FABRIC

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

Cost-benefit analysis and business models of large-scale deployment of on-road charging

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LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
B2B	Business to Business
CAPEX	Capital Expenditure
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
LCA	Life Cycle Analysis
LCC	Life Cycle Costs
OPEX	Operating Expenses
RES	Renewable Energies
SP	Sub Project
TCO	Total Cost of Ownership
TEN-T	Trans-European Network for Transport
WPT	Wireless Power Transfer (generally referred to static /stationary charging)

REVISION CHART AND HISTORY LOG

REV	DATE	REASON
V1	6/06/18	First Version
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V3	18/06/18	Final for submission
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EXECUTIVE SUMMARY

FABRIC project aimed to study the feasibility of dynamic wireless power transfer (DWPT) solutions for charging electric vehicles.

The objective of the work presented in Deliverable 5.5.2 was to propose potential business models for on-road charging solutions for infrastructure owners and for electric vehicles drivers and to carry out a cost-benefit analysis at a social level, by considering general aspects at society-level that are important for authorities. Three scenarios have been selected as the most promising ones which are:

1. **Motorway Scenario**. In 2030, it will be economically feasible to have 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 locations 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 setup of e-Corridors.
2. **Periurban Scenario**. This refers to dynamic charging of heavy vehicles and buses in areas with high traffic density, from periurban logistic centres or ports 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 Scenario**. This will likely be the first entry point for DWPT in 2030 using bus stops as static charging points and some trenches ahead summing up to 25 m 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.

The next step was to agree on a work hypothesis with a high probability of occurring and to identify the factors that experts believe could affect the deployment of dynamic charging corridors. To this end, a workshop was organized in June 2017 in Strasbourg, to which FABRIC experts and members of the External Reference Group were invited. The impact factors (technical and non-technical) were discussed there. As a result of these discussions, the three scenarios and their boundary conditions were confirmed to carry out the detailed analysis of each scenario.

The objective of the economic study was to establish the most probable fixed photo for each scenario and thus establish an order of magnitude on the system costs.

An important input to the system is to evaluate the deployment of electric vehicles equipped with DWPT systems. This demand study was carried out in the deliverable D5.4.2 on the supply chain, since that expected deployment would affect supplies. On this deployment all the calculations and

the expected tariffs that justified the business model from the investor's point of view were established.

The analysis of the potential business niches (motorway, periurban and urban) were implemented for three different perspectives:

a. Perspective of the investor in the e-Road (which could be the administration itself or a private investor who accesses the service through a competitive tender) using the CANVAS model
b. Perspective of the vehicle user trying to clarify under what conditions that vehicle could be acquired (Cost-benefit analysis and Total Cost of Ownership calculation)
c. Perspective of the Public Administration that decides to promote this technology. The criterion of the Administration is necessarily the broadest and is identified with a Social Cost-Benefits analysis in the wider sense, that is to say including other aspects besides the economic ones

The main conclusions of the study are indicated below.

From the Investor's Perspective. The need for a critical mass of vehicles makes it difficult to cover the expected expenses if the deployment of vehicles does not happen as indicated by the demand study. Even so, it will be necessary to incentivize the rate so that the user finds it interesting to charge dynamically until the year 2050, at which point the motorway and periurban scenarios the rate will no longer require said incentive.

The only exception is the urban bus scenario, which with a strategy of reducing the size of the battery as far as possible (battery shrink), can be profitable from the start, if the decision is made to replace the entire fleet and bet on this technology.

From the user's perspective. The TCO was calculated comparatively with internal combustion vehicles. All electric or DWPT vehicles are in principle more expensive than their petrol or diesel equivalents nowadays and it is not clear that the user could decide to invest in them, except in the case of urban buses. The improvement in cost reduction; i.e. due to battery price reduction will also affect the pure electric vehicles and differences in costs will be kept constant. However, the transition from static or stationary charge to dynamic is relatively simple and if the standard in society is to charge statically at homes or offices, this technology could have a chance to succeed. The biggest threat to this technology is the appearance and deployment of ultra-chargers (above 150 kW) on the main highways combined with very cheap batteries. The reason is that to achieve an equivalent charge to that supplied by an ultra-charger, it is necessary to travel more slowly on the e-Roads, compensating the lost time at the static charger, thus having little or no advantage

in travel time (please check figure 8 in this report, to understand this conclusion). Cheap batteries in addition will extend all-electric range.

The weight reduction of the energy storage in commercial vehicles is another factor and this has been considered under the battery shrink concept applied to the urban scenario and periurban scenario for heavy trucks. The rest of light vehicles needs to apply the range extension concept or will be not able to compete with other charging alternatives.

Finally, from the perspective of the Administration, technology still needs to evolve. It is foreseen that the common technology in 2030 will allow 50 kW of power transfer for light vehicles. However, tests carried out so far, have been up to 20 kW, so this transition is still pending. The urban bus scenario could be very interesting because the DWPT cost is lower than its direct competitors (pure electric bus and diesel bus) if we only consider the vehicles and the infrastructure for recharging in the garage. If we add the cost of deploying e-Trenches at bus stops, the overall TCO exceeds the rest but for an acceptable amount and yet the environmental benefits are very visible (approximately 70% less emissions than a conventional bus and 40% less than a pure electric one). That is why we think that the first entry point can be this niche, although for its implementation, it is necessary to replace the entire bus fleet for reasons of economics of scale.

1 INTRODUCTION

FABRIC project aimed to study the feasibility of dynamic wireless power transfer (DWPT) solutions for charging electric vehicles. The project developed three charging prototypes, integrated them in two test sites and organised tests with the system in order to collect data for its analyses.

The present Deliverable 5.5.2 was generated in the framework of WP5.5, which aimed 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. Building on the technological developments of Subprojects 2 and 3 and especially on the experiences gained and results of the tests in Subproject (4), the aim of the work was to propose potential business models for on-road charging solutions for infrastructure owners and for electric vehicles drivers. Deployment in WP5.5 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. Given the nature of the work in this WP, stakeholder workgroups were formed who were actively involved in each of the tasks. The stakeholders included not only the consortium partners, but also the project External Reference Group and other stakeholders related to on-road charging.

The work followed two trajectories in the research. First, it developed ideal-typical business models and sets of requirements with the partners in the consortium to create a consortium-supported plan of how this set of partners see deployment themselves. This resulted in a virtual business plan plus a set of requirements for the public administrative domain surrounding it. The second trajectory was to make a cross-acceptance study for business models and governance structures in other domains and to review them for their applicability in the on-road charging domain. To bring on-road charging to the market, there are three sets of competences that need to be present in market players: construction & implementation knowledge, operations & maintenance knowledge and service provider knowledge. This task has investigated how and where the most promising clustering of this knowledge can be achieved to positively influence the uptake of electric vehicles with on-road charging capability. Studies in the construction, service, electricity, supply and vehicle technology markets have led to a report with blue prints and guidelines on how to make the jump from test site level to the implementation in the society at large. A SWOT analysis to identify barriers, opportunities, strengths, weaknesses, market actors, competitors is also included.

The cost-benefit analysis gives an account of the total economic effects of a large-scale on-road charging deployment on all aspects of society. In a case such as this, a large part of potential economic gains is on the side of travellers, which is not normally considered in a financial cost-benefit analysis from a business perspective. Health benefits due to reduced PM10 and NOx

emissions in the urban areas had to be considered as will the impact of on-road charging on the oil price and vice versa.

The work used the estimates of the most likely deployment and pricing frameworks for a selected urban area from Deliverable 5.5.1 “Assessment of traffic operations and management through combining ITS and on-road charging” and the system performance estimates according to the results in the same deliverable, particularly with regard to travel time and charging costs, to derive indicators of the traveller surpluses one could expect from large-scale deployment.

The deliverable is structured as follows. Section 2 presents the methodology followed and the three most prominent scenarios that were selected, motorway, periurban and urban scenario. Section 3 presents the proposed business models for the infrastructure owners for the three scenarios, while section 4 presents the business model for the driver of a vehicle able to charge dynamically. Section 5 presents a cost-benefit analysis at a social level, by considering general aspects at society-level that are important for stakeholders. Section 6 is the conclusions.

2 METHODOLOGY

The relation between proposing business models and conducting a social cost benefit analysis is often complicated, as the two approaches use different logic on partially overlapping underlying analysis.

Business model logic is to determine whether it is worth to pursue the efforts to develop a business activity that will yield (economic) returns to the business. Social cost benefit analysis logic is to determine whether it is positive to invest (mostly public) money into benefits for society as a whole. The latter approach therefore accumulates different types of value, monetarised into one public value.

The work presented in this deliverable focuses on the potential deployment of DWPT technology. The partners decided to focus on three different perspectives: Infrastructure investors DWPT-equipped EV owners and Public Administrations (mainly road administrations in the European context).

With the aim to also include the wider impacts as accumulated in a social cost benefit analysis, the wider effects beyond the business cases are described either positive or negative on top of the business model results, specifically addressing the Public Administrations. However, depending on the governance construct of a niche in the transportation market, these wider impacts could also be relevant for Infrastructure Investors, when one considers the possibilities of integrative mobility providers that both own infrastructure and service supplied on top of these.

The great number of variables involved in the ramp up of the DWPT technology in the future market, guided the partners to establish an approach to face the problem based on the CANVAS model initially proposed by Alexander Osterwalder[1] based on his earlier work on Business Model Ontology[2]. The model may be depicted using the template represented below although all the fields will be duly explained within this deliverable.

[1] http://nonlinearthinking.typepad.com/nonlinear_thinking/2008/07/the-business-model-canvas.html

[2] Alexander Osterwalder (2004). The Business Model Ontology - A Proposition in A Design Science Approach. PhD thesis University of Lausanne.

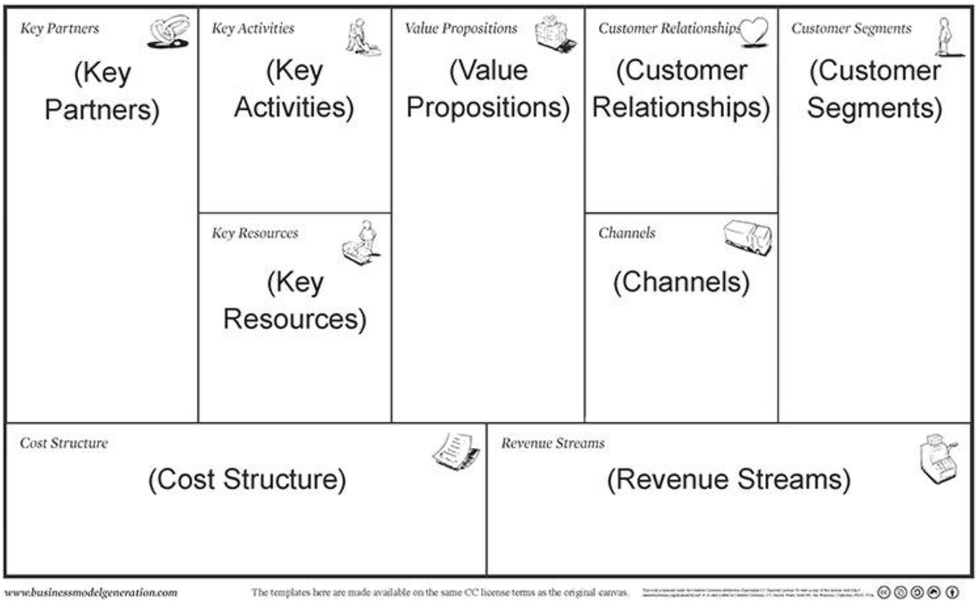

Figure 1 Business model CANVAS.

The Business Models follow the structure of building blocks described in the CANVAS, describing:

1. The value proposition of what is offered to the market;
2. The segment(s) of clients that are addressed by the value proposition;
3. The distribution channels to reach clients and offer them the value proposition;
4. The relationships established with clients;
5. The key resources needed to make the business model possible;
6. The key activities necessary to implement the business model;
7. The key partners and their motivations to participate in the business model;
8. The revenue streams generated by the business model (constituting the revenue model);
9. The cost structure resulting from the business model.

The business models are created as "fixed pictures" using several assumptions according to experts' consensus

Infrastructure investors. The first analysis was performed using the CANVAS model, considering the view point of the infrastructure investors, or in other words, those companies willing to invest in the charging e-corridors expecting revenues due to the e-DWPT traffic flow.

DWPT-EV owners. A second analysis was implemented considering the view point of the DWPT EV owners; namely, which reasons may motivate an end-user to invest in a DWPT-EV describing

all the factors affecting the purchasing decision. For this analysis, the Total Cost of Ownership (TCO) of such a vehicle was calculated and compared to an ICE vehicle.

Administrations*.* Public administrations, particularly road administrations, may play a significant role in the early stages of the technology ramp up, through different supporting measures like incentives, grants, taxes reduction, public procurements of innovative services, etc. The decision process in the case of the administrations will consider the pure economic factors as the externalities; and wider benefits for the society, for example environmental impact, health issues, safety aspects, etc. The Administration analysis was based on the infrastructure analysis but adding the externalities to conduct a social cost-benefit analysis which includes the impacts for the society as a whole.

The most important factors affecting a go/no go decision in relation to the DWPT technology are presented in the following table. They have derived from previous work in the FABRIC project and have been discussed with external experts.

Legend
Fully treated
Partially estimated
Not treated

Business Models
From Administration
From infrastructure Investor
From DWPT-EV owner

Time to market	Action type	Pavement Construction methods	Demand Estimation	Competing Technologies	Other affecting factors
2,030	Existing Road Reconstruction	Full lane cons/reconstruction	EVs Demand estimation	Battery Capacity	Technology breakthrough
2,050	New dedicated road construction	Prefabricated lane	E-Corrid. Demand estimation	EVs Consumption and Autonomy	Safety (autonomous driving)
	Cost Calculations	Trench based		Super and Ultrachargers	Health concerns
	LCC Infrastructure	Micro-trench based		Wireless Static /Station. Charging	Regulation
	* Agency costs			Standards and plug-in interoperability	Environmental issues
	* User costs			Hydrogen vehicles	Economic issues (EV and infrastr.)
	LCC WPT module at vehicle			Other clean techn. (gas, hybrids...)	Grid impact
	Cost-benefit analysis			Conventional Diesel/Gasoline	Supply chain impact

Table 1. Affecting factors to the e-Corridors business model

On 19 June 2017, FABRIC held a stakeholder workshop as a side-event to the ITS European Congress in Strasbourg. The workshop was entitled “Validation of most promising scenarios related to an extensive adoption of on-road charging solutions for EVs (dynamic charging)”, and all partners involved in SP5 were invited as well as the members of the External Reference Group. It was also publicised to other interested stakeholders attending the ITS Congress. These affecting factors were submitted in advance to the participants for review, highlighting the importance of the political decision makers in the business ramp up. The business opportunities were also underlined as summarised in the chart below.

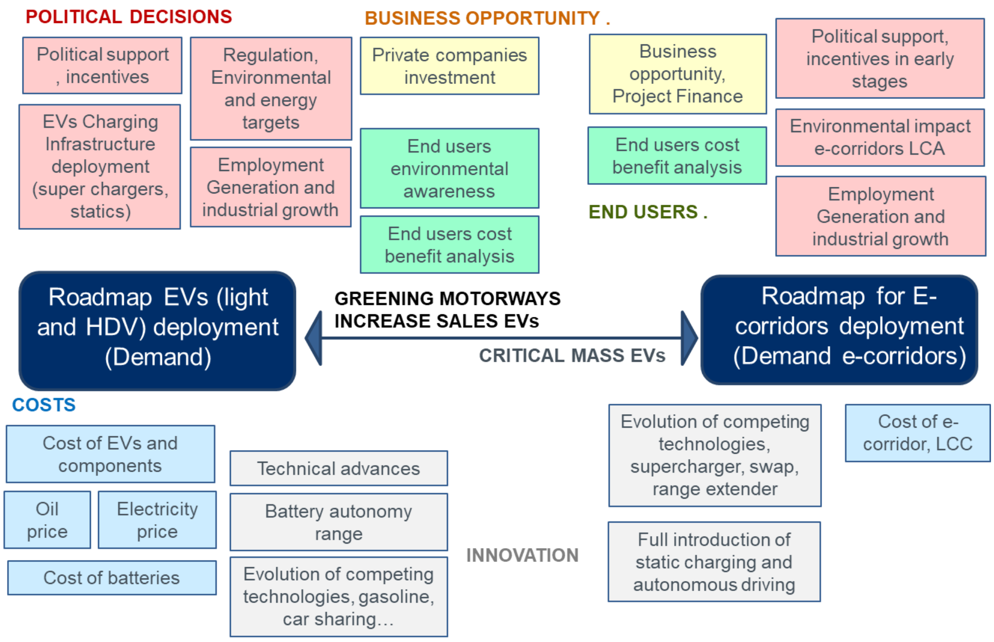

Table 2. Overview of business opportunities and affecting factors

Different round tables were organised in the workshop combining experts from complementary areas of knowledge, including technology experts, market analysts, regulation experts and business developers. A table of questions were submitted for discussion and some conclusions arose from that exercise. In addition, the selected three scenarios for a quick deployment of the e-Corridor technology were scrutinized for the experts' approval. These three scenarios were selected among the ten that are identified in Deliverable 5.2.1 "Feasibility study on societal perspectives towards on road charging and set of current data regarding societal dimension", where a PESTEL (Political, Economic, Social, Technological, Environmental and Legal) analysis was conducted. The selected three scenarios are described below.

1. **Motorway Scenario**. In 2030, one 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 core TEN-T infrastructure (mostly larger motorways with 3 to 4 lanes per direction) will be the most appropriate for the e-Corridors set up. In 2050, the expertise gained over 20 years will lead to e-lanes being implemented in one of the motorway lanes at the time of construction or periodic renewal instead of one constructed externally, reducing costs (e-Roads).
2. **Periurban Scenario.** This refers to the dynamic wireless 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 (for intercity buses) travelling a daily distance of around 250 km

with e-Corridors of 10 km length. It will be highly recommended to set up business contracts between Industry Service companies and the infrastructure owners to ensure a minimum number of daily charging events in the e-launchers.

3. **Urban Scenario**. Likely, the first entry point of DWPT systems in 2030 will be using bus stops as static charging points and some trenches ahead summing up 25 m 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.

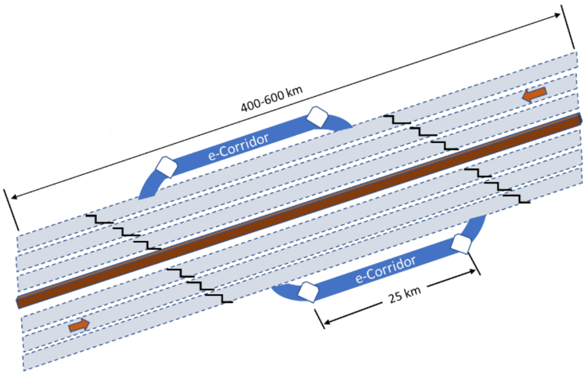

Figure 2. 2030. Ten-T. Dedicated e-Corridors in motorways

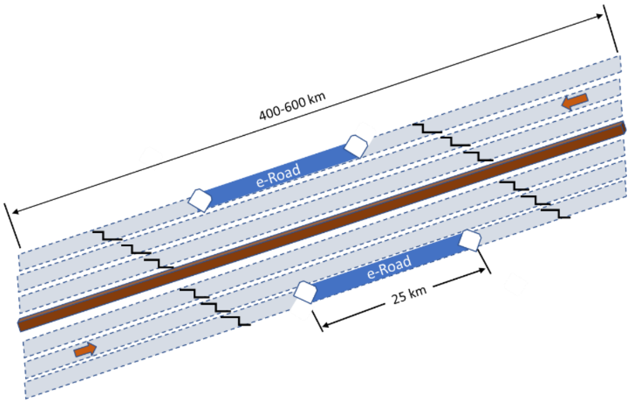

Figure 3. 2050. Ten-T. E-Roads in motorways

The following table includes the subjects for discussion scrutinized and verified by the experts in the Strasbourg workshop.

