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THE FEASIBILITY OF A LARGE SHARE OF ZE HDVs IN THE 2030 FLEET DEPENDS ON LOT OF FACTORS

SUPPLY

- Technology readiness
- Availability of attractive products
- Cost competitiveness
  - battery price development
  - price of diesel and electricity (incl. cost of (fast) chargers)
- Availability of charging infrastructure
  - e.g. dependent on EU Alternative Fuels Infrastructure Directive and national measures

DEMAND

- Sustainability strategies of the logistics sector
- Effective policies applying to both truck manufacturers and end users
  - Stringent CO_2 target for HDVs
  - ZEV requirements in the HDV CO_2 Regulation
  - National and municipal policies
    - Fiscal stimulation and/or subsidies
    - Urban access restrictions: e.g. Dutch Green Deal Zero Emission City Logistics

BUT THERE'S A LOT HAPPENING w.r.t. ZE HDVS

- Currently, developments with respect to the technical feasibility and costs of battery-electric HDVs are going much faster than anticipated.

ZE VEHICLES

- Fast increase in the commercial availability of electric buses
  - e.g. Solaris, Optare, BYD, VDL, ADL, Van Hool, Volvo, Dennis
- Small OEMs offering battery-electric trucks commercially
  - e.g. GINAF (rigid truck), EMOSS (rigid truck and tractor)
- Many OEMs are developing and testing battery-electric trucks or announce market introduction
  - BYD, Daimler, MAN, VDL (DAF based), Fuso, Tesla, Nicola
- Volvo and Scania test catenary trucks
- Toyota develops a hydrogen truck
- Battery prices are dropping fast

CHARGING

- Rollout of ultra-fast charging (@ 350 kW) networks across the EU (>10,000 charging points) announced by E.ON and two other consortia
  - Backed by several large OEMs
  - This would reduce charging time of 900 kWh long-haul truck to 2.5 hours
- Tesla has announced the deployment of 1 MW chargers.

€

- **Perspective on technical and economic feasibility is rapidly improving**

INDICATIVE ASSESSMENT OF TECHNICAL FEASIBILITY AND COST-EFFECTIVENESS OF BATTERY-ELECTRIC HDVs

- This chapter presents results of an indicative assessment of the applicability of battery-electric propulsion in two different logistic applications for trucks.
- Using an in-house model, developed by TNO, and assumptions on the characteristics of typical reference vehicles, mission profiles for the applications and overnight charging vs. day-time opportunity charging, the following parameters have been estimated:
  - the fuel consumption of the conventional reference trucks:
  - the minimum battery size for full-day operation of the electric trucks;
  - the required power of the electric power train;
  - the electricity consumption of the ZE HDVs, taking into account the impact of battery weight.
- Combining these results with estimates for the future costs of batteries, powertrain components, diesel and electricity, and maintenance, estimates have been made of the:
  - differential in vehicle purchase costs between the conventional HDVs and the ZE HDVs;
  - costs of the energy consumed by both vehicles;
  - the difference in maintenance costs;
  - the resulting overall **difference in total costs of ownership (ΔTCO)** of conventional HDVs and ZE HDVs.

KEY ASSUMPTIONS

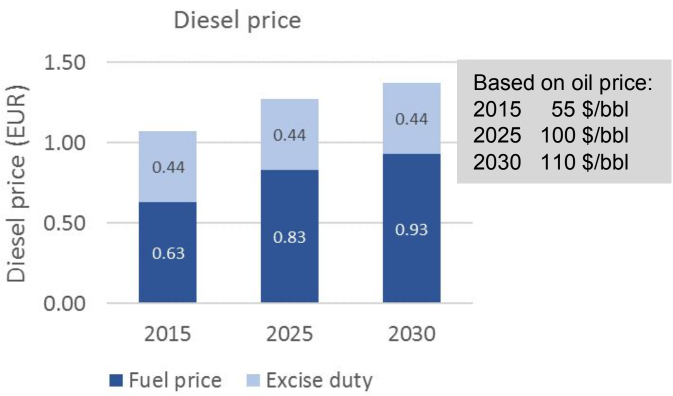
- The table below presents the assumptions on a range of input data that have been used for the comparative cost assessment of conventional (ICE-based) and battery-electric HDVs.

