FABRIC

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

Analysis of deployment scenarios, standardisation and harmonisation

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LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
BEV	Battery Electric Vehicle
CAPEX	Capital Expenditure
DoW	Description of Work
DPT	Dynamic Power Transfer (conductive or wireless)
DWPT	Dynamic Wireless Power Transfer
DWPT-EV or HDV	Light vehicle or heavy vehicle equipped with the DWPT system on board
Dx.x.x	Deliverable x.x.x
E-CORRIDOR	Dynamic charging corridor in a motorway (25 km length)
E-LAUNCHER	Dynamic charging corridor in a motorway in the periurban area (10 km)
E-TRENCHES	Small dynamic and static charging installations at bus stops (25 m length)
E-ROAD	General meaning for any type of dynamic charging system
E-LANE	A specific lane of the motorway equipped for dynamic charging (in opposition to dedicated lane (external to the motorway)
EV	Electric Vehicle
EMF	Electromagnetic fields
EMC	Electromagnetic compatibility
EMI	Electromagnetic interference
HDV	Heavy Duty Vehicle
ICT	Information and Communication Technologies
OPEX	Operating Expenses
RES	Renewable Energies
SP	Sub Project
TCO	Total Cost of Ownership
WPT	Wireless Power Transfer (generally referred to static /stationary charging)

REVISION CHART AND HISTORY LOG

REV	DATE	REASON
V1	25/5/18	Template and work distribution
V2	5/6/18	Draft section of standards
V3	15/6/18	Introduction of dynamic standards (CIRCE)
V4	16/6/18	First draft simulation section (QiE)
V5	17/6/18	Last section (summary) by KTH
V6	18/6/18	Draft complete for internal revision
V7	19/6/18	Peer review
V8	20/6/18	Final Draft for submission
V9	14/2/19	Final version revised after EC review

EXECUTIVE SUMMARY

The aim of FABRIC project was to evaluate the feasibility and analyse the impacts from the large-scale deployment of dynamic wireless power transfer (DWPT) solutions. After an exhaustive analysis, the result is that the potential investment in this technology incorporates a high risk. Main reasons are:

- **New product:** equipment for dynamic transfer of energy from the pavement to an EV
- **New technology:** still pending development for the most recommended power transfer
- **New market:** the potential customers are still unaware of the technology)

The result of previous analyses identified three potential market niches that may occur with certain probability at different times. These three scenarios are:

1. **Motorway Scenario**. Dedicated external lanes (e-Corridors) of 25 km length (in both directions) for light and heavy electric-vehicles.
2. **Periurban Scenario**. Dedicated external lanes (e-Launchers) of 10 km length for dynamic charging of heavy vehicles and buses in areas with high density traffic, from periurban logistic centres, ports, etc. to the city centre or among close cities (intercity buses).
3. **Urban Scenario**. Likely to be the first entry point by using the bus stops as static/dynamic charging points. At each stop, 25 m for dynamic charging (e-Trenches).

The document performs an exhaustive sensitivity analysis on the results of the "still picture" that was identified in previous works to determine how different variables can affect each of the scenarios.

The main conclusion of these studies is that the technology still needs trials and substantial advances in several aspects. Besides, the introduction in the market depends on many conditions (including threats and opportunities) that must occur simultaneously.

In general terms, we can indicate that main enabling technologies for DWPT are wireless static charging and autonomous driving, which should be market standard before DWPT can be scaled up massively. As demonstrated in the project, transfer efficiency is a key parameter for the introduction of DWPT, which calls for best possible alignment, something that can only happen when the vehicle circulates autonomously.

The **motorway scenario** will be the last to occur (starting in year 2050) and will do so with a low percentage of probabilities, basically because a critical mass of DWPT-ready vehicles is required. Another reason is the chicken and egg effect, since the lack of infrastructure will discourage potential buyers of DWPT vehicles whose costs will be higher than those of conventional electric. The great threat that looms over the technology is the development of ultra-chargers above 150 kW capacity or that the autonomy of batteries reaches the figures of ICE vehicles (around 1.000 km).

The **periurban scenario** is more likely to occur and to do so from 2040. The conditions are more favourable because on periurban highways the average speed is lower (estimated at 60 km/h instead of 100 km/h of national motorways). Circulation speed in e-corridors is critical for the amount of energy transferred. In addition, there is usually a high number of heavy vehicles commutating between peripheral logistics areas and city centres. For this scenario to occur, it would be necessary obtain a critical mass of vehicles by signing pre-agreements between entrepreneurs with large fleets of heavy vehicles and owners of electric corridors.

Finally, the **urban bus scenario** might be the first entry point estimated for the year 2030. The most important reason for this is that vehicles battery can be reduced dramatically, which reduces the cost of the bus. Secondly, the bus remains relatively long time close to bus stops, which enables high energy transfer in small stretches of e-Trenches. Customers are guaranteed, since it is the whole public bus service and the size of the bus allows much better shielding of high frequency emissions and increase the power transfer protecting the users, and finally, the bus lane is already a restricted space easily adaptable for e-Trenches. Simulations of this scenario have shown that the TCO of the DWPT bus is significantly lower than the rest of the competitors (pure electric bus and ICE bus). However, if we analyse the problem from a global perspective, the cost of DWPT infrastructure in the city makes the system still the most expensive, especially if we do not consider externalities, for example, particulate or CO_2 emissions of conventional buses. The analysis of the life cycle of 100% electric buses also shows that their global emissions are also much higher if we consider the manufacture and recycling of large high-power batteries. Therefore, the urban scenario can happen with a high probability.

The document has also presented a simulation study seen from the eyes of the owner of a DWPT-ready vehicle. In all cases, except for the urban bus, TCO is the highest compared to the other options. The criterion of the owner will be to adapt or buy the vehicle only in the case of having

nearby charging infrastructure and will always seek the maximum extension of autonomy to save inconvenience.

The restrictions that are imposed on ICE vehicles due to pollution episodes and the perception that the extension of the autonomy of conventional batteries has a limit and that ultra-fast charging is not simple or cheap, will facilitate the entry of this technology, although with a low probability of happening and always with the help of subsidies (incentives) till a critical mass of DWPT-EVs will be reached. The price of oil is another important factor to make the leap to the electric vehicle and later to DWPT.

The document ends with a review of the integrating efforts that are being carried out in relation to the regulations for the interoperability of the static charge and the detection of additional needs to subsequently adapt this regulation to the dynamic charging. The additional problems that dynamic charging will introduce in the regulations are related to:

- Communications at the speed of transit (latency problems),
- Transition from current 20 kW to 50 kW in light vehicles and from 50 kW to 100 kW for heavy vehicles and the expected impact on the occupants
- Introduction of variable speed (not contemplated in the static charging)
- Introduction of asymmetric system concepts between the primary and secondary coil on board to increase the tolerances due to misalignment
- Increase of the air-gap tolerances
- Development of better shielding systems on board which can generate conflicts with the manufacturers, since long coils would be needed on board (which generates space restrictions) and small coils in the pavement.

1. INTRODUCTION

The aim of FABRIC project was to evaluate the feasibility and analyse impacts from the large-scale deployment of dynamic wireless power transfer (DWPT) solutions. The aim of the work presented in this document is to use a series of holistic approaches to assess the long-term implementation and operation of on-road charging systems in urban and extra-urban areas. Each of these assessments builds on the technological development in FABRIC Subprojects (2 and 3) and especially on the results of the technological evaluation Subproject (4). Potential business model canvasses for the on-road charging solutions tested are delivered. Deployment in this work has a business and market dimension in which availability of competences and market ordering through existing and potential positions of parties is of crucial influence on the deployment. The work presented in this report includes the deployment scenario dimension and addresses also the dimension of standardisation and harmonisation that will influence whether there will be one joint future in deployment of charging solutions. Given the nature of the work presented here, stakeholder workgroups were formed who actively participated in each of the tasks. The stakeholders include not only the consortium partners, but also the reference group of FABRIC and other stakeholders related to on-road charging.

This report is divided in three main blocks of information, with a dedicated chapter each:

Chapter 2. Deployment Scenarios analysis

D5.5.2 transmitted a fixed picture of the potential business conditions in three specific market niches called “motorway scenario”, “periurban scenario” and “urban bus scenario”. These “pictures” where sustained under several assumptions, also fixed, which can evolve in different ways which are necessarily also uncertain. The exercise presented in this report has been to simulate such variables in different conditions and see how the program react to them (sensitivity analysis). A Profit and Losses account, balance sheet and cash flow has been also prepared for each market niche to determine potential profits for the EV-mobility operators.

Chapter 3. Standardization, harmonization and innovation in the transition from WPT to DWPT

The ultimate deployment blocker of on-road charging would be that the car driver needs different tools and actions for every piece of on-road charging technology he may encounter when travelling throughout Europe. However, full standardisation and mandatory harmonisation in this developing domain will hinder innovation in the market too. This task will produce a report on how

to best handle these aspects in a way that would facilitate the deployment of on-road charging in Europe. The report will review all the multilateral organizations facing the wireless technologies in transport and will identify the missing standards in the transition from static to dynamic wireless charging.

A procedure for electric energy transfer from grid to vehicle (G2V) basically includes:

- The power transfer from the grid energy source to the vehicle on board energy storage through an Electric Vehicle Supply Equipment (EVSE)
- The Vehicle-to-Grid Communication Interface (V2G CI) which involves:
    - The Electric Vehicle Communication Controller (EVCC).
    - The Supply Equipment Communication Controller (SECC).

The prescriptions for the power transfer need to be standardized, for the Wireless Power Transfer systems, in order to assure:

- The safety with respect to persons and to electric-electronic apparatuses.
- The interoperability of the system elements for a general use.

And to establish:

- The procedure to be followed for the approach to charging spot and for the operation.
- The human-machine interface system and the prescription for use.
- The protocols for communications.
- The management of the system Vehicle - User- Infrastructure.

Chapter 4. Main FABRIC conclusions

Finally, main project conclusions will be added at the end of the document.

2. DEPLOYMENT SCENARIOS ANALYSIS

2.1 Economic Projections

In FABRIC deliverable D5.5.2, a "fixed picture" was taken to estimate the business model associated to the three scenarios identified with certain options to be deployed in the market ahead of 2030. The information was given for three specific moments (2030, 2040 and 2050) and represent the point of view of the **investor (infrastructure owner and operator of the installation)**.

The three scenarios where:

1. **Motorway Scenario**. In 2030, we can expect dedicated external lanes (e-Corridors) of 25 km length (in both directions) for light and heavy electric-vehicles dynamic charging in the most crowded motorways (gaining travel time) between two spots at about 400 to 600 km and providing a range extension of 10% to 20%. The TEN-T infrastructure (larger motorways with 3 to 4 lanes per direction) will be the most appropriate for the e-Corridors set up.
2. **Periurban Scenario**. Dynamic charging of heavy vehicles and buses in areas with high density traffic, from periurban logistic centres, ports, etc. to the city centre or among close cities (intercity buses) travelling a daily distance of around 250 km with e-Corridors of 10 km length.
3. **Urban Bus Scenario**. Likely to be the first entry point in 2030 by using the bus stops as static charging points and some trenches ahead each of 25 m length for dynamic charging (e-Trenches). Cities with trolley lanes will be easily adaptable for dynamic charging if the number of e-buses is sufficient to justify the infrastructure investment.

In addition, from the **point of view of the EV owner**, an estimation was done to evaluate the TCO (Total Cost of Ownership) of the different DWPT-Vehicles comparing them with some other equivalent using gasoline, diesel or being pure electric (BEV).

Finally, some additional externalities affecting the business opportunity were considered including them within the **wider vision of the administrations** which should take investment and promotion decisions.

The complete details of these visions and scenarios are included in D5.5.2, however we will include also here the main table to be used as reference to understand further explanations.

We have organised the current chapter structure for the three scenarios according to the following structure:

- View point of investor (Forecast P&L, balance, cash flow and main ratios)
- View point of EV owner (sensitivity analysis modifying some parameters)
- View point of Administrations (sensitivity analysis modifying some key parameters)

2.2 Motorway Scenario

The assumptions for the calculations in the motorway scenario are summarised below:

Assumption Business Model (Income)			
IMPUT DATA	EV	eHeavy	Units
a. E-corridor length	25		km
b. Average consumption on highways	0.25	1.5	kWh/km
c. Travel Speed	100	80	km/h
d. Time to cross the e-corridor	15	18.75	min
e. Charging efficiency	80%	80%	%
f. Power transfer	62.5	125	kW
g. Billable power charged	50	100	kW
h. Absorbed Electricity per charging cycle	12.50	31.25	kWh
i. Industrial Elect. Price	**0.08**	**0.08**	€/kWh
j. Electricity cost /vehicle in charging event (household	1.00	2.50	€

[1] We call "billable" the gross power transfer because although in the invoice the user willl see the net energy transferred, he will pay for the gross energy transferred among other concepts

[2] The industrial owner of the e-Road will be charged with the industrial tariff in those kWh transferred to users

Table 1. Assumption for the business model.

Assumption P&L Statement	
Items	
Taxes	25%
Interest rate	5%
Electricity Price Light Veh	0.17
Electricity Price Heavy	0.27

Table 2. Assumptions for the P&L statements

Assumption Balance sheet	
Items	
Loan	70%
Equity	30%

Table 3. Assumptions for balance sheet.

All these parameters can be modified, and the program recalculate all the outputs.

2.2.1 *Investor point of view (Motorway Scenario)*

Below, we add as a reference, the same table as used in D5.5.2 to clarify the business opportunity in the Motorway scenario. This scenario was the last to enter in our view and will require and strong economic support from the Administrations and promotion actions to speed up the introduction of the DWPT technology among users. As mentioned in D5.5.2, there are high risks associated to this scenario mainly represented by the "chicken and egg problem" and the competing technologies as the high range batteries or the ultra-chargers (above 150 kW).

MOTORWAY BUSINESS MODEL				EV	2031	eHeavy	EV	2040	eHeavy	EV	2050	eHeavy
				88%	Both	12%	88%	Both	12%	88%	Both	12%
1. Total amount of vehicles charging e-corr. per day	*Demand est.		Veh/day		880			3,688			9,331	
2. Amount of vehicles split in class	[1]*88%-[1]*12%		Veh/day	832		49	3,345		342	8,211		1,120
3. Daily billable absorbed electricity of charging traffic in kWh	[h]*[2]/[e]		kWh/day	12,994		1,898	52,272		13,365	128,304		34,992
4. Electricity cost for daily traffic	[i]*[3]		€/day	**1,040 €**		**152 €**	**4,182 €**		**1,069 €**	**10,264 €**		**3,499 €**
5. Yearly electricity cost	[4]*365		€/year	379,418 €		55,434 €	1,526,342 €		390,258 €	3,746,477 €		1,277,208 €
6. Total yearly electricity costs	[5a]+[5b]		€/year elec		434,852 €			1,916,600 €			5,023,685 €	
7. Yearly Cost of the infrastructure	*Cost Infrastruct		€/year infr		3,904,057 €			3,700,203 €			3,496,349 €	
8. Total equilibrium point (electricity +infrastructure)	[6]+[7]		€/year		4,338,909 €			5,616,804 €			8,520,034 €	
9. 50 % financing and benefits for infrastr. investor	50%*[8]	50%	€/year		1,952,029 €			1,850,102 €			1,748,175 €	
10. TOTAL REQUIRED INCOMES BUSINESS MODEL	**[8]+[9]**		**€/year**		**6,290,938 €**			**7,466,905 €**			**10,268,209 €**	
11. Required tariff to cover business model	[10]/([3a]+[3b])*365)		**€/kWh tariff**		**1.16**			**0.31**			**0.17**	
12. Electricity price	[i]		€/kwh elec	0.08		0.08	0.08		0.08	0.08		0.08
13. Cost Surplus needed to cover the business model	[11]-[12]		€/kWh fee	1.08		1.08	0.23		0.23	0.09		0.09
14. Absorbed Electricity per charging cycle	[h]*[2]		kWh/EV	12.50		31.25	12.50		31.25	12.50		31.25
15. Average consumption on highways	[b]		kWh/km	0.25		1.50	0.25		1.50	0.25		1.50
16. Autonomy range extension	[14]/[15]		km	50.00		20.83	50.00		20.83	50.00		20.83
17. Cost of charging event for drivers to cover business model	[14]*[11]		€/charge	**14.47**		**36.17**	**3.90**		**9.74**	**2.15**		**5.38**
18. Cost added km	[17]/[16]		€/km	**0.29**		**1.74**	**0.08**		**0.47**	**0.04**		**0.26**
Cost of Consumption compared with ICE during extended range												
19. Equival cost/km of gasoline (1,20 €/l)/gasoil (1,2€/l)	[3.5]*[1.2]/100	1.20	€/km	**0.04**		**0.40**	**0.04**		**0.40**	**0.04**		**0.40**
20. Cost differences between fuel and electricty [1]	[19]-[18]	1.15	€/km	**-0.25**		**-1.33**	**-0.04**		**-0.07**	**-0.00**		**0.14**
21. Total savings in the extended autonomy	[20]*[16]		€	**-12.37**		**-27.78**	**-1.80**		**-1.35**	**-0.05**		**3.00**
22. Required incentive for a comparable cost to ICE [2]	**[11]-([19]*[16]/[14])**		€/kwh elec	**0.99**		**0.89**	**0.14**		**0.04**	**0.00**		**-0.10**
21. Min. electricity prices for a sustanable business model in the motorway sc.			€/kwh elec	**0.17**		**0.27**	**0.17**		**0.27**	**0.17**		**0.27**

Table 4. "Fixed Picture" for the Business Model of the Motorway Scenario.

Although this table was included in deliverable D552 “Cost-benefit analysis and business models of large-scale deployment of on-road charging” we add here the explanation to interpreter the information.

The above table compares in three specific moments; 2031, 2040 and 2050 different key parameters; in one hand, according to the number of vehicles equipped with DWPT system on board (lines 1) derived from the demand estimation (table 7) and considering 88% of light vehicles and 12% of heavy vehicles (lines 2), the *required tariff to cover the business model* (line 11). This has been calculated through lines 3 to 10. The required income to cover the business model represents the necessary incomes for the e-Road owner to guaranty the solvency of the investment. It includes, the payment of the electricity consumed by the e-Road users, the payment of the works down (annual depreciation), and an extra percentage (in the example an additional 50%) over the sum up of the previous two concepts (equilibrium point). This figure reaches €6,29 Million in 2031. Then, we divide this figure by the yearly absorbed electricity (light and heavy vehicles) and we reach the *required tariff to cover the business model*. This is the €/kwh that you need to charge to every driver if you want to recover your investment. In the other hand, line 17 brings the Cost of one charging event considering the business model. This parameter represents how much you should pay when you transit the full 25 km e-Corridor. If you are a light vehicle, in 2031 you should pay 14,47 € and you get by this money only a range extension of 50 km (line 16), that means that you pay 0,29 €/ extended km. Then we introduce the cost of an equivalent gasoline vehicle with an average consumption of 0,04 €/km (line 19). Thus, if you rest both figures, you obtain a surplus of 0,25 €/km when using the DWPT system. For the full 25 km e-Road, you pay an additional 12,37 € than if you were driving with a gasoline vehicle. This high figure is due to the fact, that the number of DVPT EV vehicles using the e-Road in 2031 is very limited, so the depreciation of the investment costs done among so few numbers of vehicles if very high. That is the reason why we need a governmental incentive to compensate in the ramp up process the high initial cost. This incentive is calculated in line 22 (0,99 €/ kW charged). If we move now to 2050, with a total number of DWPT vehicles of 9.331. we see that in these conditions, no governmental incentive is required.

We must pinpoint that the calculations consider an increase in costs of 50% to cover financial expenses and the high expected margin for the infrastructure investor because of the high risk of the operation. These figures could be reduced or increased depending on the investor profile, project debt and the expected margin acceptable for the investor.

2.2.1.1 Main Economic Results (P&L, Balance, Free Cash Flow and Ratios)

Based on these assumptions, a P&L table, balance, free cash flow and main economic ratios, were prepared to visualize the evolution of the business opportunity over time.

PROFIT AND LOSSES. MOTORWAY																						
Items	**%**	**Total**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**	**2046**	**2047**	**2048**	**2049**	**2050**
Net Income from Users			996.444	1.177.128	1.391.427	1.645.786	1.947.925	2.307.104	2.734.440	3.243.286	3.849.709	4.573.045	5.044.731	5.566.025	6.053.318	6.553.677	7.096.945	7.686.915	8.327.723	9.023.880	9.780.305	10.268.209
Net Income from Government			5.294.493	5.234.744	5.143.704	5.014.975	4.840.879	4.612.205	4.317.884	3.944.608	3.476.363	2.893.860	2.663.879	2.392.113	2.162.425	1.928.011	1.659.295	1.352.765	1.004.572	610.503	165.943	0
TOTAL INCOMES MOTORWAY		**157.981.245**	6.290.938	6.411.872	6.535.132	6.660.760	6.788.804	6.919.310	7.052.324	7.187.895	7.326.072	7.466.905	7.708.610	7.958.138	8.215.743	8.481.687	8.756.240	9.039.680	9.332.295	9.634.382	9.946.248	10.268.209
Inflaction Rate	**1,50%**	**185.039.140**	6.290.938	6.508.051	6.732.656	6.965.013	7.205.389	7.454.061	7.711.316	7.977.448	8.252.766	8.537.585	8.946.156	9.374.280	9.822.892	10.292.972	10.785.549	11.301.698	11.842.548	12.409.280	13.003.134	13.625.407
Growth rate %			-	1,89%	1,89%	1,89%	1,89%	1,89%	1,89%	1,89%	1,89%	1,89%	3,14%	3,14%	3,14%	3,14%	3,14%	3,14%	3,14%	3,14%	3,14%	3,14%
R + D costs		**1.111.111**	**1.111.111**																			
Operating Costs		**9.987.896**	**505.013**	**504.521**	**504.030**	**503.539**	**503.048**	**501.910**	**501.420**	**500.931**	**500.443**	**499.955**	**498.819**	**498.332**	**497.845**	**497.359**	**496.873**	**495.740**	**495.255**	**494.771**	**494.287**	**493.804**
Labour	0,10%	8.023.510	405.000	404.595	404.190	403.786	403.382	402.979	402.576	402.173	401.771	401.370	400.968	400.567	400.167	399.766	399.367	398.967	398.568	398.170	397.772	397.374
Consumable	0,10%	713.201	36.000	35.964	35.928	35.892	35.856	35.820	35.785	35.749	35.713	35.677	35.642	35.606	35.570	35.535	35.499	35.464	35.428	35.393	35.357	35.322
Depreciation Operation Equipment		239.760	12.960	12.960	12.960	12.960	12.960	12.312	12.312	12.312	12.312	12.312	11.664	11.664	11.664	11.664	11.664	11.016	11.016	11.016	11.016	11.016
Labour Overtime and outsource	0,10%	902.199	45.540	45.494	45.449	45.404	45.358	45.313	45.267	45.222	45.177	45.132	45.087	45.042	44.997	44.952	44.907	44.862	44.817	44.772	44.727	44.682
Other Operating Costs	0,10%	109.227	5.513	5.508	5.502	5.497	5.491	5.486	5.480	5.475	5.469	5.464	5.459	5.453	5.448	5.442	5.437	5.431	5.426	5.420	5.415	5.410
Maintenance Costs		**1.613.750**	**82.231**	**82.067**	**81.903**	**81.739**	**81.575**	**81.412**	**81.249**	**81.087**	**80.925**	**80.763**	**80.601**	**80.440**	**80.279**	**80.119**	**79.959**	**79.799**	**79.639**	**79.480**	**79.321**	**79.162**
Preventive maintenance	0,20%	1.254.907	63.946	63.818	63.690	63.563	63.436	63.309	63.182	63.056	62.930	62.804	62.678	62.553	62.428	62.303	62.178	62.054	61.930	61.806	61.683	61.559
Corrective maintenance	0,20%	358.843	18.285	18.249	18.212	18.176	18.140	18.103	18.067	18.031	17.995	17.959	17.923	17.887	17.851	17.816	17.780	17.744	17.709	17.674	17.638	17.603
Renewal costs		**37.735**	**0**	**0**	**0**	**0**	**0**	**2.560**	**2.554**	**2.547**	**2.541**	**2.534**	**2.528**	**2.522**	**2.516**	**2.509**	**2.503**	**2.497**	**2.490**	**2.484**	**2.478**	**2.472**
Refurbishment	0,25%	37.735						2.560	2.554	2.547	2.541	2.534	2.528	2.522	2.516	2.509	2.503	2.497	2.490	2.484	2.478	2.472
Disposal Costs		**-20.196**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-20.196**
Cost of asset disposal		864.864																				864.864
Residual value		-885.060																				-885.060
COSTS OF SALES		**12.730.296**	1.698.356	586.588	585.932	585.278	584.624	585.882	585.223	584.565	583.908	583.252	581.948	581.294	580.640	579.987	579.335	578.035	577.385	576.735	576.086	555.242
Inflation Rate	**1,50%**	**14.534.310**	1.698.356	595.387	603.642	612.012	620.498	631.162	639.909	648.777	657.768	666.884	675.375	684.734	694.224	703.845	713.599	722.678	732.693	742.846	753.141	736.779
EBITDA		**170.504.831**	**4.592.582**	**5.912.664**	**6.129.014**	**6.353.001**	**6.584.891**	**6.822.900**	**7.071.407**	**7.328.671**	**7.594.997**	**7.870.700**	**8.270.781**	**8.689.545**	**9.128.668**	**9.589.128**	**10.071.950**	**10.579.020**	**11.109.855**	**11.666.434**	**12.249.994**	**12.888.629**
Depreciation CAPEX		60.785.464	1.974.143	1.974.143	1.974.143	1.974.143	1.974.143	2.502.479	2.502.479	2.502.479	2.502.479	2.502.479	3.603.875	3.603.875	3.603.875	3.603.875	3.603.875	4.076.596	4.076.596	4.076.596	4.076.596	4.076.596
EBIT		**109.719.367**	**2.618.439**	**3.938.520**	**4.154.871**	**4.378.858**	**4.610.748**	**4.320.421**	**4.568.928**	**4.826.192**	**5.092.518**	**5.368.221**	**4.666.907**	**5.085.671**	**5.524.794**	**5.985.253**	**6.468.076**	**6.502.424**	**7.033.259**	**7.589.838**	**8.173.397**	**8.812.033**
Financial Expences		18.129.543	1.312.805	1.251.971	1.190.672	1.157.231	893.601	1.124.559	1.035.030	929.311	826.261	726.485	1.225.211	1.113.073	974.612	841.193	713.704	808.671	683.884	556.711	437.555	327.001
Earning Before Tax		**91.589.824**	**1.305.634**	**2.686.549**	**2.964.199**	**3.221.627**	**3.717.147**	**3.195.862**	**3.533.898**	**3.896.881**	**4.266.257**	**4.641.736**	**3.441.696**	**3.972.598**	**4.550.181**	**5.144.060**	**5.754.372**	**5.693.753**	**6.349.375**	**7.033.127**	**7.735.842**	**8.485.031**
Taxes		22.897.456	326.408	671.637	741.050	805.407	929.287	798.965	883.474	974.220	1.066.564	1.160.434	860.424	993.149	1.137.545	1.286.015	1.438.593	1.423.438	1.587.344	1.758.282	1.933.961	2.121.258
NOPAT		**68.692.368**	**979.225**	**2.014.912**	**2.223.149**	**2.416.220**	**2.787.860**	**2.396.896**	**2.650.423**	**2.922.661**	**3.199.693**	**3.481.302**	**2.581.272**	**2.979.448**	**3.412.636**	**3.858.045**	**4.315.779**	**4.270.315**	**4.762.031**	**5.274.845**	**5.801.882**	**6.363.774**

Table 5. Profit and Losses Account for the Motorway Scenario (Infrastructure view point)

In the next table, we include the balance sheet corresponding to the investment done.

BALANCE. MOTORWAY	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
ASSETS																				
Non Current Assets																				
Property, plant and equipment	37.508.720	37.856.144	38.205.551	38.556.923	31.429.254	40.588.167	38.460.671	36.260.217	33.985.096	31.633.564	53.489.913	50.047.081	46.488.930	42.812.773	39.015.872	46.324.651	41.846.380	37.223.337	32.452.187	27.529.528
Total Assets	**37.508.720**	**37.856.144**	**38.205.551**	**38.556.923**	**31.429.254**	**40.588.167**	**38.460.671**	**36.260.217**	**33.985.096**	**31.633.564**	**53.489.913**	**50.047.081**	**46.488.930**	**42.812.773**	**39.015.872**	**46.324.651**	**41.846.380**	**37.223.337**	**32.452.187**	**27.529.528**
LIABILITIES																				
Non-Current Liabilities																				
Loans	26.256.104	25.039.428	23.813.441	23.144.614	17.872.029	22.491.183	20.700.607	18.586.216	16.525.216	14.529.708	24.504.219	22.261.465	19.492.248	16.823.859	14.274.077	16.173.416	13.677.688	11.134.228	8.751.104	6.540.021
Equity	11.252.616	11.837.491	12.377.199	13.189.160	11.141.005	15.309.124	15.363.168	15.023.578	14.537.220	13.904.163	25.504.392	25.204.345	24.017.234	22.576.279	20.883.749	25.835.457	23.898.377	21.327.078	18.426.238	15.187.624
Profit/Losses (previous year)	**0**	**979.225**	**2.014.912**	**2.223.149**	**2.416.220**	**2.787.860**	**2.396.896**	**2.650.423**	**2.922.661**	**3.199.693**	**3.481.302**	**2.581.272**	**2.979.448**	**3.412.636**	**3.858.045**	**4.315.779**	**4.270.315**	**4.762.031**	**5.274.845**	**5.801.882**
Total Liabilities	**37.508.720**	**37.856.144**	**38.205.551**	**38.556.923**	**31.429.254**	**40.588.167**	**38.460.671**	**36.260.217**	**33.985.096**	**31.633.564**	**53.489.913**	**50.047.081**	**46.488.930**	**42.812.773**	**39.015.872**	**46.324.651**	**41.846.380**	**37.223.337**	**32.452.187**	**27.529.528**
Net Liabilities (Total Assets - Total Liabilities)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Inflaction Rate	1,50%																			

Table 6. Balance Sheet (Motorway Scenario)

We have also calculated the Free Cash Flow and base on it the VAN and TIR of the installation and some other ratios.

FREE CASH FLOW MOTORWAY	2.031	2.032	2.033	2.034	2.035	2.036	2.037	2.038	2.039	2.040	2.041	2.042	2.043	2.044	2.045	2.046	2.047	2.048	2.049	2.050
NOPAT	979.225	2.014.912	2.223.149	2.416.220	2.787.860	2.396.896	2.650.423	2.922.661	3.199.693	3.481.302	2.581.272	2.979.448	3.412.636	3.858.045	4.315.779	4.270.315	4.762.031	5.274.845	5.801.882	6.363.774
Depreciation	1.974.143	1.974.143	1.974.143	1.974.143	1.974.143	2.502.479	2.502.479	2.502.479	2.502.479	2.502.479	3.603.875	3.603.875	3.603.875	3.603.875	3.603.875	4.076.596	4.076.596	4.076.596	4.076.596	4.076.596
CAPEX	-40.593.974	0	0	0	0	-10.566.716	0	0	0	0	-25.564.289	0	0	0	0	-11.820.233	0	0	0	0
Investment in working capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FREE CASH FLOW	**-37.640.606**	**3.989.055**	**4.197.292**	**4.390.364**	**4.762.003**	**-5.667.341**	**5.152.902**	**5.425.140**	**5.702.172**	**5.983.781**	**-19.379.143**	**6.583.323**	**7.016.510**	**7.461.920**	**7.919.653**	**-3.473.322**	**8.838.627**	**9.351.441**	**9.878.478**	**10.440.370**
Inflaction Rate	1,50%																			

Key Ratios MOTORWAY

Items	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
EBITDA/Incomes (%)	73,0%	92,2%	93,8%	95,4%	97,0%	98,6%	100,3%	102,0%	103,7%	105,4%	107,3%	109,2%	111,1%	113,1%	115,0%	117,0%	119,0%	121,1%	123,2%	125,5%
Cost of Sales/Income (%)	27,0%	9,1%	9,0%	8,8%	8,6%	8,5%	8,3%	8,1%	8,0%	7,8%	7,5%	7,3%	7,1%	6,8%	6,6%	6,4%	6,2%	6,0%	5,8%	5,4%
EBIT /Incomes(%)	41,6%	2.014.912	2.223.149	2.416.220	2.787.860	2.396.896	2.650.423	2.922.661	3.199.693	3.481.302	2.581.272	2.979.448	3.412.636	3.858.045	4.315.779	4.270.315	4.762.031	5.274.845	5.801.882	6.363.774
NOPAT/Incomes (%)	15,6%	31,4%	34,0%	36,3%	41,1%	34,6%	37,6%	40,7%	43,7%	46,6%	33,5%	37,4%	41,5%	45,5%	49,3%	47,2%	51,0%	54,8%	58,3%	62,0%
Sales Growth (%)	-	1,9%	1,9%	1,9%	1,9%	1,9%	1,9%	1,9%	1,9%	1,9%	3,1%	3,1%	3,1%	3,1%	3,1%	3,1%	3,1%	3,1%	3,1%	3,1%
Net Profit/Equity (%)	8,7%	17,0%	18,0%	18,3%	25,0%	15,7%	17,3%	19,5%	22,0%	25,0%	10,1%	11,8%	14,2%	17,1%	20,7%	16,5%	19,9%	24,7%	31,5%	41,9%
Equity/Assets Ratio (%)	30,0%	31,3%	32,4%	34,2%	35,4%	37,7%	39,9%	41,4%	42,8%	44,0%	47,7%	50,4%	51,7%	52,7%	53,5%	55,8%	57,1%	57,3%	56,8%	55,2%

Table 7. Free Cash Flow and Key Ratios (Motorway Scenario)

The business opportunity seems not to be very attractive. Considering an index discount rate of 5%, NPV rises € 6,82 Million for a huge investment of 77.4 Million € (NPV), with the IIR being a small 6.8%. For the calculations in table 5, we consider an inflation rate of 1,5%, as the European Investment Bank goal is to reach an annual 2% although to be realistic, 1,5% is more achievable. Operating costs and maintenance costs are assumptions as FABRIC was not able to measure these costs and we have considered a small improvement in costs every year. This improvement is higher in maintenance and refurbishment than in operation expenses. The reason is that the team allocated to the service will probably keep constant as there is a minimum staff required for the daily activities, but maintenance and refurbishment have some more chance for optimization.

This motorway case considers a high contribution from the administrations providing incentives until the last decade where the volume of DWPT-EV and DWPT-HDV vehicles will be enough to make the business sustainable. During first year for instance, incomes for the investor (e-Road operator) coming from the Administrations reaches 5.2 Million € in front of 1 Million that comes from the users. In the next table, we show the growing trend on the incomes, for the first 10 years without applying the inflation rate, depicting also how the contribution of the administrations in the tariff is being reduced over time.

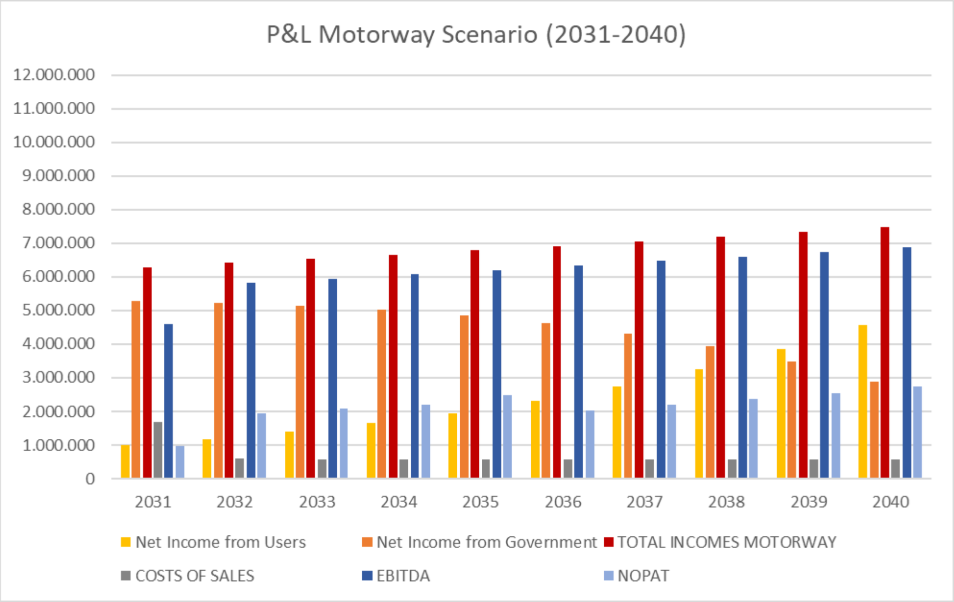
INCOME STATEMENT	MOTORWAY SCENARIO											
Items	**UNITS**	**Total**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**
Light Vehicles (Amout/Year)	**units/y**		**303,534**	**354,305**	**413,569**	**482,746**	**563,494**	**657,749**	**767,769**	**896,192**	**1,046,096**	**1,221,074**
Charged electricity kWh/year	kWh/y		4,742,719	5,536,029	6,462,035	7,542,933	8,804,631	10,277,373	11,996,459	14,003,095	16,345,379	19,079,454
Tariffs	€/KWh		1.16	1.00	0.87	0.75	0.65	0.56	0.49	0.42	0.36	0.31
Required Incentive	€/KWh		0.99	0.83	0.70	0.58	0.48	0.39	0.32	0.25	0.19	0.14
Electricity Price to users	€/KWh		0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Income from Users	€/y	**72,693,444**	809,353	944,733	1,102,758	1,287,215	1,502,526	1,753,852	2,047,217	2,389,653	2,789,368	3,255,943
Income from Government	€/y	**53,238,558**	4,679,624	4,604,382	4,504,629	4,376,388	4,215,041	4,015,229	3,770,724	3,474,287	3,117,502	2,690,580
Income Light Vehicles	**€/Y**	**125,932,002**	**5,488,977**	**5,549,115**	**5,607,387**	**5,663,603**	**5,717,567**	**5,769,082**	**5,817,941**	**5,863,940**	**5,906,871**	**5,946,523**
Heavy vehicles (Amout/Year)	**units/y**		**17,739**	**22,035**	**27,370**	**33,998**	**42,231**	**52,457**	**65,159**	**80,938**	**100,537**	**124,883**
Charged electricity kWh/year	kWh/y		692,930	860,723	1,069,147	1,328,040	1,649,625	2,049,082	2,545,267	3,161,604	3,927,186	4,878,155
Tariffs	€/KWh		1.16	1.00	0.87	0.75	0.65	0.56	0.49	0.42	0.36	0.31
Required Incentive	€/KWh		0.89	0.73	0.60	0.48	0.38	0.29	0.22	0.15	0.09	0.04
Electricity Price for heavy vehicles	€/KWh		0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Income Users	€/y	**26,574,579**	187,091	232,395	288,670	358,571	445,399	553,252	687,222	853,633	1,060,340	1,317,102
Income Governament	€/y	**5,474,665**	614,870	630,362	639,075	638,587	625,838	596,976	547,160	470,321	358,861	203,280
Income Heavy vehicles	**€/Y**	**32,049,243**	**801,961**	**862,757**	**927,745**	**997,158**	**1,071,237**	**1,150,228**	**1,234,382**	**1,323,954**	**1,419,201**	**1,520,382**
Total NET Income (Light + Heavy)	**€/Y**	157,981,245	6,290,938	6,411,872	6,535,132	6,660,760	6,788,804	6,919,310	7,052,324	7,187,895	7,326,072	7,466,905

Table 8. Distribution of revenues in the Motorway Sc. and trend in the required incentives from governments

All these tables may easily vary depending on several factors:

- Cost of infrastructure
- Prices of industrial electricity (considered 0.08 €/kWh paid by the infrastructure owner)
- Penetration of DWPT Vehicles in the market.
- Cost of petrol (if petrol rises, the tariff admitted by DWPT' users could be higher)
- Incentives policy. This business opportunity is not sustainable unless a great initial support from public authorities is ensured.

We can also represent the P&L results in a figure organised in two decades as shown below.



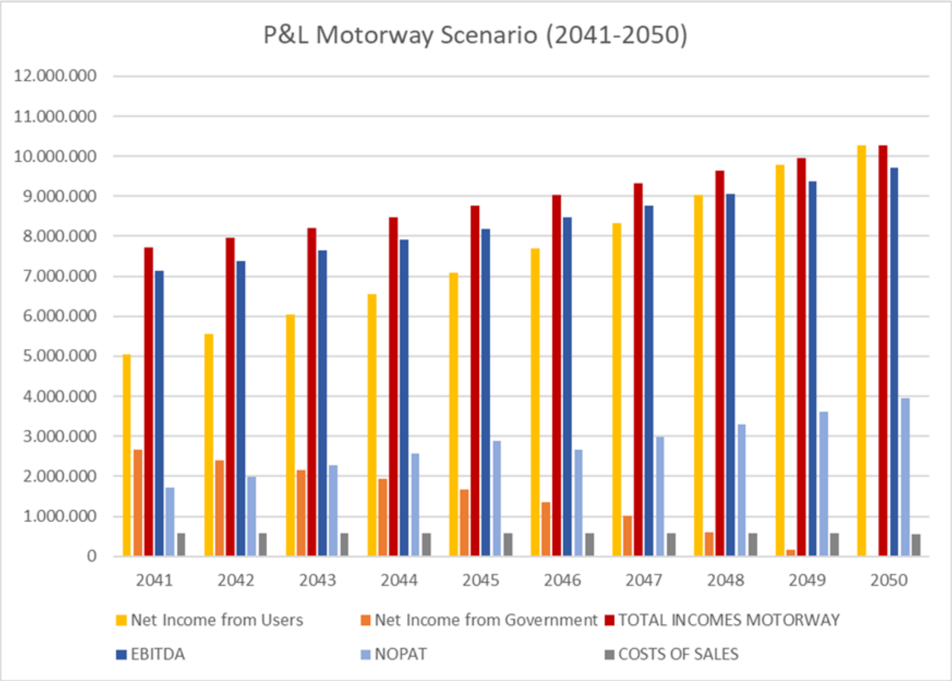


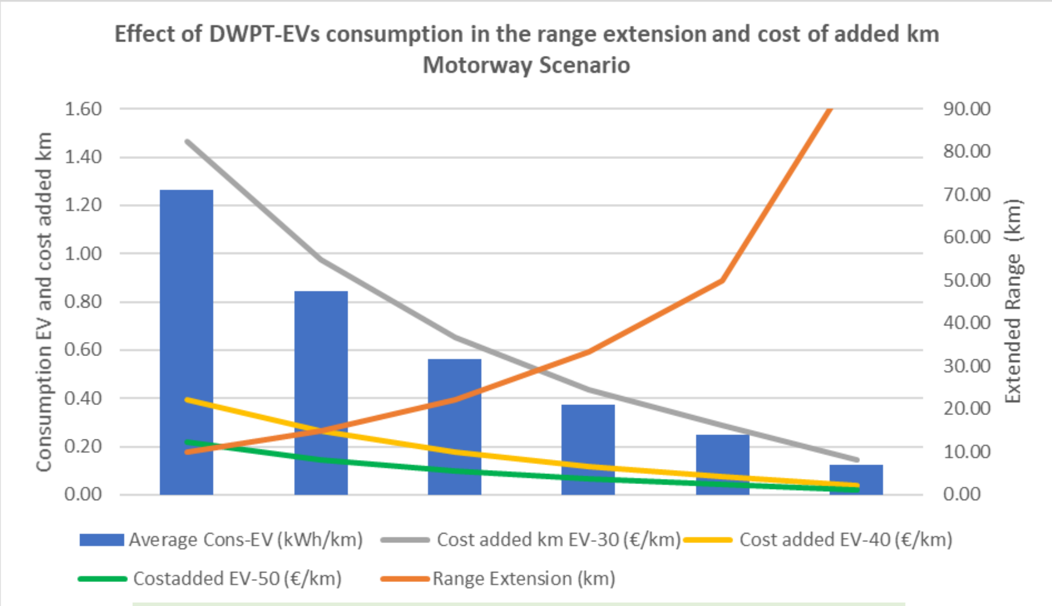
Figure 1. P&L Motorway Scenario (2031-2040) and (2041-2050)

The variation in the NOPAT every five years is due to the re-investment process to renew the roads that introduce additional CAPEX depreciation and consequently less NOPAT (Net Operating Profits after Taxes). This is based upon the finding of D5.3.4.

2.2.1.2 Sensitivity Analysis Motorway Scenario

The number of potential analysis and how the system varies is infinite, but we present hereunder some preliminary results modifying some variables which could vary in the future significantly.

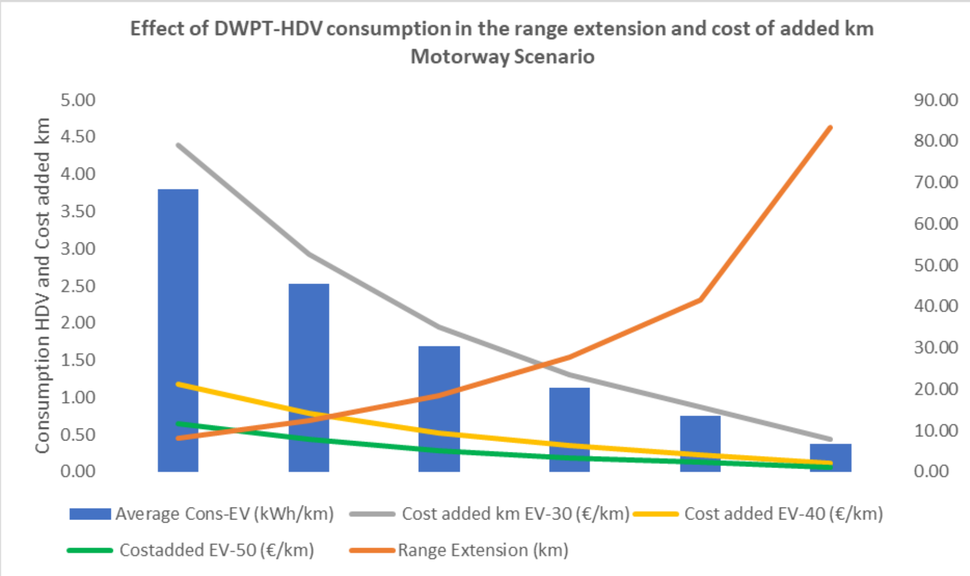
The first exercise done is to provide a clear picture of the evolution of the range extension when varying the average DWPT-EV consumption. In the base scenario we considered 0.25 kWh/km, but here we increase it till 1.27 kWh/km (blue columns). The more vehicle consumption, the less range extension when charging at the e-Roads. Accordingly, if we calculate the cost of the “added km of range extension” in year 30, 40 and 50, we see that the highest the consumption is, and the range extension reduced, the cost of each extended km is also higher. This cost effect is reduced as soon as we increase the number of DWPT vehicles in the roads from year 30, compared with years 40 and 50. The cost of the extended km (€/km) corresponds to row 18 in the business model. Later in the bottom lines this cost is compared against the equivalent ICE car impacting also in the necessary tariff.



