Electric and Hybrid Electric Vehicle Technology

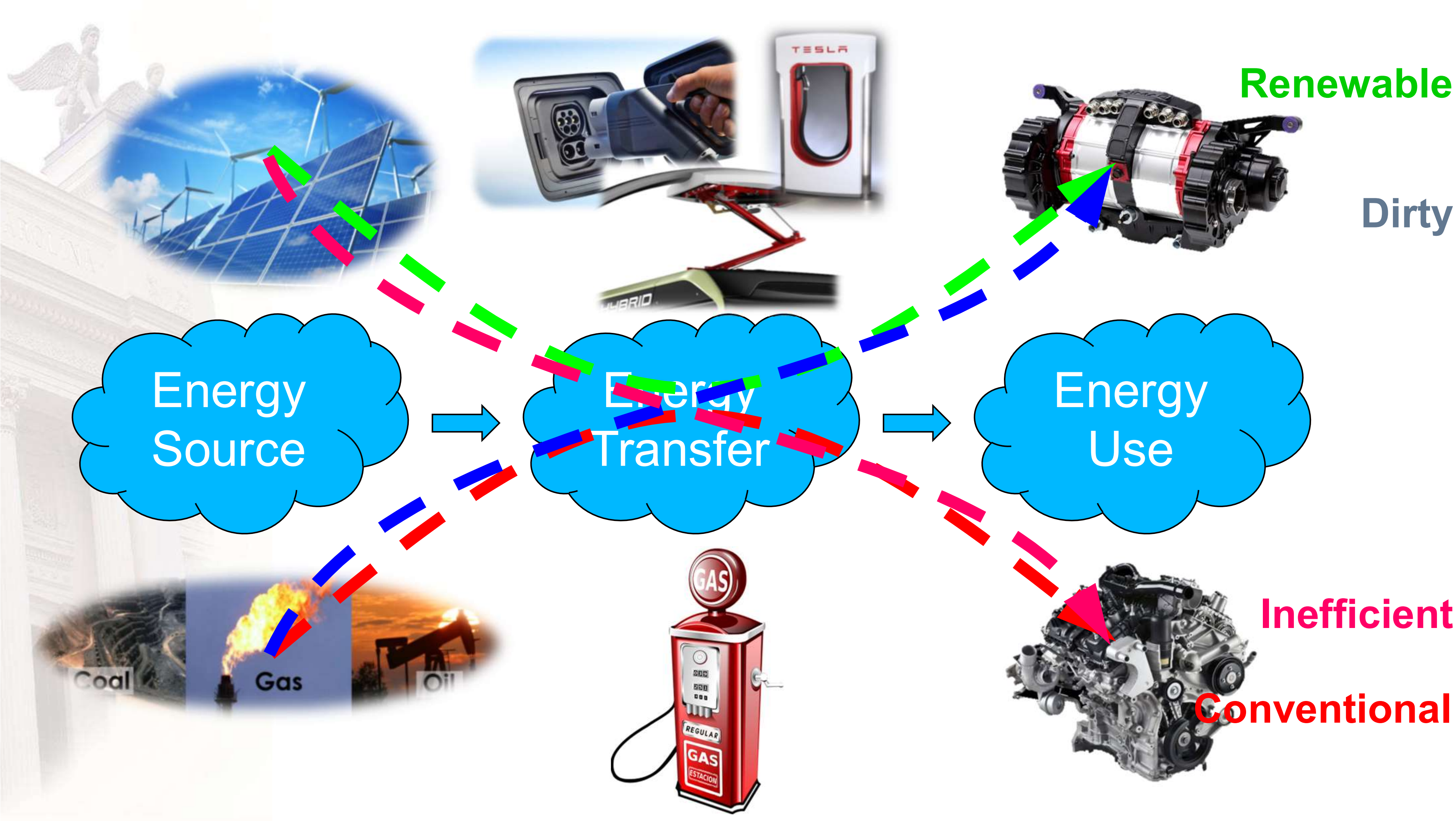
2020

Today’s lecture

- A message from Mats
- A description of the course
- An introduction to the subject

The Course

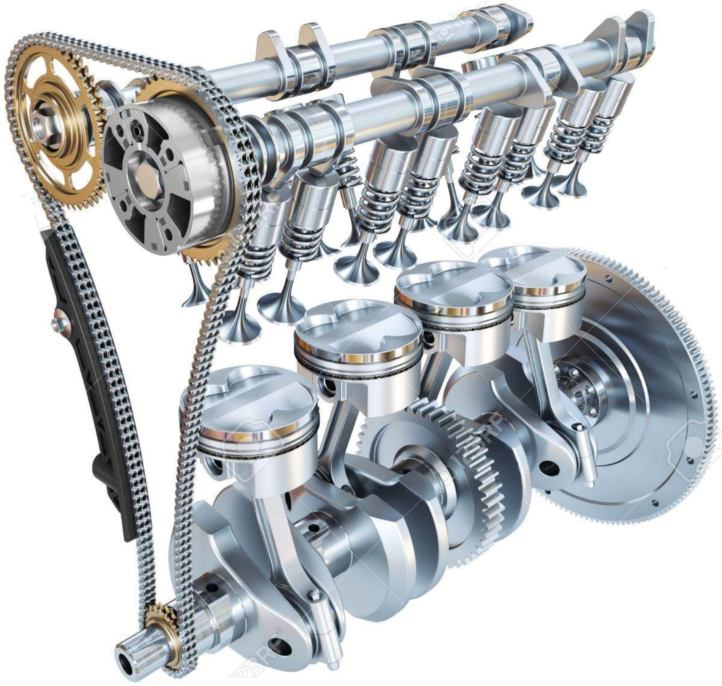
Lect #	Exc #	HA1	HA2	Calender Week	Date	Time	Location	Contents
1				36	2020-09-01	15:15 - 17:00	M:D + Zoom	Introduction to Electro Mobility
2					2020-09-02	10:15 - 12:00	Zoom	Veh dynamics, the ideal vehicle
3					2020-09-03	15:15 - 17:00	Zoom	Non ideal - The ICE + Mechanical Transmissions
4		#1 Out			2020-09-04	10:15 - 12:00	Zoom	Simulation and Home Assignment 1 presentation
	1			37	*2020-09-09*	*08:15 - 10:00*	*KC:M Em4-5*	*Support on Home assignment 1*
					2020-09-09	*10:15 - 12:00*	*KC:M Em4-5*	
					2020-09-11	*10:15 - 12:00*	*KC:M Em4-5*	
5				38	2020-09-15	15:15 - 17:00	Zoom	Hybrid System Components (battery, traction drive system)
6					2020-09-16	10:15 - 12:00	Zoom	Hybrid Conceps 1: The Parallel Hybrid, Modelling and Control
7			# 2 out		2020-09-18	13:15 - 15:00	Zoom	Home assigment 2: handout
	2	# 1 back		39	*2020-09-23*	*08:15 - 10:00*	*KC:M Em4-5*	*Support on Home Assignment 2*
					2020-09-24	*13:15 - 15:00*	*KC:M Em4-5*	
					2020-09-25	*10:15 - 12:00*	*KC:M Em4-5*	
8				40	2020-10-01	10:15 - 12:00	Zoom	Hybrid Conceps 2: The Series and Complex Hybrid, Mild Hybridisation, the 48 V hybrid
9					2020-10-02	10:15 - 12:00	Zoom	Charging, concepts, cost and applications
	3			41	*2020-10-06*	*09:00 - 15:00*	*TBD*	*Study tour to industry*
					2020-10-07	*08:15 - 10:00*	*KC:M Em4-5*	*Support on Home Assignment 2*
					2020-10-07	*10:15 - 12:00*	*KC:M Em4-5*	
					2020-10-08	*13:15 - 15:00*	*KC:M Em4-5*	
10				42	2020-10-14	13:15 - 15:00	Zoom	Charging continued
11					2020-10-14	15:15 - 17:00	Zoom	Auxilliary loads and Electric Safety
	4				*2020-10-18*	*08:15 - 10:00*	*KC:M Em4-5*	*Support on Home Assignment 2*
					2020-10-18	*10:15 - 12:00*	*KC:M Em4-5*	
			# 2 back		*2020-10-18*	*15:15 - 17:00*	*KC:M Em4-5*	
				44	2020-10-23	08:00 - 13:00	MA 10G	Written examination - Internet based examination to be expected !



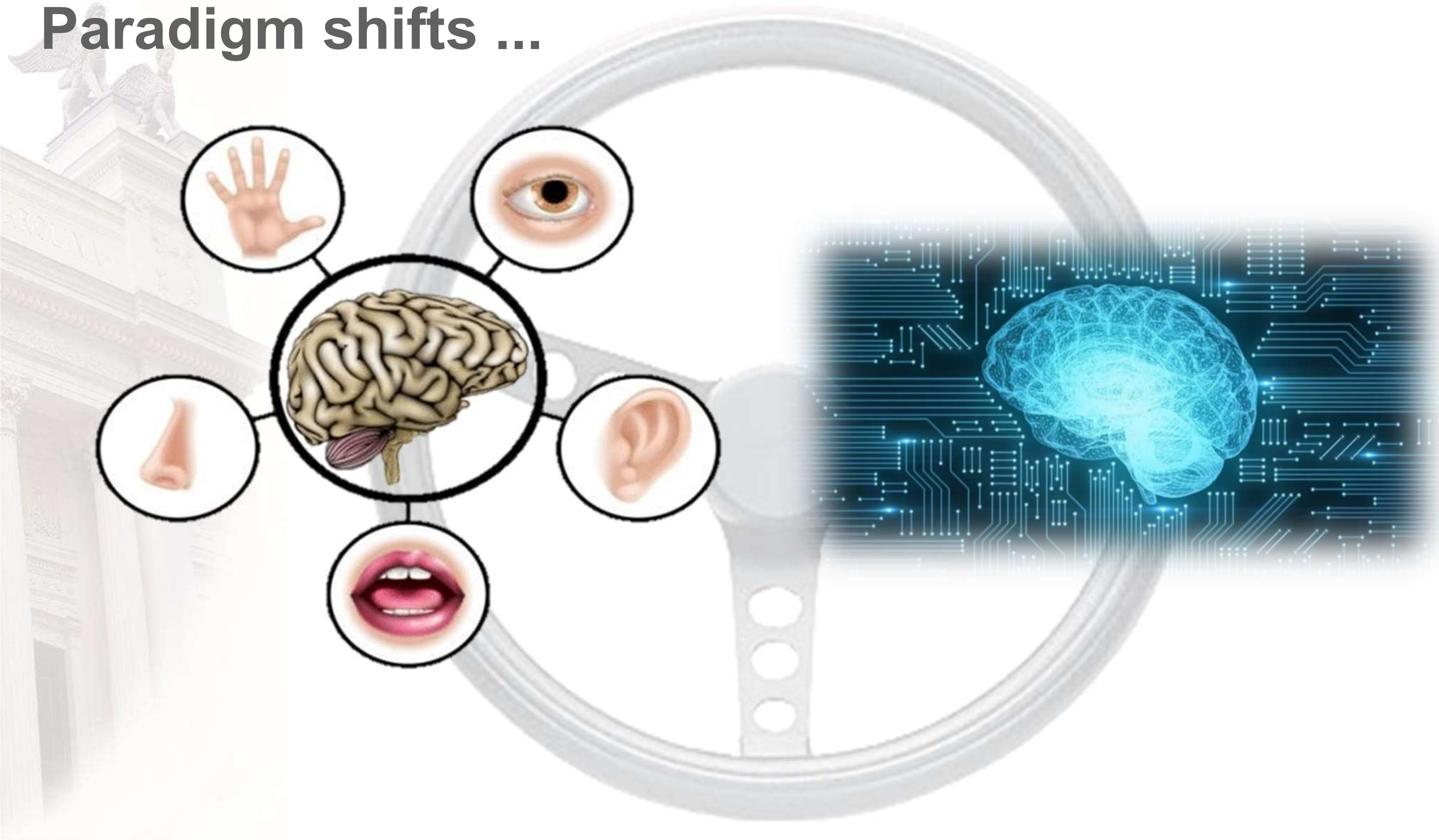
Renewable
Dirty
Inefficient
Conventional
Energy Source
Energy Transfer
Energy Use
Coal
Gas
Oil
TESLA
HYBRID
GAS
REGULAR
GAS
ESTACION

Paradigm shifts ...

