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Feasibility analysis and development of on-road charging solutions for future electric vehicles

E-Road take-up: Business model approach and other expected impacts

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1. Methodology

Steps followed by the study presented

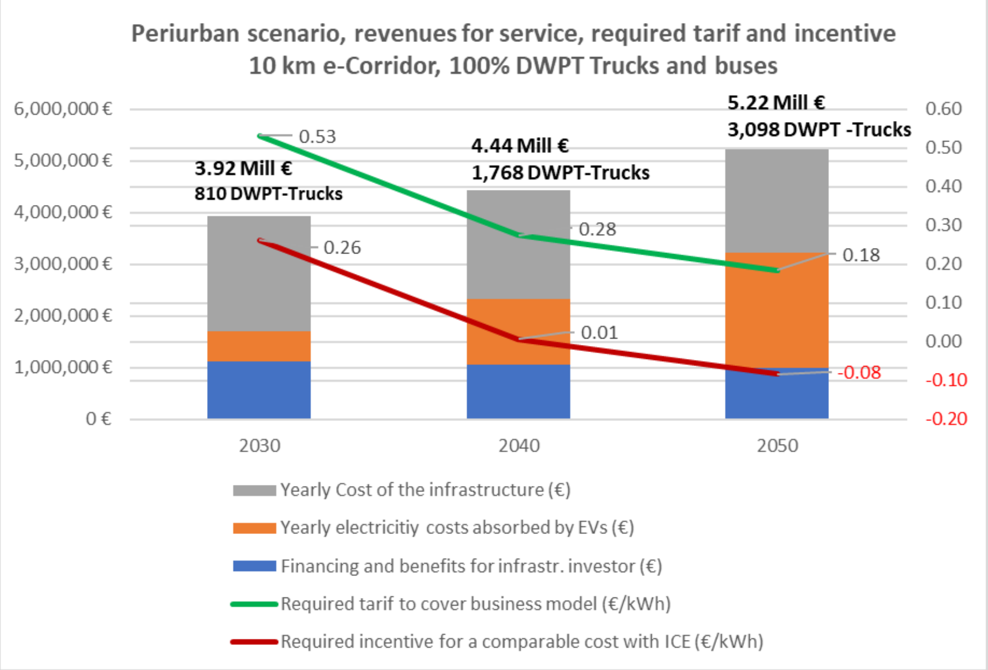
1. **PESTEL Analysis**. From 10 initial Reference Scenarios with options for wireless charging, preselection of 3 (Motorway, Periurban and Urban)
2. **Demand estimation of EVs** (light and heavy) penetration over time
3. **Demand estimation of DWPT-EVs** penetration over time based on previous point.
4. **Life Cycle Cost Analysis (LCCA).** Estimation of infrastructure costs for the three selected scenarios (CAPEX, OPEX, disposal costs and user costs during works)
5. **Business model (fix picture) from the perspective of the infrastructure owner** (Required tariff in €/kWh to cover the business model (infrastructure, electricity costs, debt and reasonable margin according to number of DWPT vehicles in years 2030, 2040 and 2050). Required incentives from governments to equal ICE consumption costs with DWPT-EV consumption costs).
6. **Business model (fix picture) from the perspective of the vehicle owner**. Comparative TCO with plug-in and ICE vehicles (costs and CO_2 emissions)
7. **Business model (fix picture) from the perspective of Administrations** (holistic vision including externalities (other benefits for citizens)
8. **Real case. Forecast** (P&L, Balance and cash flow during 20 y) to check business opportunity.
9. **Sensibility analysis** to determine strength of the business models under different parameters variations (cost of fuel, vehicle consumption, electricity costs, etc)

2. Factors taken into account (1)

- Example of Results from the perspective of the **infrastructure owner**
- **Periurban scenario**

This perspective answer the question. *Will an investor be willing to invest in an e-Road?*

IMPUT DATA	eHeavy	Units
a. E-corridor length (e-Launcher)	10	km
b. Average consumption in highways	1.5	kWh/km
c. Travel Speed	50	km/h
d. Time to cross the e-corridor	12	min
e. Charging efficiency	80%	%
f. Billable Gross Power transfer [1]	125	kW
g. Net power transfer	100	kW
h. Absorbed Electricity per charging cycle	20.00	kWh
i. Average European Industrial Electricity Price [2]	**0.08**	€/kWh [1]
j. Electricity cost per vehicle in charging event	1.58	€