Average Cons-EV (kWh/km)	Range Extension (km)	Cost added km EV-30 (€/km)	Cost added EV-40 (€/km)	Costadded EV-50 (€/km)
1.27	9.88	1.46	0.39	0.22
0.84	14.81	0.98	0.26	0.15
0.56	22.22	0.65	0.18	0.10
0.38	33.33	0.43	0.12	0.06
0.25	50.00	0.29	0.08	0.04
0.13	100.00	0.14	0.04	0.02

Figure 2. Sensitivity Analysis (EV Consumption/ Range Extension/Cost of Extended km)

The same simulation was done for the DWPD-HDV vehicles in the Motorway scenario. The results are presented hereinafter.



Average Cons-EV (kWh/km)	Range Extension (km)	Cost added km HDV-30 (€/km)	Cost added HDV-40 (€/km)	Cost added HDV-50 (€/km)
3.80	8.23	4.39	1.18	0.65
2.53	12.35	2.93	0.79	0.44
1.69	18.52	1.95	0.53	0.29
1.13	27.78	1.30	0.35	0.19
0.75	41.67	0.87	0.23	0.13
0.38	83.33	0.43	0.12	0.06

Figure 3. Sensitivity Analysis (HDV Consumption/ Range Extension/Cost of Extended km).

The conclusions are similar as in the previous case. High consumption rates of 3.80 kWh/km generate a very reduced range extension and high cost in year 2030 although later these figures are minimised due to the increased number of vehicles crossing the e-Corridor.

The second simulation done is reflected in the next figure. We have simulated the behaviour of the required incentive from the government depending on the vehicle consumption. The incentive is relatively flat, so the incentive is less substantially affected by the average vehicle consumption than in the case of the HDV. The highest the consumption is (with less range extension), the highest the government incentive required is, (in €/kWh of energy charged). The incentive is then reduced overtime as soon as the number of DWPT-EV grows.

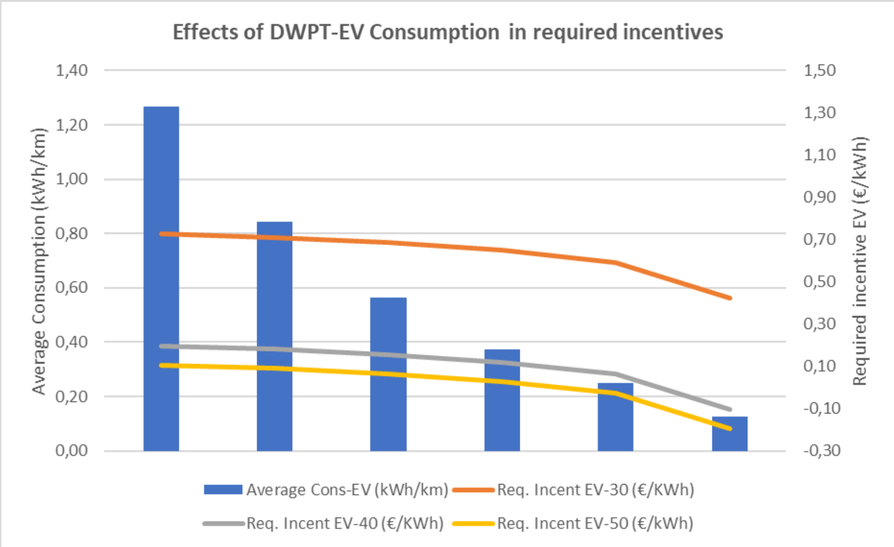


Figure 4. Sensitivity Analysis. Effect in required incentive depending on light EV Consumption

The next figure provides the same table for HDV vehicles in the motorway scenario.

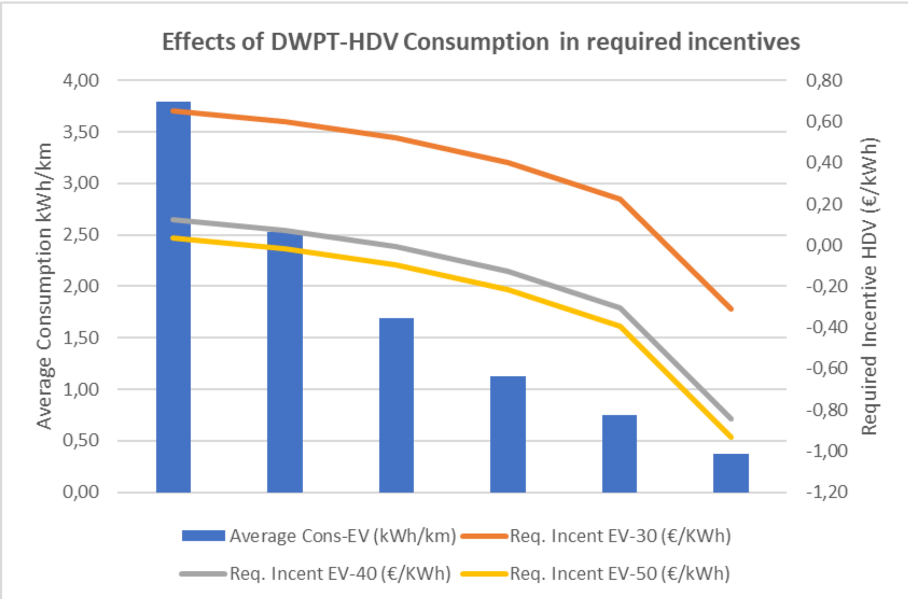


Figure 5. Sensitivity Analysis. Effect in required incentive depending on HDV Consumption

In the HDV sector, the required incentive is more sensible to the average vehicle consumption. More vehicle consumption represents more required incentives (because range extension is highly reduced and the number of DWPT-HDV is lower than in the case of the light vehicles).

Finally, a simulation was carried out modifying the infrastructure costs and gasolines prices, and base on that modifications, the required incentives were identified.

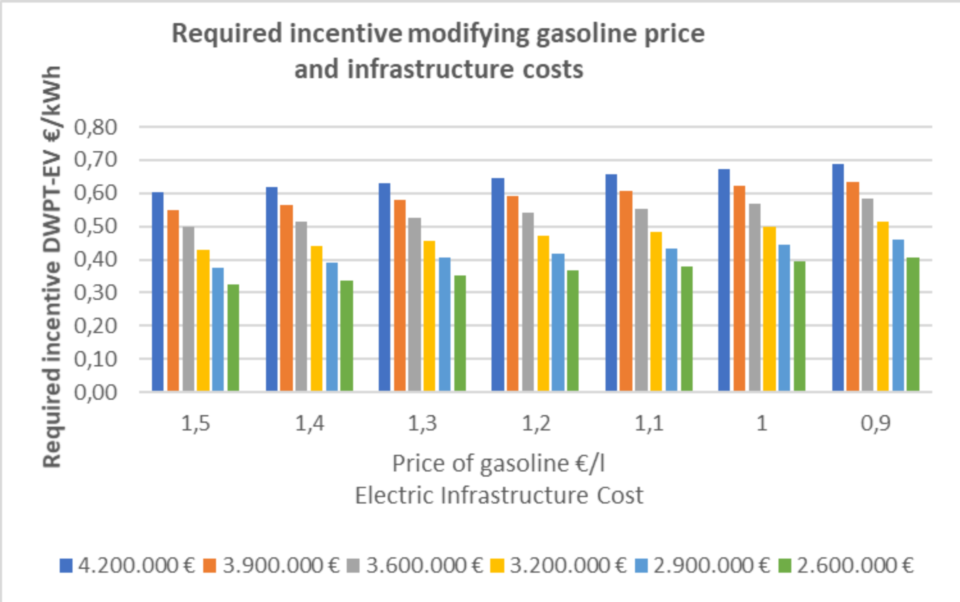


Figure 6. Required incentive versus gasoline price and infrastructure cost.

The results show that infrastructure costs impact a lot in the required incentive and the gasoline prices also but to a minor extent. The figure reflects that with a given cost of the infrastructure (i.e. €4,2 Million), if you reduce the price of the gasoline (from 1,5 €/l to 0,9€/l VAT included), then, the required incentive from the government is higher (10 cents/kwh more). The reason is clearly explained because the cost of charging must compete with reduced costs of the gasoline so, the distance between both costs makes necessary to increase the government support. In addition, the figure reflects that less infrastructure costs reduced the required incentive as the cost of the kwh is minimised coming closer to the cost of the gasoline. Thus, any improvement in the manufacturing, operation or maintenance of the e-Roads will make the technology significantly more competitive and the same can be said if the costs of fuel grow (due to the lack of reserves or by any other reason).

2.2.2 *Vehicle owner view point (Motorway Scenario)*

2.2.2.1 *Reference Scenario*

The reference scenario from the vehicle owner viewpoint has been deeply described in D5.5.2. The main assumptions were stated in the following tables first for light vehicles and then for heavy.

Comparison / RANGE EXTENDER ESTRATEGY **TRUCKS** MOTORWAY

Ref.DWPT-Heavy Truck /E-TRUCK			Ref. Heavy Vehicle Diesel (12 tons)		
VEHICLE AND INFRASTRUCTURE MAIN PARAMETERS					
Vehicle Battery autonomy	250	km	Vehicle autonomy	886	km
Vehicle Battery capacity	417	kWh			
			Power	270	CV
E-Road length	25	km	Consumption	35.0	l/100 km
E-Road billable Power transfer	100	kW	Tank	310	litros
Average speed in e-Corridor	80	km/h	Cost Diesel	1.15	€/l
Absorbed electricity in e-Road	114	kWh			
Range extension after e-Road	78	km			
Total range distance	328	km			
Average Consumption TTW	2	kWh/km		3.09	kWh/km
Average Consumption WTW	5	kWh/km		3.71	kWh/km
Total Consumption in total range	531	kWh		1,014	kWh
CAPEX					
ACQUISITION COSTS					
Life time	10	years		10	years
Adquisition basic vehicle cost	**175,000**	€		**125,000**	€
Adaptation plug-in to WPT in vehicle	4,500	€			
Adaptation WPT to DWPT in vehicle	4,500	€			
Total Acquisition Costs	**184,000**	€			
km /year	65,000	Km/y		65,000	Km/y
Total Km	650,000	km		650,000	km
INFRASTRUCTURE COSTS					
Plug-in ultracharger in garage (150 kW)	80,000	€			
Adaptation parking to WPT	4,500	€			
OPEX					
MAINTENANCE COSTS					
Yearly maintenance	2,800	€/y		8,400	€/y
Replace Battery (evey 5 years)	41,700	€		0	€
Total cost maintenance (10 y)	69,700	€		84,000	€
INSURANCE COSTS					
Insurance/year	2,000	€/y		2,000	€/y
Total Insurance (10 y)	20,000	€		20,000	€
CONSUMPTION ELECTRICITY / FUEL					
Cost electricity headquarter	0.08	€/kwh	Diesel Consumption Costs	0.40	€/km
Cost in ultra-charger	0.65	€/kwh			
Cost electricity in e-Road	1.16	€/kwh[1]			
Cost Full charge at headquarter	33.4	€			
Cost charging in e-road (no incentive)	132.66	€			
Total charging cost electricity in range	166.02	€	**Cost Diesel in range**	132.02	€
CO2 emissions (g CO_2.equiv/km) 2030	434.18	gr CO2/km		1,016.14	gr CO2/km
CO2 emissions (g CO_2.equiv/km) 2050	124.41	gr CO2/km		1,016.14	gr CO2/km
TOTAL EMISSION IN RANGE DISTANCE 2030	142,411	grCO2		333,294	gr CO2
TOTAL EMISSION IN RANGE DISTANCE 2050	40,806	grCO2		333,294	gr CO2

Table 9. Reference scenario for light vehicles the Motorway scenario.

The information included in the left side of the table, was collected from FABRIC but also from the internet open sources. It includes the cost estimation for the DWPT equipment on board which is the sum up of the adaptation of a conventional electric vehicles to the WPT (static or stationary charging equipment valued at 2,500 €) plus the adaptation of the WPT to DWPT (Static to dynamic transition) worth at 1,500 €. So, the full adaptation will cost, according to some of the FABRIC OEMs around 4,000 €. In addition, below the last block of information, under the heading "Consumption of electricity, fuel", we found also some comparable costs of the electricity low chargers at home (0,12 €/kWh), with the cost of electricity at the e-Roads (year 2,030) considered 1,16 €/kWh (without incentives) according to table 4, and finally the cost of charging at an ultrafast charger. Ultrafast charger means here from 150 kW to 450 kW. Some sources of information were checked to identify these costs. The companies Tesla[1], Ionity[2], Allego[3] or EFACEC[4] at the cutting edge of the technology provides some traces of which the costs will be. Within the FastCharge Consortium, a partnership with companies as BMW, Daimler, Porsche, Allego, Siemens and others, the idea is to develop a 450 kW and provide the electricity under two frameworks; 0.59 €/KWh or a flat rate of 9,99 €/month plus 0,35 €/kWh. Allego, in their current ultrafast chargers (175kW) requires 0.69 €/kWh, so we have considered 0.65 €/kWh as an acceptable mean tariff.

The right column represents a conventional gasoline car with the average prices of mid-2018.

The same table was created for the HDV vehicles in the motorway's scenario, depicted hereinafter. In this case the trucks are considered fuelled by diesel.

All these prices and assumptions are considered fix to establish a reference comparison. In the next pages however we will introduce variations on these figures to assess the competitive position of the dynamic charging technology against its major competitor (the ultra-fast chargers). There are two additional technologies which were not considered in this comparison as there is a lack of feasible data due the immaturity of the technologies; we are referring to the battery swapping and the hydrogen vehicles. There are however many hydrogen vehicles already in operation in some countries (specially in US and Japan). However, the technology and the infrastructure associated seems to be more complex and expensive that the one linked to batteries. In addition, Europe seems to have bet for the batteries according to the strategic plans addressed to the transition from fossil fuels to electrification.

[1] https://www.tesla.com/support/supercharging
[2] https://ionity.eu/
[3] https://www.allego.eu/
[4] https://www.efacec.pt/

Comparison / RANGE EXTENDER ESTRATEGY **TRUCKS** MOTORWAY

Ref.DWPT-Heavy Truck /E-TRUCK			Ref. Heavy Vehicle Diesel (12 tons)		
VEHICLE AND INFRASTRUCTURE MAIN PARAMETERS					
Vehicle Battery autonomy	250	km	Vehicle autonomy	886	km
Vehicle Battery capacity	417	kWh			
			Power	270	CV
E-Road length	25	km	Consumption	35.0	l/100 km
E-Road billable Power transfer	100	kW	Tank	310	litros
Average speed in e-Corridor	80	km/h	Cost Diesel	1.15	€/l
Absorbed electricity in e-Road	114	kWh			
Range extension after e-Road	78	km			
Total range distance	328	km			
Average Consumption TTW	2	kWh/km		3.09	kWh/km
Average Consumption WTW	5	kWh/km		3.71	kWh/km
Total Consumption in total range	531	kWh		1,014	kWh
CAPEX					
ACQUISITION COSTS					
Life time	10	years		10	years
Adquisition basic vehicle cost	**175,000**	€		**125,000**	€
Adaptation plug-in to WPT in vehicle	4,500	€			
Adaptation WPT to DWPT in vehicle	4,500	€			
Total Acquisition Costs	**184,000**	€			
km /year	65,000	Km/y		65,000	Km/y
Total Km	650,000	km		650,000	km
INFRASTRUCTURE COSTS					
Plug-in ultracharger in garage (150 kW)	80,000	€			
Adaptation parking to WPT	4,500	€			
OPEX					
MAINTENANCE COSTS					
Yearly maintenance	2,800	€/y		8,400	€/y
Replace Battery (evey 5 years)	41,700	€		0	€
Total cost maintenance (10 y)	69,700	€		84,000	€
INSURANCE COSTS					
Insurance/year	2,000	€/y		2,000	€/y
Total Insurance (10 y)	20,000	€		20,000	€
CONSUMPTION ELECTRICITY / FUEL					
Cost electricity headquarter	0.08	€/kwh	Diesel Consumption Costs	0.40	€/km
Cost in ultra-charger	0.65	€/kwh			
Cost electricity in e-Road	1.16	€/kwh[1]			
Cost Full charge at headquarter	33.4	€			
Cost charging in e-road (no incentive)	132.66	€			
Total charging cost electricity in range	166.02	€	**Cost Diesel in range**	132.02	€
CO2 emissions (g CO_2 equiv/km) 2030	434.18	gr CO2/km		1,016.14	gr CO2/km
CO2 emissions (g CO_2 equiv/km) 2050	124.41	gr CO2/km		1,016.14	gr CO2/km
TOTAL EMISSION IN RANGE DISTANCE 2030	142,411	grCO2		333,294	gr CO2
TOTAL EMISSION IN RANGE DISTANCE 2050	40,806	grCO2		333,294	gr CO2

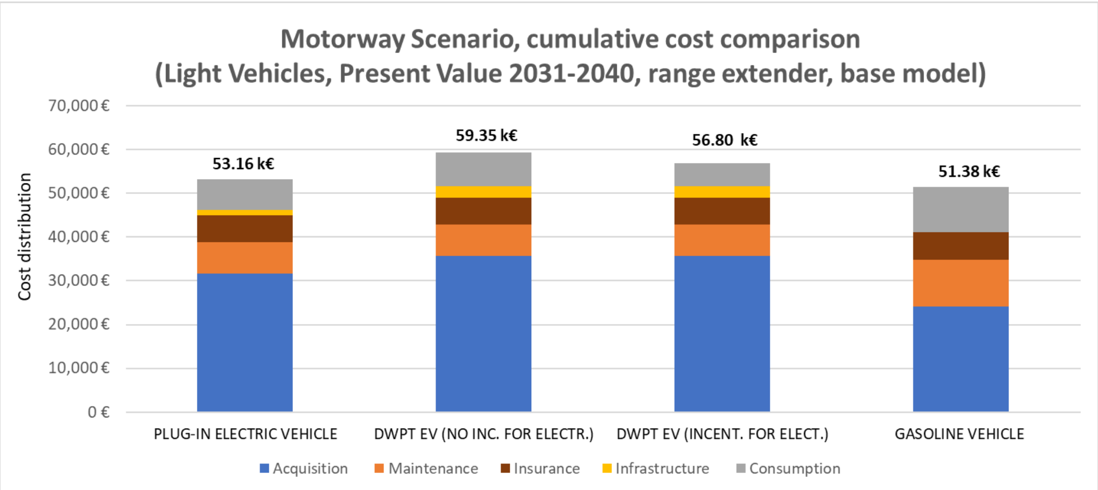
[1]This data comes from Global business model

Table 10. Reference scenario for heavy vehicles the Motorway scenario.

Total Cost of Ownership. With the assumptions of the previous table we made the calculation of the TCO considering four main options;

1. Cost of the plug-in vehicle charged at home and at the motorways in ultra-fast chargers. For the cost comparison, the same number of extra km that the vehicle makes when charging dynamically has been adapted as if it should has charged in the ultra-fast facilities. Namely, for a total of 20.000 km/year, 17.699 km are supposed to be charged at home and 2,301 km in the ultra-fast charged.
2. The second column represents the TCO for the DWPT case with no incentives (2,301 km charged dynamically at a rate of 1.16 €/kWh in 2030, been reduced progressively due to the number of users)
3. In the third one, we consider the DWPT case with governmental incentives (2,301 km at a rate of 0.17 €/kWh in period 2030-2040). We have stated that the cost of charging at the ultra-fast equipment is reduced 1% in cost every year due to economies of scale. The incentivized tariff is kept constant during the 10 years period from the vehicle owner view.
4. Finally, conventional vehicles that make 20,000 km/year using gasoline as energy source.

The following figures summarise the results.

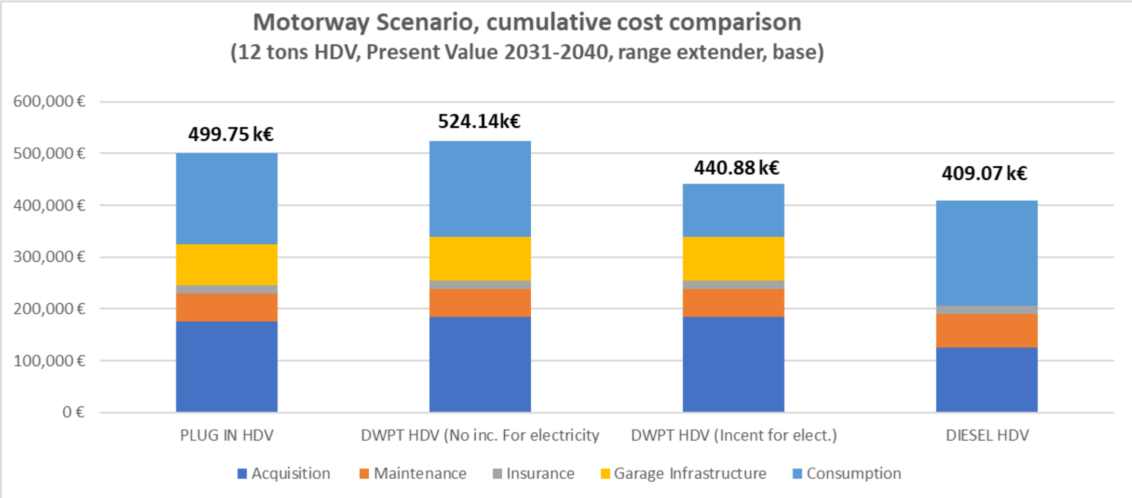


TCO/Concepts MOTORWAY	PLUG-IN ELECTRIC VEHICLE	DWPT EV (NO INC. FOR ELECTR.)	DWPT EV (INCENT. FOR ELECT.)	GASOLINE VEHICLE
Acquisition	31,600 €	35,600 €	35,600 €	24,050 €
Maintenance	7,210 €	7,210 €	7,210 €	10,815 €
Insurance	6,215 €	6,215 €	6,215 €	6,215 €
Infrastructure	1,200 €	2,500 €	2,500 €	0 €
Consumption	6,935 €	7,824 €	5,276 €	10,302 €
TOTAL TCO	53,161 €	59,350 €	56,801 €	51,383 €

Table 11. TCO Comparison of light vehicles in the Motorway Scenario

The cheapest TCO (vehicle owner) option is the gasoline vehicle, but very close to the plug-in one. DWPT are clearly more expensive during the whole lifespan (10 years) being reduced if some incentives are provided by government when charging.

For the heavy vehicles in the motorway scenario, the results are as follows.



TCO/Concepts MOTORWAY	PLUG IN HDV	DWPT HDV (No inc. For electricity	DWPT HDV (Incent for elect.)	DIESEL HDV
Acquisition	175,000 €	184,000 €	184,000 €	125,000 €
Maintenance	54,427 €	54,427 €	54,427 €	65,263 €
Insurance	15,539 €	15,539 €	15,539 €	15,539 €
Garage Infrastructure	80,000 €	84,500 €	84,500 €	0 €
Consumption	174,786 €	185,676 €	102,414 €	203,266 €
TOTAL TCO	499,752 €	524,142 €	440,880 €	409,067 €

Table 12. TCO Comparison of heavy vehicles in the Motorway Scenario

In this case, the plug-in HDV and the DWPT-HDV are quite close in costs although still far from the conventional trucks. The difference with the light vehicles' scenario is due to the fact that HDV vehicles charge more kWh in the e-Corridor due to the minor speed (80 km/h versus 100 km/h for light vehicles), making the ultra-charging electric costs much higher, what jeopardise the plug-in option. We can deduct from this table that the speed when crossing the e-corridors (or the power transfer) is critical in the comparison between ultrafast charging and dynamic charging although both options are still far away from the conventional pollutant vehicles. Thus, the main conclusions from this first analysis are:

In both cases (light and heavy vehicles) DWPT charging is significative more expensive for an end-user than conventional gasoline or diesel options at this starting moment.

However, when comparing DWPT with the ultrafast charging at the motorways, HDV are benefitted from the low speed and in that case DWPT and ultrafast charging for Plug-in HDV could be considered equivalent in costs.

It is important to mention that Plug-in HDV however would require a large part of the cargo space to locate the battery, whilst the shrink strategy for the DWPT-HDV would allow to maintain that space almost identical to conventional HDV

2.2.2.2 Sensitivity analysis from the owner viewpoint in the Motorway scenario

Before entering in the sensibility analysis, we must provide some inputs on the relation between the petrol and electricity prices. In this sense, the US DOE's Office of Energy Efficiency & Renewable Energy released an interesting comparison of fuel price fluctuations. As it turns out in the next chart, electricity pricing is pretty stable, although the chart does reveal some periodic changes in winter vs. summer.

On the other hand, gasoline prices could change by upwards of 100% in relatively short period – which could be good, or really not-so-good for consumers after a new ICE (internal combustion engine) purchase.

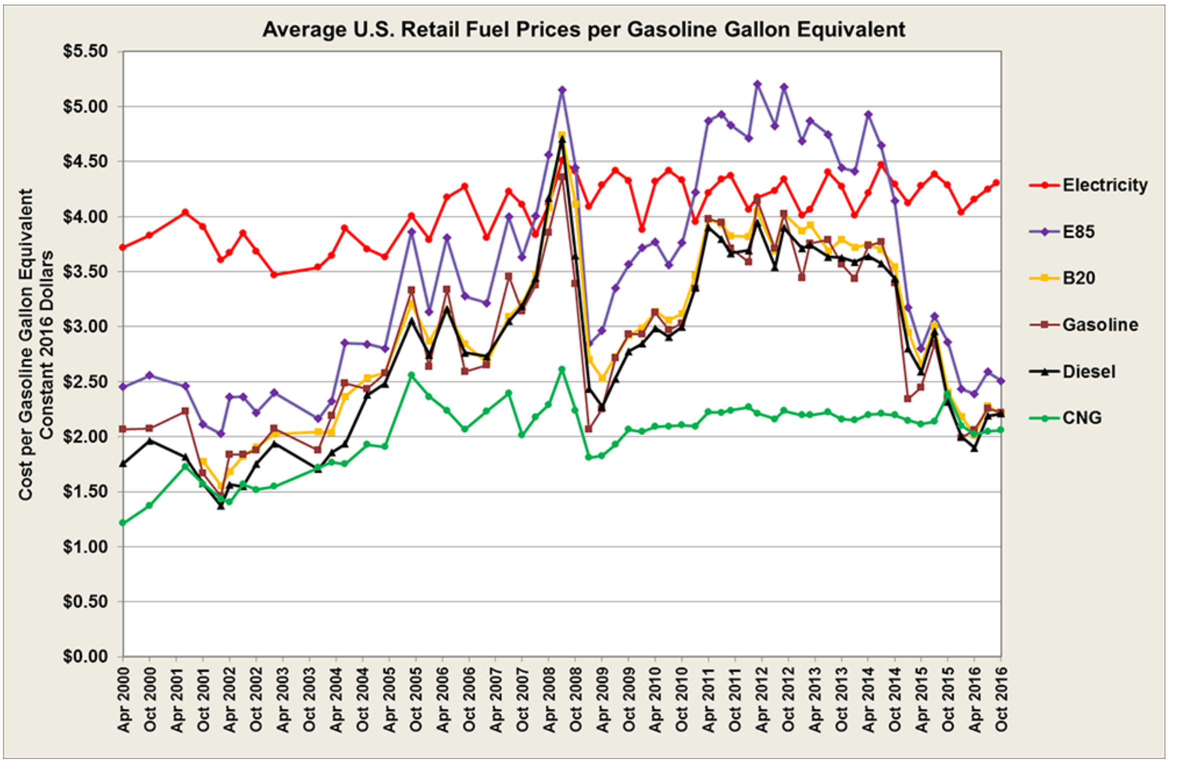


Figure 7. Fluctuations among electricity and gasoline prices (DOE).

Retail prices for most transportation fuels have been highly volatile over the past 16 years as they depend on many factors complex to be controlled, whilst electricity prices show only cyclical price variations from the summer months to the winter months.

On the other hand, according to the EU Energy Outlook 2050[5], the coverage of the demand by energy sources in EU-28 will be as it is explained in the next figure. The gross electricity generation covering the demand will increase by 18 % till 2050 as a result of higher demand by cause of proceeding electrification of the heat and transport sectors. While the production from coal-fired power plants will significantly decline, the production of natural gas will double. In 2050, fluctuating renewable energies will generate 36 % of electricity while over 44 % will be produced by controllable conventional power plants. The remaining electricity production will be generated by controllable renewable energy technologies such as biomass power plants.

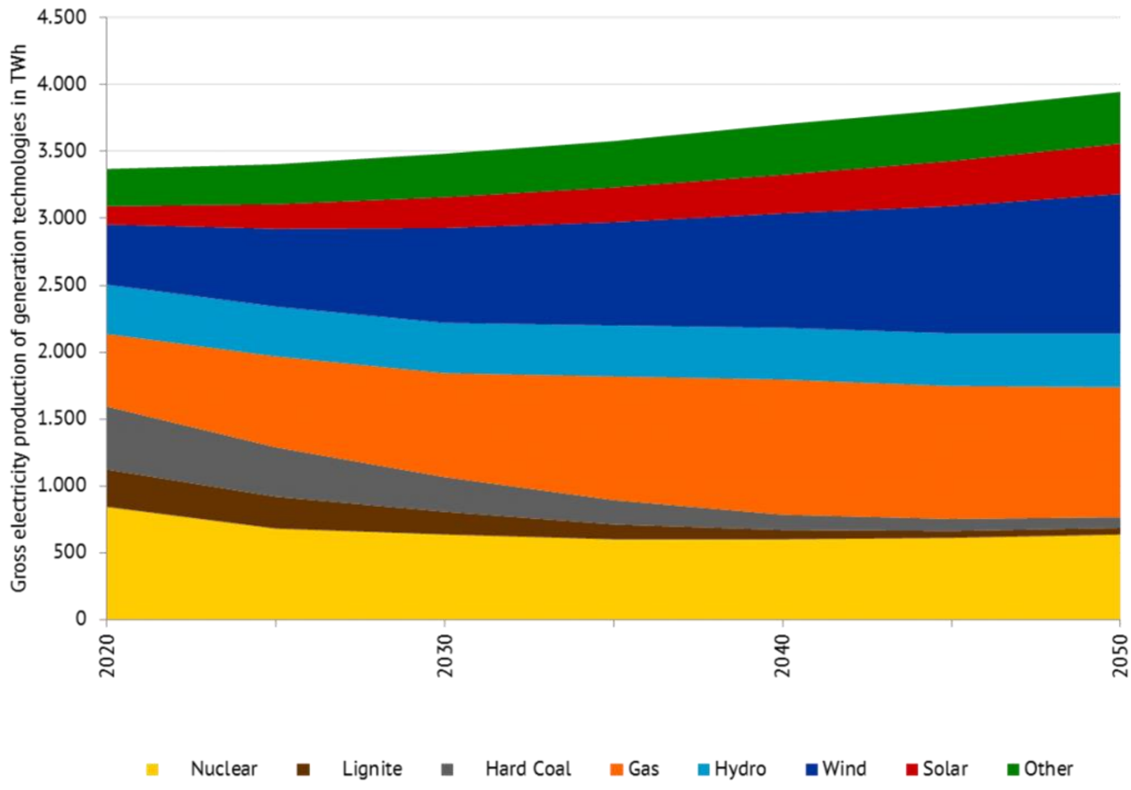


Figure 8. Demand side. Energy sources distribution in EU28 till 2050

[5] https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2050-energy-strategy

According to this report and other similar, the forecast will bring the following prices' evolution.

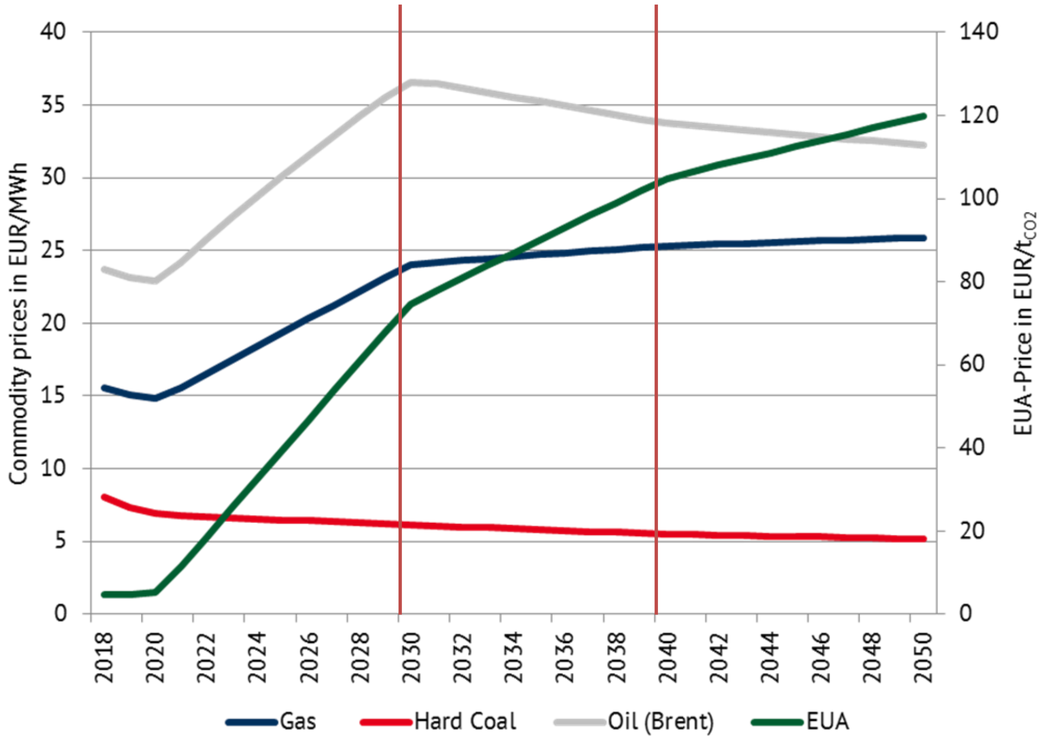


Figure 9. Commodity prices forecast (real: EUR 2015), source: Energy Brainpool

This diagram has been used later in this report to establish the sensibility analysis considering the most likely future scenarios. We can see that in the first 10 years (from 2020 to 2030) prices of oil and electricity grow very fast. From 2030 to 2040, electricity prices still move up at less speed whilst oil slow down slightly. From 2040 to 2050, electricity prices still move up with less slope and petrol continue to reduce prices also with slightly less slope.

In the transition period to electrification, petrol producers move up prices to reach the greatest economic return as possible in the period of subsistence of the ICE vehicles until the effective transition to electric where the demand for oil will fall as of 2030. Thus, the scenario described in figure 9 could be admissible.

2.2.2.2.1 Light Vehicles

As said, all these considerations are taken to stablish an appropriate sensibility analysis. For instance, we will consider the following assumptions for light vehicles in motorways.

SENSIBILITY ANALYSIS

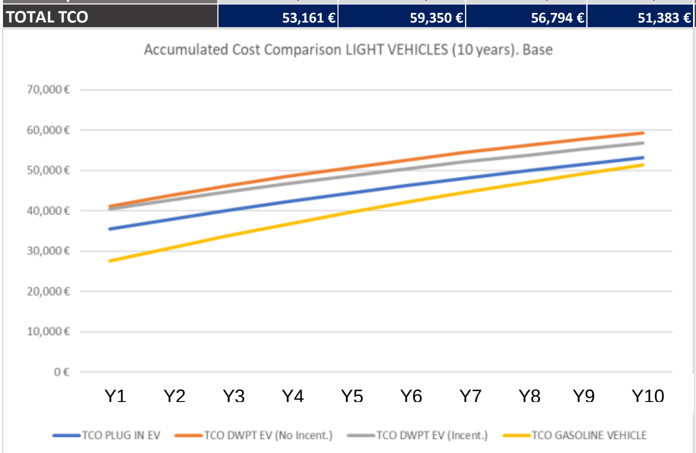
Initial Variables		Base	2030	2035	2040
Cost of electricity at home	€/kWh	0.12	0.3	0.38	0.45
Cost of ultrafast charging	€/kWh	0.65	0.65	0.81	0.98
Cost of petrol	€/km	0.066	0.099	0.090	0.072
Acquisition Costs plug-in	€	31,600	31,600	28,500	27,000
Acquisition Costs DWPT	€	35,600	35,600	32,000	30,500
Acquisition Costs ICE	€	24,050	24,050	19,000	15,500

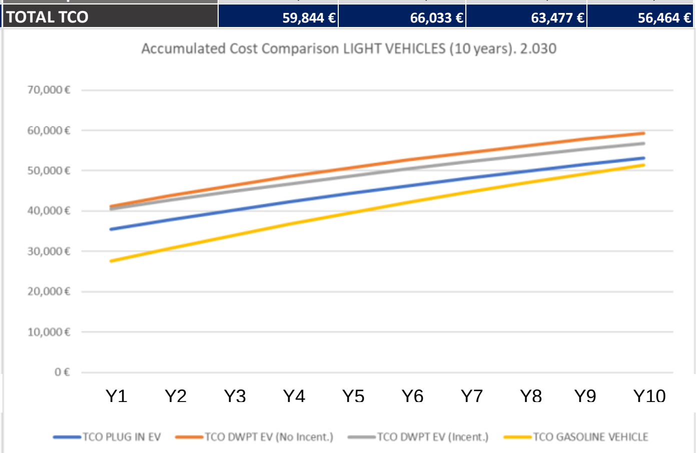
Table 13. Sensibility analysis (LV, Motorway scenario)

In the next lines, we have implemented these sensibility analyses to measure the approach or separation among the different mobility options in the motorway scenario. We consider always 10 years of depreciation life of vehicles. The study was designed considering the base case (as if the e-Corridors started activity today at current energy prices), 2,030 case with the activities starting at that moment and energy prices projected according to the forecasts, 2035 (intermediate scenario) and 2,040 (applying the projections till 2,050.

TCO/Concepts MOTORWAY. Base	PLUG-IN ELECTRIC VEHICLE	DWPT EV (NO INC. FOR ELECTR.)	DWPT EV (INCENT. FOR ELECT.)	GASOLINE VEHICLE
Acquisition	31,600 €	35,600 €	35,600 €	24,050 €
Maintenance	7,210 €	7,210 €	7,210 €	10,815 €
Insurance	6,215 €	6,215 €	6,215 €	6,215 €
Infrastructure	1,200 €	2,500 €	2,500 €	0 €
Consumption	6,935 €	7,824 €	5,269 €	10,302 €
TOTAL TCO	53,161 €	59,350 €	56,794 €	51,383 €

TCO/Concepts MOTORWAY- 2,030	PLUG-IN ELECTRIC VEHICLE	DWPT EV (NO INC. FOR ELECTR.)	DWPT EV (INCENT. FOR ELECT.)	GASOLINE VEHICLE
Acquisition	31,600 €	35,600 €	35,600 €	24,050 €
Maintenance	7,210 €	7,210 €	7,210 €	10,815 €
Insurance	6,215 €	6,215 €	6,215 €	6,215 €
Infrastructure	1,200 €	2,500 €	2,500 €	0 €
Consumption	13,618 €	14,507 €	11,952 €	15,383 €
TOTAL TCO	59,844 €	66,033 €	63,477 €	56,464 €





TCO/Concepts MOTORWAY. 2,035	PLUG-IN ELECTRIC VEHICLE	DWPT EV (NO INC. FOR ELECTR.)	DWPT EV (INCENT. FOR ELECT.)	GASOLINE VEHICLE
Acquisition	28,500 €	32,000 €	32,000 €	19,000 €
Maintenance	7,210 €	7,210 €	7,210 €	10,815 €
Insurance	6,215 €	6,215 €	6,215 €	6,215 €
Infrastructure	1,200 €	2,500 €	2,500 €	0 €
Consumption	17,199 €	15,747 €	14,929 €	13,985 €
TOTAL TCO	60,325 €	63,672 €	62,855 €	50,015 €

TCO/Concepts MOTORWAY. 2040	PLUG-IN ELECTRIC VEHICLE	DWPT EV (NO INC. FOR ELECTR.)	DWPT EV (INCENT. FOR ELECT.)	GASOLINE VEHICLE
Acquisition	27,000 €	30,500 €	30,500 €	15,500 €
Maintenance	7,210 €	7,210 €	7,210 €	10,815 €
Insurance	6,215 €	6,215 €	6,215 €	6,215 €
Infrastructure	1,200 €	2,500 €	2,500 €	0 €
Consumption	20,447 €	17,649 €	17,528 €	11,188 €
TOTAL TCO	62,072 €	64,075 €	63,954 €	43,718 €

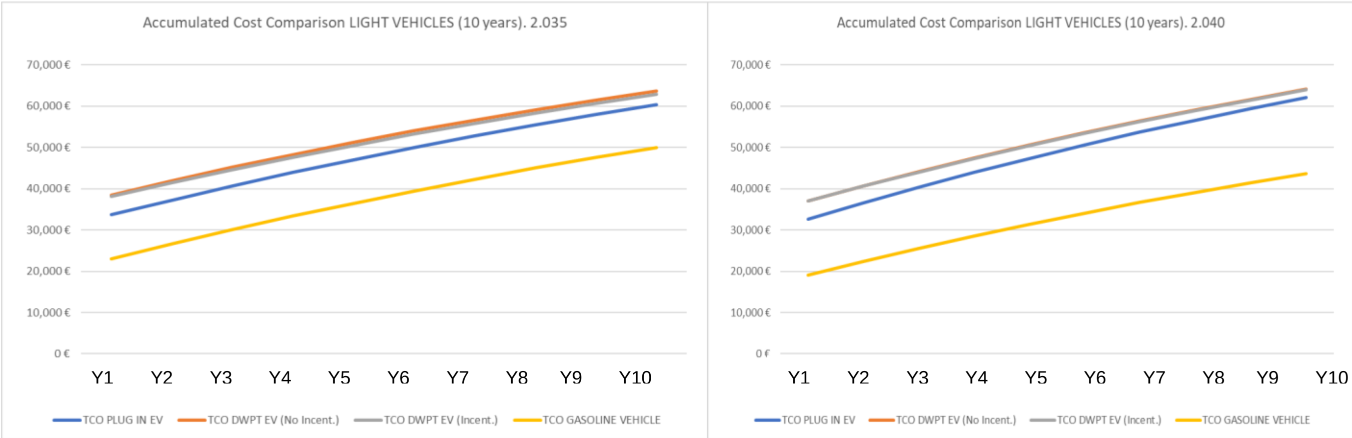


Figure 10. Evolution of costs between years 2031-2040, sensibility analysis , LDV, Motorway scenario

The main conclusions are:

- In 2030, TCO for plug-in vehicles will be somehow more expensive than ICE cars but close thanks to the rise of petrol before the phase out moment. DWPT will be still far in prices even with the electric tariffs at e-Corridors incentivized by government.
- In 2035, ICE cars will reduce prices dramatically to release stock before the 2040 phase out. At that moment TCO for plug-in will be slightly the same (the rise in electricity costs is offset with the reduction of the acquisition costs). DWPT will approach but it is still more expensive as it shares the base electric vehicle with the Plug-in, but DWPT add an expensive equipment for the dynamic charging. Although e-Road tariffs will be smaller than ultrafast chargers, the difference will not offset the high cost of additional equipment on board. The limitation in power transfer will jeopardise the fast penetration of this technology.
- In 2040 the ICE cars will be likely sold for outside city traffic, but inside the cities the limitations will be very probably high. At that moment the price of ICE cars will be the lower (considered as an old technology unless a great optimization on emissions will be performed). In 2040 it will not be necessary to incentivize DWPT as the number of vehicles on electrified motorway will allow a reduction on the e-Road tariffs, even below the prices at home. However, the TCO for plug-in will remain cheaper and DWPT will be assigned to high level purchasing capacity owners.

2.2.2.2.2 HDV

The same exercise has been done for the heavy vehicles in the motorway scenario. The sensibility analysis is based in the following inputs:

SENSIBILITY ANALYSIS HDV MOTORWAY SCENARIO

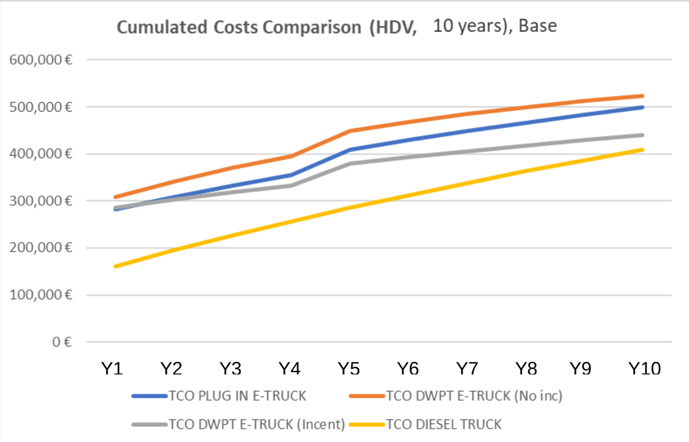
Initial Variables		Base	2030	2035	2040
Cost of electricity headquarter	€/kWh	0.08	0.2	0.25	0.30
Cost of ultrafast charging	€/kWh	0.65	0.65	0.81	0.98
Cost of diesel	€/km	0.40	0.56	0.50	0.45
Acquisition Costs plug-in	€	175,000	175,000	157,000	150,000
Acquisition Costs DWPT	€	184,000	184,000	165,000	157,000
Acquisition Costs ICE	€	125,000	125,000	100,000	90,000

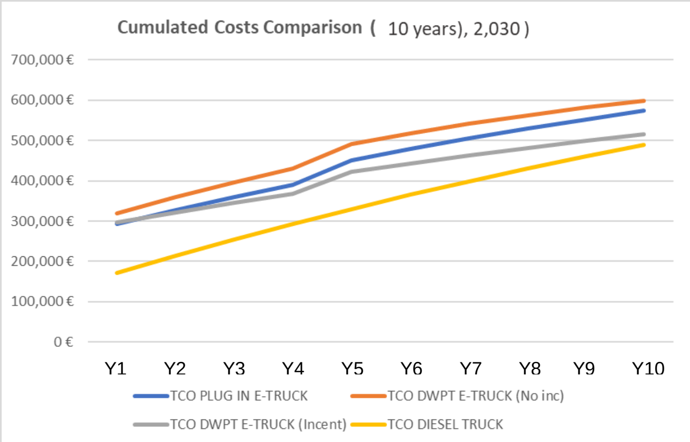
Table 14. Sensibility analysis (HDV, Motorway scenario)

The sensibility analysis provides the following figures and tables

TCO/Concepts MOTORWAY	PLUG IN HDV	DWPT HDV (No inc. For electricity	DWPT HDV (Incent for elect.)	DIESEL HDV
Acquisition	175,000 €	184,000 €	184,000 €	125,000 €
Maintenance	54,427 €	54,427 €	54,427 €	65,263 €
Insurance	15,539 €	15,539 €	15,539 €	15,539 €
Garage Infrastructure	80,000 €	84,500 €	84,500 €	0 €
Consumption	174,786 €	185,676 €	102,414 €	203,266 €
TOTAL TCO	499,752 €	524,142 €	440,880 €	409,067 €

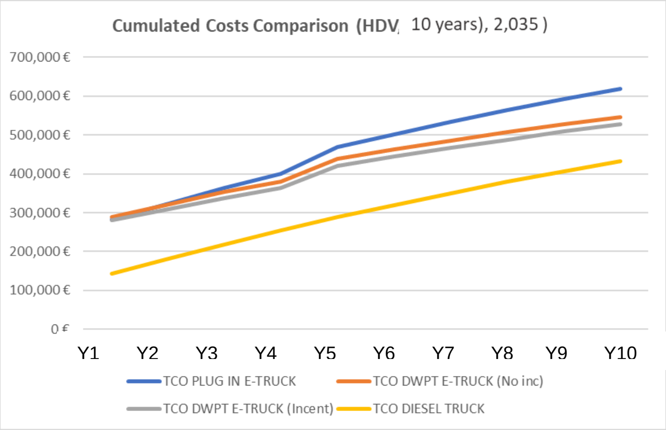
TCO/Concepts MOTORWAY. 2,030	PLUG IN HDV	DWPT HDV (No inc. For electricity	DWPT HDV (Incent for elect.)	DIESEL HDV
Acquisition	175,000 €	184,000 €	184,000 €	125,000 €
Maintenance	54,427 €	54,427 €	54,427 €	65,263 €
Insurance	15,539 €	15,539 €	15,539 €	15,539 €
Garage Infrastructure	80,000 €	84,500 €	84,500 €	0 €
Consumption	249,613 €	260,504 €	177,241 €	282,804 €
TOTAL TCO	574,579 €	598,969 €	515,707 €	488,606 €





TCO/Concepts MOTORWAY. 2,035	PLUG IN HDV	DWPT HDV (No inc. For electricity	DWPT HDV (Incent for elect.)	DIESEL HDV
Acquisition	157,000 €	165,000 €	165,000 €	100,000 €
Maintenance	54,427 €	54,427 €	54,427 €	65,263 €
Insurance	15,539 €	15,539 €	15,539 €	15,539 €
Garage Infrastructure	80,000 €	84,500 €	84,500 €	0 €
Consumption	311,536 €	226,681 €	208,419 €	252,504 €
TOTAL TCO	618,502 €	546,147 €	527,885 €	433,305 €

TCO/Concepts MOTORWAY 2,040	PLUG IN HDV	DWPT HDV (No inc. For electricity	DWPT HDV (Incent for elect.)	DIESEL HDV
Acquisition	150,000 €	157,000 €	157,000 €	90,000 €
Maintenance	54,427 €	54,427 €	54,427 €	65,263 €
Insurance	15,539 €	15,539 €	15,539 €	15,539 €
Garage Infrastructure	80,000 €	84,500 €	84,500 €	0 €
Consumption	375,380 €	239,597 €	239,597 €	227,254 €
TOTAL TCO	675,346 €	551,063 €	551,063 €	398,055 €



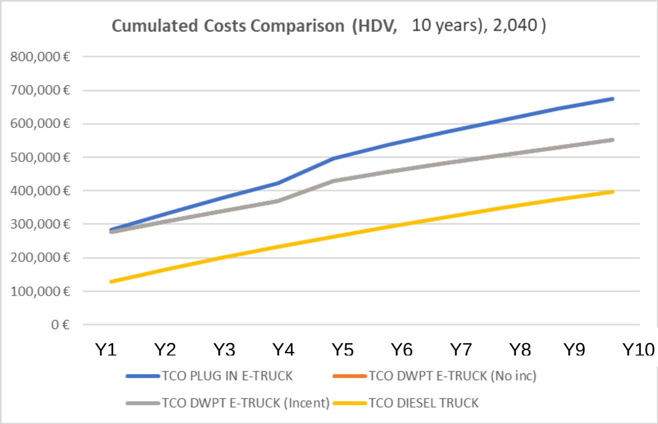


Figure 11. Evolution of costs between years 2031-2040, sensibility analysis , HDV, Motorway scenario

The conclusions from these tables are the following:

Base case.

