EV's and future Charging Solutions

Professor Mats Alaküla
*Industrial Electrical Engineering at **Lund University***
*Senior Technology Advisor, **AB Volvo***
*Scientific Leader, **Swedish Electro Mobility Research Centre***

Renewable

Dirty

Energy Source

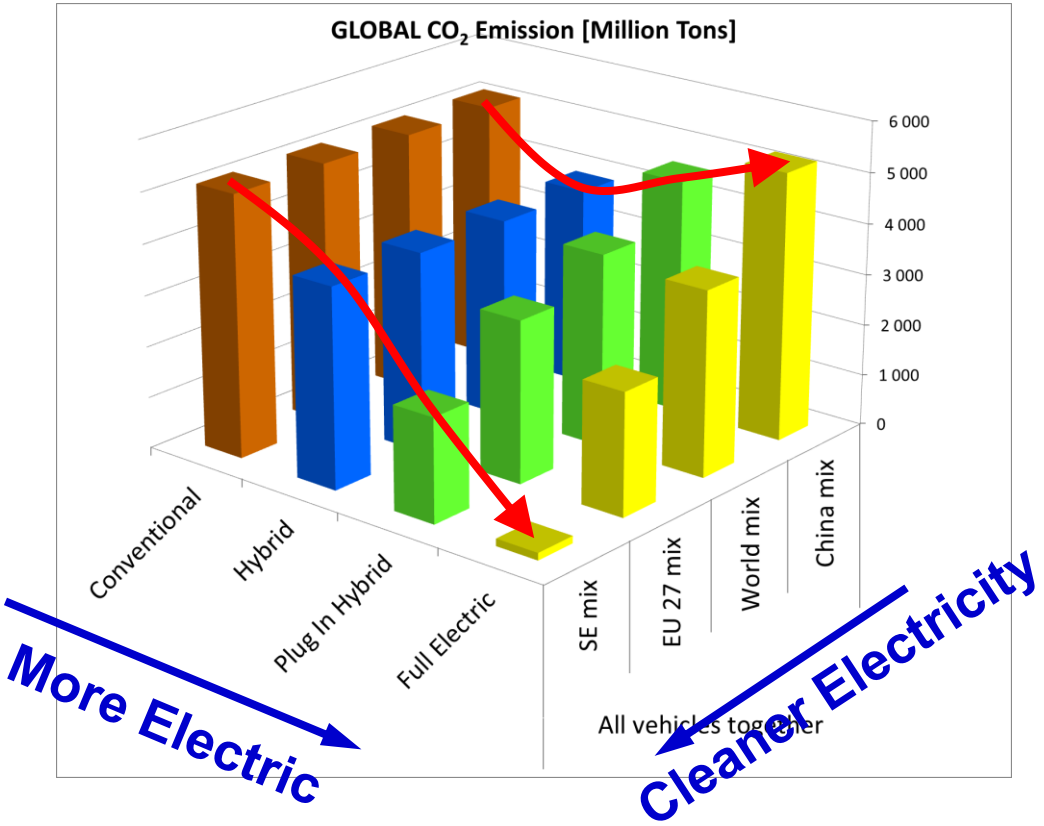
Energy Transfer

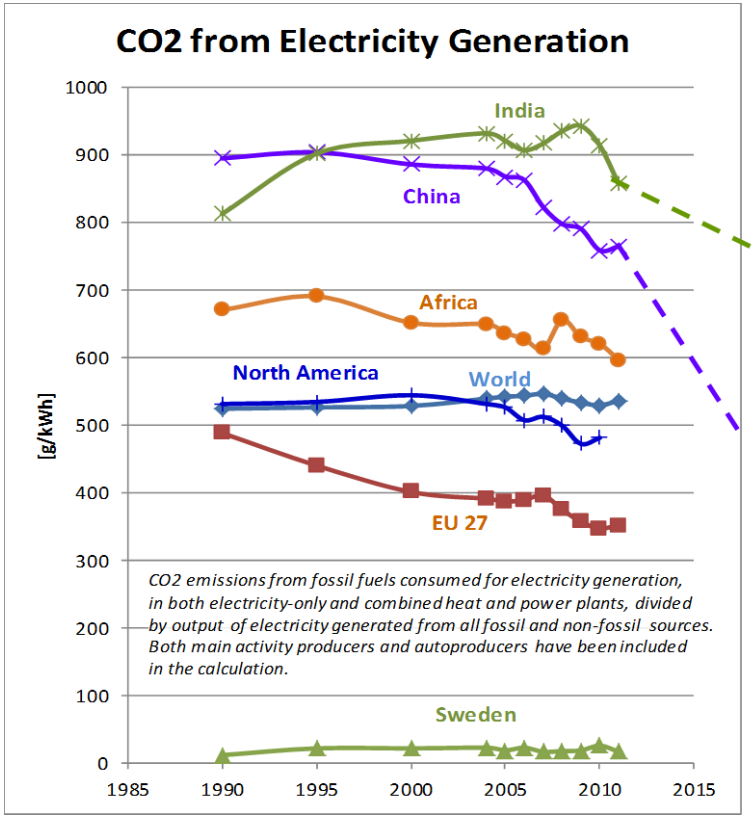
Energy Use

Inefficient

Conventional

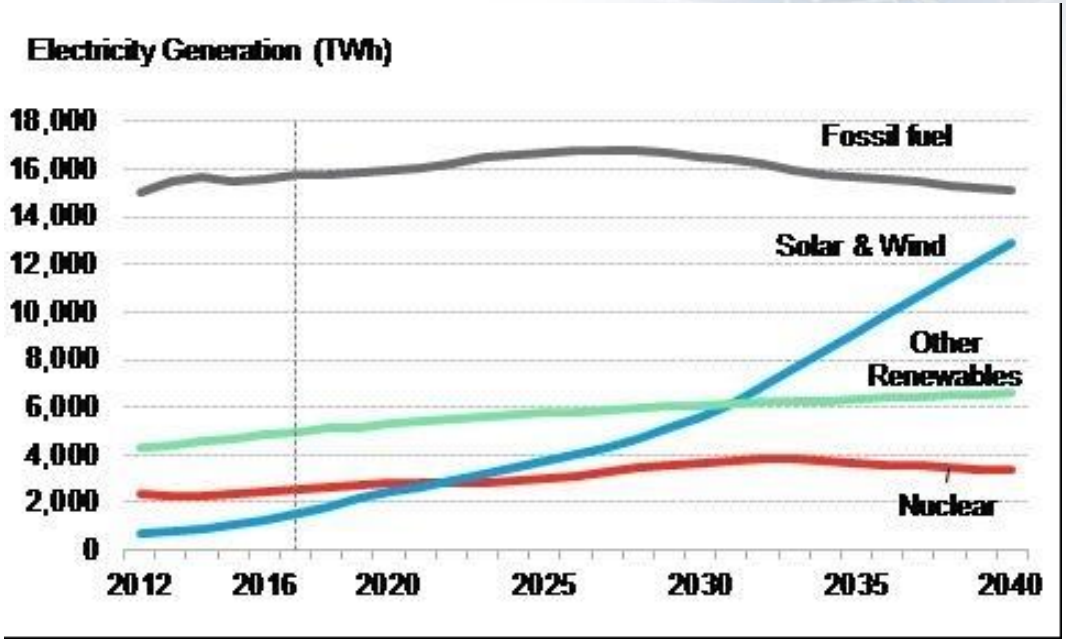
Electro mobility is important





Solar and Wind Growth

- New Energy Outlook 2017 (NEO), the latest long-term forecast from Bloomberg New Energy Finance.
- Solar + Wind = 34% of El.gen by 2040
- Solar cheaper than Coal in:
  - German, Australia, US and Italy (now)
  - China, India, Mexico, UK and Brazil (2021)



http://www.pveurope.eu/News/Markets-Money/Costs-of-solar-further-rapidly-falling-cheaper-than-coal

The last Century

The Charging Challenge is NOT new ...

Pushing the limits …

>600 kg

120 kW

600 kW

”Trolley”

And everybody is involved ...

By 2021, 30 BEVs with over 200 miles autonomy have been announced to be launched


Chevrolet Bolt (240m)


2018 Nissan Leaf (200+m)


Jaguar crossover (300m)


Volvo SPA (300m)

Note: *Includes announced and speculated launches*


Aston Martin RapidE (200+m)


Hyundai / KIA SUV (200-300m)


PSA EMP2 (280m)


Ford Model E (200m)


Audi R8 gen 2 (280m)


Pajun EV (250m)


Audi Q6 (300+m)


VW eGolf (300m)


Boxster (300m)


VW Phaeton (300+m)


Audi Q8 (370+m)


Porsche Mission E (310 m)

Mercedes-Benz

Mercedes will have a dedicated architecture for electric vehicles known as Electric Vehicle Architecture (EVA) with the aim of 300+ miles on this platform


EQ


Larger than GLS - Coupe


Saloon – S Class


Between C & E Class


B class with 250M range

TESLA


Model S (220- 302m)


Model X (220- 289m)


Model 3 (215+ m)


Model Y (250+ m)