Motorway Scenario					
Business approach	Investor Infrast	User	Administration		
Length e-road	10 km	25 km	50 km		
Range Extension	50 km Light Veh	17 km E-Trucks	42 km E-vans		
Safety distance between cars	1 s	1,5 s	2 s		
Speed in the e-corridor	60 km/h	80 km/h	100 km/h	120 km/h	Free?
Autonomous driving available ?	Yes	No			
Wireless Static charging available ?	Yes	No			
Power transfer Static available ?	20 kW	50 kW	100 kW	150 kW	
Penetration static wireless	5%	10%	20%	40%	
Construction method	Full lane	Prefabricated	Trench	Micro Trench	
Same lane / E-corridor	E-lane	E-Corridor			
Supply chain (copper costs)	Increase tendency				
Time to market	2030	2040	2050	Cost impact	
Demand Est. Electric Vehicles	Impact on potential number of vehicles				
Demand Est. E-Corridors	Costs of supply chain				
Density of roads (cars/AATD)	5,000	10,000	18,000		
User costs	Construction	Operation			
Cost of charging at e-Corridor	Must be profitable and acceptable for users				
Cost of e-corridor /km	1 Million €	2 Million €	3 Million €	4 Million €	
Features Competing technologies	Battery range	Charger range	Fuel cells range	other clean	Diesel/Gasol
Cost Competing technologies	Battery Cost	Charger costs	Fuel cells costs	other clean	Diesel/Gasol
Other limitations	Health	Technical	Administrative		
Public incentives	Yes	No			
Standards impact	Decarbonization				
User view point	Additional 1.000 € are justified?				
Administration view point	From 30 to 50 Million € justify to provide so small range extension?				

Periurban Scenario		
Same conditions than motorway and…		
Availability of space for e-corridors?	Yes	No
Battery reduction important?	Reduce costs	Increase space
Range extension sufficient	High cost for a very reduced range extension	
Future batteries autonomy	Maybe not needed DWPT for the daily drive cycle.	
Enough charging fleet?	Maybe not sufficient number of e-trucks and e-buses	

Bus Scenario			
Daily route justify DWPT?	Last e-buses with 500 km autonomy		
Stationary/Static charging is enough	Maybe 1/2 of utra-rapid charging at garage after round is enough		
Public authorities in favour	Yes	No	Environmental awareness
New standards help	Yes	No	
Manufacturers in favour	Yes	No	
Cost bus electrification	2 or 3 times conventional buses		Cost Reduction?
Cost of electricity for buses	1/2 cost of equivalent diesel		Trend
User costs in construction	Cities already collapsed…		
Enough number of buses for e-trench ?	Maybe buses crossing the e-trenches are nor enough		

Table 3. Subjects for discussion in the Strasbourg workshop per scenario

The analysis concluded with a business model for infrastructure owners for the three selected scenarios. This economic analysis has determined the price of each charging event and the required incentive, if needed, to cover the costs. Then, a SWOT analysis is also added for all the scenarios highlighting the main strengths, weaknesses, threats and opportunities for DWPT. Specifically, for DWPT-EV owners the analysis was based on comparing the TCO costs between a DWPT -EV and an ICE car. The analysis also included The TCO of a Plug-in car that stops and charges in the middle of the distance with an ultra-charger just for the extra range extension given by the e-Corridor. The analysis is repeated with and without incentives in the dynamic charging process.

The analysis for Administrations is based on the main findings for each scenario (namely figures on costs, fuel savings and CO_2 emissions reductions) on top of which other aspects are introduced in the balance that could be considered by an administration before taking an investment decision (for examples impacts on health, noise, safety…).

2.1 Assumptions for the Business models

The next table describes the open questions answered by the experts during the workshop and the corresponding consensus reached in the round meetings.

	FABRIC Consensus		Assumptions /Explanation
OPEN QUESTIONS	**2030**	**2050**	
TECHNOLOGY IN THE EVs			
Average battery range for light electric vehicles	400 km	600 km	According to the Demand report (Deliverable 5.4.2.) and the analysis of the expected average range for batteries in light vehicles in 2030 and 2050.

Average battery range for HDV and intercity busses	200 km	300 km	Same as previous comment
TECHNOLOGY IN THE E-ROADS			
Action type. Same lane than conventional vehicles or dedicated e-corridor?	Dedicated lane	Same lane	The conclusion in the Strasbourg workshop was that initial deployment shall require a dedicated lane due to lack of expertise on O&M (2030). Later in 2050, there will be no problem to adapt an existing lane to WPT-EVs because differences on speed keeping at a maximum of 90km/h or the existence of small debris in the pavement (event metallic) will not substantially impact the charging process. However, it is recommended to keep such a lane as “green lane” (just for EVs) to avoid a very heavy traffic and provide a clear advantage for users. Also, the autonomous driving inside the lane is highly recommended to keep steady the distance between consecutive vehicles, keep the average speed and above all to avoid misalignment.
Pavement Construction. Full lane, prefabricated, trench base or micro-trench base	Full lane	Prefabricated lane	Consensus among experts suggests that the initial dedicated lane will be bespoke manufactured due to the lack of expertise. In 2050, the maturation curve will move to prefabricated modules when moving to the conventional lanes. The need to reduce user costs (avoiding traffic congestions during construction) will likely delay the introduction of trench or micro-trench base technologies until they will be fully developed.
Technology precursors Full Introduction of wireless static charging in the markets (in % of other with other solutions)	100%	100%	A consensus was reached that the introduction of the wireless static charging must be the predecessor for the subsequent wireless dynamic charging technology. Cost adaptation from Static to Dynamic was fixed around additional 400 €-1.500 € in light vehicles.
Power transfer Dynamic Power Transfer for light vehicles: 20, 50, 100 kW?	50kW	50KW	Sufficient power transfer capacity is required to allow recharging in a given e-corridor length (i.e. 25 km) and provide a substantial advantage in terms of extended autonomy range (maybe 20%, for a conventional 400 km battery autonomy). In addition, the 50kW module will permit an easy adaptation to Heavy Vehicles which will be a multiplier of this module (3 or 4 modules). The 50 kW modules for light vehicles is not an existing technology but manufacturers consider this power transfer as ideal by technical and economic reasons.
Power transfer Dynamic Power Transfer for heavy vehicles?	100 kW	250 KW	Electric Heavy Vehicles will be the first entry point for such technologies (buses and electric trucks). Electric Buses will be used initially in city centres to avoid pollution. Nowadays, they are limited by the battery size but wireless static and later dynamic charging (when the fleet of WPT-buses will be larger) might allow the use of bigger buses (battery reduction concept). Trucks and intercity buses that run the same route daily will be the next step as an option to gradually replace the very polluting conventional heavy vehicles. Dynamic wireless charging will be required to reduce the battery size and enable sufficient autonomy range.
Technical requirements	Minimum 25m	Minimum 25m	Autonomous driving will reduce the safety distance between consecutive vehicles from the 2 s for

Average distance between consecutive Vehicles			reaction, currently imposed by law and representing between 60 and 70 meters of safety distance, to 1 s that will establish a minimum safety distance of 25-30 meters. This will significantly increase the number of vehicles that can be charged simultaneously in the e-Corridors
Technical requirements Length of e-corridor	About 25km (one or two times in 400 km to 600 km distances)	About 25km (one or two times in 400 km to 600 km distances)	Building new infrastructure (a dedicated lane) will be required at the very beginning to avoid problems during O&M tasks. The capital expenditure (CAPEX) will be higher than readapting one of the conventional lanes but at same time the user costs will be minimized (no affection to the traffic during construction). In 2050, a cost reduction is expected overtime if a special machinery is designed to prepare the holes and the coil installation. Thus, on existing congested motorways, the use of one of the lanes will be possible if the stock of EVs in the road is high (consensus was 40%). However, that lane should preferably be less busy than others (for example if only clean vehicles can run through it) keeping an advantage on EVs users. Initially, the adaptation of the motorway will be done in a single lane per direction (in the slowest one) building a dynamic e-Corridor of about 25 km in stretches of 400 km with power transfer of 50 kW (or multiples of this figure for HVs). Ideally those motorways might be multilane (3 or 4 lanes per direction) to mitigate problems during the construction phase
Technical Requirements How much range extension should the e-Corridors provide?	15%-20% as agreed upon in Strasbourg)	33% (depends on business models)	As agreed in Strasbourg, the competing technologies (superchargers) will be the major threat for the technology if in the future they may enable an 80% capacity charging at only 5 min. For that reason, a 20% to 30% of autonomous increase in e-Corridors is needed at a reasonable cost (better below the fast charging).
Technical Requirements Average speed within the e-corridor	max 27.7 m/s (100km/h)	max 33.3 m/s (120km/h)	Although some technologists are working nowadays for energy transfer at 50km/h, the technology must evolve to usual speeds in motorways (120 km/h). Apparently, this speed will not be a technical barrier.
COMPLEMENTARY OR COMPETING TECHNOLOGIES			
Competing products like superchargers	150 kW	350 kW	Nowadays the conductive superchargers reach 145 kW, enabling 80% charge in 30 min. The massive deployment of these technologies at reasonable prices in the market could jeopardise the introduction of the dynamic charging due to economic reasons. However, the easiness, convenience and user friendliness of interoperable Wireless Power Transfer systems, possibly also supported by driving assistance techniques, should be a convincing argument for a complementary alternative to the conductive charging.
Autonomous driving Autonomous driving needed when charging on the e-Corridor?	Not needed, but preferred	yes	Autonomous driving will improve misalignment (which reduces energy transfer efficiency). It seems that autonomous driving will be a common technology from 2025 ahead.
Conductive charging Should conductive dynamic charging be considered in	Conductive dynamic charging is an	Conductive dynamic charging is an	Probably some examples will be available in the market for this technology although competing technologies could jeopardise its market introduction.

the business model and if so to what extent. Specifically, for the HDV/Bus Scenario.	option with some supporters within the FABRIC partners	option with some supporters within the FABRIC partners	Conductive charging is relevant but is beyond the scope of this task.
Fuel cell vehicles. Does fuel cell vehicles deployment affect DWPT?	To some extent	To some extent	Probably fuel cell technology will be deployed in parallel. Technology barriers of fuel cell vehicles are like those from DWPT; lack of infrastructures and high costs. However, the impact will not be very high as the expected penetration of the technology will be slow.
COSTS			
Battery price will decrease dramatically	>100$/kWh	>80$/kWh	The Life Cycle impact of the battery on energy and environment remains an important argument to encourage the review of the sizing of the battery in consideration to the range extension offered by an appropriate infrastructure network of Wireless Power Transfer systems. This is especially appropriate for heavy vehicles (trucks and buses). On the contrary Light vehicles require range extension.
Present Value e-Corridor /year: around	€3.9 Mio/ year	€3.5 Mio/ year	Final figures for CAPEX show a present value of 3,9 Mio €/ year (3 Mio €/ km) in 2030 and 3,5 Mio €/ year (2.75 Mill €/ km) in 2050 during an average life of 20 years. These figures provide a market opportunity for the dynamic charging.
Oil price How will the oil price develop?	Rise moderately	Rise moderately	Oil prices will start to rise again, but with a rising numbers of EVs, a rise in renewable energy and general efforts to reduce energy consumption they would level out and therefore not dramatically rise or even fall.
Depreciation installations Average depreciation period for the e-Corridor.	20 y	20 y	Road pavements lifetime is estimated between 40 to 60 years. However, system infrastructure (electronics, communications, etc.) lasts usually between 20 to 30 years, so a prudent consensus for the dynamic charging infrastructure is 20 years.
Electricity prices How will the electricity price develop?	Stable	Decrease	Decrease in price in the short term might be cancelled out by the increase in demand (move from ICE to EVs).
Extra cost on board Extra cost of transforming a static wireless charging module mounted on an EV to a dynamic wireless charging device.	400€-1500€	300€-1000€	Agreed upon in Strasbourg meeting and using Politecnico di Torino (POLITO) figures.
BUSINESS SCENARIOS			
Deployment Scenarios E-Roads on motorways, or inside or around cities? (different for each scenario)	Scenario 1: Electric Buses within cities. Scenario 2 (2035): Heavy vehicles, short distances from outside to the city centre and intercity buses at a distance rounding	Scenario 3: Light cars /duty vans in crowded motorways form TEN-T with a green lane running distances between 400 km to 600 km	According to Strasbourg workshop experts.

	200km to 300 km		
% EVs in motorways How many EVs will be on roads	25%	58%	In 2040 the figure might be 44% according to deliverable D5.4.2 Supply chain (e-Corridors demand section)
% EVs equipped DWPT How many EVs will be ready for dynamic wireless charging	60%	100%	For economic reasons, a critical mass of EVs in the roads is required to reach volume enough to make the e-Corridors sustainable. However, some incentives will be required at the beginning to move on investors. This 60% stock of EVs will be reached in 2030 according to demand estimation. EVs will then grow very rapid to almost full compatibility by 2050.
Owner of e-Corridors To what extent will the business model consider the grid connection? (responsible only for the service but not for the grid supply or responsible for all the energy supply infrastructure)	Probably government ownership	Some investors will likely invest on this type of infrastructure as soon as the business model shall be already demonstrated by public authorities and a critical mass of EVs will be on the road fully prepared for wireless static charging	Initially, the local or national authorities will be needed as road owners to launch e-Corridors through incentives or by the procurement of innovative technology tool. Later on, the business model will allow private investors as soon as the critical mass of EVs equipped with DWPT will be on the roads.

Table 4: Table of Assumptions on Dynamic Wireless Charging Technology

3 BUSINESS MODELS FOR THE INFRASTRUCTURE OWNERS

3.1 Motorway Scenario

According to the experts' discussions, the motorway scenario is based in the use of the battery as a range extender. It is foreseen for light and heavy vehicles in very dense highways with a critical mass of electric vehicles in the roads and a percentage of those equipped with DWPT systems. The e-Corridors will be built initially in a dedicated external lane to avoid user costs (added costs due to traffic congestion) during the assembly process and later using one of the conventional lanes when prefabricated modules will be available and construction times will be significantly reduced. The e-Corridors will be established in the middle of trenches of 400 km where one sets the average autonomy of a light electric vehicle in 2030. The intermediate e-Corridors will reduce the anxiety effect of drivers enabling them to recover such distance with the assurance that they can recharge between 10% to 20% extra autonomy without wasting time (in opposition to the competing conductive or inductive static stations).

MOTORWAY SCENARIO				
km e-Corridor	25			km
Safety distance (s)	2			s
Driving cycle: Constant highway speed (km/h)	100			km/h
Number of vehicles per day (approx.)	12,000			units
Traffic profile: max/avg ratio	3			units
Max. number of vehicles per km (safety rule)	17			Veh/km
Max. number of vehicles per km (accepted rule)	15			Veh/km
Max. number of vehicles per e-corridor	375			Veh/e-cor
Time to cross the e-corridor	0.25			h
Max. hourly traffic (veh/h)	1500			Veh/h
light Vehicles / Total vehicles (in %)	88%	88%	88%	%
Dynamic Power transfer (kW)	20	50	100	kW
Total POWER required for the e-corridor	9.7	23.4	45.5	MW/e-cor
Energy recharged in the e-corridor				
One vehicle (kWh)	5.0	12.5	25.0	kWh/veh
Total on average day (MWh)	60	150	300	MWh/day
Range extension (km)				
Standard (assuming 0.15 kWh/km)	33	83	167	km
Highway (assuming 0.25 kWh/km)	20	50	100	km
Number of coils in the e-corridor	12,500			coils
Number of LV transformers per e-corridor	25	25	25	LV units
Nominal power per LV transformer (MVA)	0.4	1.0	1.9	MVA
Number of HV/MV transformers	1	1	2	HV-MV Trafo
Nominal power per MV transformer (MVA)	10	25	24	MVA/MV Trafo

Table 5. Input parameters as a base for the motorway scenario calculation (12.000 AADT charging vehicles).

For heavy vehicles the distances will be reduced to 250 km. In the next table, we calculate the energy requirements from the grid in case we make some assumptions. These base parameters are the input data that will be latterly used for the business model.

The number of vehicles in this table exceeds the numbers we will use in the business model in years 2030, 2040 and 2050, but the idea is to calculate the grid requirements in the worst case.

The central column represents the most likely and expected scenario with 50 kW power transfer for light vehicles. Heavy vehicles will likely need 100 kW. The total number of coils used will be 12,500, with an approximate length of 1.50 m each and 0.5 m between two consecutives (based on the POLITO technology). We consider a maximum of 12,000 vehicles using the e-Corridor daily (likely to be reached in 2050 or later). In that case, the energy requirements from the grid might be 1 HV-MV trafo, 25 MVA and 25 LV units of 1 MVA each.

3.1.1 Key resources needed to make the business model possible

a. **A heavily used highway, with three lanes per direction and a critical mass of electric vehicles equipped with DWPT is needed**. A simulation was done with the following assumptions.

ASSUMPTIONS FOR THE MOTORWAY TRAFFIC	No.	Unit
Length e-corridors	25	km
Daily Traffic per lane in selected motorways (ADDT)	18,000	units
Number of lanes	3	units
Total number of daily traffic	54,000	units
Light vehicles	88	%
Total number of daily light vehicles	47,520	units
Total number of daily light vehicles/lane	15,840	units
Heavy vehicles	12	%
Total number of daily heavy vehicles	6,480	units
Total number of daily heavy vehicles/lane	2,160	units

Table 6. Assumptions for traffic in the motorway scenario

In the next table, from the total 18,000 vehicles per lane the basic scenario for electric vehicles (without DWPT equipment) was prepared according to the estimations of EV penetration, then the FABRIC scenario (right column) was also calculated with some of the EVs equipped with DWPT. Superchargers and e-Corridors coexist in the FABRIC scenario. E-corridors in the TEN-T network are not significant (only 32 in 20 years in Europe for this scenario, although 600 in the periurban are also expected).