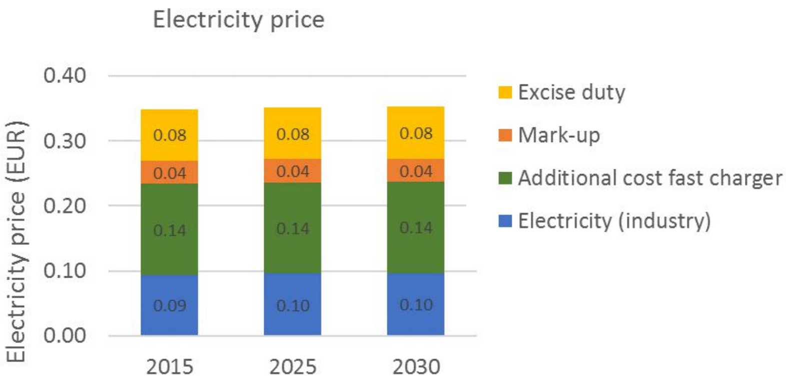
	2015	2025	2030	Source
Battery energy density [Wh/kg]	125	200	200	TNO estimate based on various literature sources
Battery costs [€/kWh]	350	200	120	TNO estimate based on [McKinsey 2017], [Bloomberg 2017], [IRENA 2017]
Costs of other EV components*	€ 5,860 + 26 €/kW	€ 3,050 + 13.5 €/kW	€ 3,050 + 13.5 €/kW	Based on in-house expert knowledge
Costs of replaced ICE components**	€ 50 + 65 €/kW	€ 50 + 65 €/kW	€ 50 + 65 €/kW	Based on in-house expert knowledge
Costs of maintenance [€/km]: EV / ICEV	0.11 / 0.12	0.11 / 0.12	0.11 / 0.12	[ICCT 2017]
Battery lifetime [no. of cycles]	3000	5000	5000	[FREVUE 2017]

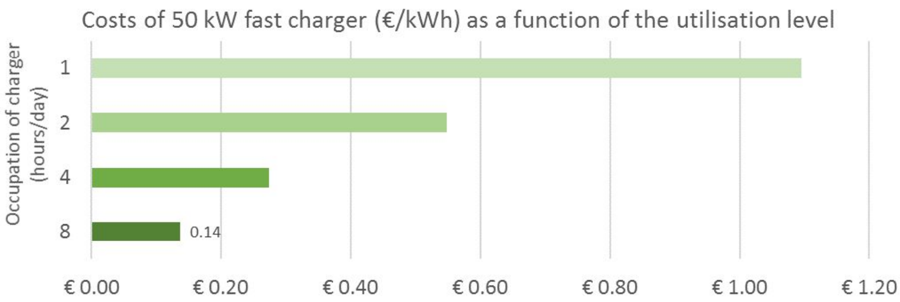
*) Electric motor, inverter, boost converter, heat pump, control unit, harness and safety, regenerative braking system
**) Internal combustion engine, aftertreatment system, transmission and fuel tank

KEY ASSUMPTIONS: FUEL AND ELECTRICITY PRICES

› Assumptions for the diesel price and base electricity price for 2015 and 2030 are based on the EU reference scenario [EU 2015].