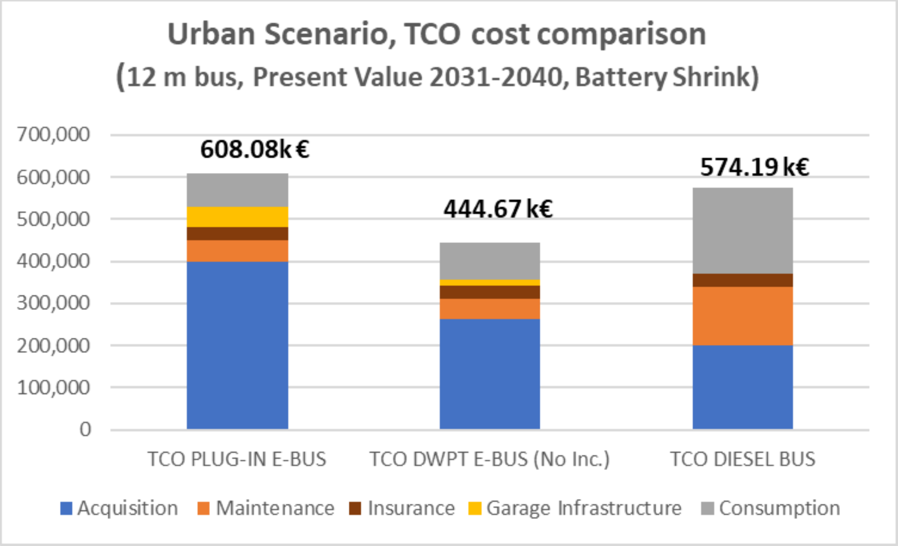
Set of variables enable to be modified in the model for the Periurban scenario

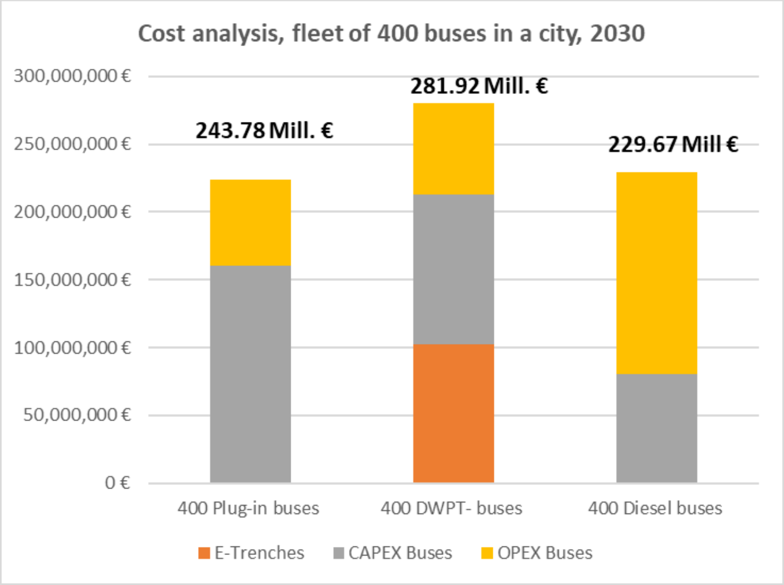
Required tariff and required incentive (subsidies) to make the business model sustainable for a given number of DWPT-HDV crossing the e-Launchers in 2030, 2040 and 2050

2. Factors taken into account (2)

- Example of results from the perspective of the **vehicle owner**
- **Urban scenario**

This perspective answer the question. *Will the end-user be willing to pay for a DWPT-EVs?*