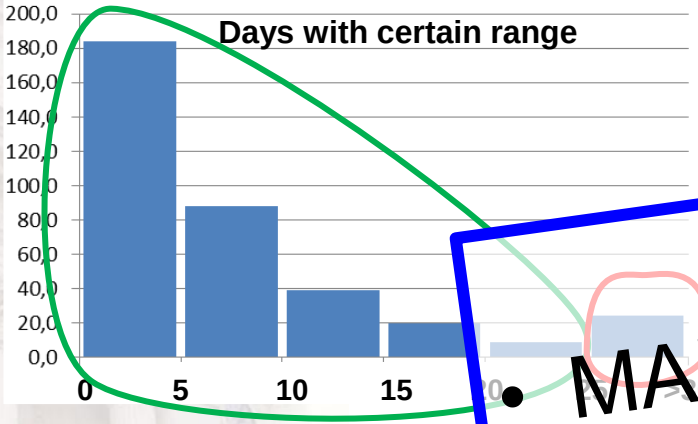

Roadster 2.0 (target 400 m)

Post 2020, new set of super car electrics is set to compete with Tesla such as NextEV, Faraday Future, etc with 200+m range

Existing | 2016 | 2017 | 2018 | 2019 | 2020 | 2021

Possibilities

Static is not easy...



Challenge:

- MANY fast chargers
- Large amounts of batteries

Example: 1:342
Norway: 1:<100

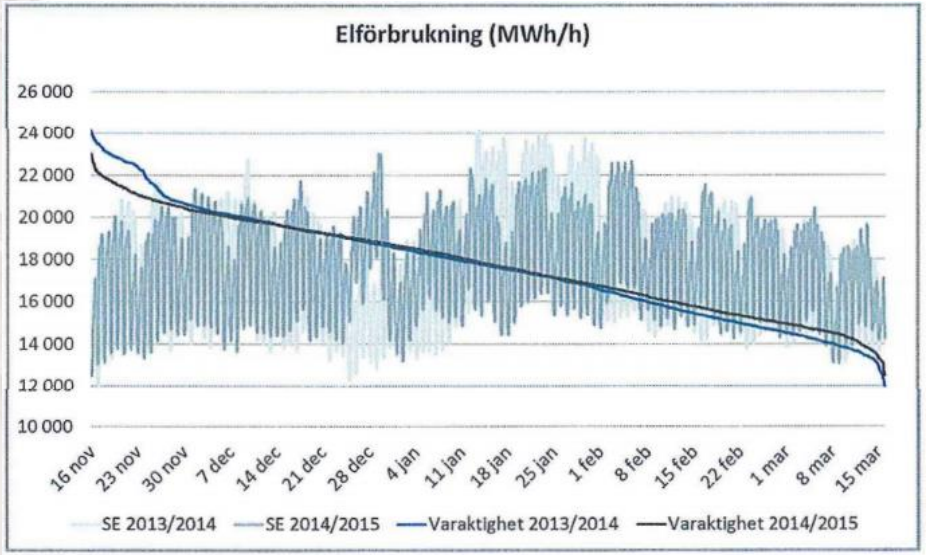
Do we have Power & Energy?

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!

Electric Energy Production in Sweden



Figur 1. Timmedelvärde för elförbrukningen i Sverige vintrarna 2013/2014 och 2014/2015[1]. Källa: Svenska kraftnäts

	Vattenkraft	Vindkraft	Kärnkraft	Övr. värmekraft + solkraft	Totalt
Effekt (MW)	16 155 (+5)	5 425 (+955)	9 531	8 452 (+330)	39 563 (+1 290)
Produktion (TWh)	64,2	11,5	62,2	13,3	151,2

Tabell 1. Installerad effekt (MW) 2014-12-31 per produktionsslag i Sverige, förändring sedan 2013-12-31 samt preliminär produktion för 2014. Källa: Svenska kraftnät, Svensk Energi och Svensk Vindenergi.

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 attractive!

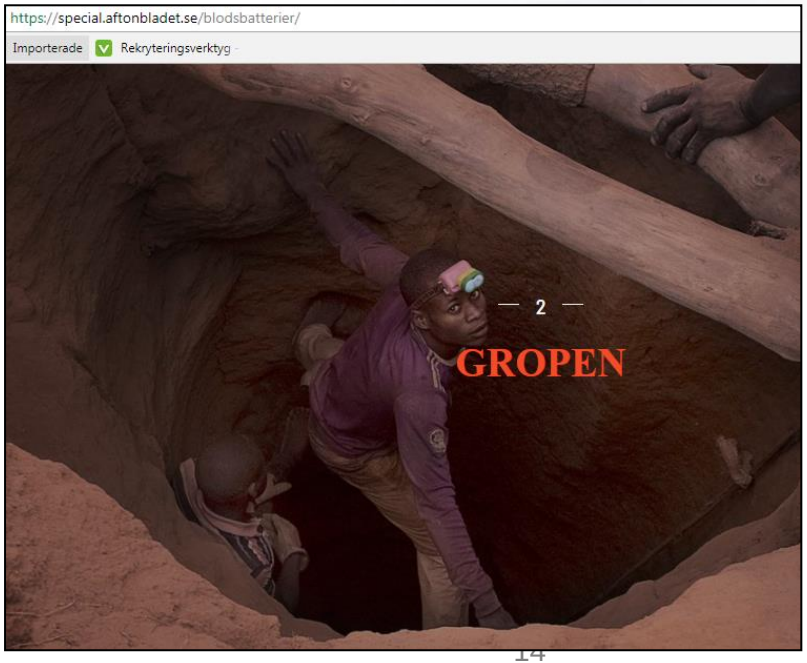
Cobolt...