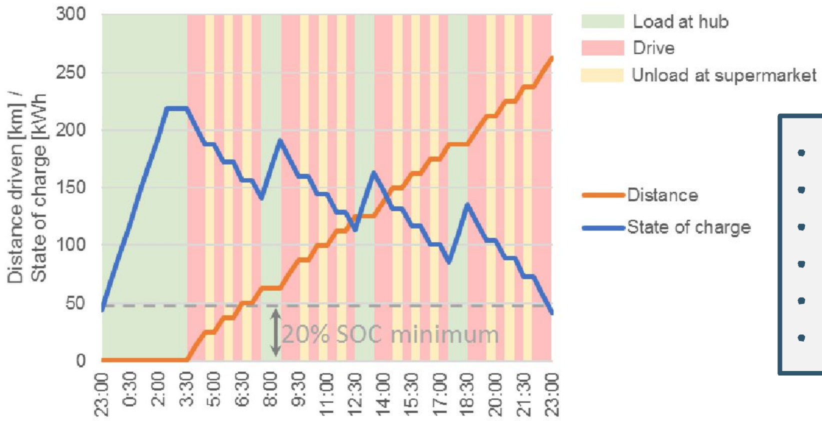




› The costs of the charging infrastructure that need to be attributed to the costs of charged electricity strongly depend on the utilisation of the charging station.

› The occupation level has a trade-off with the charger's availability over the day.

CASE: SUPERMARKET SUPPLY
MEDIUM RIGID TRUCK (2350 KG PAYLOAD)

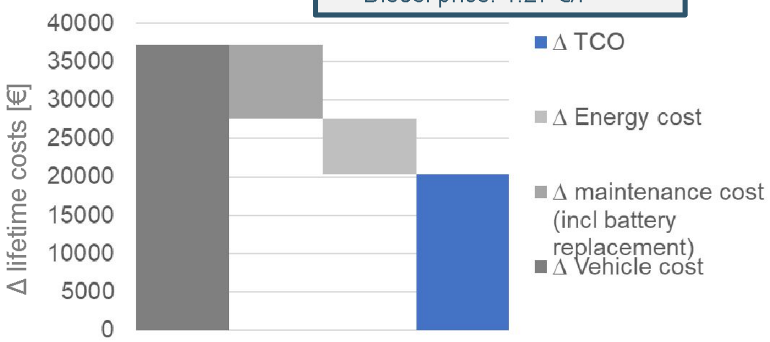


› A smaller battery and faster charging would further improve the business case

- Average speed of 25 km/h
- Drive 10.5 hours per day (= 263 km/day)
- 630,000 km in 8 years lifetime
- Charger: 50 kW
- Required battery: 219 kWh (incl. max. 80% DoD)
- Energy use: 1.4 kWh/km (incl. mass penalty)