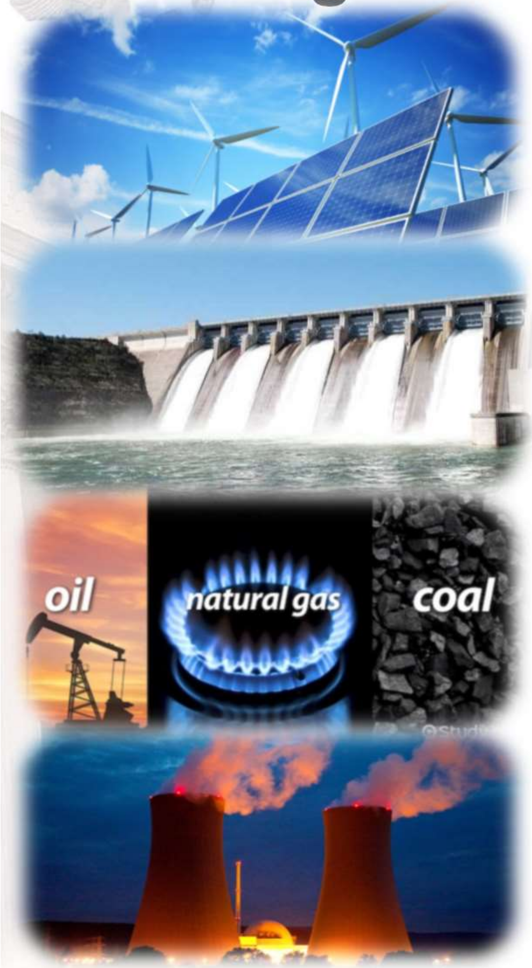
Paradigm shifts ...



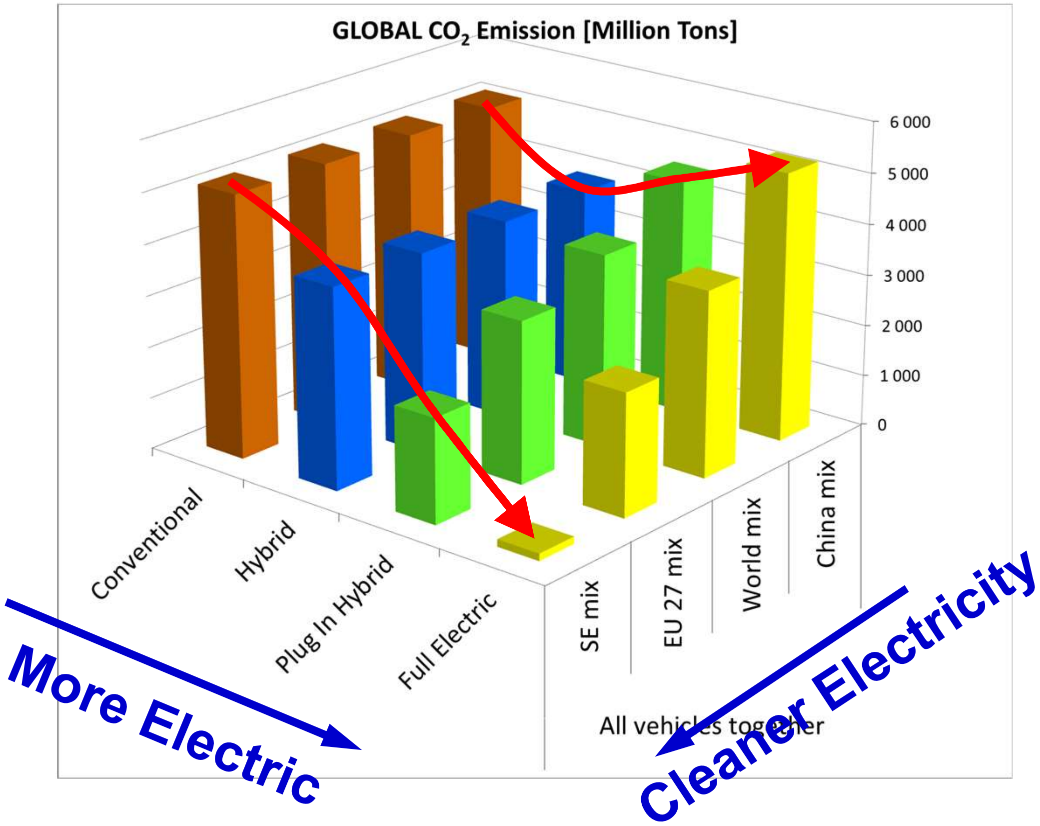
Paradigm shifts ...

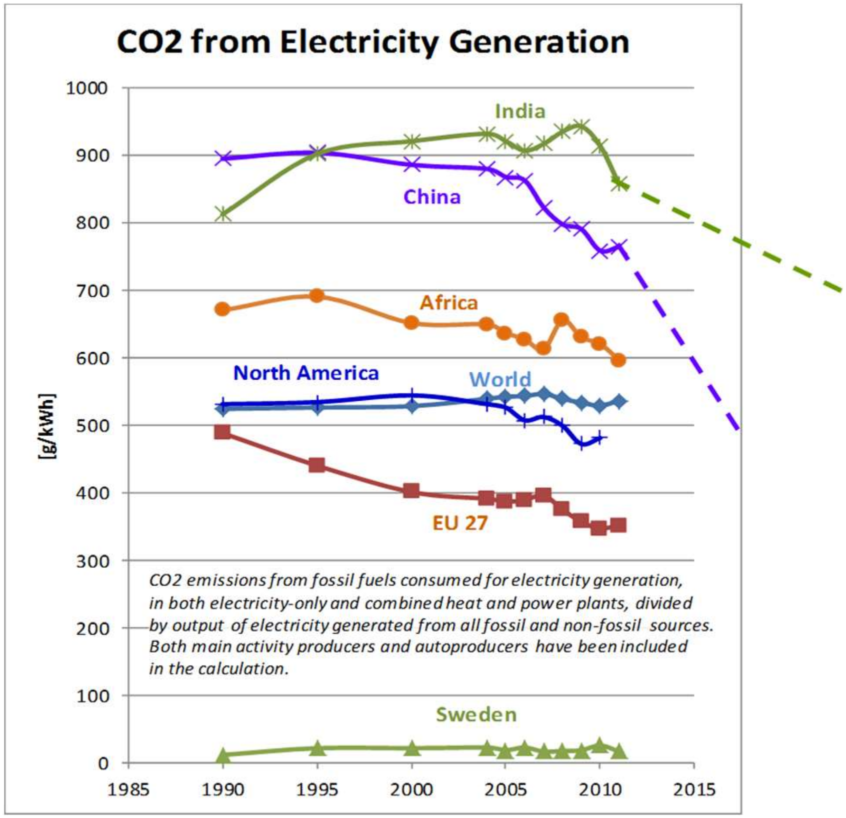


Challenge 1 – Power and Energy



Electro mobility is important





Do we have enough?

Sweden as example:

- We use about 80 TWh of Gasoline and Diesel
- When all vehicles are electric, we will need about 27 TWh electricity per year = 74 GWh/day.
- Our maximum power generation capacity is about 30+ GW
  - If we charge in 6 hours: 12 GW charging power – **NOT POSSIBLE**
  - If we charge in 12 hours: 6 GW charging power – **MAYBE POSSIBLE**
  - If we charge in 24 hours: 3 GW – **POSSIBLE**

Conclusion? – We need to be smart when charging!

Is it worth the trouble?

- Comparing Kia Niro Hybrid, Plug In Hybrid and Full Electric
- Low/High CO_2 **emissions from battery manufacturing**
- Short/Long **battery lifetime**
- Swedish/Chinese **CO_2 intensity in electricity generation**
- Not much difference on the **hybrid** !
- The **Plug In Hybrid** emits about half the CO_2, in the best case
- The **Full Electric** emits 1/10[th] of the CO_2, in the best case

			Kia Niro			
			Hybrid	*Plug In*	*Full El*	
Battery Size			1,56	8,9	64	[kWh]
Fuel Consumption			0,48	0,21	0	[l/10km]
El energy consumption			0	0,93	1,59	[kWh/10km]
CO2 emissions from burning gasoline			2684			[g/liter]
CO2 emissions from manufacturing gasoline			599			
CO2 emissions from battery manufacturing						
Low	50	[kg/kWh]	78 000	445 000	3 200 000	[g]
High	[illegible]	[kg/kWh]	234 000	1 335 000	9 600 000	
Battery life						
Short			100 000			[km]
Long			[illegible]			
CO2 emissions from battery ageing						
Low manufacturing emissions, Short lifetime			8	45	[illegible]	[g/10km]
Low manufacturing emissions, Long lifetime			3	15	107	
High manufacturing emissions, Short lifetime			23	134	960	
High manufacturing emissions, Long lifetime			8	45	320	
CO2 emissions from Electricity generation						
Low (Sweden)			30			[g/kWh]
High (China)			900			
Total Emissions						
From gasoline			1 576	689	0	[g/10km]
From battery manufacturing, best case			2,6	14,8	106,7	
From battery manufacturing, worst case			23	134	960	
From electricity generation, best case			0	28	48	
From electricity generation, worst case			[illegible]	[illegible]	[illegible]	
Total CO2, min			1 578	732	154	
Total CO2, max			1 599	1 660	2 391	

Yes, it is definitively worth the trouble!

… as electricity gets cleaner …

… the EV's do too

Size Matters ...

Vehicle Type	Average Tractive Power	Average Speed	Typical Distance	Battery Needed	
	[Watt]	[km/h]	[km]	[kWh]	[kg]
Bicycle	50	15	80	0,3	2,1
Scooter	500	35	100	1,8	11
Car	18 000	100	300	68	422
City Bus / Distribution Truck	40 000	30	200	333	2 083
Coach Bus / Long Haul Truck	90 000	80	350	492	3 076
Boeing 747 Cargo Ship	70 000 000	900	9200	894 444	5,59E+06

Battery Data		
Energy Density	0,2	[kWh/kg]
Cycling Depth	80%	[%]

Energy Storages

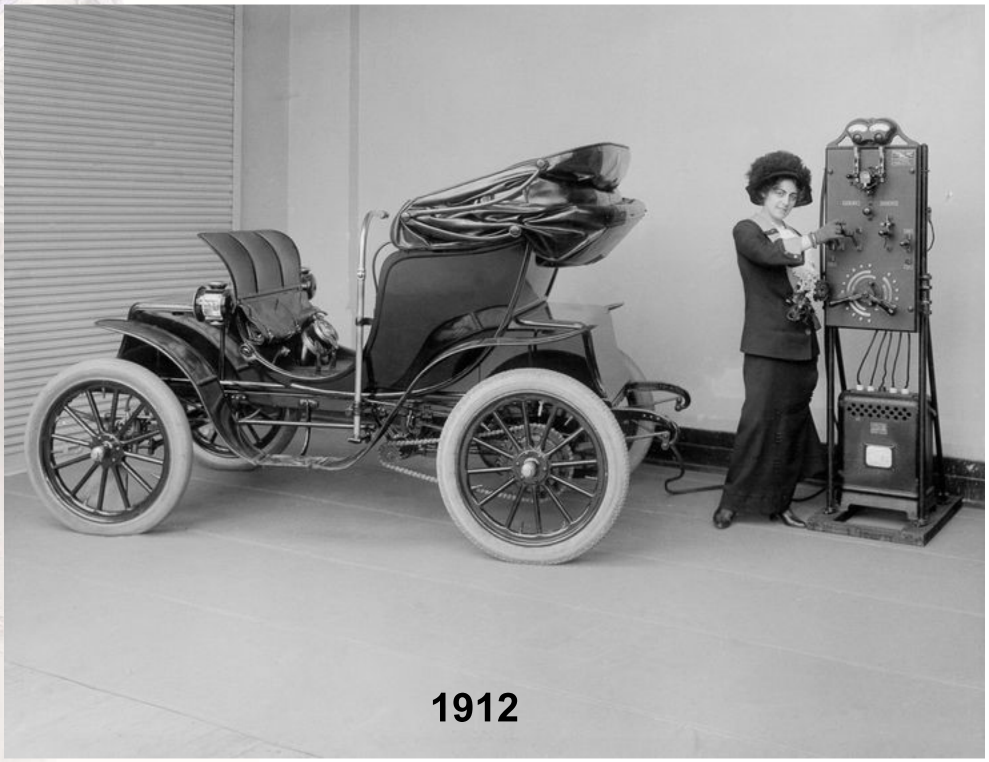
50 liter = 500 kWh = ... = 2.5 ton

10 kWh/liter
14 kWh/kg

0.05 ... 0.2 kWh/kg

The last Century

The Charging Challenge is NOT new ...