All costs are placed in 2030 but considering the current energy costs except cost of the ultrafast charger foreseen from the begging to year 2030 (where they will be in full operation). The diesel vehicles are the cheapest in TCO followed by the DWPT-HDV incentivized and the plug-in HDV. The DWPT-HDV with no incentives is almost 30% more expensive than the conventional Diesel. This scenario reflects that DWPT-HDV in motorways is not very interesting at this moment.

Year 2030.

The scenario for 2030 reflects that conventional trucks will be the cheapest as they will be very close to be phase out and manufacturers will reduce sharply the costs. They won't be used likely in periurban and urban areas. According to the estimations for the evolution of the electricity prices, it will rise fast, the same as the petrol, and that will introduce high cost for operation and maintenance, jeopardising pure electric and DWPT vehicles, however the distance between e-HDV and DWPT-HDV (no inc.) will come closer as the energy at home will rise more than that at the motorway.

Year 2035.

In 2,035 the DWPT-HDV will be cheaper than plug in HDV, thanks to the higher number of DWPT-HDV at motorways, they will push the costs of charging down although at same time the cost of charging at headquarters will rise. Diesel HDV continue reducing costs as sales are limited by regulation on petrol vehicles.

Year 2040

More DWPT vehicles at roads makes them to be substantially cheaper than plug in-HDV as they are massively on the roads and the charging tariffs can be reduced. Diesel-HDV are at the lowest cost as they are going to be phase out soon. There will be likely some sales for third countries with no strict regulation or for special vehicles like emergency vehicles, etc that need a guarantee of performance. Prices of incentive and non-incentive DWPT-HDV are even as the number of vehicles in the motorways allow to reduce charging prices to a figure that makes the business model sustainable.

2.2.3 Administration view point (Motorway Scenario)

The administrations must consider the benefits for the citizens from a holistic view point. In this sense, they should make a comparison of the required investments in the e-Roads, the avoided fuel consumed and the avoided CO_2 emissions. The analysis could have been made widely if calculating other externality costs like savings for the health system due to the clean air, the environmental costs, etc. However, we have just included those parameters that were measured at the FABRIC project.

2.2.3.1 Reference data

The reference data for the Motorway scenario from the Administration view point, collects the following information; Present value of a conventional road, present value of an e-corridor (the e-corridor will be external to the main highway lanes until 2050), total emissions avoided by the substitution of the internal combustion engine by the electric one and total fuel saved in case the expected DWPT-EV and DWPT-HDV vehicles charge in the e-corridor. This information was taken from D534 (pavement costs) and D553 for the global warming data. The cost of fuel was considered according to the simulations done in the previous chapters (trends in fuel costs). These data will be used to obtain a snapshot of the expected savings during a given year thanks to the switch from fossil vehicles to DWPT. The total global warming comparing pure electric vehicles and DWPT is not significant as showed in D553 and that's the reason why we don't compare BEVs with DWPT-EVs in this analysis.

MOTORWAY SCENARIO	Units	2,030	2,040	2,050	Nº	Unit
Cost Road						
Conventional road Present Value/km	€/km	1,289,483	1,111,160	932,837	25	km
E-corridor Present Value /km	€/km	3,096,687	2,918,857	2,741,027	25	km
Nº of DWTP Light Vehicles /year	uds	303,534	1,221,074	2,997,181	452	km
Nº of DWTP Heavy Vehicles /year	uds	17,739	124,883	408,707	328	km
Global Warming						
DWPT -LV	g CO2-eq/km.veh	142.99	115.97	88.94	452	km
DWPT-HDV	g CO2-eq/km.veh	434.18	279.30	124.41	328	km
Gasoline LV	g CO2-eq/km.veh	176.00	176.00	176.00	452	km
Diesel HDV	g CO2-eq/km.veh	1,016.14	1,016.14	1,016.14	328	km
Avoided emissions						
CO_2 emission avoided LV	g CO2-eq/km.veh	33.01	60.04	87.06	452	km
CO_2 emission avoided HDV	g CO2-eq/km.veh	581.96	736.85	891.73	328	km
Cost of fuel						
Light Vehicle	€/km	0.099	0.090	0.072	5.1	l/100 km
Heavy Venicle	€/km	0.560	0.504	0.454	35	l/100 km

Table 15. Assumptions to compare ICEV and DWPT-EVs

In deliverable D534 a deep study was performed to compare the LCC of a conventional road trench (1 lane of 25 km) and an external e-corridor prepared for dynamic charging. The results are shown in columns 2030, 2040 and 2050. The cost per km of the e-Corridor varies from 2.4 to 2.94 times the cost of a conventional lane. It was calculated that a light vehicle crossing the 25 km e-Corridor with a battery autonomy of 400 km will just increase it by 52 km at 100 km/h. In the case of the heavy vehicles, the battery autonomy was set in 250 km with an increase of 78 km due to the 25 km of e-Corridor. The greater extension is on the ground that the HDV speed was 80 km/h instead. Less speed implies greater autonomy extension.

The second concept in the table is the global warming effect measured in g CO_2 equivalent/km and vehicle. This calculation reflects different figures for DWPT-LV and DWPT-HDV in years 2030, 2040 and 2050. The reason is that the concept includes the vehicle production, the battery production and the energy consumed WTW and also the infrastructure. The WTW concept (energy to produce vehicles) generates the major impact on the global warming as it depends a lot on the number of vehicles implemented as fixed costs are distributed among a major number of vehicles. Then the same calculation is done for the ICEV vehicles with no change in the period. The reason is that the production of conventional vehicles does not vary significantly.

Finally, the last concept includes the market price of fuel that varies over time according with the predictions of figure 9. We considered a fix consumption of 5,1 l/100km for ICEV light vehicles and 35 l/100 km for ICEV HDV vehicles although it could also change in the future.

RESULTS		2,030	2,040	2,050
Global Cost Road				
Total Cost Conventional Road	€	32,237,085	27,779,001	23,320,917
Total Cost E-Corridor	€	77,417,177	72,971,421	68,525,665
Extra Cost E-corridor	**€**	**45,180,092**	**45,192,420**	**45,204,748**
Global Warming				
Global Emissions DWPT-LV	tons CO2-equiv	19,618	64,004	120,489
Global Emissions DWPT-HDV	tons CO2-equiv	2,526	11,440	16,678
Global Emissions Gasoline LV	tons CO2-equiv	24,147	97,139	238,432
Global Emissions Diesel HDV	tons CO2-equiv	5,912	41,623	136,219
Avoided Emissions				
Global avoided LV	tons CO2-equiv	4,529	33,135	117,942
Global avoided HDV	tons CO2-equiv	3,386	30,182	119,542
Total Avoided by year	**tons CO2-equiv**	**7,915**	**63,317**	**237,484**
Fuel Consumption & cost				
Global LV Consumption avoided	l	6,997,066	28,148,196	69,091,027
Global LV fuel cost avoided	€	13,644,278	49,400,084	97,003,801
Global HDV Consump. avoided	l	2,036,437	14,336,518	46,919,513
Global HDV fuel cost avoided	€	3,258,300	20,644,586	60,807,689
Total Consumption Avoided	**l**	**9,033,503**	**42,484,714**	**116,010,540**
Total Consumption Avoided	**€**	**16,902,578**	**70,044,670**	**157,811,490**

Table 16. Results from the point of view of the administrations.

The results reflect the following:

- The construction of a complete new 25 km e-Corridor supposes around €45,1 Million extra compared to a conventional road.
- The penetration of the DWPT-EV in a single 25 km e-Corridor, according to the forecast in a period of one year, will prevent the emissions of 7.915 tons of CO_2 equivalent in year 2030, 63.317 tons in 2040 and 237.484 tons in 2040. The global impact will be as easy as multiply these avoided emissions by the number of e-Corridors installed.
- The penetration of the DWPD-EV in a single 25 km e-Corridor, according to the forecast in a period of one year, saves 9,033 m^3 of fuel in 2030, 42,484 m^3 in 2040 and 116,010 m^3 in 2050 that represents 16,902 k€, 70,044 K€ and 157,811 k€ respectively.

These results are reflected in the following table:

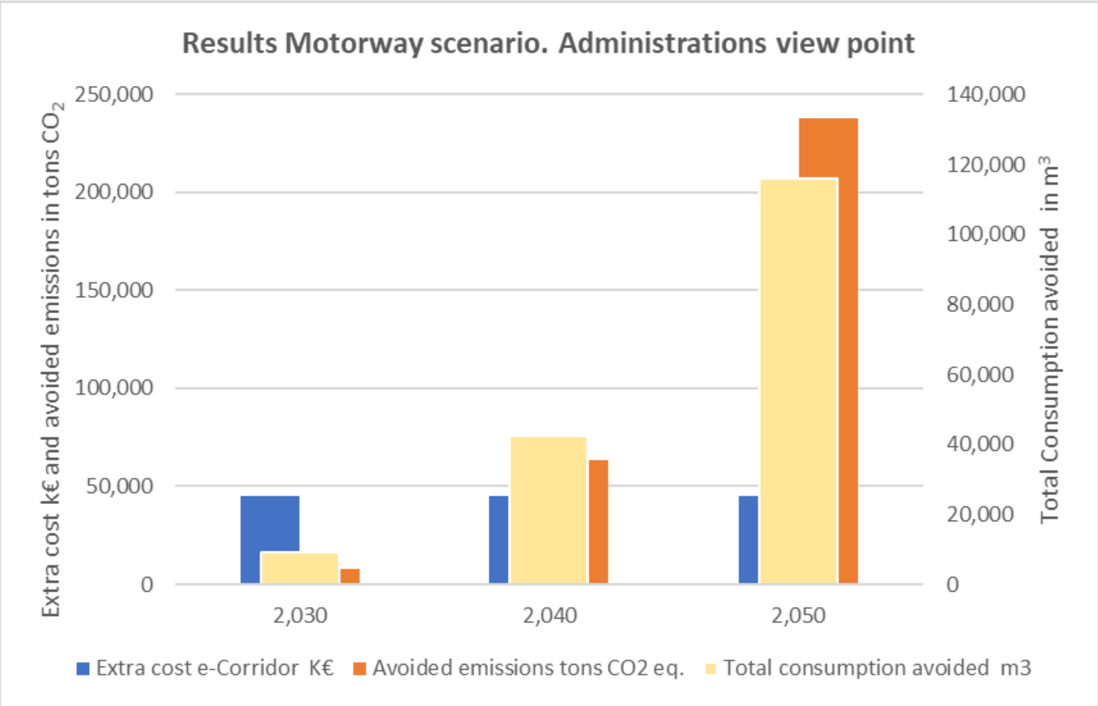


Figure 12. Motorway Scenario. 25 km e-corridor. Administration view point.

2.2.3.2 Sensitivity analysis. Administration. Motorway Scenario

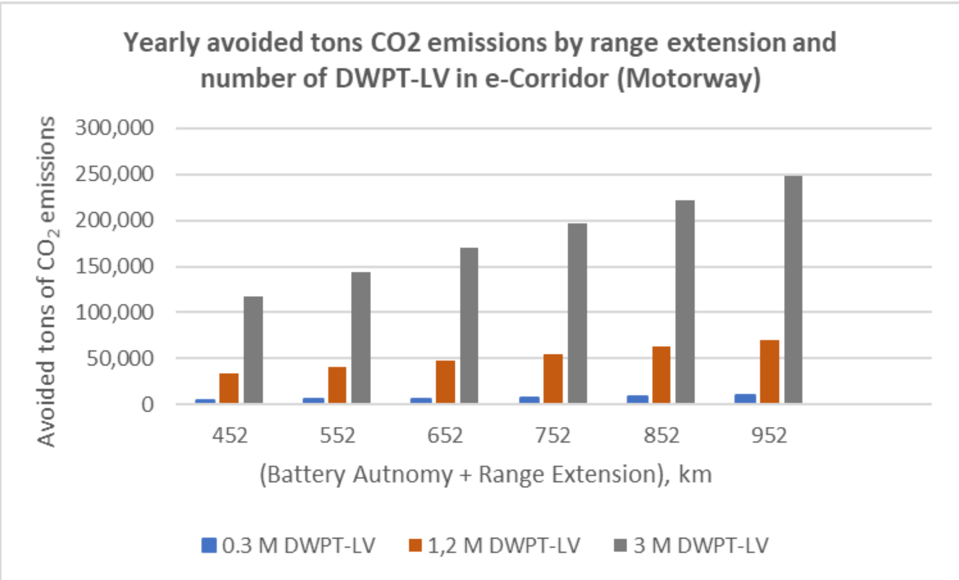
The most relevant aspects from the point of view of the administration is to quantify the savings in fossil fuels and the impact in CO_2 emissions. The proposal for the sensitivity analysis in the section is described in the following chart.

SIMULATION	Year	2,030	2040	2050			
No. of DWPT-LV		303,534	1,221,074	2,997,181			
No. of DWPT-HDV		17,739	124,883	408,707			
Battery + Range extension DWPT-HD'		452	552	652	752	852	952
Battery + Range extension DWPT-LV		328	428	528	628	728	828
QUESTIONS							
1. Yearly avoided tons of CO_2 depending on range extension (battery efficiency and power transfer) and number of yearly DWPT vehicles							
2. Yearly fuel savings according to range extension and number of yearly DWPT vehicles							

Table 17. Conditions for the simulation Motorway Scenario

2.2.3.2.1 *Administration. Motorway. Avoided CO2 emissions by DWPT-EV Sensitivity analysis*

The following figure shows the results for light vehicles in motorways.



Avoided tons CO2	DWPT-LV	2,030		2,040		2,050
	4,529	303,534	33,135	1,221,074	117,942	2,997,181
	452	4,529	452	33,135	452	117,942
	552	5,531	552	40,466	552	144,036
	652	6,533	652	47,796	652	170,129
	752	7,535	752	55,127	752	196,223
	852	8,537	852	62,458	852	222,316
	952	9,539	952	69,788	952	248,410

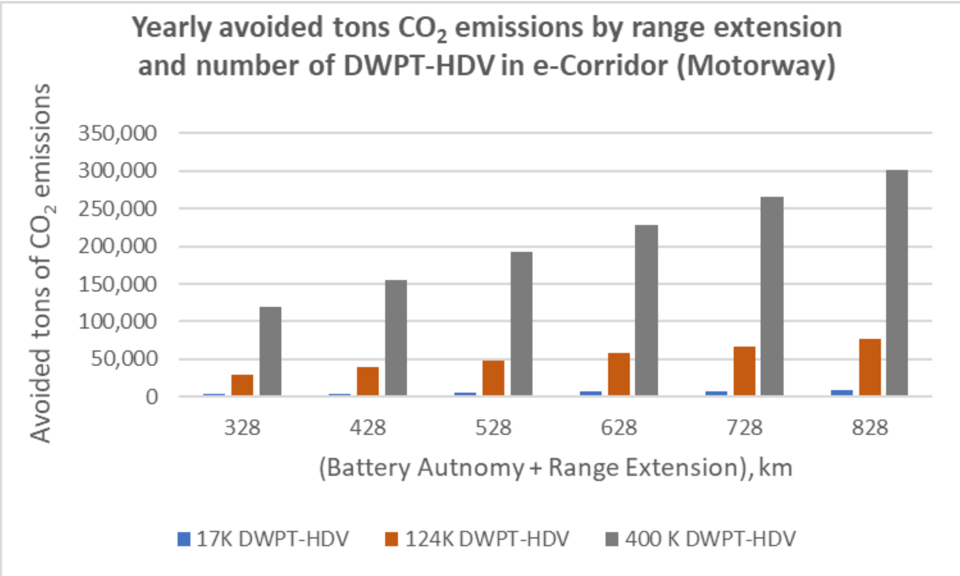
Figure 13. Yearly effect on avoided CO_2 emissions in an e-Corridor when increasing the number of DWPT-LV and the battery autonomy (by the range extension)

The range extension in a DWPT Light Vehicle can be increased through different methods:

- Reducing the speed though the e-Corridor (base case considers 100 km/h)
- Improving the efficiency of the power transfer although efficiency is quite high nowadays (around 90-95%)
- Raising the power transfer level from 20 or 50 kW to higher figures.

We can see in the simulation that progressive addition of 100 km of autonomy, raises the avoided tons of CO_2 emissions between 20% to 12%.

The same exercise was done for DWPT-Heavy Vehicles (HDV) with similar results.



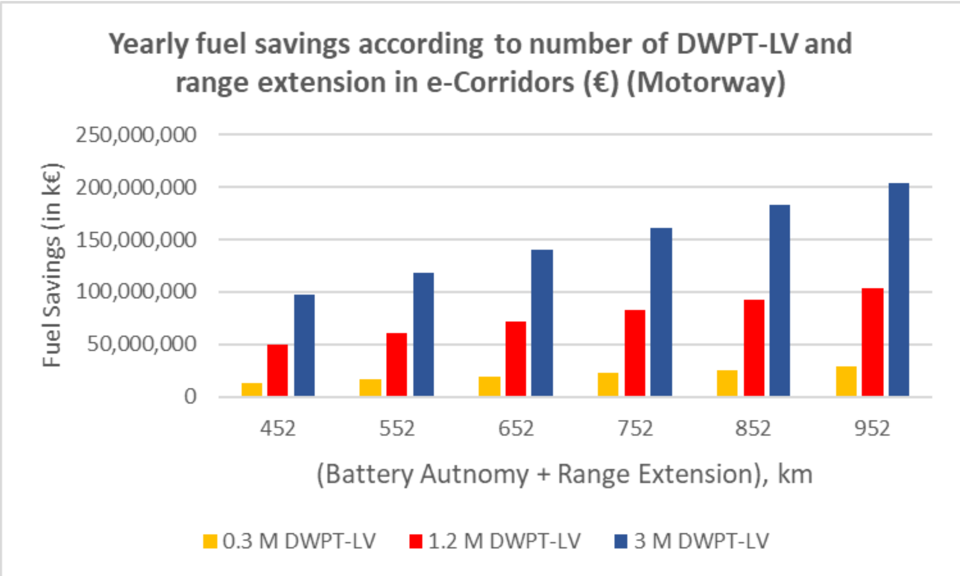
Avoided	DWPT-HDV	2,030		2,040		2,050
tons CO_2	3,386	17,739	30,182	124,883	119,542	408,707
	328	3,386	328	30,182	328	119,542
	428	4,418	428	39,384	428	155,987
	528	5,451	528	48,586	528	192,433
	628	6,483	628	57,788	628	228,878
	728	7,515	728	66,990	728	265,324
	828	8,548	828	76,192	828	301,769

Figure 14. Yearly effect on avoided CO_2 emissions in an e-Corridor when increasing the number of DWPT-HDV and the battery autonomy (by the range extension)

In this case, a progressive addition of 100 km of autonomy, raises the avoided tons of CO2 emissions from 30% to 14% as the emissions of conventional HDVs are higher.

2.2.3.2.2 Motorway Scenario. Fuel saved (in €) with the variation of the number of DWPT-EV and range extension

The second exercise pretends to evaluate how much fuel is saved (in monetary value, €) when introducing a higher number of DWPT-EVs overtime through an e-Corridor and how these savings evolve in case the battery autonomy is extended thanks to the range extension provided by the e-Corridor dynamic charging. Firstly, we made the simulation for light vehicles (LV) and later for heavy vehicles (HDV).

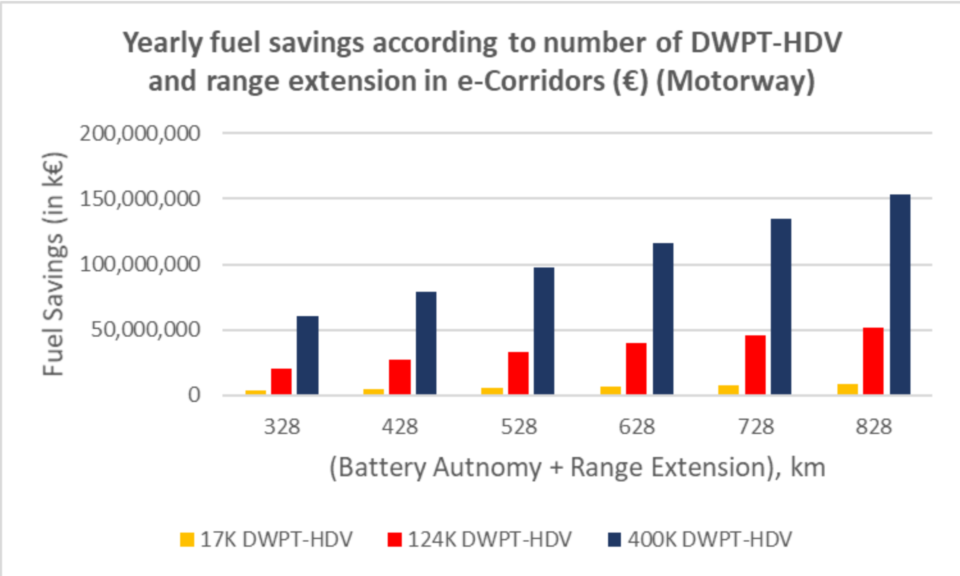


	DWPT-LV	2,030		2,040		2,050
Fuel Saved	13,644,278	303,534	49,400,084	1,221,074	97,003,801	2,997,181
	452	13,644,278	452	49,400,084	452	97,003,801
	552	16,662,924	552	60,329,306	552	118,464,819
	652	19,681,570	652	71,258,528	652	139,925,837
	752	22,700,215	752	82,187,750	752	161,386,855
	852	25,718,861	852	93,116,972	852	182,847,873
	952	28,737,506	952	104,046,195	952	204,308,891

Figure 15. Motorway Scenario. DWPT-LV. Effect on fuel savings when increasing the number of DWPT-LV and the battery autonomy (extended by the e-Corridor charging)

A progressive extension of 100 km in the battery autonomy supposes an improvement in fuel savings in the range of 22% to 12% from the base cases (13,644k € in 2,030, 49,400 k in 2,040 and 97,003 k in 2,050).

The same exercise was done for the DWPT-HDV scenario with similar conclusions although with major percentage of fuel savings. A progressive increase in 100 km of extra autonomy, infers fuel improved savings from 30% to 14% compared with the base scenario.



	DWPT-HDV	2,030		2,040		2,050
Fuel Saved	3,258,300	17,739	20,644,586	124,883	60,807,689	408,707
	328	3,258,300	328	20,644,586	328	60,807,689
	428	4,251,684	428	26,938,667	428	79,346,619
	528	5,245,068	528	33,232,748	528	97,885,548
	628	6,238,452	628	39,526,829	628	116,424,478
	728	7,231,836	728	45,820,910	728	134,963,407
	828	8,225,220	828	52,114,991	828	153,502,337

Figure 16. Motorway Scenario. DWPT-HDV. Effect on fuel savings when increasing the number of DWPT-HDV and the battery autonomy (extended by the e-Corridor charging)

The main conclusions of this study are:

- Approximately, 7 times smaller number of DWPT-HDV vehicles than DWPT-LV have a parallel effect on avoided emissions and fuel savings.
- Any increase in the vehicle autonomy range improves a lot the fuel savings and the avoided emissions. Every 100 km added to the vehicles, increase the avoided emissions and the fuel savings on a progressive range from 20% to 12% in light vehicles and 30% to 14% in HDV vehicles over the base scenario.

- The reduction of the speed when crossing the e-Corridor improves a lot the avoided emissions and the fuel savings. That is the main explanation to understand why the HDV vehicles in the periurban scenario driving at lower speed due to traffic conditions (50 km/h) will provide a much better business model as we will see hereinafter.

2.3 Periurban Scenario

The assumptions taken for the calculations in the periurban scenario are summarised below:

PERIURBAN SCENARIO		
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	€

[1] We call "billable" the gross power transfer because although in the invoice the user willl see the net energy transferred, he will pay for the gross energy transferred among other concepts

[2] The industrial owner of the e-Road will be charged with the industrial tariff in those kWh transferred to users

Table 18. Assumption for the business model

Assumption P&L Statement	
Items	
Taxes	25%
Interest rate	5%
Electricity price*	0.27
Assumption Balance sheet	
Items	
Loan	70%
Equity	30%

*Minimum electricity charging price to make the business model sustainable

Table 19. Assumptions for balance sheet and P&L Statement.

All these parameters can be modified, and the program recalculates all the outputs.

2.3.1 Investor view point (Periurban Scenario)

Below, we add as a reference the same table we used in D552 to clarify the business opportunity in the Periurban scenario. This scenario will require as well some economic support from the Administrations (in the way of subsidies to reduce the charging tariff to the users) and promotional actions to speed up the introduction of the DWPT technology among users. The periurban scenario, in case the forecast might be fulfilled, should be sustainable in 2040.

PERIURBAN BUSINESS MODEL			eHeavy 2030	eHeavy 2040	eHeavy 2050
1. Total amount of vehicles charging e-corr. per day	*Demand est.	Veh/day	810	1,768	3,098
2. Daily billable absorbed electricity of charging traffic in kW	[h]*[1]/[e]	kWh/day	20,250	44,194	77,449
3. Electrcity cost for daily traffic	[i]*[2]	€/day	1,596 €	3,482 €	6,103 €
4. Yearly electricity cost in one e-launcher	[3]*365	€/year	582,431 €	1,271,096 €	2,227,587 €
5. Yearly Cost of the infrastructure	*Cost Infrastruct	€/year infr	2,230,328 €	2,113,869 €	1,997,411 €
6. Total equilibrium point (electricity +infrastructure)	[4]+[5]	€/year	2,812,759 €	3,384,966 €	4,224,998 €
7. 50 % financing and benefits for infrastr. investor 50%	50%*[5]	€/year	1,115,164 €	1,056,935 €	998,705 €
8. TOTAL REQUIRED INCOMES BUSINESS MODEL	**[6]+[7]**	**€/year**	**3,927,923 €**	**4,441,901 €**	**5,223,703 €**
9. Required tariff to cover business model	[8]/([2]*365)	**€/kWh tariff**	**0.53**	**0.28**	**0.18**
10. Electricity price	[i]	€/kWh elec	0.08	0.08	0.08
11. Cost Surplus needed to cover the business model	[9]-[10]	€/kWh fee	0.45	0.20	0.11
12. Absorbed Electricity per charging cycle	[h]	kWh/EV	20.00	20.00	20.00
13. Average consumption in highways	[b]	kWh/km	1.50	1.50	1.50
14. Autonomy range extension	[12]/[13]	km	13.33	13.33	13.33
15. Cost of charging event for drivers	[12]*[9]	€/charge	**10.63**	**5.51**	**3.70**
16. Cost electricity per extended km	[15]/[14]	€/km	**0.80**	**0.41**	**0.28**
Cost of Consumption compared with ICE during extended range					
17. Equivalent cost/km of gasoil (1.15€/l)	[35]*[1.15]/100	€/km	**0.40**	**0.40**	**0.40**
18. Cost differences between gasoil and electricty [1]	[17]-[16]	€/km	**-0.39**	**-0.01**	**0.13**
19. Total savings in the extended autonomy	[14]*[18]	€	**-5.26**	**-0.14**	**1.67**
20. Required incentive for a comparable cost [2]	**[9]-([17]*[14]/[12]**	**€/kWh elec**	**0.26**	**0.01**	**-0.08**
21. Min. electricity prices for a sustanable business model in the periurban sc.		**€/kWh elec**	**0.27**	**0.27**	**0.27**

[1] A negative figure indicates that fuel is cheaper than electricity.
[2] A negative figure means that no incentive is required.

Table 20. "Fixed Picture" for the Business Model of the Periurban Scenario.

This table reflects the required incentives during years 2,030, 2,040 and 2,050 considering a fixed price of diesel of 1,15 €/l, to make the business model sustainable considering a number of HDV traveling through the e-Launcher within a year. Later, we will modify these assumptions in the sensibility analysis. We can see that the required tariffs are 0.53, 0.28 and 0.18 respectively. These tariffs are higher in 2,030 and 2,040, than the equivalent costs for diesel trucks, so drivers will not be willing to pay unless an incentive is paid to subsidize the tariff by the administrations and reach 0.27 €/kWh. In to 2050, the required tariff is lower than the equivalent for diesel trucks existing margin to produce significant revenues. As we mentioned in D552, pre-agreements will be needed among strong commercial companies with large fleets of trucks or buses daily travelling through the same roads and the infrastructure owners for a suitable business model.

Based on these assumptions, a P&L table, balance, free cash flow and main economic ratios, were prepared to visualize the evolution of the business opportunity over time.

P&L PERIURBAN SCENARIO

	%	Total	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Income from Users		**91,251,022**	1,983,319	2,162,978	2,358,911	2,572,593	2,823,058	3,078,784	3,357,676	3,661,831	3,993,538	4,355,293	4,749,817	5,006,858	5,277,809	5,563,423	5,864,493	6,181,856	6,516,393	6,869,034	7,240,759	7,632,600
Income from Government		**11,454,334**	1,944,604	1,818,983	1,677,830	1,519,683	1,325,517	1,126,864	905,830	660,330	388,084	86,609	0	0	0	0	0	0	0	0	0	0
TOTAL INCOMES		**102,705,356**	**3,927,923**	**3,981,960**	**4,036,741**	**4,092,276**	**4,148,575**	**4,205,648**	**4,263,506**	**4,322,161**	**4,381,622**	**4,441,901**	**4,749,817**	**5,006,858**	**5,277,809**	**5,563,423**	**5,864,493**	**6,181,856**	**6,516,393**	**6,869,034**	**7,240,759**	**7,632,600**
Inflaction rate	**1.50%**	**114,159,689**	**3,927,923**	**4,041,690**	**4,097,293**	**4,153,660**	**4,210,803**	**4,268,733**	**4,327,459**	**4,386,993**	**4,447,346**	**4,508,530**	**4,821,064**	**5,081,961**	**5,356,976**	**5,646,874**	**5,952,460**	**6,274,584**	**6,614,139**	**6,972,070**	**7,349,371**	**7,747,089**
Growth rate %			-	1.36%	1.36%	1.36%	1.36%	1.36%	1.36%	1.36%	1.36%	1.36%	6.48%	5.13%	5.13%	5.13%	5.13%	5.13%	5.13%	5.13%	5.13%	5.13%
R + D costs		**444,444**	**444,444**																			
Operating Costs		**6,422,249**	**325,031**	**324,719**	**324,408**	**324,096**	**323,785**	**322,826**	**322,516**	**322,205**	**321,896**	**321,586**	**320,629**	**320,320**	**320,011**	**319,703**	**319,395**	**318,439**	**318,132**	**317,824**	**317,518**	**317,211**
Labour	0.10%	4,814,106	243,000	242,757	242,514	242,272	242,029	241,787	241,546	241,304	241,063	240,822	240,581	240,340	240,100	239,860	239,620	239,380	239,141	238,902	238,663	238,424
Consumable	0.10%	713,201	36,000	35,964	35,928	35,892	35,856	35,820	35,785	35,749	35,713	35,677	35,642	35,606	35,570	35,535	35,499	35,464	35,428	35,393	35,357	35,322
Depreciation Equipment operation		239,760	12,960	12,960	12,960	12,960	12,960	12,312	12,312	12,312	12,312	12,312	11,664	11,664	11,664	11,664	11,664	11,016	11,016	11,016	11,016	11,016
Labour Overtime and outsource	0.10%	581,259	29,340	29,311	29,281	29,252	29,223	29,194	29,164	29,135	29,106	29,077	29,048	29,019	28,990	28,961	28,932	28,903	28,874	28,845	28,816	28,788
Other Operating Costs	0.10%	73,923	3,731	3,728	3,724	3,720	3,716	3,713	3,709	3,705	3,702	3,698	3,694	3,691	3,687	3,683	3,679	3,676	3,672	3,668	3,665	3,661
Maintenance Costs		**1,025,641**	**52,263**	**52,159**	**52,054**	**51,950**	**51,846**	**51,743**	**51,639**	**51,536**	**51,433**	**51,330**	**51,227**	**51,125**	**51,023**	**50,921**	**50,819**	**50,717**	**50,616**	**50,514**	**50,413**	**50,313**
Preventive maintenance	0.20%	763,481	38,904	38,827	38,749	38,671	38,594	38,517	38,440	38,363	38,286	38,210	38,133	38,057	37,981	37,905	37,829	37,754	37,678	37,603	37,527	37,452
Corrective maintenance	0.20%	262,160	13,359	13,332	13,305	13,279	13,252	13,226	13,199	13,173	13,147	13,120	13,094	13,068	13,042	13,016	12,990	12,964	12,938	12,912	12,886	12,860
Renewal costs		**22,641**	**0**	**0**	**0**	**0**	**0**	**1,536**	**1,532**	**1,528**	**1,525**	**1,521**	**1,517**	**1,513**	**1,509**	**1,506**	**1,502**	**1,498**	**1,494**	**1,491**	**1,487**	**1,483**
Refurbishment	0.25%	22,641						1,536	1,532	1,528	1,525	1,521	1,517	1,513	1,509	1,506	1,502	1,498	1,494	1,491	1,487	1,483
Disposal Costs		**-8,078**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-8,078**
Cost of asset disposal		345,946																				345,946
Residual value		-354,024																				-354,024
COSTS OF SALES		**7,906,897**	**821,739**	**376,878**	**376,462**	**376,046**	**375,631**	**376,105**	**375,687**	**375,270**	**374,853**	**374,437**	**373,373**	**372,958**	**372,543**	**372,129**	**371,715**	**370,654**	**370,241**	**369,829**	**369,418**	**360,928**
Inflaction rate	**1.50%**	**8,013,174**	**821,739**	**382,531**	**382,109**	**381,687**	**381,266**	**381,746**	**381,322**	**380,899**	**380,476**	**380,053**	**378,974**	**378,552**	**378,131**	**377,711**	**377,291**	**376,214**	**375,795**	**375,377**	**374,959**	**366,342**
EBITDA		**106,146,515**	**3,106,184**	**3,659,159**	**3,715,184**	**3,771,973**	**3,829,538**	**3,886,986**	**3,946,137**	**4,006,094**	**4,066,871**	**4,128,477**	**4,442,091**	**4,703,409**	**4,978,845**	**5,269,163**	**5,575,170**	**5,898,370**	**6,238,344**	**6,596,693**	**6,974,411**	**7,380,747**
Depreciation CAPEX		34,493,941	1,020,841	1,020,841	1,020,841	1,020,841	1,239,587	1,239,587	1,239,587	1,239,587	1,239,587	2,094,393	2,094,393	2,094,393	2,094,393	2,094,393	2,290,113	2,290,113	2,290,113	2,290,113	2,290,113	2,290,113
EBIT		**71,652,574**	**2,085,343**	**2,638,318**	**2,694,343**	**2,751,132**	**2,589,951**	**2,647,400**	**2,706,550**	**2,766,508**	**2,827,284**	**2,034,083**	**2,347,697**	**2,609,015**	**2,884,452**	**3,174,770**	**3,285,056**	**3,608,257**	**3,948,231**	**4,306,580**	**4,684,298**	**5,090,634**
Financial Expenses		11,866,320	678,859	597,381	1,108,681	1,546,194	608,600	540,022	487,804	437,313	388,333	815,421	757,184	671,532	640,629	511,655	528,532	452,824	376,774	305,033	237,904	175,645
Earning Before Tax		**49,813,582**	**1,406,484**	**2,040,937**	**1,585,662**	**1,204,939**	**1,981,351**	**2,107,378**	**2,218,747**	**2,329,195**	**2,438,951**	**1,218,662**	**1,590,513**	**1,937,483**	**2,243,823**	**2,663,116**	**2,756,524**	**3,155,433**	**3,571,457**	**4,001,547**	**4,446,394**	**4,914,988**
Taxes		12,453,396	351,621	510,234	396,415	301,235	495,338	526,844	554,687	582,299	609,738	304,666	397,628	484,371	560,956	665,779	689,131	788,858	892,864	1,000,387	1,111,599	1,228,747
NOPAT		**37,360,187**	**1,054,863**	**1,530,703**	**1,189,246**	**903,704**	**1,486,013**	**1,580,533**	**1,664,060**	**1,746,896**	**1,829,213**	**913,997**	**1,192,885**	**1,453,112**	**1,682,867**	**1,997,337**	**2,067,393**	**2,366,575**	**2,678,592**	**3,001,160**	**3,334,796**	**3,686,241**

Table 21. Profit and Losses Account for the Periurban Scenario (Infrastructure view point)

In the next table, we include the balance sheet corresponding to the investment done.

BALANCE. PERIURBAN	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
ASSETS																				
Non Current Assets																				
Property, plant and equipment	19,395,974	18,650,760	35,229,214	49,735,361	20,663,454	19,638,019	18,577,172	17,480,081	16,345,897	33,743,928	31,819,458	29,829,661	30,052,599	25,647,951	28,033,392	25,590,720	23,068,460	20,464,775	17,777,788	15,005,588
TOTAL ASSETS	**19,395,974**	**18,650,760**	**35,229,214**	**49,735,361**	**20,663,454**	**19,638,019**	**18,577,172**	**17,480,081**	**16,345,897**	**33,743,928**	**31,819,458**	**29,829,661**	**30,052,599**	**25,647,951**	**28,033,392**	**25,590,720**	**23,068,460**	**20,464,775**	**17,777,788**	**15,005,588**
LIABILITIES																				
Non-Current Liabilities																				
Loans	13,577,182	11,947,614	22,173,620	30,923,875	12,172,006	10,800,444	9,756,071	8,746,260	7,766,668	16,308,419	15,143,676	13,430,648	12,812,570	10,233,091	10,570,638	9,056,481	7,535,486	6,100,660	4,758,074	3,512,908
Equity	5,818,792	5,648,283	11,524,891	17,622,240	7,587,744	7,351,563	7,240,568	7,069,761	6,832,332	15,606,296	15,761,785	15,206,128	15,786,917	13,731,993	15,465,417	14,466,846	13,166,399	11,685,522	10,018,554	8,157,883
Profit/Losses (previous year)	**0**	**1,054,863**	**1,530,703**	**1,189,246**	**903,704**	**1,486,013**	**1,580,533**	**1,664,060**	**1,746,896**	**1,829,213**	**913,997**	**1,192,885**	**1,453,112**	**1,682,867**	**1,997,337**	**2,067,393**	**2,366,575**	**2,678,592**	**3,001,160**	**3,334,796**
TOTAL LIABILITIES	**19,395,974**	**18,650,760**	**35,229,214**	**49,735,361**	**20,663,454**	**19,638,019**	**18,577,172**	**17,480,081**	**16,345,897**	**33,743,928**	**31,819,458**	**29,829,661**	**30,052,599**	**25,647,951**	**28,033,392**	**25,590,720**	**23,068,460**	**20,464,775**	**17,777,788**	**15,005,588**
Net Liabilities (Total Assets - Total Liabilities)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Inflaction Rate	1.50%																			

Table 22. Balance Sheet (Periurban Scenario)

We have also calculated the Free Cash Flow and base in it the VAN and TIR of the installation and some other ratios.

FREE CASH FLOW PERIURBAN	2,031	2,032	2,033	2,034	2,035	2,036	2,037	2,038	2,039	2,040	2,041	2,042	2,043	2,044	2,045	2,046	2,047	2,048	2,049	2,050
NOPAT	1,054,863	1,530,703	1,189,246	903,704	1,486,013	1,580,533	1,664,060	1,746,896	1,829,213	913,997	1,192,885	1,453,112	1,682,867	1,997,337	2,067,393	2,366,575	2,678,592	3,001,160	3,334,796	3,686,241
Depreciation	1,020,841	1,020,841	1,020,841	1,020,841	1,239,587	1,239,587	1,239,587	1,239,587	1,239,587	2,094,393	2,094,393	2,094,393	2,094,393	2,094,393	2,290,113	2,290,113	2,290,113	2,290,113	2,290,113	2,290,113
CAPEX	-20,861,259	0	0	0	0	-4,713,026	0	0	0	0	-19,840,764	0	0	0	0	-4,893,906	0	0	0	0
Investment in working capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FREE CASH FLOW	-18,785,556	2,551,544	2,210,087	1,924,545	2,725,600	-1,892,907	2,903,646	2,986,483	3,068,799	3,008,390	-16,553,486	3,547,506	3,777,261	4,091,730	4,357,507	-237,218	4,968,706	5,291,273	5,624,909	5,976,354
Inflaction Rate	1.50%																			

KEY RATIOS PERIURBAN																				
Items	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**	**2046**	**2047**	**2048**	**2049**	**2050**
EBITDA/Incomes (%)	79.1%	91.9%	92.0%	92.2%	92.3%	92.4%	92.6%	92.7%	92.8%	92.9%	93.5%	93.9%	94.3%	94.7%	95.1%	95.4%	95.7%	96.0%	96.3%	96.7%
Cost of Sales/Income (%)	20.9%	9.5%	9.3%	9.2%	9.1%	8.9%	8.8%	8.7%	8.6%	8.4%	7.9%	7.4%	7.1%	6.7%	6.3%	6.0%	5.7%	5.4%	5.1%	4.7%
EBIT /Incomes(%)	53.1%	66.3%	66.7%	67.2%	62.4%	62.9%	63.5%	64.0%	64.5%	45.8%	49.4%	52.1%	54.7%	57.1%	56.0%	58.4%	60.6%	62.7%	64.7%	66.7%
NOPAT/Incomes (%)	26.9%	38%	29%	22%	36%	38%	39%	40%	42%	21%	25%	29%	32%	36%	35%	38%	41%	44%	46%	48%
Sales Growth (%)	-	1.36%	1.36%	1.36%	1.36%	1.36%	1.36%	1.36%	1.36%	1.36%	6.48%	5.13%	5.13%	5.13%	5.13%	5.13%	5.13%	5.13%	5.13%	5.13%
NOPAT/Equity (%)	18.1%	27.1%	10.3%	5.1%	19.6%	21.5%	23.0%	24.7%	26.8%	5.9%	7.6%	9.6%	10.7%	14.5%	13.4%	16.4%	20.3%	25.7%	33.3%	45.2%
Equity/Assets Ratio (%)	30.0%	30.3%	32.7%	35.4%	36.7%	37.4%	39.0%	40.4%	41.8%	46.2%	49.5%	51.0%	52.5%	53.5%	55.2%	56.5%	57.1%	57.1%	56.4%	54.4%

Table 23. Free Cash Flow and Key Ratios (Periurban Scenario)

The business opportunity is much positive in the periurban than the motorway scenario. The main reason of this advantage must be found in the required tariff to cover the business model which is lower in the periurban (0.58 in year 2,030) than the one needed in the motorway scenario (1.16 in 2,030). In the periurban areas (especially in those areas close to logistic centres, ports, etc.) it is envisaged that a higher number of daily HDV will cross the e-launchers and that will reduce the required tariff per user. In addition, the average speed in the motorway is 80 km/h for HDV whilst in the periurban is just 50 km/h due to the dense traffic, what also increase substantially the extended autonomy and that reduce the costs per each extender km reducing the distance with the equivalent ICE HDV.

Considering a discount rate of 5%, the Net Present Value (NPV) of the investment reaches 3,747,755 € and the IRR accounts for 7%.

In the next table, we split the incomes between the administration (incentive) and the contributions of users and we add the growing trend in the incomes according to the HDV on the roads, we just include the first 10 years as from year 2041 onward, the contribution of the administrations is not required (we reached the 0,27 €/KWh to make the business sustainable).

INCOME STATEMENT. PERIURBAN											
Items	Total	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Heavy vehicles (Amout/Year)		**295,650**	**322,431**	**351,639**	**383,492**	**418,230**	**456,115**	**497,432**	**542,492**	**591,634**	**645,227**
Charged electricity kWh/year		7,391,250	8,060,786	8,790,973	9,587,303	10,455,769	11,402,905	12,435,837	13,562,337	14,790,881	16,130,713
Required Tariffs		0.53	0.49	0.46	0.43	0.40	0.37	0.34	0.32	0.30	0.28
Required Incentive		0.26	0.23	0.19	0.16	0.13	0.10	0.07	0.05	0.03	0.01
Electricity Price to users		0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Income from Users	**91,251,022**	1,983,319	2,162,978	2,358,911	2,572,593	2,823,058	3,078,784	3,357,676	3,661,831	3,993,538	4,355,293
Income from Government	**11,454,334**	1,944,604	1,818,983	1,677,830	1,519,683	1,325,517	1,126,864	905,830	660,330	388,084	86,609
TOTAL INCOMES	**90,416,713**	**3,927,923**	**3,981,960**	**4,036,741**	**4,092,276**	**4,148,575**	**4,205,648**	**4,263,506**	**4,322,161**	**4,381,622**	**4,441,901**

Table 24. Distribution of revenues in the Periurban Sc. and trend in the required incentives from governments

All these tables may easily vary depending on several factors:

- Cost of infrastructure
- Prices of industrial electricity (considered 0.08 €/kWh paid by the infrastructure owner)
- Penetration of DWPT Vehicles.
- Cost of petrol (if petrol rises, the tariff admitted by DWPT-users could be higher)
- Incentives policy. This business opportunity is not sustainable unless a great initial support from public authorities is ensured.

