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Baseline Assessment of ESCALATE Zero Emission Long-Haul Truck Demonstrations Regarding Total Cost of Ownership

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Executive Summary

The paper deals with baseline analysis for total cost of ownership of the pilot demonstrations of ESCALATE project, dealing with modular and scalable powertrains for various vehicle configurations in long-haul trucking. The baseline TCO methodology and results for battery electric, fuel cell electric and FC range-extending BET is analysed based on the final designs of the demonstrator vehicles and their foreseen pilot use cases and operational scenarios.

Keywords: Electric Vehicles, Fuel Cell Electric Vehicles, Heavy Duty Electric Vehicles & Buses, Fast and Megawatt Charging Infrastructure, Modelling & Simulation

1 Background

Heavy duty vehicles (HDVs), despite forming only about 2% of Europe's vehicle fleet, contribute to about a quarter of European road transport emissions. To match the 2040 climate target and Fit for 55 package, the EU is currently transitioning to zero emissions in the HDV sector, with the European parliament having adopted measures to reduce emissions from trucks and buses by 45% for the period 2030-2034, 65% for 2035-2039 and 90% as of 2040. In response, the market is already shifting. The sales of battery electric HDVs (including light medium and heavy trucks and buses) in the EU are more than doubled in 2023. However, in terms of fleet share, the numbers remain very low: only about 0.35% of trucks in the EU are battery electric.

For electrification of HDVs, it is essential that a holistic approach comprising technological, environmental, and economic aspects towards vehicle deployment are considered. This ensures that the rapid development in key technologies, especially batteries and charging is accounted for. Environmental aspects can be analysed through life cycle assessment (LCA), whereas techno-economics through total cost of ownership (TCO) analysis is a good indicator of overall competitiveness and viability of different vehicular and system solutions.

The project ESCALATE puts forward four physical zero-emission truck demonstrators piloted in real operation by freight operators on regional and long-haul missions of three zero-emission modular and scalable powertrain approaches: fully electric truck (BET), fuel cell truck (FCT) and fuel cell range extended BET. The pilots are currently under development and will commence in 2025. The LifeCostDrive strategy (LCDS) of ESCALATE [1], provides a tailored approach, addressing vital aspects of sustainability, economic considerations, and vehicular performance, centred on zero-emission heavy-duty fleet and the cross-analysis on TCO is part of the overall assessment.

2 Approach and methodology

Innovative modular and scalable next generation powertrain solutions are analysed for zero-emission trucks operating in regional and long-haul missions. This includes different combinations of energy options for these powertrains, including the necessary infrastructure options and implications for energy procurement. The methodology for the TCO analysis will include combination of BET, FCT and different degrees of BET and FCT hybridization (range extending BET) to be analysed in conjunction of various combinations of input parameters and their variation across all ESCALATE pilots. The collection of input and operational environment parameters from the four physical pilots will ensure the real design and operational data to provide a diverse dataset to cover system-level alternatives through a regional freight case study highlighting a few freight operator usage scenarios. The baseline operational scenarios will be based on the initial haulier plans on route and schedule and will later be refined based on real tracked data. Energy consumption will first be based on modelling and simulation using the approach described in [2] and [3] for one of the ESCALATE pilots, later to be validated from real data collected from the pilot operations.

The current paper presents methodology and elements of the life cycle costing part of the ESCALATE approach through TCO analysis. The methodology of the TCO covers both capital and operational expenditures arising from owning and operating zero-emission trucks, including all three main powertrain and prime mover energy options as well as supporting infrastructures they require. Besides presenting the methodology for TCO analysis as part of ESCALATE’s LCDSLifeCostDrive strategy, the study will cross-analyse the four physical pilot demonstrations across Europe, namely 1) SISU pilot in Finland, 2) BMC pilot in Turkey-Bulgaria and France-Germany, 3) Electra pilot in the UK and Germany, and 4) Ford pilot in France-Spain [4].

2.1 Powertrain and vehicle configurations

For the cross-analysis of the pilots, we constructed representative powertrain and vehicle configurations for the demonstrator vehicles relevant for the ESCALATE project. The designs boil down to the following four powertrain and prime mover variants, which can also be derived from the conceptual analysis presented earlier [2]:

A. Conventional diesel truck (baseline case across the analysis)

B. Battery electric truck with a large battery aiming at maximum range with overnight depot charging,

C. Battery electric truck with an intermediate battery combining overnight depot charging and fast opportunity charging,

D. Range-extending plug-in battery electric fuel cell truck (two variants analysed, depending on the energy management strategy, see section 2.3)

E. Fuel cell truck with a small non-chargeable battery.

The details of zero-emission powertrains and operational configurations are given in Table 1, as well as the hauler-specific operational scenarios planned for the actual piloting phase in 2025 This initial TCO baseline assessment contains the demonstrator designs and operational planning as of preparation status in early 2025.