- 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 ...

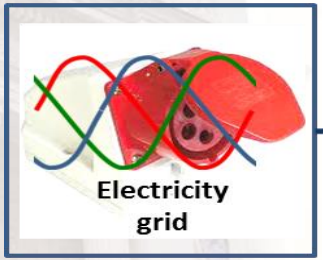
- Maybe / Maybe not?

- A method to reduce the need for batteries is attractive!



Static Charging

On board / Off board = AC / DC



Off board

On board

- **”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, workshop visit, ...*
  - Usually connected 1...3 times per day
  - *Automatic connection **absolutely necessary !!!***

OPPcharge

Panto on infra = Low Bus cost

OPPcharge

a common interface for opportunity charging

ABB TOSA

Panto on BUS, Drives bus cost

BYD

Manual, Low Cost Infra

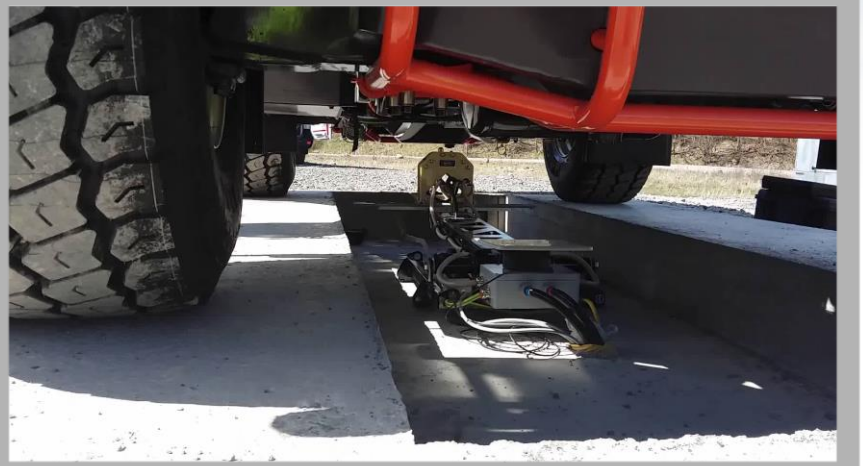
Bombardier Primove

Inductive, BIG and heavy

Like a **city bus**

Even the Car industry is trying ...

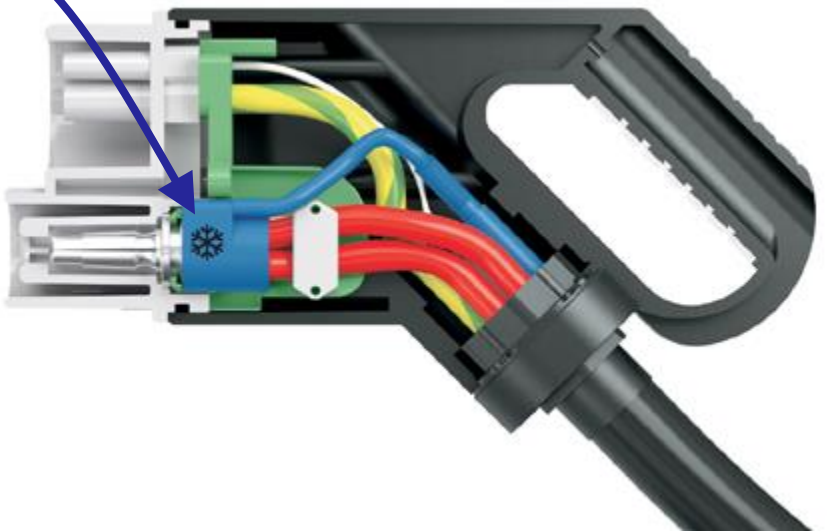
And also Off Road ....