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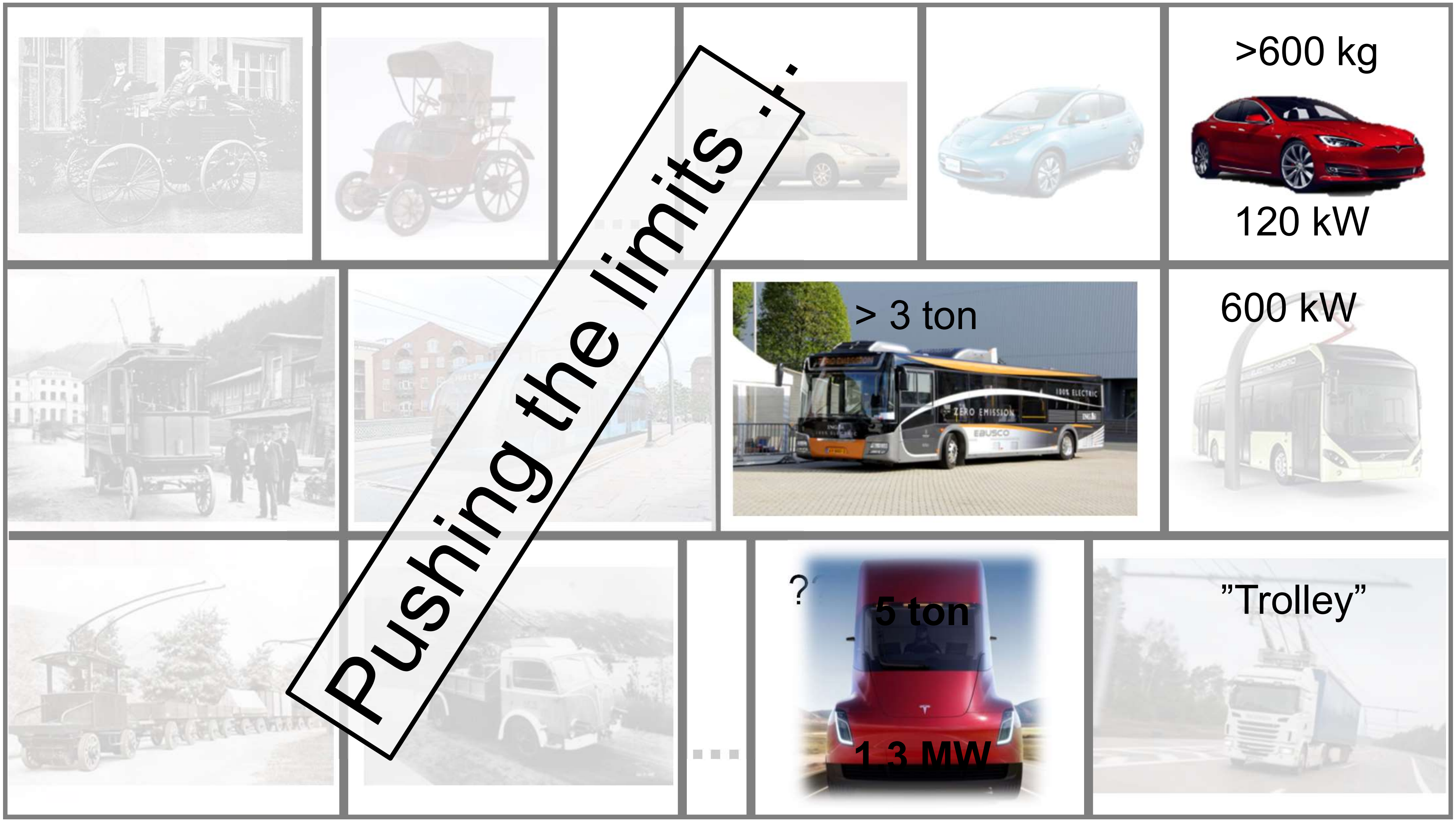
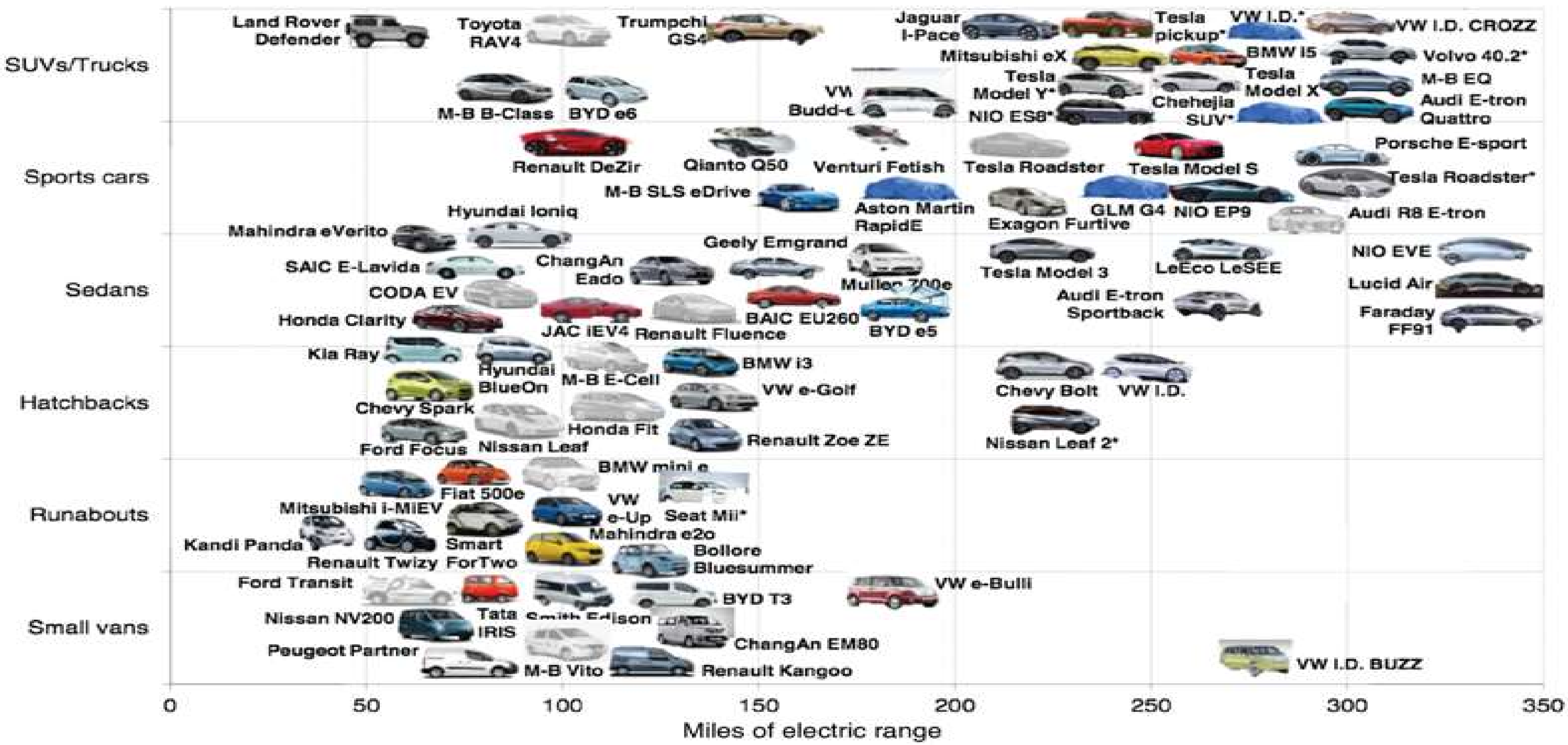
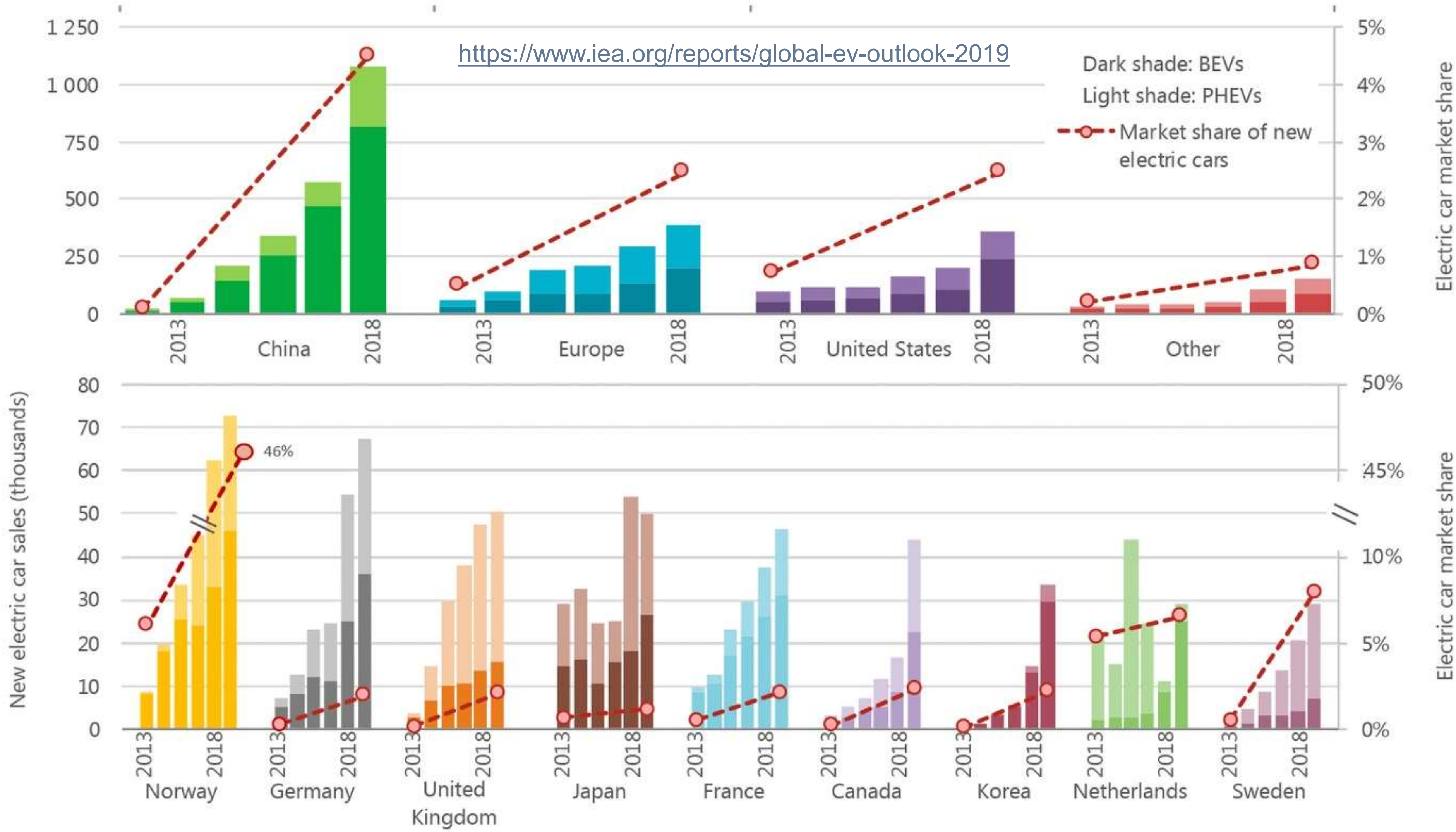

Pushing the limits ...
>600 kg
120 kW
> 3 ton
600 kW
?
5 ton
1.3 MW
"Trolley"

Electric-Car Boom

https://www.greenpolicy360.net/w/Category:Transportation

Models by style and range available through 2020

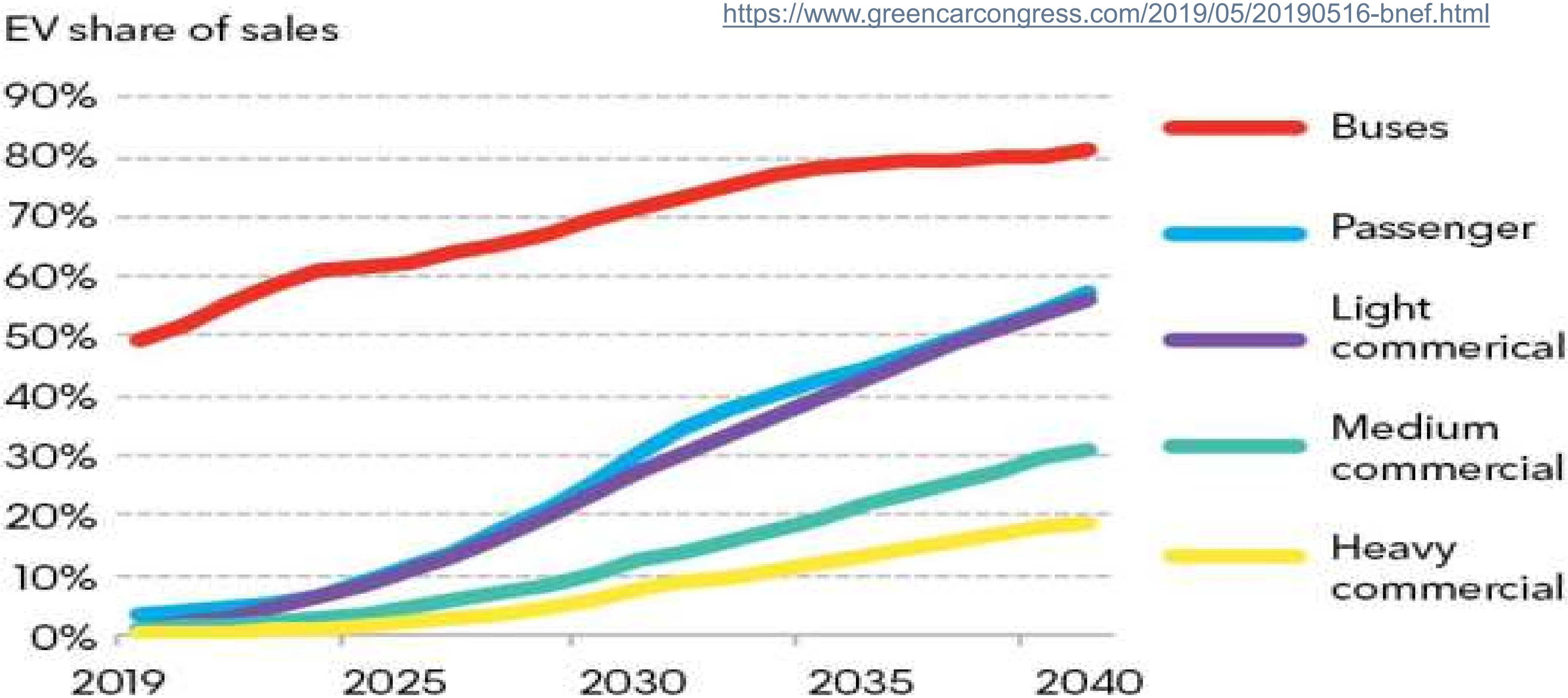




https://www.iea.org/reports/global-ev-outlook-2019
Dark shade: BEVs
Light shade: PHEVs
Market share of new electric cars
1 250
1 000
750
500
250
0
5%
4%
3%
2%
1%
0%
2013
China
2018
Europe
United States
Other
Electric car market share
New electric car sales (thousands)
80
70
60
50
40
30
20
10
50%
45%
10%
5%
46%
Norway
Germany
United Kingdom
Japan
France
Canada
Korea
Netherlands
Sweden