We can also represent the P&L results in a figure organised in two decades as shown below.

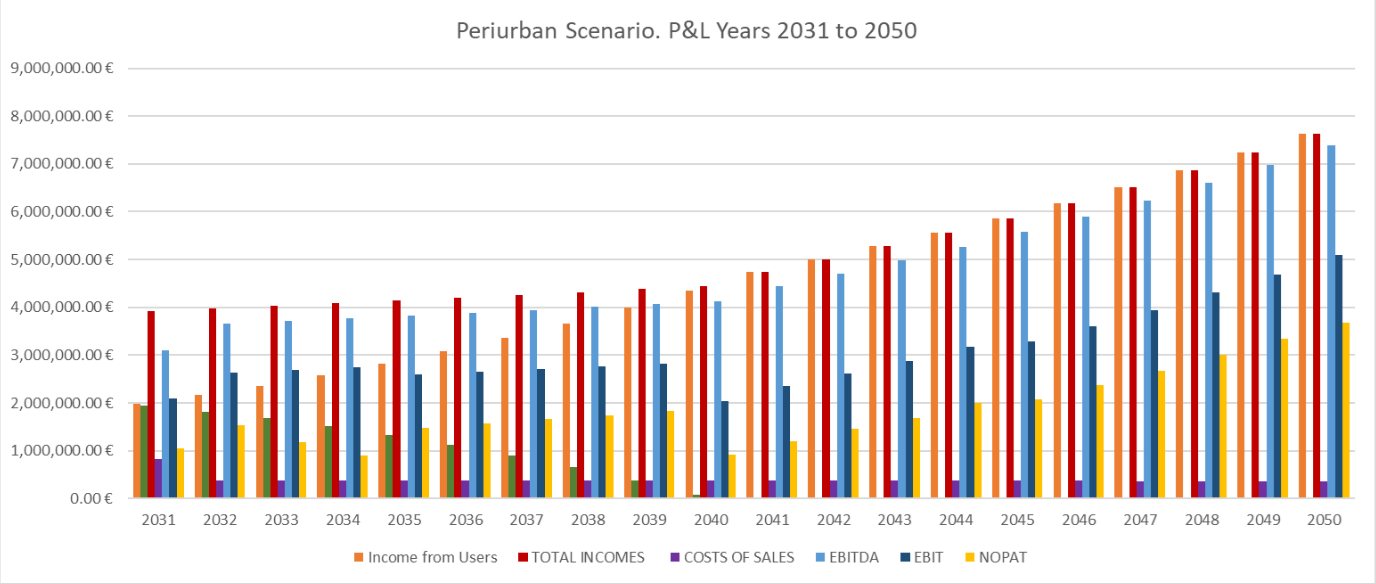


Figure 17. P&L Periurban Scenario (2031-2040) and (2041-2050)

The main difference with the motorway scenario is that in the second decade (2041 to 2050), there is no need for governmental contributions (no incentives required) as the business model is sustainable.

2.3.1.1 Sensitivity Analysis Periurban Scenario

We present here some preliminary results of variables which could vary significantly in the future. The next figure provides the evolution of the range extension when varying the average DWPT-HDV consumption. In the base scenario we considered 1.5 kWh/km, but here we increase it till 3.11 kWh/km. We also calculate the cost of the "added km of range extension" in year 30, 40 and 50. As soon as we reduce the consumption, the range extension is increased and the cost of the added km reduced. The cost of the extended km (€/km) corresponds to row 16 in the business model and is the cost against we compare the equivalent ICE truck diesel costs, impacting in the required tariff to make the business model sustainable.

Average Cons-HDV (kWh/km)	Range Extension (km)	Cost added km HDV-30 (€/km)	Cost added km HDV-40 (€/km)	Cost added km HDV-50 (€/km)
3.11	6.43	1.65	0.86	0.57
2.59	7.72	1.38	0.71	0.48
2.16	9.26	1.15	0.59	0.40
1.80	11.11	0.96	0.50	0.33
1.50	13.33	0.80	0.41	0.28
1.20	16.67	0.64	0.33	0.22

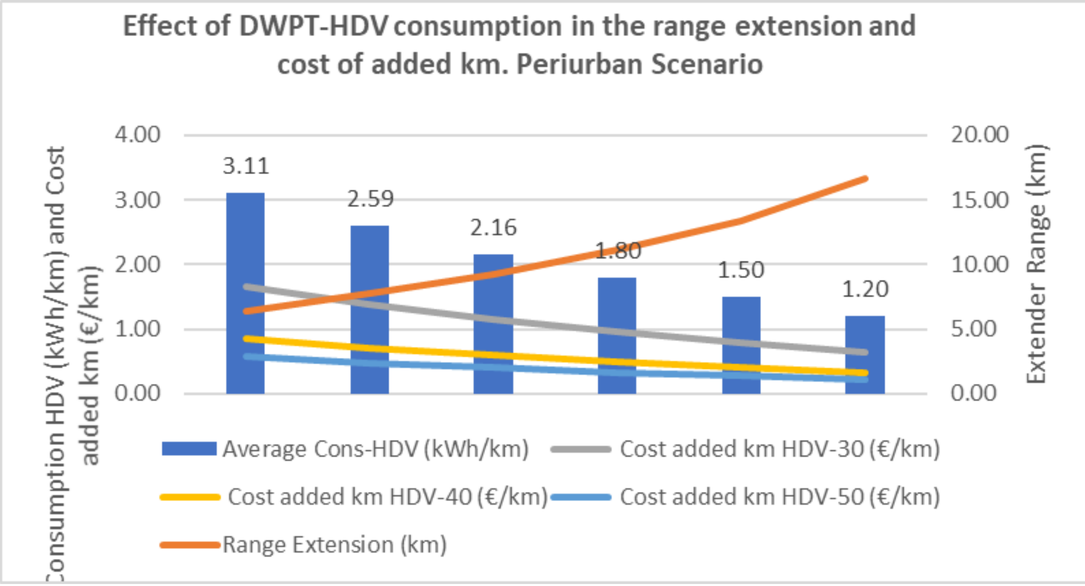
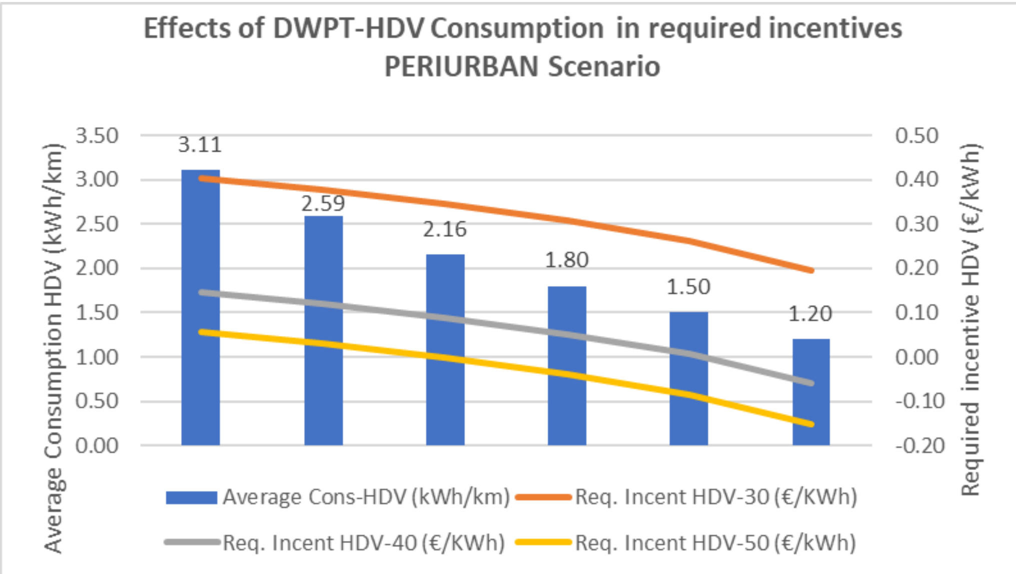


Figure 18. Sensitivity Analysis Periurban (HDV Consumption/ Range Extension/Cost of Extended km)

In the next figure, we have simulated the behaviour of the required incentives in years 2,030, 2,040 and 2,050, from government depending on the HDV consumption. Less vehicle consumption means less required incentives. The red, grey and yellow lines are parallel but 2,050 requires less incentives as the number of vehicles on the road are higher. In deed from year 2,040 the figures are negative, representing that no incentives are required as we have seen in previous chapter.



Average Cons-HDV (kWh/km)	Req. Incent HDV-30 (€/KWh)	Req. Incent HDV-40 (€/KWh)	Req. Incent HDV-50 (€/kWh)
3.11	0.40	0.15	0.06
2.59	0.38	0.12	0.03
2.16	0.35	0.09	0.00
1.80	0.31	0.05	-0.04
1.50	0.26	0.01	-0.08
1.20	0.20	-0.06	-0.15

Figure 19. Sensitivity Analysis Periurban. Effect in required incentive depending on HDV Consumption

The required incentive is quite sensible to the average vehicle consumption. More HDV consumption represents more required incentives (because the range extension is highly reduced).

Finally, a simulation was carried out modifying infrastructure costs and diesel prices, and based on these modifications, the required incentives were identified.

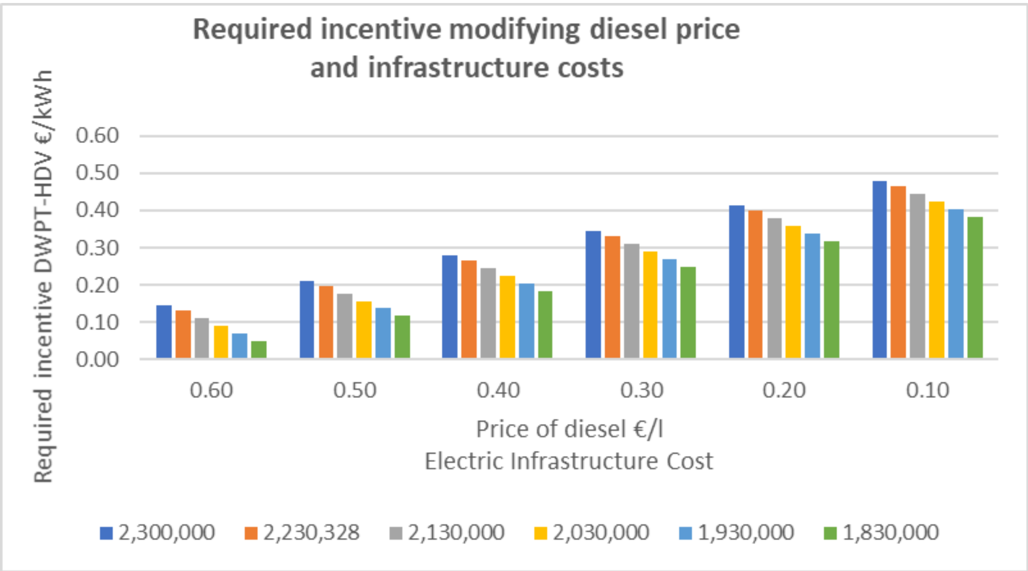


Figure 20. Required incentive versus gasoline price and infrastructure cost.

The results show that infrastructure costs have a large impact on the required incentive (2030). Diesel prices have much more impact than the one observed in light vehicle case of the motorway scenario. This is due to the reduced number of trucks compared to EVs.

2.3.2 Vehicle owner viewpoint in the Periurban scenario

2.3.2.1 Reference scenario

The reference scenario from the vehicle owner viewpoint was deeply described in D552. The main assumptions are stated in the following table for heavy vehicles (HDV) in the periurban scenario.

Comparison / RANGE EXTENDER ESTRATEGY **TRUCKS/BUS** PERIURBAN

Ref.DWPT-Heavy Vehicle /e-HEAVY			Ref. Heavy Vehicle Diesel (12 tons)		
VEHICLE AND INFRASTRUCTURE MAIN PARAMETERS					
Vehicle Battery autonomy	250	km	Vehicle autonomy	886	km
Vehicle Battery capacity	417	kWh			
			Power	270	CV
E-Road length	10	km	Consumption	35.0	l/100 km
E-Road billable Power transfer	100	kW	Tank	310	litros
Average speed in e-Corridor	60	km/h	Cost Diesel	1.15	€/l
Absorbed electricity in e-Road	72.72	kWh			
Range extension after e-Road	68	km			
Total range distance	318	km			
Average Consumption TTW	1.54	kWh/km		3.0	kWh/km
Average Consumption WTW	4.56	kWh/km		3.6	kWh/km
Total Consumption in total range	490	kWh	Diesel in the range	950.82	kWh
CAPEX					
ACQUISITION COSTS					
Life time	10	years		10	years
Adquisition basic vehicle cost	**175,000**	€		**125,000**	€
Adaptation plug-in to WPT in vehicle	4,500	€			
Adaptation WPT to DWPT in vehicle	4,500	€			
Total Acquisition Costs	**184,000**	€			
km /year	65,000	Km/y		65,000	Km/y
Total Km	650,000	km		650,000	km
INFRASTRUCTURE COSTS					
Plug-in ultracharger garage (150 kW)	80,000				
Adaptation parking to WPT	4,500				
OPEX					
MAINTENANCE COSTS					
Yearly maintenance	2,800	€/y		8,400	€/y
Replace Battery (evey 5 years)	41,700	€		0	€
Total cost maintenance (10 y)	69,700	€		84,000	€
INSURANCE COSTS					
Insurance/year	2,000	€/y		2,000	€/y
Total Insurance (10 y)	20,000	€		20,000	€
CONSUMPTION ELECTRICITY / FUEL					
Cost electricity headquarter	0.08	€/kwh	Diesel Consumption Costs	0.40	€/km
Cost in ultra-charger	0.65	€/kwh			
Cost electricity in e-Road	0.53	€/kwh[1]			
Cost Full charge at headquarter	33.4	€			
Cost charging in e-road (no incentive)	38.54	€			
Total charging cost electricity in range	71.90	€	**Cost Diesel in range**	128.00	€
CO2 emissions (g CO_2equiv/km) 2030	374.99	gr CO2/kWh		339.85	gr CO2/kWh
CO2 emissions (g CO_2equiv/km) 2050	121.80	gr CO2/km		1,016.14	gr CO2/km
TOTAL EMISSION IN RANGE DISTANCE	119,247	grCO2		323,133	gr CO1
TOTAL EMISSION IN RANGE DISTANCE	38,732	grCO2		323,133	gr CO2

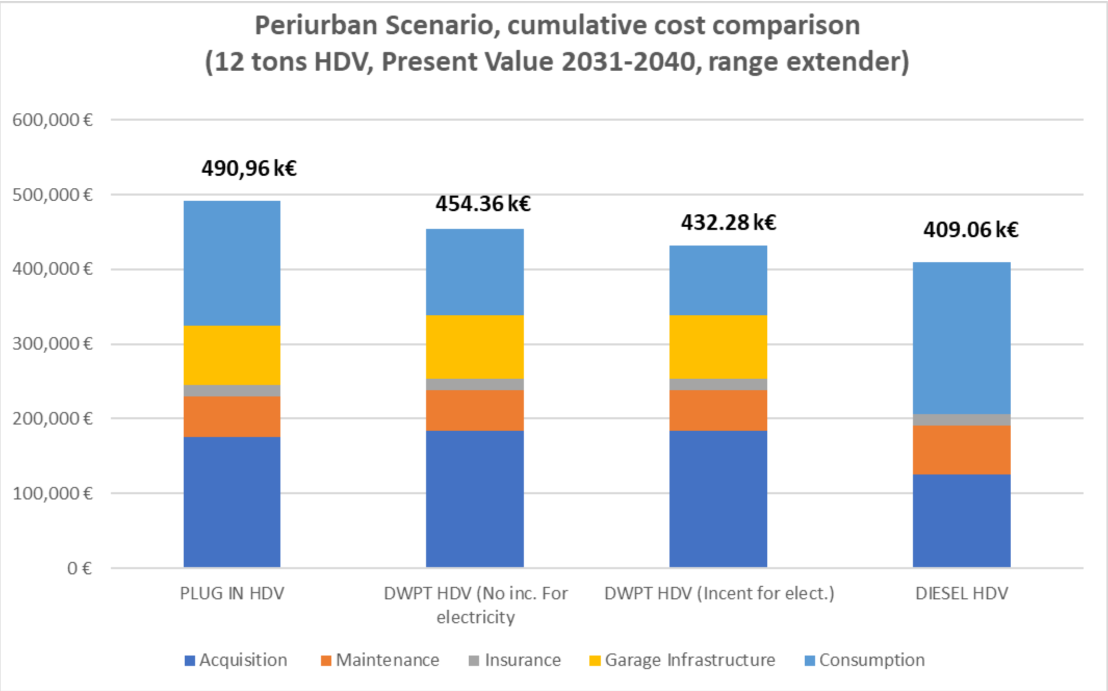
These two data comes from Global business model

Table 25. Reference scenario for heavy vehicles in the Periurban scenario.

Total Cost of Ownership. With the assumptions of the previous table we made the calculation of the TCO considering four main options;

5. Cost of the plug-in HDV charged at headquarter (with no VAT) and at the periurban roads in ultra-fast chargers. For the cost comparison, the same number of extra km that the HDV makes when charging dynamically has been adapted as if it should has charged in the ultra-fast facilities. Namely, for a total of 65.000 km/year, 51,101 km are supposed to be charged at headquarters and 13,899 km in the ultra-fast charged.
6. The second column represents the TCO for the DWPT case with no incentives (13,899 km charged dynamically at a rate of 0,53 €/kWh in 2030, been reduced progressively due increase in the number of HDV users)
7. In the third one, we consider the DWPT case with governmental incentives (13,899 km at a rate of 0.27 €/kWh in period 2030-2040). We have stated that the cost of charging at the ultra-fast equipment is reduced 1% in cost every year due to economies of scale. The incentivized tariff is kept constant during the 10 years period from the HDV owner view.
8. Finally, conventional HDVs that makes 65,000 km/year using diesel as energy source.

The results are summarised in the Total Cost of Ownership (TCO) figure below, addressing HDV vehicles comparing the DWPT options (with and without incentives), with the pure electric (plug-in) and the equivalent ICE trucks.



TCO/Concepts PERIURBAN	PLUG IN HDV	DWPT HDV (No inc. For electricity	DWPT HDV (Incent for elect.)	DIESEL HDV
Acquisition	175,000 €	184,000 €	184,000 €	125,000 €
Maintenance	54,427 €	54,427 €	54,427 €	65,263 €
Insurance	15,539 €	15,539 €	15,539 €	15,539 €
Garage Infrastructure	80,000 €	84,500 €	84,500 €	0 €
Consumption	165,995 €	115,902 €	93,815 €	203,266 €
TOTAL TCO	490,960 €	454,368 €	432,281 €	409,067 €

Figure 21. TCO Comparison of HDV vehicles in the Periurban Scenario

In this scenario, the DWPT-HDV vehicles are equipped with extender range batteries of the same size and autonomy as the equivalent pure plug in HDVs. The difference is that DWPT charges in the e-Launchers and the pure electric HDV charges in ultra-chargers. The differences in costs are due to the acquisition costs (DWPT-HDV incorporates the DWPT equip on board) and in the consumption costs as the due payment dynamically are below those in the ultra-chargers even without an incentive (subsidy from governments). In our exercise the ICE-HDV remains the cheaper.

The first simulation exercise done tries to evaluate the evolution of the TCO (for the four options), in case the acquisition costs of the base electric HDV might be reduced and the if the ultra-chargers also reduce the charging tariff in parallel.

2.3.2.2 Sensitivity analysis (HDV owner viewpoint, periurban)

In section 2.2.2.2, we described the trends on the energy prices (petrol and electricity) for the next 31 years according to the EU Energy Outlook 2050[6]. We will perform the same exercise done in section 2.2.2.2.2 for the motorway scenario but in this case applied to the periurban. We will confirm that results are much positive for the dynamic charging in this scenario than in the previous one. For the sensibility analysis, we have established 4 scenarios (base, 2,030, 2,040, and 2,050). The difference between base and 2,030 is only the cost of diesel and electricity. In the first case, we applied current tariffs and in the second the expected tariffs according to forecasts.

SENSIBILITY ANALYSIS

Initial Variables		Base	2030	2035	2040
Cost of electricity headquarter	€/kWh	0.08	0.2	0.25	0.30
Cost of ultrafast charging	€/kWh	0.65	0.65	0.81	0.98
Cost of diesel	€/km	0.40	0.56	0.50	0.45
Acquisition Costs plug-in	€	175,000	175,000	157,000	150,000
Acquisition Costs DWPT	€	184,000	184,000	165,000	157,000
Acquisition Costs ICE	€	125,000	125,000	100,000	90,000

-

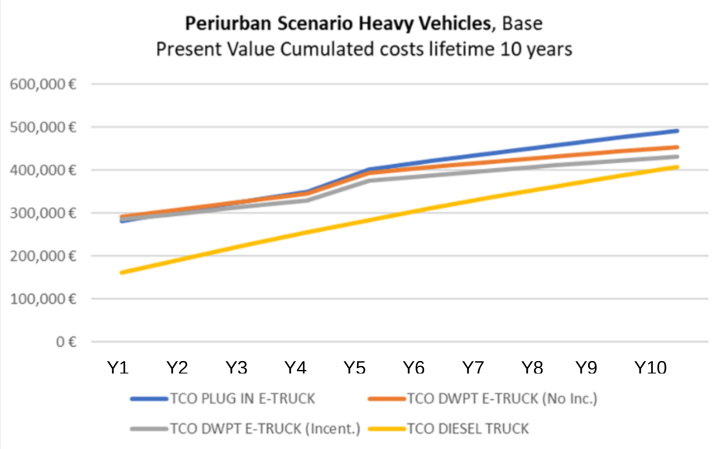
Table 26. Sensibility analysis for HDVs in the periurban scenario

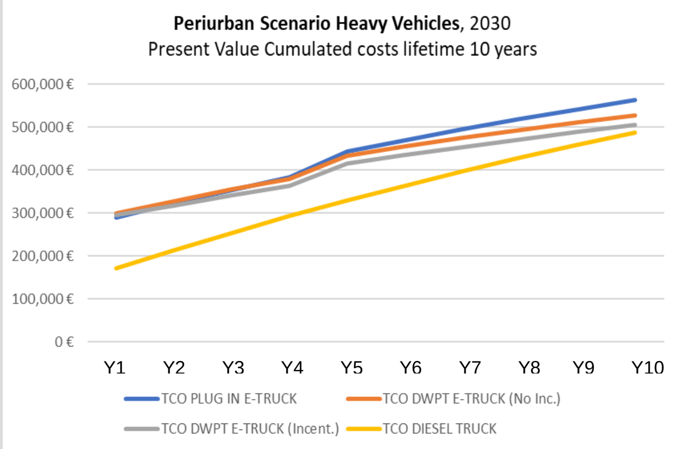
[6] https://ec.europa.eu/energy/sites/ener/files/documents/trends_to_2050_update_2013.pdf

The results are shown below:

TCO/Concepts PERIURBAN, Base	PLUG IN HDV	DWPT HDV (No inc. For electricity	DWPT HDV (Incent for elect.)	DIESEL HDV
Acquisition	175,000 €	184,000 €	184,000 €	125,000 €
Maintenance	54,427 €	54,427 €	54,427 €	65,263 €
Insurance	15,539 €	15,539 €	15,539 €	15,539 €
Garage Infrastructure	80,000 €	84,500 €	84,500 €	0 €
Consumption	165,995 €	115,902 €	93,815 €	202,003 €
TOTAL TCO	490,960 €	454,368 €	432,281 €	407,804 €

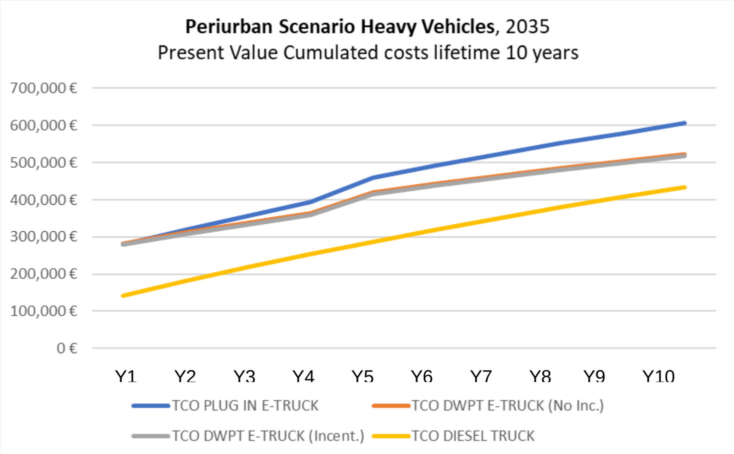
TCO/Concepts PERIURBAN. 2030	PLUG IN HDV	DWPT HDV (No inc. For electricity	DWPT HDV (Incent for elect.)	DIESEL HDV
Acquisition	175,000 €	184,000 €	184,000 €	125,000 €
Maintenance	54,427 €	54,427 €	54,427 €	65,263 €
Insurance	15,539 €	15,539 €	15,539 €	15,539 €
Garage Infrastructure	80,000 €	84,500 €	84,500 €	0 €
Consumption	239,364 €	189,271 €	167,184 €	282,804 €
TOTAL TCO	564,330 €	527,737 €	505,650 €	488,606 €

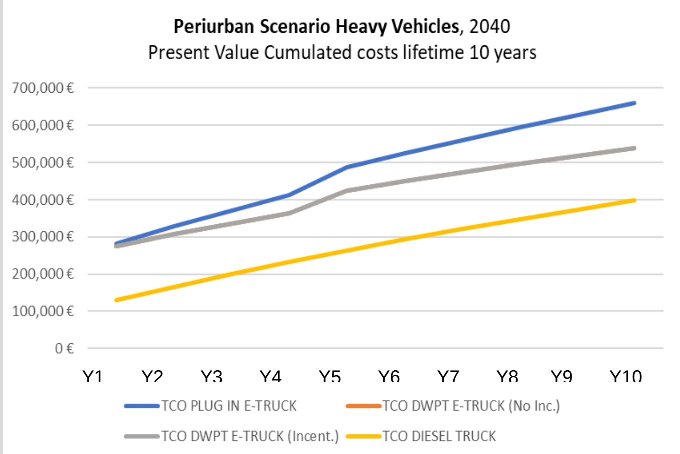




TCO/Concepts PERIURBAN 2035	PLUG IN HDV	DWPT HDV (No inc. For electricity	DWPT HDV (Incent for elect.)	DIESEL HDV
Acquisition	157,000 €	165,000 €	165,000 €	100,000 €
Maintenance	54,427 €	54,427 €	54,427 €	65,263 €
Insurance	15,539 €	15,539 €	15,539 €	15,539 €
Garage Infrastructure	80,000 €	84,500 €	84,500 €	0 €
Consumption	298,754 €	202,752 €	197,754 €	252,504 €
TOTAL TCO	605,720 €	522,218 €	517,220 €	433,305 €

TCO/Concepts PERIURBAN. 2040	PLUG IN HDV	DWPT HDV (No inc. For electricity	DWPT HDV (Incent for elect.)	DIESEL HDV
Acquisition	150,000 €	157,000 €	157,000 €	90,000 €
Maintenance	54,427 €	54,427 €	54,427 €	65,263 €
Insurance	15,539 €	15,539 €	15,539 €	15,539 €
Garage Infrastructure	80,000 €	84,500 €	84,500 €	0 €
Consumption	359,946 €	228,325 €	228,325 €	227,254 €
TOTAL TCO	659,912 €	539,791 €	539,791 €	398,055 €





Main conclusions:

- In base scenario and in 2,030, the dynamic charging options result cheaper than the plug in. The rationale is on the grounds that HDV in the periurban of a city represent a much bigger number of vehicles crossing the e-Launcher daily than in the Motorway scenarios. That's reduce the price of the charging event to make the business model sustainable,

whilst the cost of charging at the ultrafast equipment is almost fixe wherever you install the charger. In other words, the investor in an e-Launcher can adapt the pricing to the number of DWPT vehicles crossing it and recover the investment done (especially if they sign agreements with duty companies in the surroundings of the e-Launcher ensuring a minimum critical mass of daily vehicles), but the ultrafast chargers will likely stablish same energy prices for all the equipment regardless where they are located (Motorways or periurban).

- The diesel HDV will be always cheaper than alternatives, as OEMs will try to sell them as fast as possible due to the upcoming phase out. However, the sales will slow down fast as the use of this vehicles will be restricted more and more and costumers will refuse to buy them.

2.3.3 Administration view point (Periurban Scenario)

As in the case of the Motorway scenario, the administrations must consider the benefits of the dynamic charging from an overarching viewpoint and in this sense, the FABRIC project has considered the savings of CO_2 emissions and the fuel savings thanks to the introduction of the dynamic charging technology. Other externality costs have not been considered like the health impact or other environmental considerations.

2.3.3.1 Reference data

The reference data for the Periurban scenario from the Administration view point, gathers the following information; Present value of a conventional lane, present value of an e-launcher (external to the main highway), total fuel saved in case we use a DWPT-HDV vehicles charging in the e-launcher and total emissions avoided by the substitution of the internal combustion engine by the electric engine.

PERIURBAN SCENARIO		2,030	2,040	2,050	HDV	Unit
Cost of road						
Conventional road Present Value/km	€/km	1,289,483	1,111,160	932,837	10	km
E-Launcher Present Value/year	€/km	4,444,272	4,189,055	3,933,838	10	km
Nº of DWTP Heavy Vehicles /y	uds	295,650	645,227	1,130,755	318	km
Global Warming						
DWPT-HDV	g CO2-eq/km.veh	374.99	248.40	121.80	318	km
Diesel HDV	g CO2-eq/km.veh	1,016.14	1,016.14	1,016.14	318	km
Avoided emissions						
CO_2 emission avoided HDV	g CO2-eq/km.veh	641.15	767.75	894.34	318	km
Cost of fuel						
Heavy Vehicle	€/km	0.560	0.504	0.454	35	l/100 km

Table 27. Assumptions to compare ICE-HDV ad DWPT-HDV in the periurban scenario

In deliverable D534, a deep study was performed to compare the LCCA (Life Cycle Cost Analysis) of a conventional road trench (one lane of 10 km) and an external e-Launcher prepared for dynamic charging. The results are shown in columns 2,030, 2,040 and 2,050 of the previous table. The cost of an e-Launcher is from 3.4 to 4.2 times higher than a conventional lane. It was calculated that an HDV truck or bus crossing the e-Launcher with a battery autonomy of 250 km full at headquarters, will enlarge such autonomy in 68 km (be aware that in the motorway scenario the extension of the HDV autonomy was 78 km but in a trench of 25 km). The reason of this great difference is the average speed of the vehicles (in motorway 80 km/h and in periurban 50 km/h by virtue of the traffic density that reduce such speed). In the above table, we include also the CO_2 emissions comparing diesel and electric and the cost of the fuel in case a diesel HDV travelled 318 km. We considered a fix consumption of 35l/100 km for the ICE HDV although it could also change in the future.

In the next table, we present the main results; extra costs for the e-Launcher, global avoided CO_2 emissions, and global avoided fuel consumption (in m^3 and €)

PERIURBAN. Concept	Unit	2,030	2,040	2,050
Global Cost Road				
Total Cost Conventional Road	€	12,894,834	11,111,600	9,328,367
Total Cost E-Launcher	€	44,442,715	41,890,549	39,338,383
Extra Cost E-Launcher	**€**	**31,547,881**	**30,778,949**	**30,010,017**
Global Warming				
Global Emissions DWPT-HDV	tons CO2-equiv	35,255	50,966	43,797
Global Emissions Diesel HDV	tons CO2-equiv	95,534	208,494	365,384
Avoided Emissions				
Global avoided HDV	tons CO2-equiv	60,279	157,527	321,587
Fuel Consumption & cost				
Global HDV Consump. avoided	m^3	32,906	71,814	125,853
Global HDV fuel cost avoided	K€	52,649	103,412	163,106

Table 28. Periurban. Main environmental and energy results.

The main conclusions of these results are the following:

- The construction of an e-launcher reaches between 30 to 31 Million € extra compared with a conventional road.
- The penetration of the DWPT-HDV in a single 10 km e-Launcher, according to the forecast of vehicles, in a period of one year, will prevent the emissions of 60,279 tons of CO2 in 2.030, 157,527 tons in 2,040 and 321,587 tons in 2,050. The worldwide impact will be as simple as multiplying these avoided emissions by the number of e-Launchers installed.

- The penetration of the DWPT-HDV in a single 10 km e-Launcher, according to the forecast of vehicles, in a period of one year, saves 32,906 m^3 of diesel in 2,030, 71,814 m^3 in 2,040 and 125,853 m^3 in 2,050

These results are reflected in the following table:

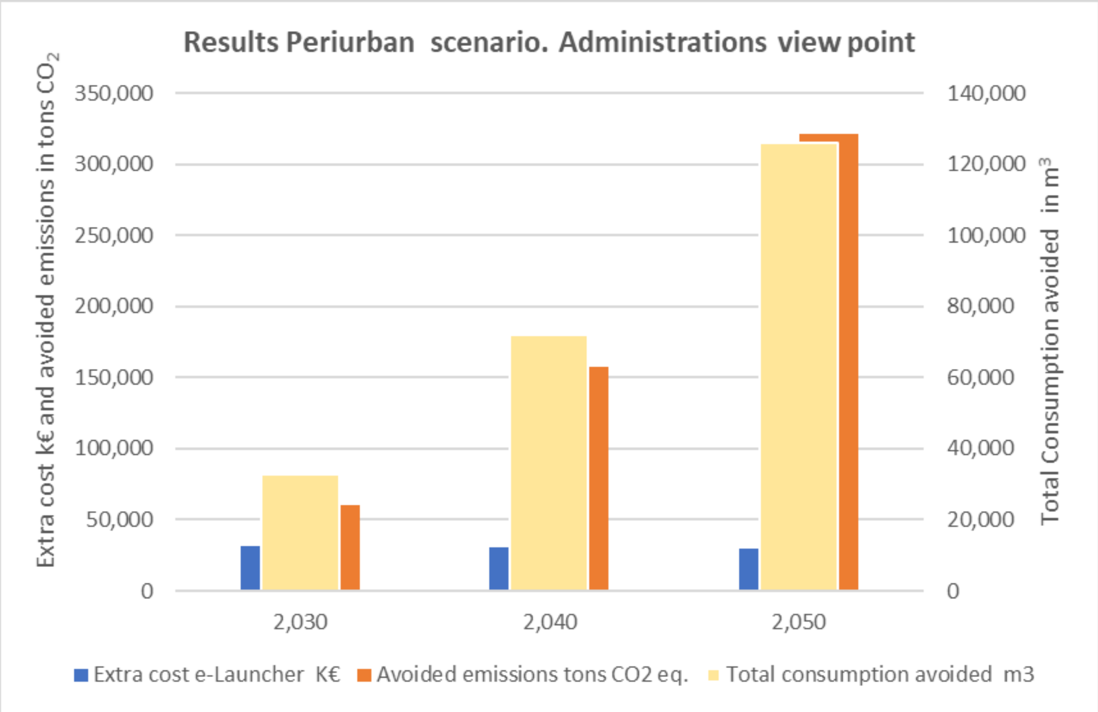


Figure 22. Periurban Scenario. 10 km e-Launcher. Administration view point.

2.3.3.2 Sensitivity analysis. Administration. Periurban Scenario

The most relevant aspects from the point of view of the administration is to quantify the savings in fossil fuels and the impact in CO_2 emissions. The proposal for the sensitivity analysis in the section is described in the following chart.

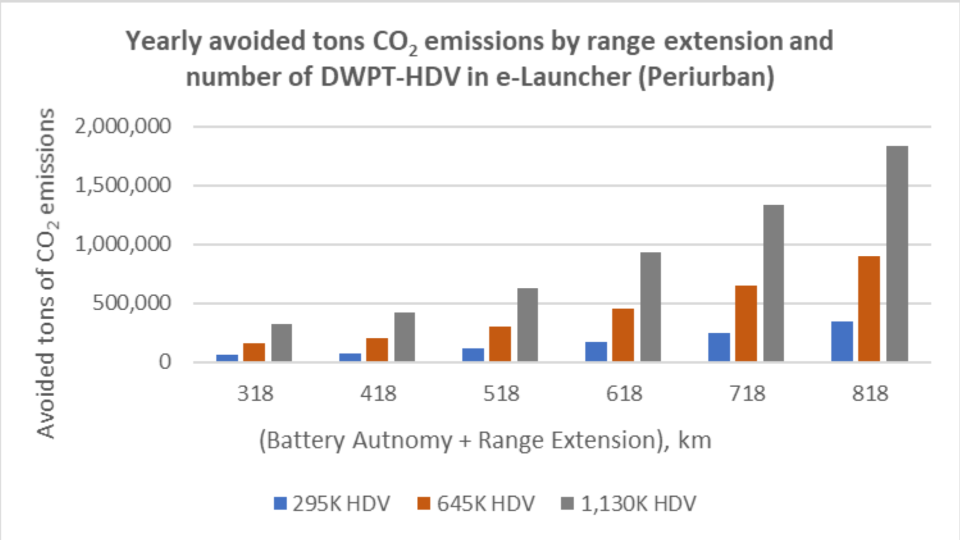
PERIURBAN SCENARIO
Sensibility Analysis

SIMULATION	**Year**	**2,030**	**2040**	**2050**			
No. of DWPT-HDV		295,650	645,227	1,130,755			
Battery + Range extension DWPT-HDV		318	418	518	618	718	818
QUESTIONS							
1. Yearly avoided tons of CO_2 depending on range extension (battery efficiency and power transfer) and number of yearly DWPT-HDV							
2. Yearly fuel savings according to range extension and number of yearly DWPT-HDV							

Table 29. Conditions for the simulation in the Periurban Scenario

2.3.3.2.1. Administration. Periurban. Avoided CO_2 emissions by DWPT-HDV. Sensibility Analysis.

The following figure shows the results for HDV vehicles in Periurban roads.



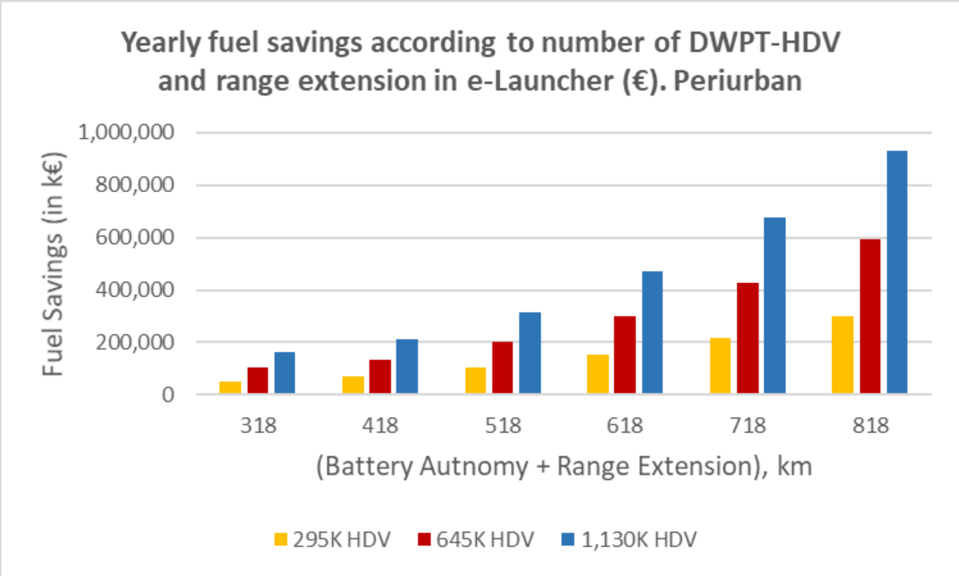
DWPT-HDV	2,030		2,040		2,050	
	60,279	295,650	157,527	645,227	321,587	1,130,755
	318	60,279	318	157,527	318	321,587
Avoided	418	79,234	418	207,064	418	422,715
tons CO_2	518	117,146	518	306,138	518	624,971
	618	174,012	618	454,749	618	928,354
	718	249,835	718	652,897	718	1,332,866
	818	344,613	818	900,582	818	1,838,506

In parallel to the motorways' section, the increase in the range extension in just 100 additional km., may increase the avoided emissions by 31%. That happens till the end of the simulation, with variations in the different slots between 31% and 49%. These percentages are higher than those indicated in the motorway scenario that varies between 12% and 20%. Thus, any reduction in the speed, improvement in the efficiency of the power transfer or raising in the transference power infer very significant additional savings in CO_2 emissions.

2.3.3.2.2. Administration viewpoint. Periurban Scenario. Fuel savings varying the number of HDV vehicles and the range extension

The second exercise pretends to assess how much fuel (diesel) could be saved (in €) when increasing the number of HDV crossing the e-Launcher and how these savings evolve in case the battery autonomy is extended thanks to the e-Launchers dynamic charging.

The results are summarized in the following figure and table:



	DWPT-HDV	2,030		2,040		2,050
	52,649	295,650	103,412	645,227	163,106	1,130,755
	318	52,649	318	103,412	318	163,106
	418	69,206	418	135,931	418	214,397
Fuel Saved	518	102,319	518	200,970	518	316,979
	618	151,988	618	298,528	618	470,852
	718	218,213	718	428,606	718	676,016
	818	300,995	818	591,203	818	932,471

A progressive extension of 100 km in the battery autonomy supposes a great improvement in fuel savings in the range of 31% to 49% from the base case (52,649 K€ in 2,030, 103,412 k€ in 2,040 and 163,106 k€ in 2,050). Be aware that savings in the Periurban scenario are higher than in the Motorway and the additional range extension infers more percentage of gaining in terms of CO_2 emissions or fuel savings.

The main conclusions of this study in the Periurban scenario are:

- In the periurban scenario, the option for dynamic charging seems to be better than the superfast chargers on the grounds that the business model is better supported by two reasons; the number of daily vehicles crossing the e-Launchers is higher (some of them could recharger even more than once a day), the speed in the e-Launcher is under 50 km/h in view of the traffic density or the speed limitations. Both reasons, make the business model feasible. In addition, the emissions are highly reduced close to the city centres, what represents an important factor to consider.

2.4 Urban Bus Scenario

The Urban Bus Scenario is apparently the most suitable to happen earlier. The battery shrink strategy reduces the acquisition costs of the buses substantially and the daily transition of 400 buses given many rounds within a city makes the business model possible. As extensively described in D5.5.2, we include here the input parameters:

IMPUT DATA (ONE BUS ONE E-TRENCH)	eBus	Units
a. E-Trench length	0.025	km
b. Average consumption in city	1.5	kWh/km
c. Travel Speed in e-trenches	3	km/h
d. Total time to cross an e-trench	0.5	min
e. Charging efficiency	80%	%
f. Gross Power transfer	125	kW
g. Net power transfer	100	kW
h. Electricity absorbed per charging cycle	0.83	kWh
i. Average European Industrial Electricity Price [2]	**0.08**	€/kWh
j. Electricity cost per vehicle in charging event	0.07	€
Battery bus capacity	41	KWh

Note 1. In the Urban scenario the bus consumption is the minimun required to cover the range extension (battery shrink strategy) and not the maximum possible energy absorbed
as in the motorway and periurban scenarios.

CITY SERVICE CONDITIONS	Quantity	Units
k. Number of buses	400	buses
l. Number of routes	40	routes
m. Driving cycle	SORT 1-1-2-2-3-3	
n. Average Daily route (km), 1 direction (half trip)	9	km
o. Number of stops per route	27	stops/route
p. Total number of stops/bus day	972	stops/city
q. Time for one route (round trip)	0.5 h (1 h)	
r. Service time (h) = nº of round trips (2 routes:1 trip)	18	trips
s. Consumption bus on average	1.5	kWh/km

Table 30. Tables describing the service conditions (Urban Bus Scenario)

Assumptions Economic Statement	
Items	
Taxes	25%
Interest rate	5%
Tariff (€/KWh)	0.15
Items	
Loan	50%
Equity	50%

Table 31. Table describing main assumptions for Economic statements in the Urban Bus Scenario

2.4.1 From the e-Infrastructure viewpoint

In this case, the investors, will most likely be the local administrations as owners of the public transport service. This is the reason why this scenario presents better options as there is no need to generate profits, as in public services, incomes must simply cover the expenses. The fixed picture we defined in D552, is depicted below:

URBAN BUS BUSINESS MODEL FOR 1.080 E-TRENCHES, 400 BUSES				eBus 2030	eBus 2040	eBus 2050
1. Total amount of buses charging in 1 e-Trench per day		*Demand est.	Bus/day	400	400	400
2. Daily consumed electricity per bus		[b]*2*[n]*[r]/[e]	kWh/day	608	608	608
3. Totaldaily consumed electricity for all buses		[1]*[2]	kWh/day	243,000	243,000	243,000
4. Total Yearly electricity consumed by all buses		[3]*365	kWh/y	88,695,000 €	88,695,000 €	88,695,000 €
5. Total Yearly electricity costs all fleet		[4]*[i]	€/year electr.	6,989,166 €	6,989,166 €	6,989,166 €
6. Yearly Cost of the infrastructure in the city		*Cost Infrastruct	€/year infr	5,106,570 €	4,839,925 €	4,573,281 €
7. Total equilibrium point (electricity +infrastructure)		[5]+[6]	€/year	12,095,736 €	11,829,091 €	11,562,447 €
8. 30 % financial for infrasture CAPEX	30%	30%*[6]	€/year	1,531,971 €	1,451,978 €	1,371,984 €
9. TOTAL REQUIRED INCOMES BUSINESS MODEL		**[7]+[8]**	**€/year**	**13,627,707 €**	**13,281,069 €**	**12,934,431 €**
10. Required tariff to cover business model		[9]/([3]*365)	**€/kWh tariff**	**0.15**	**0.15**	**0.15**
11. Electricity price		[i]	€/kWh elec	0.08	0.08	0.08
12. Cost Surplus needed to cover the business model		[11]-[12]	€/kWh fee	0.07	0.07	0.07
13. Electricity consumed per charging cycle (trench)		[e]*[2]/[p]	kWh/trench	0.50	0.50	0.50
14. Average consumption in city		[b]	kWh/km	1.50	1.50	1.50
15. Autonomy range extension in one e-trench		[13]/[14]	km	0.33	0.33	0.33
16. Cost of charging event (trench) for drivers		[11]*[14]	€/charge	**0.08**	**0.07**	**0.07**
17. Cost electricity per extended km generated by the trench		[17]/[16]	€/km	**0.23**	**0.22**	**0.22**
18. Equivalent cost/km of gasoil (1,15€/l)	35	[35]*[1.15]/100	€/km	**0.40**	**0.40**	**0.40**
19. Cost differences between gasoil and electricty [1]		[18]-[17]	€/km	**0.17**	**0.18**	**0.18**
20. Total savings in the extended autonomy in one e-trench		[19]*[15]	€	**0.06**	**0.06**	**0.06**
21. Required incentive for a comparable cost [2]		**[10]-([18]*[15]/[13])**	**€/kWh elec**	**-0.11**	**-0.12**	**-0.12**
22. Min. electricity prices for a sustanable business model in the urban sc.			**€/kWh elec**	**0.27**	**0.27**	**0.27**

Figure 23. "Fixed Picture" for the Business Model of the Urban Bus Scenario.