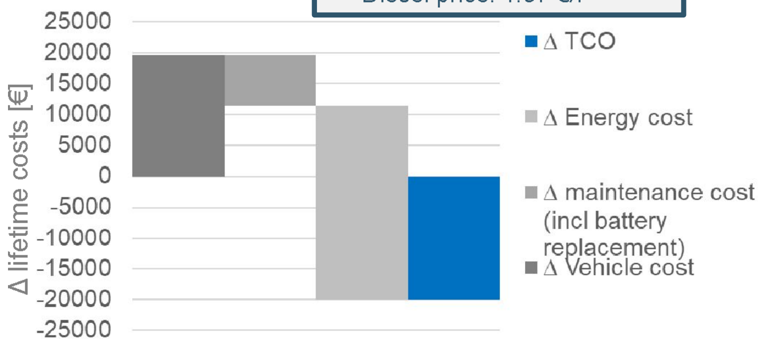
2025

- Electricity price: 0.35 €/kWh
- Diesel price: 1.27 €/l

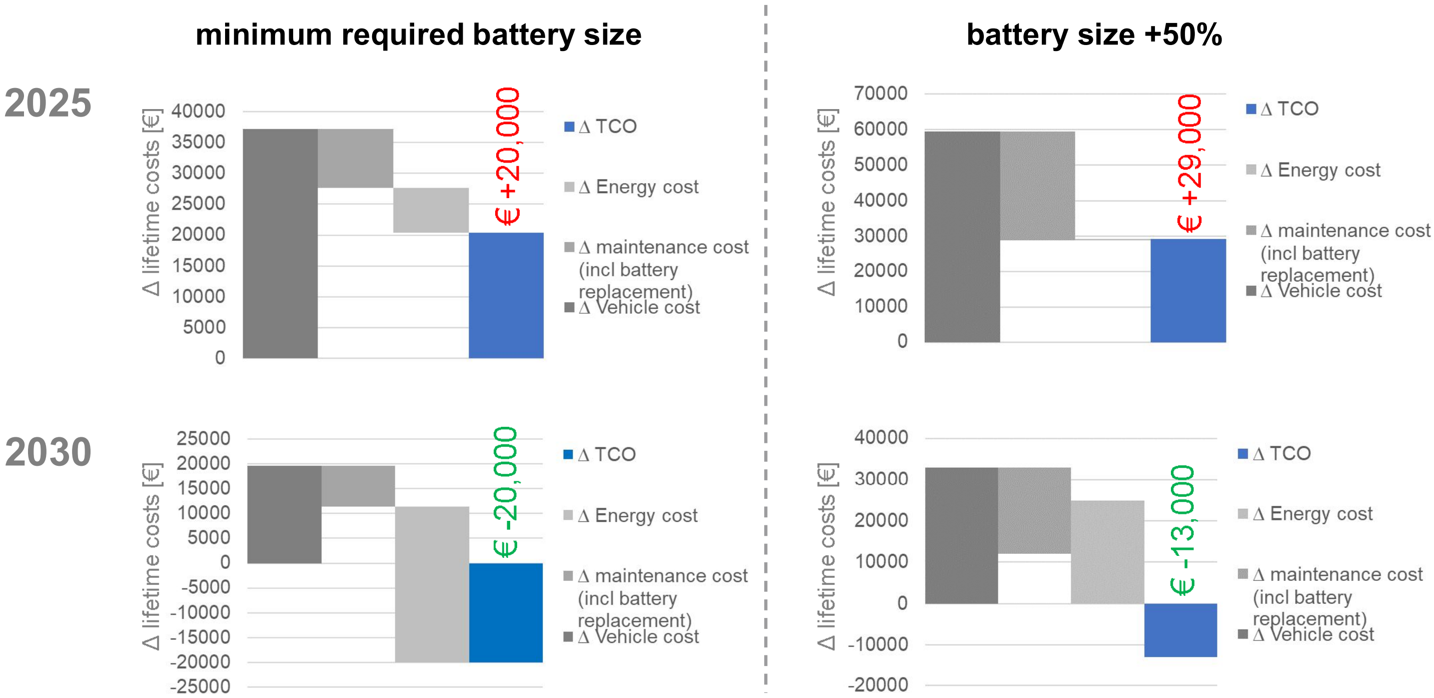


2030

- Electricity price: 0.36 €/kWh
- Diesel price: 1.37 €/l

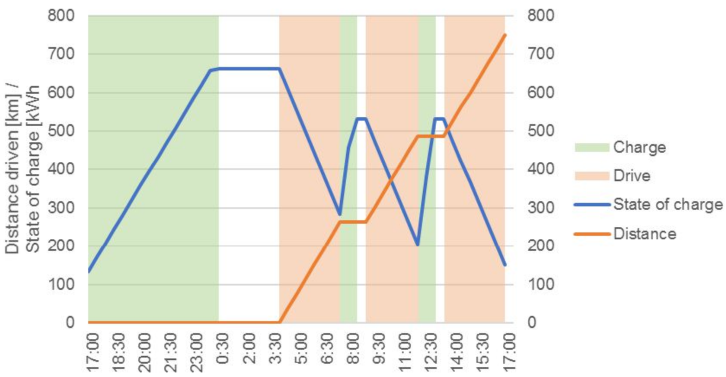


CASE: SUPERMARKET SUPPLY – RIGID TRUCK INFLUENCE OF BATTERY SIZE ON LIFETIME ΔTCO



› Developments over time in battery costs and in the price of diesel relative to electricity have a larger impact on the cost-effectiveness of battery-electric trucks than the size of the battery.