EV share of annual vehicle sales by segment

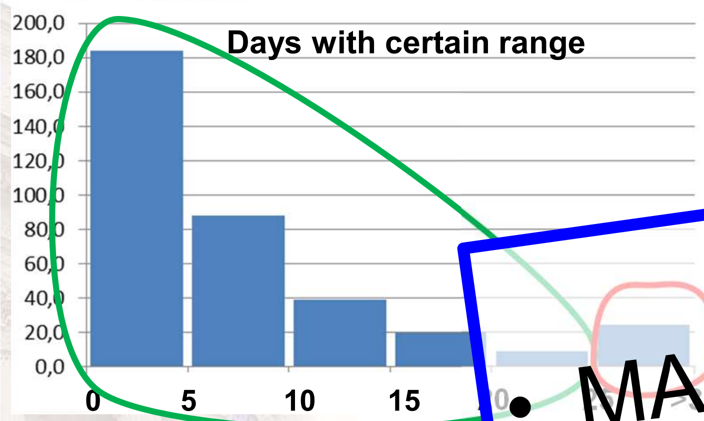
https://www.greencarcongress.com/2019/05/20190516-bnef.html

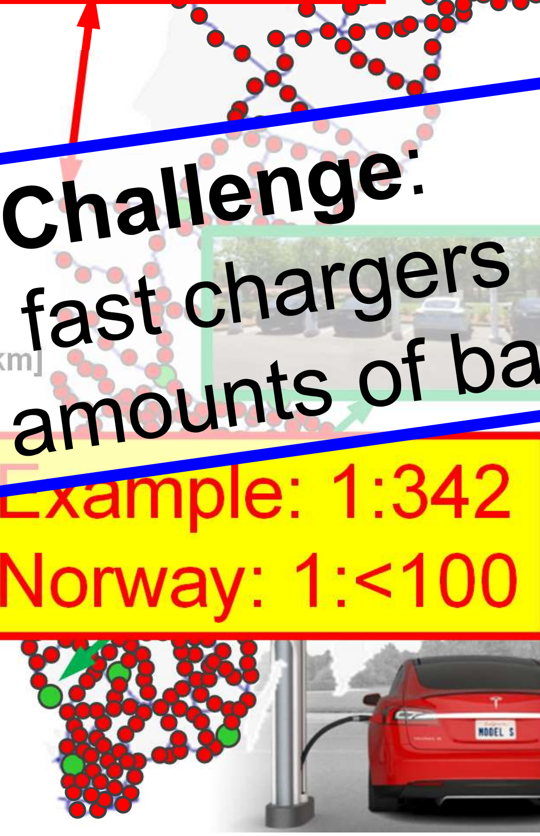


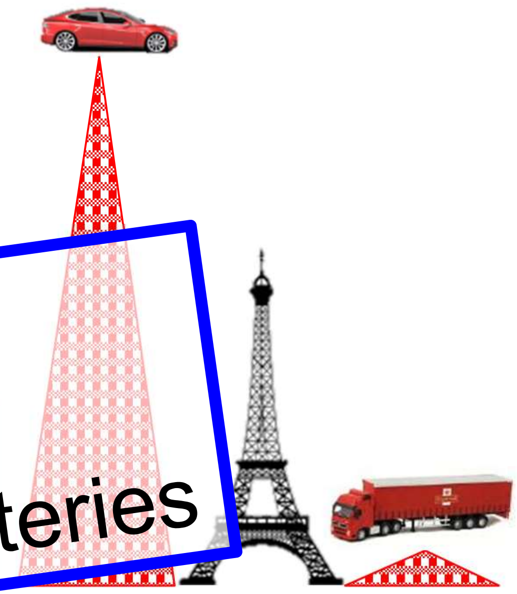
Source: BloombergNEF. Note: Passenger car and bus figures are global. Commercial vehicle segment adoption figures in both charts cover the main markets of China, Europe and the U.S.

Possibilities

Static is not easy...







Challenge:

- MANY fast chargers
- Large amounts of batteries

Example: 1:342
Norway: 1:<100

Lithium ...

- There are >1 billion cars in the world,
- Assume 100 kWh/vehicle
- Assume 200 g Lithium/kWh [1)]

  = 20 million tonnes of pure Lithium needed
- Resources? 14 million Tonnes [2)]

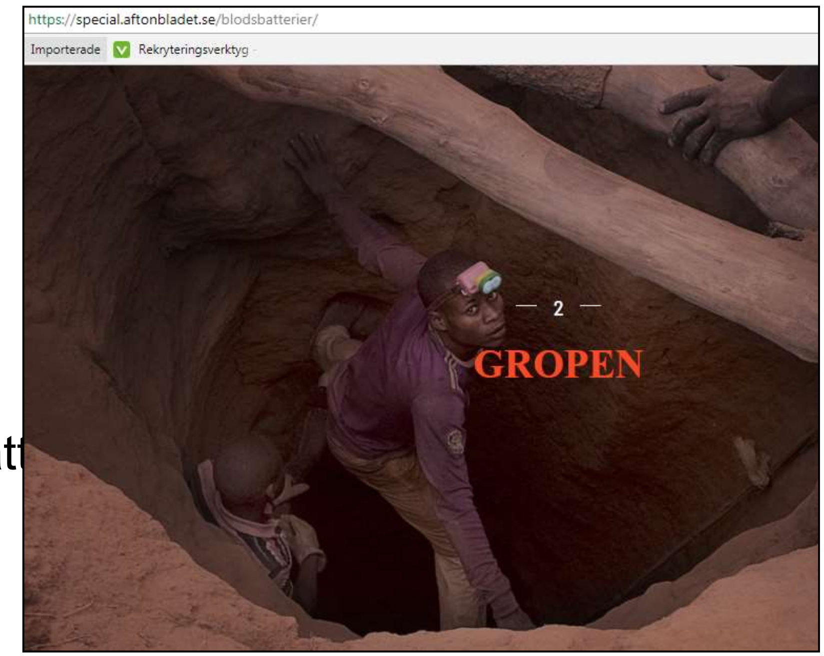
- Maybe / Maybe not?

- A method to reduce the need for batteries is at

Cobolt...

- There are >1 billion cars in the world,
- Assume 100 kWh/vehicle
- Assume 300 g Cobolt/kWh

  = 30 million tonnes of pure Cobolt needed
- Cobolt is in supply deficit ...
- Maybe / Maybe not?
- A method to reduce the need for batteries is att

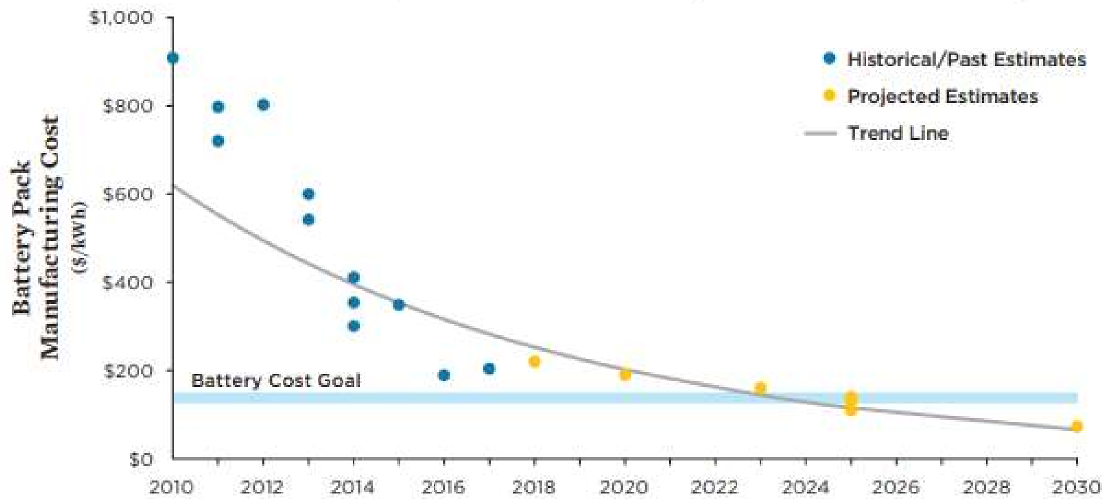


Battery Cost development

- The Cost of EV Traction Batteries is falling fast

EV Battery Pack Manufacturing Costs Predicted to Fall over Time

Manufacturing Costs Are—and Are Expected to Continue—Falling



If battery costs continue to decline as EV production increases, within several years they will reach the $125–$150 target that makes EVs competitive with conventional gasoline vehicles.

Note: Battery cost estimates include both academic analysis and statements from automakers. Multiple data points in a given year represent estimates from multiple analyses. Trend line represents exponential best fit of battery cost data.

SOURCES: ARB 2017; SOULOPOULOS 2017; VOELCKER 2017; SLOWIK, PAVLENKO, AND LUTSEY 2016; VOELCKER 2016; NYKVIST AND NILSSON 2015.

https://www.ucsusa.org/sites/default/files/attach/2017/09/cv-factsheets-ev-incentives.pdf

Battery 2’nd Life

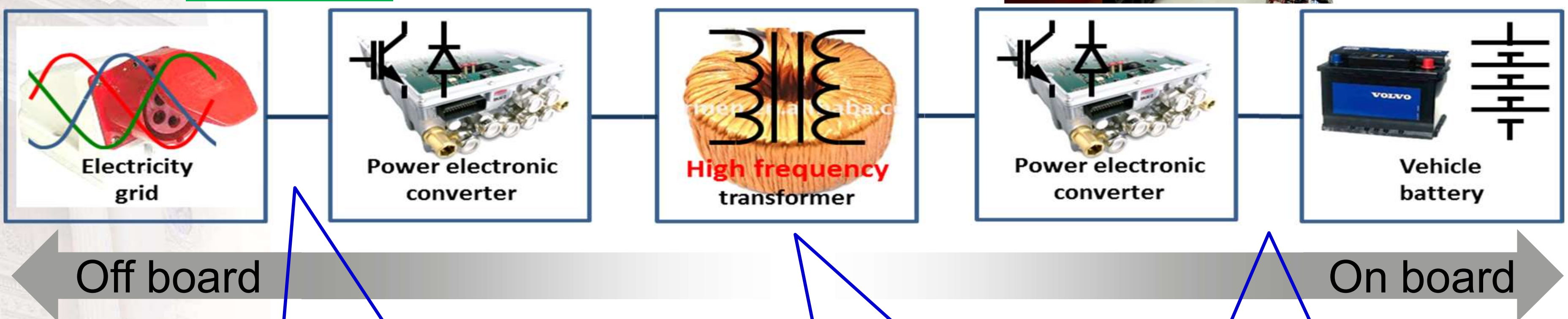
- EV’s use the battery until 85-90 % capacity is left
- After leaving the vehicle, another 5...10 years of life remains.
- Grid Energy storage is an important application

Daimler, 10’s of MW and MWh

Tesla, 560 MW and129 MWh

Static Charging

On board / Off board = AC / DC



- ”AC Charging”
- **Automation missing**
- **High power plug missing?**
- 10...100 MW/m^2

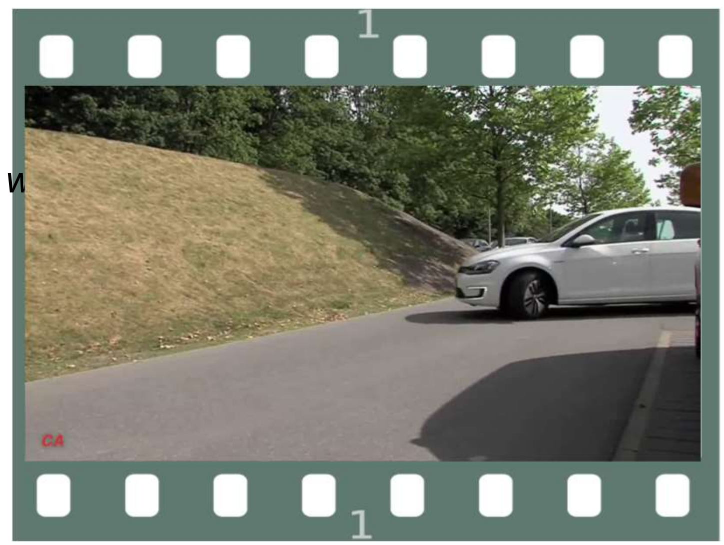
- **”Wireless Charging”**
- 10...100 kW/m^2

- **” DC Charging”**
- **Automation missing**
- 10...100 MW/m^2

Who needs an Automatic Charging Connection ... ?