The baseline vehicle with a conventional diesel powertrain is Volvo FH 42 tractor (4 x 2) with a curb weight of 7000 kg [5], or a Volvo FH 64 (6 x 4) with a curb weight of 9000 kg [6]. All semi-trailers were assumed to be 3-axle trailer with a weight of 7500 kg, which is the mass defined for the standard semi-trailer in the declaration of CO_2 values for heavy-duty vehicles according to Commission Regulation (EU) 2017/2400 [7]. The maximum allowable GVW of the baseline vehicles is 40 tonnes resulting in payload capacities of 25.5 tonnes and 23.5 tonnes of the 4x2 and 6x2/6x4 configurations, respectively. The maximum allowable GVW of the vehicles with zero-emission powertrains was assumed to be 42 tonnes, and any weight above this resulted in loss of payload capacity. For the demonstrator 1, there is also a HCT configuration, which includes two semi-trailers and a dolly of 2500 kg and has the maximum GVW of 68 tonnes for the baseline vehicle and 70 tonnes for the zero -emission vehicle.The baseline vehicle for the BET design is Volvo FH 42 Tractor Electric with a 450 kWh battery [8], [9]. The specific energy of the battery pack was assumed to be 5.6 kg/kWh, FC gravimetric power density 2.8 kg/kW, and the H_2 storage tank gravimetric density 17 kg/kgH_2.The gravimetric density of the e-motor and inverter was assumed to be 1.07 kg/kW

Table 1 Basic information on ESCALATE demonstrators including curb weights assessed for the vehicles in their nominal configuration.

	Demonstrator 1 (SISU)	**Demonstrator 2 (BMC)**	**Demonstrator 4 (ELECTRA)**
Vehicle type	Fuel cell range extended BET	Fuel cell truck	Battery-electric truck
Axle configuration	6x4	4x2	6x4
Battery capacity (kWh)	644 (NMC)	30 (LTO)	1100 (NMC)
Fuel cell power (kW)	120 kW	240 kW	-
Hydrogen capacity (kg)	58	80	-
Electric motor nominal power (kW)	221	300	350
Tractor curb weight (kg)	11634	7349	12986
Gliders (semitrailer) weight (kg)	7500 / 17500	7500	7500
Max payload	22866 / 41500	25500	21514
GVW	42000 / 70634	40125	42000
Payload capacity vs diesel	97%	100%	92%

2.2 Pilot missions, infrastructure and operational schemes

The pilot locations, routes and operational missions for the baseline analysis were derived from the preliminary ESCALATE piloting plan. The general high-level information on the pilots and their key related infrastructure are listed in Table 2.

The anticipated driving cycles and elevation curves for the long-haul missions are illustrated in Figure 1. The driving cycles were generated by VTT's Smart eFleet toolbox and they are based on combinations of real road sections between origin-destination, route topology and speed limits. The approach is described in [10].

Table 2 Basic information on ESCALATE demonstrators including curb weights assessed for the vehicles.

	Pilot 1 (SISU)	Pilot 2 (BMC)	Pilot 4 (ELECTRA)	Pilot 5 (FORD)
Mission analysed (LH)	Jyväskylä (J)–Helsinki (H) (FI) (roundtrip)	Gebze – Izmir (TR) (roundtrip?)	Cwmbran – Dundee (UK)	Geneva-Lyon-Barcelona (CH-FR-ES)
Mission length (km)	540	417	726	809
Average speed on mission (km/h)	72 (a) 69 (b)	74	76	76
mandatory breaks needed	1	1	2	2
Primary vehicle configuration	3-axle semitrailer (a) HCT* (b)	3-axle semitrailer	3-axle semitrailer	3-axle semitrailer
Key infrastructure	H2 refuelling (J) MCS charging (H) Depot charging (CCS) (J)	H2 refuelling O/D	CCS charging O/D Optional opportunity charging during mandatory breaks	H2 refuelling O/D