CASE: LONG HAUL TRACTOR-TRAILER (24.270 KG PAYLOAD)

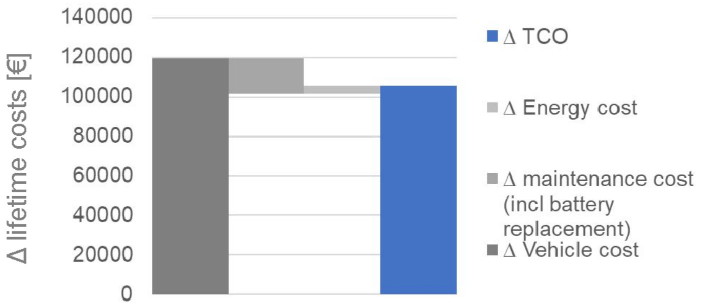


- Average speed of 75 km/h
- Drive 10 hours per day (= 750 km/day)
- 1.8 mln km in 8 years lifetime
- Overnight charger: 75 kW
- Fast charger during rest: 350 kW
- Required battery: 663 kWh (incl. 80% max. DoD)
- Energy use: 1.5 kWh/km (incl. mass penalty)

› A smaller battery and faster charging would further improve the business case

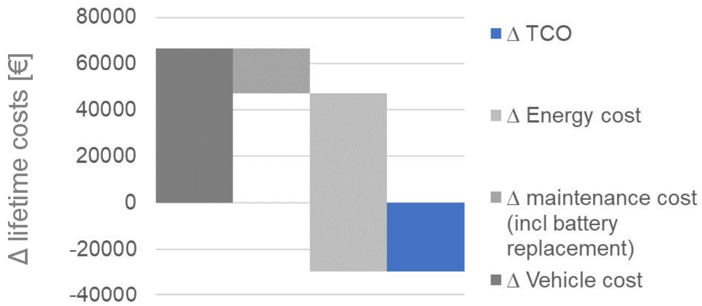
2025

- Electricity price: 0.35 €/kWh