The fixed picture above just includes 30% of required extra incomes (line 8) to cover the business models instead of the 50% we set in the motorway and periurban scenarios, as there is no need to generate profits. If the buses should have been engineered with fossil fuels, the minimum required tariffs to cover the business model should reach 0,27 €/kWh, but as we see in line 10, in this case is much lower (0.15 in all cases). That's leave some room to reduce the bus tickets.

We include the main economic calculations considering a ratio of 50% equity and 50% debt. The NOPAT presents much better scores than previous scenarios.

2.4.1.1 Main Economic Results (P&L, Balance, Free Cash Flow and Ratios)

Based on these assumptions, a P&L table, balance, free cash flow and main economic ratios, were prepared to visualize the evolution of the business opportunity over time.

PROFIT AND LOSSES. URBAN

Items	%	Total	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Income from Users			13,627,707	13,627,707	13,627,707	13,627,707	13,627,707	13,627,707	13,627,707	13,627,707	13,627,707	13,627,707
Income from Government												
NET INCOMES		**272,554,132**	**13,627,707**	**13,627,707**	**13,627,707**	**13,627,707**	**13,627,707**	**13,627,707**	**13,627,707**	**13,627,707**	**13,627,707**	**13,627,707**
Inflaction rate	**1.50%**	**315,122,551**	**13,627,707**	**13,832,122**	**14,039,604**	**14,250,198**	**14,463,951**	**14,680,910**	**14,901,124**	**15,124,641**	**15,351,510**	**15,581,783**
Growth rate %			-	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R + D costs		**1,200,000**	**1,200,000**									
Operating Costs		**9,592,330**	**484,618**	**484,140**	**483,662**	**483,185**	**482,708**	**481,908**	**481,432**	**480,957**	**480,482**	**480,008**
Labour	0.10%	8,023,510	405,000	404,595	404,190	403,786	403,382	402,979	402,576	402,173	401,771	401,370
Consumable	0.10%	356,600	18,000	17,982	17,964	17,946	17,928	17,910	17,892	17,874	17,857	17,839
Depreciation oper. Equipment		119,880	6,480	6,480	6,480	6,480	6,480	6,156	6,156	6,156	6,156	6,156
Labour Overtime and outsource	0.10%	974,375	49,183	49,134	49,085	49,036	48,987	48,938	48,889	48,840	48,791	48,742
Other Operating Costs	0.10%	117,965	5,954	5,949	5,943	5,937	5,931	5,925	5,919	5,913	5,907	5,901
Maintenance Costs		**1,742,850**	**88,810**	**88,632**	**88,455**	**88,278**	**88,101**	**87,925**	**87,749**	**87,574**	**87,399**	**87,224**
Preventive maintenance	0.20%	1,355,299	69,062	68,923	68,786	68,648	68,511	68,374	68,237	68,100	67,964	67,828
Corrective maintenance	0.20%	387,550	19,748	19,709	19,669	19,630	19,591	19,552	19,512	19,473	19,434	19,396
Renewal costs		**40,754**	**0**	**0**	**0**	**0**	**0**	**2,765**	**2,758**	**2,751**	**2,744**	**2,737**
Refurbishment	0.25%	40,754						2,765	2,758	2,751	2,744	2,737
Disposal Costs		**-21,812**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cost of asset disposal		934,053										
Residual value		-955,865										
COSTS OF SALES		**12,554,122**	**1,773,427**	**572,772**	**572,117**	**571,463**	**570,809**	**572,598**	**571,939**	**571,282**	**570,625**	**569,969**
Inflaction rate	**1.50%**	**12,715,833**	**1,773,427**	**581,363**	**580,699**	**580,035**	**579,372**	**581,187**	**580,518**	**579,851**	**579,184**	**578,518**
EBITDA		**302,406,718**	**11,854,279**	**13,250,759**	**13,458,905**	**13,670,163**	**13,884,579**	**14,099,724**	**14,320,606**	**14,544,790**	**14,772,326**	**15,003,265**
Depreciation		75,611,515	2,516,845	2,516,845	2,516,845	2,516,845	3,087,448	3,087,448	3,087,448	3,087,448	3,087,448	4,276,696
EBIT		**226,795,203**	**9,337,434**	**10,733,914**	**10,942,060**	**11,153,318**	**10,797,132**	**11,012,276**	**11,233,158**	**11,457,342**	**11,684,878**	**10,726,568**
Financial Expences		0	1,673,702	1,365,977	1,219,064	1,108,913	1,356,516	1,247,809	1,121,013	997,282	877,373	1,421,636
Earning Before Tax		**206,817,951**	**7,663,732**	**9,367,937**	**9,722,996**	**10,044,406**	**9,440,616**	**9,764,467**	**10,112,145**	**10,460,060**	**10,807,506**	**9,304,932**
Taxes		51,704,488	1,915,933	2,341,984	2,430,749	2,511,101	2,360,154	2,441,117	2,528,036	2,615,015	2,701,876	2,326,233
Net Earnings		**155,113,463**	**5,747,799**	**7,025,953**	**7,292,247**	**7,533,304**	**7,080,462**	**7,323,350**	**7,584,109**	**7,845,045**	**8,105,629**	**6,978,699**

Items	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Income from Users	13,627,707	13,627,707	13,627,707	13,627,707	13,627,707	13,627,707	13,627,707	13,627,707	13,627,707	13,627,707
Income from Government										
NET INCOMES	**13,627,707**	**13,627,707**	**13,627,707**	**13,627,707**	**13,627,707**	**13,627,707**	**13,627,707**	**13,627,707**	**13,627,707**	**13,627,707**
Inflaction rate	**15,815,510**	**16,052,743**	**16,293,534**	**16,537,937**	**16,786,006**	**17,037,796**	**17,293,363**	**17,552,763**	**17,816,055**	**18,083,295**
Growth rate %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R + D costs										
Operating Costs	**479,210**	**478,736**	**478,263**	**477,791**	**477,319**	**476,524**	**476,053**	**475,582**	**475,112**	**474,642**
Labour	400,968	400,567	400,167	399,766	399,367	398,967	398,568	398,170	397,772	397,374
Consumable	17,821	17,803	17,785	17,767	17,750	17,732	17,714	17,696	17,679	17,661
Depreciation oper. Equipment	5,832	5,832	5,832	5,832	5,832	5,508	5,508	5,508	5,508	5,508
Labour Overtime and outsource	48,694	48,645	48,596	48,548	48,499	48,451	48,402	48,354	48,305	48,257
Other Operating Costs	5,895	5,889	5,883	5,878	5,872	5,866	5,860	5,854	5,848	5,842
Maintenance Costs	**87,049**	**86,875**	**86,702**	**86,528**	**86,355**	**86,182**	**86,010**	**85,838**	**85,666**	**85,495**
Preventive maintenance	67,693	67,557	67,422	67,287	67,153	67,018	66,884	66,751	66,617	66,484
Corrective maintenance	19,357	19,318	19,279	19,241	19,202	19,164	19,126	19,087	19,049	19,011
Renewal costs	**2,730**	**2,724**	**2,717**	**2,710**	**2,703**	**2,696**	**2,690**	**2,683**	**2,676**	**2,670**
Refurbishment	2,730	2,724	2,717	2,710	2,703	2,696	2,690	2,683	2,676	2,670
Disposal Costs	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-21,812**
Cost of asset disposal										934,053
Residual value										-955,865
COSTS OF SALES	**568,990**	**568,335**	**567,682**	**567,029**	**566,377**	**565,403**	**564,752**	**564,103**	**563,455**	**540,995**
Inflaction rate	**577,525**	**576,860**	**576,197**	**575,535**	**574,873**	**573,884**	**573,224**	**572,565**	**571,906**	**549,110**
EBITDA	**15,237,985**	**15,475,882**	**15,717,337**	**15,962,402**	**16,211,133**	**16,463,912**	**16,720,139**	**16,980,198**	**17,244,148**	**17,534,185**
Depreciation	4,276,696	4,276,696	4,276,696	4,276,696	4,787,236	4,787,236	4,787,236	4,787,236	4,787,236	4,787,236
EBIT	**10,961,289**	**11,199,186**	**11,440,640**	**11,685,706**	**11,423,897**	**11,676,677**	**11,932,903**	**12,192,963**	**12,456,913**	**12,746,950**
Financial Expences	1,292,649	1,133,732	980,445	833,794	936,719	604,773	645,547	511,045	383,471	265,793
Earning Before Tax	**9,668,640**	**10,065,454**	**10,460,195**	**10,851,911**	**10,487,178**	**11,071,904**	**11,287,357**	**11,681,918**	**12,073,442**	**12,481,156**
Taxes	2,417,160	2,516,363	2,615,049	2,712,978	2,621,795	2,767,976	2,821,839	2,920,479	3,018,360	3,120,289
Net Earnings	**7,251,480**	**7,549,090**	**7,845,147**	**8,138,934**	**7,865,384**	**8,303,928**	**8,465,517**	**8,761,438**	**9,055,081**	**9,360,867**

Table 32. Profit and Losses Account for the Urban Bus Scenario (Infrastructure view point)

In the next table, we include the balance sheet corresponding to the investment done.

Balance Sheet URBAN SCENARIO	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
ASSETS																				
Non Current Assets																				
Property, plant and equipment	47,820,057	45,982,760	44,079,585	42,108,968	51,576,036	49,023,619	46,383,024	43,652,181	40,828,977	63,746,976	59,739,900	55,598,269	51,318,947	46,898,736	54,282,705	39,282,140	43,773,535	38,264,081	32,579,495	26,715,761
Total Assets	**47,820,057**	**45,982,760**	**44,079,585**	**42,108,968**	**51,576,036**	**49,023,619**	**46,383,024**	**43,652,181**	**40,828,977**	**63,746,976**	**59,739,900**	**55,598,269**	**51,318,947**	**46,898,736**	**54,282,705**	**39,282,140**	**43,773,535**	**38,264,081**	**32,579,495**	**26,715,761**
LIABILITIES																				
Non-Current Liabilities																				
Loans	33,474,040	27,319,538	24,381,290	22,178,251	27,130,323	24,956,178	22,420,253	19,945,644	17,547,452	28,432,728	25,852,988	22,674,644	19,608,896	16,675,883	18,734,371	12,095,451	12,910,937	10,220,907	7,669,414	5,315,865
Equity	14,346,017	12,915,422	12,672,342	12,638,470	16,912,409	16,986,979	16,639,421	16,122,428	15,436,480	27,208,619	26,908,213	25,672,145	24,160,961	22,377,707	27,409,400	19,321,305	22,558,670	19,577,656	16,148,642	12,344,815
Profit/Losses (previous year)	**0**	**5,747,799**	**7,025,953**	**7,292,247**	**7,533,304**	**7,080,462**	**7,323,350**	**7,584,109**	**7,845,045**	**8,105,629**	**6,978,699**	**7,251,480**	**7,549,090**	**7,845,147**	**8,138,934**	**7,865,384**	**8,303,928**	**8,465,517**	**8,761,438**	**9,055,081**
Total Liabilities	**47,820,057**	**45,982,760**	**44,079,585**	**42,108,968**	**51,576,036**	**49,023,619**	**46,383,024**	**43,652,181**	**40,828,977**	**63,746,976**	**59,739,900**	**55,598,269**	**51,318,947**	**46,898,736**	**54,282,705**	**39,282,140**	**43,773,535**	**38,264,081**	**32,579,495**	**26,715,761**
Net Liabilities (Total Assets - Total Li	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Inflaction Rate	1.50%																			

Table 33. Balance Sheet (Urban Bus Scenario)

We have also calculated the Free Cash Flow and base in it the VAN and TIR of the installation and some other ratios.

FREE CASH FLOW URBAN	2,031	2,032	2,033	2,034	2,035	2,036	2,037	2,038	2,039	2,040	2,041	2,042	2,043	2,044	2,045	2,046	2,047	2,048	2,049	2,050
NOPAT	5,747,799	7,025,953	7,292,247	7,533,304	7,080,462	7,323,350	7,584,109	7,845,045	8,105,629	6,978,699	7,251,480	7,549,090	7,845,147	8,138,934	7,865,384	8,303,928	8,465,517	8,761,438	9,055,081	9,360,867
Depreciation	2,516,845	2,516,845	2,516,845	2,516,845	3,087,448	3,087,448	3,087,448	3,087,448	3,087,448	4,276,696	4,276,696	4,276,696	4,276,696	4,276,696	4,787,236	4,787,236	4,787,236	4,787,236	4,787,236	4,787,236
CAPEX	-50,336,902	0	0	0	0	-12,294,024	0	0	0	0	-27,603,429	0	0	0	0	-12,765,851	0	0	0	0
Investment in working capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FREE CASH FLOW	**-42,072,258**	**9,542,798**	**9,809,092**	**10,050,149**	**10,167,909**	**-1,883,226**	**10,671,557**	**10,932,493**	**11,193,077**	**11,255,395**	**-16,075,253**	**11,825,787**	**12,121,843**	**12,415,630**	**12,652,619**	**325,312**	**13,252,753**	**13,548,674**	**13,842,317**	**14,148,103**
Inflaction Rate	1.50%																			

Key Ratios URBAN																				
Items	**2,031**	**2,032**	**2,033**	**2,034**	**2,035**	**2,036**	**2,037**	**2,038**	**2,039**	**2,040**	**2,041**	**2,042**	**2,043**	**2,044**	**2,045**	**2,046**	**2,047**	**2,048**	**2,049**	**2,050**
EBITDA/Incomes (%)	87.0%	97.2%	98.8%	100.3%	101.9%	103.5%	105.1%	106.7%	108.4%	110.1%	111.8%	113.6%	115.3%	117.1%	119.0%	120.8%	122.7%	124.6%	126.5%	128.7%
Cost of Sales/Income (%)	68.5%	78.8%	80.3%	81.8%	79.2%	80.8%	82.4%	84.1%	85.7%	78.7%	80.4%	82.2%	84.0%	85.7%	83.8%	85.7%	87.6%	89.5%	91.4%	93.5%
EBIT /Incomes(%)	68.5%	78.8%	80.3%	81.8%	79.2%	80.8%	82.4%	84.1%	85.7%	78.7%	80.4%	82.2%	84.0%	85.7%	83.8%	85.7%	87.6%	89.5%	91.4%	93.5%
NOPAT/Incomes (%)	42%	52%	54%	55%	52%	54%	56%	58%	59%	51%	53%	55%	58%	60%	58%	61%	62%	64%	66%	69%
Sales Growth (%)	-	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NOPAT/Equity (%)	40.1%	54.4%	57.5%	59.6%	41.9%	43.1%	45.6%	48.7%	52.5%	25.6%	26.9%	29.4%	32.5%	36.4%	28.7%	43.0%	37.5%	44.8%	56.1%	75.8%
Equity/Assets Ratio (%)	30.0%	28.1%	28.7%	30.0%	32.8%	34.7%	35.9%	36.9%	37.8%	42.7%	45.0%	46.2%	47.1%	47.7%	50.5%	49.2%	51.5%	51.2%	49.6%	46.2%

Table 34. Free Cash Flow and Key Ratios (Urban Bus Scenario)

In the P&L tables we have considered the assumptions of the business models which includes the cost of the electricity consumed by the DWPT- buses, the e-trenches infrastructure costs and an extra amount (30% of previous costs in the bus scenario) to cover the debt and the owner benefits (in this case 0 as it is a public service), but not the cost of the buses or the extra infrastructure in the garages. With that perspective, the required tariff in the Urban Bus Scenario to cover such expenses is the lowest from the three possible scenarios. Assuming a discount rate of 5%, the model shows a Net Present Value of 59.3 Million € and an IIR of 19.4%. This excess in cash flow indicated that for the reference case taken, it is still possible to reduce the selected tariff/kWh and continue in positive numbers.

However, these tables do not include neither the plug-in charging expenses at the garage at the end of the daily activity nor the acquisition and operation costs of the bus (only the payment of the consumed electricity). The complete picture was described in D552. We add here (in yellow colour) those extra expenses in a comparative table with an equivalent plug-in bus (with a large battery) and a diesel bus.

2,030	Main Features 2030	Electric Infrastructure (Depreciation 10 years)						CAPEX Buses		OPEX Buses (10 years)		TOTAL
Type of Service	400 buses, 12 m	Unitary Cost	Nº Ultra-ch.	Extra garage	Trafo	Extra in city	Total	Un. Cost	Total Cost	Un.Cost	Total OPEX	
PLUG-IN (350 kWh)	Plug in Electric 350 kWh,	80,000	240	19,200,000	550,000		**19,750,000**	400,000	**160,000,000**	160,078	**64,031,109**	**243,781,109**
DWPT (44.5 kWh)	DWPT 41 kWh, 1.5 kWh/km	80,000	24	1,920,000	55,000	102,131,394	104,051,394	276,100	**110,440,000**	168,570	**67,427,826**	**281,919,220**
ICE Diesel	ICE-Diesel							200,000	**80,000,000**	374,192	**149,676,604**	**229,676,604**

Table 35. Extra expenses at the garage (Urban Bus Scenario)

Hereunder we include a table with these results for year 2,030.

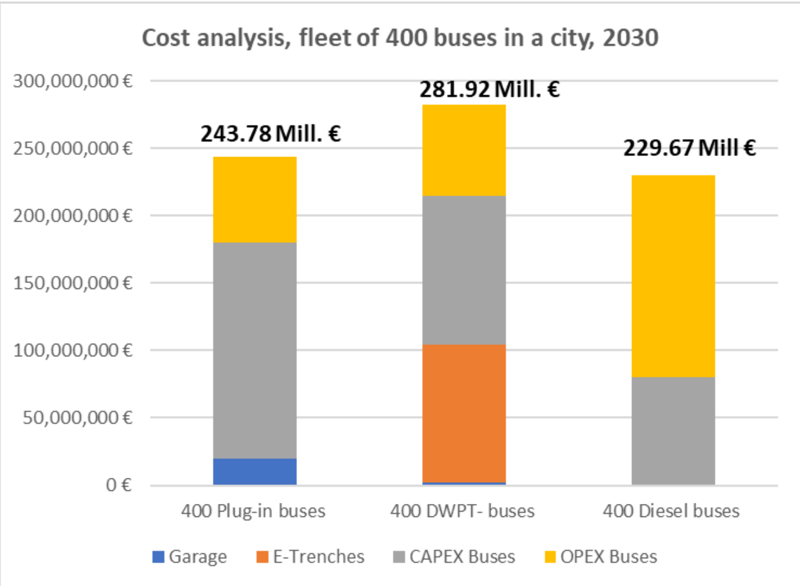


Figure 24. Overall costs for a fleet of 400 buses distributed in a city

Assuming the size of the fleet and the conditions of the business model, the conclusion from this chapter is that if we just consider the infrastructure and the energy consumed by the buses, the cost per kWh, is 0.15 €/kWh, which is cheaper to an equivalent ICE bus. However, if you add the rest of costs, they overpass the other options although with some remarks; firstly, the plug-in buses reduce the available free space for passengers as batteries are much higher (in the DWPT the philosophy and calculations were made under the battery shrink concept), thus the service will be better provided by the DWPT-bus with more space available for passengers. Compared with the ICE-buses, DWPT do not pollute at all. In addition, the installations at the garage may last for more than 10 years with just a retrofitting, so the amortization of the CAPEX will be extended for more time.

The advantage of the Urban Bus Scenario compared with Motorway and Periurban scenarios is that you have a guarantee of use of the e-Trenches during the whole lifetime of the installation and that circumstance minimises the risk of no critical mass of vehicles which is one of the most negative affecting factors when assessing the business risk.

We include hereinafter a diagram with the P&L results of the 20 years analysed. In the second decade, there will be a slight variation of the figures due to the cost reduction associated to the construction or retrofitting of the e-trenches (experience curve).

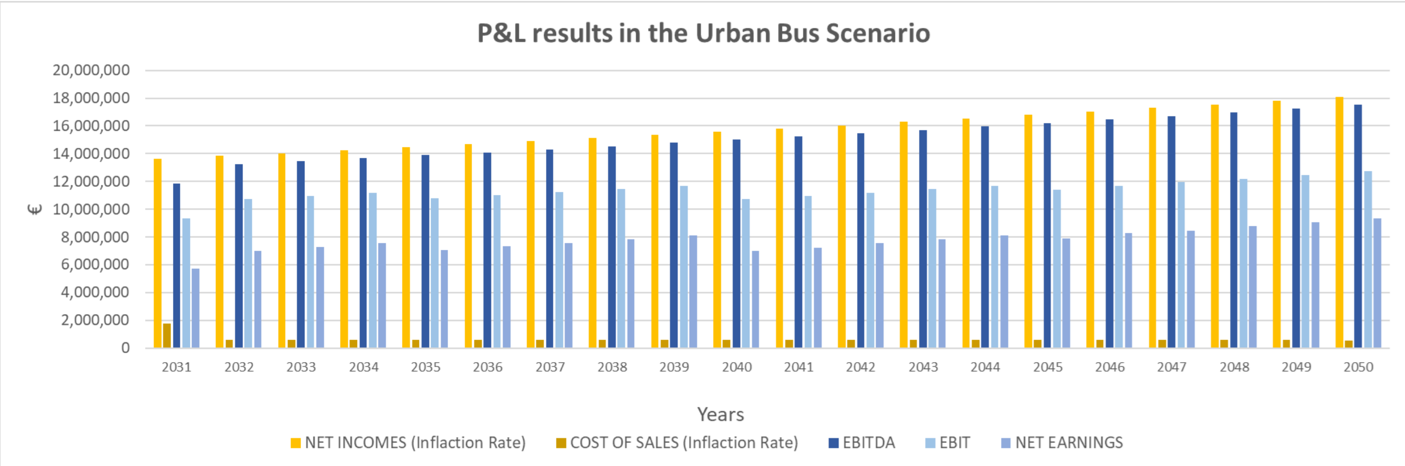


Figure 25. P&L results in the Urban Bus Scenario

2.4.1.2 Sensitivity Analysis Urban Bus Scenario

The previous sensitivity analysis in the Motorway and Periurban scenarios have limited application in the Urban Bus Scenario as the number of buses and the "daily charging events" keeps constant reducing the options. We add a single simulation to see the impact of increase bus consumption toward the required incentive.

Average Cons-BUS (kWh/km)	Range Extension (km)	Cost added km BUS-30 (€/km)	Req. Incent BUS-30 (€/KWh)
3.11	6.43	1.65	0.02
2.59	7.72	1.38	0.00
2.16	9.26	1.15	-0.03
1.80	11.11	0.96	-0.07
1.50	13.33	0.80	-0.11
1.20	16.67	0.64	-0.18

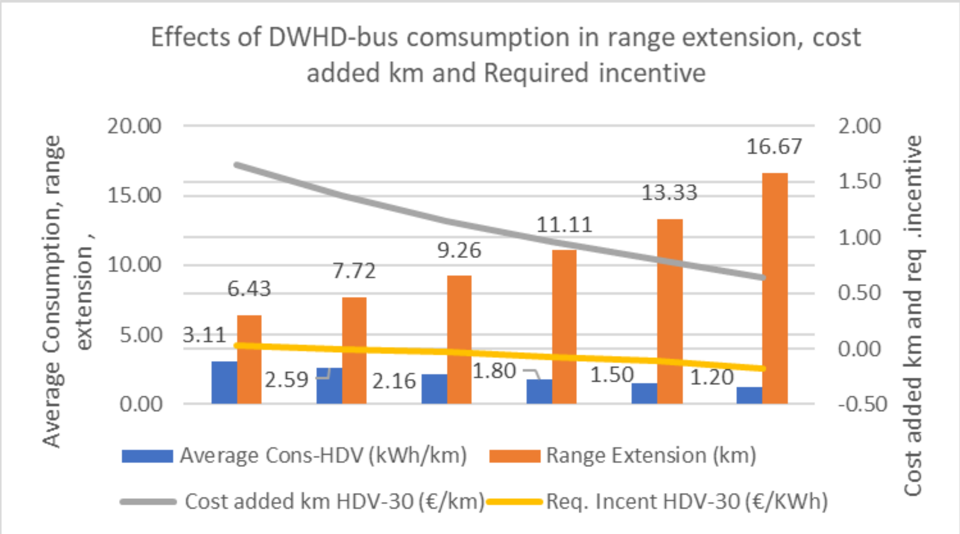


Figure 27. Effects of DWHD-bus consumption in range extension, cost added km and Required incentive

As we said in previous chapter, the business model for the DWPT-buses in the conditions established in the analysis is sustainable, in the sense that the required tariff (0.15 €/kwh absorbed from the grid) is 0.11 €/kwh lower than the consumption of a diesel bus. If we increase the bus consumption, then, the range extension is reduced and the cost for an extender km increased. If we reach 2.59 KWh/km consumption, then the tariff will be even with the equivalent diesel bus or in other words, the required incentive from governments to keep the business model sustainable is kept below zero until an average consumption of 2.59 €/kWh. The range extension is also reduced maybe compromising the extended autonomy and thus the service with just 25 m of e-trenches in each bus stop. Hence, if the consumption is increased a redesign of the whole system must be implemented.

2.4.2 From vehicle perspective (also owned by local Administration)

The owners of the vehicles are the same administration that owns the e-trenches infrastructure. That the reason why this scenario requires an overarching approach from all perspectives.

2.4.2.1 *Reference scenario*

From the bus perspective, the DWPT-bus was compared with an equivalent Plug-in bus and a diesel bus, with the same service characteristics.

Comparison /BATTERY SHRINK STRATEGY Buses URBAN

Ref. DWPT-Bus / Plug-in bus			Ref. Bus Diesel (Urban 30 seats)		
VEHICLE AND INFRASTRUCTURE MAIN PARAMETERS					
Fix Daily Distance	313.2	km	Vehicle autonomy	886	km
Total Security daily distance	333.2	km			
Vehicle Battery autonomy	41	km			
Vehicle Battery capacity	44.85	kWh	Power	270	CV
E-Road length (crossed in 1 day)	24.3	km	Consumption	35.0	l/100 km
E-Road billable Power transfer	100	kW	Tank	310	litros
Average speed in e-Corridor	60	km/h	Cost Diesel	1.15	€/l
Absorbed electricity in e-Road	14.5	kWh			
Range Extension	292.2	km			
Average Consumption TTW	1.11	kWh/km		2.98	kWh/km
Average Consumption WTW	3.3	kWh/km		3.58	kWh/km
Total Consumption in total range	347.65	kWh		933.34	kWh
CAPEX					
ACQUISITION COSTS					
Life time	10	years		10	years
Adquisition basic vehicle cost	**250,000**	€		**200,000**	€
Adaptation plug-in to WPT in vehicle	6,000	€			
Adaptation WPT to DWPT in vehicle	6,000	€			
Total Acquisition Costs	**262,000**	€			
km /year	65,000	Km/y		65,000	Km/y
Total Km	650,000	km		650,000	km
INFRASTRUCTURE COSTS					
Plug-in ultracharger garage (150 kW) 0.5	80,000	€			
Adaptation parking to WPT	4,500	€			
OPEX					
MAINTENANCE COSTS					
Yearly maintenance	6,000	€/y		18,000	€/y
Replace Battery (evey 5 years)	4,485	€			
Total cost maintenance (10 y)	64,485	€		180,000	€
INSURANCE COSTS					
Insurance/year	4,000	€/y		4,000	€/y
Total Insurance (10 y)	40,000	€		40,000	€
CONSUMPTION ELECTRICITY / FUEL					
Cost electricity headquarter	0.08	€/kwh	Diesel Consumption Costs	0.40	€/km
Cost in ultra-charger on road	0.24	€/kwh			
Cost electricity in e-Road (no incentive)	0.15	€/kwh[1]			
Cost Full charge at headquarter	3.3	€			
Cost charging in e-road (no incentive)	3.65	€			
Total charging cost electricity in range	6.9	€	**Cost Diesel in range**	126.1	€
CO2 emissions	500.90	gr CO2/kWh		305.46	gr CO2/kWh
CO2 emissions	556.00	gr CO2/km		910.26	gr CO2/km
TOTAL EMISSION IN RANGE DISTANCE	174,139	grCO2		285,093	gr CO2

Table 36. Assumptions for bus comparison

It is interesting to compare the results of the TCO for the buses isolated from the e-infrastructure cost and later add it. If we just compare the buses, the DWPT-bus (without incentives form the beginning) is by far the cheapest using the battery shrink strategy.

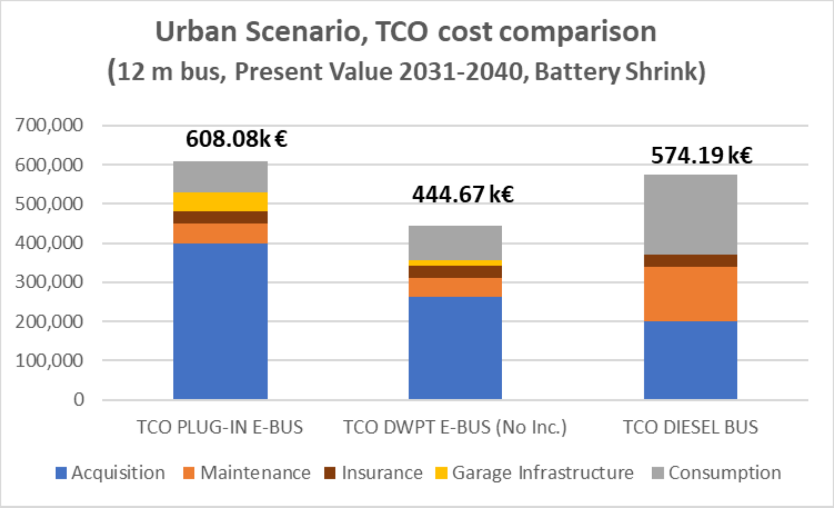


Figure 26. TCO comparison (e-Trenches excluded)

But if we add the e-Trenches infrastructure, then the situation for the whole fleet (400 buses) presents the following outcomes.

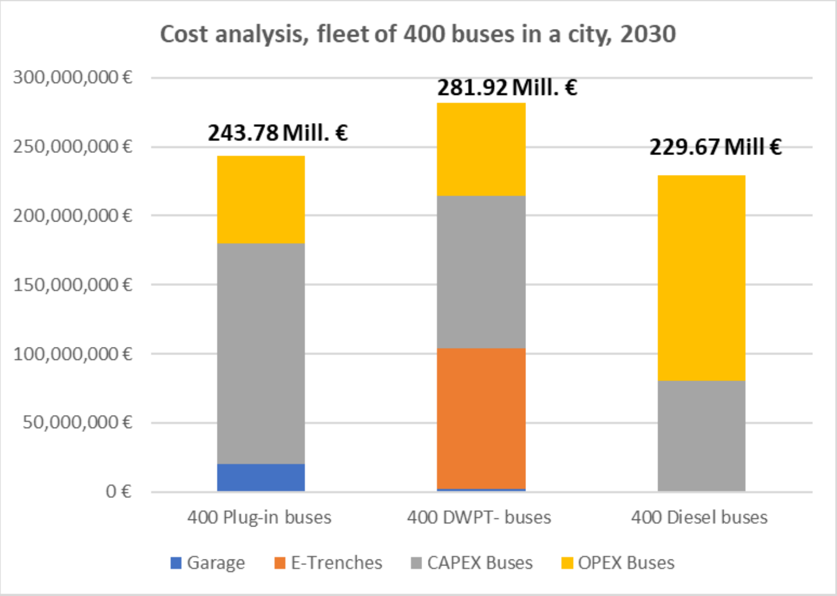


Figure 27. TCO Fleet of 400 buses with the analysed technologies.

The result is that the DWPT technology is still a 22% more expensive than the equivalent ICE and 15% more than the equivalent in full battery bus version. The orange colour represents in the chart the added infrastructure costs. However, from the environmental view point DWPT is the best option.

The previous calculations came from the following assumptions:

2,030	Main Features 2030	Electric Infrastructure (Depreciation 10 years)						CAPEX Buses		OPEX Buses (10 years)		TOTAL
Type of Service	400 buses, 12 m	Unitary Cost	Nº Ultra-ch.	Extra garage	Trafo	Extra in city	Total	Un. Cost	Total Cost	Un.Cost	Total OPEX	
PLUG-IN (350 kWh)	Plug in Electric 350 kWh,	80,000	240	19,200,000	550,000		**19,750,000**	400,000	**160,000,000**	160,078	**64,031,109**	243,781,109
DWPT (44.5 kWh)	DWPT 41 kWh, 1.5 kWh/km	80,000	24	1,920,000	55,000	102,131,394	104,051,394	276,100	**110,440,000**	168,570	**67,427,826**	281,919,220
ICE Diesel	ICE-Diesel							200,000	**80,000,000**	374,192	**149,676,604**	229,676,604

Table 37. Cost concepts included to calculate the TCO of a full service with 400 buses.

From the parameters included in the formula, some of them could vary a lot. For instance, ultra-fast chargers of 350 kWh or above, could cost between 60.000€ to 150.000 € and the evolution over time is unknown as they are still not massively deployed in the market. Electric components may also vary, the price of the copper in the next 20 years is also uncertain, but for sure it will be summited to market pressures due to the high demand. Finally, the operation and maintenance costs of the e-trenches is an incognita nowadays as this technology has not been used commercially during the required period to raise lessons learnt. In summary, the market must be scrutinized in the next years as the market opportunity for this niche is not so far away and will bring many beneficial advantages for citizens.

2.4.2.2 Sensitivity analysis.

We will proceed in the same way than previous chapters. In relation to the buses, there are three main differences compared with former scenario:

- The number of vehicles of the fleet keeps constant as the service is offered complete from the very beginning.
- The required tariff to fulfil the business model is obtained from the initial moment. 0.15 €/ kWh is less than the 0.27 €/kWh that should be the payment in the case the bus carried a diesel engine. The consequence is that no incentive is required from the administrations. However, the required infrastructure at garage is very expensive and adding that concept, exceed the costs of alternatives as we have seen. Nevertheless, the advantage compared with the plug-in bus might be that the available space for passengers should be greater. In the bus scenario the concept is battery shrink versus extender range in the rest of scenarios, meaning that the battery inside the bus occupies the minimum required space to comply with the service.

- Finally, the ultra-fast chargers service cost, also at the garage, are cheaper than those set in the motorways or periurban roads. The reason is that the owner of the buses is the public administration with no need to make profits when charging them. That benefit the alternative plug-in option.

We add hereunder the results of the sensibility analysis considering the following simulation conditions:

SENSIBILITY ANALYSIS. Urban buses.

Initial Variables		Base	2030	2035	2040
Cost of electricity headquarter	€/kWh	0.08	0.2	0.25	0.30
Cost of ultrafast charging	€/kWh	0.24	0.24	0.30	0.36
Cost of diesel	€/km	0.40	0.56	0.50	0.45
Acquisition Costs plug-in	€	400,000	400,000	360,000	324,000
Acquisition Costs DWPT	€	265,000	265,000	240,000	215,000
Acquisition Costs ICE	€	200,000	200,000	185,000	175,000

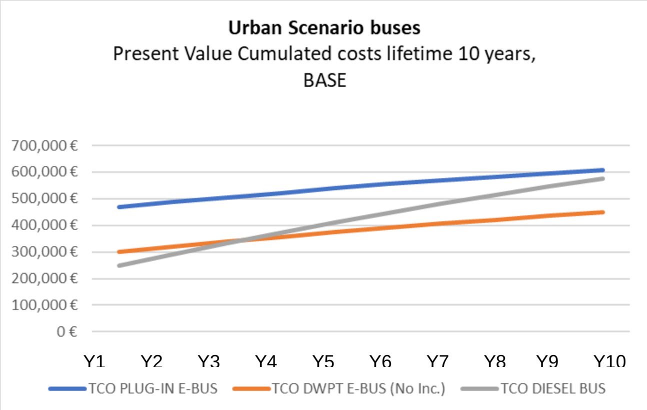
Table 38. Simulation conditions for the Urban buses scenario

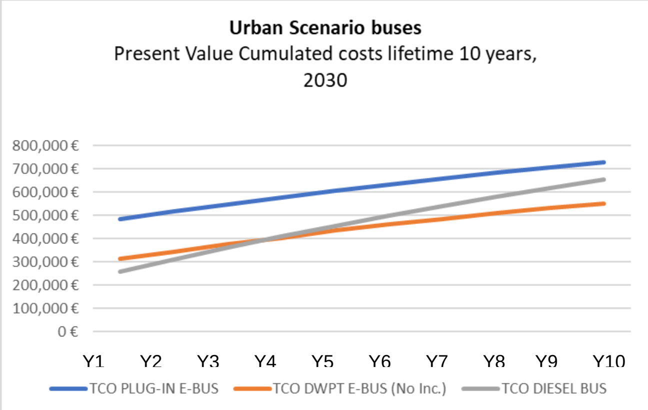
The results are the following, considering that:

- Buses are depreciated in 10 years
- Base scenario represents the nowadays conditions for the energy costs
- 2030 will be the starting moment for the service applying the energy costs foreseen according to the EU forecast
- 2035 and 2040 are the simulations considering the expected evolution of energy costs and the most likely scenario inside cities where a ban for diesel buses will be likely in place and plug-in buses will compete with WPT and DWPT-buses.

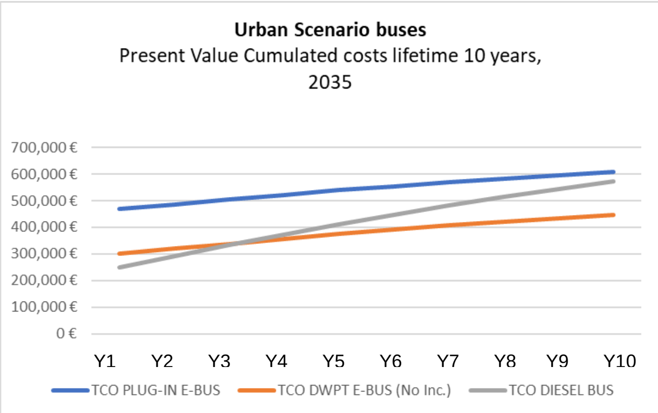
TCO. Concept URBAN.BASE	TCO PLUG-IN E-BUS	TCO DWPT E-BUS (No Inc.)	TCO DIESEL BUS
Acquisition	400,000 €	265,000 €	200,000 €
Maintenance	50,130 €	50,130 €	139,848 €
Insurance	31,077 €	31,077 €	31,077 €
Garage Infrastructure	48,000 €	14,100 €	0 €
Consumption	78,870 €	87,362 €	203,266 €
TOTAL	608,078 €	447,670 €	574,192 €

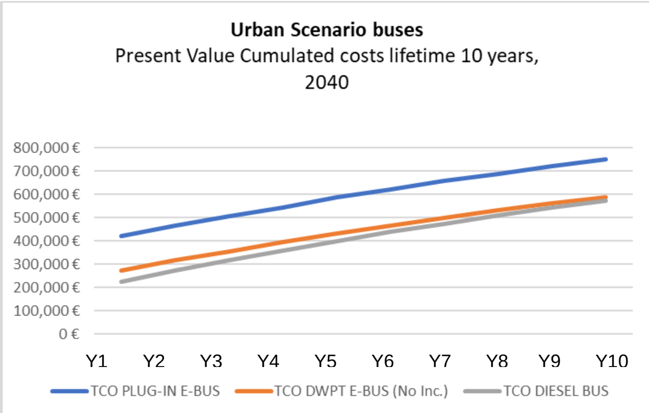
TCO. Concept URBAN. 2030	TCO PLUG-IN E-BUS	TCO DWPT E-BUS (No Inc.)	TCO DIESEL BUS
Acquisition	400,000 €	265,000 €	200,000 €
Maintenance	50,130 €	50,130 €	139,848 €
Insurance	31,077 €	31,077 €	31,077 €
Garage Infrastructure	48,000 €	14,100 €	0 €
Consumption	197,175 €	191,110 €	282,804 €
TOTAL	726,383 €	551,417 €	653,730 €





TCO. Concept URBAN. 2035	TCO PLUG-IN E-BUS	TCO DWPT E-BUS (No Inc.)	TCO DIESEL BUS	TCO. Concept URBAN. 2040	TCO PLUG-IN E-BUS	TCO DWPT E-BUS (No Inc.)	TCO DIESEL BUS
Acquisition	360,000 €	240,000 €	185,000 €	Acquisition	324,000 €	215,000 €	175,000 €
Maintenance	50,130 €	50,130 €	139,848 €	Maintenance	50,130 €	50,130 €	139,848 €
Insurance	31,077 €	31,077 €	31,077 €	Insurance	31,077 €	31,077 €	31,077 €
Garage Infrastructure	48,000 €	14,100 €	0 €	Garage Infrastructure	48,000 €	14,100 €	0 €
Consumption	246,469 €	234,338 €	252,504 €	Consumption	295,763 €	277,566 €	227,254 €
TOTAL	735,677 €	569,646 €	608,430 €	TOTAL	748,971 €	587,874 €	573,179 €





The main conclusion of this analysis is that the DWPT-Buses is the cheapest option from the very beginning although the diesel bus is coming closer in the intention to boost sales in front of the upcoming ban of diesel buses inside the city. Some other alternatives as the gas buses or the hydrogen and fuel cell buses has not been analysed, but apparently the DWPT options seems to be one of the best.

2.4.3 Administrations view point

The administration viewpoint includes the externalities in addition to the economic factors. The bus scenario is especially sensible to these aspects as the pollution of conventional buses directly impact in the health of the population. The same exercise made in previous scenarios has been implemented for the DWPT buses. A simulation was created to assess the avoided CO_2 emissions thanks to the substitution of the conventional diesel buses by those with dynamic and static charging. Besides, the second simulation calculates the fuel savings (in economic terms). In this simulation, the same volume of petrol is eliminated in years 2030, 2040 and 2050, as the number of buses in operation keeps the same. However, the figures show a cost reduction. The reason is that the cost of the fuel will suffer a reduction overtime to spur sales in advance to the foreseeable petrol ban in the public transport.

Clean air in the urban areas, eliminating CO_2 emissions and pollutants is very relevant for the public administrations and will be considered as a relevant aspect to bet on this type of vehicles. The competing technology (plug-in buses), holds a great disadvantage in the sense that the volume of the battery will reduce the space available for passengers inducing the need of additional buses addressed to the same users and thus, increasing costs.

The results of the simulations are described hereinafter.

	DWPT-BUS	2,030		2,040		2,050
	31,675	146,000	35,717	146,000	39,759	146,000
	292	31,675	292	35,717	292	39,759
Avoided tons CO_2	392	42,522	392	47,948	392	53,375
	492	64,217	492	72,412	492	80,606
	592	96,760	592	109,107	592	121,454
	692	140,150	692	158,034	692	175,918
	792	194,387	792	219,193	792	243,998

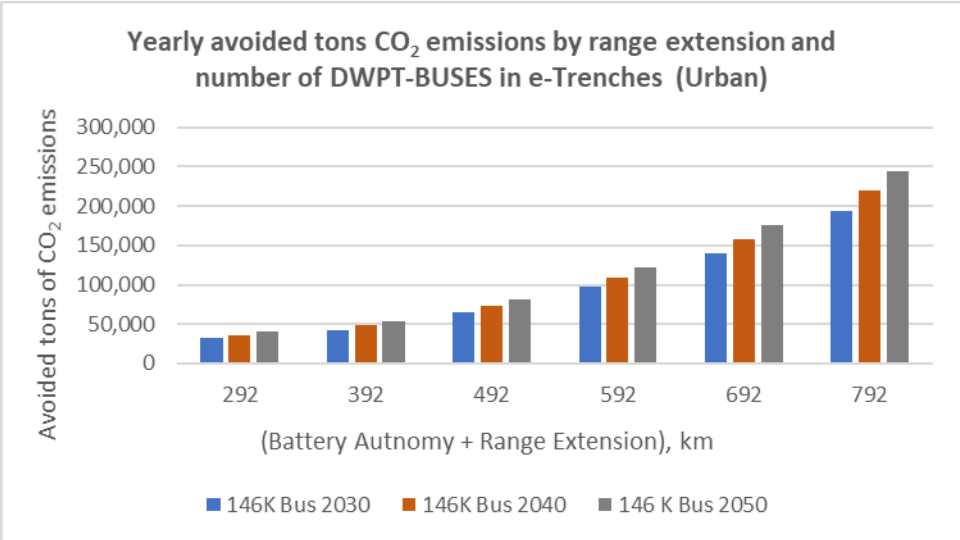


Table 39. CO2 emissions avoided in years 2030, 2040 and 2050 modifying range extension

The increase of the range extension in just 100 km, as a result of battery efficiency improvements or increase of the power transfer impacts considerably on the avoided emission (from 29% to 46% progressively every 100 additional km)

In relation with the diesel savings overtime, when increasing the range extension, results are shown below.

	DWPT-BUS	2,030		2,040		2,050
	23,874	146,000	21,487	146,000	19,338	146,000
	292	23,874	292	21,487	292	19,338
	392	32,050	392	28,845	392	25,960
Fuel Saved	492	48,402	492	43,562	492	39,206
	592	72,930	592	65,637	592	59,073
	692	105,634	692	95,071	692	85,563
	792	146,514	792	131,863	792	118,676

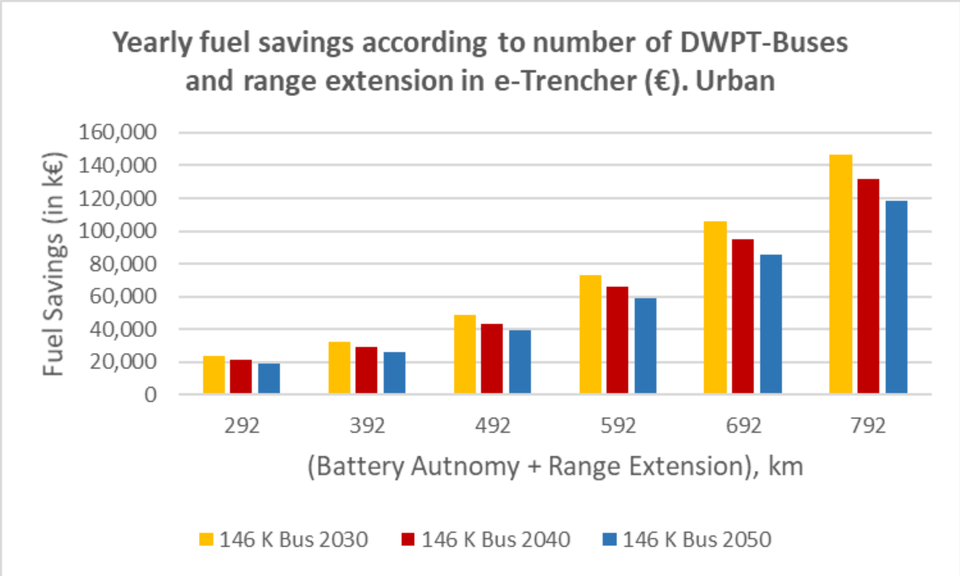


Figure 28. Yearly diesel savings depending on range extension. Bus Scenario

Figures shows that the increase of the range extension in the urban circuit (considering the initial battery autonomy of 41 km and a range extension of 292 km in total) is very relevant for the fuel savings which are increased very fast.