*2 x 3-axle semitrailer + dolly

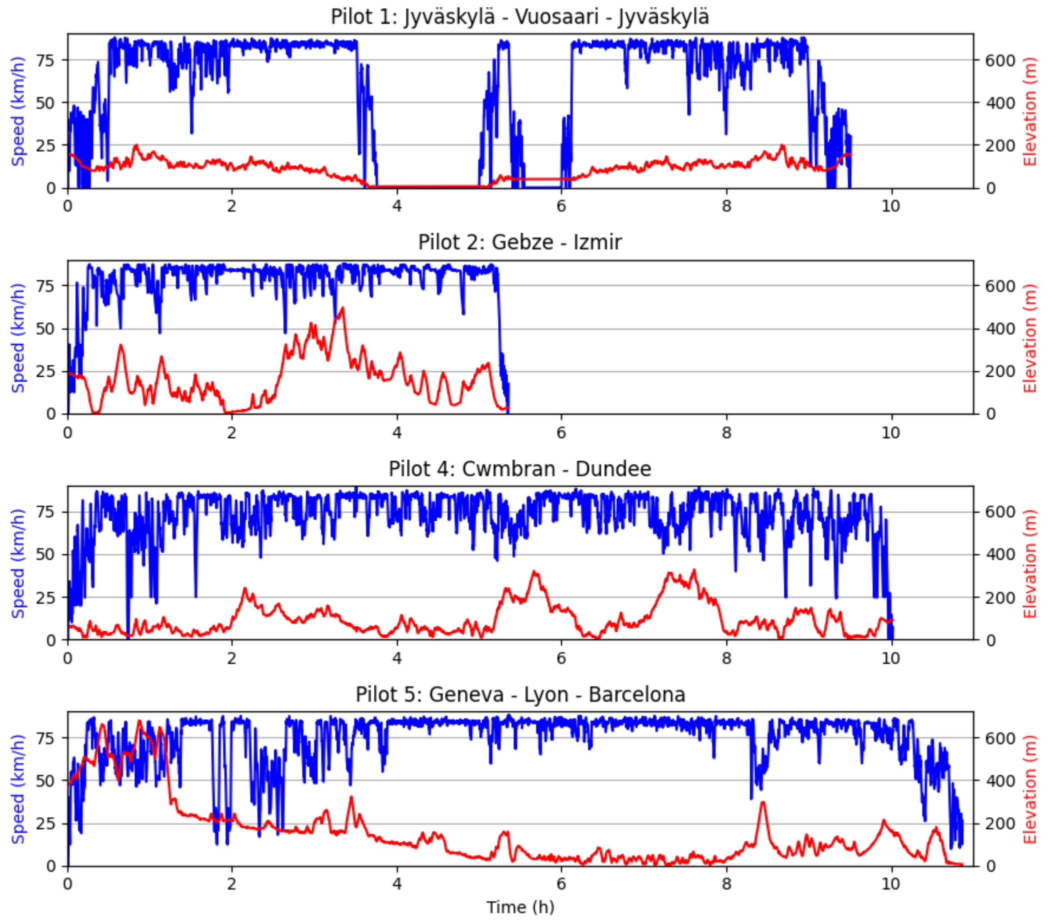

Figure 1. Driving cycles for the pilot missions.

2.3 TCO matrix and key inputs to simulation

Combining the powertrain and vehicle configuration with the pilot missions resulted in the analysis matrix shown in Table 3. For pilot 1 the missions a and b represent the nominal and HCT case, respectively.

Table 3 Overview of the matrix analysing the energy consumption and driving times through simulation.

Configuration (demonstrator #)	Pilot 1a	Pilot 1b	Pilot 2	Pilot 4	Pilot 5
A (baseline)	Diesel GVW 40t	Diesel GVW 68t	Diesel GVW 40t	Diesel GVW 40t	Diesel GVW 40t
B (dem. 4 with depot charge only)	BET GVW 42t	BET GVW 72t	BET GVW 42t	BET GVW 42t	BET GVW 42t
C (dem. 1 as a BET with opp.charge)*	BET GVW 42t	BET GVW 70.9t	BET GVW 42t	BET GVW 42t	BET GVW 42t
D1 (dem. 1 w/o opportunity charge)	BET-FCRE GVW 42t	BET-FCRE GVW 70.9t	BET-FCRE GVW 42t	BET-FCRE GVW 42t	BET-FCRE GVW 42t
D2 (dem. 1 with. opportunity charge)	BET-FCRE GVW 42t	BET-FCRE GVW 70.9t	BET-FCRE GVW 42t	BET-FCRE GVW 42t	BET-FCRE GVW 42t
E (dem. 2)	FCET GVW 40.3t	n/a	FCET GVW 40.3t	FCET GVW 40.3t	FCET GVW 40.3t

*Configuration C carries in this analysis about 1300 kg of unnecessary weight due to the FC and H_2 tank of demonstrator 1, which are not used in this configuration.

