Electrification of Transport

A pilot project in Stavanger

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Boreal Transport Norge

The Backdrop

The Economist
August 2013

The Economist
January 2015

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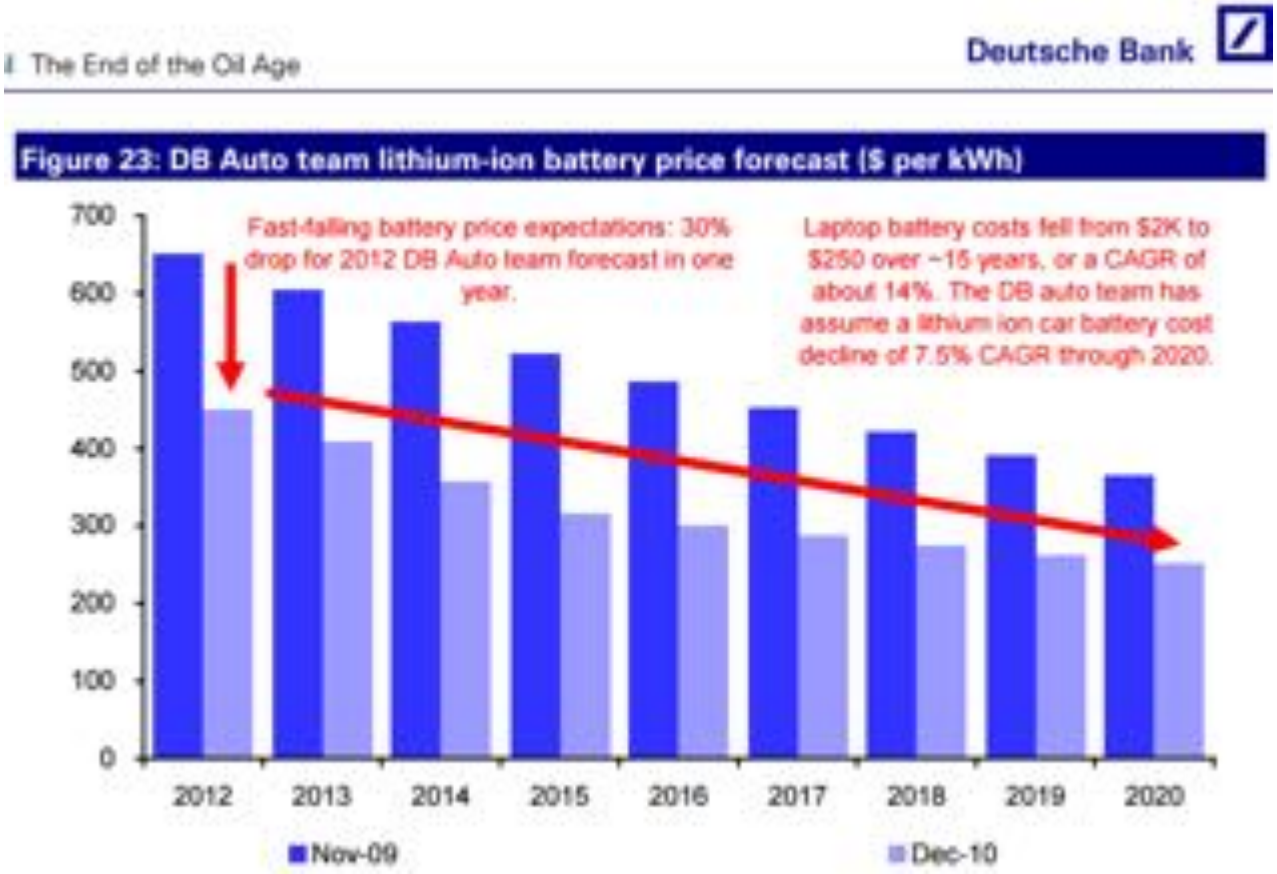
International Energy Agency