- Diesel price: 1.27 €/l

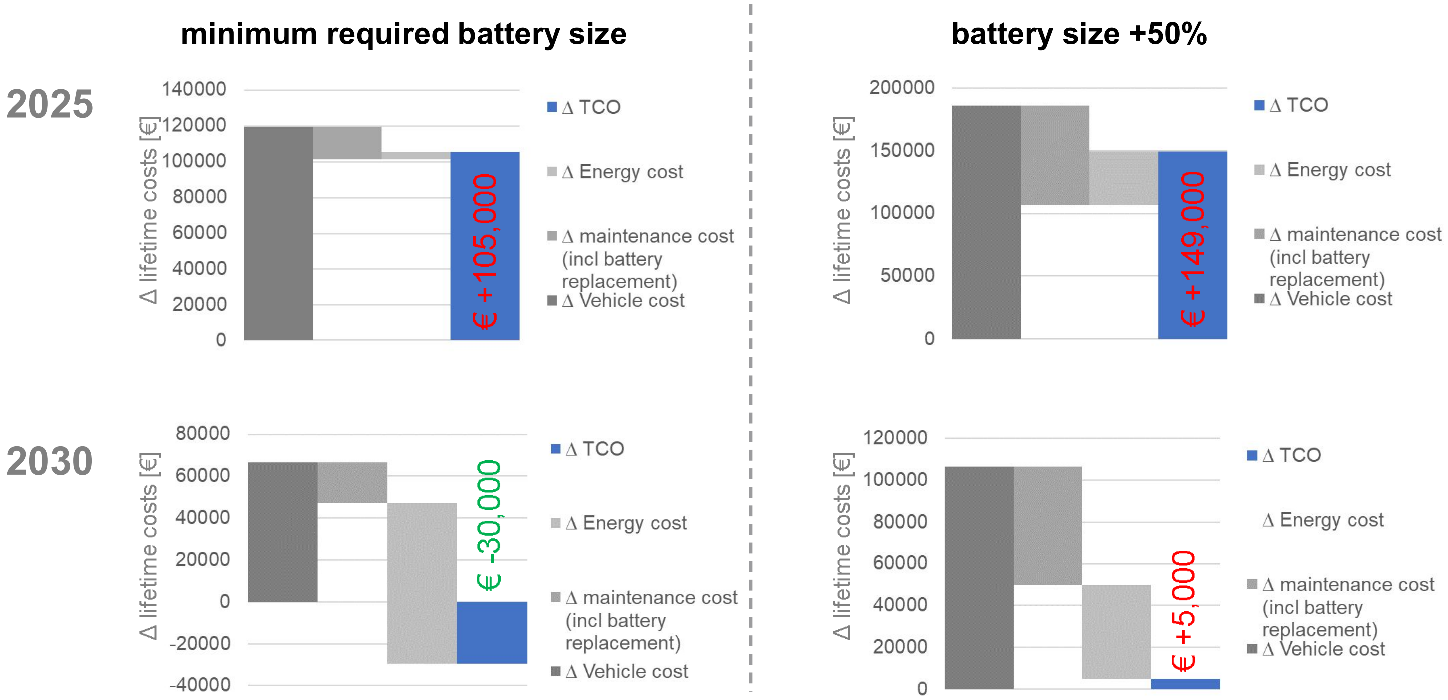


2030

- Electricity price: 0.36 €/kWh
- Diesel price: 1.37 €/l



CASE: LONG HAUL – TRACTOR-TRAILER
INFLUENCE OF BATTERY SIZE ON LIFETIME ΔTCO

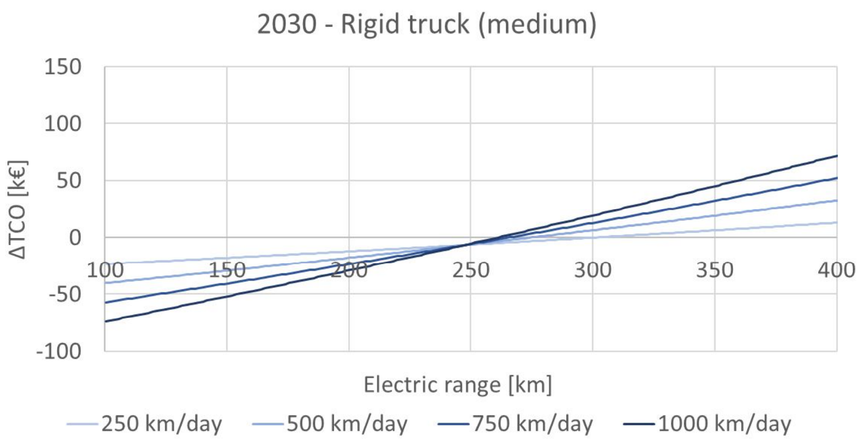


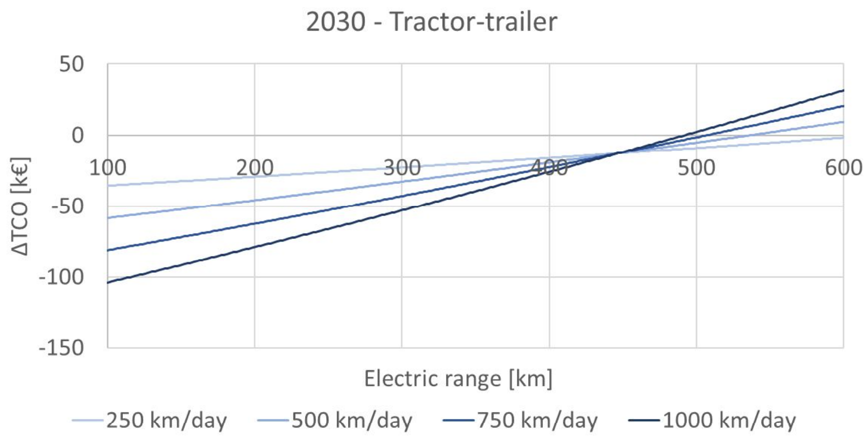
- Developments over time in battery costs and in the price of diesel relative to electricity have a larger impact on the cost-effectiveness of battery-electric trucks than the size of the battery.