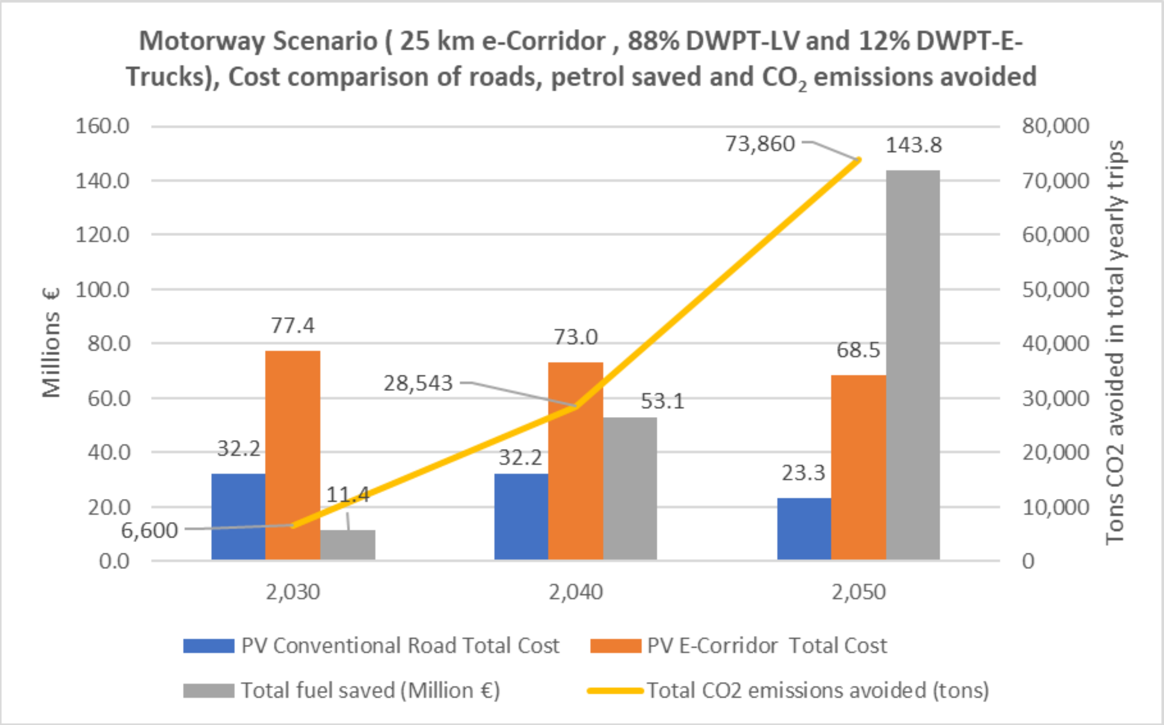
TCO Comparison of buses: Plug-In bus, DWPT-bus and Diesel bus without considering the infrastructure costs (lifetime 10 years, CAPEX and OPEX)

TCO Comparison of full service: Plug-In bus, DWPT-bus and Diesel bus including e-infrastructure costs (e-trenches, 400 buses)

2. Factors taken into account (3)

- Example of results from the perspective of the **Administration**
- **Motorway scenario**

Question:
Should the administration promote and incentivize dynamic charging technology?



In the motorway scenario, there should be a subsidy to reduce the tariff charged to users till 2050, however the CO_2 gaining and the petrol saved is huge in case of technology adoption, compared to ICE

3. Motorway scenario – Main Results

MOTORWAY SCENARIO (E-Corridors)		
Basic Conditions	**Desirable Conditions**	**Main limitations (threats)**
* 25 km length (in both directions) in the most crowded motorways	* Static charging must be standard among users	* Ultra-chargers above 150 kW are fully deployed in electric stations in motorways
*Between two spots at about 400 to 600 km and providing a range extension of 10% to 20%. Average speed 100 km/h EV and 80 km/h HDV	* Autonomous driving must be a standard	* Battery autonomy reaches 800 km or above for EVs at affordable cost
* For DWPT-EV (88%) and DWPT-HDV (12%) vehicles. A critical mass of daily traffic is needed, 8,200 DWPT-EV and 1.,129 DWPT-HDV (2050) to make the business model sustainable.	* A minimum of net 50 kW power transfer for DWPT-EV and net 100 KW for DWPT-HDV	* Risk of no incentives provided by authorities in the ramp-up process. (Required incentive 0.99 €/kWh for EVs and 0.62 €/kWh for HDV in 2030)
Probability of Occurrence	**Time to market**	**Costs Summary**
* Around 25% *Conventional users are very sensitive to prices and afraid of their health	* From 2050 onward *There won't be enough EVs on road to justify the investment till 2,050.	*6.3 M € (2030), 7.5 M€ (2040), 10.2 M€(2050) per 25 km E-Corridor lane to cover costs and investor margin * Required tariff (2030, 2040, 2050), (1.16, 0.31,0.17) €/kWh