Oil Market Report August 2015

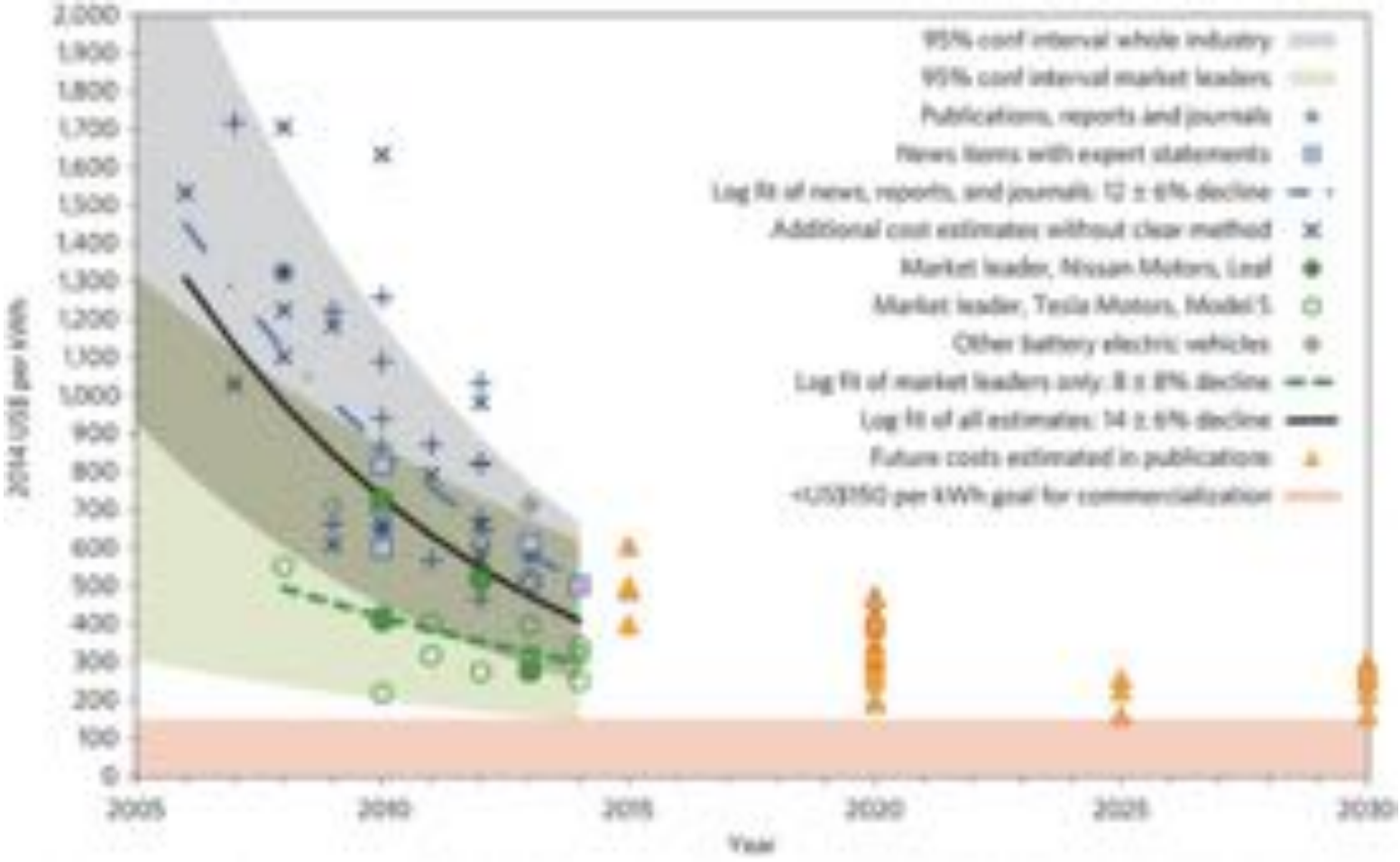
Deutsche Bank 2010:

Lithium-ion battery cost of 250$/kWh in 2020



Stockholm Environment Institute

Björn Nykvist & Måns Nilsson (2014)



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Stockholm Environment Institute