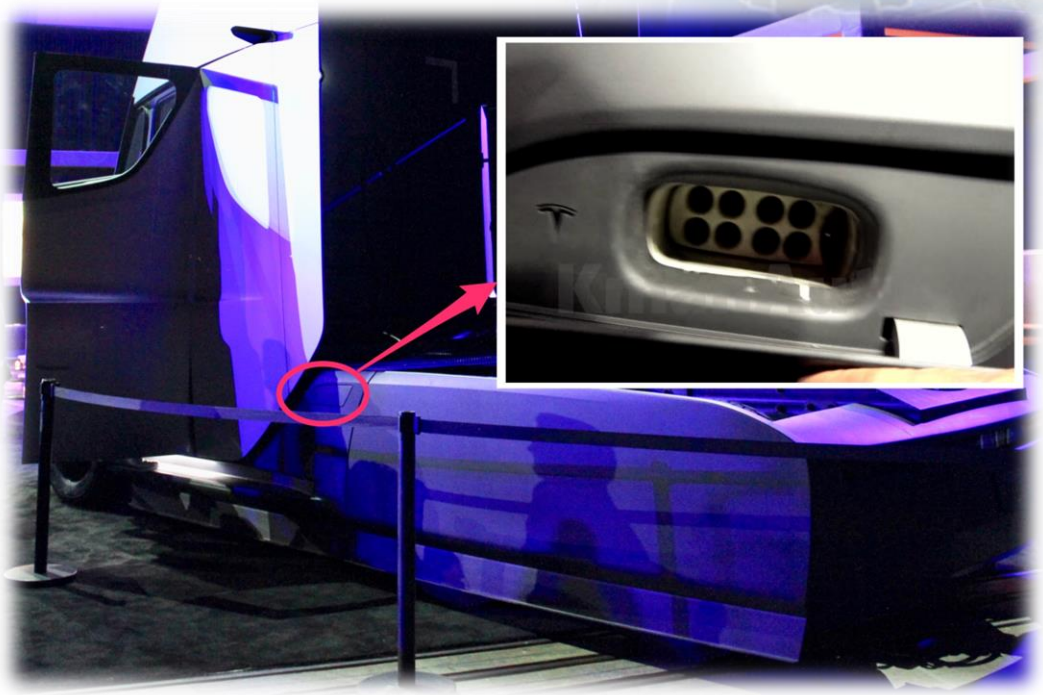
The gardening industry is leading ...

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

What is Dynamic Charging ?

- Charging while the vehicle is moving
  - *Even at highway speed!*
- Inductive or Conductive
- Traditional solutions with Trams, Trolley Buses and Trains
- New Solutions emerging fast