4. Periurban scenario – Main Results

PERIURBAN SCENARIO (E-Launchers)		
Basic Conditions	**Desirable Conditions**	**Main limitations (threats)**
*10 km length e-Launcher for DWPT-Trucks and DWPT-Buses (both DWPT-HDV) in areas with high density traffic, from periurban logistic centers, ports, etc. to the city center or among close cities (intercity buses)	* Static charging and autonomous driving to be standard among users	* Ultra-chargers above 350 kW are fully deployed in electric stations in periurban highways
*100% DWPT-HDV making a daily distance of around 250 km (some iterations) and getting a range extension of 5%. Average speed 60km/h	* Pre-agreements between owners of large HDV fleets and infrastructure owners to ensure a daily traffic	* Battery autonomy reaches 800 km or above for e-HDVs at affordable cost
Over 1,750 DWPT-HDV charging daily are required to make the system sustainable (no incentives required)	* A minimum of net 100 KW power transfer for DWPT-HDV	* No incentives are provided by authorities in the ramp-up process. (Required incentive 0.26 €/kWh for DWPT-HDV in 2030)
Probability of Occurrence	**Time to market**	**Costs Summary**
* Around 50%	* From 2040 onward	*Required tariff (2030, 2040, 2050), (0.53, 0.28, 0.18) €/kWh
* ICE-HDV are very pollutant and Diesel consumption is high. There is an option to cleaning the periurban highways	*Demand estimations indicates that specific areas in the periurban shows a great volume of HDVs	*3.9 M € (2030), 4.4 M€ (2040), 5.2 M€(2050) per 10 km E-Launcher lane (Required incomes for investor)

5. Urban bus scenario – Main Results

URBAN SCENARIO (E-Trenches)		
Basic Conditions	**Desirable Conditions**	**Main limitations (threats)**
The complete bus service in a given city must be adapted to DWPT, maximizing the number of buses charging daily. The study was done for a service of 400 buses and 40 lines.	*The city must adopt the DWPT infrastructure. No way to progressive adoption as a critical mass of charging events is needed and all bus stops must be simultaneously adapted.	* Ultra-chargers above 350 kW are fully deployed in electric stations in periurban highways
The strategy in this case is battery shrink, reducing the battery size to the maximum and using e-trenches in each bus stops for the additional range extension.	* Pre-agreements between owners of large HDV fleets and infrastructure owners to ensure a daily traffic	* Battery autonomy reaches 800 km or above for e-Buses at affordable cost.
There are 972 bus stops in the city. Each bus makes 18 round trips. The length of the e-trenches is 25 m combining static and dynamic charging during stops.	* A minimum of net 100 KW power transfer for DWPT-Buses	* Static power transfer spots could be the main competing alternative at the end of the round trips
Probability of Occurrence	**Desirable Conditions**	**Costs Summary**
* Around 75%	* From 2030 onward	Required tariff for 2030 onward is 0.15 €/kWh.
* ICE-Buses are very pollutant and Diesel consumption is high. Plug-In buses emit much more CO_2 if we consider the whole life cycle. There is an option to cleaning the urban air.	The TCO for the DWPT-buses is the lowest although a complete view including the e-infrastructure, makes this option as the most expensive although costs savings are possible	3.9 M € (2030), 4.4 M€ (2040), 5.2 M€(2050) per 10 km E-Launcher lane (Required incomes for investor)

6. Main software results

DEVELOPED SOFTWARE	RESULTS
1. Life Cycle Cost Analysis (Motorway, Periurban and Urban)	• Net Present Value of all costs associated to installation, operation and maintenance of an e-Corridor, e-Launcher and e-city trenches (CAPEX, OPEX)
2. Business Model for the three scenarios from perspective of infrastructure owner (after CANVAS). “Fix picture”.	• Minimum tariff needed to cover infrastructure costs, electric consumption costs, debt and reasonable margin in 2030, 2040 and 2050 • Required incentive (subsidy) from government in the ramp-up process until a critical mass of DWPT-EVs will be operative (depending on demand forecast)
3. Business model from the perspective of the DWPT-EV owner	• TCO Comparison between plug-in EV, ICE and DWPT for the three scenarios
4. Real Case. Forecast P&L, balance, free cash Flow and main ratios	• The “fix picture” of software “point 2” is now analysed making the economic forecasts for each scenario
5. Simulations with Business models from perspectives of infrastructure owner and vehicle owner	• System model very sensible to variations of different parameters introducing positive or negative effects. High risk