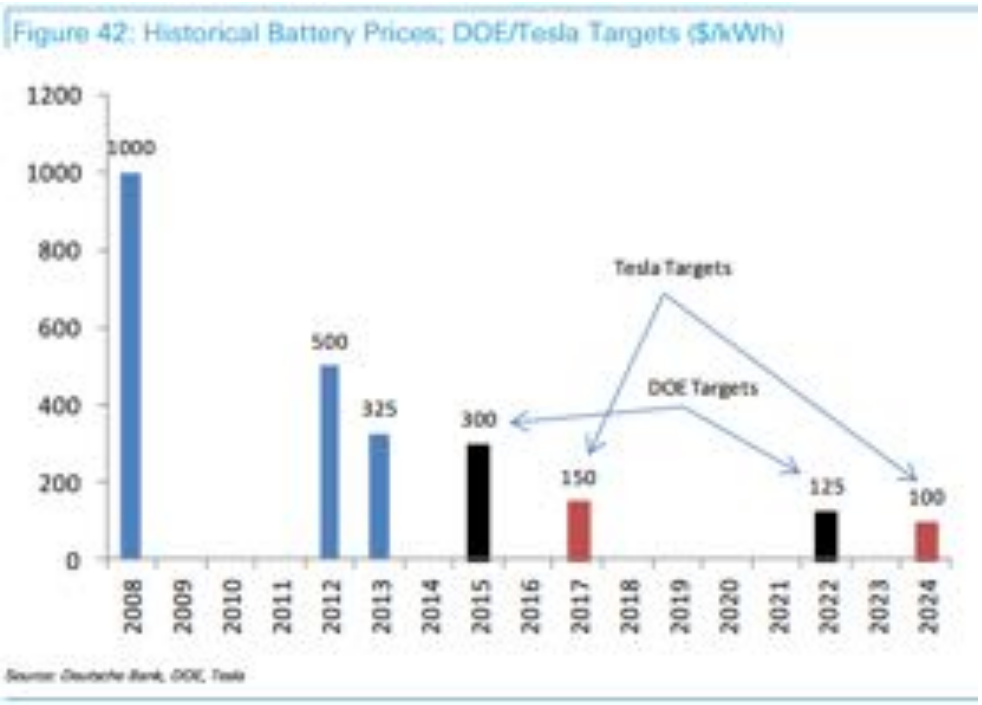
Björn Nykvist & Måns Nilsson (2014)

Nykvist & Nilsson show that:

- industry-wide cost estimates declined by approximately 14% annually between 2007 and 2014, from above US$1,000 per kWh to around US$410 per kWh
- the cost of battery packs used by market-leading BEV manufacturers are even lower, at US$300 per kWh, and has declined by 8% annually.

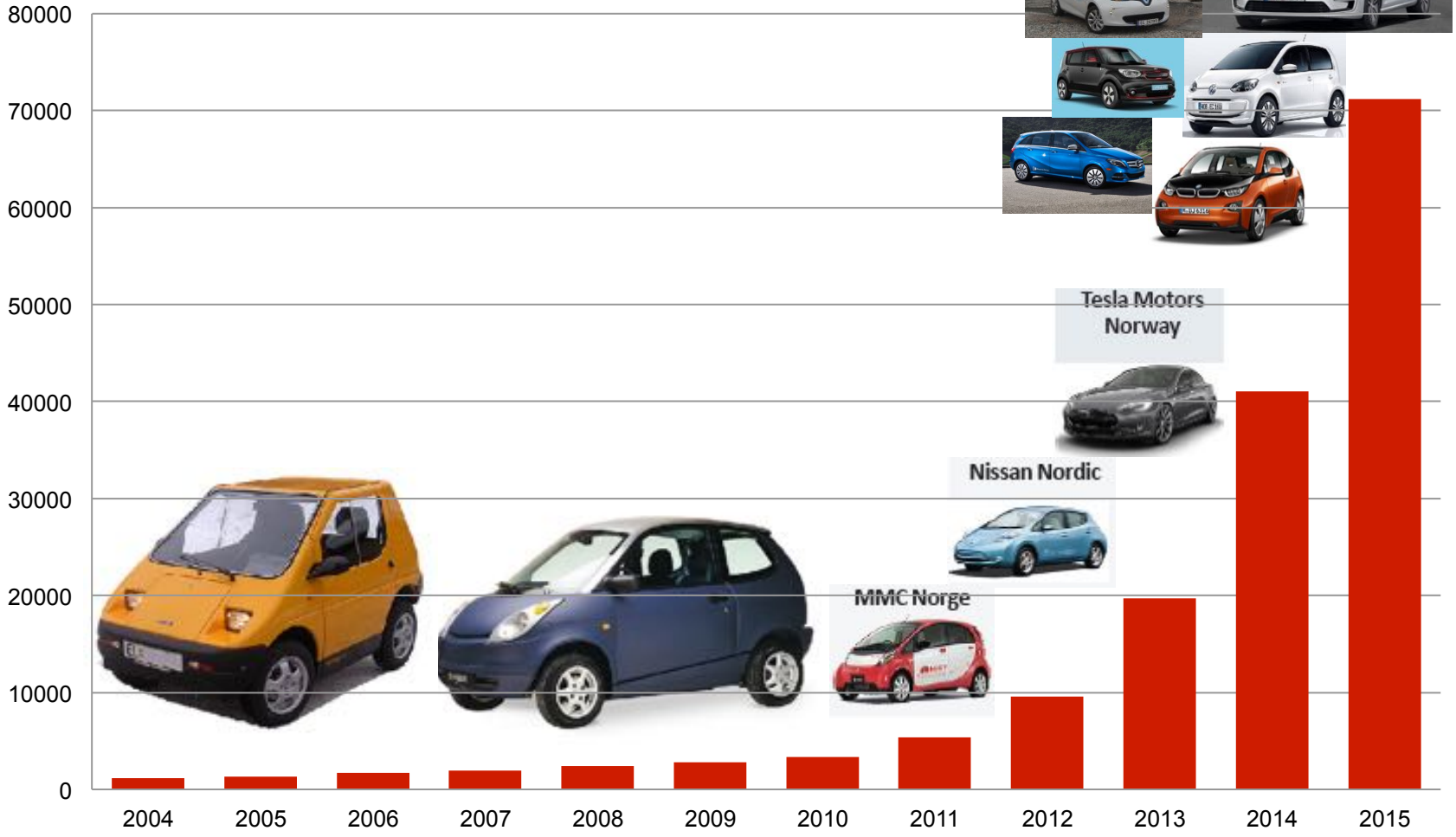
Deutsche Bank 2015:

”We believe 20-30% yearly cost reduction is likely, which could bring conventional lithium ion batteries at commercial/utility scale to the point of mass adoption potential before 2020”



Total EVs in Norway

2015 estimated per July



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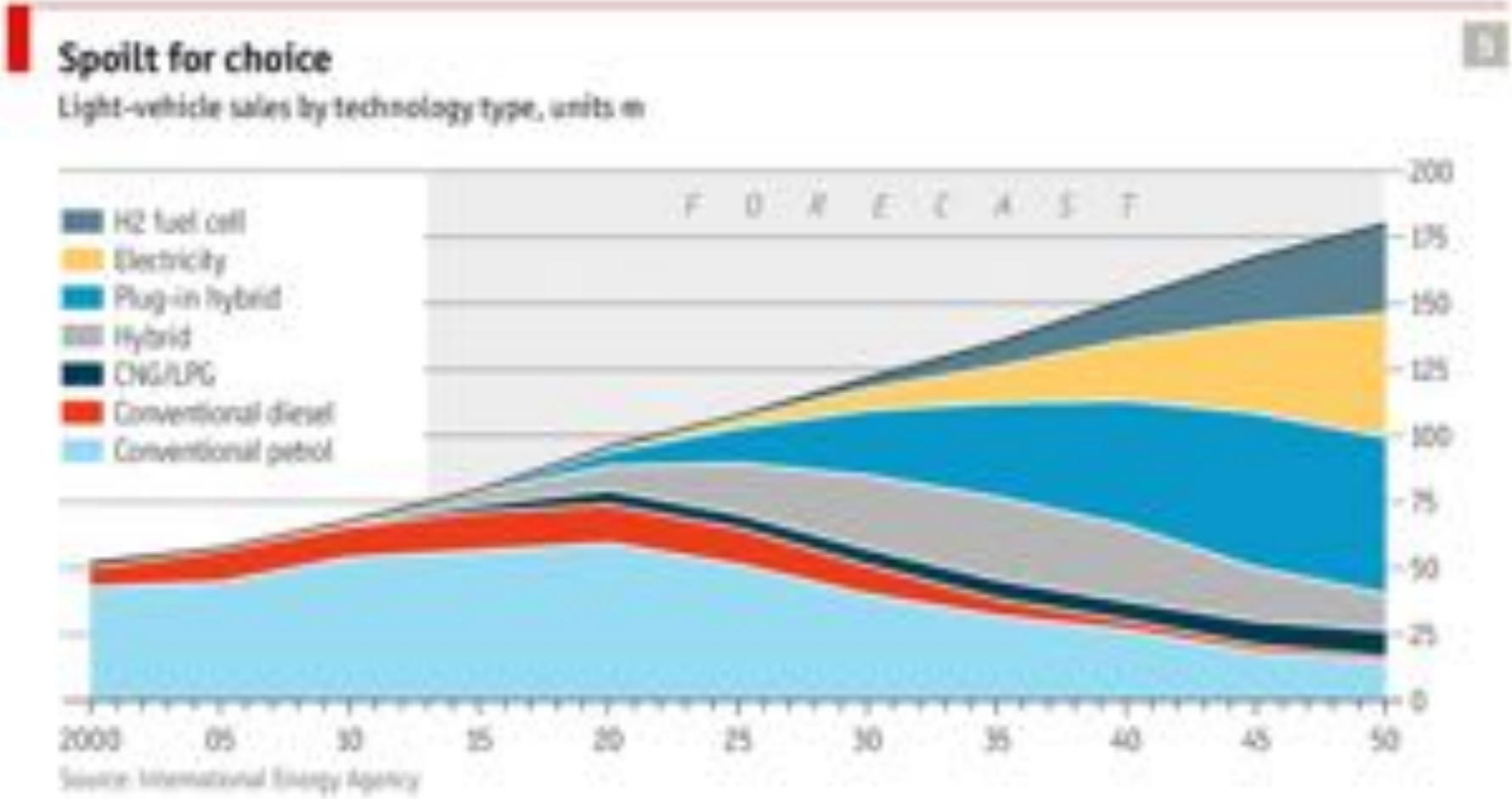
Light-vehicles towards 2050