The conclusions in the bus scenario is clear; it is in our opinion the first entry point for the dynamic charging technology. The business model is positive compared with the alternatives if we do not consider the cost of the infrastructure in the garages as we must foresee also fast chargers at the garages to charge the buses at night in addition to the e-trenches. However, from the administrative point of view the elimination of emissions and pollutants in the city and the additional space for passengers in the buses by means of the reduced battery size, is a perfect combination that can justify the investment.

However, all buses in a city must switch to this technology at same time to reach the right figures in the model although we understand that the technology will enter progressively but it won't be until the full fleet will be in operation with this system when the technology will be feasible.

3. STANDARDISATION, HARMONISATION AND INNOVATION

3.1 Organisations involved in standards development

3.1.1 ISO

3.1.1.1 Overview

The **International Organization for Standardization (ISO)** was founded in 1946 during a meeting of 25 countries which met at the Institute of Civil Engineers in London where they decided to create a new international organization to facilitate the international coordination and unification of industrial standards. The organisation officially began their operation on the 23 February of 1947. The organisation consists of 161 national standard bodies and 780 technical committees and subcommittees which take care of the development of the standards.

The organisation has 135 fulltime employees working at the ISO's Central Secretariat in Geneva, Switzerland.

To date, the organisation has published 22,172 international standards which covers almost all aspects of technology and manufacturing.[7]

3.1.1.2 Activities

The vision of ISO is: "ISO standards used everywhere". This goal should be reached through their main activities.

They set out to:

- Ensure a creditable and coherent collection of standards that are used effectively by industries and bring recognized benefits to economies.
- Enabling their members to successfully reach their markets, promote ISO standards and deliver ISO content to their customers.
- Producing International Standards in a clear, understandable language, that are easy to read and user friendly.

[7] https://www.iso.org/home.html

- Increasing the uptake of standards as business performance tools.
- Development of support information that complements International Standards.
- Implementation of IP protection policies that are respected and understood by customers and developers. [8]

3.1.2 IEC

3.1.2.1 Overview

The **International Electrotechnical Commission (IEC)** is a not-for-profit, quasi-governmental organization, founded in 1906. The IEC's members are National Committees, and they appoint experts and delegates coming from industry, government bodies, associations and academia to participate in the technical and conformity assessment work of the IEC.

IEC's Vision is "IEC everywhere for a safer, more efficient world", while its Mission is "to achieve worldwide use of IEC International Standards and Conformity Assessment Services that ensure the safety, efficiency, reliability and interoperability of electrical, electronic and information technologies, to enhance international trade, facilitate broad electricity access and enable a more sustainable world."

3.1.2.2 Activities

The International Electrotechnical Commission is the leading global organization that publishes consensus-based International Standards and manages conformity assessment systems for electric and electronic products, systems and services, collectively known as electrotechnology. IEC publications serve as a basis for national standardization and as references when drafting international tenders and contracts.

The IEC develops International Standards for all electrical, electronic and related technologies. Adoption is voluntary, although they are often referenced in national laws or regulations around the world. Experts from all over the world develop IEC International Standards. Since International Standards generally reflect the best experience of industry, researchers, consumers and regulators worldwide, and cover common needs in a variety of countries, they constitute one of

[8] https://www.iso.org/files/live/sites/isoorg/files/archive/pdf/en/iso_strategy_2016-2020.pdf

the important bases for the removal of technical barriers to trade. For this reason, in its TBT (Technical Barrier to Trade) Agreement, the WTO(World Trade Organization) recommends its members to use International Standards rather than regional or national ones whenever possible. Adopting IEC International Standards or using them for reference in national laws or regulations facilitates trade in the field of electrotechnology.

Conformity assessment refers to any activity that determines whether a product, system or service corresponds to the requirements contained in a specification. A specification, often a standard, is a technical description of the characteristics a product, service or object are required to fulfil. The IEC not only supports all forms of conformity assessment it also runs three CA Systems, each of which operates schemes based on third-party conformity assessment certification. Together they establish that a product is reliable and will meet expectations in terms of performance, safety, efficiency, durability and other criteria[9].

3.1.3 SAE International

3.1.3.1 Overview

The **SAE International (Society of Automotive Engineers)** organisation consists of more than 128.000 engineers and technical expert in the fields of automotive, aerospace and commercial-vehicle industries. SAE International has a global presence and strives for their core competencies which are life-long learning and voluntary consensus in the development of standards. SAE international's mission is to advance mobility knowledge and solutions for the benefit of humanity. Their vision is to act as the leader of connecting as well as educating mobility professionals to enable clean, accessible and safe mobility solutions.

3.1.3.2 Activities

The main activities of SAE are publications of their globally recognized magazines, Aerospace Engineering, off highway Engineering and Automotive Engineering International as well as keeping the mobility community informed of the latest developments in the area. One of the

[9] http://www.iec.ch/index.htm

benefits of the membership of SAE is that these magazines are included. Another activity of SAE are publications which are distributed to their customers in more than 65 countries each year and are based on the organisations wide knowledge within the technical area.

The organisation does also provide professional development and training. This program has expanded over the last 20 years and the organisation currently provides more than 450 professional developments each year. [10]

3.1.4 UL (Underwriters Laboratories)

3.1.4.1 Overview

UL (Underwriters Laboratories) is a global company with more than 120 years of expertise and it works with customers and stakeholders to help them navigate market complexity. UL brings clarity and empowers trust to support the responsible design, production, marketing and purchase of the goods, solutions, and innovations of today and tomorrow. It connects people to safer, more secure, more sustainable products, services, experiences and environments – enabling smarter choices and better lives. UL's Vision is "Working for a Safer World".

3.1.4.2 Activities

UL helps companies demonstrate safety, confirm compliance, enhance sustainability, manage transparency, deliver quality and performance, strengthen security, protect brand reputation, build workplace excellence, and advance societal wellbeing. Some of the services offered by UL include: inspection, advisory services, education and training, testing, auditing and analytics, certification software solutions, and marketing claim verification.

UL provides expertise across two strategic businesses to promote safe living and working environments around the world. These distinct UL businesses work closely with industries, authorities and customers to keep safety ahead of innovation in an evolving global landscape. In every market UL is helping companies keep pace with regulatory demands while strengthening the position of their brand and business[11].

[10] https://www.sae.org/standards/

[11] https://www.ul.com/

3.2 International Standard on Wireless Power Transfer systems

Hereinafter all international standards in process dealing with wireless power transfer systems are listed, as of the time of writing this report (June 2018):

- ISO 19363 Electrically propelled road vehicles – Magnetic field wireless power transfer element – Safety and interoperability requirements.
- IEC 61980 Electric vehicle wireless power transfer (WPT) systems.
- Part 1: General requirements.
- Part 2: Specific requirements for communication EV and infrastructure.
- Part 3: Specific requirements for the magnetic field power transfer systems.
- ISO/IEC 15118 Road vehicle to grid communication interface.
- Part 1: General information and use case definition.
- Part 2: Network and application protocol requirements.
- Part 6: General information and use-case definition for wireless communication.
- Part 7: Network and application protocol requirements for wireless communication.
- Part 8: Physical layer and data link layer requirements for wireless communication.
- SAE J2954 Wireless Charging of Electric and Plug-in Hybrid Vehicles (SAE TIR J2954 published on May 31th 2016).
- SAE J2836/6 J2847/6 J2931/6 Communication for inductive charging.
- SAE J1773 Electric Vehicle Inductively Coupled Charging (published as recommended practice).
- UL 2750 Wireless EV charging.

In the figure below, we include what are the main subjects of interest for the standards under development. The right-hand side column represents in red colour the topic of interest. The lower long oval represents the wireless charging installation at the pavement and the small oval above the WPT system on board. “Com” means communication between pavement and vehicle. In relation to the codes at the left, they all indicate the step in the process to finalise the standardization process. Specifically:

- IS = International standard
- TS = Technical Specification

- PAS = Public available specification
- TR = Technical Report
- CD1 = Committee Draft 1
- CD2 = Committee Draft 2
- DIS = Draft International Standard
- FDIS = Final Draft International Standard

STANDARD			FOCUS
IEC 61980-1	IS	*Electric vehicle wireless power transfer (WPT) systems Part 1: general requirements*	COM
IEC 61980-2	TS	*Part 2: Specific requirements for communication between electric road vehicle (EV) and infrastructure with respect to wireless power transfer (WPT) systems*	COM
IEC 61980-3	TS	*Part 3: Specific requirements for the magnetic field wireless power transfer systems*	COM
ISO 19363	PAS	*Electrically propelled road vehicles Magnetic field wireless power transfer – safety and interoperability requirements*	COM
ISO/IEC 15118	IS	*Road vehicles – vehicle to grid communication interface*	COM
SAE J2954	TIR	*Wireless charging of electric and plug-in hybrid vehicles*	COM
SAE 2847/6	RP	*Wireless charging communication between plug-in electric vehicles and the utility grid*	COM

Figure 29. Basic focus of the standards

3.2.1 Timeline of development of the standards

The following figures reports the timeline for the development of the standards listed:

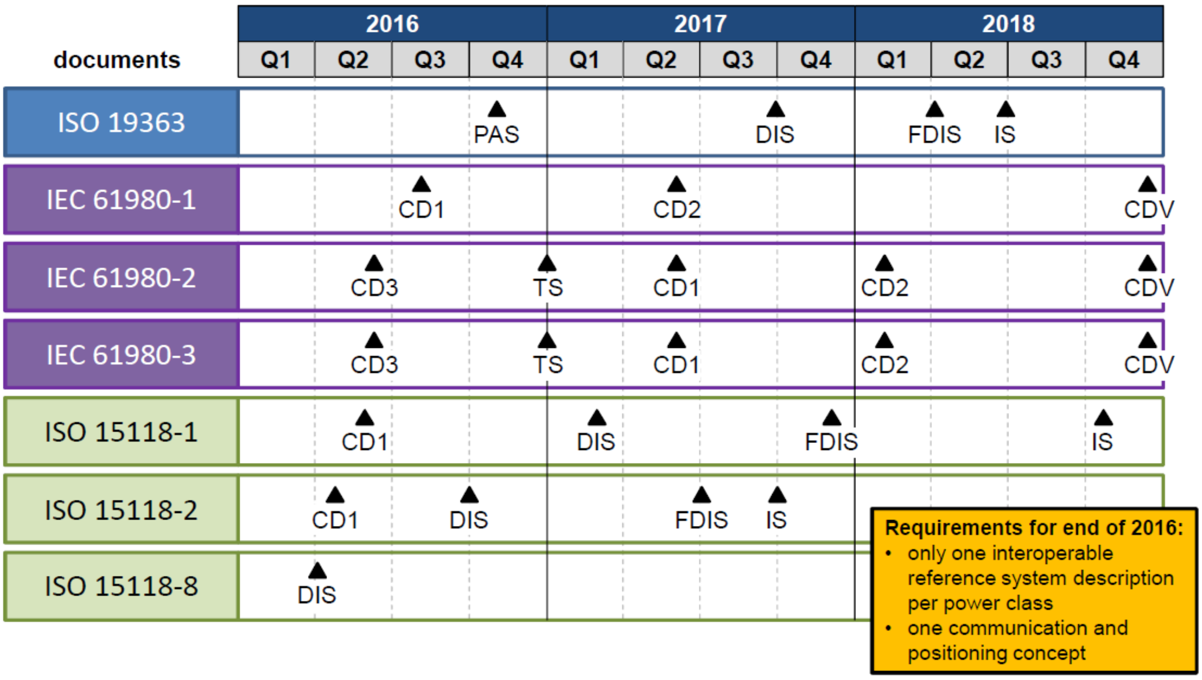


Figure 30. Proposal for timeline of ISO19363

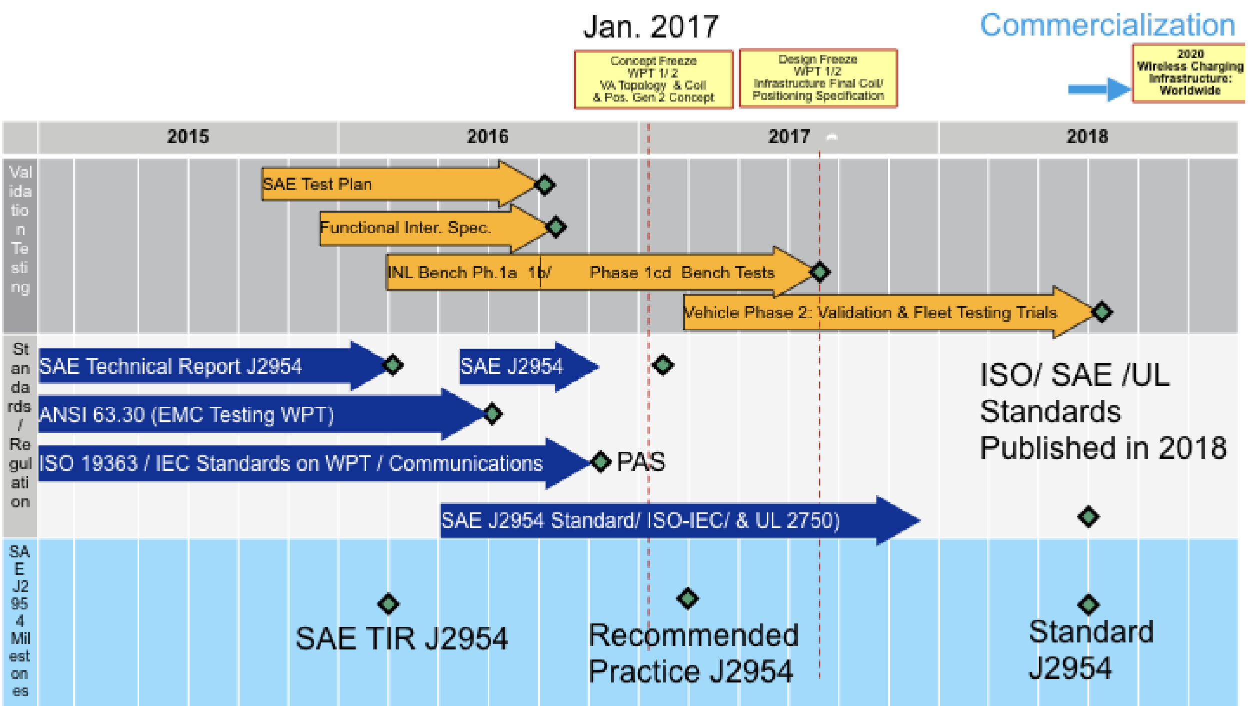


Figure 31. SAE J2954 timing plan

3.2.2 System interoperability parameters

All vehicles using WPT need to standardize the following parameters to allow interoperability among them. These are for that reason, at the same time the parameters subject to revision by the different standards.

In the FABRIC deliverable D3.3.3 a detailed analysis of interoperability has been carried out for existing solutions (static and dynamic) and the ones being developed within FABRIC. Conclusions of D3.3.3 are exposed here, as they are most relevant for the standardising process.

In D3.3.3. it has been stated that the major concerns for EV inductive charging systems regarding their interoperability are:

- Safety and Security
  - Electrical safety, supply-side
  - Electrical safety, vehicle-side
- Magnetic fields
- Electromagnetic compatibility (EMC)
- Communications
- Reliability
- Performance & efficiency

According to this list, the following parameters have been analysed in D3.3.3:

- Communication
  - Method (carrier)
  - Protocols
  - Guiding systems
- Construction and Geometry
  - Coil geometry
  - Lateral misalignment tolerance
  - Air gap and tolerances
  - Achievable vehicle velocity
- Electromagnetic
  - Operational frequency
  - Magnetic field intensity
  - Achievable secondary coil voltage
  - Power rating and power

- Other
    - Charging efficiency
    - Safety considerations (Shielding, EMC, Heating, etc.)
    - Costs to accomplish interoperability

A total of 14 parameters have been analysed for combinations of 9 different solutions, resulting in 850 different scores. Results have been summarised in the following Table 40, calculating average of the 72 scores obtained for each parameter. Scores have been defined as follows:

- 0: Systems are not interoperable / no data available
- 1: Systems are perfectly interoperable

As can be observed, the most critical category for interoperability is the one related to the design parameters of the electromagnetic field. Lowest scores are mainly due to lack of data for the analysis, which is also an indicator for uncertainty in this analysis. On the other hand, highest values are indicating both, high level of data availability and good interoperability. For velocity, only dynamic systems have been considered to calculate the interoperability score.

Communication	0.50	0.58	Communication method
		0.56	Communication protocol
		0.36	Position tracking
Construction and Geometry	0.56	0.60	Coil geometry
		0.61	Lateral misalignment
		0.46	Air gap and tolerance
Electromagnetic	0.38	0.78	Achievable velocity
		0.36	Operational frequency
		0.17	Magnetic field intensity
		0.40	Secondary Voltage
		0.63	Power rating
Other	0.44	0.49	Efficiency
		0.56	Safety
		0.28	Interoperability cost

Table 40. Interoperability scores obtained from FABRIC deliverable D3.3.3.

Critical areas have been identified for each parameter and will be summarised below:

Interoperability parameter	Critical areas
Communication method	All solutions, except PRIMOVE have identified WLAN and 802.11p as the wireless communication link covering Vehicle-to-Infrastructure communications related to the management of the charging process.
Communication protocol	Great variety of protocols has been observed, but charging solutions could adopt ISO 15118 as the higher layer communications protocol for charging.
Position tracking	General lack of data. If all guiding ability is self-contained in the vehicle (similar to the VICTORIA solution), interoperability mainly is reduced to communication standards.
Coil geometry	In general, coil geometry by itself is not critical for interoperability
Lateral misalignment	Coil geometry was considered, so interoperability is high. Score is worse due to absence of information from PRIMOVE.
Air gap and tolerance	Very heterogeneous physical parameter, identified as critical to improve/adjust towards interoperability of the different systems.
Achievable velocity	As speed can be easily adapted, interoperability is high
Operational frequency	There are two frequencies which are not interoperable and divide low to medium-power systems and high-power systems in two non-interoperable applications.
Magnetic field intensity	General lack of data.
Secondary Voltage	Similar to frequency, 2 typical on-board DC voltage ranges can be identified: Light vehicles: 300–400 V, Heavy vehicles: 600–800 V
Power rating	All systems could theoretically be interoperable, but efficiency is a limiting factor.
Efficiency	General lack of data. In general, it can be expected that efficiency will be reduced due to interoperability of different solutions.
Safety	Although power transfer can be established for virtually any combination of coil geometries, safety is not always fulfilled. Especially, if primary coils are too large
Interoperability cost	Adaptation costs for static solutions are high. Also, PRIMOVE resulted in the least interoperable system of the study.

Table 41. Summary of interoperability considerations from FABRIC D3.3.3.

3.3 Summary of the standards in preparation for static WPT

The standards address the technical aspects of the Wireless Power Transfer systems and give prescriptions related to the construction and the use of the devices to assure the safety and functionality of the systems, with indication of boundary conditions related to the energy efficiency, the interoperability and the operating use.

The prescriptions address the hardware for power transfer by magnetic field between primary and secondary coil on ground and on vehicle respectively and the relevant communication necessary for the inherent operation.

ISO and IEC standards are mainly dedicated respectively to the vehicle and to the ground infrastructure.

A group of standard ISO/IEC is dedicated to the communications vehicle to infrastructure for the approach coordination and planning of the service request by the user to the charging station.

All standards are developed according to the similar structure with respect to the items to be treated.

In the section 5 a cross reference is shown for the different standards.

Recent activities of the standardization have been finalized to the harmonization of the items among the different standards and to put in evidence the relevant reference.

Hereinafter we include the basic focus of the main standards:

- ISO 19363: Vehicle Assembly (VA) requirements, System definition, definition of power classes and Z (ground clearance) class, Safety and interoperability, Sequence of operation.
- IEC 61980-1: Ground Assembly (GA) and general system requirements, Installation, Use cases, interoperability, command and control communication, EMC, EMF.
- IEC 61980-2: Power transfer process with respect to communication, operation phase descriptions, activities specification.
- IEC 61980-3: Specific requirements for the magnetic field wireless power transfer systems, reference circuits for primary and secondary device.
- ISO/IEC 15118-1: Vehicle to grid communication: general information and use-case definition.
- ISO/IEC 15118-2: Network and application protocol requirements.

- ISO/IEC 15118-6: General information and use-case definition for wireless communication.
- ISO/IEC 15118-7: Network and application protocol requirements for wireless communication.
- ISO/IEC 15118-8: Physical layer and data link requirements for wireless communication.
- SAE TIR J2954: Wireless Power Transfer for Light-Duty Plug-in Electric Vehicles and Alignment Methodology: Definition of power classes and Z classes – prescriptions for both primary and secondary devices, VA and GA, operation phases sequence and communication.

The summary presented in the following is mainly based on the standard ISO 19363, IEC 61980 and SAE TIR J254, and its status of development at the end 2017. Apparently, no new advances have been incorporated to date. All of them are focused in WPT but not DWPT. However, we incorporate also a chapter “section 6” to underline the transition from WPT to DWPT which is the main added value from FABRIC.

3.3.1 ISO 19363 Electrically propelled road and vehicles- magnetic field wireless power transfer element- Safety and interoperability requirements

3.3.1.1 Contents of ISO 19363

- Scope.
- Normative references.
- Terms and definitions.
- Environmental conditions.
- System description.
- Classification of EV power circuits.
- MF-WPT power transfer requirements.
- Power transfer test procedure.
- Communication and activities.
- EMC requirements.
- Safety requirements.
- Owner’s manual and marking.

- Bibliography.

3.3.1.2 Scope

The document defines the requirements and operation of the on-board vehicle equipment that enable magnetic field wireless power transfer (MF-WPT) for traction battery charging of electric vehicles. It is intended to be used for passenger cars and light duty vehicles.

The present edition covers stationary applications (charging while vehicle is not in motion, according to SAE J2954).

3.3.1.3 Normative references

Documents reported in the standard, **indispensable** for its application:

- ISO 6469-3, Electrically propelled road vehicles – Safety specifications – Part 3: Protection of persons against electric shock.
- ISO 14117, Active implantable medical devices – Electromagnetic compatibility – EMC test protocols for implantable cardiac pacemakers, implantable cardioverter defibrillators and cardiac resynchronisation devices.
- ISO 15118-8, Road vehicles – Vehicle to grid communication interface – Part 8: Physical layer and data link layer requirements for wireless communication
- ISO 16750-3, Road vehicles – Environmental conditions and testing for electrical and electronic equipment – Part 3: Mechanical loads.
- ISO 16750-4, Road vehicles - Environmental conditions and testing for electrical and electronic equipment – Part 4: Climatic loads.
- ISO 16750-5, Road vehicles – Environmental conditions and testing for electrical and electronic equipment – Part 5: Chemical loads.
- IEC 61786-1, Measurement of DC magnetic, AC magnetic and AC electric fields from 1 Hz to 100 kHz with regard to exposure of human beings – Part 1: Requirements for measuring instruments.
- ICNIRP 2010, Guidelines for limiting exposure to time varying electric and magnetic fields (1 Hz – 100 kHz).
- ICNIRP 1998, Guidelines for limiting exposure to time varying electric and magnetic fields (up to 300 kHz).

3.3.1.4 Terms and definition

Principals terms and definitions applied in ISO and IEC standards on Wireless Power Transfer.

- **Alignment:** relative position of primary device to secondary device
- **EV communication controller EVCC:** embedded system within the vehicle, that implements the communication between the vehicle and the SECC to support specific activities.
- **EV device:** on board component assembly, comprising the secondary device, the EV power electronics and the EV communication controller, as well as the mechanical connections between the components necessary for wireless power transfer.
- **EV power circuit EVPC:** electrical component assembly that includes the secondary device and EV power electronics, as well as the mechanical connections between the components.
- **EVPC power class:** power class of an EVPC defined according to the MF-WPT input power class of the supply device it is designed to operate.
- **EV power electronics:** on-board electronics, including all housing and covers, that convert the AC power from the secondary device to DC power having suitable voltages and currents provided to the battery system or the traction battery.
- **Fine positioning:** relative movement of the secondary device in relation to the primary device with the goal of reaching optimal alignment.
- **MF-WPT system:** system consisting of the supply device and the EV device including wiring, housing and covers used to transfer energy using magnetic field.
- **Pairing:** process by which an EV is correlated with the unique dedicated primary device at which it is located and from which power will be transferred.
- **Primary device:** device external to the source of the MF-WPT, including all housing and covers.
- **Secondary device:** device mounted on the EV, including all housings and covers, that captures the magnetic field sourced by the primary device.
- **Secondary device ground clearance:** vertical distance between the ground surface and

the lowest point of the secondary device.

- **Supply device:** off-board component assembly comprising the primary device, the supply power electronics and the SECC, as well as the mechanical connections between the components necessary for wireless power transfer.
- **Supply equipment communication controller SECC:** entity which implements the communication to one or multiple EVCCs.
- **Supply power circuit:** off-board component assembly comprising the supply power electronics and primary device, as well as the mechanical connections between the components.
- **Supply power electronics:** off-board electronics, including all housings and covers, that supply the electric power to the primary device.
- **System efficiency:** efficiency from AC or DC power supply (input of the supply device to the output of the EV device.

3.3.1.5 Environmental conditions

Potential environmental stresses and related tests and requirements for electronic systems/components mounted in specific locations on/in the vehicle are described in ISO 16750:

- Mechanical loads according to ISO 16750-3, test procedure type VI, vehicle body.
- Climate loads according to ISO 16750-4.
- Chemical loads according to ISO 16750-5.

The parts of the EVPC (EV power circuit) located underneath the underbody of the EVPC shall meet the minimum IP degree of IP57 from the outside of the vehicle in road position.

The parts of the EVPC located other than underneath the underbody of the EVPC shall meet the minimum IP degree of IP55 from the outside of the vehicle in road position.

Compliance shall be checked in accordance with ISO 20653.

3.3.1.6 Subsystem description

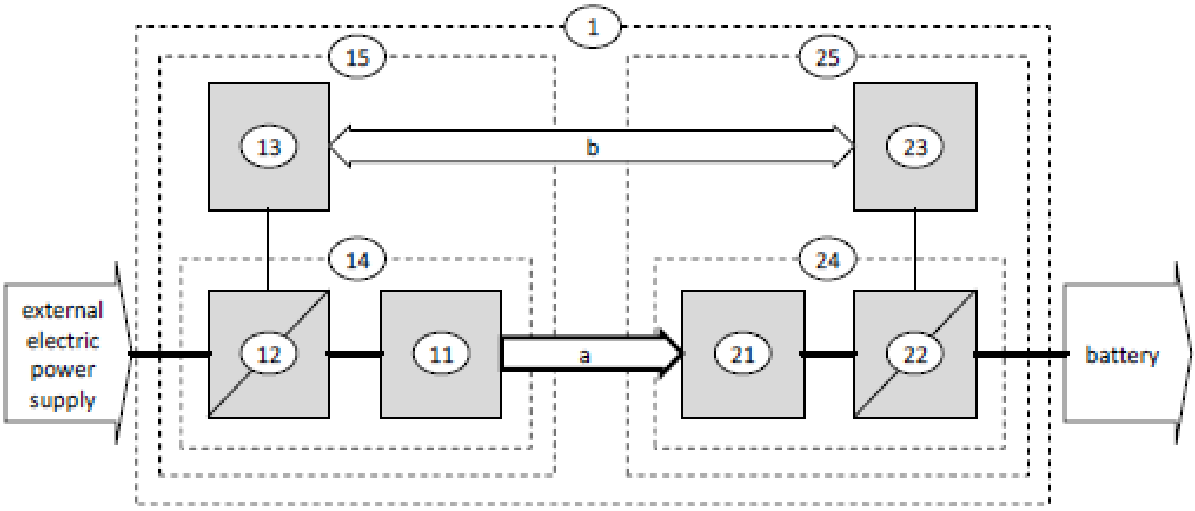


Figure 32. Structure of MF-WPT system

1: MAGNETIC FIELD WIRELESS POWER TRANSFER (MF-WPT) SYSTEM

a: Wireless power flow	**b:** Communication
11: Primary device (off board)	**12:** Supply power electronics
13: Supply equipment communication controller (SECC)	**14:** Supply power circuit equipment
15: Supply device	**21:** Secondary device
22: EV power electronics	**23:** EV communication controller (EVCC)
24: EV power circuit (EVPC)	**25:** EV device

3.3.1.7 Classification of EV power circuits

The classification serves to determine specific interoperability requirements in clauses 7 EVPC power classes:

- MF-WPT1: EVPC designed to operate with supply device:

  input power < 3,7 kW

- MF-WPT2: EVPC designed to operate with supply device:

  3,7 kW < Input power < 7,7 kW

- MF-WPT3: EVPC designed to operate with supply device:

7.7 kW < Input power < 11.1 kW

- MF-WPT4: EVPC designed to operate with supply device:

11.1 kW < Input power < 22 kW

NOTE: The Standard IEC 61980 specifies the corresponding MF-WPT input power classes

Z class	Secondary device ground clearance (mm)
Z1	100 to 150
Z2	140 to 210
Z3	170 to 250
Note: Alternative for Z3 as 200 to 250 mm under discussion Alternative for Z1 as lower than 100 mm in consideration	

Figure 33. Z classes

3.3.1.8 MF- WPT power transfer requirements

3.3.1.8.1 General

Interoperability refers to the capability of the supply device and the EV device being able to transfer power wirelessly in a safe and efficient manner, based on compliance with the requirements in this document.

3.3.1.8.2 Frequency

The power transfer shall be operated within the system frequency range respectively at the nominal frequency.

Description	Frequency [kHz]
System frequency range	81,38 to 90,00
Nominal frequency	85,00 +/- 0,1

A fixed frequency system shall transfer the power at the nominal frequency.

Frequency tuneable systems may transfer power at any frequency within the system frequency range. For frequency tuneable systems, the nominal frequency is typically observed under optimal alignment and while the system is in a steady state.

NOTE: To optimize the system efficiency, the MF-WPT system [or the supply power circuit] may tune the frequency within the system frequency range.

3.3.1.8.3 Alignment tolerance requirements

AXIS	ALLIGNMENT TOLERANCE
Axis X (driving direction)	+/- 75 mm
Axis Y (transversal direction)	+/- 100 mm

The EV may have the capability to assist the driver in aligning the vehicle for proper coupling between the primary and secondary device. This functionality may require some support from the supply power circuit and standardization of this mechanism may be desired. The definition of this mechanism does not preclude the use of alternate mechanisms by the EV.

3.3.1.8.4 Requirements for transferable power

A product EVPC shell be able to deliver the requested power under steady state conditions up to the maximum rated power specified by the EV manufacturer.

Conformance shall be confirmed by testing with the corresponding reference supply device(s). A requested change in power delivery shall not cause a DC output voltage overshoot of a product EVPC by more than +/-250 V/m with the peak voltage not higher than 10% of the nominal DC output voltage. The DC output voltage ripple amplitude of a product EVPC shall not exceed +/-8 V.

3.3.1.8.5 Efficiency requirements

System efficiency is defined from AC or DC power supply (input-supply-terminals of all off-board power and control electronics) to the connecting point of the electrical load on the vehicle side.

The minimum system efficiency supported by a product EVPC shall be:

- With optimal alignment: 85%
- Within alignment tolerance: 80%

If auxiliary loads (e.g. thermal management for foreign object detection) are mandatory for a system specific application, their power consumption shall also be included in the system efficiency calculation.

3.3.1.9 Power transfer test procedure

3.3.1.9.1 General

Conformance with the power transfer requirements requires conformance with the previous clause.

3.3.1.9.2 Test procedure

The product EVPC, when tested with the reference supply power circuit, shall meet the power transfer requirements of 4.1.8.4 and the efficiency requirements of 4.1.8.5 over the secondary device ground clearance range specified by the EVPC manufacturer.

Conformance shall be tested at ambient temperature of 25°C +/- 5 °C with EVPC attached to the vehicle at its intended position and connected to the battery (or a simulated DC load).

Power transfer and system efficiency shall be tested in the measurement position as specified in the following figures.

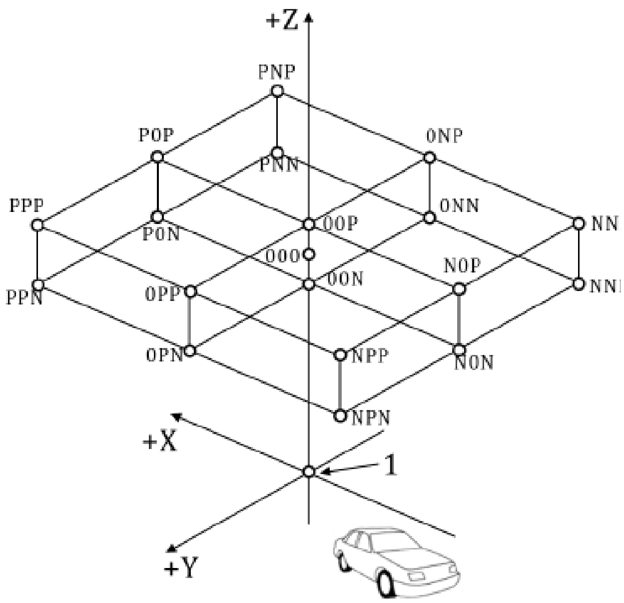


Figure 34. Measurement position

Measurement point as per Figure 2	X	Y	Secondary device ground clearance range
P P P	+75	+100	max
P P N			min
P 0 P		0	max
P 0 N			min
P N P		-100	max
P N N			min
0 P P	0	+100	max
0 P N			min
0 0 P		0	max
0 0 0			mid
0 0 N			min
0 N P		-100	max
0 N N			min
N P P	-75	+100	max
N P N			min
N 0 P		0	max
N 0 N			min
N N P		-100	max
N N N			min

Figure 35. Measurement point

3.3.1.10 Communication and activities

3.3.1.10.1 Protocol sequence and associated messages

For power transfer, the following activities apply:

- Communication setup.
- Service selection – compatibility parameters exchange.
- Fine positioning.
- Pairing.
- Final compatibility check.
- Initial alignment check.
- Start power transfer.
- Perform power transfer.
- Stop power transfer.
- Terminate communication.

3.3.1.10.2 Communication

WPT requires a wireless communication between the supply device and the EV device. The communication PHY/MAC shall comply with ISO 15118-8.

3.3.1.10.3 Activities

For several activities the usage of signals supplemental to communication are needed. The corresponding requirements will be allocated in IEC61980-2, IEC61980-3, ISO 19363.

3.3.1.10.4 Communication setup

Communication setup shall be initiated by the EVCC. The EVCC shall be able to verify communication is properly established. Communication set up shall comply to ISO15118-2. Conformance shall be checked according to ISO15118 series.

Note: The sequence and communication are presented in detail in the following pages.

3.3.1.10.5 Service selection

The EVCC shall request available services and possible power transfer options from the SECC according to IEC61980-2. The EV shall choose the fine positioning method, initial alignment check method and pairing method during service selection. Conformance shall be checked according to ISO15118 series.

The EVCC shall send the following parameters for service selection:

- EVPC power class.
- Maximum receivable power.

- Maximum secondary device ground clearance.
- Minimum secondary device ground clearance.
- Minimum operating frequency.
- Maximum operating frequency.
- Type of geometry of the secondary device.
- Circuit topology.
- Fine positioning methods.
- Pairing methods.
- Initial alignment check methods.
- Manufacturer ID.
- Manufacturer specific data container.
- Specific Service Provider (optional).

The EVCC expects corresponding information from the SECC according to IEC61980-2.

3.3.2 IEC 61980-1 Electric vehicle wireless power transfer systems. Part 1: General requirements

3.3.2.1 Content of IEC 61980

- Scope.
- General system requirements.
- Communication.
- Protection against electric shock.
- Specific requirements for WPT systems.
- Service and test conditions.
- Electromagnetic compatibility (EMC).
- Use cases.
- EMF, protection from electromagnetic field.

3.3.2.2 Part 1 General requirements

Note: the structure and the contents of this document are substantially consistent with the corresponding items of ISO 19363, IEC 61980-2-3 and ISO/IEC 15118 series. The synthesis which follows refers to the complementary aspects, while, for the corresponding topics, reference is made to the other standards, which are harmonized with the present one.

3.3.2.2.1 Scope

This part of the IEC 61980 applies to the equipment for the wireless transfer of electric power from the supply network to electric road vehicles for purposes of supplying electric energy to the RESS and/or other on-board electrical systems in an operational state when connected to the supply network, at standard supply voltages ratings per IEC 60038 up to 1000V AC and up to 1500V DC. This standard also applies to Wireless Power Transfer equipment supplied by on-site storage system (e.g. buffers).

The standard does not apply to WPT vehicle power supply circuit, which is covered by ISO 6464 series, ISO 19363 and high-level communication, which are covered in ISO/IEC 15118 series.

3.3.2.2.2 General requirements

3.3.2.2.3 Scheme of the Wireless Power Transfer system

3.3.2.3 See ISO 19363, System description.

3.3.2.3.1 Measurement convention, test procedure

3.3.2.4 See ISO 19363.

3.3.2.4.1 Efficiency

3.3.2.5 See ISO 19363.

3.3.2.5.1 Distance between the primary and secondary device (mechanical air gap)

3.3.2.6 See ISO 19363.

3.3.2.6.1 Command and control communication

The command and control communication between the EV supply equipment and the EV exchange information necessary to start, control and terminate the process of WPT is reported in IEC 61980-2.

3.3.2.6.2 High level communication

Any information exceeding the information covered by the command and control communication is covered in ISO/IEC 15118.

3.3.3 IEC 61980-2 Electric vehicle wireless power transfer systems. Part 2: Specific requirements for communication between electric road vehicle and infrastructure with respect to WPT system

3.3.3.1 Contents (synthesis)

- Scope.
- Communication of WPT system architecture.
- Power transfer operation process and phases description.
- Activities.
- Control process states.
- Sequence and message parameters.

3.3.3.2 Scope

Aspects covered in this standard:

- Operational characteristics and functional characteristics of the WPT communication subsystem.
- Communication requirements for WPT system while driving are under consideration.
- Communication requirements for bidirectional power transfer are under consideration.

3.3.3.3 Communication of WPT system architecture. General

All safety relevant interaction between the supply device and the EV shall be established via command & control communication.

In addition to the command & control communication, the supply device and the EV may be able to use optional HLC functions according to **ISO/IEC 15118** series in order to exchange non-safety relevant parameters between the supply device and the EV (e.g. approaching, authentication, billing etc.). HLC can start before command & control and end after command & control communication.

Key steps in the WPT process (such as start, perform and stop of power transfer or safety related functions) shall be managed through command & control communication and signals only.

In addition to the command & control communication, the supply device and the EV may be able to use HLC to exchange additional parameters for WPT between the supply device and the EV (e.g. charging profiles, billing etc.).

System architecture

The following slides show the configuration of the communication control system and the relevant nomenclature.

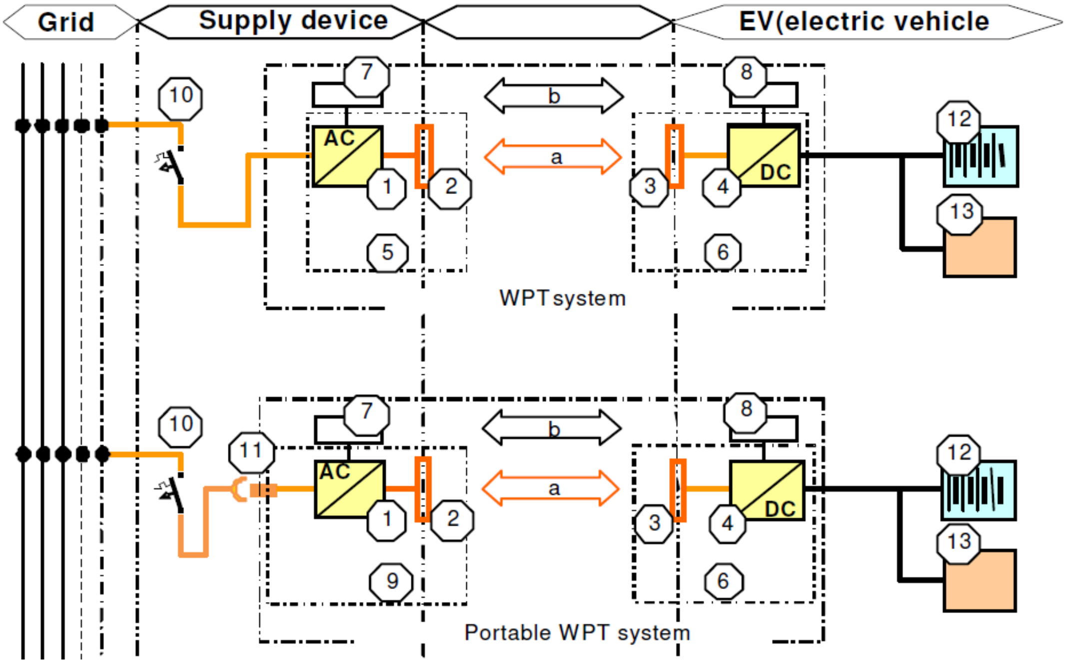


Figure 36. WPT system schematic, equivalent to schematic in ISO 19363

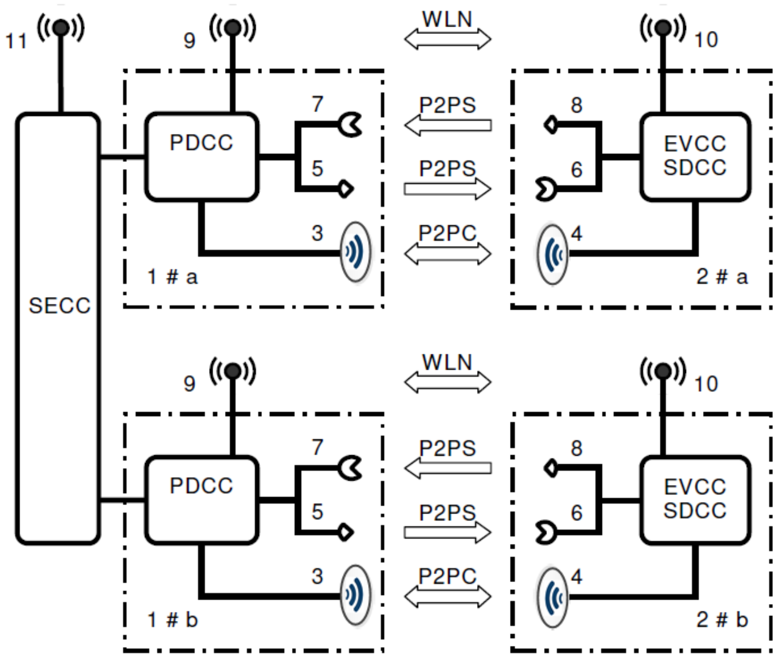


Figure 37. Wireless communication control system architecture

Key	Name	Abbreviation
1	Supply device	
2	Electric vehicle	EV
3	Primary device communication controller antenna	PDCC antenna
4	Secondary device communication controller antenna	SDCC antenna
5	Primary device communication controller signaller	PDCC signaller
6	Secondary device communication controller detector	SDCC detector
7	Primary device communication controller detector	PDCC detector
8	Secondary device communication controller signaller	SDCC signaller
9	Primary device communication controller WLN antenna	PDCC WLN antenna
10	Secondary device communication controller WLN antenna	SDCC WLN antenna
11	Supply equipment communication controller WLN antenna	SECC WLN antenna
NOTE 1 Key list also applies to Figure 3 to 9		

Figure 38. Nomenclature of the communication system architecture

3.3.3.4 Power transfer operation process and phases description

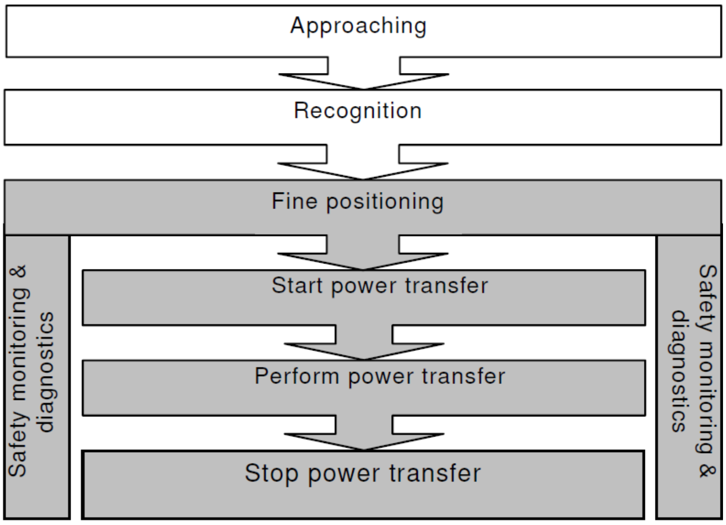


Figure 39. Operation phases of the wireless power transfer process

3.3.3.5 Activities

3.3.3.5.1 Approaching

It begins with the user deciding for a dedicated possibility for power transfer. It ends with the EV detecting the SECC's communication systems.

3.3.3.5.2 Recognition of supply device

In accordance to **ISO/IEC 15118 series.**

UC (Use case) select charging spot in accordance with **IEC 61980-1.**

Communication setup.

Exchange of compatibility information.

UC for identification, authentication and authorization.

3.3.3.5.3 Communication setup

It will be initiated by EVCC.

Communication setup any take place during:

- UC select charging spot (WPT spot).
- UC fine positioning.

- UC pairing confirmation.

3.3.3.5.4 Fine positioning

It is where the EV enters into the chosen WPT spot and some form of guidance is provided to the driver of the EV with the goal of having the EV and the supply device properly positioned to each other.

Fine positioning. General

This sequence describes how the EV moves from near to supply device to parking.
Different methods for fine positioning shall be supported by the communication protocol.
Command & control communication shall support several fine positioning methods:

- Manual:
  - ✓ Driver is expected to manoeuvre the EV without any support (shall be supported).
  - ✓ Other methods (optional).
- Low power (magnetic) excitation from supply device (method name Primary LPE):
  - ✓ Supply device activates a low power magnetic signal that the EV is able to detect. The EV provides signals to the driver towards the supply device.
- Low power (magnetic) excitation from EV (method name Secondary LPE):
  - ✓ The EV activates a low power magnetic signal that the supply device is able to detect. The EV will query the supply device for vectors to the supply device.
- Bluetooth Smart signal from supply device (method name: Primary Bluetooth):
  - ✓ Supply device activates a Bluetooth Smart signal that the EV is able to detect. The EV provides signals to the driver towards the supply device.
- Bluetooth Smart signal from EV (method name: Secondary Bluetooth)
  - ✓ The EV activates a Bluetooth Smart signal that the supply device is able to detect. The EV will query the supply device for vectors to the supply device.
- Radar detection of EV by supply device (method name: Primary Radar)
  - ✓ The supply device activates a radar system that is able to detect the EV's position. The EV will query the supply device for vectors to the supply device.
- Radar detection of supply device by EV (method name: Secondary radar)
  - ✓ The EV activates a radar system that is able toto detect the supply device's position.

- ✓ The EV provides signals to the driver towards the supply device.