7. Dominant patterns found in simulations

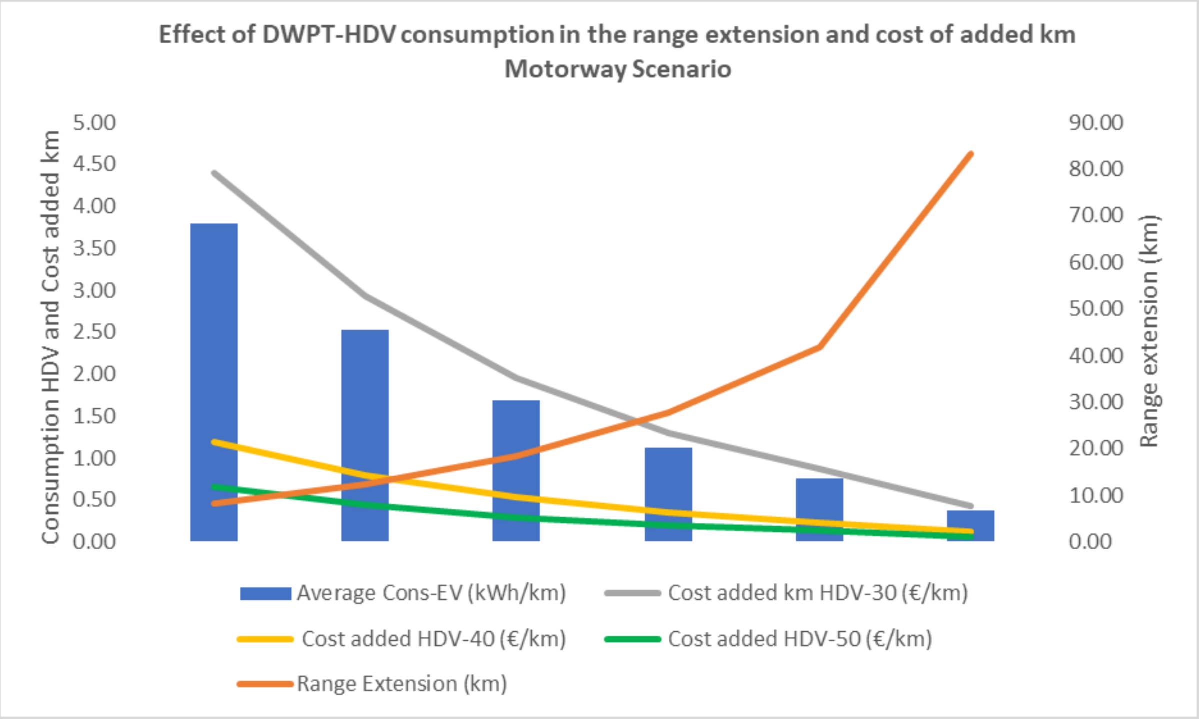
Many simulation exercises has been carry out from all the perspectives

Results: any modification in the reference conditions highly modifies the business opportunity (positive or negative)

Affecting factors:

- ✓ Electricity costs
- ✓ Fuel costs
- ✓ Ultra-chargers costs and deployment speed
- ✓ Battery autonomy
- ✓ Vehicle consumption
- ✓ Infrastructure costs (specially OPEX)
- ✓ DWPT Equipment cost on board, etc.

Example of impacts of HDV consumption in the range extension and cost of added km



8. Conclusions

- **Time to market** for the three scenarios is not the same. First entry point will be likely the urban scenario in 2030, then the Periurban in 2040 and finally the Motorway in 2050.
- T**echnology breakthroughs** need to be solved:
  - increasing the power transfer (from 20kW to 50 kW),
  - shielding of vehicles against EMF/EMC
  - adapt static regulation standards to dynamic.
- This **technology is expensive** and only in specific market niches (like urban buses) it will have sufficient options
- The **technology ramp-up will highly depend on the evolution of the competing technologies** like the fast deployment of ultra-chargers or the disruptive increase in battery autonomy.
- The **involvement of the Administrations** in promotion of DWPT is a key factor to overcome the "valley of death" as the adoption of the technology by the end-users will not be possible until a sufficient number of e-Roads will be operative (chicken and egg problem) and subsidies are required.
- Simulations demonstrate that **range extension can be affected by many factors** (increase in vehicle consumption, increase in speed, dealignment, low power transfer efficiency…) jeopardizing the supposed advantages.

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Thank you!

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