- **Commercial Vehicles**
  - *May be Opportunity Charged up to 10 ... 20 times a day*
  - *The power level is high!*
  - *Automatic connection* ***absolutely necessary !!!***

- **Autonomous private (?) vehicles**
  - *Maybe a Spotify/Netflix/Uber kind of vehicle*
  - *Must be able to autonomously arrange washing, charging, w*
  - Usually connected 1...3 times per day
  - *Automatic connection* ***absolutely necessary !!!***

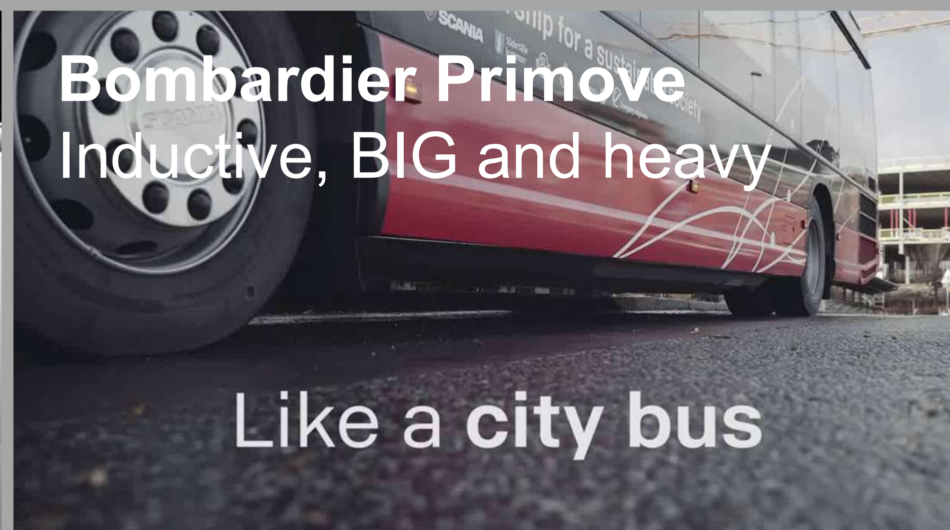


OPPcharge
Panto on infra = Low Bus cost

ABB TOSA
Panto on BUS, Drives bus cost

BYD
Manual, Low Cost Infra

Bombardier Primove
Inductive, BIG and heavy



Even the Car industry is trying ...

And also Off Road ....

The gardening industry is leading ...

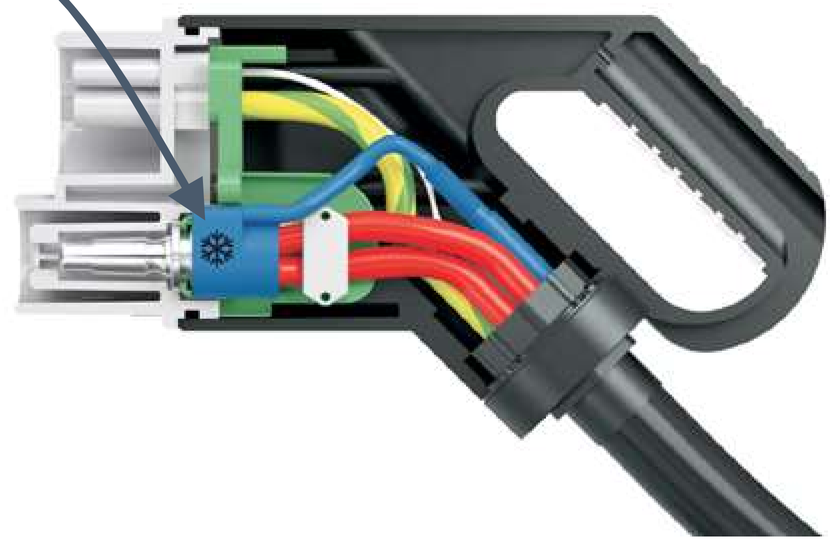
But we are still pushing the limits ...

- Same CCS-plug, now called ”CCSplus”, boosted with water cooling.

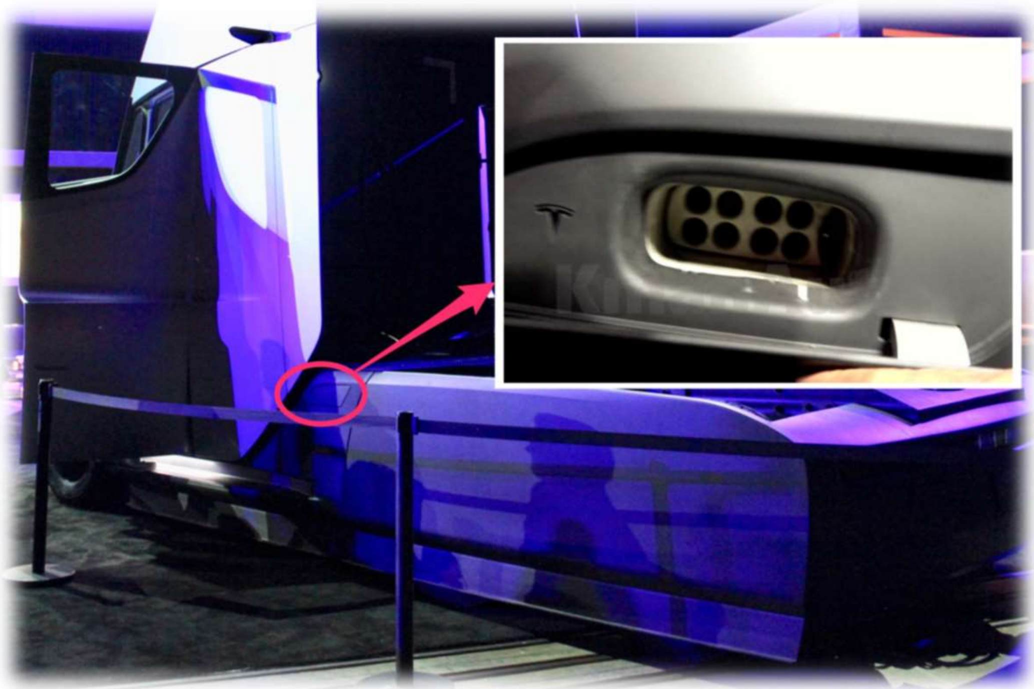
- Current limits pushed towards 350 Ampére and beyond.

  = 260 ... 500 kW, depending

- Still no automation!



Tesla Semi Analysis ...



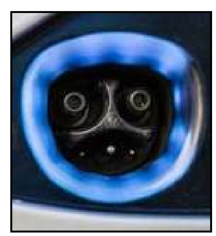
Technical facts

Given Facts

- GVW = 80000 lbs = 36 287 kg
- Drag Coefficient = Cd = 0.36
- Drivetrain: 4 PM motors from Model 3
- Acceleration 0-60 mph = 0-97 km/h
  - Tractor only: 5 seconds
  - Full load (80000 lbs): 20 seconds
- Hill climbing: 5 % slope @ 65 mph = 105 km/h
- Range: 300/500 miles = 483/805 km
- Charging time: 400 miles = 644 km in 30 minutes

Calculated Facts

- Energy consumption = about 1 kWh/km
- Tractor weight = 9 tons
- Traction motors = 4 x 137/192 kW (cont/peak)
- Battery Energy = 850 – 950 kWh (depends on DoD)
- Battery Weight = 4.2 – 4.7 tons (@ 0.2 kWh/kg)
- Charging power
  = almost 1.3 Megawatt for Fast Charging
  = 100 kW for Night Time Charging
- MEGA Charging Connector: Seems to be 4xSUPER Charging Connector


X 4 =


The Perfect Charging Connection ...

Is **automatic**

Works with both
small and **BIG** vehicles

Can be used both when
standing still and when moving

Can be used both
in the city and on the highway

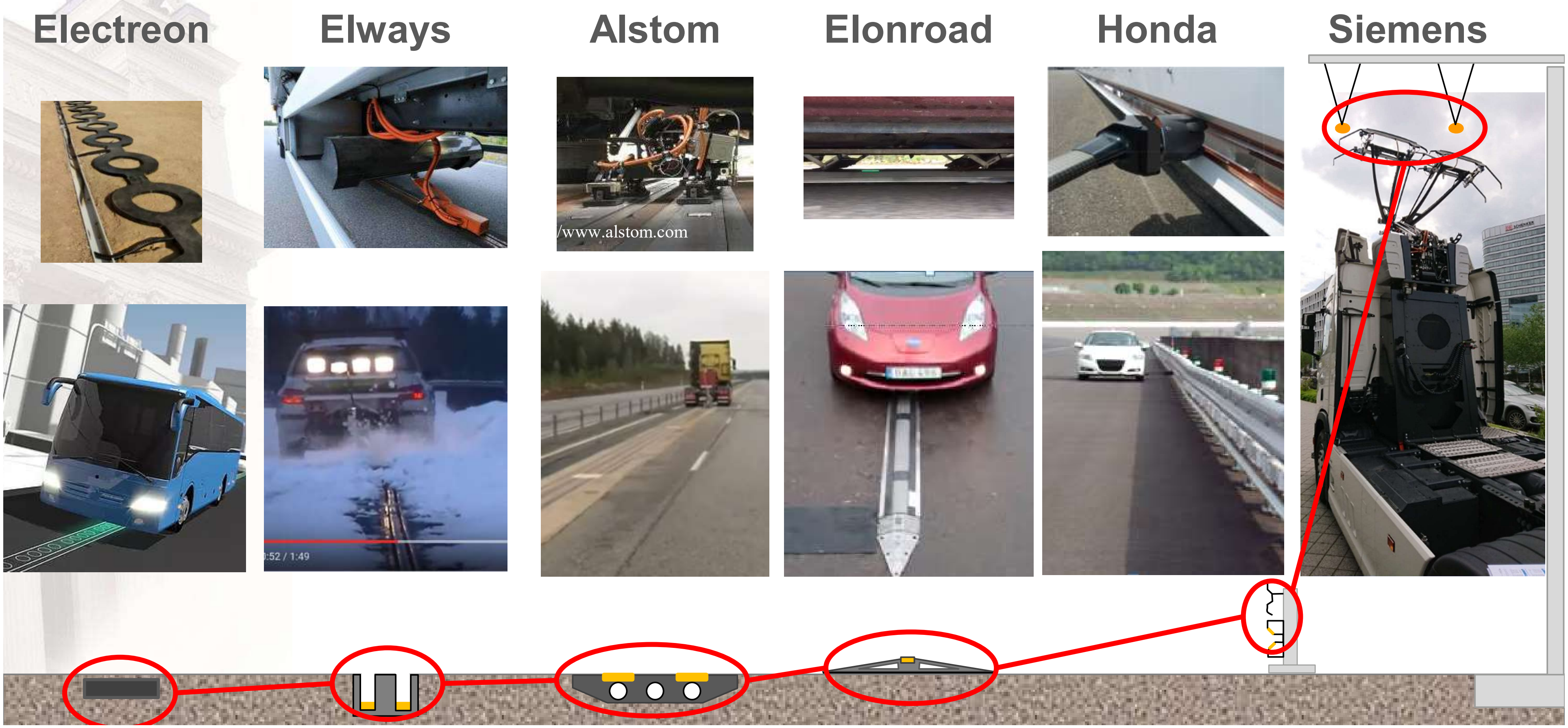
Dynamic Charging

Dynamic charging ?