- Augmented reality on the supply device (method name: Primary AR)
  - ✓ The EV will have visual signals that the supply device can recognize using augmented reality. The EV will query the supply device for vectors to the supply device.
- Augmented reality on EV (method name: Secondary AR)
  - ✓ The supply device will have visual signals that the EV can recognize using augmented reality. The EV provides signals to the driver towards the supply device.

3.3.3.5.5 Pairing

The pairing activity shall enable both the SECC and the EVCC to uniquely identify the primary device on which the EV is placed on.

- The pairing activity may have the following characteristics (pre-conditions):
  - ✓ Pre-programmed recognition (e.g. private garage with EV and supply device automatically recognized.
  - ✓ Primary device emits a signal that is recognized by the EV.
  - ✓ Secondary device emits a signal that is recognized by the supply device.
- Post conditions:
  - ✓ Successful confirmation of pairing by EVCC.
  - ✓ Successful confirmation of pairing by SECC.

3.3.3.5.6 Final compatibility check

After pairing, the EVCC shall provide its compatibility check information and shall request a compatibility check to the SECC.

The SECC shall respond to the EVCC with the compatibility check information and confirmation.

- The final compatibility check may have the following characteristics.
  - ✓ Exchange and negotiate WPT parameters by communication between the EV and the SECC.
- Preconditions:
  - ✓ Successful pairing confirmation.

- Actions:
    - ✓ WPT parameter exchange.
- Post conditions:
    - ✓ EVCC and SECC shall confirm compatibility with each other.

3.3.3.5.7 Initial alignment check

An initial alignment check shall be successfully performed before start power transfer.

- The initial alignment check may have the following characteristics:
    - ✓ An efficiency check of power transfer (not at maximum power).
    - ✓ A sufficiently accurate signal from the secondary device to the primary device.
    - ✓ A sufficiently accurate signal from primary device to secondary device.
- Preconditions:
    - ✓ Fine positioning completed.
- Actions:
    - ✓ Initial alignment check.
- Post conditions:
    - ✓ SECC shall confirm successful alignment.
    - ✓ EVCC shall confirm successful alignment.

3.3.4 SAE TIR J2954 Wireless power transfer for light-duty plug-in electric vehicles and alignment methodology

The section is harmonized with the corresponding ISO and IEC standards under development. This section includes, in particular, specifications for vehicle and ground (infrastructure) assemblies. The following tables are taken from the presentation of SAE Representative at the IEA Workshop in Rotterdam in June 2016, dedicate to Wireless Power Transfer. The technical specifications of the primary and secondary units are here reported.

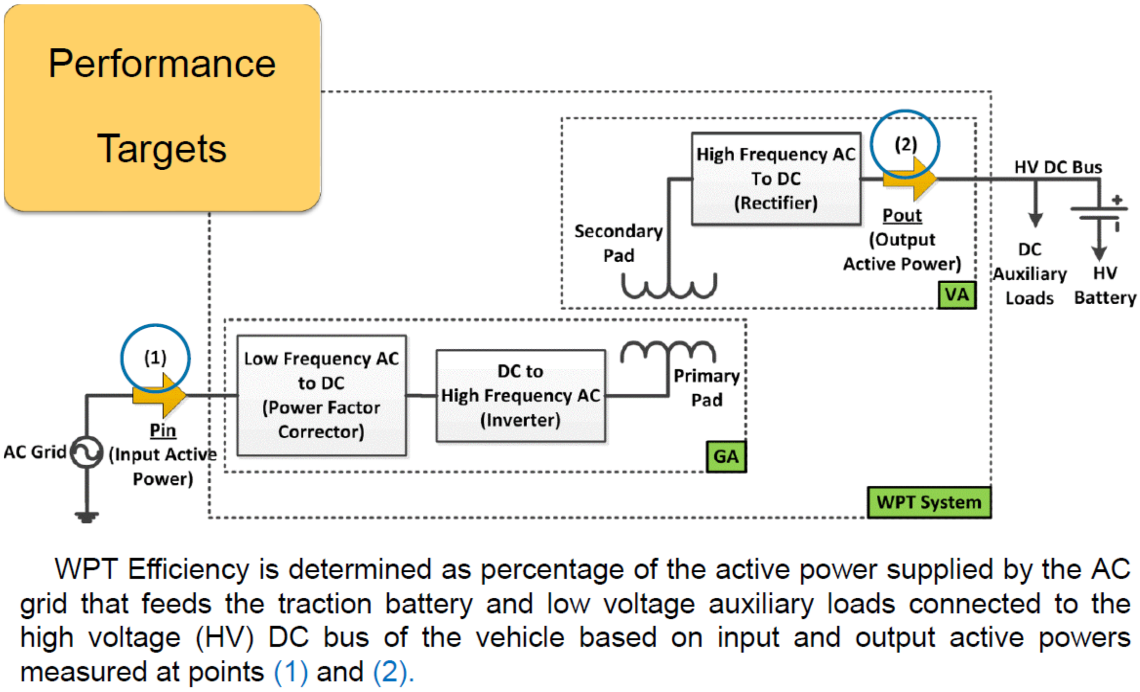


Figure 40. System efficiency

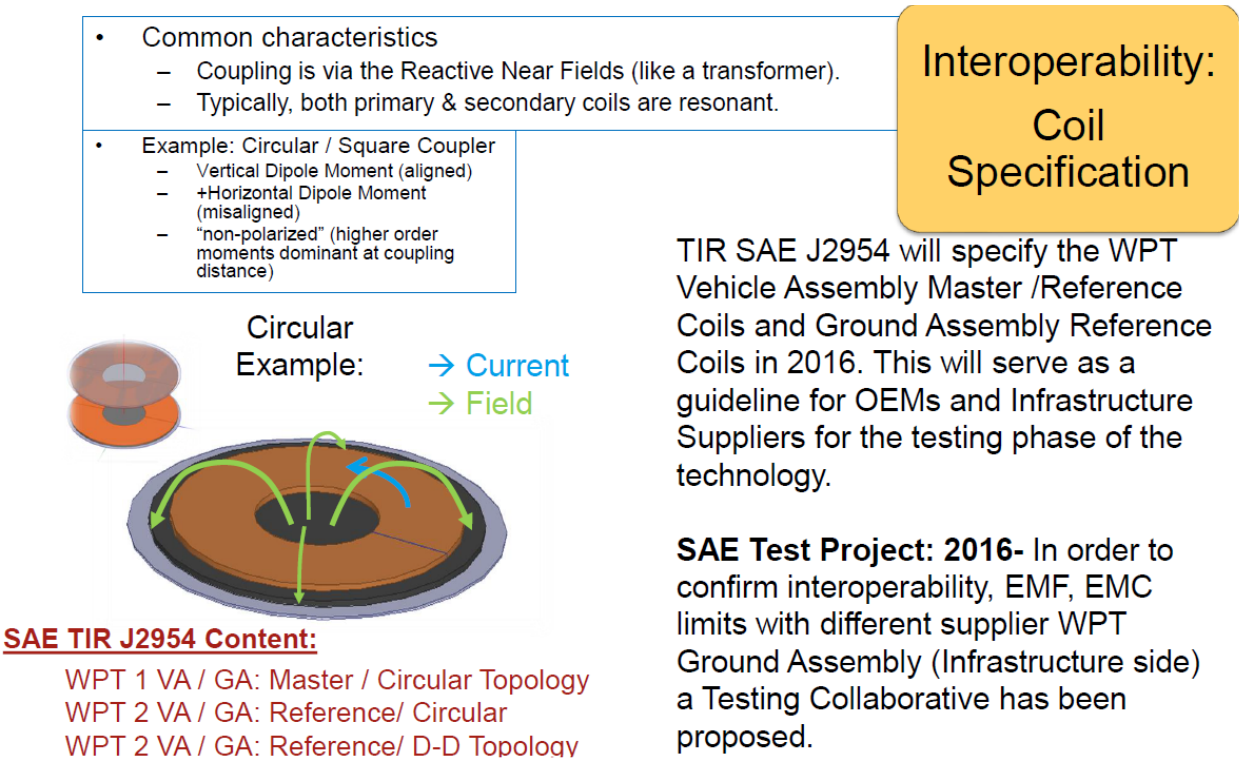


Figure 41. "Master reference" Coil Specification

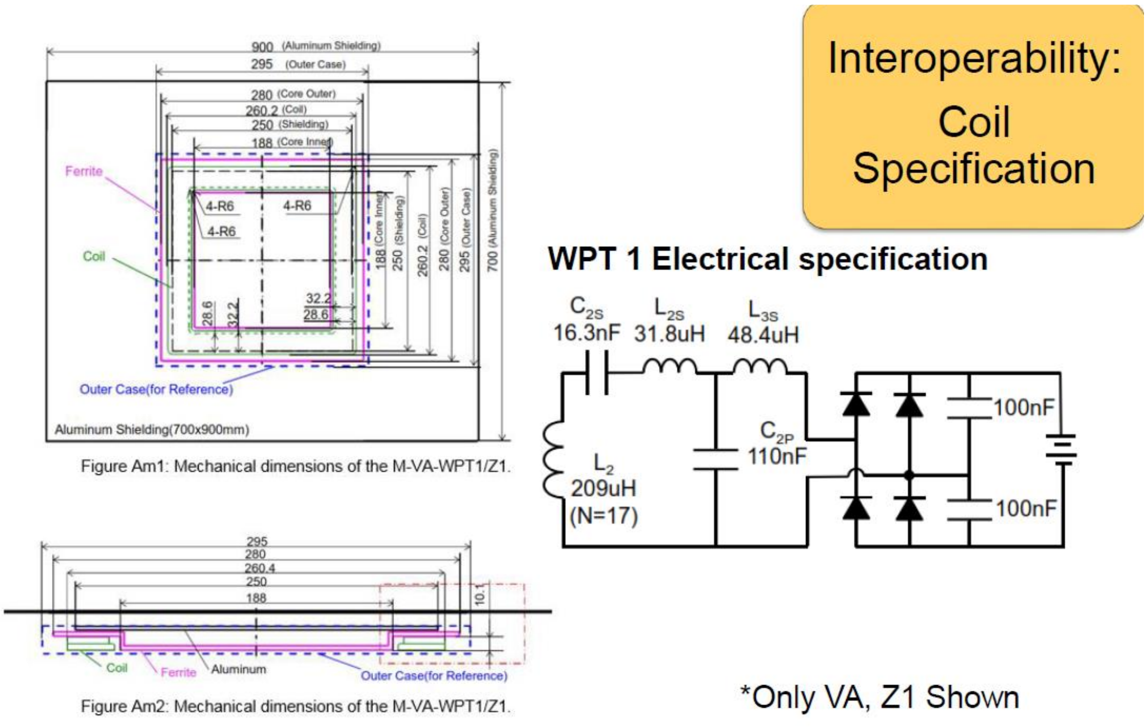


Figure 42. WPT1, Z1, Z2 Coil specification. "Master Coil Set": circular topology

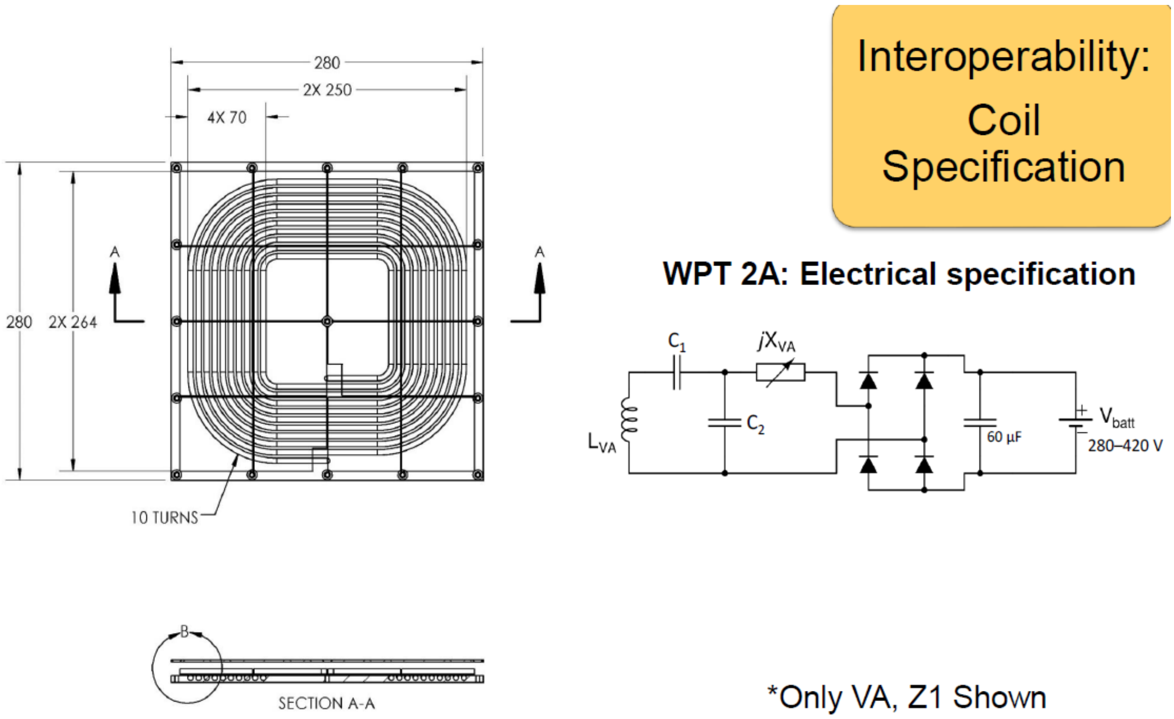


Figure 43. WPT2, Z1-3 Coil specifications: Reference Coil Set: Circular topology

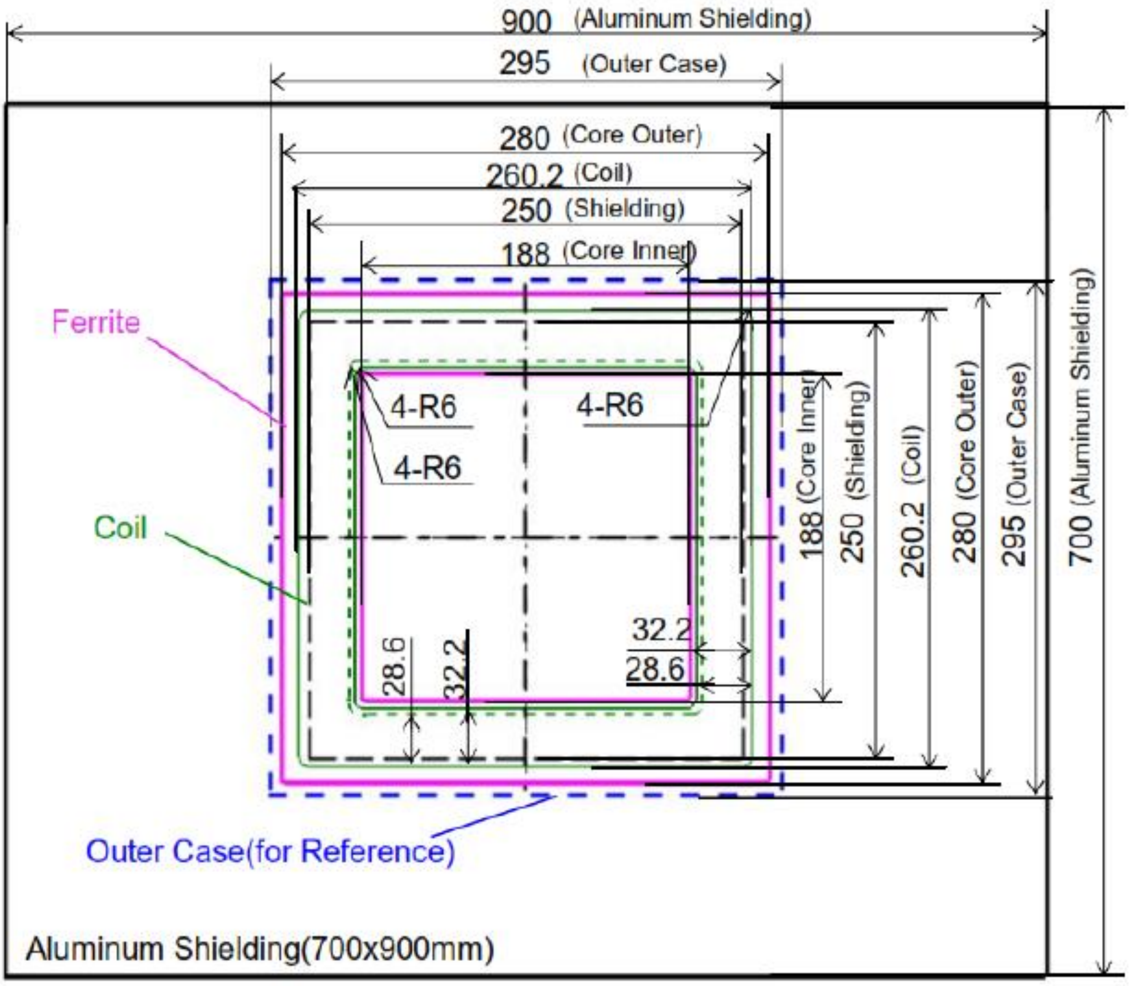


Figure 44. Mechanical dimensions of the M-VA- WPT1/Z1

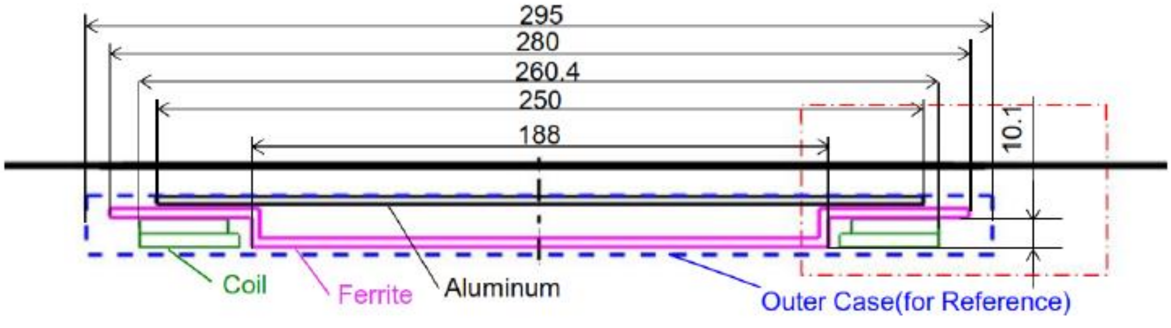


Figure 45. Mechanical dimensions of the M-VA- WPT1/Z1

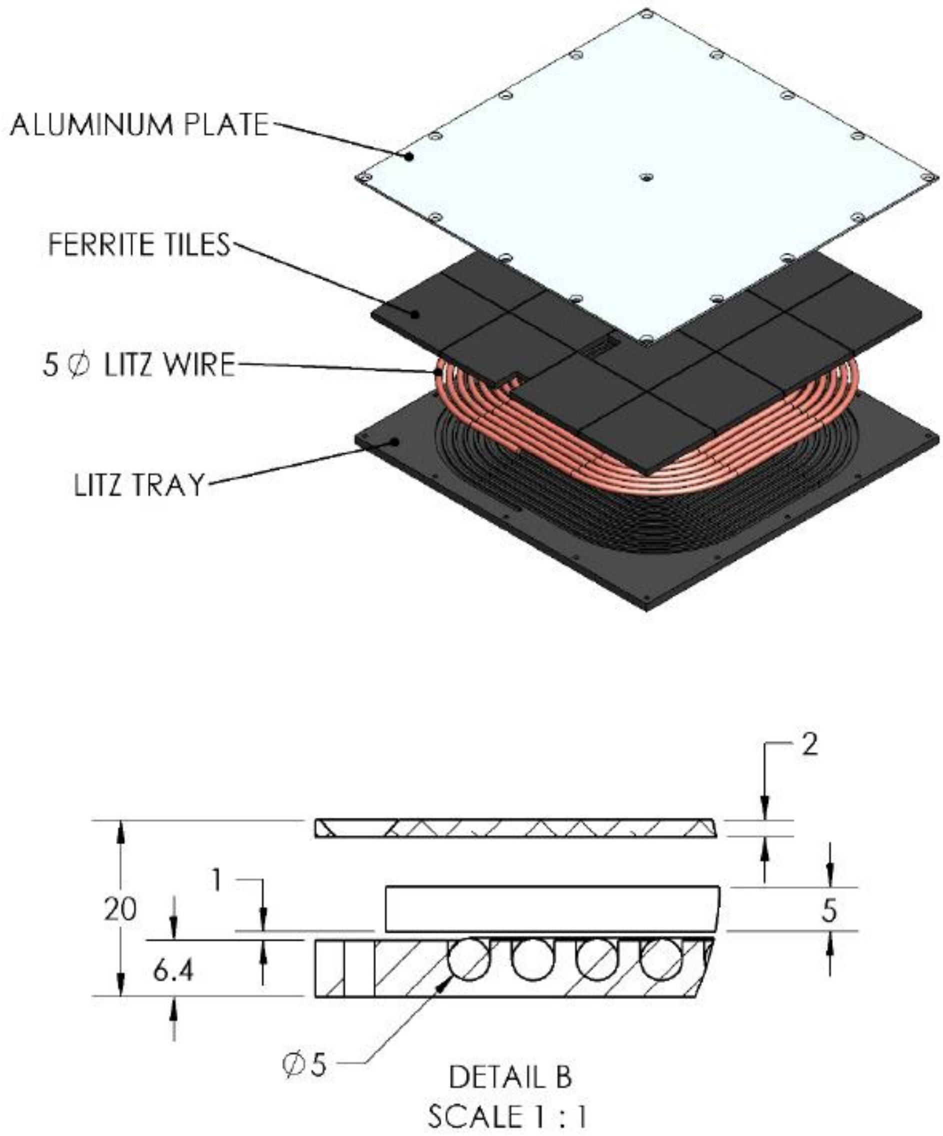


Figure 46. Mechanical dimensions of the VA-WPT2/Z1

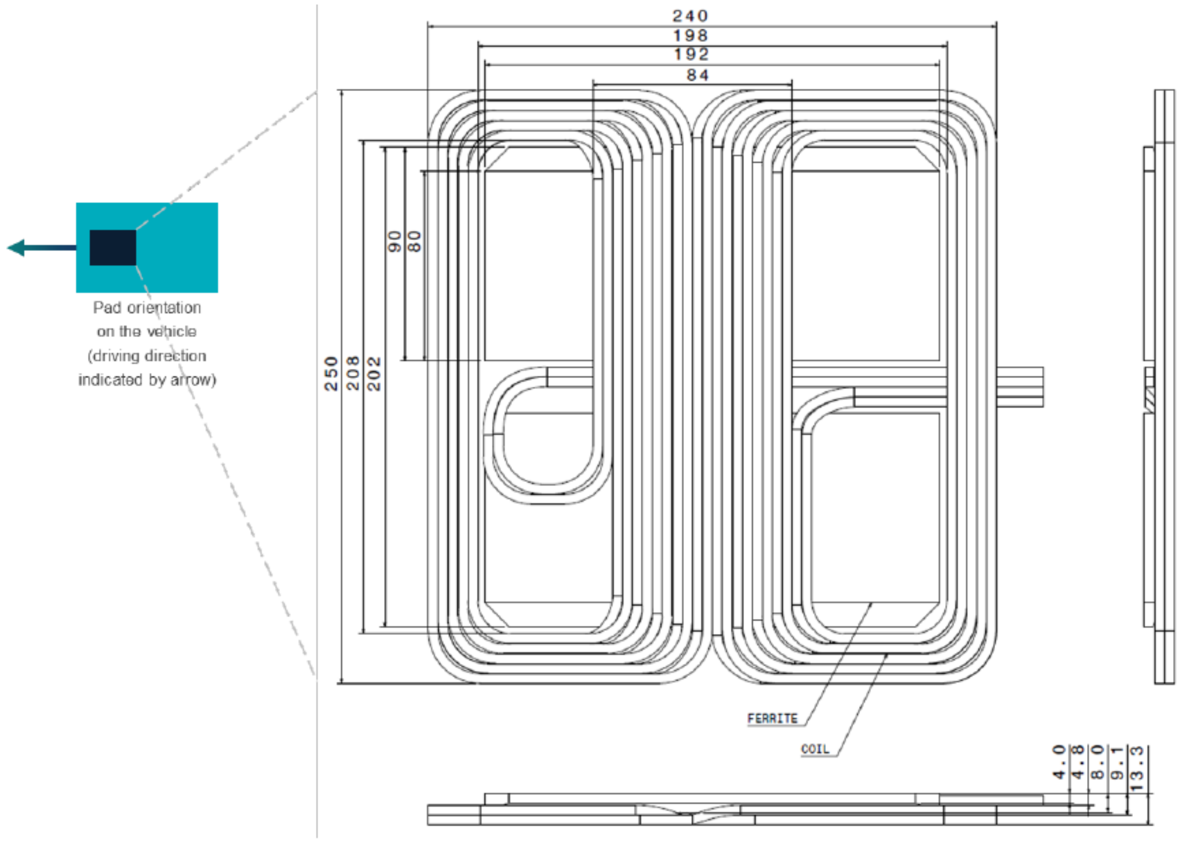


Figure 47. Mechanical dimensions of the VA-WPT2/Z1

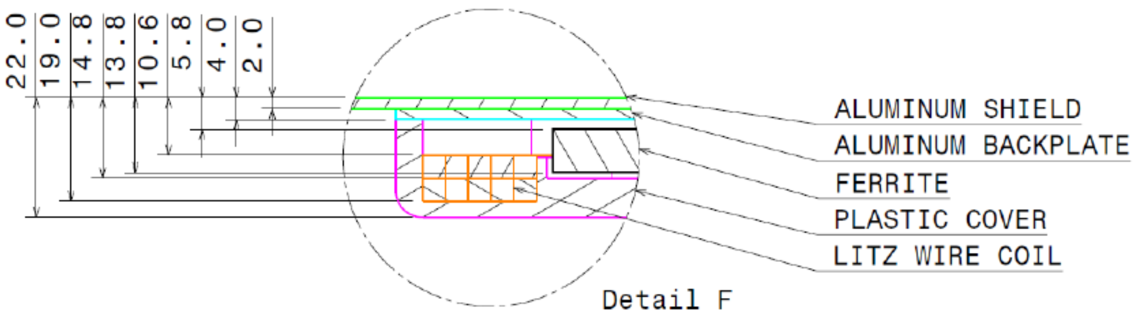


Figure 48. Detailed cross-section view of the VA-WPT2/Z1

	Coil + ferrite only	Housing (w/o vehicle shield)
L x W x H [mm]	240 x 250 x 13.3	250 x 260 x 20

Figure 49. Mechanical dimensions of the VA-WPT/Z1

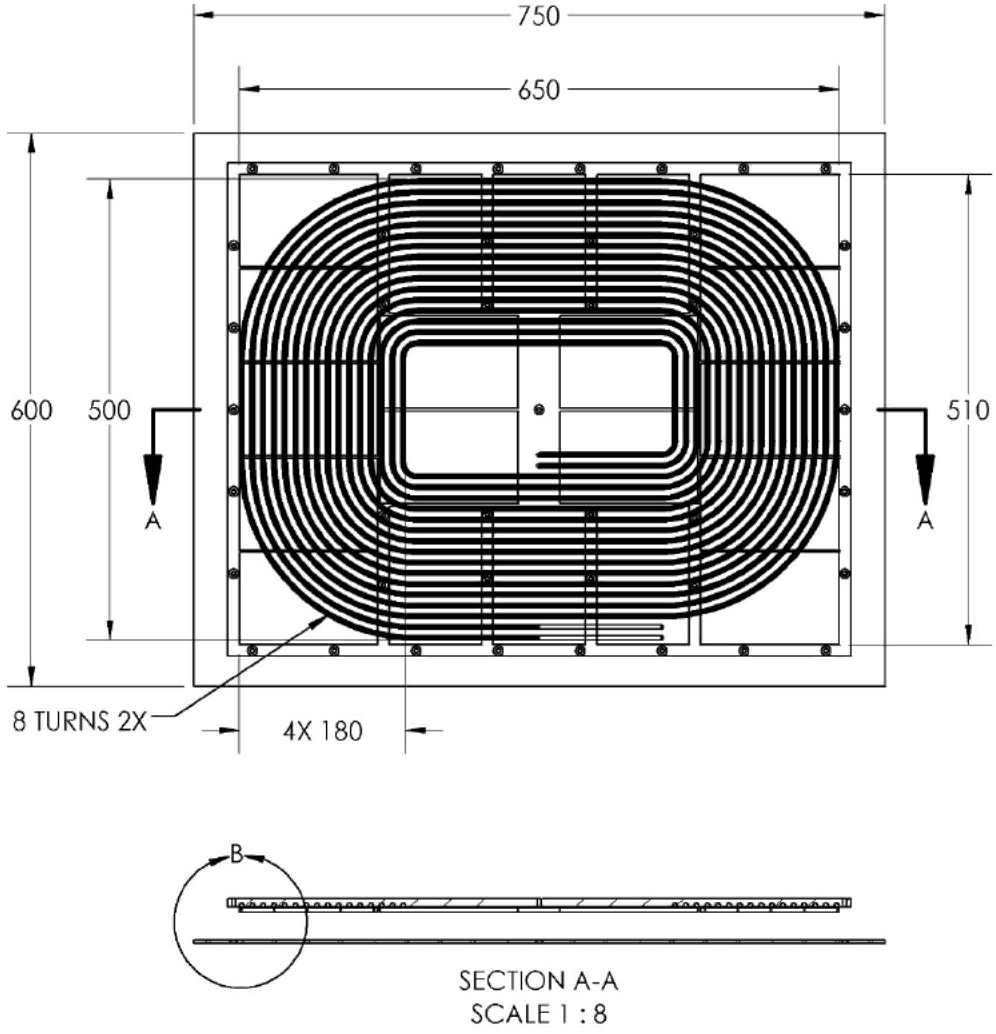
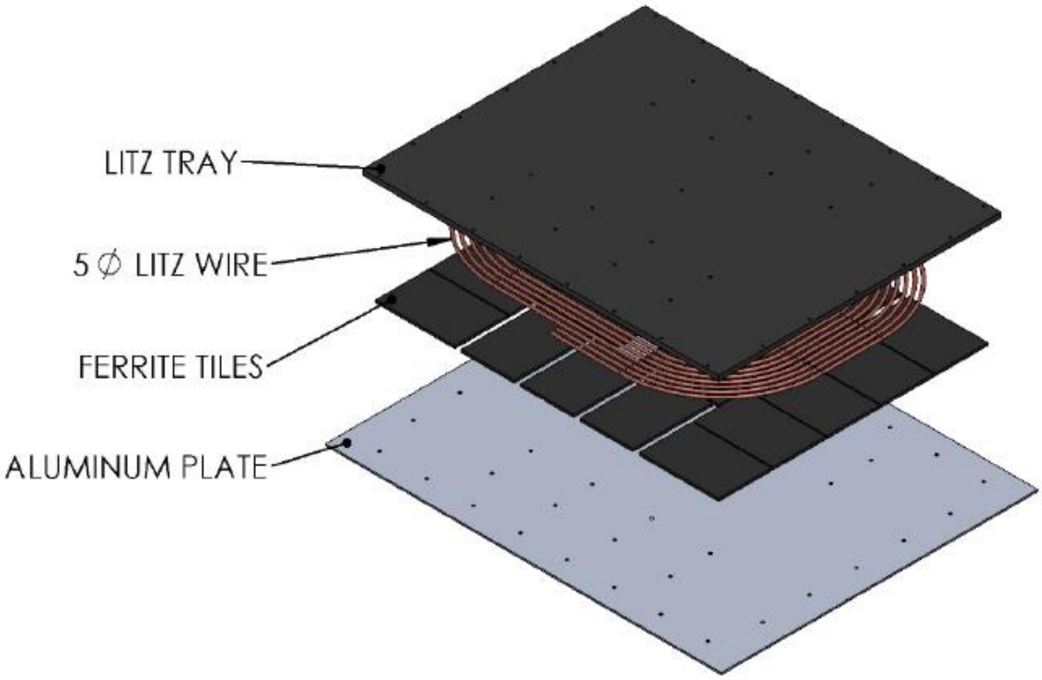
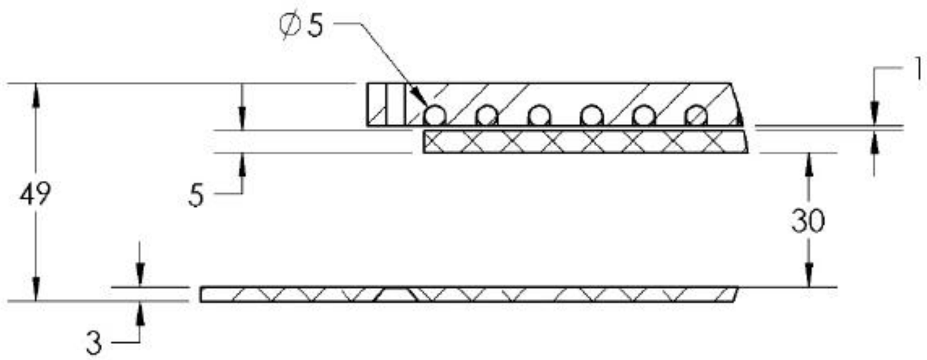


Figure 50. Dimensions of reference R-GA-2 for WPT2 (7,7 kVA) (Primary device on ground)





DETAIL B
SCALE 1 : 2

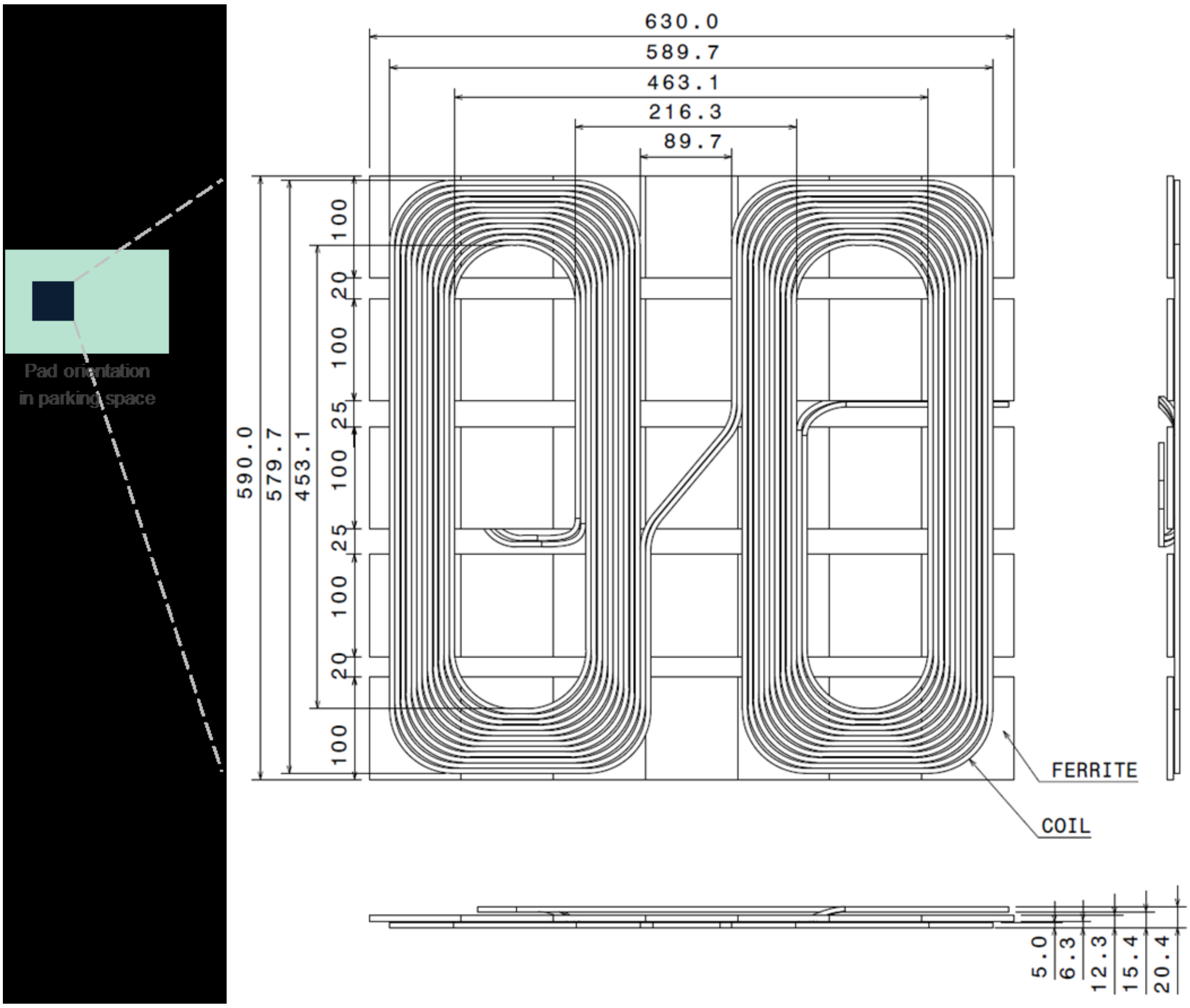


Figure 51. Mechanical dimensions of the GA (Primary device on ground)

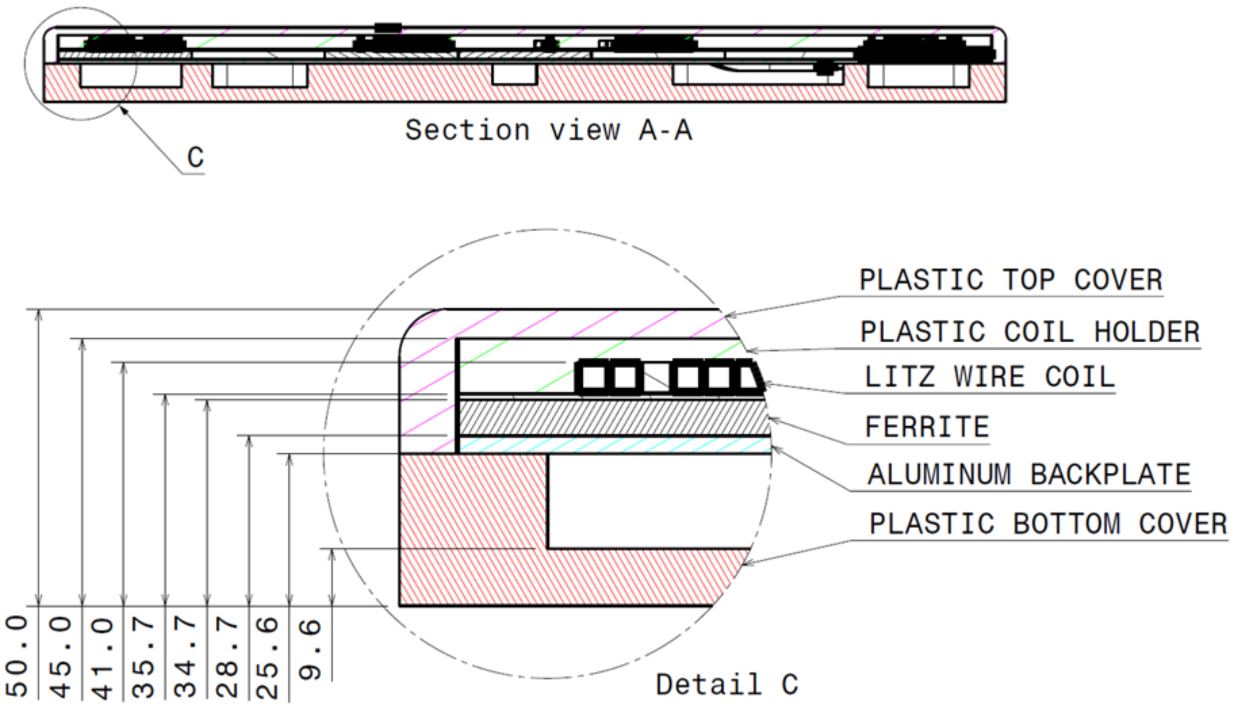


Figure 52. Section view and detail

3.3.5 ISO/IEC 15118-1 Vehicle to grid communication interface. General information and use-case definition

3.3.5.1 Scope

ISO 15118 specifies the communication between electric vehicles and the electric vehicle supply equipment (EVSE). The communication parts of this generic equipment are the electric vehicle communication controller (EVCC) and the supply equipment communication controller (SECC). The purpose of this part is the description of terms and definitions, general requirements and use cases as the basis of the other parts of ISO /IEC 15118. ISO/IEC 15118 provides a general overview and a common understanding of aspects influencing the charge process, payment and load levelling.

3.3.5.2 Normative references

- IEC 61851-1 Electric vehicle conductive charging system – Part 1: General requirements.
- ISO 8713 Electric road vehicles – Vocabulary.
- IEC 62052-11 Electricity metering equipment (AC) – General requirements, tests and test conditions – Part 11: Metering equipment.
- IEC 62053-21 Electricity metering equipment (AC) – Particular requirements – Part 21:

Static meters for active energy (classes 1 and 2).

3.3.5.3 Terms and definitions

The terms and definitions given in ISO 8713 and the following (excerpts from ISO/IEC 15118-1) apply:

- **Demand Clearing House (DCH):** Entity for grid negotiation that provides information on the load of the grid.
- **Distribution System Operator (DSO):** Item responsible for the voltage stability in the distribution grid.
- **E-Mobility Operator:** Entity with which the customer has a contract for all services related to EV operation.
- **E-Mobility Operator ID:** Unique identification related to the contract between the vehicle user or the vehicle itself and the E-mobility operator, which identifies the issuer of the contract ID.
- **E-Mobility Operator:** may be used for roaming services.
- **E-Mobility Operator Clearing House (EMOCH):** Entity mediating between two clearing partners to provide validation services for roaming regarding contracts of different E-Mobility Operators.

3.3.5.4 Use case elements. General

Classification of the elementary use cases for the communication system between EVCC and SECC.

Possible elementary use cases:

- Start of charging process.
- Communication setup.
- Certificate handling.
- Identification, Authentication and Authorisation.
- Target setting and charge scheduling.
- Value added services.
- End of charging process.

Note: The elementary use cases for the communication system between EVCC and SECC are

common for conductive and wireless power transfer procedure. ISO/IEC 15118-1 specifies further the details of the procedure applicable for the conductive power transfer. the procedure for wireless power transfer is specified in ISO/IEC 15118-6-7-8.

3.3.6 ISO/IEC 15118-2 Vehicle to grid communication interface. Network and application protocol requirement

3.3.6.1 Scope

The purpose of this part 2 of ISO/IEC 15118 is to detail the communication between an EV (BEV or a PHEV) and an EVSE for both conductive and wireless charging.

This part 2 defines messages, data model, XML/EXI based data representation format, usage of V2GTP (Vehicle to Grid Transfer Protocol), TLS (Transport Layer Security), TCP (Transmission Control Protocol) and IPv6 (Internet Protocol standard).

In addition, the document describes main service sequences of conductive charging, wireless charging and revers power transfer and how data link layer services can be accessed from a layer 3 (OSI) perspective.

The data link layer and physical layer functionality of wireless communication is described in part 8 of this standard.

3.3.7 ISO/IEC 15118-6 Vehicle to grid communication interface. General information and use-case definition for wireless communication

3.3.7.1 Use case elements

Reference is made with the use cases reported in 15118-1 (see Scope).

3.3.7.2 Use case function groups as defined in ISO/IEC 15118-1

- Start of charging process.
- Communication setup.
- Certificate handling.
- Identification, Authentication and Authorisation.
- Target setting and charge scheduling.
- Value added services.
- End of charging process.

For wireless power transfer, the sequence is shown which illustrates the situation of the approach

to the charging spot and the steps to be performed.

In figure below, we get the situation where the driver approaches the charging area, then the EV associates, and starts fine positioning (out of scope of this standard), then pairing and finally power transfer may start.

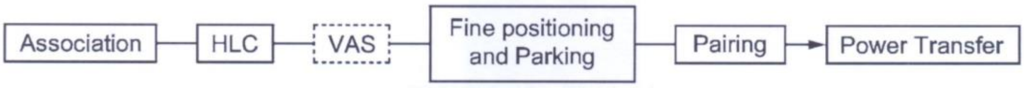


Figure 53. Sequence illustrating the situation "Associate then park" in case of WPT

In the figure below, we get the situation where the driver approaches the charging area, then starts fine positioning (out of the scope of this standard), wireless association, HLC then pairing and power transfer. In this example fine positioning comes first because wireless communication is not required by the technology used for this fine positioning.

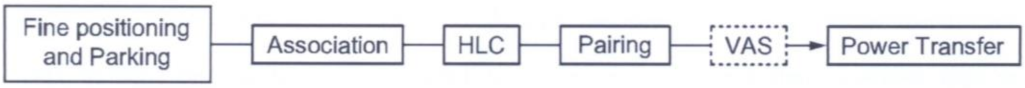


Figure 54. Sequence illustrating the situation "Park then Associate" in case of WPT

Note that above sequences are only examples of sequences of events that might happen in order for an EV to be charged at an EVSE. The sequence may vary depending on the actual implementation of the EV and charging infrastructures.

In ISO/IEC 15118-7, shall define requirement sets for protocol and include additions and extensions to Network and application protocol requirements already described in 15118-2 for wireless communication.

Data Link Layer based on Efficient XML (Extensible Mark-up Language) Interchange XMI.

The following data should be exchanged between SECC and EVCC bidirectionally for the different steps:

Primitive name	A-Data.indication
Entity to support	SECC
Parameter Name	**Description**
A_Msg	- Session Setup - Service Discovery - Service Detail - Service and Payment Selection - Payment Details - Charge Authorization - Charge Parameter Discovery - FinePositioning - AlignmentCheck - Pairing - Power Delivery - Charging Status - Metering Receipt - Certificate update - Certificate installation - Cable Check - Pre Charging - Current Demand - Power Demand - Welding Detection - Session Stop

The document specifies the Message requirements for the data exchange for the various steps.

3.3.8 ISO/IEC 15118-8 Vehicle to grid communication interface. Physical layer and data link layer requirements for wireless communication

3.3.8.1 Scope

This part 8 of the 15118 International Standard specifies the requirements of the physical and data link layer for a High-Level Communication (HLC), directly between battery electric vehicles (BEV) or plug-in hybrid electric vehicles (PHEV) based on a wireless communication technology and the electrical charging installation Electric Vehicle Supply Equipment (EVSE).

For wireless power transfer, charging sites according to IEC 61980 and ISO 19363 are covered by this part of ISO 15118.

Note: these requirements are applicable to both conductive and wireless power transfer technology.

3.3.8.2 Wireless communication requirements

EVCC and SECC make use of Wireless Local Area Network (WLAN) as specified in IEEE 802.11-2012 for wireless communication.

This standard covers use-cases in relationship to wireless communication, considering different range requirements for the communication channel:

- **Discovery:** The EVCC has entered the communication range of the SECC(s) and associate to an appropriate SECC to start HLC for further steps (approx. 5 m to 30 m range).
- **Fine positioning:** Alignment of the primary and secondary device for efficient power transfer (approx. 10 cm to 5 m range).
- **Charging control:** e.g. Power request from vehicle to EVSE (approx. 5 cm to 5 m range): The distance between EVCC and SECC for Charging Control can vary depending on the installation location of the wireless communication module and antenna of EVCC and SECC. (from Annex A, informative, of 15118-8, see following slide).