No.		BASIC SCENARIO (without e-Corridors)						FABRIC SCENARIO (with e-Corridors)					
	LIGHT VEHICLES IN MOTORWAYS	**2,030**		**2,040**		**2,050**		**2,030**		**2,040**		**2,050**	
1	Percentage of fleet that it is electric	25	%	44	%	58	%	25	%	44	%	58	%
	Light EVs	11,880	units	20,909	units	27,372	units	11,880	units	20,909	units	27,372	units/day
2	Nº electric vehicles that use motorways	50	%	60	%	70	%	70	%	80	%	100	%
	Light EVs in motorways	5,940	units	12,545	units	19,160	units	8,316	units	16,727	units	27,372	units/day
3.	No. Of light EVs equiped with WPT (dynamic charging)	0	%	0	%	0	%	60	%	75	%	100	%
	Light EVs-WPT in motorways	0	units	0	units	0	units	4,990	units	12,545	units	27,372	units/day
3	Users that recharge in motorway superchargers	20	%	20	%	20	%	20	%	30	%	40	%
	Light EVs charging in supercharger in motorways	1,188	units	2,509	units	3,832	units	1,663	units	5,018	units	10,949	units/day
4	Users that recharge in motorway e-corridors							10	%	20	%	30	%
	Light Evs-WPT charging in e-corridors in motorways							832	units	3,345	units	8,211	units/day
	% of users charging in e-corridors/EVs equiped with WPT							17	%	27	%	30	%
	HEAVY VEHICLES IN MOTORWAYS	**2,030**		**2,040**		**2,050**		**2,030**		**2,040**		**2,050**	
5	Percentage of fleet that it is electric	25	%	44	%	58	%	25	%	44	%	58	%
	e-HDVs	1,620	units	2,851	units	3,732	units	1,620	units	2,851	units	3,732	units/day
6	Nº electric heavy vehicles that use motorways	10	%	20	%	30	%	30	%	60	%	100	%
	e-HDVs in motorways	162	units	570	units	1,120	units	486	units	1,711	units	3,732	units/day
7	No. Of e-HDV equiped with WPT (dynamic charging)	0	%	0	%	0	%	60	%	75	%	100	%
	e-HDVs-WPT in motorways	0	units	0	units	0	units	292	units	1,283	units	3,732	units/day
8	Users that recharge in motorway superchargers	20	%	20	%	20	%	20	%	30	%	40	%
	e-HDV charging in supercharger in motorways	32	units	114	units	224	units	97	units	513	units	1,493	units/day
9	Users that recharge in motorway e-corridors							10	%	20	%	30	%
	e-HDV charging in e-corridors in motorways							49	units	342	units	1,120	units/day
	% of users charging in e-corridors/EVs equiped with WPT							17	%	27	%	30	%
10	Nº of e-corridors in motorways	0	units	0	units	0	units	10	units	10	units	12	units

Table 7. Forecast number of EVs equipped with DWPT (light and heavy) in a congested highway (18.000 vehicles / lane / day)

FORECAST 5 KEY COUNTRIES Year	AADT/lane (in km) [1] > 12.000 veh	Maximum e-corridors /500 km	2030-40	2040-50	2050-60
European Union (20 countries+France)	**12.727**	**32**	**10**	**10**	**12**
Germany	3.159	6	2	2	2
Norway	89	2	0	0	2
United Kingdown	2.408	6	2	2	2
France	3.582	8	2	2	4
Netherlands	1.323	4	2	2	0
TOTAL (FIVE KEY COUNTRIES)	**10.561**	**26**	**8**	**8**	**10**
REST OF COUNTRIES	**2.166**	**6**	**2**	**2**	**2**

[1] In the case of France with no data, an estimation of the ADDT/lane has been done
[2] In the case of Norway, the length of the motorways network is reduced but one road has been identified within TEN-T
[3] Some slight adjutaments have been done to provide an even number of e-corridors
[4] The e-corridors are not acummulative

Table 8. Forecast e-Corridors in the most pro-active EU countries and/or more heavily trafficked highways

b. **Autonomous driving must be the standard** at the time the e-Corridors are deployed to avoid misaligning when charging, preventing efficiency reduction and reducing distance among consecutive vehicles (1 s reaction time represents 25 m distance whilst 2 s reaction time around 60 m) to increase the number of vehicles recharging at same time and rising the invoicing.

c. **Static/Stationary wireless charging must be massively adopted** in advance of DWPT. At that moment, the cars will be shielded against electromagnetic fields and end-users shall feel safe with the technology, thus being quite easy to later adapt their vehicles to dynamic charging.

d. **A minimum of 50 kW power transfer in light vehicles and 100 kW in heavy vehicles** is required to allow sufficient energy transfer to enlarge the autonomy and justify the investment in the DWPT system on board, at an average speed of 100 km/h in light vehicles and 80 km/h in heavy vehicles. 50 kW power transfer in light vehicles is a feasible technology according to experts from the technical point of view and keeping the passengers safe from electromagnetic fields.

e. **At least 60% of electric vehicles must be equipped with DWPT systems on board in 2030 and 100% in 2050.** The **electric fleet stock must be 28% in 2030 and 58% in 2050** (this final figure was revised after expert's comments and last demand reports updates)[3].

f. The **yearly present value costs** for the construction of e-Corridors must be in the order of **3.9 Million € in 2030 (without considering the cost of land) and 3.5 Million € in 2050**.

g. If **battery technology reaches 800 km autonomy** or if **fuel cell technology can provide 800 km autonomy** and the infrastructure is widely spread out at an affordable cost, there will be no need for recharge in motion.

h. If the new **superchargers reduce charging times to 5 – 10 minutes** and can recharge 80% of the autonomy of 400 km, there will be no need to recharge in motion.

i. **A commitment from authorities** is needed at the very beginning to promote and encourage the technology, as it will not be profitable till a massive adoption. Some pre-agreements among industrial transport companies and infrastructure owners will be recommendable to ensure a critical mass of vehicles recharging daily.

[3] https://www.bloomberg.com/news/articles/2017-07-06/the-electric-car-revolution-is-accelerating

j. **The copper cost must be kept constant.** A significant increase in such costs will jeopardise the introduction of the technology. However, some tensions are possible due to the high demand in the worldwide trend of electrification.

k. **Supply chain.** Any increase in the costs of fossil fuels will benefit the ramp up of electrification. The climate change consequences and the awareness of citizens will be also a pushing factor for the technology.

l. Finally, the **automobile sector must commit to the technology** and invest in it

3.1.2 Key activities necessary to implement the business model (motorway scenario)

The key activities from the point of view of an infrastructure investor are:

a. Technical capacity to set up the e-Corridor (manufacturing, operation and maintenance)
b. Financial strength to support the initial high investments
c. Authorization from the energy authorities as electric loads system operator
d. Ability to analyse the market and identify market niches (areas with critical mass of electric vehicles equipped with DWPT)
e. Sign pre-agreements with industrial companies and daily traffic across the motorway where the e-Corridors are placed to ensure a minimum number of daily charging events.

3.1.3 Key partners and their motivations to participate in the business model

a. *Energy Authorities***.** Incentive for shifting to electrification of transport and become independent from fossil fuels and therefore mitigating climate change by reduction of CO_2 emissions as well as improvement of air quality which directly protects the citizens' health. Public procurement for innovative technology is seen as an appropriate tool to enhance the technology market introduction.

b. *E-corridor investor and operator***.** Interest to generate long term profits during the amortization period established in 20 years. However, there is a high risk to generate losses if any of the market threats mentioned harms the technology.

c. *Industrial operators.* Industries with electric vehicles fleets, especially with heavy trucks and vans, will be willing to use the e-Corridors to enlarge the autonomy of their vehicles and reduce time losses when charging.

d. *End*-users must be willing to pay the tariffs at an affordable price compared with other options (conventional vehicle, superchargers, fuel cell vehicles, etc).

e. *All the supply chain* in the DWPT-EV manufacturing must be committed to invest in the new technologies.

3.1.4 Client segment(s) addressed by the value proposition

This will be especially useful for **medium distance commuters** who already have the burden of traveling these long distances regularly. This user-profile travels every day or at least twice a week to another city in a relative distance (maybe 200 km to 400 km). If they could save every day an hour of charging time, this would amount to a huge advantage for them.

Another advantage is the reduction of range anxiety. This, of course, can be achieved as well by static charging, but again this requires the user to stand still with a relatively long charging time of static charging. Due to the charging time advantage, it is assumed, that the e-Corridors will pull people who bought their EV initially only for the city and therefore have a relatively short range of around 300 to 400 km. This user-profile would have to recharge during a daily journey (out and back) of that extent to reduce anxiety for any contingency increasing the travel time in around 160 km (80 km per direction, equivalent to a total of an hour recharging static). If this user-profile would be able to save one static charging, this could encourage users to take their city-EV and use them for their medium distance travel.

The other segment of clients are the **industrial or commercial drivers**, especially those distributing goods, parcel or letters, in the early morning. For those professionals, time is money, and the possibility to recharge in motion could provide a great economic advantage.

3.1.5 Customers' relationships (motorway scenario)

The clients are those using the e-Corridors. The relationships with them are crucial to keep the business profitable. The relations with conventional customers are paramount:

a. In a first step**, campaigns to explain the technology and its benefits** (economic savings, health, environmental protection) must be carried out to convince end-users to invest in the EV adaptation to DWPT. This process will not be complex or expensive, in case the wireless stationary/static charging will be a standard. Indeed, the dynamic charging capability should be sold as a car option (packet dynamic charging) at a reasonable price.

b. The **customers will make their own cost-benefit judgment** and will not invest in the vehicle adaptation unless the e-Corridors will be in place in a motorway they use frequently and after a deep analysis. Some discounts per use must be offered and some incentives (especially at the very beginning) to facilitate their decision making. As this is a typical "chicken and egg" business problem, authorities must provide the appropriate context and commit to the technology in advance of users.

3.1.6 Communication and distribution channels to reach clients and offer them the value proposition

The dynamic charging capability must be an option offered within the pack of EV features and most OEMs must contribute to communicate the technology, to allow a massive and quick penetration of the technology. According to the FABRIC experts the adaptation of an electric car equipped with wireless static/stationary charging to dynamic, will be relatively cheap (from 400 to 1.500 €). **Dynamic charging must be also promoted by the public authorities through innovative public purchase, adopting an easy applied normative, providing incentives during charge events and/or through additional actions (tax reduction, etc).**

Dynamic charging needs to be considered as a standard in most electric vehicles and fully adopted by end-users that will feel safe and comfortable with the technology. A cost-benefit analysis from the point of view of the end-user might be prepared to raise awareness, not only with the economic benefits but also with the externalities and its clear advantages as the environmental positive impact, the health safety, the autonomous extension, the gaining in the travel time, etc. The value proposition of what is offered to the market must be explicit. **The value proposition is the non-stop charging possibility while traveling at normal speeds (100 km/h) using a less congested lane within crowded motorways, saving costs, energy and travel time and producing benefits to the environment.** In addition, the extension in autonomy allowing users to run longer distances with the same electric vehicle reducing the CO_2 footprint and shortening the range anxiety. The trip will be safe and comfortable using the new connected car appliances like autonomous driving, safety gadgets, pack of WIFI services and the wireless dynamic charging equipment.

3.1.7 Business model (motorway scenario)

The business model has been prepared following the assumptions presented in chapter 2.1 and the cost structure identified in deliverable D5.3.4. Detailed LCA/LCC assessment of environment and cost impact of E-roads, where the costs for an e-Corridor (2030) and an e-Road (2050) are presented. The figures used in this deliverable are those from the POLITO option and those of the SAET solution are quite similar.

The following exercise tries to identify the cost of an extended km of electric autonomy, comparing it with the average cost of one km generated by a fossil fuel car. All the cost concepts have been included (electric infrastructure and e-Corridor/e-Road construction) plus the investor expected margin and financial charges.

The model, according with the expected DWPT-EV deployed in years 2030, 2040 and 2050 (light and heavy), calculates the total required incomes to make the model feasible. Then the required

tariff in €/ kW is calculated considering that the income must serve to pay the electricity tariff plus and additional amount to cover costs. Then, the cost of one single charging event is calculated by type of vehicle. As we consider the range extension, we can easily deduce the cost of one km of extended autonomy. Then, we compare this figure with the cost of a fossil fuel car km. The last line shows the required incentive to cover costs (or not) in €/kwh electric to be comparable to a conventional car cost.

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. Billable Gross Power transfer [1]	62.5	125	kW
g. Net power transfer	50	100	kW
h. Net Absorbed Electricity per charging cycle	12.50	31.25	kWh
i. Average European Industrial Electricity Price [2]	**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 9. Input data assigned to the motorway scenario

Above, we have included the main assumptions for the business model calculation in the motorway scenario. Light EVs represent the 88% of the traffic and e-Heavy 12%. The price of the electricity that the e-Road owner will pay to the energy utility, will be the same for any type of vehicle, as they will be charged with the industrial tariff (on average 0.08 €/kWh in Europe). However, as system efficiency is 80% (energy provided/ energy absorbed from grid), the billable payment will be 0.10 €/kWh. This figure must not be confused with the user tariff, that will be different as it will include also amortization of investment, contribution to debt or company margin (in addition to the cost of the electricity).

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 i	[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 n	[14]*[11]		€/charge	**14.47**		**36.17**	**3.90**		**9.74**	**2.15**		**5.38**
18. Cost electricity per extended 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 (1,30 €/l)/gasoil (1,15€/l)	[3.5]*[1.15]/100	35	€/km	**0.04**		**0.40**	**0.04**		**0.40**	**0.04**		**0.40**
20. Cost differences between fuel and electricty [1]	[19]-[18]		€/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**	**0.98**	**0.89**	**0.14**	**0.13**	**0.04**	**0.00**	**-0.01**	**-0.10**

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

Table 10. Business model for the motorway scenario (years 2030, 2040 and 2050)

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 represent 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. Deliverable 5.5.4 Analysis of deployment scenarios, standardisation and harmonisation, includes a project finance and a sensitivity analysis to check the effect of the debt and other variable in the figures. It is very likely also that the expertise gained during first installations will move the margin down.

All the assumptions could also suffer from radical variations if several affecting factors modify the final figures; i.e. number of DWPT-EV on the road, electricity prices, vehicles' consumption, power transfer on board, autonomy range extension, cost of petrol and/or gasoline or even other effects

like the penetration of competing technologies, etc. As mentioned, in D5.5.4 a sensitivity analysis is performed to include such possible variations.

The billing model is based in all cases in the usage time, or in other words, no money is charged unless you don't use the e-Corridor. However, some other options could be managed, there could be maybe a flat rate, a fix payment regardless how much you use the e-Road or different prices depending on time use, stimulating the use in hours of low traffic and discouraging in peak hours, etc. We have not considered all these extra scenarios as the number of options is infinite.

3.1.8 CANVAS model

Hereinafter we include the CANVAS model associated to the motorway scenario.

Business Model Canvas

SCENARIO	MOTORWAY. E-CORRIDORS 25 km LENGTH		
Design by	QI EUROPE	Date	may-18

KEY PARTNERS

* Energy Authorities
* E-corridor investor and operator
* Industrial operators. Industries with electric vehicles fleets
* End-users must be willing to pay the tariffs at an affordable price
* All the supply chain in the DWPT-EV manufacturing must be compromised to invest

KEY ACTIVITIES

*Technical capacity to set up the e-Corridor
*Financial strength to support the initial investments
*Authorization from the energy authorities as electric loads system operator
*Analyse the market identifying market niches
*Sign pre-agreements with industrial companies

KEY RESOURCES

*Congested highway with three lanes and a critical mass of DWPT-EV
*Autonomous driving must be a standard
*Static/Stationary wireless charging massively adopted
*Minimum of 50 kW and 100 kW power transfer for light and heavy vehicles
*60% of EV equipped with DWPT in 2030 and 100% in 2050
* Yearly Present Value cost in 2030, 3.9 Million € and 3.5 Million in 2050
*Battery autonomy and charging installations must not improve too much
*Authorities and OEMs must promote
* Copper cost must kept constant

VALUE PROPOSITION

* The value proposition is the non-stop charging need while traveling at normal speeds (100 km/h for light vehicles and 80 km/h for heavy vehicles using a less congested lane within crowded motorways, saving costs, energy and travel time.

RELATIONS WITH CUSTOMERS

* Some campaigns to explain the technology and its benefits (economic savings, health,
* The customers will make their own cost-benefit analysis and will not invest in the vehicle adaptation unless the e-Corridors will be in place in a motorway they use frequently and after a deep analysis

CHANELS FOR DISTRIBUTION

*Most OEMs must contribute to communicate the technology to allow a massive and quick penetration of the technology
* Dynamic charging must be also promoted by the public authorities through innovative public purchase, adopting an easy applied providing incentives during charge events and/or through

CLIENTS

* medium distance commuters who already have the burden of traveling these long distances regularly.
* industrial or commercial drivers, especially those distributing goods, parcel or letters, in the early morning

COST STRUCTURE

For the infrastructure
(e-Corridor, €)

FABRIC PROJECT LCCA Summary	MOTORWAY SCENARIO			
	POLITO		SAET	
	2030-25 km	2050-25 km	2030-25 km	2050-25 km
PRESENT VALUES	e-Corridor	e-Road	e-Corridor	e-Road
TOTAL PRESENT VALUES	77,417,177	68,525,665	78,745,118	71,328,301
Present Value (per each of the 20 years)	3,870,859	3,426,283	3,937,256	3,566,415
Present Value per km	3,096,687	2,741,027	3,149,805	2,853,132
Type of vehicles	88% e-DWPT light Vehicles and 12% e-Heavy vehicles			

Total Cost of Ownership the vehicles (TCO). DWPT-light EV and DWPT-e-TRUCK (12 TONS)

YEAR	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	TOTAL	TOTAL PV
TCO DWPT EV (€)	41,122	2,925	2,841	2,768	2,705	2,650	2,603	2,563	2,527	2,497	65,201	59,350
TCO DWPT E-TRUCK (€)	308,768	36,347	32,955	30,021	69,183	25,287	23,388	21,746	20,325	19,096	587,115	524,142

REVENUES STREAMS

Required incomes to make the e-laucher sustainable and the required tariff and incentive for users to even the cost of an equivalent ICE car or truck for the same distance.

BUSINESS MODEL FOR THE SCENARIO		2030	2040	2050
TOTAL REQUIRED YEARLY INCOMES MOTORWAY	€/year	6,290,938 €	7,466,905 €	10,268,209 €
Required tariff to cover business model	€/kWh tariff	1.16	0.31	0.17
Required incentive for a comparable cost to ICE	€/kWh elec	0.98	0.13	-0.01

A negative figure means that no incentive is required.
Please check details in the deliverable report.

Table 11. CANVAS model (motorway scenario)

3.2 Periurban Scenario

The periurban scenario is addressed to heavy vehicles in the surrounding of major cities or between nearby cities. The e-launchers (e-Corridors or e-Roads with less extension, around 10 km instead of 25 km as in the motorway scenario) will provide extra capacity to allow the reduction in the size of the battery of heavy duty vehicles (HDVs) going from surrounding areas (like ports or logistic centres) to the city centres or intercity buses travelling daily distances (of 250 km) between nearby cities, enabling a new class of vehicles to compete with the conventional heavy vehicles and buses.

The basic parameters adopted for the calculations are depicted in the next table.

PERIURBAN SCENARIO				
km e-Corridor (e-launchers)		10		km
Safety distance (s)		2		s
Driving cycle: Constant highway speed (km/h)		80		km/h
Number of vehicles per day (approx.)		3,600		units
Traffic profile: max/avg ratio		4		units
Max. number of vehicles per km (safety rule)		17		Veh/km
Max. number of vehicles per km (according traffic)		8		Veh/km
Max. number of vehicles per e-corridor		188		Veh/e-cor
Time to cross the e-corridor		0.13		h
Max. hourly traffic (veh/h)		600		Veh/h
Dynamic Power transfer (kW)	50	100	150	kW
Total POWER required for the e-corridor	11.7	23.4	35.2	MW/e-cor
Energy recharged in the e-corridor				
One vehicle (kWh)	6.3	12.5	18.8	kWh/veh
Total on average day (MWh)	23	45	68	MWh/day
Range extension (km)				
e-Trucks (assuming 0.75 kWh/km)	8	17	25	km
e-Vans and e-buses (assuming 0.30 kWh/km)	21	42	63	km
Number of coils in the e-corridor		5,000		coils
Number of LV transformers per e-corridor	10	10	10	LV units
Nominal power per LV transformer (MVA)	1.2	2.5	3.7	MVA
Number of HV/MV transformers	1	1	2	HV-MV Trafo
Nominal power per MV transformer (MVA)	12	25	18	MVA/MV Trafo

Table 12. Input parameters as a base for the periurban scenario calculation (3,600 AADT charging vehicles).