Bombardier PRIMOVE

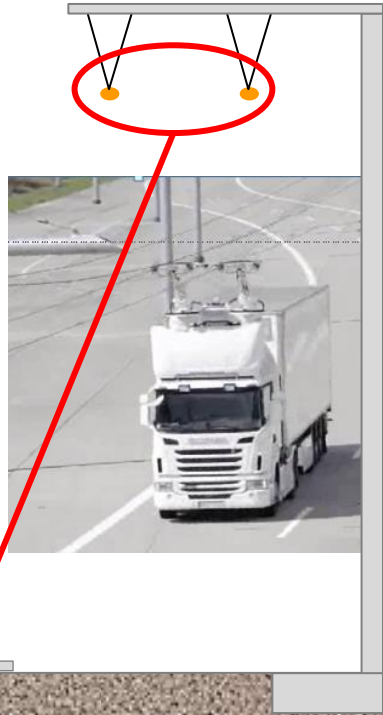
ALSTOM APS

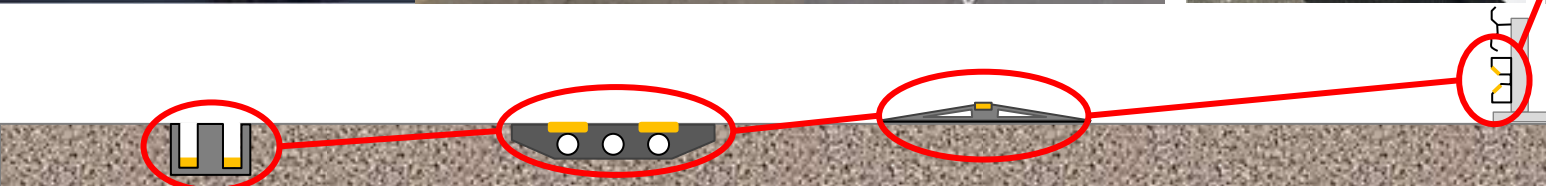
OLEV

Siemens *e*Highway

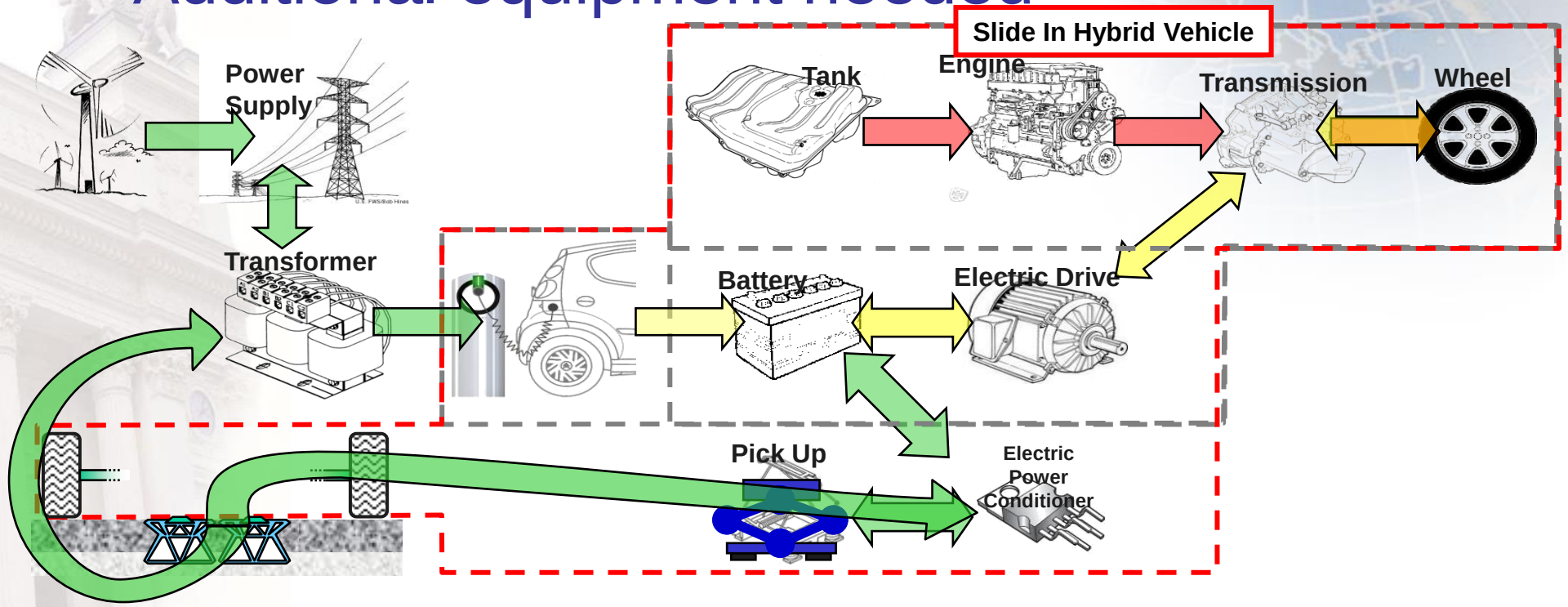
Conductive ERS concepts

Elways **Alstom** **Elonroad** **Honda** **Siemens**



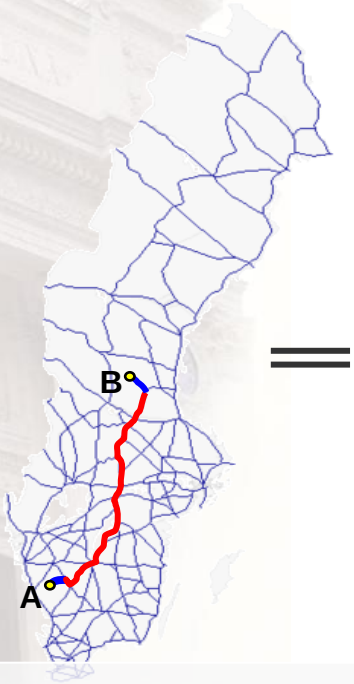


Additional equipment needed

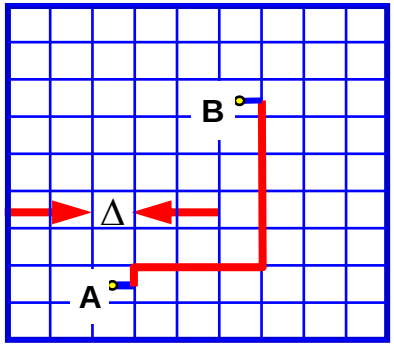


Activated in sections ...