3.3.8.3 Shortest possible distance

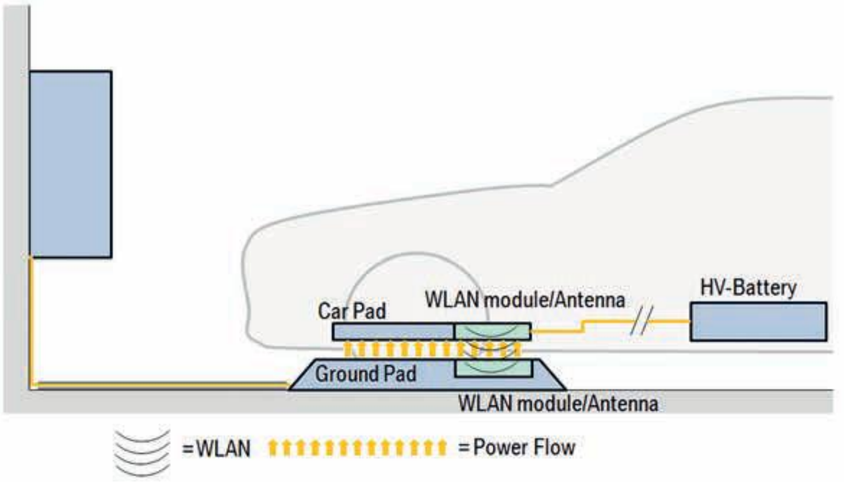


Figure 55. Shortest possible distance between wireless communication Module/Antenna

3.3.8.4 Typical distance

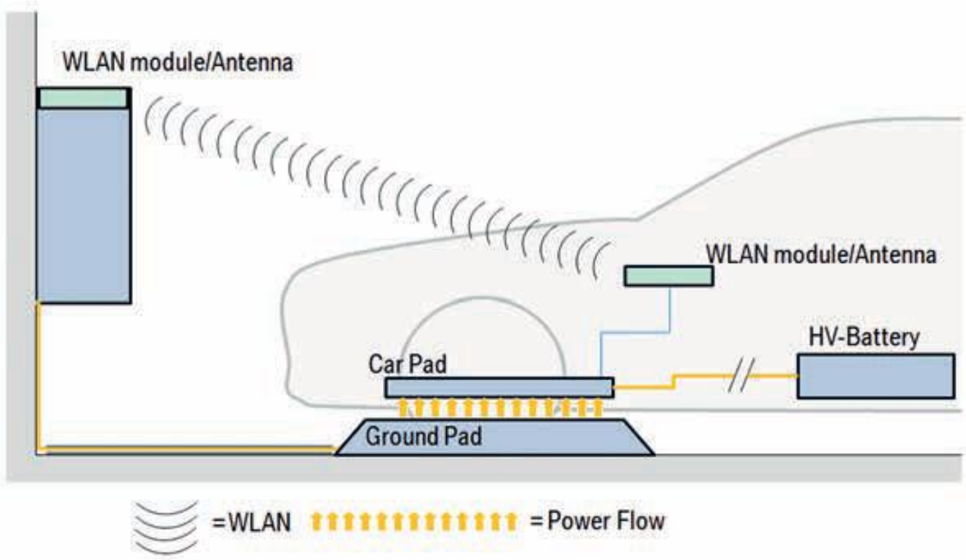


Figure 56. Typical distance between wireless communication Module/Antenna

3.4 Standards harmonization

The following figures show a cross reference among the various standards dealing with Wireless Power Transfer, according to the different subjects, which are dealt with in the standards, tackled under the aspects related with the scope of the specific standard.

The cross reference refers to the situation of the standard development at the end of 2016 and has been prepared for the work to be done for harmonization, starting from the ISO meeting of Ulm, January 2017 and continuing with further meetings, with representatives of ISO, IEC and SAE, including Torino meeting, September 2017.

The FABRIC tasks are indicated related to the standards topics.

Standard / Subject	SAE TIR J2954	ISO 19363	IEC 61980-1	IEC 61980-2	IEC 61980-3
	WPT for Light-Duty Plug-in/ Electric Vehicles and Alignment Methodology	Magnetic field WPT Safety and Interoperability	WPT systems General requirements	Communication requirements Vehicle-Infrastructure	Specific requirements for the Magnetic Field WPT
• WPT System • General system requirements • Interoperabiliy o Task 2.2.2 o Task 2.3.2 o D 23.1	• 5.1 Power classification • 5.2 Z Classes • Compatibility	• 5 System description • MF-WPT Structure (R.IEC 61980-1 8.1) • 6 MF-WPT interoperability • 6.1 General (R.IEC 61980-3, 7.103) (R.IEC 61980-2, 5.4.2) • 6.2 Classification of EV- power circuits (R.IEC 61980-3, 6.3) • 6.2.2 MF-WPT classes (R.SAE J2954, 5.1) • Table 1 MF-WPT Class interoperability requirements • 6.2.3 Z classes (R.SAE J2954, 5.2)	• 6 Classification • 6.4 Areas of protection (R.ISO 19363, 10.4) • 7 Interoperability • 8 General system requirements • 8.1 General WPT (R.ISO 19363, 5) • 8.2 Efficiency • 8.2.1 WPT System-efficiency (R.IEC 61980-3, 8.2.301) (ISO 19363, 6.3.4)	• 5.1 General System schematics (R.ISO 19363, 5) • See ISO/IEC15118 for optional HLC functions • 5.2 System architecture • 5.3 Configurations • 5.3.2-5.3.6 (A-E) • 5.4.1 General System requirements • 5.4.2 Interoperability (R.ISO 19363, 6.1) • 5.4.3 System configuration • 5.4.4 OSI layers • 5.4.5 Security • 5.4.6 Timing requirm. in annexes (A-E)	• 6 Classification (R.IEC 61980-1, 6) • 6.1.301 Pole geometry • 6.1.302 Resonant circuit topology • 6.3 Transfer power classes MF-WPT input power classes (R.ISO 19363, 6.2) • 7 Interoperability • 7.301 General (Ann. A-B) • 7.302 Interoperability of-power classes (R.ISO 19363, 6.2.2) • 8.2.301 MF-WPT system-efficiency (R.IEC 61980-1, 8.2.1, ISO 19363, 6.3.4)
• Performance requirements • Interoperabilit y • Positioning • Sequence of operation • Frequency o Task 3.3.4	• 6.1 General system requirements • 6.2 Functional/ Physical requirements • 6.2.3 Description of wireless charging operation • 6.2.5 Frequency • 6.2.6 Nominal position • 6.2.7 Offset • 6.2.8 Rotation, Roll, Yaw • 6.2.9 Allowance for Reactance	• 6.3 Performance requirements • 6.3.2 Alignment tolerance requirements • 6.3.3 Power transfer requirements • 6.3.4 System efficiency-requirements • 6.4 Frequency (R.SAE 6.2.5)	• 8.2 Efficiency • 8.2.1 WPT System efficiency (R.IEC 61980-3, 8.2.301) (ISO 19363, 6.3.4)	• 6 General Operation phases (figure 9) • 7 Operational phases • 7.1 Approaching • 7.2 Recognition of supply device • Use cases according to ISO/IEC 15 118	• 7.303 Nominal frequency (ISO 19363, 6.4, SAE 6.2.5) • 7.304 Magnetic coupling annexes (A-E) • 7.305 Resonant circuit in annexes (A-E) • 7.308 Gap classes (R.cfr.SAE 2954, 5,2, ISO 19363, 6.2.3)

Table 42. Cross reference "WPT systems: General"

Standard / Subject	SAE TIR J2954	ISO 19363	IEC 61980-1	IEC 61980-2	IEC 61980-3
	WPT for Light-Duty Plug-in/ Electric Vehicles and Alignment Methodology	Magnetic field WPT Safety and Interoperability	WPT systems General requirements	Communication requirements between Vehicle and Infrastructure	Specific requirements for the Magnetic Field WPT
• Interoperability • Functions • Sequence of operation o Task 2.3.1 o Task 2.3.2 o Task 2.5.1 o Task 2.5.2 o D 23.1 o D 24.1 o D 25.1 o D 25.2 o D 25.3	• 8 Interoperability • 8.1 General • 8.2 Interoperability performance requirements • 13 Communication Hardware, Software and Protocol • 13.1 Introduction Rely on SAE J2836/6, J2847/6 and J2931/6 • 13.2 Functions supported by communication • 13.2.1 WPT charging spot discovery • 13.2.2 Guidance and Alignment • 13.2.3 Power Transfer Cycle Control • 13.2.4 Monitoring of the Charging Process • 13.2.5 Support for Alignment • 13.3 Methods of Alignment • 13.4 Minimum functionality of the Alignment System • 13.5 Location of GA magnetic center	• 7 Functions • 7.2 Service selection • 7.2.2 Parameters to be exchanged for interoperability (R.SAE 8.2, IEC 61980-2, IEC 61980-3,Table1, 2) • 7.3 Fine positioning • 7.4 Pairing • 7.5 Final compatib. check • 7.6 Initial allignment check • 7.7 Start power transfer • 7.8 Power saver mode • 7.9 Perform power transfer • 7.10 Stop power transfer • 8 Sequence and communication • 8.1 General (defined in ISO 15118-2) • 8.2 Sequence of functions (R.61980-3, ISO/IEC 15118-7) • 8.2.1 Protocol flow stages and associated messages (R.SAE 13) • 8.2.2 Basic definition for Error Handling (R.ISO 15118-2) • 8.3 Communication (R.ISO 15118-8)	• Annex A Use cases (informative) • A.1 General • A.2 Use case descriptions (R. IEC 61980-2, -3, ISO 19363 and SAE J2954) • A 2.1 UC Select «charging spot» • A 2.2 UC Compatibility check • A 2.3 UC Fine Positioning • A 2.4 UC Pairing Confirmation • A 2.5 UC Start Power Transfer • A 2.6 UC Perform Power Transfer • A 2.7 UC Safety Monitoring and Diagnostics • A 2.8 UC Stop Power Transfer (Ref. IEC 61980-2, -3 for the corresponding phases)	• 7.2 Recognition of supply device (info) (R.IEC 61980-1, annex A, ISO 15118) • 8 Activities • 8.1 Communication-setup (figure 11) • 8.2-7.3 Fine positioning • 8.3 Pairing (figure14) • 8.4 Final compatibility check (figure 14) • 8.5 Initial alignment check (figure 14) • 8.6 Start Power Transfer (figure 15) • 8.7.1 Time scheduled power transfer (info) (figure 17 and 20) • 8.7.2 Power saver wake up • 8.7.3 Sleep/power-saver (figure 17) • 8.8 Perform power transfer (61980-3) • 8.9 Stop power transfer (figure 18) • 8.11 EV leave WPT spot (figure 19) • D24.1	• 8.301.1 Functions provided by MF-WPT system, see IEC 61980-2, Cl.7 R.ISO 19363, Cl.7.3-10 • 8.301.2 Optional MF-WPT functions • 8.301.3 Details of the Mf-WPT functions • 8.301.3.1 Final compatibility check • 8.301.3.2 Initial alignment check • 8.301.3.3 Start power-transfer • 8.301.3.4 Perform-power transfer • 8.301.3.5 Stop power transfer • 8.301.3.6 User initiated stop power transfer • 8.301.3.7 Safety-monitoring & diagnostic (R.SAE J2954, 13.2.4) • 8.301.4 Power transfer state. See IEC 61980-2 Cl.8

Table 43. Cross reference "WPT systems: Functions, sequence (1)"

Standard / Subject	SAE TIR J2954 WPT for Light-Duty Plug-in/ Electric Vehicles and Alignment Methodology	ISO 19363 Magnetic field WPT Safety and Interoperability	IEC 61980-1 WPT systems General requirements	IEC 61980-2 Communication requirements between Vehicle and Infrastructure	IEC 61980-3 Specific requirements for the Magnetic Field WPT
• Interoperability • Functions • Sequence of operation o Task 3.3.1 o Task 3.3.3 o D 24.1 o D 33.1 o D 33.3 o D 34.2	See chart Function, Sequence (1)	See chart Function, Sequence (1)	See chart Function, Sequence (1)	• 8.12 Safety monitoring & diagnostics • 8.12.2 Continuous alignment check • 8.12.3 Communication link monitoring • 8.13 Terminate communication • 8.14 Terminate safety monitoring & diagnostics. Control process states • 9.1.1 Supply device state diagram • 9.1.2 Stand by • 9.1.3 Service initiated • 9.1.4 Awaitin alignment • 9.1.5 Idle • 9.1.6 Power transfer • 9.1.7 Service terminated occupied • 9.1.9 Sleep Mode • 9.2 Supply device state transition • 9.3.1 EV state diagram • 9.3.2 Stand by • 9.3.3 Service initiated • 9.3.4 Awaiting alignement • 9.3.5 Idle • 9.3.6 Power transfer ready • 9.3.7 Power transfer active • 9.4 EV state transition • 9.5 System state definition • D24.1	See chart Function, Sequence (1)

Table 44. Cross reference "WPT systems: Functions, sequence (2)"

Standard / Subject	SAE TIR J2954	ISO 19363	IEC 61980-1	IEC 61980-2	IEC 61980-3
	WPT for Light-Duty Plug-in/ Electric Vehicles and Alignment Methodology	Magnetic field WPT Safety and Interoperability	WPT systems General requirements	Communication requirements between Vehicle and Infrastructure	Specific requirements for the Magnetic Field WPT
• Design • Dimensions ○ Task 3.3.1 ○ D 33.1 ○ D 33.3 ○ D 34.1 ○ D 34.2 ○ D 34.3 ○ D 34.3 ○ D 35.1	• 7 Physical dimensions and Parameters • 7.1-7.4 GA coil mounting • 7.4-7.9 VA coil location • Assembly sizes related to interoperability are specified in Appendix • 8 Interoperability • 8.1 General • 8.2 Interoperability performance requirements • 8.3 Master-VA specifications (Table 11) • 8.3.1 M-VA-WPT1/Z1 • Mechanical design in Appendix Am • Electrical design in Appendix Ae • 8.3.2-8.3.6 M-VA-WPT1/Z2, Z3 • WPT2/Z1, Z2, Z3 • Mechanical and electrical design in Appendices • 8.3.7 Reference-GA specifications (Table 12) • 8.3.8-8.3.10 R-GA-1, -2, -3 • Mechanical and electrical design in Appendices	• 6.5 Reference EV devices • Reference EV devices for MF-WPT1 and MF-WPT2 are described in Annexes A , B, C, D (R.SAE TIR J2954 8.3, 8.3.1, 3.2, 3.3, 3.4, 3.5, 3.6) (R. IEC 61980-3, Annexes). Corresponding reference supply devices proposals (informative) • For MF-WPT1 and MF-WPT2 Annex E (R.SAE TIR J2954 8.3.7, 8.3.8, 83.9, 8.3.10) (R.IEC 61980-3, Annexes)	• 8.3 Measurement convention • 8.3.3 Measurement convention of parking space • 8.3.4 Measurement convention of offset • 8.3.5 Measurement convention of the primary device • 8.3.6 Distance between primary and secondary device • 8.3.7 Primary device mounting • 8.3.8 In- ground - mounting • 8.3.9 On- ground - mounting • 8.4 Primary and secondary device construction (R.61080-3) (R. ISO 19363) • 8.8 Circuit topology (R.61080-3) • 9 Communication (R.61080-2)		• Annex A (normative)- Groud Mounted Primary Device (System AA) • Annex B (normative)- Magnetic field WPT- (System BB) • Annex C (normative) Magnetic field WPT- (System CC) • Annex D (informative) Parameters • Annex E (informative) Magnetic Field MF-WPT for Heavy-duty vehicles. Annex F (informative) Control loop

Table 45. Cross reference "WPT systems: Design, dimensions"

Standard / Subject	SAE TIR J2954	ISO 19363	IEC 61980-1	IEC 61980-2	IEC 61980-3
	WPT for Light-Duty Plug-in/ Electric Vehicles and Alignment Methodology	Magnetic field WPT Safety and Interoperability	WPT systems General requirements	Communication requirements between Vehicle and Infrastructure	Specific requirements for the Magnetic Field WPT
• EMC • Safety o Task 3.4.4 o Task 4.6.1	• 9 ELECTROMAGNETIC COMPATIBILITY (EMC) -- ELECTROMAGNETIC EMISSIONS • 9.1.1 Radiated emission due to WPT (R.ANSI C63.30) • 9.1.2 Unintentional Radiation (R.CISPR11 – EN 55011) • 9.1.3 Intentional Radiation (R.EN300330) • 9.2 Conducted Emissions • 9.2.2 Conducted Immunity • 9.2.3 Electrostatic Discharge • 9.3 Component EMC • 9.3.1 Electromagnetic Immunity (R.EN 61000-4-3, IEC 61000-4-6) • 9.3.6 Electrical Fast Transients (R.IEC 61000-4-1-11) • 9.3.8 Magnetic Field Immunity (R.IEC 61000-4-8)	• 9 EMC requirements The device shall be compliant with the EMC outlined by CISPR/D (under development) • 10 Safety requirements • 10.1 Protection in case of unintended power transfer • 10.2 Protection against electrical shock Design and testing for protection shall be in accordance with ISO 6469-3 Note: Requirements on post-crash electrical safety are specified in ISO 6469-4 • 10.3.1 Protection against overcurrent • 10.3.1 Overload protection For live conductors of voltage class Bcicuits according to their cross sectional area • 10 3.2 Short circuit protection. Cross sectional area of live conductors of voltage class B shall have a short circut current withstand rating (I2t) according to max. short-circuit current of an electric power source	• 11 Specific requirements for WPT systems • 11.5 Overload protection and shortcircuit withstand (R.ISO 19363, 10.3.1, 10.3.2)		

Table 46. Cross reference "WPT systems: EMC. safety"

Standard / Subject	SAE TIR J2954	ISO 19363	IEC 61980-1	IEC 61980-2	IEC 61980-3
	WPT for Light-Duty Plug-in/ Electric Vehicles and Alignment Methodology	Magnetic field WPT Safety and Interoperability	WPT systems General requirements	Communication requirements between Vehicle and Infrastructure	Specific requirements for the Magnetic Field WPT
• EMF o Task 3.4.4	10 Emf Exposure to Humans & implanted medical devices (R: ISO 19363, 10.4) • 10.1 General • EMF management regions illustrated in Figure 18 and 19 (R.ISO 19363, 10.4.2) • 10.2 Application Vehicle Level EMF Requirements Compliance with guidelines referenced in ICNIRP 2010 (R.ISO 19363, 10.4.3) • Table 8 and 9: EMF exposures reference levels and basic restriction levels referenced in ICNIRP 2010 • Appendix M- EMF LIMITS • Table M1-International EMF limit comparison • Table M2-Methods of measurement • Table M3-EMF regions and specification (R.10.1,10.2) (R.ISO 19363,10.4.2) • Appendix N-UL reference standards for ground assembly	• 10.4 Protection of humans against electromagnetic effects (R. SAE J2954, 10) • 10.4.1 General • 10.4.2 Protection areas (R.SAE J2954, 10.1) • 10.4.3 Requirements for protection against exposure to hazardous electromagnetic fields • In accordance with ICNIRP Guideline 2010 (R. SAE J2954, 10.2) • 10.4.4 Requirements to protect functionality of active implantable medicala devices (AIMDs) (R.ISO 14117-1) • Table 9 – Limits for AIMD	• Annex C (informative) • EMF, protection from electromagnetic field • C.1 Protection from electromagnetic field • C.2 Assessment of electronic and electrical equipment • C.3 EMF measurement procedure • C.4 Measurement points		

Table 47. Cross reference "WPT systems: EMF-safety"

Standard / Subject	SAE TIR J2954	ISO 19363	IEC 61980-1	IEC 61980-2	IEC 61980-3
	WPT for Light-Duty Plug-in/ Electric Vehicles and Alignment Methodology	Magnetic field WPT Safety and Interoperability	WPT systems General requirements	Communication requirements between Vehicle and Infrastructure	Specific requirements for the Magnetic Field WPT
• Testing o D 44.1 o D 44.2 o D 44.3 o Task 4.7.1 o Task 4.7.2	• 14 Testing Requirements and Procedures • 14.3.1 Efficiency • 14.4.2 Testing Components and Setup • 14.4.3 Bench Test Setup • 14.4.4 Vehicle Test Setup • 14.5 Equipment Compliance with IEC 61000-3-7, IEEE C95.3.1, CISPR 25, sec. 6.3 • Appendix A-M-VA-WPT1/Z1 • Specification (Ref 8.3) • Specifications for optimal operation with R-GA-1 in Appendix G • Appendix A-M-VA-WPT1/Z2 • Specification (Ref. 8.3) (see previous item) • Appendix D, E, F • VA-WPT2/Z1, /Z2, /Z3 • Reference Proposal Specification (Ref. 8.3) • Appendix G-R-GA-1 Reference Specification (see Appendix A and B)	• 6.6 Test procedure Measurement position Figure 2 and Table 6 • 7.16 Test procedure (test requirements for- the functions are under development)			

Table 48. Cross reference "WPT systems: EMC. safety"

Standard / Subject	ISO/IEC 15118-1	ISO/IEC 15118-2	ISO/IEC 15118-6	ISO/IEC 15118-7	IEC 61980-8
	General information and use-case definition	Network and application protocol requirements	General information and use case definition for wireless communication	Network and application protocol for wireless communication	Physical layer and data link layer requirements for wireless communication
• General requirements • System architecture • Sequence of operation • Positioning • Charging controlling • Protocols • V2G communicatio n o D 22.1, 23.1 o D 24.1, 25.1 o D 25.2, 25.3 o D 32.1, 32.2 o D 36.1, 36.2 o D 36.3, 36.4 o D 36.5 o Task 3.2.1 o Task 3.2.2 o Task 4.3.1 o Task 4.3.2 o D 43.1, 43.2	• 7.1 Use case elements • Function groups (Fig. 4) Overview of elements of use cases (Table 2) • 7.2 Start of charging process [A] • 7.3 Communication set-up [B] • 7.4 Certificate handling [C] • 7.5 Identification and authorisation [D] • 7.6Target setting and charging scheduling [E] • 7.7 Charging controlling and rescheduling [F] • 7.8 Value added services [G] • 7.9 End of charging process [H] (R. ISO 19363, 7.3—7.10)	• 5 Conventions • 5.1 Definition of OSI based services • 6 Document overview. Figure2 describes the organization of the different ISO/IEC 15118 documents and the usage, according to OSI layered architecture (V2G communication document overview) • 7 Basic requirements for V2G communication (R.ISO/IEC 15118-1) • 7.2 Service primitive- concept of OSI layered architecture • 7.3 Security concept • 8 Application Layer messages Annex A Mapping of Part 1 use case-elements Annex B ISO/IEC15118 message element names to SAEJ2847/2 Annex C Schema definition	• Requirements • 5.1 General (R.15118-1) • 5.2 Communication infrastructure • Infrastructure with a unique SECC (Fig.1) • 6 Actors (R. 15118-1, 7.1) • 7 Use case elements • 7.1General description-wireless specificity • Use case function (ISO/IEC 15118-1,Fig.2) • 7.2.3 In case of WPT Sequence illustrating the situation (fig.5) «Associate the park» • Situation (fig.6)«Park the associate» • 7.3 Wireless communic. sequence of functions (R. 15118-1, 7.2 - 7.9) • Table 2 Overview of elements of use cases, (R.15118-1, R. ISO-19363,7.3- 7,10) • 8 Use case description (R.15118-1, 15118-2) • D22.1	• 5 Conventions • 5.1 Definition of OSI- based services (Ref, 15118 -2, 5.1) • Document overview (Ref. 15118-2) • 7 Basic requirements for V2G communication (Ref. 15118-6) • 7.2 Serviceprimitive-concept of OSI layered architecture (Ref. 15118-2) • 7.10 Application-layer (Ref. 15118-2) • 8 Application Layer messages (Ref. 15118-2) • 8.4.2.1 Pairing (Ref. ISO 19363,SAE • J2954 and IEC 61980) • 8.4.3 Common messages (R.15118, no changes) • 8.6 Identification-Modes and Message • Set definitions • Annexes A,B,C (R.15118-2) • D23.1	• 5.1 Definition of OSI-based services (Ref. ISO/IEC 10731) System architecture • 6.1 Communication layers overview (Fig.1 Overview of 15118-1,ISO 15118-2 and 15118-8) • 7 Wireless commun. requirements • 7.1 Overview EVCC and SECC make use of WLAN as specified in IEEE 802.11-2012 • 7.2 SECC requirements • 7.2.1 WLAN technology (R.IEEE/Std 802.11-2012) • 7.2.2 WLAN frequency- and channel (R.ISO 15118-1 Rev.2) • 7.2.6.1 Pairing with wireless power transfer (R.IEC 61980 , ISO 19363) • 7.3.1 EVCC WLAN technology (R.IEEE/Std 802.11-2012) • Annex A Mounting location of wireless communication module/antenna • Annex B Interference scan and auto channel selection example

Table 49. Cross reference "Road vehicles- vehicle to grid communication"

3.5 Static to dynamic standards

3.5.1 Introduction

This chapter is dedicated to a discussion of specific topics, which are relevant for a revision of standardization process, mostly centred on ISO 19363.

There have been discussions between FABRIC and ISO about the opportunity to open a New Item Proposal for the development of this topic, which could be a new standard or an addendum to the existing one. The outcome of these discussions was to first consolidate ISO 19363, consistently and harmonized with the IEC and SAE standard, for the moment, structured for static wireless power transfer. Inputs from previous chapters of this FABRIC report will be very useful for this process.

It should be mentioned here, that the IEEE standards organization has initiated an activity focusing on pre-standardization efforts for dynamic wireless charging, which will be complementary to the SAE standard. It is considered possible and timely, at the conclusion of the research activities of FABRIC, to address the standard for dynamic wireless power transfer (DWPT). The analysis presented in this chapter is intended to be useful for this purpose.

The following topics have been identified to address standardization of DWPT:

- Communications and autonomous driving
- Power classes
- Vehicle Speed
- Coil sizes
- Variable air-gap
- Misalignment
- EMF (shielding of moving system)

In the following sections, first some considerations are given regarding communication issues for DWPT. IEC 61980-2 is not mentioned specifically in this revision, but as it is dedicated to communications, all comments on communication are relevant to it. Finally, a revision of the ISO 19363 and SAE TIR J2954 standards is presented with specific comments regarding DWPT.

3.5.2 Considerations regarding communications for DWPT

FABRIC project introduces one of the most relevant topics for the future of electric vehicles charging systems, the dynamic charge. The development of suitable communication protocols between vehicle and road-side infrastructure represents a real challenge, as control of the charging process need to be ensured while the vehicle is moving.

Based on the parts 1 to 3 of the IEC 15518, that describe a complex communication protocol for high-power wired charging systems, a new version of this protocol has been under development last years with the aim to adapt these protocols to the idiosyncrasies of wireless (static) charging. Parts 6 to 8 of the IEC 15118 are covering these issues, like for example the necessity of *correct alignment and the pairing process* that was not present for wired charging.

Nevertheless, dynamic wireless charge (DWPT) brings up new issues not covered by the existent standards. The most relevant concern is the ***speed of the vehicle and how it affects the activation of the DWPT***. For low speeds, variable latency of wireless communications might not affect the process. For higher speeds, like on motorways, this latency becomes critical, if current standard solutions are employed.

Taking WiFi as an example, latency can reach up to hundreds of milliseconds. At 120 km/h (33.3 m/s), a vehicle will move 3.3 m in 100 ms, which can cause an inadmissible mismatch between control and power transfer equipment.

The range of standard WiFi might also be an issue, as it is limited to approximately 100 m. This means that the entire communication process before activation of the DWPT should take less than 3 seconds (the time a vehicle needs to travel 100 m at 120 km/h).

A possible approach to solve this problem is to reduce the number of messages needed to be exchanged during the dynamic charging process. In fact, important information to be transmitted is very limited:

- Initial authentication of the vehicle
- Position of the vehicle
- Charging power level

The remaining parameters are not critical for the correct activation and deactivation and should be moved to a less time-critical instant using mobile phone communication for example, when the vehicle is still far away from the charging zone.

Another issue might arise if the highway lane is not exclusively dedicated for DWPT. In this case, it could be possible that if the activation is not correct, power transfer is activated under a vehicle without WPT equipment of not willing to recharge. In this case, magnetic field emissions might affect the vehicle and passengers.

In any case, it must be guaranteed, that ***DWPT coils will be activated only when the receiving vehicle is moving over it,*** to avoid field emissions to other vehicles close to it.

To overcome the issue of latency for wireless communication, DWPT sections of sufficient length can be pre-activated. Then, for activation and deactivation of individual coils, other systems can be employed, that react faster to the pass of the vehicle (***such as presence sensors***). A similar approach was implemented in the FABRIC test track installed by VeDeCoM and Qualcomm. The 100-m test track was divided into 4 sections of 25 m length, which were activated one after another while the vehicle passed. In the VICTORIA project, a reduced protocol was developed and tests with presence sensoring where carried out, minimising communication requirements during the charging process.

3.5.2.1 Autonomous driving

Autonomous driving (AD) an overarching topic, with important impacts on communication and design requirements. It is considered that AD will be market-ready before 2030, when first relevant infrastructures for DWPT are expected. Future standards for DWPT must be aligned with those covering AD. Within FABRIC, there has been a consensus that AD will solve alignment issues and provide interoperability between systems, as each car will guide itself independently on road conditions. Standards for road constructions should be developed in order to favour a precise tracking of the vehicle. Also, speed control and platooning are features which should be addressed

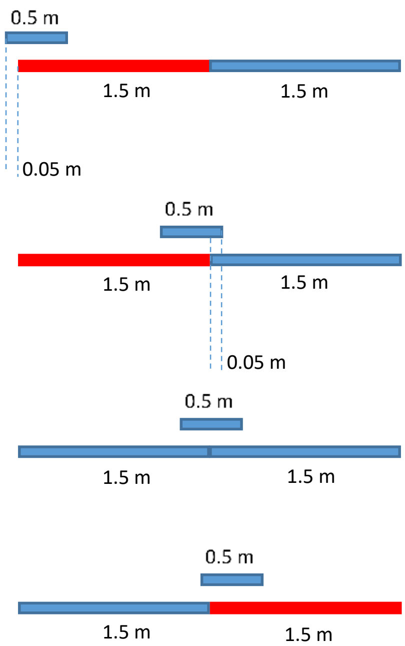
3.5.3 Comments on ISO 19363

The revision of ISO 19393 will follow the structure of the standard and provide comments to relevant sections. Those which are not considered to be critical for DWPT are omitted.

3.5.3.1 Terms and definitions (1)

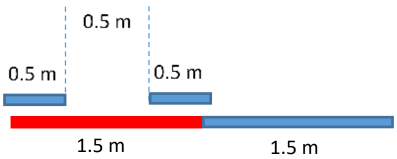
Include references to:

- Vehicle Speed
    - Moment of start/stop charging depending on vehicle speed
    - Charged energy depending on vehicle speed
- Activation time: How much time is needed before the vehicle reaches the coil, to activate charge process
- Deactivation time: How much time is needed from sending signal until deactivation of the charging process
- Time to nominal power: how long the primary needs to reach nominal power transfer
- Different DWPT charging modes should be considered. Depending on coil configurations and sizes, continuous or impulse charging will be obtained.
    - **Impulse charge with one short on-board coil:** On-board coil is shorter (e.g. 0.5 m) than ground coil (1.5 m), assuming zero distance between ground coils (see figure below, red-coloured ground coils are activated). Due to limitations of allowed misalignment in X direction (± 0.05 m for 0.5-m coil), the charging process only can be done 1.1 m each 1.5 meters (ratio: 73%), as shown in the picture below. The ration is increased for shorter coils, but power rating might become an issue for smaller coil.



Assuming 50 kW power transfer at 100 km/h, with 73% transfer ratio, 0.37 kWh/km of energy is transferred.

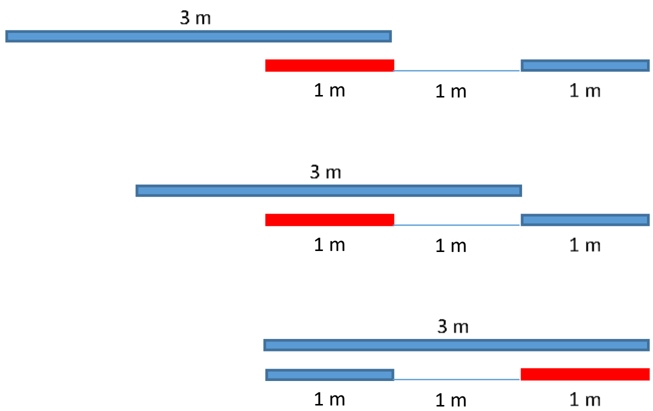
- **Continuous charging with 2 short on-board coils:** The situation described in a) can be improved, installing 2 coils on-board, in a manner, that the second coil can start receiving before the first one is shut down (see picture below). Notice that in this configuration both on-board coils could be receiving power at the same time, which is not desirable, as the objective was to avoid power pulses.



Assuming 50 kW power transfer, energy of 0.5 kWh/km is transferred at 100 km/h (100% of the time, power is being transferred to the vehicle).

Despite the considerable improvement, the advantage of smaller coils on-board is fading with this solution, and shielding issues of long ground coils are not solved.

- **Continuous charge with long on-board coil:** If the on-board coil is for example 3 times longer than the ground coil, the configuration shown in the picture below is possible, which permits smooth hand-over from one ground-coil to another. Ground coils can be separated, which results in less copper buried in the road.



Transferred energy per km is identical to case b), but system complexity on-board is reduced and shielding is improved sensibly.

3.5.3.2 Classification of EV power circuits (6)

- EVPC power classes: Power classes 1 and 2 seem to be irrelevant for dynamic charging, as there is too little time for the charging process (too low speed would be required to transfer relevant amounts of energy)
- Two additional power classes should be considered for dynamic mode:
  - 22 kW to 50 kW for light vehicles
  - 50 kW to 100 kW (or higher) for heavy vehicles
- Higher power levels can be achieved with multiple receiver coils in large vehicles like buses and trucks. Three 50-kW coils for example, would be able to create 150 kW DWPT power
- Z classes: It might be necessary to foresee the possibility of variable air-gap during the charging process

3.5.3.3 MF-WPT power transfer requirements (7)

3.5.3.3.1 Alignment tolerance requirements (7.3)

- In X-direction (start/stop of charging):
  - indicate the point where power transfer starts and stops, while the upper coil passes over the lower coil
  - define start and stop in terms of time, relative to the moment when coils have reached a certain (mis)alignment in X
- In Y-direction (misalignment):
  - Misalignment should be increased (in circulation it is more difficult to fix a position).
  - Possibility of variable misalignment should also be foreseen throughout the loading process
  - At high speed, misalignment for a single coil can be considered fixed
  - Introduce some reference to autonomous driving for alignment in y-direction
- Increase misalignment tolerance:
  - Design one coil smaller than the other (primary or secondary smaller)

  - Primary or secondary might be larger/smaller without distinction. In any case, alignment tolerance will increase for the entire track where the two coils are facing each other.
- The arrangement with long coil on board is better for shielding, since the vehicle in any charging position "covers" the transmitter coil. With this solution, continuous charging is possible

3.5.3.3.2 Requirements for transferrable power (7.4)

- Increase the levels of DC output voltage ripple amplitude of product EVPC shall not exceed +/-? V.
  - During the dynamic charging process, transitions from one emitter coil to another occur
  - These transitions produce variations in the power transfer of up to 100%, which produce voltage variations
  - New limits of voltage variation need to be defined, according to the variations that can occur
  - Depending on the inductive coupling topology (series or parallel connection of the resonant capacitor), voltage variations will be larger or smaller
- Increased ripple must be supported by the on-board system or mitigating systems, such as large capacities connected to the DC bus need to be foreseen
- With continuous charge, current ripple is strongly reduced

3.5.3.3.3 Efficiency requirements (7.5)

Efficiency changes in the power transfer process from the point of worst alignment to best. Since the electronic control circuit will presumably have to find the optimum operating point, its response time is limited by the speed of the vehicle and the size of the coils.

Therefore:

- To define the efficiency, alignment conditions need to be defined.
- An average efficiency needs to be defined as misalignment changes throughout the charging process

- Proposed efficiency values for static charging seem reasonable also for dynamic.

3.5.3.4 Power transfer test procedure (8)

3.5.3.4.1 Test procedure (8.2)

- The test procedure, apart from stationary mode, should include a set of tests at different speeds with different misalignments and air-gaps.
- In case of coils of different sizes, it will be necessary to measure the power transferred in different positions between coils in standstill and in operation

3.5.3.5 Communication and activities (9)

3.5.3.5.1 Communication (9.1)

There are two options for communication:

- The vehicle communicates one-by-one with each charging point (coil)
  - ✓ The whole identification process must be very fast to allow charging.
  - ✓ Communication needs to start before actual charging process starts
  - ✓ Charging infrastructure must be prepared at arrival of the vehicle to avoid delays
- The vehicle communicates with a management system which controls several dynamic charging points (sections of the track)
  - there is more margin and it serves for a group of chargers

Alignment check:

- The alignment check should include a "compatible-vehicle" check
- It could happen that the primary received the start order and that for some reason the vehicle that is not the correct one, or that it arrives late
- The alignment checks in any case must be made during the transfer process, so that if it is detected that the transfer is made below certain efficiency conditions, it must be interrupted.
- Depending on vehicle speed, there might be no time for any adjustment
- Specific protocols should be added for initiation of autonomous driving mode (assistance for alignment and speed)

Start-Stop process for charging:

- The process of starting and stopping power transfer will be very fast
- It is foreseeable that the ramp-up will be done before or during the alignment and compatible-vehicle check
- Existing on the primary side, capacity for vehicle detection and compatible-vehicle check
- Power transfer stop may be due to:
  - ✓ an explicit termination order (need of communication)
  - ✓ or the detection of non-compatible conditions (e.g. the vehicle is no longer on the primary) → no need for communication.
- The power transfer operation process can be described as shown in the picture below, which has been adapted from **IEC 61980-2** "Electric vehicle wireless power (WPT) systems – Part 2".

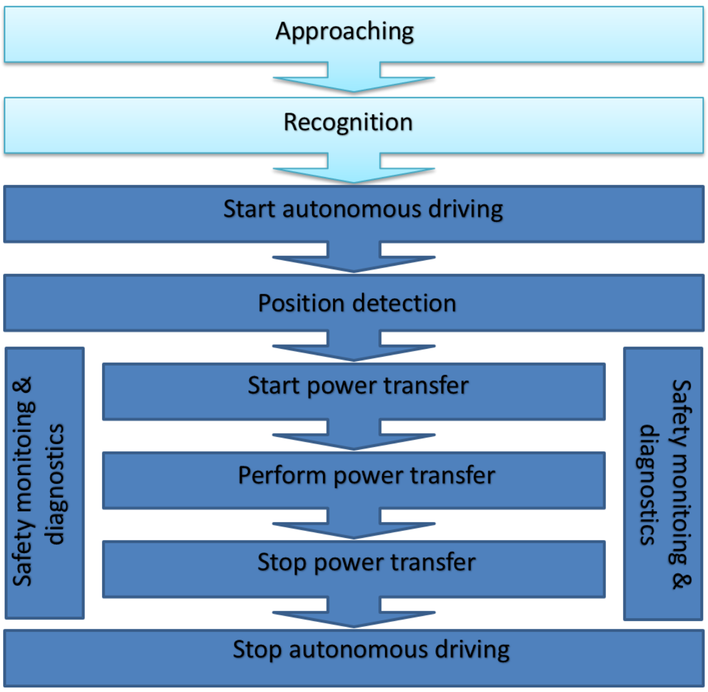


Figure 57. Proposal for operation phases of the dynamic wireless power transfer (DWPT) process.

3.5.3.5.2 Activities (9.2)

3.5.3.6 Service selection

- In the EVCC shall send the following parameters for service selection, is necessary to add:
    - Minimum EV speed
    - Maximum EV speed

3.5.4 Comments on SAE TIR J2954

GA Coil mounted height (7.2)

Only make sense for dynamic power transfer:

- Flush mounted (Category B)
- Ground surface (Category C)

Emissions, EMI, EMF

It should be considered that the emissions are contained in the entire power transfer process, with the vehicle in motion.

Test Bench

A specific test bench must be defined for secondary in motion.

3.6 Conclusions on standardization for DWPT

3.6.1 Current status

A consistent frame of International Standards related to Wireless Power Transfer technology is under advanced Phase of development by ISO, IEC, SAE and UL. The elaboration of these standards is performed in interactive collaboration, in the aim of achieving effective harmonization among them.

References are clearly reported in the standard and the further developments are performed interactively.

The situation summarized in this report refers to the status of development at the end of 2017. The timeline depicted for the development of the different standards brings to their predicted availability by end of 2018 with an appropriate definition for the development to industrial products

of Wireless Power Transfer Interoperable systems, for the related communication system and for their application and practical utilization.

3.6.2 FABRIC contribution for standardization of dynamic wireless charging

Based on experience gained within the FABRIC project and associated activities such as the VICTORIA project in Spain, important topics have been identified regarding DWPT which are not addressed in current standards and standard drafts for static wireless and conductive charging.

- Communications and autonomous driving
- Autonomous driving
- Power classes
- Vehicle Speed
- Coil sizes
- Variable air-gap
- Misalignment
- EMF (shielding of moving system)

Communications is a major, if not the most critical issue for DWPT. Latency of standard wireless communication protocols, such as WiFi are not suitable for real-time control of each individual coil if the vehicle is moving fast. Therefore, a hierarchical approach seems to be the most adequate solution, providing enough time for communication between vehicle and ground infrastructure to prepare the charging process. The basic idea is to pre-activate sections of the DPWT lane by standard protocols, such as WiFi and activate individual coils with fast-acting presence sensors which might not require any communication at all.

Other main issues are related with power levels, vehicle speed and misalignment due to the movement of the vehicle. Also, air-gap variations need to be considered during the charging process. Higher power levels are needed, to achieve reasonable amounts of energy transferred in relatively short time. For many parameters, wider tolerances are required, and autonomous driving needs to be considered as main requirement to keep tolerances. Another issue is the transition from one primary coil to another. Design of a DWPT system need to consider these technical constraints, which leads to the conclusion that it will be beneficial to have one short and one large coil. Discussions are ongoing, if the short coil should be installed on-board or in the

road. For shielding and on-board control, a large coil in the vehicle is the preferred solution. If simplicity and low weight on-board is the priority, the small coil should be mounted on-board.

The standardisation process for wireless charging is still ongoing for static charging (ISO 19363). Major efforts are being done to obtain harmonization with IEC and SAE standards. Contributions from FABRIC are arriving just in time to contribute to this process and provide input to the development of a specific standard or an addendum to the existing one for DWPT.

4 Conclusions

As the aim for the entire FABRIC project was to assess the feasibility of on-road charging with special focus on DWPT, we aim to summarise the findings into main conclusions for this assessment. It is important to assess the results of the FABRIC deliverables, and particularly those within SP5 in a scientific manner. The assessments and analyses performed focussed on three key scenarios as logical combinations of design parameters from today's understanding of the transportation system. The scenarios have functioned as condensation points to gain insights in the sensitivity of the overall transportation system performance in terms of money, emissions, energy and few other parameters. In the conclusions, we will abstract from the exact scenarios, and continue on the lessons learned regarding the key parameters.

First and foremost, the motivation for eRoads is to contribute to the European path towards zero CO_2 emissions from the transportation sector. eRoads with DWPT have proven to be a clear advantage in a future where electricity is produced green (2050) and where the battery size of a vehicle can be shrunk to a fraction (10%) of a regular battery-powered vehicle. However, the lower Well-to-Wheel (WTW) efficiency of DWPT compared to regular charging can easily undo any savings from the lower battery weight. It is therefore key to look further into increasing the efficiency of wireless power transfer in general, and DWPT in particular for future use in the transportation system

Another positive aspect found is that the introduction of DWPT infrastructure contributes very little to the overall emissions of the transport system, as utilisation rates will be very high in metropolitan areas and major corridors (TEN-T).

The scenarios also found that having few DWPT eRoads available does not really provide a chance for battery size reduction, as the relative amount of energy gather on the eRoad compared to the routes travelled is relatively small. Improving capacity of DWPT is a key aspect to overcome this, but it also has consequences for the deployment options available. The major advantages of DWPT will only be gained after large-scale eRoads have been deployed and batteries will be shrunk. It is therefore feasible as an emission reducing option for vehicles with very regular travel patterns, like urban buses and specific point to point cargo routes. This conclusion is in line with other developments worldwide like the Swedish (conductive) pilot projects and the KAIST and BOMBARDIER bus developments.

From an investment point of view, eRoads are expensive. Their installation is predicted to be in the range of 2-4 million EUR/km, and their maintenance costs are estimated to be 2.5 – 4 times higher than from a regular road. The total costs of ownership of diesel powered, battery powered and DWPT-enabled vehicles have been compared and show that only in case of the scenario

with low speeds (and therefore a high energy transmission per meter of infrastructure) and maximum battery reduction (urban buses with regular routes), that DWPT can be beneficial. In all other scenarios, major incentives from the government are needed to make DWPT an attractive option compared to battery-powered vehicles.

At the start of the FABRIC project, significant questions were raised regarding the options to integrate DWPT technology in real-world roads. A range of experimental and computational tests have proven that DWPT can be safely integrated in the road, when using high-quality, currently available, binder materials. Construction methods can be chosen such that low-temperature asphalt can be used to cover the coils. Constructions with concrete gutters for placing coil pads can be integrated into the pavement when paying good attention to the boundary layers. Not all construction materials proved to be neutral for wireless power transmission. Further work is needed with more production-ready coil constructions to develop final pavement designs for eRoads. National or regional assessments are needed with regards to the use of recycled material, as not all recycled material allows for thin top layer structures that are durable, and some countries limited the recycling in top layers of polymer modified binders. eRoad construction procedures must meet current highway design and construction specifications. Any departures from these standards should clearly demonstrate that the structural integrity and service life of the road remains unaffected.

Analysis of usage patterns of energy for DWPT has shown that even with a very large uptake of eRoads, that electricity grids are not significantly blocking the deployment. Due to the expected usage patterns, eRoad deployment may even be beneficial for local integration of solar power, particularly in Southern Europe.

Deployment locations for eRoads need to be carefully chosen, as simulation studies have shown significant effects on travel routes when few eRoads are available for general passenger vehicles. This leads to important questions regarding stepping stones of eRoad deployment.

If there is a system, like urban buses, for which eRoads can be a beneficial option, then it is positive to deploy DWPT technology, as this can be used by many types of vehicles, unlike conductive overhead wires. Other vehicles being equipped with DWPT technology can opportunistically use compatible infrastructure where available but could get their main power from other solutions. Efficiency of DWPT is key to make such development steps a positive net reducer of CO2 emissions. Sufficient availability of other (ultra-fast) charging solutions is key to avoid lock-in to scarce eRoads.

Such piggy-backing deployment could benefit from developments in static wireless charging if standards would make the two modes of wireless power transfer compatible. There is however a

significant gap between the current wireless standards and standardisation efforts and the needs of DWPT.

A framework for assessing the EMF/EMC safety in urban environments is missing, and therefore it is not yet possible to determine the health effects of DWPT deployment in Urban Bus Scenarios. This is topic for further research.

Summarising, FABRIC has proven that eRoads with DWPT are technically feasible, and under certain circumstances even financially viable and with positive environmental effects. Further developments could focus on efficiency and capacity. Their role in the overall transformation of the European transport sector is uncertain, and will largely depend on the developments of other electrification technologies.

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