With 3,600 heavy vehicles charging dynamically with a power transfer of 100 kW, the energy required in the grid might be 1 HV-MV trafo of 25 MVA and 10 LV units with 2.5 MVA each. It

must be noted that 3,600 e-DWPT heavy vehicles is a very high number, which is not even expected by experts in 2050. According to the demand analysis presented in D.5.4.2 Report on the maturity, reliability, efficiency and stability of the supply chain, the expected situation for e-HDVs in this type of roads surrounding major cities will be as follows, (with and without e-Launchers).

	BASIC SCENARIO (without e-Launchers)						FABRIC SCENARIO (with e-Launchers)					
PERIURBAN HEAVY VEHICLES	**2,030**		**2,040**		**2,050**		**2,030**		**2,040**		**2,050**	
Percentage of fleet that it is electric	25	%	44	%	58	%	25	%	44	%	58	%
e-HDVs	1,620	units	2,851	units	3,732	units	1,620	units	2,851	units	3,732	units/day
Nº e-HDV that moves in urban and periurban areas	100	%	100	%	100	%	100	%	100	%	100	%
e-HDVs in periurban areas	1,620	units	2,851	units	3,732	units	1,620	units	2,851	units	3,732	units/day
No. Of light EVs equiped with DWPT (dynamic charging)	0	%	0	%	0	%	60	%	75	%	100	%
e-HDVs-DWPT in periurban areas	0	units	0	units	0	units	972	units	2,138	units	3,732	units/day
e-HDV Users recharging in headquarters or urban static chargers	100	%	100	%	100	%	100	%	100	%	100	%
e-HDV charging in supercharger in headquarters	1,620	units	2,851	units	3,732	units	1,620	units	2,851	units	3,732	units/day
e-HDVs users that recharge in periurban e-launchers							50	%	62	%	83	%
e-HDV charging in e-launchers in periurban							810	units	1,768	units	3,098	units/day
% of users charging in e-launchers/e-HDV equiped with WPT							83	%	83	%	83	%
Nº of e-Launchers in periurban areas	0	units	0	units	0	units	80	units	120	units	200	units

Table 13. Deployment scenario of e-DWPT heavy vehicles in Periurban areas

The initial assumptions for these calculations start with the same figures presented for the motorway scenario in Table 3. Thus, we consider a flow of 18.000 vehicles per lane, from which 12% are heavy vehicles. Then we apply the percentages of the above table 10 to reach the number of DWPT e-HDVs charging at the periurban e-Launchers.

3.2.1 Key resources needed to make the business model possible (periurban)

The periurban scenario requires the following conditions:

a. **Heavily used bypasses or peripheral highways with space available to set up an e-Launcher** (reduced length e-Corridors of 10 km long) to feed a **sufficient critical mass of e-Trucks and/or e-Buses that justifies the investment done.** The required DWPT-Trucks and DWPT-Buses to reach positive figures in the business model must be around 1,400 charging daily in the same e-Launcher.

b. **Autonomous driving and static/stationary wireless charging must be a standard** for the same reasons described in the motorway scenario.

c. **A minimum of 100 kW power transfer is required for the heavy vehicles to enlarge the autonomy in a sufficient extent** with **80 km/h** of average speed when crossing the e-Launchers.

d. **OEMs must be committed to e-Trucks and e-Buses manufacturing** and a percentage of them must be equipped with the DWPT system (60% in 2030 and 100% in 2050).

e. The **cost for the infrastructure** (10 km length of e-Corridor in 2030 and e-Road in 2050, both called generically e-Launchers) will move from 2.2 Million €/year (4.4 Million €/ km) in 2030 to

2 Million €/year (4 Million €/ km) in 2050, considering CAPEX and Operating Expenses (OPEX) and a lifetime of 20 years (D5.3.4.).

f. **Support of governments is required** at the early stages of the deployment and the **competing technologies must advance moderately** (in case they reach major challenges, the dynamic charging would lose the market race), as explained in the motorway scenario.

g. Finally, and most important in this scenario, there must be a commitment by the local **distribution and freight companies** and of the **local bus companies** (public and/or private), through bilateral **contracts pre-established with the owners of the infrastructures,** to carry out the dynamic charging, daily. The e-heavy vehicles will likely cross over the e-Launcher more than once per day.

3.2.2 Key activities necessary to implement the business model (Periurban)

The key activities for the Periurban scenario, from the point of view of an infrastructure investor are:

a. Technical capacity to set up the e-Launchers (manufacturing, operation and maintenance).
b. Financial strength to support the initial high investments.
c. Authorization from the energy authorities as electric loads system operator.
d. Ability to analyse the market and identify market niches (areas with critical mass of heavy traffic, including buses potentially equipped with DWPT). These areas must be placed in the surroundings of crowded cities and there must be connection nodes between logistic parks and the centre of the cities or dry ports or maritime ports with unloading of containers.
e. Signing pre-agreements with industrial duty or public or private bus companies with electric heavy fleets and daily traffic across the motorway where the e-Launcher will be placed to ensure a minimum number of daily charging events.
f. There must be space available to set up the e-Launchers of at least 10 km long, initially in parallel to the road (2030) and later using one of the lanes (2050).

3.2.3 Key partners and their motivations to participate in the business model

The key partners for the Periurban scenario, are:

a. **Large industrial companies** with heavy fleets, environmentally aware, with daily routes of distribution of goods near cities. They must sign pre-agreements with the e-Launcher owners to use them daily at a given fix price. Ideally, trucks will travel through the e-Launchers several times a day, increasing rotation and making the infrastructure more profitable. Parcel, postal, or merchandise distribution companies will be the most interested in such bilateral contracts.
b. **Public and private bus companies** making daily routes among nearby cities. Pre-agreements with them are also required.

c. As these users are professionals and thus, taxes and VAT will be refunded, and the electricity cost will be reduced. The **administrations** will be willing to accept and facilitate this special condition for professionals.

d. **Supply chain stakeholders**. The International Road Transport Association (ASTIC)[4] in a recent report indicates that heavy road transport accounts for 6% of CO_2 emissions. The NOx emissions of a diesel truck with the Euro 6 standard reach 210 mg compared to the 80 mg of a diesel light vehicle, so we can conclude that a truck emits approximately 3 times more NOx than a light vehicle. The heavy vehicles manufacturers have, then, a good market opportunity with this technology, because the concept of battery shrink is likely the only option to combine enough autonomy with the high-power requirements demanded by a heavy truck or bus. For this reason, all the supply chain must be aware of the need to switch from the current pollutant diesel trucks or buses to the electric clean option with dynamic charging capacity.

3.2.4 Client segment(s) addressed by the value proposition (periurban scenario)

- Industrial companies with a large fleet of trucks making daily distribution of goods in the neighbourhood of crowded cities.
- Public and private bus companies making daily routes between nearby cities.

3.2.5 Customers' relationships (periurban scenario)

In this scenario, the relations with the clients will be B2B, so the awareness campaigns should be led by the owners of the e-Launchers towards the nearby industrial companies. Public administrations, in their idea of promoting clean technologies, should facilitate the implementation of these solutions through incentives, tax discounts or any equivalent promotion measure.

The decision to invest in electric heavy vehicles is a significant financial outlay and probably a strategic decision of great significance for a goods distribution company. The cost of the vehicle with a battery of great autonomy probably doubles and the option of buying a vehicle with less autonomy (cheaper) but equipped for dynamic charging will rely on the existence of nearby e-Corridors to load. Therefore, the purchase decision is linked to the environmental awareness of industrial deciders and the proper vehicle costs, but also on the investments in e-Corridors sponsored by the authorities.

[4] www.astic.net/page/homepage

In the B2B relationships, a wide agreement must be set up combining industrial owners, e-Launchers future owners and energy authorities. All of them must agree in advance to switch to the clean technology.

3.2.6 Communication and distribution channels to reach clients and offer them the value proposition (periurban scenario)

As mentioned before, the communication channels will be through direct B2B interviews between energy administrations, industrial companies and owners of e-Launchers. **The value proposition must be described in terms of cost savings for vehicle owners in the charging process and the pollutants' reduction**. A win-win scenario must be described with benefits for all the actors. Initially, several industrial operators must be convinced by the authorities to guarantee a minimum mass of e-heavy vehicles charging and the sustainability of the e-Launchers. Later some other actors must sum up.

As described in the business model, the energy authorities will need to provide an initial incentive to partially grant the electric charging tariff until some more industrial operators join the initiative.

3.2.7 Business model (periurban scenario)

In the next table the input data for the periurban scenario is described.

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 14. Input data assigned to the periurban scenario

The Periurban model is presented below. The breakeven point is reached almost in 2040 with around 1,768 HDVs charging on a daily basis.

The scenario is more positive than the motorway one because the comparable gasoil consumption costs per km for the HDVs, makes the electric alternative a good substitutive option (better than in the case of light vehicles).

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**

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

Table 15. Periurban business model for years 2030, 2040 and 2050

In 2050 with almost 3,100 e-HDVs charging in the e-Launchers, the cost of the electricity/km in any extended km after crossing the e-Launcher will be 0.28€ cheaper than the equivalent consumption of the diesel HDVs (0,40 €/km).

As in the case of the motorway scenario, the gross margin for the investor to pay the debt and for the industrial profit, has been set at 50% of the total costs (including infrastructure costs and electricity costs). A project finance will be provided in D5.5.4 "*Deployment scenarios*", to check the effect of the debt in the business model through sensitivity analysis.

3.2.8 CANVAS model for periurban scenario

Business Model Canvas

SCENARIO	PERIURBAN . E-LAUNCHERS 10 KM LENGTH		
Design by	QI EUROPE	Date	may-18

KEY PARTNERS

* Large industrial companies with heavy fleets environmentally aware with daily routes of distribution of goods near cities.
* Pre-agreements with Public and private bus companies making daily routes among close cities
* The administrations will be willing to accept and facilitate this special condition for professionals.
* E-corridor investor and operator
* End-users must be willing to pay the tariffs at an affordable price
* All the supply chain in the DWPT-e-Trucks manufacturing must be compromised to invest to reduce emissions

KEY ACTIVITIES

*Technical capacity to set up the e-Corridor
*Financial strength to support the initial investments
*Authorization from the energy authorities as electric loads system operator
*Analyse the market identifying market niches
*Sign pre-agreements with industrial companies
*Space available (10 km) close to cities for e-Launchers

KEY RESOURCES

* A congested bypass or peripheral highways with space available to set up an e-Launcher
*Autonomous driving must be a standard
*Static/Stationary wireless charging massively adopted
*Sufficient critical mass of e-Trucks and/or e-Buses that justifies the investment done
*A minimum of 100 kW power transfer is required for the heavy vehicles to enlarge the autonomy (80 km/h)
* Yearly Present Value cost in 2030, 2.2 Million € and 2 Million in 2050
*Bilateral contracts pre-established between commercial companies and owners of e-launchers
*Authorities and OEMs must be compromised

VALUE PROPOSITION

*The value proposition must be described in terms of cost savings for vehicle owners in the charging process and the pollutants' reduction
*Initially, several industrial operators must be convinced by the authorities to guarantee a minimum mass of e-heavy vehicles charging and the sustainability of the e-Launchers

RELATIONS WITH CUSTOMERS

*The relations with the clients will be BTB so, the awareness campaigns should be led by the owners of the e-Launchers towards the nearby industrial companies
*In the BTB relationships, a large agreement must be set up combining industrial owners, e-Launchers future owners and energy authorities

CHANELS FOR DISTRIBUTION

*The communication channels will be through direct BTB interviews between energy administrations, industrial companies and owners of e-Launchers

CLIENTS

*Industrial companies with a large fleet of trucks making daily distribution of goods in the neighbourhood of crowded cities.
*Bus public and private companies making daily routes between close cities.

COST STRUCTURE

For the infrastructure
(e-Launcher)

FABRIC PROJECT LCCA Summary	PERIURBAN
	POLITO
	2030-10 km
PRESENT VALUES	e-Launcher
TOTAL PRESENT VALUES	44,442,715
Present Value (per each of the 20 years)	2,230,328
Present Value per km	4,444,272
Type of vehicles	100% HV/Vans

Total Cost of Ownership the vehicles (TCO).DWPT-E-Truck 12 tons

YEAR	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	TOTAL	TOTAL PV
TCO DWPT E-TRUCK (€)	290,940	21,646	20,908	20,221	61,282	18,988	18,435	17,922	17,444	16,999	504,785	454,368

REVENUES STREAMS

Required incomes to make the e-laucher sustainable and the required tariff and incentive for users to even the cost of an equivalent ICE truck for the same distance.

BUSINESS MODEL FOR THE SCENARIO		2030	2040	2050
TOTAL REQUIRED YEARLY INCOMES PERIURBAN	€/year	3,927,923 €	4,441,901 €	5,223,703 €
Required tariff to cover business model	€/kWh tariff	0.53	0.28	0.18
Required incentive for a comparable cost to ICE	€/kWh elec	0.26	0.01	-0.08

A negative figure means that no incentive is required.
Please check details in the deliverable report.

Table 16. CANVAS model (Periurban Scenario)

3.3 Urban Scenario

The Urban scenario is addressed to deploy a complete electric fleet of buses in a city, reducing the cost of the fleet because of the battery shrink strategy and installing short trenches of static and dynamic charging (25 m long, consisting of 10 m of the bus stop plus 15 additional m), in all the city bus stops. A simulation was done considering that the bus fleet initiates the daily service with the batteries fully charged and gets sufficient range extension at the bus stops, to reach the depot at the end of the service without the need of additional static (depot) recharging during the day. The initial parameters for calculation are described in the following table.

Urban Scenario, buses				
Number of buses	400			buses
Number of routes	40			routes
Driving cycle	SORT 1-1-2-2-3-3			
Average Daily route (km), 1 direction (half trip)	9			km
Number of stops per route	27			stops/route
Total number of stops	1,080			stops/city
Time for one route (round trip)	0.5 h (1 h)			
Service time (h) = nº of round trips	18			trips
Consumption bus on average	2			kWh/km
Energy required (one round trip)				
Per route / bus (kWh)	36.0			kWh
Fleet (MWh)	14.4			MWh
Energy required per day (18 h service)				
One bus (kWh)	648			kWh/bus
Fleet (MWh)	259.2			MWh/fleet
Dynamic and static Power transfer (kW)	50	100	150	kW
Total POWER required by fleet (MW) (32% simultaneously)	8	16	24	MW
Charging mode (from simulation in Otave)	Continuous	25 m at stop	10 m at stop	Matlab
km of e-corridor	360	27	11	km
Required on-board energy storage (kWh) (Matlab)	12	15	18	kWh
Required average charging time per stop (s)	48	24	16	s
Required charging time per bus and route (min)	21.6	10.8	7.2	min
Number of coils per route (2.5m/coil)	3600	270	108	coils/route
Total number of coils	144,000	10,800	4,320	total coils
Number of MV/ LV transformers per route	4.5	4.5	6.75	Trafos/route
Total number of MV/LV transformers	180x 315 kVA	180x 630 kVA	270x 630 kVA	Total Trafos
Total number of HV/MV transformers	1x 8 MVA	1x 16 MVA	1x 24 MVA	Total Trafos

Table 17. Input parameters as a base for the urban scenario calculation (400 buses, 40 routes).

The simulation was done considering a medium city with around 700,000 inhabitants, 40 bus routes with 18 km length each (two directions) and 400 buses (10 per route). Every route includes 27 stops and each bus making 18 round trips. The consumption per route and bus reaches 27 kWh, and the required on-board energy storage on the central case (100 kW power transfer) just accounts for 41 kWh (very small battery that significantly reduces the cost of the e-bus). With these figures, a calculation was done of the HV/MV required transformers (just one of 16 MWA) and 180 * 630 kVA of MV/LV with a capacity factor of 60% defined as average consumption/maximum charging capacity (607.5/1,012.5). The wireless charging is made at the bus stops in static (10 m) and later in 15 additional metres of dynamic, with 10 coils per bus stop (270 coils per route and 10.800 coils in total).

The owner of the e-Trenches (dynamic charging at bus stops and 15 m ahead) will be the same than the bus owner; for example, the municipal transport company. To give a reference on costs, we considered that a 12 m diesel bus costs on average 200,000 €; the equivalent electric bus might reach 400,000 €, but the cost of the battery shrink bus could reach just 276,100 €.

The business model generates positive results in this scenario and consequently, we consider that it will be the first entry point for such technologies. In the analysis we have introduced one main modification compared to the analyses for the previous scenarios.

- The % applied over the full costs to cover the benefits of the owner and the financial charges, decreases now to 30% (compared to 50% in the other two scenarios). The reason is that being a public service, no profits will be considered.

3.3.1 Key resources needed to make the business model possible (urban)

This scenario just relies on the decision of the public transport authorities. The scenario will not be profitable unless **a full transformation of the city is done and most buses switch to this charging system**. The adaptation of the bus stops to the wireless charging in the whole city will introduce **extra congestion generating user costs during works**, but at same time the **environmental advantages for the city** will be paramount.

In addition to the investment done in the e-Trenches, the public transport companies will need **to invest in traditional conductive charging system to be placed in the depots**. This cost has not been included in these business model for two reasons; it is very probable that at the time of decision to invest in the e-Trenches and the acquisition of buses with smaller batteries, conventional electric buses will be available in most transport companies with existing conductive chargers at depots and secondly, because a fine analysis of the dynamic charging technology will maybe allow to select a battery size that enables to keep the buses charged for the whole trip (no need of recharging at depot) but still reducing the battery size compared to conventional e-buses.

The best breakeven point will be identified for that case, varying the e-Trenches length, the battery size, the existing conductive charging capability at the depot and the corresponding costs of all these options.

The power required in the grid will be also a challenge and those cities with an **existing tram infrastructure** will be more easily adapted to the dynamic charging technology.

3.3.2 Key activities necessary to implement the business model (Urban)

The key activities for the urban scenario are the following:

a. **Technical capacity** of local authorities to set up the e-Trenches (installation, operation and maintenance)
b. **Financial capacity** to face the investment for the e-Trenches and the e-buses. Existing e-buses with capacity to charge wireless stationary or static will be easily adapted to dynamic with an estimated cost of around 6,000 €. Those buses will be oversized in relation to the battery, but they will be apt for the operation. New buses equipped with dynamic charging appliances and designed under the concept of battery shrink will be significantly cheaper, but the investment will have to be faced by the transport company progressively, making the whole investment unprofitable for some time. Hence, the strategy to incorporate this technology in a city must be taken with care to avoid financial stress.
c. Authorization from the energy authorities **as electric loads system operator**.

3.3.3 Key partners and their motivations to participate in the business model

The key partners in the urban scenario are:

a. **Public transport companies**. The motivation for these organizations is to offer a clean service to the city raising awareness to other potential users in the future.
b. **Energy local authorities**. They will be necessarily involved as energy suppliers ensuring the correct supply of energy in all bus stops.
c. **Bus users** must be appropriately informed especially in relation to the safety of the wireless power transfer system at the bus stops.

3.3.4 Client segment(s) addressed by the value proposition (urban scenario)

The segment of clients addressed by the value proposition are **all citizens** who use public transport.

3.3.5 Customers' relationships (urban scenario)

Appropriate campaigns must be implemented reassuring the population in relation to the impact of electromagnetic radiation on health, always under the safety limits through the shielding of the

vehicle. A sound campaign must be organised by the public authorities highlighting the environmental benefits that this type of vehicles brings to the citizens, both at local level, because the NOx and the CO_2 emissions are eliminated, but also considering the whole life cycle analysis, as the reduced size of the batteries also mitigate the environmental impact during the construction and the disposal of the batteries, in comparison with the equivalent diesel solution.