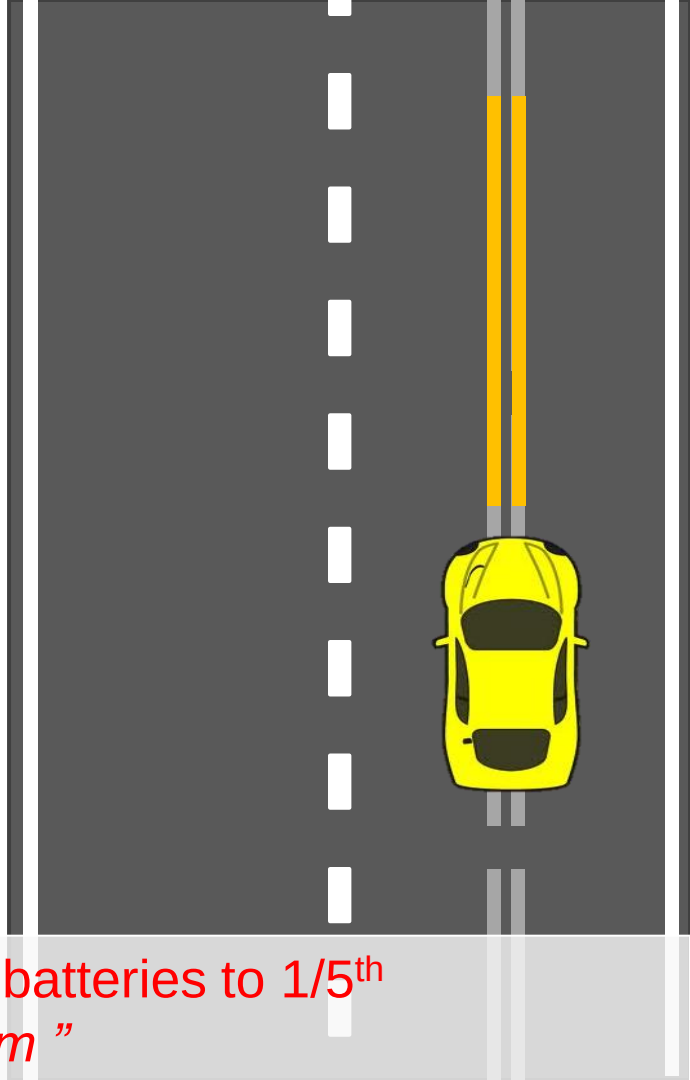
- Activated ”step by step”
- Needs little precision
- Overtaking on battery
- Reduced battery range



=

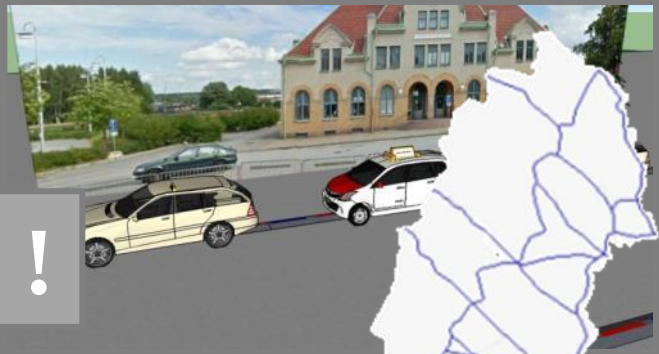


- Sweden: $\Delta = 50$ km

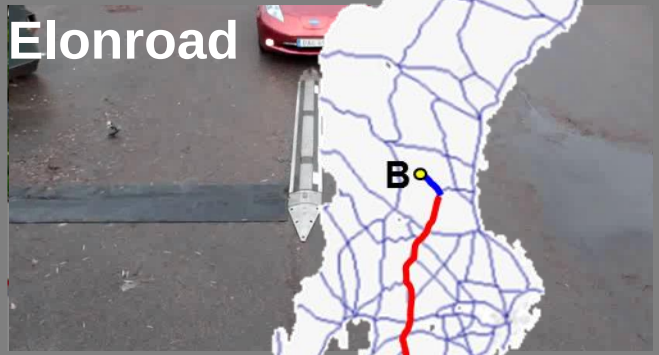


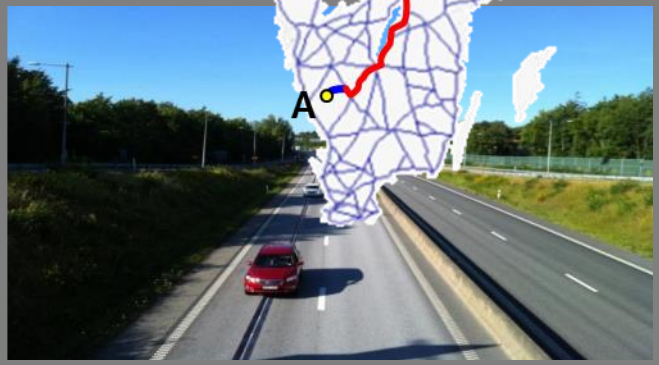
Remember: - ERS reduce the need for batteries to 1/5th

”100 km instead of 500 km ”