DEPENDENCE OF ΔTCO ON ELECTRIC RANGE AND DAILY MILEAGE

- The ΔTCO for battery-electric HDVs compared to conventional HDVs depends on assumptions w.r.t. the electric range (determined by the size of the battery) and the daily driven distance.
- The assessment includes the cost of (multiple) battery replacement(s), which are especially needed when a small battery is chosen.

- Using a larger battery increases energy consumption and therefore leads to a higher TCO.
  - Total battery costs to 1st order do not depend on battery size as a smaller battery needs more frequent replacement over the lifetime of the vehicle.

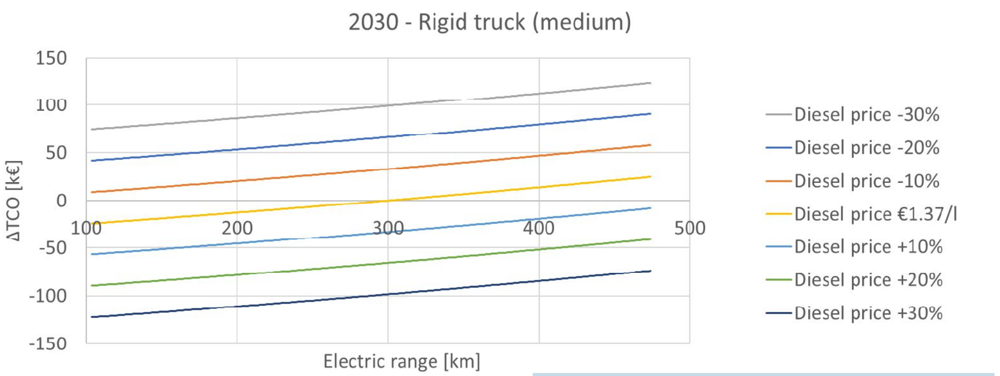




DEPENDENCE OF ΔTCO ON DIESEL AND ELECTRICITY PRICES

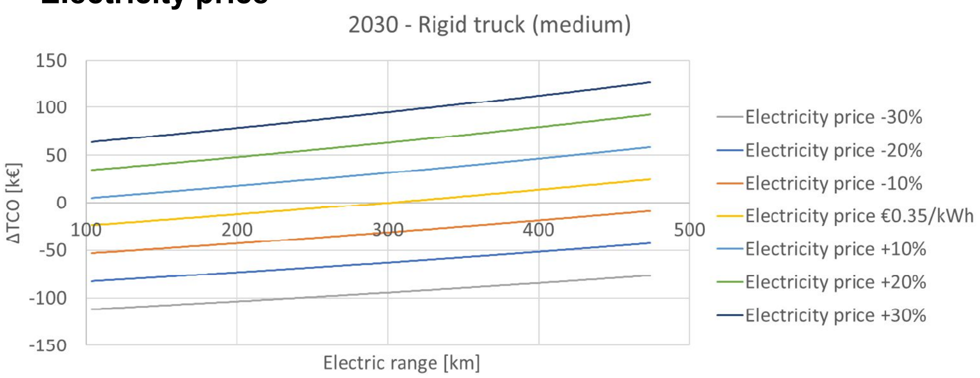
- The ΔTCO for battery-electric HDVs compared to conventional HDVs depends on the price of diesel and electricity.
- Sensitivity analysis for **medium rigid truck**
- A lower electricity price and/or higher diesel price in 2030 improve the economic feasibility of battery electric trucks and also allow their use in applications with lower daily mileage or where a larger battery is required.