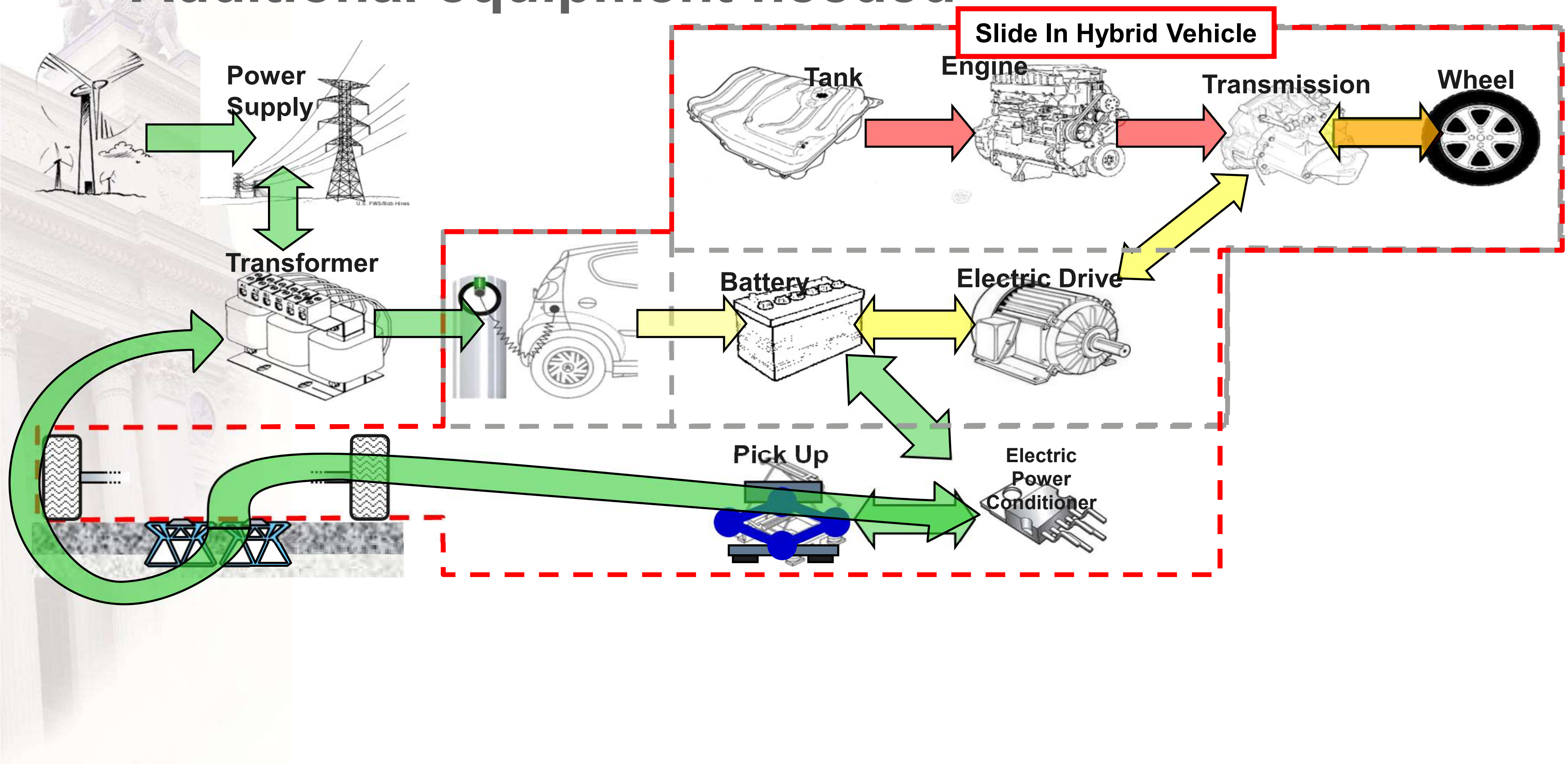
- Charging when the vehicle is moving
- Also called ”Electric Road Systems” (ERS)
- Traditionally used in Trams, Trains and Trolley buses
- Different technologies, different connections
- Many new suppliers developing
- Several demonstrations on public road

	Above	Side	Under
Conductive			
Inductive	X	X	
Capacitive	X	X	

Some ERS versions interesting for Sweden

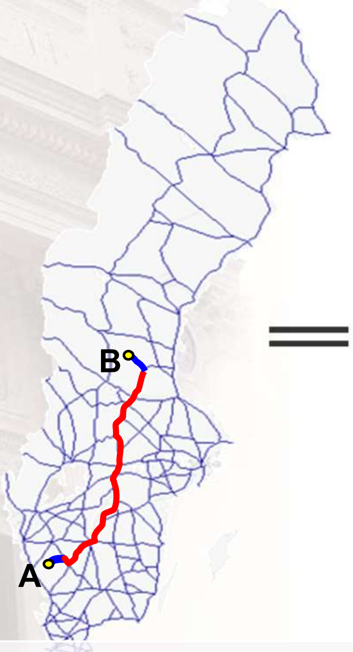


Additional equipment needed



Activated in sections ...

- Activated ”step by step”
- Needs little precision
- Overtaking on battery
- Reduced battery range



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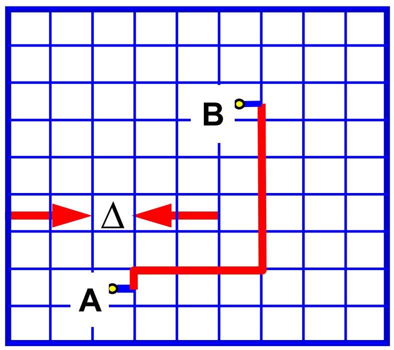
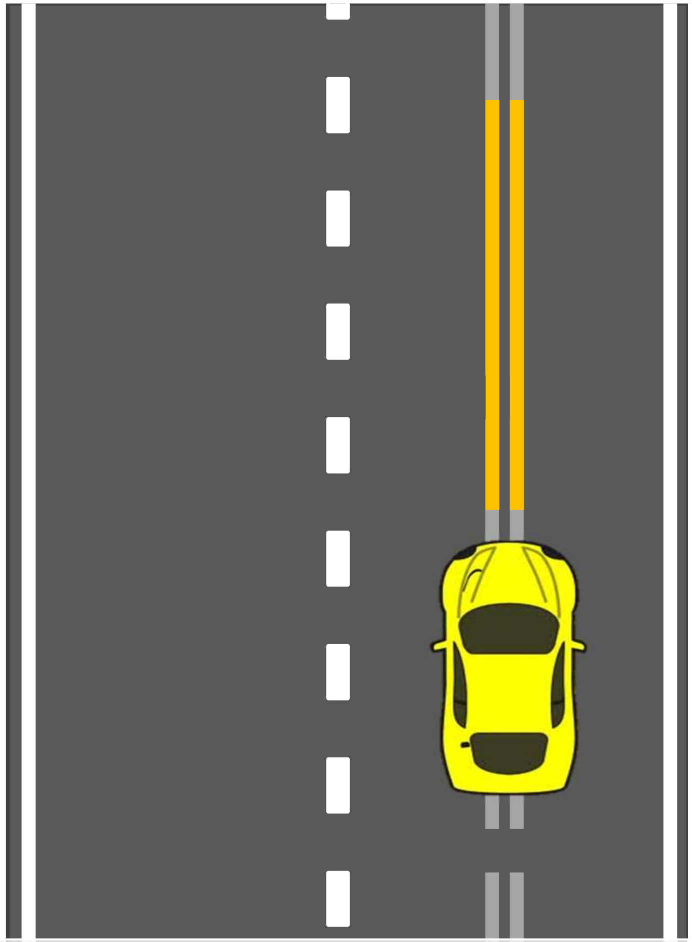


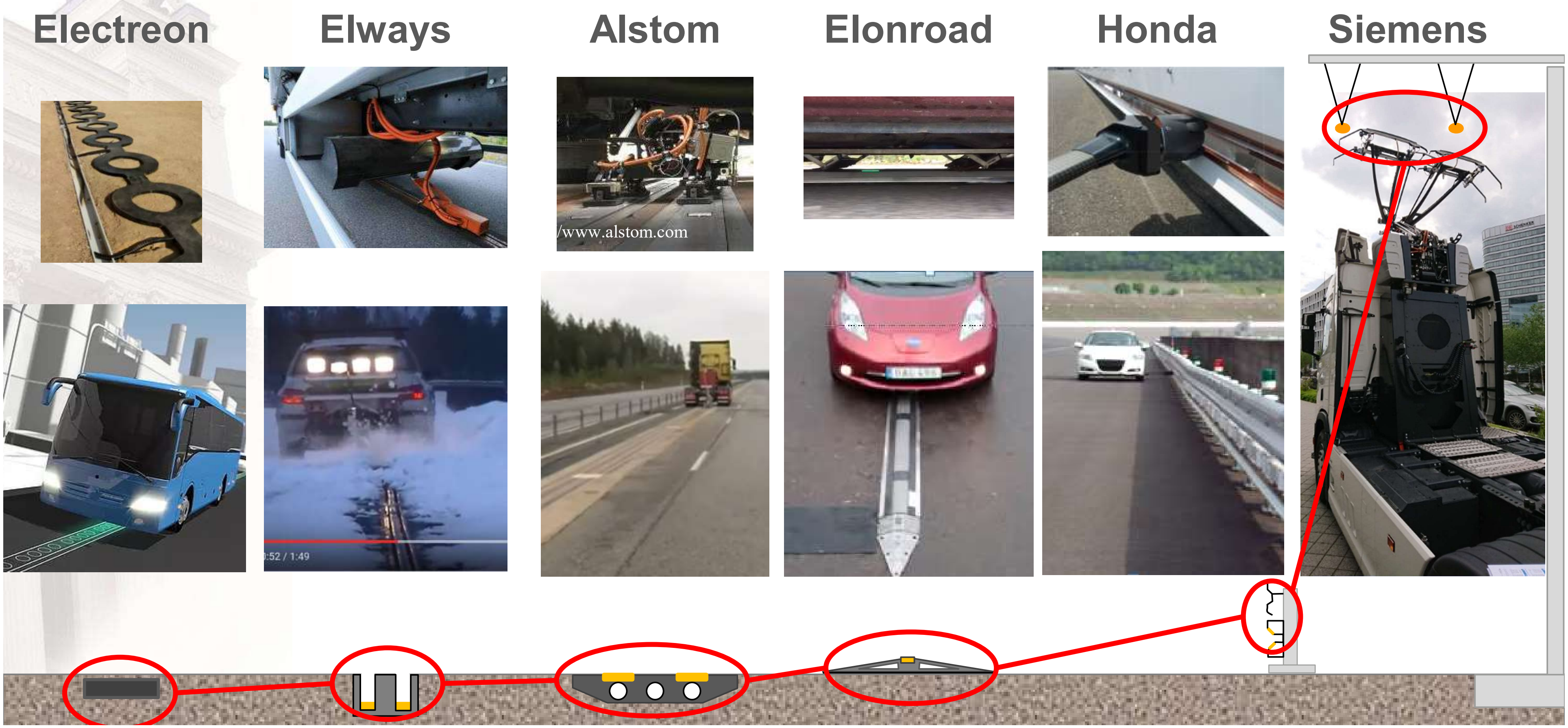
- Sweden: $\Delta = 50$ km



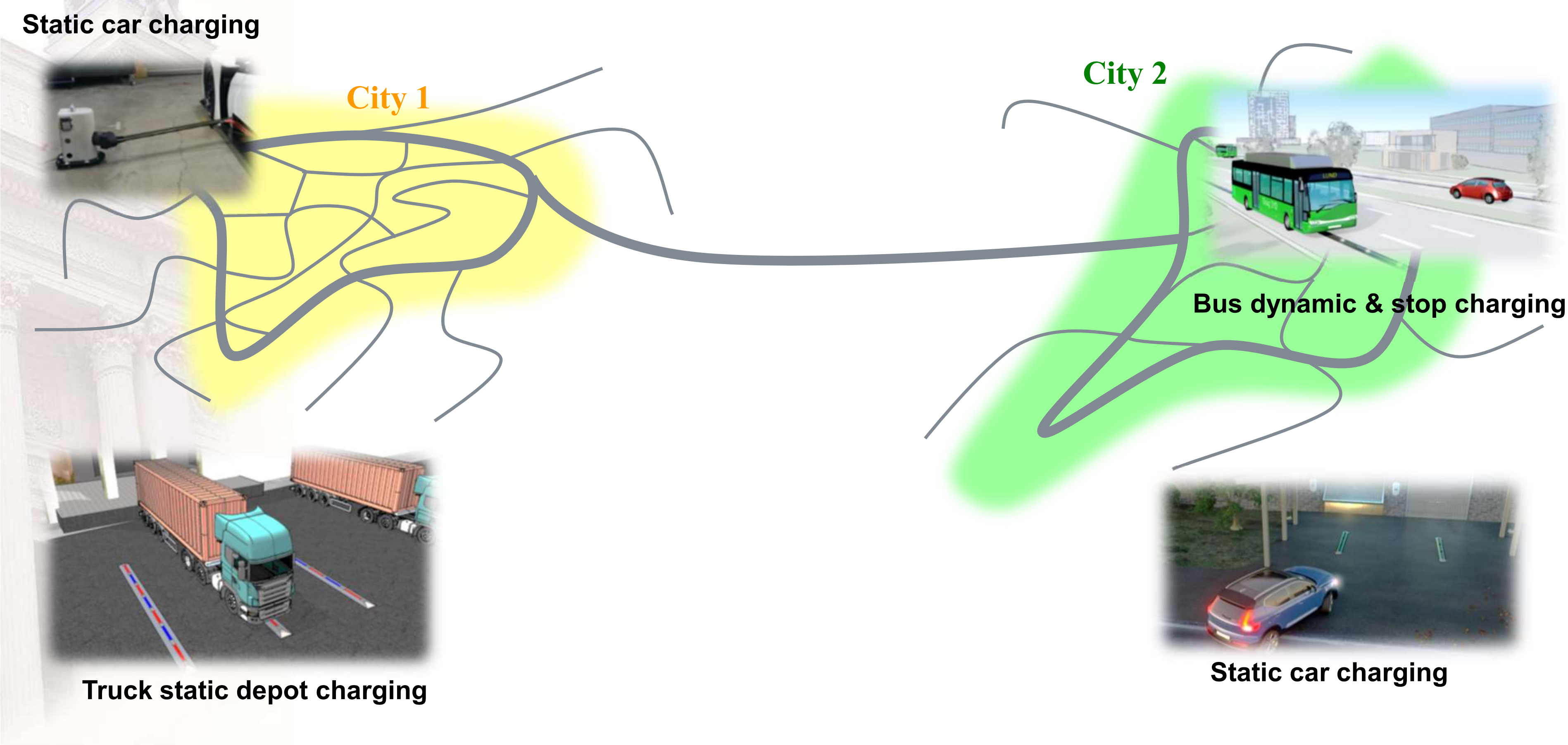
Remember: - ERS reduce the need for batteries to 1/5th