Boreal's Previous Efforts at Electrification

Back and forth ro-ro ferries: no better candidate.

- In 2008, Boreal initiated a development project for an electrical ferry together with STX Yards.
- After two years of work, we applied for funding of a demonstrator el-ferry from Nordisk Råd's Energy & Transport program, without success.
- Unfazed, we decided to participate in the MOT's competition for "the most energy & environmentally efficient ferry" for Lavik-Oppedal, in mid 2010.

The battery-electric design prevailed

- The winner offered an all electrical ferry with lithium-ion batteries for energy storage.
- We offered an all electrical ferry with super capacitors for energy storage.
- The two other competitors offered more or less complex hybrids, principally based on LNG.
- The el-ferry Ampère started serving Lavik-Oppedal in January 2015, and heralds a new generation of ferries.

Barriers to electrification in PT

- No incentives for using el-buses or el-ferries in stead of ICE buses or ferries: The increase in CapEx is not offset by the decrease in operational costs.
- Long contracts with the PTAs means that changes come very slowly.
- Little knowledge of el-buses / el-ferries among PTAs and operators equals high uncertainty which results in an elevated risk premium.
- Consequently, electrical buses and ferries in regular operation in Norway are a rarity: 1 el-ferry and 2 el-buses.

A pilot project in Stavanger

We have set out to test:

- Operational reliability of el-buses running ca. 70.000 km/year in city traffic.
- Operational range at different uses (line topography, summer/ winter, peak/off peak hour, high/low patronage)
- Impact on the organization of introducing el-buses and plug-in charging stations.

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Our approach:

- Introduction of new technology requires competence and insight as to how this affects both the organization and the operational reliability.
- Even if the electrical motor is superior to the IC-engine (significantly better efficiency, no emissions, no noise, etc.), it can not be introduced before the inherent risks are known and a plan for risk management is set up.

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El-bus pilot in Stavanger

- What we planned in spring 2012:
  - Select, build and test 3 el-buses in regular city service from June 2013 to June 2016.
- ***How it went:***

El-bus pilot in Stavanger

2012: all beginnings are hard

- In March 2012, Boreal started searching for 100% el-buses of “standard” size (12m) and with city bus design.
- None of the major European manufacturers could deliver a 12m city bus; Solaris came closest with a 9m city bus.
- Turned out we had to go to China to find it: BYD had in 2011 delivered 200 el-buses to the city of Shenzhen.
- Chinese buses made for the Chinese home market represented a huge risk, but we decided to assume it.
- We did a risk analysis of the project and applied in June for funding from Transnova.
- In October Transnova rejected our application.

El-bus pilot in Stavanger

2013: a good start; then it gets complicated

- In February, Transnova accepts our new and adjusted application, and pledges to fund 45% of the cost.
- In May, BYD raises the price considerably, straining our relation with the company.
- The project must be downsized by 1 bus. The project design allows for this, since we from the outset decided we needed 3 buses to abate for the huge uncertainty.
- In the meantime, a new competitor enters the fray: the Dutch company Ebusco can also offer 12m city buses.
- From August to December, we negotiate with both Ebusco and BYD for an offer for 2 el-buses.