3.3.6 Communication and distribution channels to reach clients and offer them the value proposition (urban scenario)

The communication campaigns must be organised using all advertising supports (TV, radio, social networks), etc. The campaigns must be firstly addressed to the young people commonly more open to new solutions and technologies but also to old people frequently more distrustful of the effects on health. The campaign must magnify the change in the energy paradigm and be focused primarily on protecting the environmental health of citizens (avoidance of NOx and CO_2 emissions). The value proposition is offering a public service which is clean, cheap and healthy to citizens for a sustainable city.

3.3.7 Business model (urban scenario)

In the next table the input data for the urban scenario is described.

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.

Table 18. Input data assigned to the urban scenario

The electricity price is the average in Europe for non-household customers (professionals). The urban model is presented 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**

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

Table 19. Urban business model for years 2030, 2040 and 2050

This model needs much more investment, almost 6 times over the periurban scenario. However, line 20 shows that considering the cost by km in comparison with a conventional diesel bus, the dynamic charging solution save 0.06 €/kWh even in 2030. The reason is that although the number of buses is just 400, the use of the e-Trenches generates 243,000 kWh/day (many rounds) and thus the cost per extender km reaches 0.23 €/km, being less than the cost with the equivalent diesel vehicle (0.40 €/km). Thus, this is the most positive scenario and likely the first entry point for DWPT. No incentive is required to make the scenario affordable (last line is negative).

3.3.8 CANVAS model for urban scenario

Business Model Canvas	SCENARIO	URBAN . E-TRENCHES IN BUS STOPS 25 m LENGTH		
	Design by	QI EUROPE	Date	may-18

KEY PARTNERS

*Public Transport Companies. The motivation for this organizations is to offer a clean service to the city raising awareness to other potential users in the future.
*Energy local authorities. They will be necessarily involved as energy suppliers
*Bus users must be appropriately informed specially in relation to the safety of the wireless power transfer system at the bus stops.

KEY ACTIVITIES

*Technical capacity of local authorities to set up the e-Trenches (installation, O&M)
*Financial capacity to face the investment for the e-Trenches and the e-buses
* Authorization from the energy authorities as electric loads system operator.

KEY RESOURCES

*The scenario will not be profitable unless a full transformation of the city will be done and most buses switch to this charging system
*In addition to the investment done in the e-Trenches, the Public Transport companies will need to invest in traditional conductive charging system to be placed in the depots
*The power required in the grid will be also a challenge and those cities with an existing tramp infrastructure will be more easily adapted to the dynamic charging technology
* The philosophy in this case is battery shrink to reduce it as much as possible.

VALUE PROPOSITION

The value proposition is offering a bus public service clean, cheap and healthy to citizens for a sustainable city.

RELATIONS WITH CUSTOMERS

*Appropriate campaigns must be implemented tranquilizing the population in relation to the impact of electromagnetic radiation on health, always under the safety limits through the shielding of the vehicle.
*A sound campaign must be organised by the public authorities highlighting the environmental benefits that this type of vehicles brings to the citizens

CHANELS FOR DISTRIBUTION

* The communication campaigns must be organised using all advertising supports (TV, radio, social networks), etc. The campaigns must be firstly addressed to the young people commonly more opened to new solutions and technologies but also to old people frequently more distrustful with the effects on health

CLIENTS

*The segment of clients addressed by the value proposition are all citizens which uses the public transport.

COST STRUCTURE

For the infrastructure
(e-Trenches)

FABRIC PROJECT LCCA Summary	URBAN
	POLITO
	2030-27 km
PRESENT VALUES	e-Trenches
TOTAL PRESENT VALUES	102,131,394
Present Value (per each of the 20 years)	5,106,570
Present Value per km	3,782,644
Type of vehicles	100% Buses

TCO-DWPT Buses 12 m

2,030 Type of Service	Main Features	Electric Infrastructure						Buses		OPEX		TOTAL
		Unitary Cost	Nº Ultra-ch.	Extra garage	Trafo	Extra in city	Total	Un. Cost	Total Cost	Un.Cost	Total OPEX	
DWPT System (150 kW)	400 buses, 41 kWh, DWPT	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

REVENUES STREAMS

Required incomes to make the e-trenches in bus stops in a city with 400 buses, sustainable and the required tariff and incentive for users to even the cost of an equivalent ICE truck for the same distance.

BUSINESS MODEL FOR THE SCENARIO		2030	2040	2050
TOTAL REQUIRED YEARLY INCOMES IN URBAN	€/year	13,627,707 €	13,281,069 €	12,934,431 €
Required tariff to cover business model	€/kWh tariff	0.15	0.15	0.15
Required incentive for a comparable cost to ICE	€/kWh tariff	-0.11	-0.12	-0.12

A negative figure means that no incentive is required.
Please check details in the deliverable report.

Table 20. CANVAS model (urban Scenario)

3.4 SWOT Analysis

A SWOT analysis was conducted aiming to identify important internal and external factors that could impact the deployment of DWPT for electric vehicles.

The analysis was carried out during a dedicated discussion that was held among participants of the workshop organised by FABRIC on 19 June 2017 in the framework of the 12th ITS European Congress in Strasbourg. The workshop was entitled "*Deployment Scenarios for Dynamic Charging of Electric Vehicles*". The SWOT discussions were held along the following four themes relevant to the above defined objective:

- **Which are the Strengths of dynamic on-road wireless charging technologies**, namely the characteristics that give them an advantage over other technologies (for example over conductive ones)?
- **Which are the Weaknesses of such technologies**, namely the characteristics that place them at a disadvantage relative to other technologies?
- **Which are the Opportunities** (elements in the environment) that such technologies could exploit to their advantage?
- **Which are the Threats** (elements in the environment) that could cause trouble for such technologies?

The outcomes of the discussions are presented in a classical SWOT table below, while the argumentation for each statement is given afterwards.

Strengths	Weaknesses
• Lower trip times • Less time to fully charge at destination • Higher driver's comfort relevant to charging • Lower anxiety and increased vehicle range • Lower Total Cost of Ownership for the vehicle • Lower retail price for the vehicle • Less visually intrusive than overhead catenary • More positive image for the owner • Easier integration with RES and smart grids	• Additional weight on the vehicle in case of range extender • Reduced available space in the vehicle in case of range extender • New safety issues due to the presence of equipment beneath the vehicle • Lower energy transfer efficiency • High installation cost in the infrastructure • Increased risk for physical harm • Stronger EMF possibly resulting in bigger risks for EMI / EMC / health • Bigger impact on infrastructure durability and lifetime • Possible reduction in road capacity • Dedicated lanes problems • No interoperability among different manufacturers • More difficult retrofitting

	• Lower maturity of charging and battery technology • Higher uncertainty on sustainability • Higher security risks
Opportunities	Threats
• Trend towards greening of transport • Trend towards autonomous driving • Trend towards Mobility as a Service • Trend towards higher RES use • Innovation potential for companies (SMEs) • Future road infrastructure	• Alternative technologies • Public concerns about safety and EMF issues

Table 21: DWPT SWOT analysis

Strengths

One strength of DWPT compared to plug-in charging technologies or battery swapping is that there is no need to stop the vehicle, so the total trip time is lower. Moreover, the time needed to fully charge the battery at the end of the trip will be lower if the vehicle was charging while driving, and this is beneficial for the vehicle usable time. Compared to overhead catenary which is also a popular technology, at least for some vehicle types, DWPT systems will be less visually intrusive, and this is especially significant for urban environment.

When charging, the driver does not need to disembark the vehicle, connect the charging cable to the available socket, which is burdensome especially for heavier vehicles, and this makes the whole charging procedure more convenient and comfortable for the driver.

As the vehicle can charge while driving, there is no risk that there will not be enough energy to complete the trip, and this will result in lower driver's range anxiety compared to other charging technologies, where the driver must locate an available and appropriate charging point, navigate there, find it indeed functional and available and ultimately charge the vehicle, before the battery runs out of energy. This of course assumes that there is an appropriate network of DWPT infrastructure.

Moreover, if the vehicle can charge while driving, batteries of smaller size will be required, and this will affect the vehicle retail price of which the battery is an important part.

One can also claim that a vehicle able to charge wirelessly while driving may create a better image for its owner, thus being another strength compared to other charging technologies.

Finally, the FABRIC D5.4.1 shows that the future e-roads configuration may allow power extraction directly by DC/DC converters which are more beneficial for the integration of renewable energy. The dynamic wireless charging system configuration facilitates additionally the integration with smart grids.

Weaknesses

Compared to other charging technologies, the DWPT will add an additional weight and will consume available space in the vehicle. The additional components of the secondary coils beneath the vehicle may create new safety risks in case of accidents or may alter the vehicle dynamics in case of crash. Still, if the battery is reduced, if new electronic architecture and components are used and if the dynamic wireless components are further industrialised, the extra weight and size may be reduced.

More significantly, at its current level of development, wireless charging systems present lower efficiency compared to conductive solutions, and this is a weakness for the energy provider if they get reimbursed only for energy that will be delivered to the vehicle and will probably have to cover the cost of energy losses. Additionally, it is a major drawback for the environment in general compared to other technologies.

Higher costs will be incurred installing such systems in the infrastructure, as broad road works will be needed, which is not the case for charging points at the road side for example.

The distributed and open topology of the roadside components of dynamic on-road wireless charging systems present increased risk for physical harm to living beings, as it more probable that a living being due to an accident comes in contact with such components, compared to charging points which are isolated.

The EMF generated by DWPT charging systems are higher than those related to conductive charging. Although the FABRIC tests show that the values are below the accepted limits, there may be increased risk for electromagnetic interference with other systems and components. This may be higher in urban environment, which is more condensed, than in open areas around motorways.

The placement of the primary components in the road infrastructure will have an impact on its durability and lifetime, which is not the case for isolated charging points or for other charging technologies.

The use of such systems typically requires that one lane is transformed in an e-lane, which will be typically reserved for vehicles able to use the dynamic wireless charging infrastructure. This will result in reduction of road capacity for conventional vehicles and there may be problems with

giving and monitoring access to the dedicated lanes. Conversely, if the e-lane were to be open to all vehicles, this would make it less attractive to DWPT vehicles because of the increased congestion and need to overtake slow moving non-equipped heavy vehicles, and also increase wear and tear on the in-road equipment.

No standards are currently available for wireless charging; therefore, the interoperability of such systems is not guaranteed, in contrast to the case of conductive charging.

To gain a critical mass of vehicles able to use the infrastructure, it will be necessary to adapt existing vehicles apart from the circulation of new compatible models. Retrofitting may be more difficult compared to other technologies, as components of bigger size and additional modifications in the electric architecture of the vehicle may be needed.

The charging technologies and the corresponding battery technology, to match and fully exploit the characteristics of the dynamic on-road charging is not as mature as other types, and this is a disadvantage. The high investment cost in infrastructure needed create uncertainty as regards the sustainability of relevant investments and therefore are a hindering factor.

Finally, the extent of the infrastructure and the needed communication with roadside units and with the vehicles, if dynamic access is to be given, create increased security risks for the energy transfer and for the whole communication chain.

Opportunities

The worldwide trend towards greening of transport is an opportunity for all charging technologies that can support the use of electric vehicles instead of fossil fuel vehicles. Other trends that offer an opportunity for DWPT are the interest towards autonomous driving, the smart grid and the Mobility as a Service concept. The efficiency of energy transfer in dynamic wireless charging depends on the alignment between the primary and secondary coils. A vehicle in autonomous mode can better keep the two coils aligned. Moreover, it will be more strenuous for the driver of an autonomous vehicle to arrange for the manual vehicle connection to a charging point, therefore the dynamic wireless charging option seems more consistent with an autonomous vehicle, and this can be seen as an opportunity for such systems.

The Mobility as a Service concept aims at offering the travellers mobility solutions specifically for their needs. The possibility to use such solutions to pre-book access and pay for the use of a dedicated e-lane may be an opportunity to promote the use of dynamic wireless charging systems.

Efforts are undertaken to increase RES share in the electricity mix. The construction of e-Roads aiming to better exploit RES availability may serve as an opportunity for such technologies.

A lot of initiatives promote innovation, especially by SMEs. This can be a vehicle to promote wireless charging technologies by smaller and even bigger companies.

The road infrastructure is being re-shaped, and it is expected that in the future it will be smarter and able to host conventional, connected and automated vehicles. In this transformation, the possibility to offer dynamic wireless charging can be pursued as one of the pillars of the future infrastructure.

Threats

The main threat to DWPT systems comes from the existence of alternative technologies like overhead charging, battery swapping, but especially by superchargers, which allow charging in minutes and are on the rise lately with the construction of first corridors across Europe. Although costly, they are not as costly as DWPT systems, neither do they impact the road infrastructure to such an extent.

Another threat to DWPT are the public concerns as regards health and other effects due to EMF. One can expect that there will be concerns similar to those created by the presence of mobile network antennas, especially in inhabited areas.

3.5 Conclusions

The main cost items and the expected tariff to cover the business model from the point of view of the infrastructure owner are summarised below. The figures also represent the required incentives which will vary progressively as the number of DWPT EVs increases and the fixed costs are distributed among a major number of users. The incentives reduce the users' tariff to the equivalent cost of using an ICE vehicle for the same trip where an e-Road was placed in between two points at a certain distance and extending the range autonomy. A negative figure in the incentive row indicates that the required tariff to cover the business model is enough compared with the expenses of an ICE vehicle, so the users at that moment shall be saving money when using the DWPT technology.

In the case of the bus scenario, considering the simultaneous deployment of 400 buses in a given city, the required tariff will be more favourable compared with an ICE bus making the same route. However, when calculating the whole picture (buses plus infrastructure), the DWPT in 2030 is the most expensive solution against pure electric buses and ICE buses, if externalities like fuel consumption and CO_2 emissions are not considered. DWPT buses improve a lot in CO_2 emissions in the whole life cycle due to the reduced battery size (battery shrink strategy) compared to pure electric buses.

3.5.1 Motorway scenario main conclusions

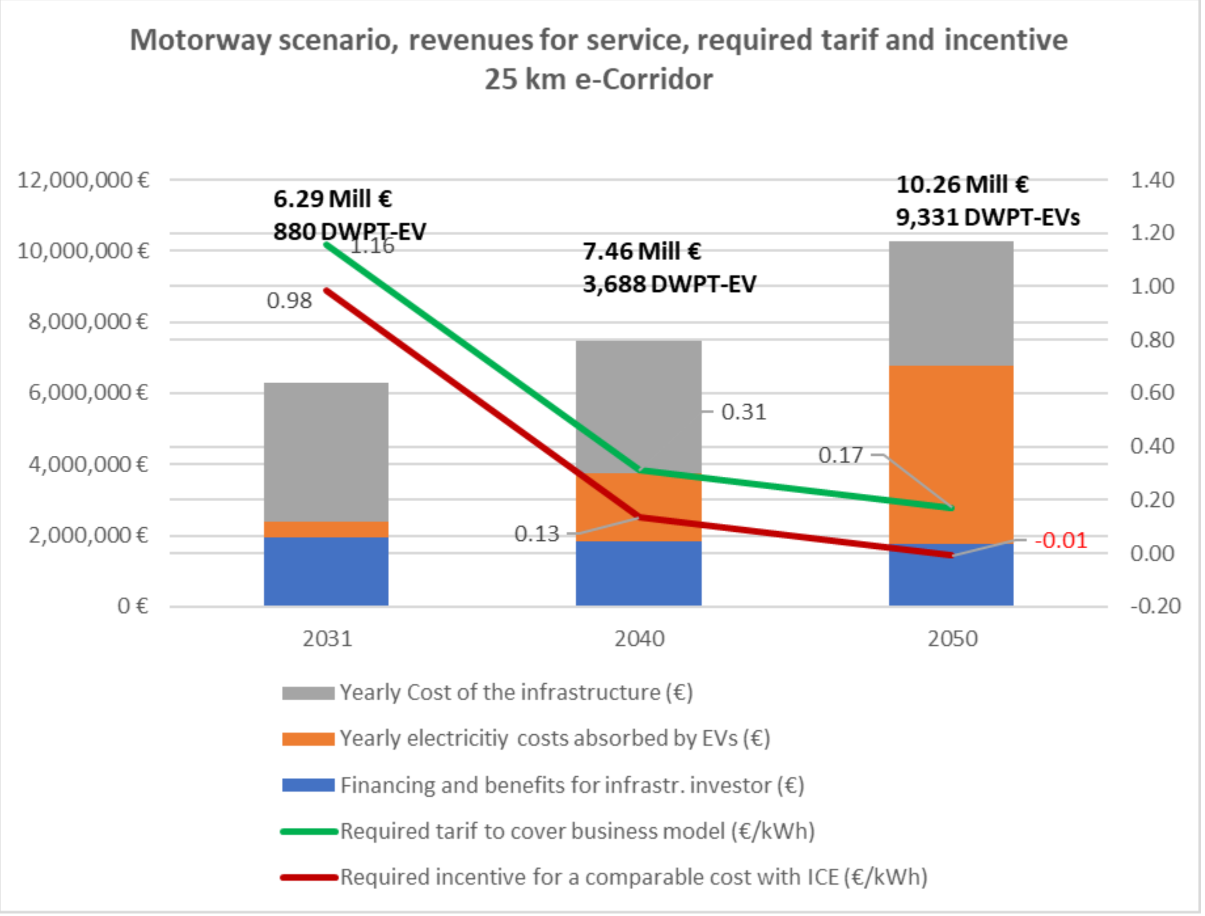

Figure 4. Summary of yearly cost in e-Corridors, required tariff and proposed incentive (Motorway Scenario)

The motorway scenario considers 25 km of e-Corridor, being an external dedicated lane till year 2050 when the e-lane will be integrated in a conventional motorway lane. The daily traffic has been distributed as 88% DWPT light vehicles and 12% DWPT heavy vehicles (European average).

A daily traffic of 9,331 vehicles will make the infrastructure sustainable and no governmental incentive will be required in 2050. But 9,331 daily traffic per lane represents a very dense traffic. The vehicles using the external e-Corridor will likely drive during the 25 km using autonomous driving with a given fixed speed gaining trip time in rush hours over the rest of the traffic (assuming the e-Corridor is reserved for DWPT EVs only and other traffic is banned from it).