Diesel price



Daily driven distance = 263 km/day

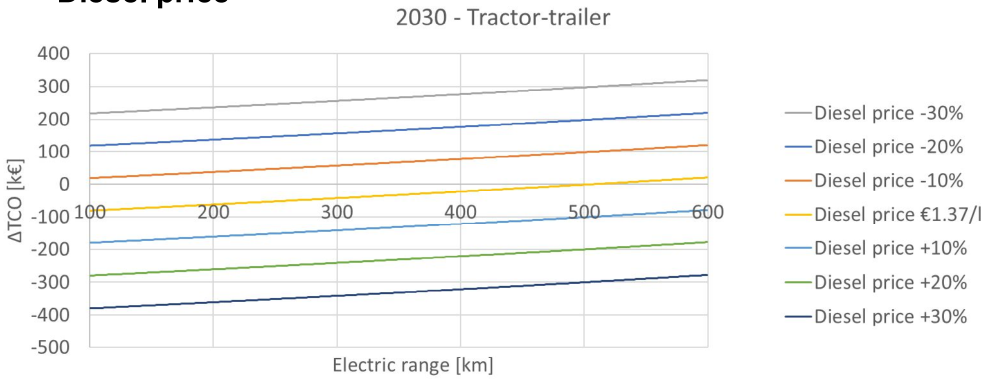
Electricity price



DEPENDENCE OF ΔTCO ON DIESEL AND ELECTRICITY PRICES

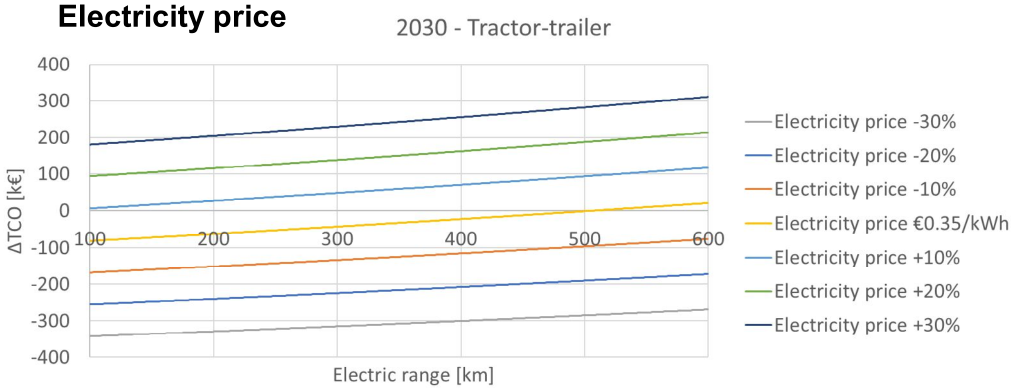
- The ΔTCO for battery-electric HDVs compared to conventional HDVs depends on the price of diesel and electricity.
- Sensitivity analysis for **tractor-trailer**
- Conclusions are similar to the case of the medium rigid truck, with ΔTCO further enhanced by the larger distances driven

Diesel price



Daily driven distance = 750 km/day

Electricity price



CONCLUSIONS

- Developments in product development and market offers for ZE HDVs are currently accelerating.

- Due to an expected rapid decrease in the price of batteries and improvements in battery performance, battery-electric HDVs are expected to be technically feasible and close to economically feasible by 2025 for a limited number of market segments.
- By 2030 battery-electric HDVs may be expected to be to economically competitive for many types of use.
- However, this would require:
  - sufficient availability of sufficiently fast chargers;
  - electricity prices (incl. infrastructure cost) at acceptable levels.
    - This depends strongly on occupation of chargers (> 30%).

- Expectations on the possible contribution of electric trucks to CO_2 reduction in the road freight sector need to be revised.

- For weight-limited transport battery mass goes at the expense of payload. Allowing higher vehicle masses will improve the business case and could lead to quicker uptake of ZE HDVs.

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