Configuration C represents a fuel cell plug in hybrid vehicle operating as a BEV. Under battery power alone, this vehicle is unable to complete any of the drive cycles, so intermediate changing is needed. The vehicle starts with the battery charged at 100%, and it is recharged to 90% during each intermediate charging event. In configuration D, the vehicle is operated in hybrid mode with the fuel cell and battery each providing power. The power split is determined by the equivalent consumption minimization strategy, which is tuned using the methodology described by Skeel et al.[3]

All configurations and missions outlined in Table 3 were simulated with a forward-facing simulation software, meaning that the actual speed depends not only on the route, but also on the powertrain performance. For the sake of comparison, the energy consumption and the active driving time was recorded for all cases.

2.4 TCO methodology and inputs

The TCO analysis largely follows the methodology and approach from several related TCO studies both on BET and FCT, the levelized cost of driving (LCOD) and NPV approach in [11]. Reference works analysing BET and FCT alongside include [12][13] and also provide useful input data from technology and market. A novelty of ESCALATE is through pilot 1 to present in addition the FC range-extended plug-in BET, and through the design of the pilot 1 demonstrator, add the MCS-capable BET (configuration C). As real operational data on zero-emission trucks continues to be scarce, the approach has extensively utilised energy consumption estimates from simulations. This brings an additional advantage of the present approach providing good flexibility to analysing a variety of different powertrain and vehicle configurations and their energy consumption. This marks an improvement compared to [11][12][13] where the energy consumption estimates were either indirectly inferred from conventional trucks, fixed, or extrapolated beyond validity.

The elements of TCO have been aggregated towards high-level analysis using the main capital (CAPEX) and operational (OPEX) cost elements to enable cross-analysis across the ESCALATE pilots without knowledge of the detailed designs and component selections. The main cost categories are first expressed as an Equivalent Annual Cost (EAC) for the first year or ownership:

$$EAC(1) = EAC_{C,v} + EAC_{C,b} + EAC_{C,fch} + EAC_{C,c} + EAC_{O,energy} + EAC_{O,S\&M} + EAC_{O,labour} \quad (1),$$

where in the subscripts C is CAPEX, O is OPEX, v is vehicle (all parts except for powertrain), b is battery, fch is fuel cell and the H_2 tanks, c is private chargers owned by the haulier, energy is the price of purchased energy (diesel, electricity, H_2), S&M is service and maintenance, labour is the salary cost of the driver. For the CAPEX categories the analysis spreadsheet uses the PMT function with interest rate, length of the contractual/ownership period in years (N, equal to depreciation time), initial purchase price and the residual value. In other words, the capital investments are treated as a leasing deal for a fixed duration with even annual payments. Public charging as a service and H2 refilling are not regarded as an investment, rather they are commodities where the retailer costs and margins are included in the price. For the OPEX categories, energy cost comes from energy consumption times average energy carrier price, and S&M are estimated based on literature. The labour cost for the driver is calculated from the simulated active driving times for the various missions, plus the mandatory break times (EU regulation of a 45 minutes break after each 4.5 hours of consecutive driving).

The TCO over the ownership period is then formed by summing up the EAC(n) over the length of the ownership period N using the NPV function

$$TCO = EAC(1) + NPV(rate, EAC(2) \dots EAC(N)) \qquad (2)$$

where the EAC(n) represents the equivalent annual cost of a year of ownership. The rate is the annual inflation/deflation rate for OPEX categories and the interest rate for CAPEX categories. Finally, the LCOD is obtained by dividing the TCO by either the total mileage run during the period (€/km), or by both mileage and payload tonnage transported during the period (€/tonne-km).

The ownership and depreciation period assumed in the analysis was 6 years and the residual value of all vehicle parts was se to 30% at the end – this is a simplification and more detailed residual value analysis will be conducted later. The interest rate was 5% and the inflation rate for OPEX categories was assumed to be 3%. Battery system price for NMC was 250 €/kWh and for LTO 1000 €/kWh, FC system price was 800 €/kW, H_2 tank price 1000 €/kgH_2 (700 bar). The actively useable area of the battery was assumed to be 85% of the SoC area, and 95% of the H_2 tank capacity. Zero-emission powertrain variants profit markup was assumed to be 30% as the market is still at an early stage. Depot chargers were assumed to be private and their price to be 400 €/kW and have a residual value of 0% at the end of the period. The price of a conventional baseline vehicle was 120 000€, one semitrailer was 70 000€