3.5.2 Periurban scenario main conclusions

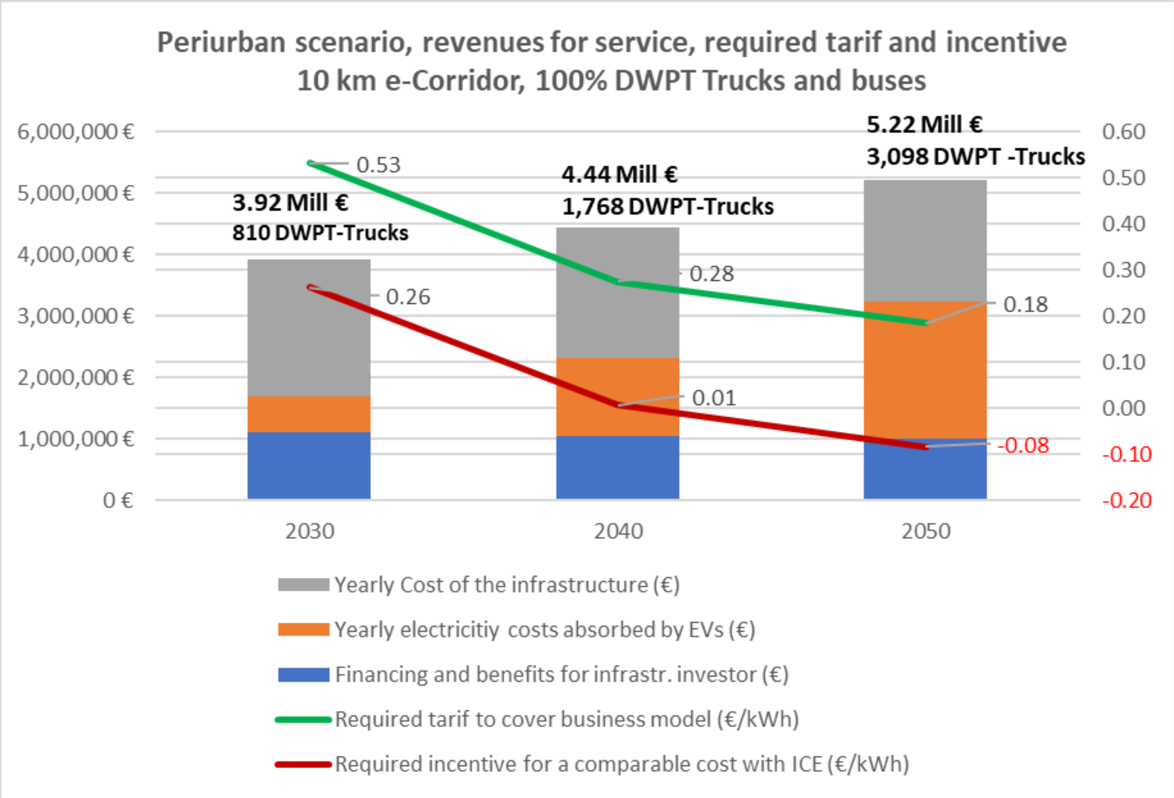

Figure 5. Summary of yearly cost in e-Launchers, required tariff and proposed incentive (Periurban Scenario)

The periurban scenario is addressed to DWPT heavy vehicles making daily trips in the surroundings of big cities or among nearby cities. The e-Launchers length is not as big as in the motorways and was fixed to 10 km. The average speed is 60 km/h instead of 80 km/h due to the usual traffic congestion close to the biggest cities. With around 1,800 DWPT heavy vehicles, n this scenario, the breakeven point is reached in 2040 compared with expenses of equivalent diesel trucks and buses. In this scenario, e-Launchers are designed for a range extension of the common autonomy of such vehicles at the time they will be deployed (from 2030 on). The same DWPT heavy vehicles will likely cross the e-Launchers several times a day.

3.5.3 Urban scenario main conclusions

The urban scenario differs from the previous ones in the sense that it has been addressed to buses and the number of them keeps the same overtime. The only parameter that changes is the cost of the infrastructure. The analysis was done to calculate the TCO of a service in a city with 400 buses. The dynamic charging installation is not a single trench of several kms but small static and dynamic charging trenches at bus stops (972 in total). The results are provided below.

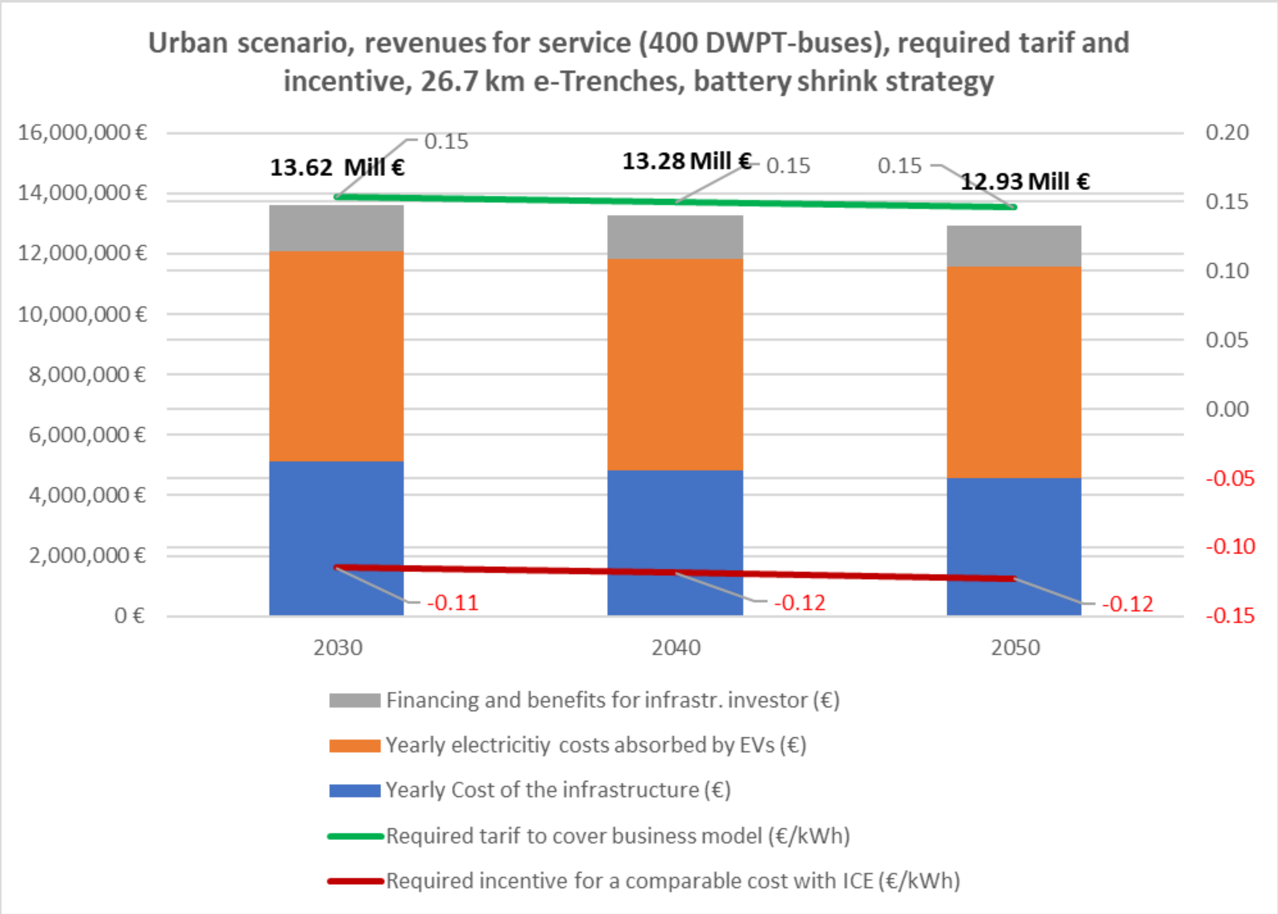

Figure 6. Summary of yearly cost in e-Trenches, required tariff and proposed incentive (Urban Scenario)

The figures differ from the previous ones in several aspects; company profits and debt are considered of 30% instead of 50% as it is a public service and it is designed just to cover costs. The electricity costs are kept constant as the number of DWPT-buses keeps the same. The cost of the infrastructure is reduced overtime due to experience curve gaining and the optimization of the construction processes. In addition, the required tariff to keep the service sustainable is being reached from the very beginning, as costs are improved over those generated by an equivalent ICE bus service. However, if we pay attention to next figure, we will see that the whole costs including garage infrastructure, town infrastructure and buses are above those of the same service with pure electric buses or fossil fuels buses. In this case we have entered in the account, the necessary infrastructures in garage that were not considered in the previous table; specifically, 150 kW ultra-chargers that will be commonly available in 2030 in the market.

Main Features 2030	Electric Infrastructure (Depreciation 10 years)						CAPEX Buses		OPEX Buses (10 years)		TOTAL
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 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 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							200,000	80,000,000	374,192	149,676,604	229,676,604

Table 22. Comparative Cost analysis (Plug in, DWPT and diesel buses) including infrastructure

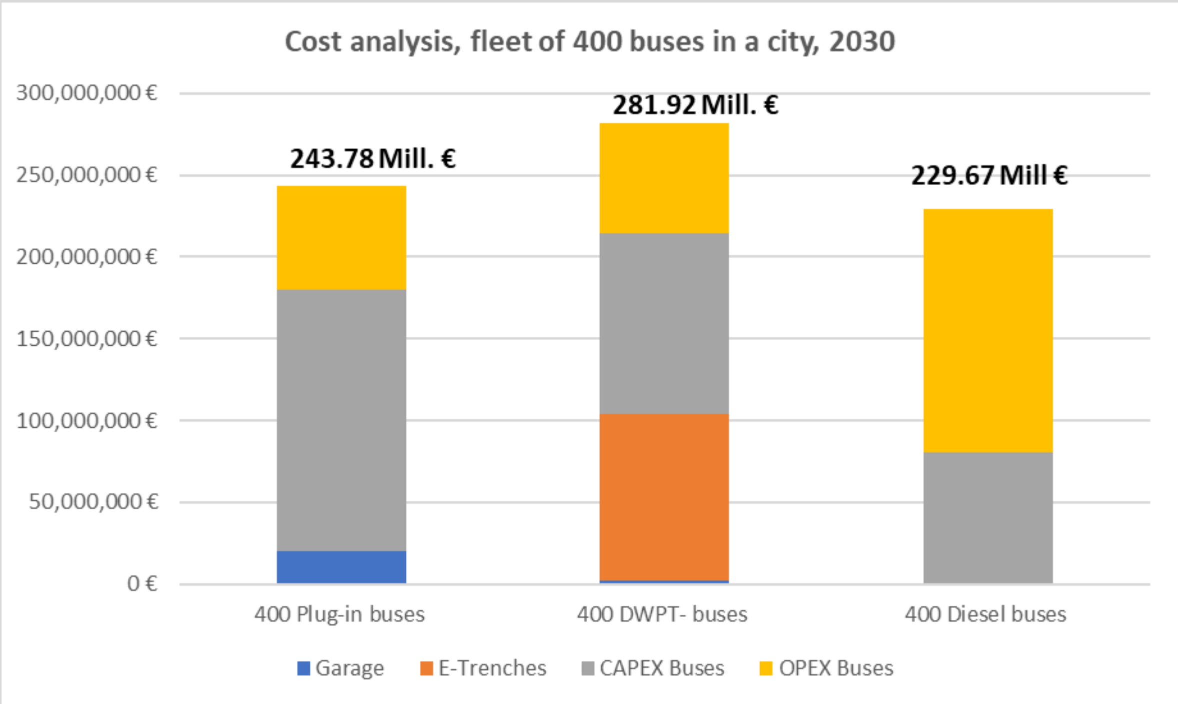

Figure 7. Comparable cost table in bus service (400 units)

The previous table and the figure show that if we don't consider the infrastructure costs in the city, the savings of the DWPT buses are very important in relation to the competing options. We have considered a depreciation period in the e-Trenches of 10 years, but this is something difficult to estimate. The progressive optimization in the e-Trenches manufacturing processes could lead to a significant TCO advance as there is a great margin for improvement. In addition, the analysis in Section 5.1 shows a reduction of CO_2 emissions if we compare ICE and DWPT buses.

4 BUSINESS MODEL FOR THE DWPT-EV DRIVER

4.1 Introduction to the point view of the DWPT-EV owner

The decision-making process for an EV owner to transform its vehicle into a DWPT or directly buy one equipped with such a system will depend on several conditions:

- Firstly, static and stationary wireless charging must be publicly accepted by the population. That implies to accept the wireless charging as the most common option, with the implication of extra regulation to ease the installation of such systems in parking facilities.
- People need also to feel safe with the high frequency radiation, something that will need some time to be accepted.
- The electricity costs will be slightly increased as the efficiency of the wireless power transfer rounds 80% instead of 95% for the plug-in devices, so for the sake of convenience users will accept paying a higher price for the service.
- Autonomous driving will be also a requirement as deviations in the e-Corridors from the centre line reduce the charging efficiency, so vehicles taking such e-Corridors will need to be perfectly aligned through autonomous driving.
- According to experts, the adaptation of a conventional EVs to static charging will cost 500 € solely in equipment on board for light vehicles and 2,500 € for heavy vehicles. We added 2,000 € in man power to such figures, so a light EV equipped with a coil for static charging will cost roughly 2,500 € and a heavy vehicle 4,500 €. The adaptation of these vehicles to dynamic charging will increase the cost in 1,500 € for the light vehicle and 4,500 € for e-trucks or e-buses. Thus, the total increase in costs to transform a light EV to dynamic charging will be 4,000 € and 9,000 € for heavy EVs.
- If this is the case, all end-users accepting these extra costs, will check if there are e-Roads close to their area of activity or if they will be able to use the e-Roads daily in long trips. Then the tariffs to be paid in the charging process must be affordable enough to convince them to use the EV instead of the ICE one.
- Another important aspect is the evolution of competing technologies; dynamic charging is currently not possible at high power transfer figures (admitted limits are likely 50 kW for light vehicles and 100 or 150 kW for heavy ones). If ultra-chargers with 350 kW are finally introduced in the market and users may charge any vehicle in less than 15 minutes at an affordable price, dynamic charging may lose interest. The amount of energy captured from the grid depends over all (apart from the power transfer) in the time one stays within the

e-road, so the slower one drives, the higher one is charged and in relation to that is the range extension or autonomy one gets.

Then, capturing sufficient energy requires a slow speed, which in turn supposes the same time losses than if one stops at an electroliner for the same period, but charging three or four times the energy. This concept is explained in the following figure.

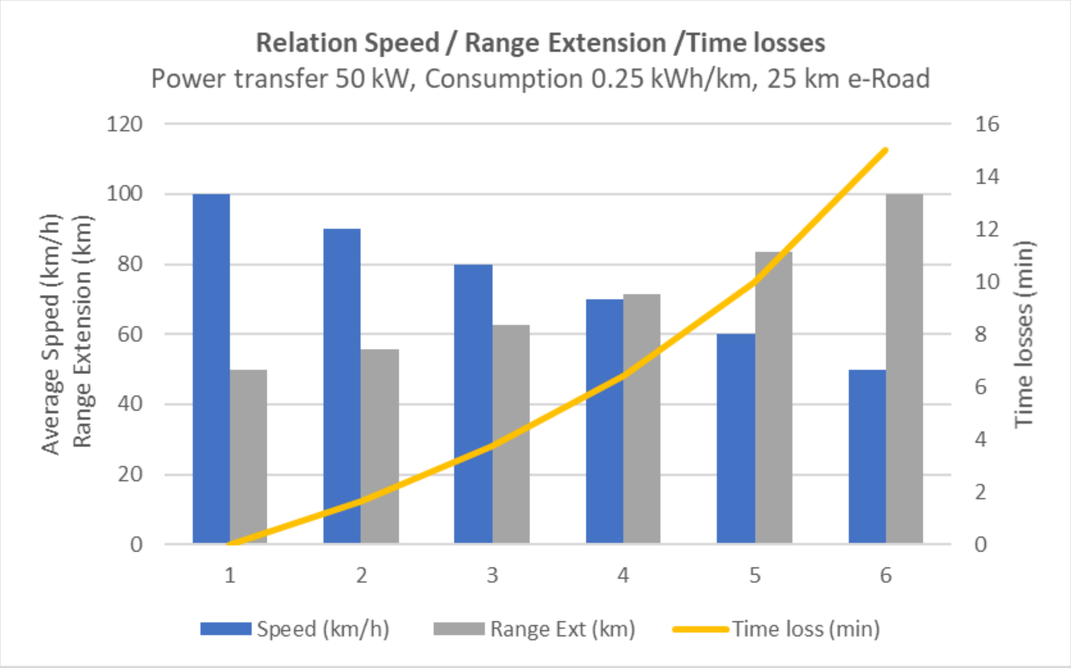

Figure 8. Relation between speed, range extension and times losses

In this example, a light DWPT-EV (with 0.25 kWh/km consumption) at 100 km/h gets a range extension of 50 km in a 25 km e-Corridor. If we reduce the speed to 50 km/h, we double the range extension to 100 km, but we lose 15 minutes. If the battery capacity is 85 kWh providing 400 km autonomy, and we find an ultra-charger of 350 kW, we will recharge the vehicle in the same 15 minutes with 400 additional km (four times the charge of the dynamic corridor). If the ultra-charger is of 150 kW (already in the market) we will charge almost 200 km in 30 minutes or the same 100 km in the same 15 minutes. The conclusion is that the evolution of the charging systems and the speed of deployment is the biggest threat to this technology.

In the next tables and figures, we will assume that users cover a reference distance every day and that an e-Corridor or an e-Launcher is operative in the middle of the trip and that this driving profile is repeated daily during a year. The analysis compares TCO between a DWPT-EV and an ICE car. We also include the TCO of a Plug-in car that stops and charges halfway through the trip

with an ultra-charger just for the extra range extension given by the e-Corridor. The analysis is repeated with and without incentives in the dynamic charging process.

4.2 TCO calculation for a user of DWPT light Vehicle in the Motorway Scenario

We first provide a table with all data used to compare three types of vehicles using different technologies. The three vehicles are; a DWPT reference vehicle, the equivalent electric vehicle with the same battery size with the same capacity without wireless charging equipment but equipped to charge plug-in in a 150 kW electroliner in the middle of the trip, and another equivalent ICE car. Costs were taken from the comparison of recent vehicles of similar power and characteristics slightly projected to year 2030. Electric consumptions were provided introducing an average driving profile for motorways (by POLITO) although the trench of the e-Corridor is theoretically driven at a constant speed (80 km/h, in the case of light vehicles). CO_2 emissions were also calculated by POLITO using the same driving mission. Base data for calculations is included in the next table.

Comparison / RANGE EXTENDER ESTRATEGY **LIGHT VEHICLES** MOTORWAY

Ref.DWPT-Light Vehicle / EV with ultracharger			Reference Light Vehicle ICE gasoline		
VEHICLE AND INFRASTRUCTURE MAIN PARAMETERS					
Vehicle Battery autonomy	400	km	Vehicle autonomy	902	km
Vehicle Battery capacity	89	kWh			
Engine power	150	CV	Power	129	CV
E-Road length	25	km	Consumption	5.1	l/100 km
E-Road billable Power transfer	50	kW	Tank	46	l
Average speed in e-Corridor	100	km/h	Cost fuel	1.30	€/l
Absorbed electricity in e-Road	33.0	kWh			
Range extension after e-Road	52.00	km			
Total range distance	452.0	km			
Average Consumption TTW	0.27	kWh/km		0.60	kWh/km
Average Consumption WTW	0.79	kWh/km		0.71	kWh/km
Total Consumption in range	122.04	kWh	Fuel in range	271.20	Kwh
CAPEX					
ACQUISITION COSTS					
Life time	10	years		10	years
Adquisition basic cost	**31,600**	€		**24,050**	€
Adaptation plug-in to WPT in vehicle	2,500	€			
Adaptation WPT to DWPT in vehicle	1,500	€			
Total Acquisition Costs	**35,600**	€			
km /year	20,000	Km/y		20,000	Km/y
Total Km	200,000	km		200,000	km
INFRASTRUCTURE COSTS					
Plug in charger	1,200	€			
Adaptation parking to WPT	2,500	€			

OPEX					
MAINTENANCE COSTS					
Yearly maintenance	928	€/y		1,392	€/y
Battery (evey 10 years)	0	€		0	€
Total cost maintenance (10 y)	9,280	€		13,920	€
INSURANCE COSTS					
Insurance/year	800	€/y		800	€/y
Total Insurance (10 y)	8,000	€		8,000	€
CONSUMPTION ELECTRICITY / FUEL					
Cost electricity at home	0.12	€/kwh	Gas Consumption Costs	0.066	€/km
Cost in ultra-charger	0.24	€/kwh			
Cost electricity in e-Road (no incentive)	1.16	€/kwh			
Cost Full charge at headquarter	10.7	€			
Cost charging in e-road (no incentive)	38.33	€			
Total charging cost electricity in range	49.01	€	**Cost Gasoline in range**	29.97	€
CO2 emissions	491.48	gr CO2/kWh		293.33	gr CO2/kWh
CO2 emissions	132.70	gr CO2/km		176.00	gr CO2/km
TOTAL EMISSION IN RANGE DISTANCE	59,980.40	grCO2		79,552.00	gr CO2

Table 23. Base data for light vehicles in the motorway scenario (CAPEX, OPEX and emissions)

The reason to compare these three types of vehicles is adopted because the IC gasoline is the reference vehicle nowadays but the upcoming phase out till 2040 or 2050 will bring for sure new technologies to the markets; mainly completely clean vehicles; hybrids will be the intermediate solution. A competition will be then generated among hydrogen and fuel cells vehicles and pure battery vehicles. PEV will have to recharging options; conductive or wireless/dynamic wireless. In this report we analyse both options for PEV. HFC EV are excluded as they will be the most expensive although they have some great advantages like the power range.

