 mln in 2025



Green eMotion – Development of an European Framework for Electromobility

The Concept of Green eMotion

Green eMotion



GREEN EMOTION

- Connection of national / regional projects
- Market place
- Interoperability and standards

National / regional projects
- Proof technology (equipment level)
- Test of operation and billing
- First business models
- Initial local consumer awareness

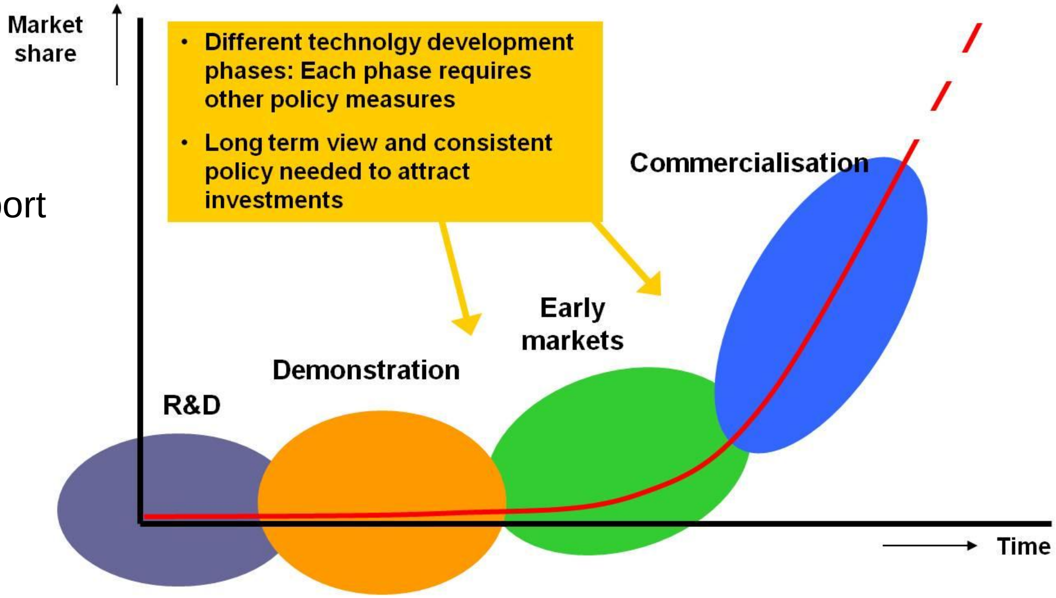
EU project Green eMotion
- Proof of interoperability
- Future proofing of protocols and interfaces
- Introduction marketplace and advanced services
- Wider consumer awareness and acceptance

Mass market (start)
- Standardised solutions for vehicles infrastructure, network and IT applications available
- Preconditions and user acceptance established

Legislative support
Incentivising policies and regulation
Consumer incentives

Summary

- Signs are that in the near-term future market penetration of EVs will remain low
- Even significant risk of electric ‘depression’ in short-term if expectations are not met and penetration remains low
- In the long term, however, there is no alternative for EVs (incl. FCEV)
- Technology development
  - Reduce cost
  - Improve range
- Policy:
  - Long-term commitment & support
  - Remove regulatory barriers
  - EV is more than cars
- Consumer
  - Inform and educate (scooter!)
  - Seduce

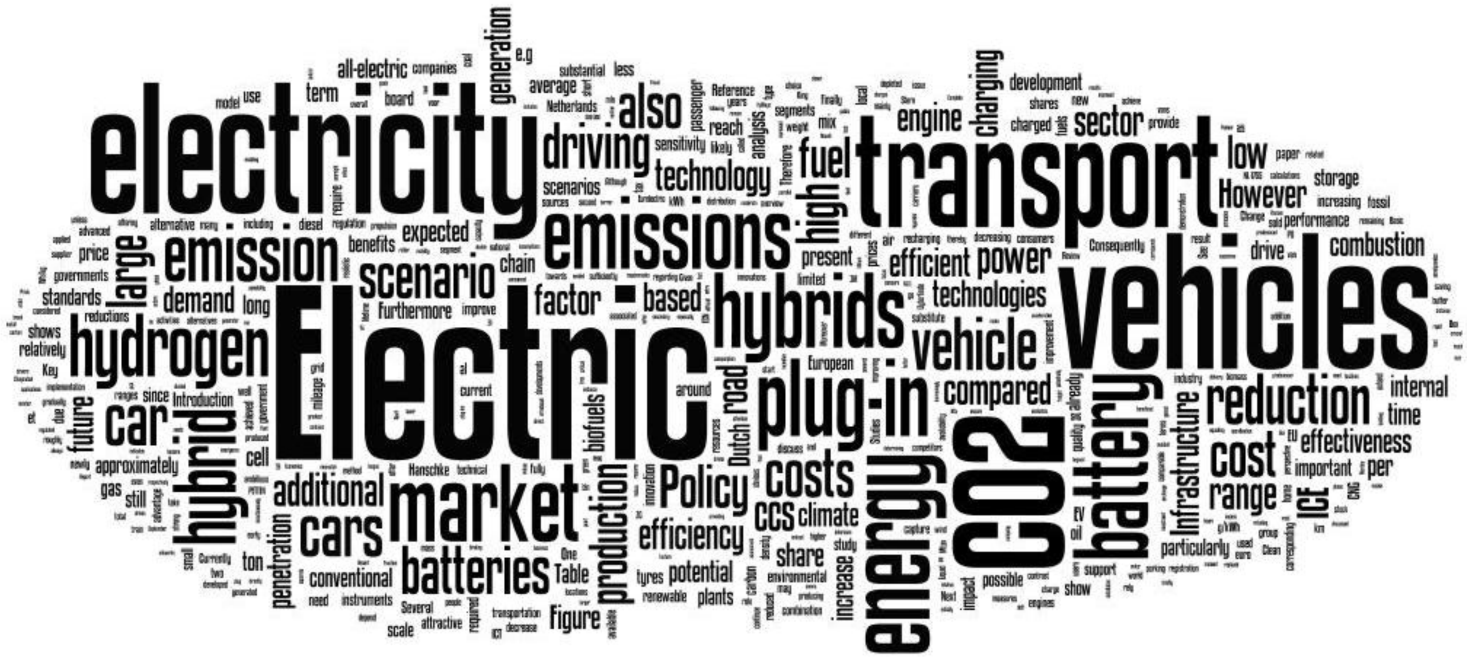


Business as usual

Action

Illustration:
Scientific American

Thanks!



www.g4v.eu

Download the full report about the European survey:

http://www.ecn.nl/docs/library/report/2011/o11030.pdf

Feedstock issue

- Many different battery chemistries
- Typically 100 – 400 g Li/kWh; at 20 kWh, typically 5 kg Li/car
- Amount of Li per car depends on:
  - Type of battery used
  - Type of car; BEV, PHEV, …
  - Size of car and range
- Other issues:
  - How much can be recycled (at present no recycling)
  - How much batteries in 'second life' before recycling
  - How much other applications
- Potential:
  - Current production about 30,000 ton/yr
  - Economically recoverable reserves at present estimated at 6,000,000 ton
  - Reserve basis estimated at 11,400,000 – 35,000,000 ton