The key inputs used in the TCO analysis are summarized in Table 4. The diesel price given is the average of 2023 and 2024 without VAT, and the electricity price is the average of 2024 without VAT. While private charging at the depot is using the electricity price directly, it is assumed that public charging as a service by a CPO increase the commodity price by a factor of 2. For H_2 price at a commercial filling station dispenser the H_2 price was assumed to be 50% higher than the production cost. Diesel prices were obtained from [14], electricity prices from [15] and H2 production prices from [16]. Service and maintenance costs for the vehicles were taken from [17] and were 18.5 €/100km for diesel trucks, FCET and FC range-extending trucks, and 13.24 €/100km for BET. European-average distance-based road charges were used for the different trucks based on [17], except in those cases where these were known to be zero (Finland). Zero-emission trucks were assumed to have 50% of the road tolls of the conventional trucks for pilot 5. The labour cost for the driver and the annual insurance cost at 2.14% of the purchase price of the vehicle were taken from [17], unless a more specific value for the country of the piloting was available.

Table 4. Summary of the key inputs to the TCO analysis.

Parameter	Pilot 1	Pilot 2	Pilot 4	Pilot 5
Main country of the pilot mission	Finland	Turkey	Great Britain	FR-ES average
Annual mileage (km)	162 000	125 100	217 800	242 700
Annual vehicle tax	1800-3600	129	230	391
Diesel price (€/l)	1.58	1.15	1.50	1.39
Electricity price (€(MWh)*	11.1	9.7	31.2	20.1
H2 production cost (€/kg)**	6.3	4.8***	5.3	6.2
Average driver wages (€/h)	50	25.6	25.6	25.6
Road tolls (€/km)	0	0.11	0.09	0.156****

*Without VAT. Additionally, 50% extra was added to these, to cover distribution and electricity taxation.
**50% on top of the production prices shown on this row was assumed for distribution and retailer capital costs and profit margin.
***The value for Turkey was estimated from [18] and using the anticipated development trend from [16].
**** Class 5-LH (800 km) from [17] used, assuming 90% highway driving and 10% local roads driving.

The annual mileage for each of the pilot cases analysed comes from the given daily mileage, further assuming that the pilot missions are driven 300 days per year and the vehicle utilization is constant during the 6 years period. Therefore, the different pilot missions will end up at different total mileages after the ownership period.

3 Results

3.1 Energy consumption on pilot missions

Simulation results are recorded in the 'TCO matrix' (see Table 5). For all cycles, the driving distance and time are reported. Driving time does not include required driver breaks. For configuration A, diesel consumption in liters is reported, as well as the fuel energy consumption, assuming an energy density of 10 kWh/l. Configuration B and C show results from a BET vehicle and a fuel cell hybrid operating as BET, respectively. In some cases, these vehicles fail to fulfil the entire driving cycle. The same is true for the fuel cell vehicle in configuration E. The simulation has been continued in these cases, and negative SOC and H2 tank levels at the end of the cycle are reported. For this purpose, the power limitations of the battery at low SOC levels had to be turned off, which might slightly affect the results.

The energy of the hydrogen consumed by the fuel cell vehicles is reported, assuming an energy density of 36 kWh/kg, to aid in comparison.

Table 5. Results from the analysis on energy consumption, executed range and driving times through simulation.

	Pilot 1a	Pilot 1b	Pilot 2	Pilot 4	Pilot 5
A	205 l (2050 kWh) 540 km 7.42 h	349 l (3490 kWh) 540 km 7.81 h	192 l (1920 kWh) 417 km 5.63 h	280 l (2800 kWh) 726 km 9.49 h	329 l (2390 kWh) 809 km 10.73 h
B	Batt: 817 kWh	FAILED (no	Batt: 701 kWh	FAILED	FAILED