From section 3.1.7, business model for the motorway scenario, we know that the tariff to cover the business models evolves from 1.16 €/kWh in 2030 to 0.31 €/ kWh in 2040. We estimated the progressive reduction of this tariff in parallel to the growth of the DWPT vehicles in the road and based on that assumption we also estimated the costs overtime in acquisition, maintenance, insurance, required charging infrastructure and consumption.

EVs charge at home at a rate of 0.12 €/ kWh and in the middle of the e-Corridor using an ultra-charger at a rate of 0.24 € /kWh just for the equivalent extender range that is reached by the wireless system. The cost of the wireless charging in the 25 km trench is equal to the absorbed energy multiplied by the mentioned tariff. Conventional ICE vehicles make such a trip using gasoline at a standard rate. All the costs are shown at present value year 2030.

The table below includes the DWPT-EV results, with and without incentives to partially reduce the required tariff to cover the business model of the infrastructure. It is important to mention that a "chicken and egg" problem is present in this sector, as due to the absence of dynamic

infrastructures (e-Roads) the less investment may be expected in EVs equipped with the DWPT system.

However, as mentioned, the adaptation of a WPT-EV (vehicle prepared for static /stationary charging) to dynamic is technically simple and not costly. In this sense, vehicles can be adapted progressively at the same time that the dynamic corridors are deployed. This adaptation includes:

- Continuous guiding / positioning system, which cannot rely, for example, on primary-side low-power excitation (as many static wireless charging systems do).
- (Adaptive) power ripple filtering, to take into account driving style and offset tolerances, in order to reduce ripple to the battery.
- Charging trigger system: As shown in a demonstration of the FABRIC French test site at Versailles in April 2017, communications cannot be used to switch the power in the road on / off; it must be something else.

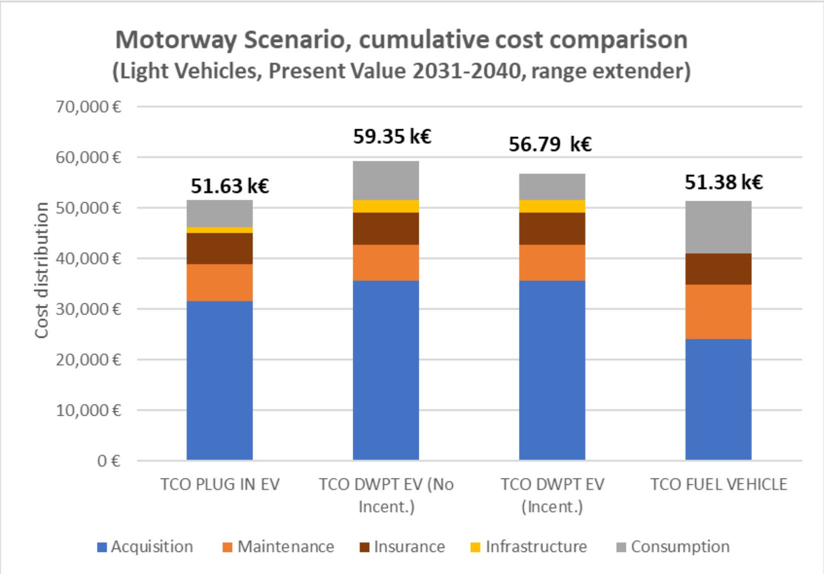

Figure 9. TCO comparison Plug-in, DWPT-EV (with and without incentives and Fuel Car)

The cost evolution over time is included hereinafter for an ICE vehicle, the pure EV, and the DWPT-EV without and with incentives.

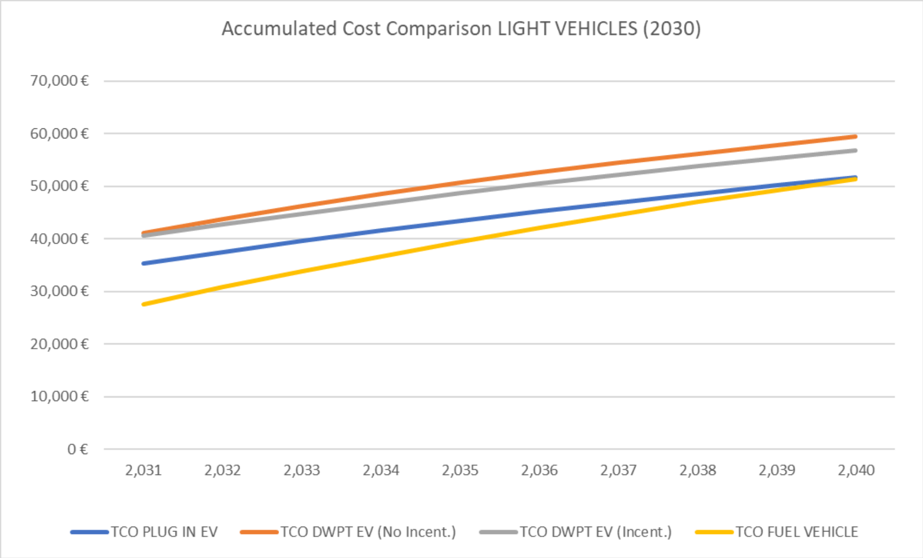

Figure 10. Accumulated cost comparison Plug-in, DWPT-EV (with and without incentives and Fuel Car)

The TCO associated with the DWPT light vehicles are above the other options even in the case that incentives will be provided. In 2050, a convergence of costs can be expected if the number of vehicles equipped with DWPT system follow the path that we have indicated. However, we don't present such figures because in 20 years' time, we can't figure out how the evolution of the competing technologies will be.

4.3 TCO calculation for a user of a DWPT Truck in the Motorway Scenario

Light vehicles on motorways currently represent 88% of traffic according to data from the Department for Transport UK[5], with the remaining 12% being heavy traffic. Based on that, we have also done the exercise for trucks in the motorway scenario. We follow again the range extender strategy. The pure e-Truck can charge at the garage in the headquarters with a rate of 0.08 €/kWh and also at the middle of the trip using an ultra-charger with a cost of 0.24 €/kW (rate used currently by Tesla). For the sake of the calculation, we assume that they charge just for the 78 km of range extension. The DWPT e-Truck initiates the trip fully charged and uses the e-Corridor to charge with 100 kW Power transfer at an average speed of 80 km/h.

[5] *Department for Transport UK, statistics 2016*

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	0.24	€/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	491.50	gr CO2/kWh		305.02	gr CO2/kWh
CO2 emissions	796.20	gr CO2/km		942.50	gr CO2/km
TOTAL EMISSION IN RANGE DISTANCE	261,153.60	grCO2		309,140.00	gr CO2

[1]This data comes from Global business model

Table 24. Base data for heavy vehicles in the motorway scenario (CAPEX, OPEX and emissions)

Then, we applied again the tariffs during charging arising from the business model of the infrastructure investor and their evolution overtime from 2031 to 2040. The TCO comparison is presented hereinafter.

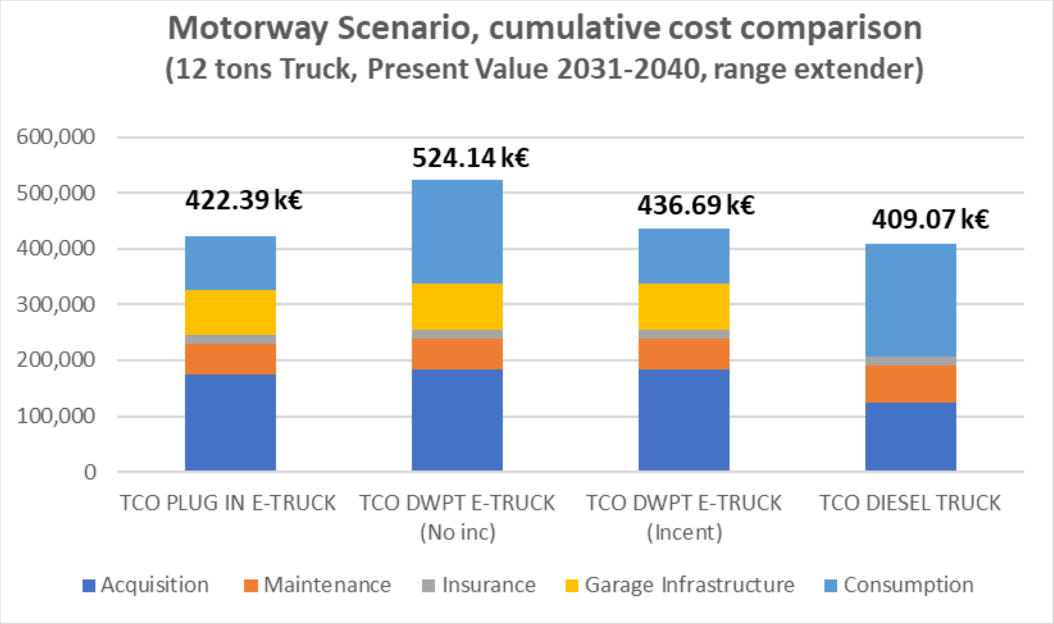

Figure 11. TCO comparison Plug-in, DWPT-Trucks (with and without incentives) and Diesel-Truck

The evolution of cost over time is as follows.

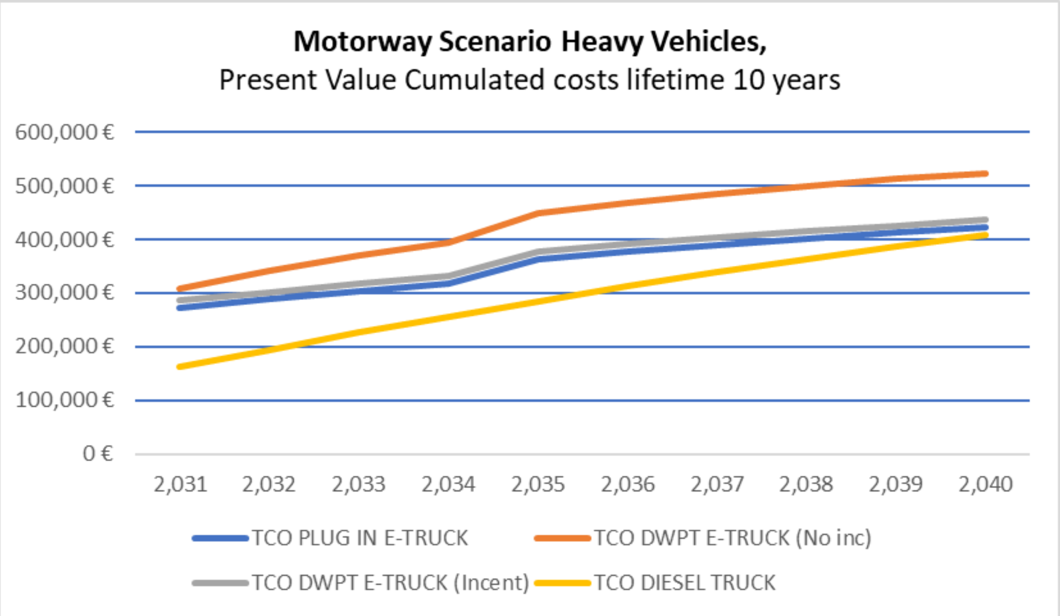

Figure 12. Accumulated cost comparison Plug-in, DWPT-Truck (with and without incentives) and Diesel Truck

As a conclusion, we can visualize in this case that the impact of the incentives to reduce the tariff is much more efficient than in the case of the light vehicles. This is due to the extended number of kms that a truck travels in a year (65,000 km instead of 20,000 km), which allows OPEX costs to offset the CAPEX earlier. Thus, after ten years, cost of diesel, pure electric and DWPT -EV are almost equivalent (in case the incentive is available).

4.4 TCO calculation for a user of a DWPT-Truck or short distance DWPT-bus in the Periurban Scenario

The TCO calculation for the Periurban scenario addressed to DWPT-trucks and short distance DWPT-buses is relatively similar to that of the Motorway one.

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	0.24	€/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	490.78	gr CO2/kWh		305.42	gr CO2/kWh
CO2 emissions	755.80	gr CO2/km		913.20	gr CO2/km
TOTAL EMISSION IN RANGE DISTANCE	240,344.40	grCO2		290,397.60	gr CO2

The main differences are that daily trips are shorter, and the e-Launcher is shorter as well (10 km instead of 25 km). Trucks and buses circulate around big cities or between close cities at an average speed of 60 km/h as periurban roads are usually much more congested than long distance motorways. These conditions make the business model different. The base data for calculation is provided hereinafter. The strategy continues to be the extender range.

Table 25. Base data for heavy vehicles in the periurban scenario (CAPEX, OPEX and emissions)

The TCO of the three options for the periurban scenario is presented below.

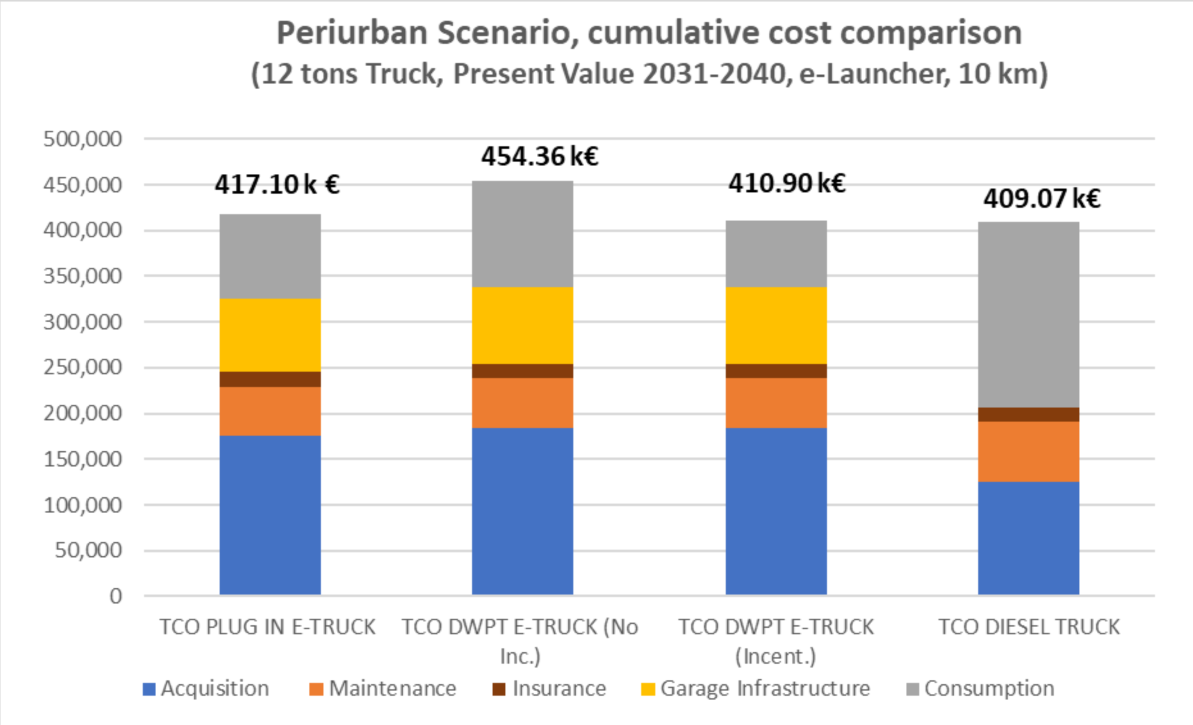

Figure 13. TCO comparison Plug-in, DWPT-Trucks (with and without incentives) and Diesel-Truck

The total costs during the life of a truck (considered to be 10 years) for the three options are very similar. This comparison does not include the infrastructure costs outside the garage where the DWPT Truck is clearly disadvantaged. In the garage we consider that both trucks (pure and DWPT) will require an ultra-charger to charge the vehicles after the working period, but in the case of the DWPT we have added the adaptation of the parking to the WPT and in the acquisition costs the transition from pure electric to DWPT. If we then sum up the high cost of the e-Launchers (without incentives), the TCO is clearly higher. In the case of the plug-in trucks we are also considering one charging process per trip using a commercial ultra-charger with a tariff of 0,24 €/ kWh. Nevertheless, the tariff when using the periurban e-Launcher moves from 0.53 €/kWh in 2031 to 0.28 €/kwh in 2040, clearly superior and with a bigger power transfer (150 kW instead of 100 kW) for the same range extension (so the necessary charging time is less). If we give incentives to the tariff until the number of trucks charging daily might be sufficient, we will see that costs converge. This will happen approximately in 2045 when the tariff will be moved to 0.24 €/kWh without tariff. The reason why 0.24 €/ kWh is the price for the ultra-chargers in public

electroliner, can be explained easily because that is the exact price that equals cost of electricity with cost of diesel (according to our calculations).

The cumulative costs in case any of the three types of trucks shall be acquired in 2030 are presented below.

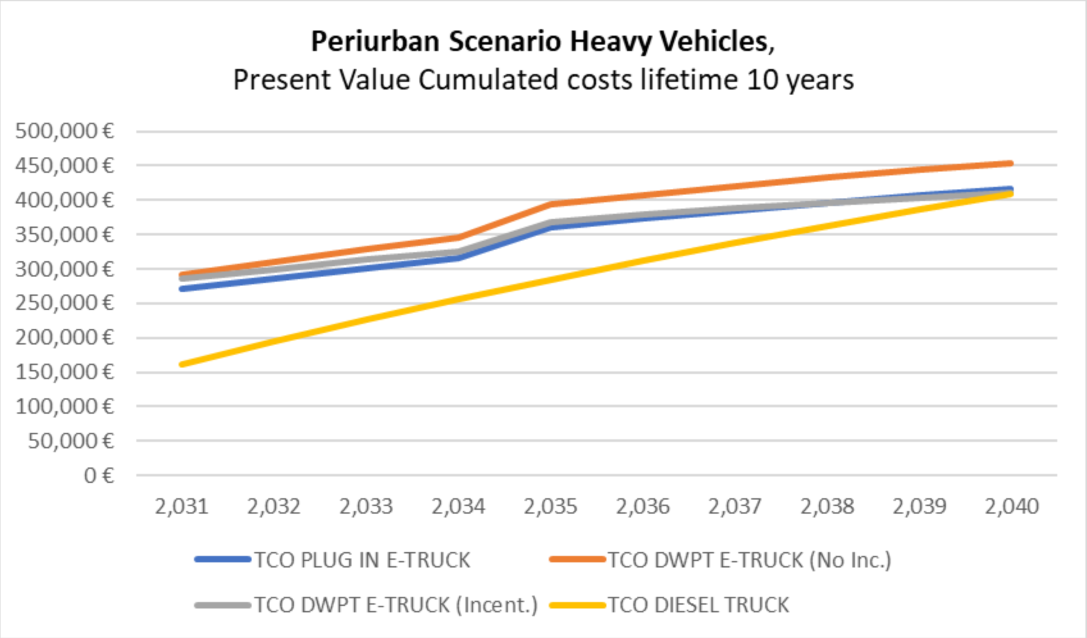

Figure 14. Cumulative costs for plug-in, DWPT and diesel heavy vehicles in the periurban scenario

DWPT (with incentive), plug-in and diesel converge in costs after 10 years. This does not happen for the DWPT (without incentives), although in 2050 the situation will be much closer.