El-bus pilot in Stavanger

2014: a contract is signed, then broken

- In March, we finally sign a contract with Ebusco; buses shall be delivered in October.
- In June, Ebusco offers improvements, without extra cost. Assured this will not delay the delivery, we accept.
- However, in October, the buses are not delivered. We caution Ebusco of the consequences if the delay is prolonged.
- In November, an inspection of the buses at the factory in Shenzhen reveals big discrepancies from the specifications in the contract.

El-bus pilot in Stavanger

2015: cut losses or soldier on; then a break

- Still no delivery in beginning of January, we consider to cancel the contract. A close call, we decide to carry on.
- In February, buses arrive in Stavanger, but are still not fulfilling all requirements of the contract.
- Finally, in March, we accept delivery of the buses, and conduct many productive trials with the buses.
- On April 8th, the County Mayor cuts the ribbon and celebrates the start of the first el-buses in regular service in Norway.
- …and we could finally start to gather operational data and build operational experience.

Technical data

- 12 m low floor city bus
  Doors: 1+2+0.
- Light weight aluminum body
  Bus net weight ca. 11,5 ton.
- Passenger seats: 37+3 folding
  Standing: ca. 50
  Room for 3 prams.

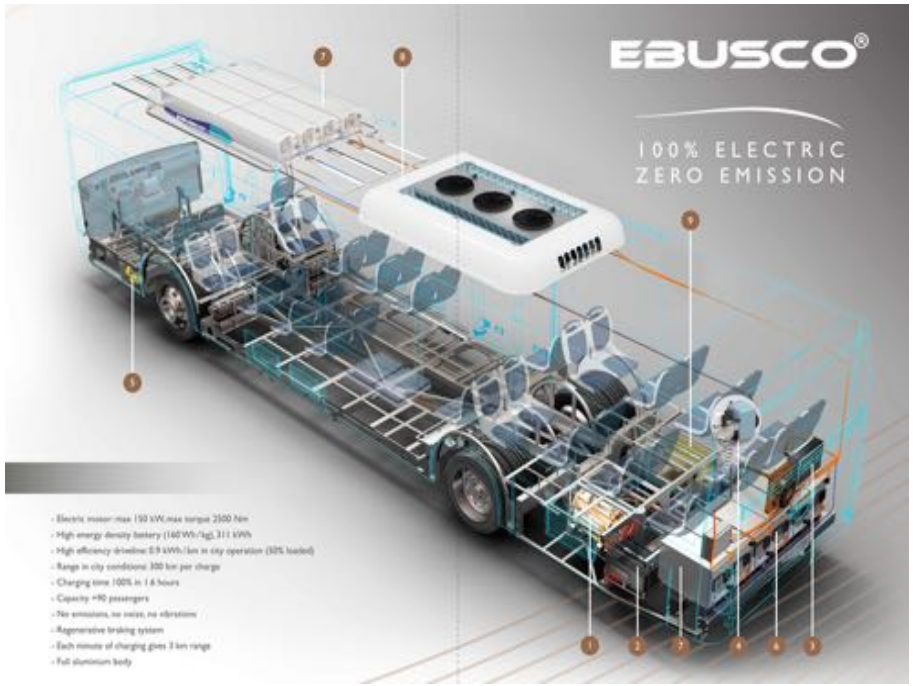

Foto: Elisabeth Tønnessen

- Lithium Iron Phosphate (LFP) batteries with 250 kWh (160Wh/kg). Battery pack ca 1.800 kg.
- Range in the summer ca. 250 km, in the winter 15-25% less.
- On-board charger 45 kW. Charging time is ca 5 hours. (Fast charging at 250 kW is available but not installed for this project)

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Which business model will prevail?

- El-buses that need proprietary charging infrastructure are inflexible and establish a barrier for innovation.
- Bus manufacturers that offer several charging options will have competitive advantage.
- Opportunity charging increases CapEx more in charging infrastructure than it decreases CapEx in bus fleet (smaller batteries).

Which business model will prevail?

- Battery cost will soon (2017) come down to 150$/kWh, making BE cars competitive with ICE cars (i.e. without any preferential treatment).
- When PTAs start to seriously ramp up the demand for BE buses, the ICE bus is doomed.

Which business model will prevail?

- *What I think:*
- Buses equipped with batteries that provide sufficient daily range for ca. 80% of the fleet.
- Slow charging of all buses by night at the depots, effect adapted to available off-time. Plug-in at first, in future inductive charging.
- Fast charging (> 250kW) available at a few carefully selected locations, with capacity for the remaining ca. 20% of the fleet.

Thank you for your attention &