	Dist: 540 km Time: 7.47 h	charging) Batt: 1288 kWh Dist: 540 km SOC: -17% Time: 7.71 h	Dist: 417 km Time: 5.55 h	Batt: 1134 kWh SOC: -3.1% Dist: 726 km Time: 9.35 h	Batt: 1216 kWh SOC: -10.6% Dist: 809 km 10.58 h
C	Batt: 1025 kWh Dist: 540 km Time: 7.50 h, w/ 1 break: 8:25 h	FAILED Batt: 1221 kWh Dist: 493 km Time: 6.99 h, w/ 1 break: 7.74 h	Batt: 807 kWh Dist: 417 km Time: 5.50 h Time w/ 1 break: 6.25 h	Batt: 1385 kWh Dist: 726 km Time: 9.68 h Time w/ 2 breaks: 11.18 h	Batt: 1500 kWh Dist: 809 km Time: 10.67 h Time w/ 2 breaks: 12.17 h
D1	H2: 27.95 kg Batt: 551 kWh Total: 1560 kWh Dist: 540 km Time: 7.50 h Time w/ 1 break: 8.25 h	H2: 50.03 kg Batt: 555 kWh Total: 2362 kWh Dist: 540 km Time: 7.90 h Time w/ 1 break: 8.65 h	H2: 15.54 kg Batt: 537 kWh Total: 1098 kWh Dist: 417 km Time: 5.45 h Time w/ 1 break: 6.20 h	H2: 50.89 kg Batt: 553 kWh Total: 2391 kWh Dist: 726 km Time: 9.62 h Time w/ 2 breaks: 11.12 h	H2: 58.00 kg Batt: 563 kWh Total: 2657 kWh Dist: 809 km Time: 10.58 h Time w/ 2 breaks: 12.08 h
D2	H2: 3.08 kg Batt: 967 kWh Total: 1079 kWh Dist: 540 km Time: 7.50 h Time w/ 1 break: 8.25 h	H2: 17.52 kg Batt: 1027 kWh Total: 1660 kWh Dist: 540 km Time: 7.90 h Time w/ 1 break: 8.65 h	n/a	n/a	n/a
E	H2: 49 kg (1764 kWh) Dist: 540 km Time: 7.50 h	n/a	H2: 42 kg (1512 kWh) Dist: 417 km Time: 5.66 h	FAILED H2: 69 kg tank: - 1kg Dist: 726 km Time: 9.48 h	FAILED H2: 74 kg tank: -6.4 kg Dist: 809km Time: 10.70 h

3.2 TCO

The estimated baseline TCO in terms of €/km (NPV) for each of the analysed cases are shown in figures 2 to 6.

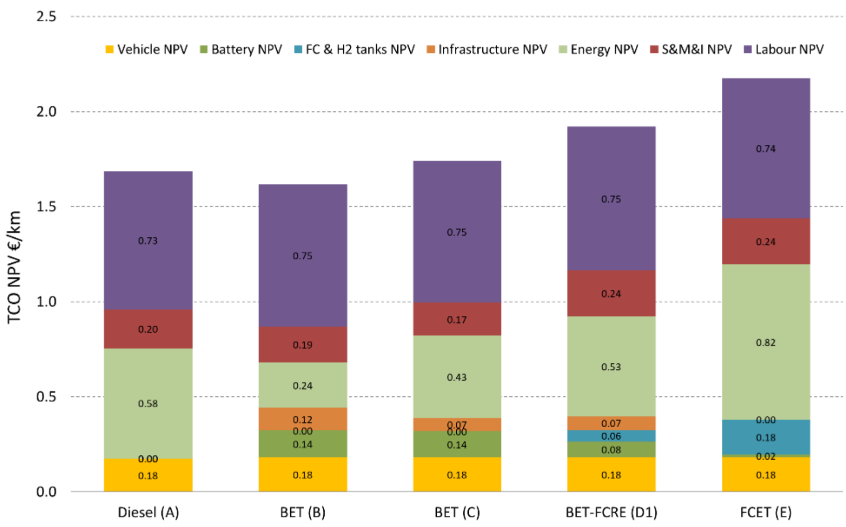

Figure 2. The estimated baseline TCO for mission pilot 1a (FI) with the different powertrain and vehicle configurations.

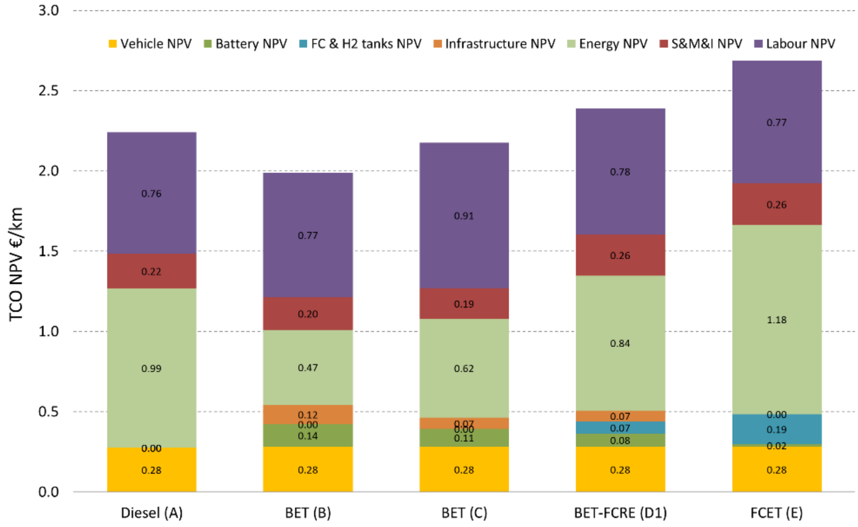

Figure 3. The estimated baseline TCO for mission pilot 1b (FI) with the different powertrain and vehicle configurations.