” 100 km instead of 500 km ”

Some ERS versions interesting for Sweden

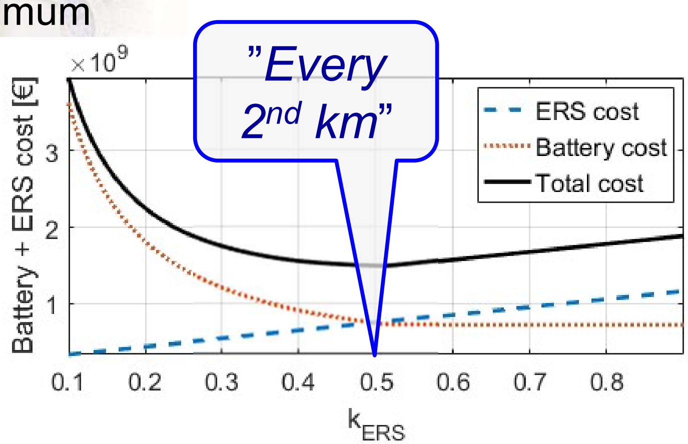


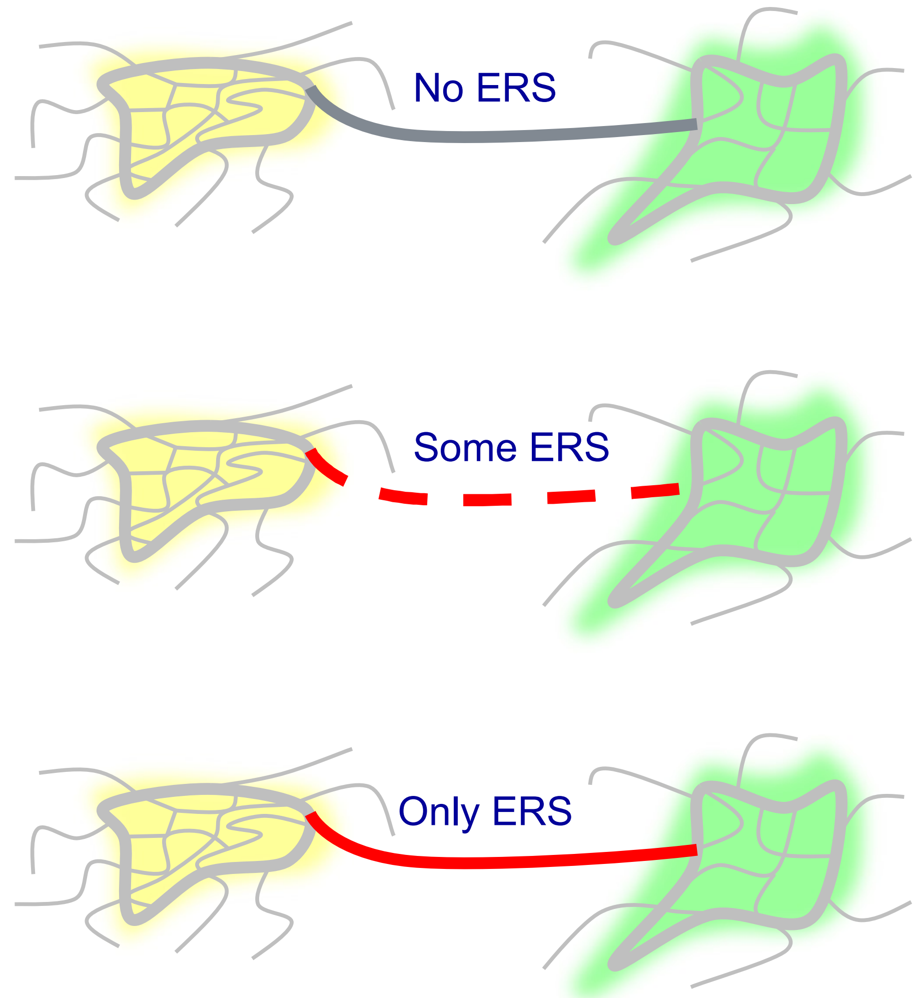
ERS inter city and static/night in city



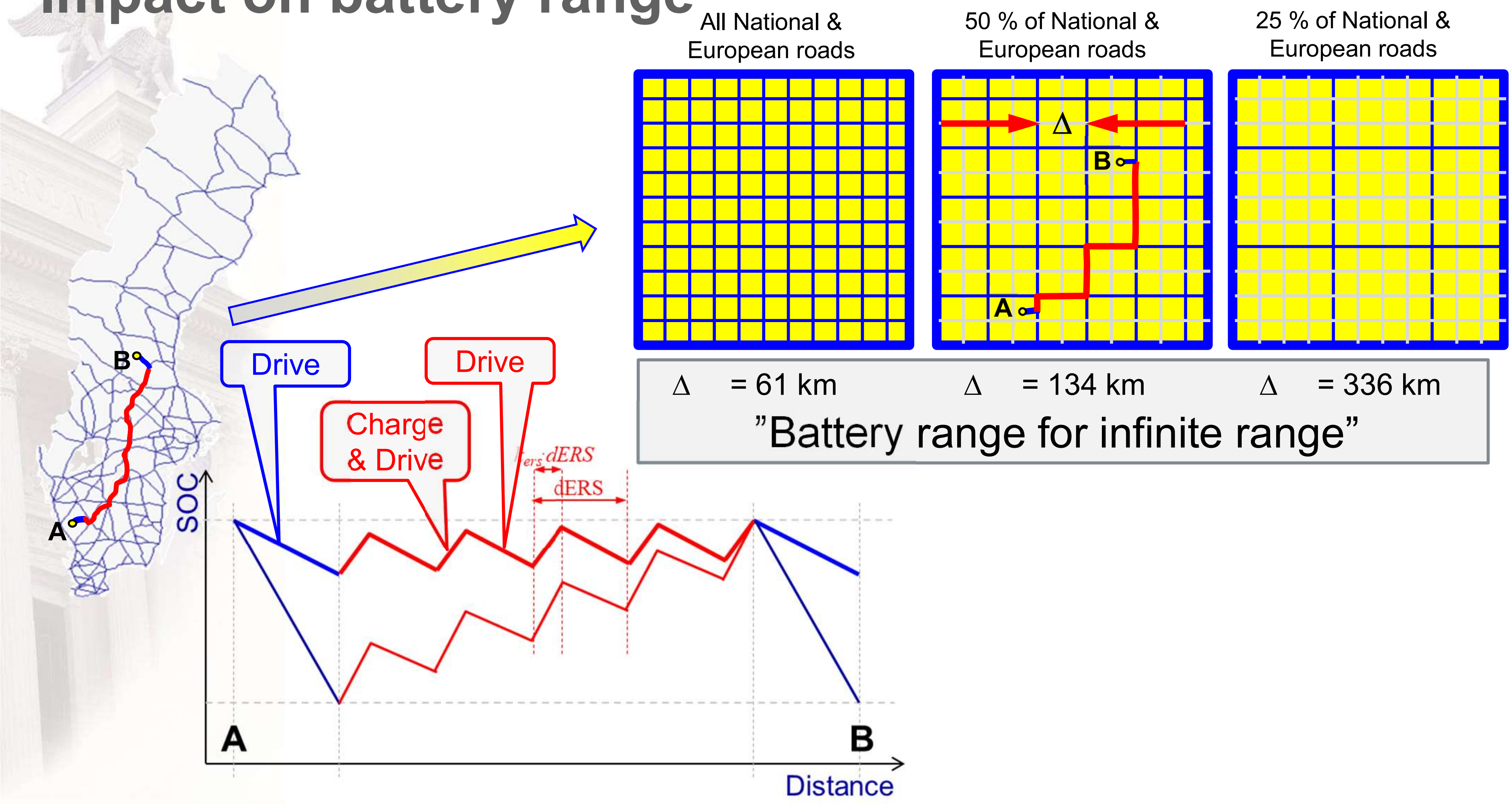
Not ERS all the way

- No ERS
  = *High battery costs, No ERS costs*
- Some ERS
  = *Lower battery costs and ERS costs*
- Only ERS
  = *Low battery cost and high ERS cost*
- ERS cost + Battery cost has an optimum