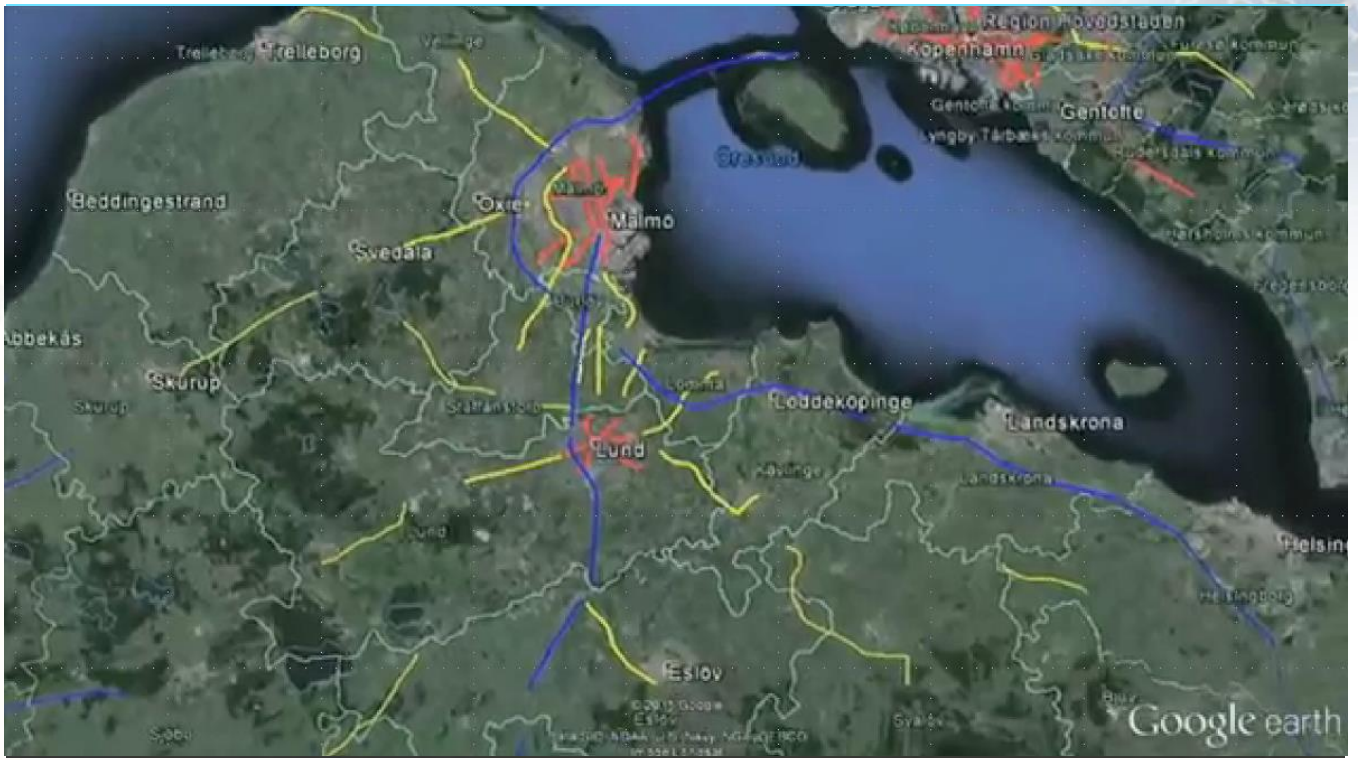


-80 % battery size !





Vision of one technology supplier ...

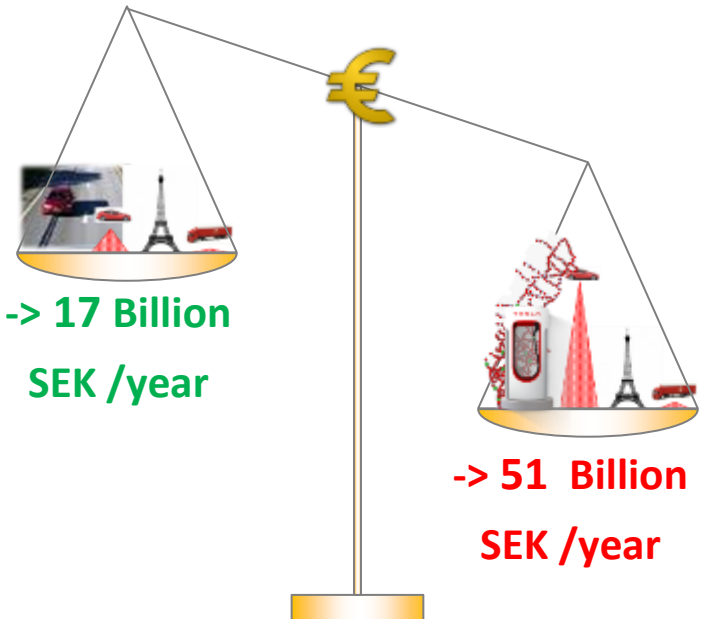



ELONROAD

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



- 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

Conclusion

- **In a societal view, huge amounts of batteries and a large number of fast charging stations is not attractive**
  - **Cars, NOT commersial vehicles is the main challenge**
- **Cost reduction on charging stations suggests AC charging**
- **AC charging MUST be Automatic and of Higher Power than today**
  - **Both these aspects are missing!**
- **Dynamic Charging / Electric Road Systems is a promising technology**

37