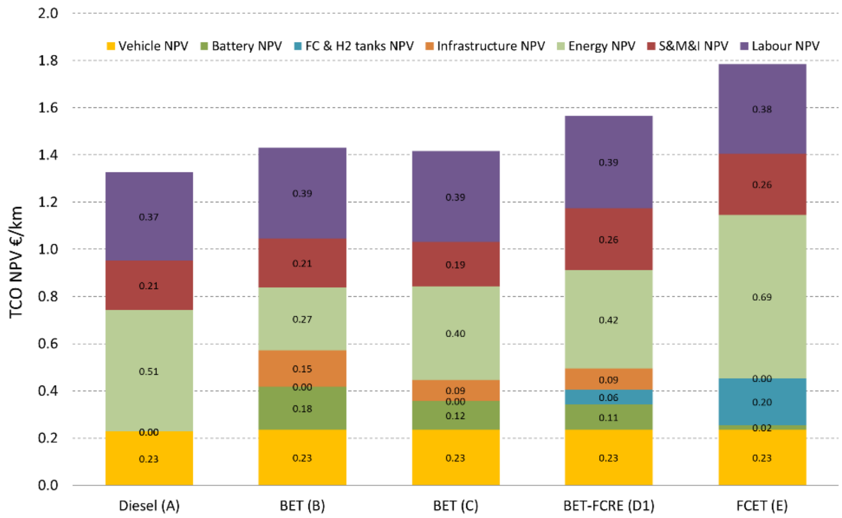

Figure 4. The estimated baseline TCO for mission pilot 2 (TR) with the different powertrain and vehicle configurations.

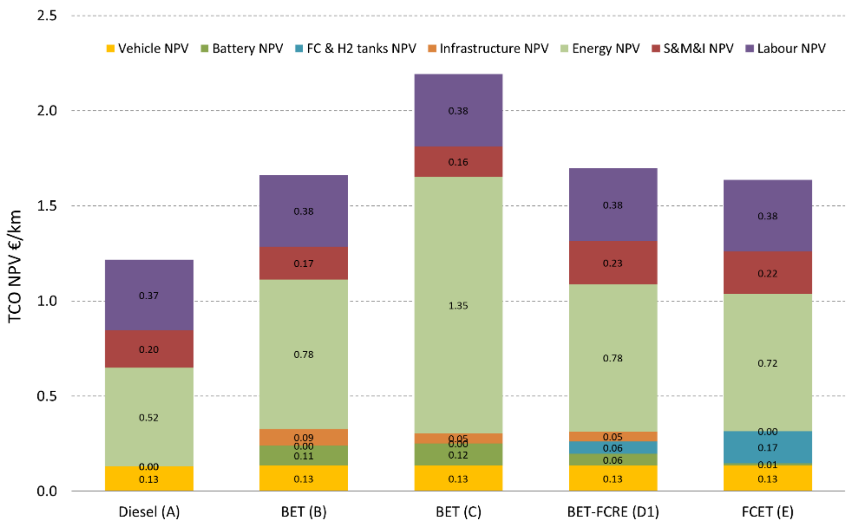

Figure 5. The estimated baseline TCO for mission pilot 4 (UK) with the different powertrain and vehicle configurations.