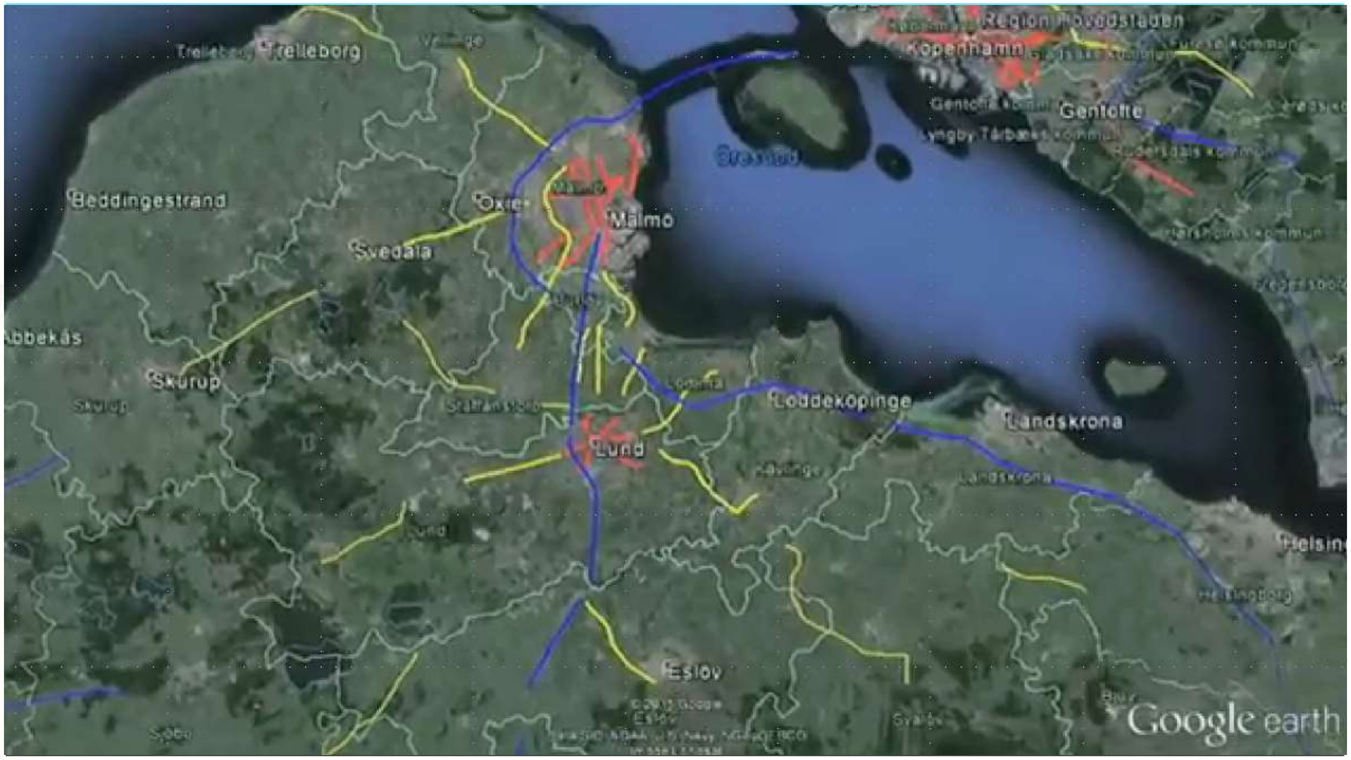




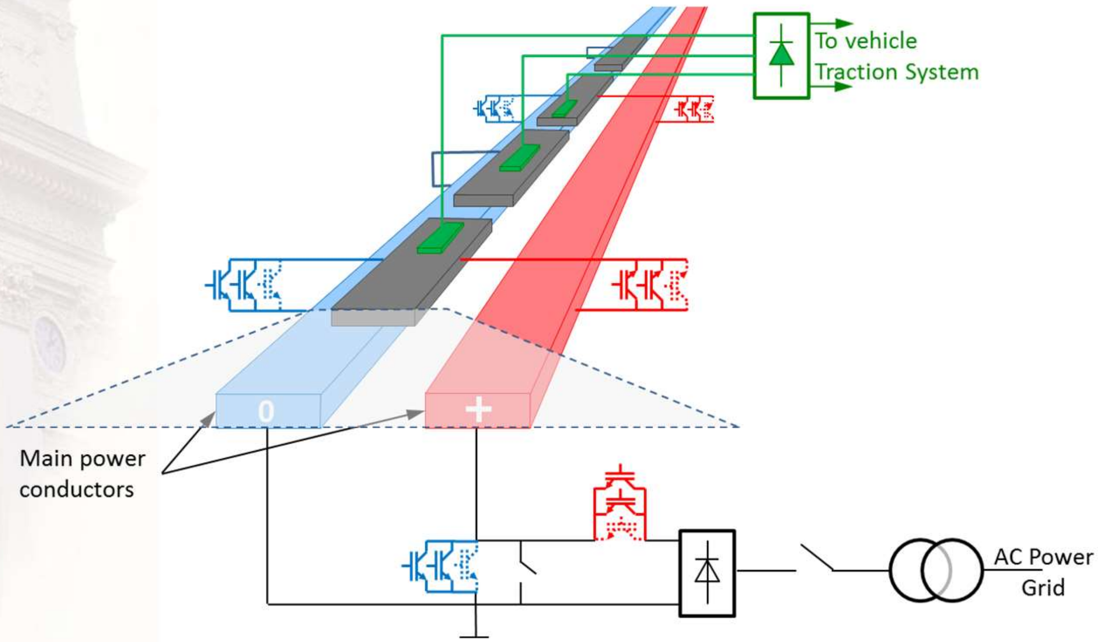
Impact on battery range



Vision of one technology supplier ...



A technology example...



ELONROAD

Sounds good, is there any problem?

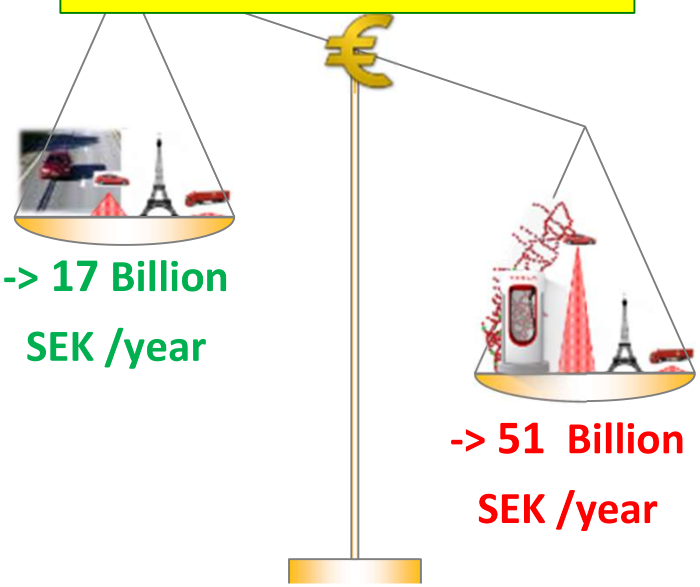
- During static charging the vehicle chassis is ALWAYS physically connected to protective earth.
- Conductive ERS supply **cannot guarantee** such connection!

Cost of Charging

Some cost analysis ...

- 5 million **cars** á **15 kWh** batteries á 1000 SEK/kWh @ 10 years lifetime
  -> 7 Billion SEK/year
- 50 000 **Heavy Duty Trucks** á **100 kWh** batteries á 1000 SEK/kWh @ 2 years lifetime
  -> 2 Billion SEK/year
- 15 600 km National and European road á 10 Million SEK/km @ 20 years lifetime
  -> 8 Billion SEK/year

- Bränsle i transportsektorn: c:a 90 TWh = 9e9 liter = 45 Milliarder SEK exkl skatter !
- Motsvarande El = 30 TWh = 30 Milliarder SEK exkl skatter !
- Skillnad = 15 milliarder SEK !



-> 17 Billion SEK /year

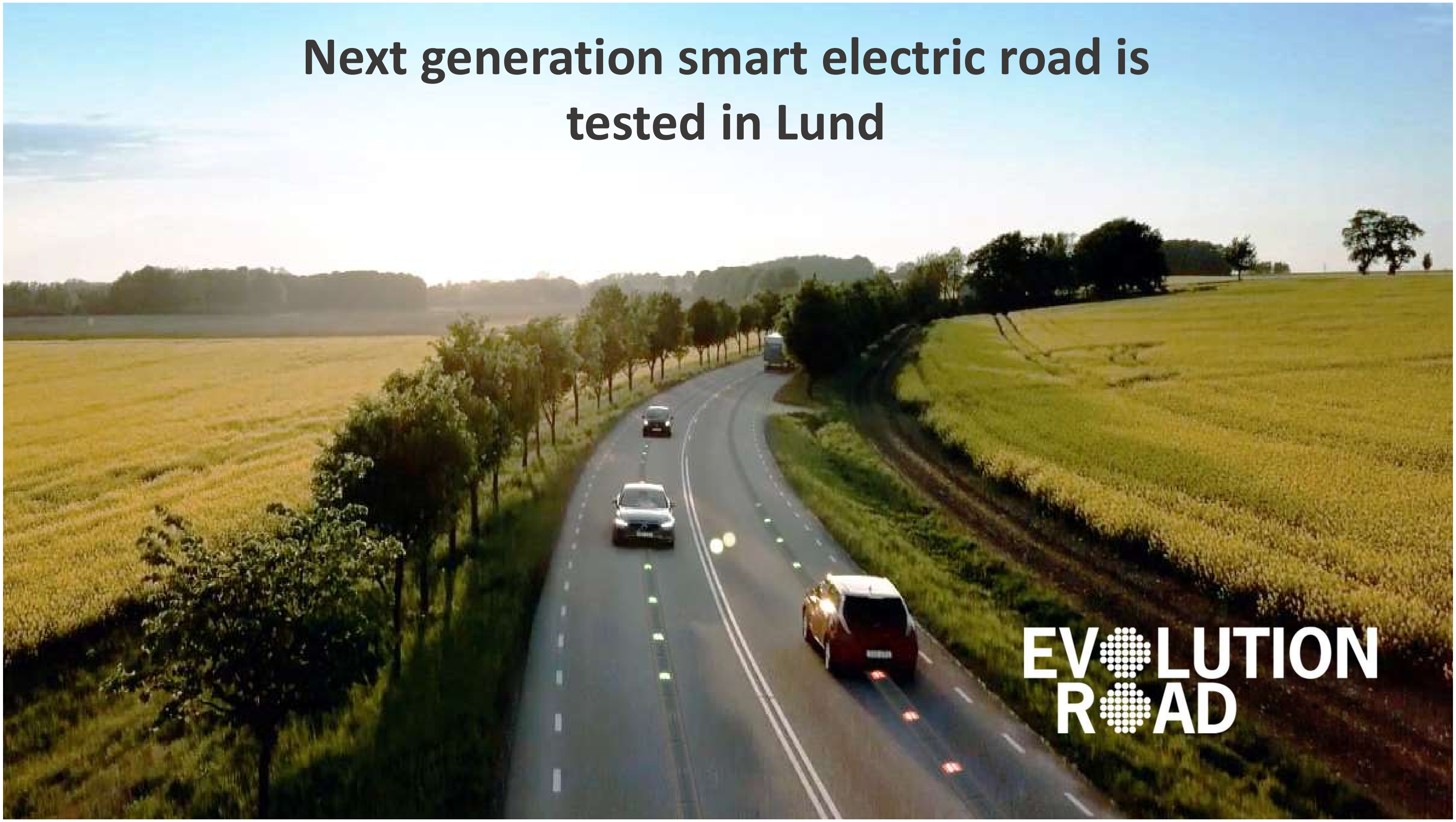
-> 51 Billion SEK /year

- 5 million **cars á 75 kWh** batteries á 1000 SEK/kWh @ 10 years lifetime
  -> 38 Billion SEK/year
- 50 000 **Heavy Duty Trucks á 500 kWh** batteries á 1000 SEK/kWh @ 2 years lifetime
  -> 12 Billion SEK/year
- 50 000 ”**Super**Chargers” á 150 kW á 6000 SEK/kW @ 25 years lifetime
  -> 1 Billion SEK/year

500 ”**MEGA**Chargers” á 1000 kW á 6000 SEK/kW @ 25 years lifetime
-> 0,12 Billion SEK/year

ERS Demo in Lund

Next generation smart electric road is tested in Lund



INNOVATION SKÅNE

ELONROAD

kraftringen

LUNDS KOMMUN

RAMBØLL

LUND UNIVERSITY

LTH FACULTY OF ENGINEERING

vti

SOLARIS
A CAF GROUP COMPANY

Skånetrafiken

TRAFIKVERKET

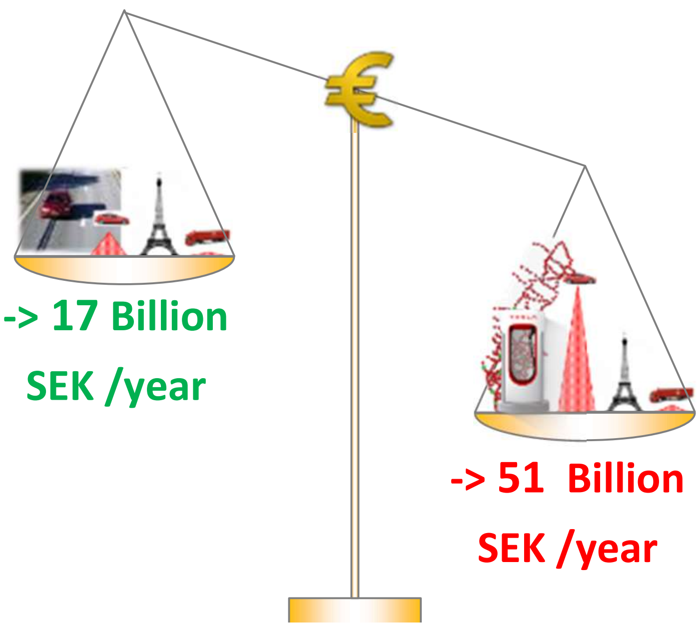
Test location: Getingevägen in Lund

Some technology details – the “pick up”

Från laddskena i vägen (1)
överförs ström till fordonet
via en avtagare (2)
som fälls ut under fordonet.
Strömmen laddar fordonets
batterier (3).

Some cost analysis ...

- 5 million **cars** á **15 kWh** batteries á 1000 SEK/kWh @ 10 years lifetime
  -> 7 Billion SEK/year
- 50 000 **Heavy Duty Trucks** á **100 kWh** batteries á 1000 SEK/kWh @ 2 years lifetime
  -> 2 Billion SEK/year
- 15 600 km National and European road á 10 Million SEK/km @ 20 years lifetime
  -> 8 Billion SEK/year



-> 17 Billion SEK /year

-> 51 Billion SEK /year

- 5 million **cars á 75 kWh** batteries á 1000 SEK/kWh @ 10 years lifetime
  -> 38 Billion SEK/year
- 50 000 **Heavy Duty Trucks á 500 kWh** batteries á 1000 SEK/kWh @ 2 years lifetime
  -> 12 Billion SEK/year
- 50 000 "**Super**Chargers" á 150 kW á 6000 SEK/kW @ 25 years lifetime
  -> 1 Billion SEK/year

500 "**MEGA**Chargers" á 1000 kW á 6000 SEK/kW @ 25 years lifetime
-> 0,12 Billion SEK/year

Challenges for the future ...

- **Charging solutions**
  - Static / Dynamic
  - Manual / Automatic
  - Availability for all
- **EV battery handling**
  - In vehicle / in the electric power grid
  - Recycling after 2’nd life
- **EV development**
  - New vehicle concepts (w/o drives and w/o emissions)
  - Approaching incremental on the drivetrains