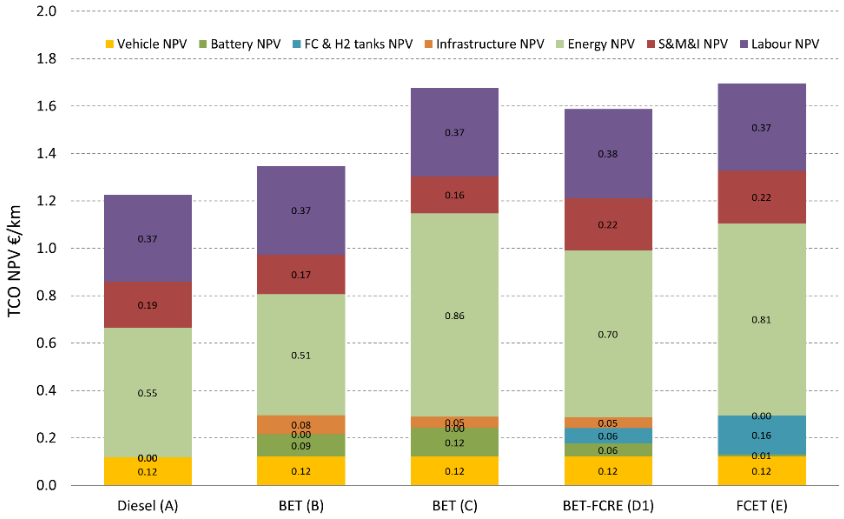

Figure 6. The estimated baseline TCO for mission pilot 5 (CH-FR-ES) with the different powertrain and vehicle configurations.

4 Discussion

The large variety of powertrain and vehicle configurations within ESCALATE showcase the variability and range of total energy consumption of the trucks on the missions analysed. The analysis presented contains several compromises as the demonstrator vehicle designs vary and include a range of base requirements and missions. Energy consumption between the prime movers is easier when converting all energy use to a single unit. Assuming a diesel energy density of 9.9 kWh/l and a hydrogen energy density of 36 kWh/kg, configuration B consumed the least energy in all cases, followed by configuration C. Both these vehicles are BEVs. Still, between configurations B and C, both being BET, quite a large difference in terms of kWh/km for the same mission can be observed, varying between 4 and 25%. The reasons behind this variation are being analysed closer.

The next lowest energy consumption comes from configuration D2, which is a fuel-cell battery hybrid that has intermediate battery charging, followed by D1 which is the same vehicle without intermediate charging. The diesel vehicle from configuration A has the highest energy consumption, followed by the fuel cell vehicle of configuration E. Though these results do not consider well-to-wheel consumption, they indicate that battery electric trucks are capable of completing long-haul driving routes with low energy consumption. In cases where intermediate charging is not available, or longer driving range is required, the BET-FCRE vehicle of configuration D1 is a promising option.

When bringing together all the high level inputs shown in the analysis towards TCO, several additional factors are highlighted. The five missions show quite different utilisations, and assuming the missions being repeated for 300 days per year the highest utilization from a single mission per day exceeds 50% when taking into account the time required for the mandatory breaks. The highest mileages during the contract period approach 1.5 million km.

Overall, BET is most often the most competitive configuration within the ZE trucks, in comparison with conventional fossil diesel. Advanced biodiesel or e-diesel was not analysed, but the sensitivity to diesel price in configuration A is clear. Of the BET variants, the configuration B with a large battery shows somewhat lower TCO except for pilot 2. The TCO for the opportunity charging BET comes with an uncertainty arising from two parts: energy consumption (higher energy consumption of configuration C compared to B came out from the simulations), and secondly the price of electricity for both private and public charging. Large differences in electricity price resulted in a range of energy cost for BET, especially when a factor of 2 was assumed for public fast charging. Almost all of the opportunity charging events during the missions was assumed to take place during the mandatory breaks. It should be noted that this will require MW charging by MCS and create the need for the CPO's to upgrade charging hubs with more powerful systems – this fact will also impede the short-term pushing down

Regarding the TCO on range-extending FC-BET and FCET, another big uncertainty comes from H_2 price. An increase of 50% from documented production price was assumed, but in reality the early market H_2 pump price for hydrogen-driven trucks is not known.

The initial results shown in this paper are still being cross-checked for inputs and assumptions at all stages of the analysis.

5 Conclusions

A range of different zero-emission truck powertrain and system implementations were analysed in terms of their powertrains, vehicular configurations and operational aspects, to cross-analyse the planned truck demonstrations in the ESCALATE project. Totally 5 different vehicle configurations operating on 4 geographically different routes in different parts of Europe were analysed. The initial results show that great variety exists in terms of powertrains, vehicle configurations, energy and infrastructure use as well as the market parameters. The relative competitiveness of the different configurations and prime mover variants depend on several factors such as the essential capital and operational costs, energy price and consumption, powertrain dimensioning and performance.

The research in the ESCALATE project continues as the demonstrator vehicles are being finalized and the actual physical pilots are rolled out later in 2025. Based on this initial baseline TCO analysis, all parts will be updated and elaborated based on the final data and operational insights. Validated results can be expected in 2026.

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