4.5 TCO calculation for a user of a DWPT-Bus in the Urban scenario.

The urban scenario is different from the previous ones. The number of buses is assumed the same in 2031 and 2040 (400), so the traffic flow keeps constant from the very beginning and the required tariff does not needs incentive (if we just consider the DWPT-bus compared with the pure electric and the diesel one and the garage required infrastructure (150 kW ultra-charged at headquarters). In this case, the cost of the electricity when charging will not be 0.24 €/kWh as in previous cases when you charge (plug in) outside the garage, because you always charge in the garage, so the cost remains 0.08 €/kWh for the plug-in bus.

In addition, the strategy for the battery is now battery shrink. This means that the battery inside the buses will be reduced to the maximum, to lower the bus acquisition costs, and the extension of the range will be reached through e-Trenches at bus stops.

The table of assumptions is presented below.

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	485.54	gr CO2/kWh		305.46	gr CO2/kWh
CO2 emissions	538.95	gr CO2/km		910.26	gr CO2/km
TOTAL EMISSION IN RANGE DISTANCE	168,799.14	grCO2		285,093.43	gr CO2

[1]This data comes from Global business model

Table 26. Base data for buses in the urban scenario (CAPEX, OPEX and emissions)

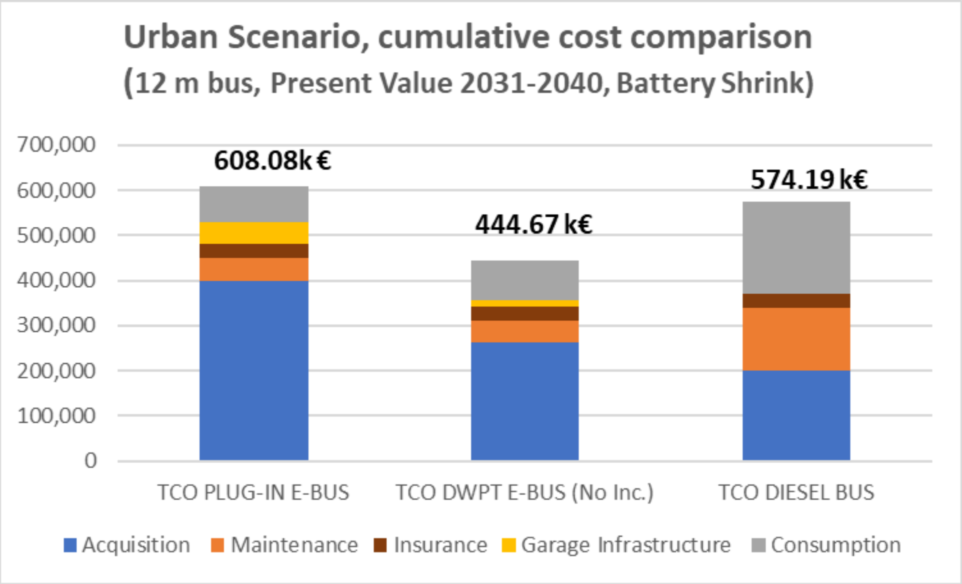

Figure 15. TCO comparison Plug-in, DWPT-buses (no incentives required) and Diesel-Bus

Be aware that due to the high number of buses and the number of daily rounds passing each bus stop several times, the required tariff to sustain the business model is lower than the equivalent for the diesel bus. So, it is clearly cheaper to use the DWPT-bus than any other option in this scenario. However, the figure does not include the costs of the infrastructure outside the garage (e-Trenches).

5 SOCIAL COST-BENEFIT ANALYSIS

As indicated in Section 2, the social cost-benefit analysis gives an account of the total economic effects of a large-scale on-road charging deployment on all aspects relevant to the society and can be considered as the viewpoint of the administrations. The social cost-benefit analysis relies on the addition of positive factors and the subtraction of negative ones to determine a net result.

In this analysis we tried to present the main figures for each scenario (costs, fuel savings and CO_2 avoided emission) and then introduce other aspects in the balance that could be considered by an administration before taking an investment decision (health, noise, safety…).

In the next sections, we have introduced the effects of installing an e-Road during one year in a given area considering a number of DWPT vehicles crossing it. We have calculated the following variables in years 2030, 2040 and 2050 for each of the given scenarios:

- Cost of setting up a conventional road with the same length than the e-Road (Present Value in the year indicated, 2030, 2040 or 2050 just considering CAPEX)
- Cost of the e-Road (present value including CAPEX and OPEX)
- According to the number of DWPT vehicles and type (light or heavy) crossing the e-Road for one year, calculation of the fuel savings in relation to an ICE vehicle
- Again, according to such number of vehicles and the differences in emissions between ICE vehicles and the DWPT ones, calculation of the avoided CO_2 emissions

5.1 Cost-benefit analysis in the motorway scenario

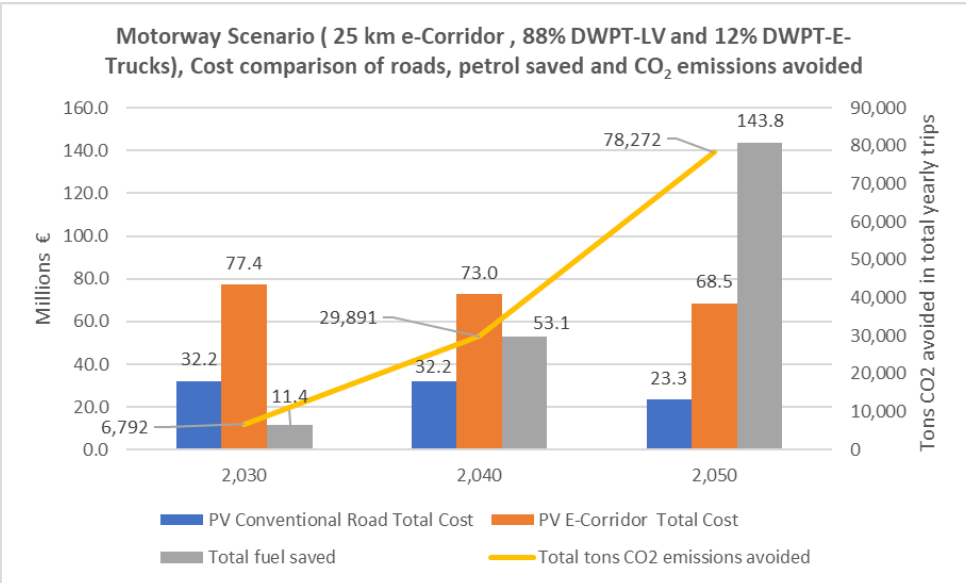

Figure 16. Cost comparison of roads expenses, petrol saved, and CO2 emissions avoided (motorway scenario)

The conventional road costs have been calculated with the same dimensions than the e-Corridor. During years 2030 and 2040 the e-Corridors are expected to be external to the main motorway in a dedicated lane. In 2050, one of the lanes of the motorway can be adapted for dynamic charging. That is the reason why the cost of the conventional lane is also lower in 2050 (the width is lower). This cost represents the cost of the construction and an additional 15% for OPEX is considered.

The cost of the e-Corridor is progressively being reduced as some experience is gained and due to the maturation process of the technology. This cost concept represents the total present value considering CAPEX and OPEX for 20 years (this figure comes also from D5.3.4)

We can see that every single e-Corridor of 25 km length saves 11.4, 53.1 and 143.8 million € in petrol expenses progressively in years 2030, 2040 and 2050 as soon as more DWPT vehicles cross them.

The CO_2 emissions avoided due to the substitution of conventional vehicles by DWPT are also significant; 6.8, 29.9 and 78.3 ktons per year.

5.2 Cost-benefit analysis in the periurban scenario

Although in this scenario the e-Launchers are only 10 km long, as they address to e-Trucks and intercity buses, their impact is very important in terms of fuel savings and emissions avoided.

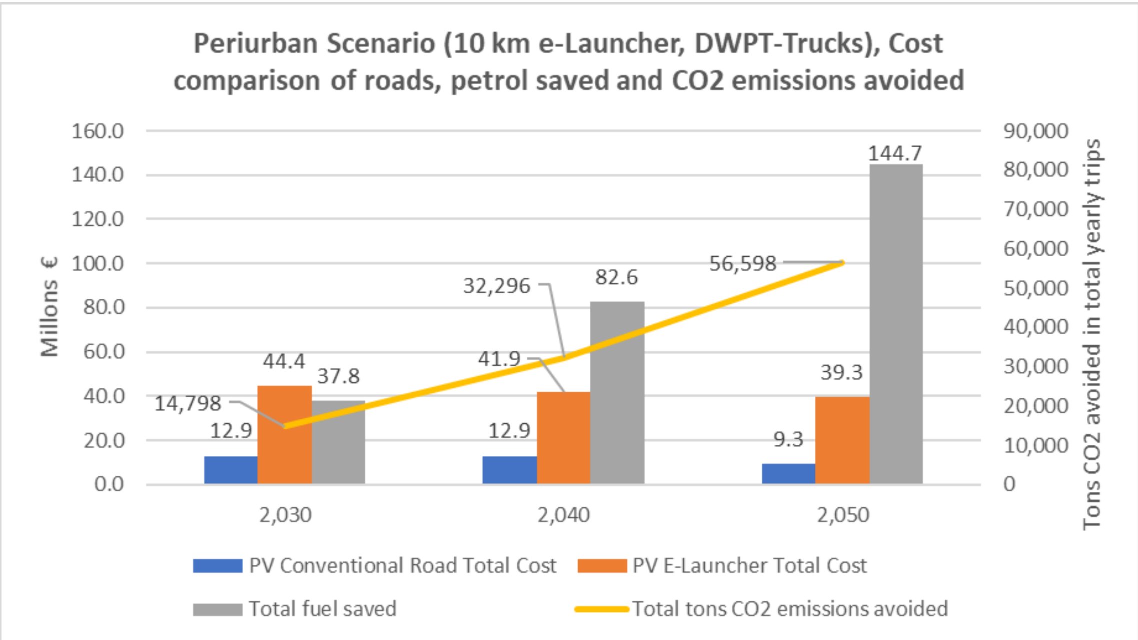

Figure 17. Cost comparison of roads expenses, petrol saved, and CO_2 emissions avoided (periurban scenario)

5.3 Cost-benefit analysis in the urban scenario

In the urban scenario, the cost of the e-Trenches is proportionally the most expensive. The cost of a total of 24.3 km of dynamic charging through the 972 e-Trenches sited in bus stops, rises to 91.9 million € whilst the 25 km of a single e-Corridor in a motorway reaches 77.4 million in 2030.

A detailed explanation of this cost differences is widely described in D5.3.4 Life Cycle Cost Analysis, but in summary the main reason is the increase in the number of electronic equipment distributed along the city. The explanation of the reduced fuel savings is due to the reduced number of buses crossing the e-Trenches yearly compared with the DWPT vehicles circulating in other scenarios. The same applies to the relatively low CO_2 savings. However, due to the low speed at the bus stops, the absorbed energy per e-Trench is at the same time proportionally very high and that was the reason why the tariff to make the business model sustainable was so small (0.15 €/ kWh) compared to other scenarios.

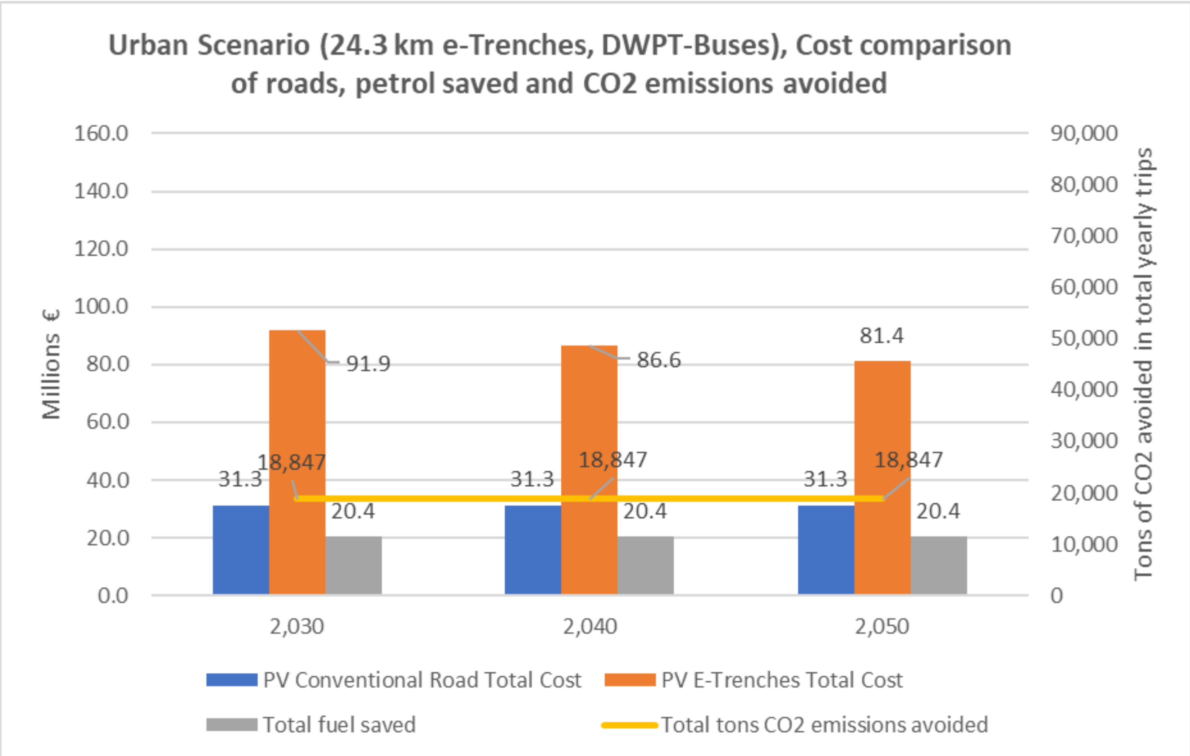

Figure 18. Cost comparison of roads expenses, petrol saved, and CO_2 emissions avoided (urban scenario)

5.4 Cost-benefit analysis global results

We include hereinafter, the deployment scenarios described in the e-Roads forecast made in deliverable D5.4.2. as regards the Supply chain. The number of cities was not determined; thus, we include here a rough estimation to visualize a potential impact with these figures.

FORECAST E-ROADS	2,030	2,040	2,050
E-Corridors	10	10	12
E-Launchers	80	120	200
E-Trenches cities	10	10	10

Table 27. Forecast of e-Road deployment

Based on these figures, we can figure out the total cost for the execution of all these e-Roads (5,249 million € in 2030, 6,623 million € in 2040 and 9,504 million € in 2050). The petrol savings and the emissions avoided have been calculated considering the cumulative figures as those e-Roads available in 2030 will continue in operation in 2040 and 2050, summing up the effects of the fuel and emissions' savings. 3,356 million € in 2,030, 17,987 in 2,040 and 63,106 in 2050 million € will be saved in petrol consumption. The avoided emissions will be 1.44 million tons in 2030, 7.43 in 2,040 and 25.71 in 2050.

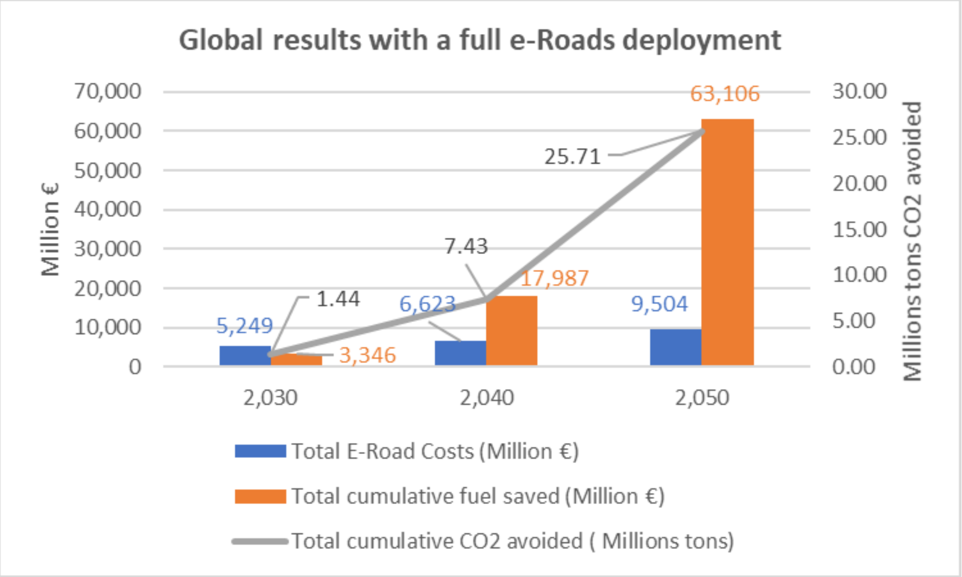

Table 28. Global results (costs, fuel savings and CO2 avoided)

5.5 Wider social cost-benefit aspects

The immediate costs and benefits of dynamic on-road charging have been assessed in the previous section. The focus so far has been on central stakeholder perspectives: the business case from the perspective of the operator, and the usage case from the perspective of a potential consumer of a dynamic charging-equipped vehicle. These are essential to assess the viability of on-road charging in practice, but they do not portray a complete picture of an implemented e-road system's effects.

If dynamic charging is to be overall beneficial, then its three promised benefits – that is, 1) greater operating efficiency due to reduced battery size, 2) reduced need for time-intensive static charging, and 3) reduced environmental externalities – need to outweigh the potential costs. While the benefits of operating efficiency have already been included in the business case analysis, the benefits of reduced charging time have not to the same extent. Moreover, while the carbon emissions for dynamic charging have been previously computed, these have not been converted to monetary equivalents for the purposes of cost-benefit analysis.

We instead address these last two issues in the following sections below. In these sections, we do not make a quantitative analysis of the costs and benefits in full, for reasons that will become clearer as we address each of the effects in turn. In short, the full costs and benefits will hang so critically upon the detailed characteristics and the specific context of a real-world implementation, that to analyse these without such context would most likely be misleading. Instead, we identify and assess the implications of a series of issues that are important to the perspective of a social cost-benefit analysis.

5.5.1 Internal Effects: Travel Time Reductions

The potential private benefits of a dynamic charging system are multiple. First, battery size could be reduced, leading to reduced purchase costs and improvements in overall energy efficiency. Second, range could be extended, providing access to a wider labour market and to a broader range of daily consumer options. Finally, top-up static charging time (in case dynamic charging is insufficient) could be reduced, possibly freeing up more time for productive activities. The actual balance of benefits is certain to be a mix of all of these and can vary across individuals due to both their choice of vehicle features, and their patterns of usage, but a minimum constraint is that additional net benefits outweigh the additional net costs of a dynamic-equipped vehicle, as discussed previously in Section 4.

In similar fashion, the benefits for heavy-duty vehicles, compared to electric-powered HDVs without dynamic charging capability, are likely to be a combination of reduced purchase cost and energy consumption, increased range, and reduced top-up charging time.

For long-haul shipments, the latter of these add up to fewer and/or shorter stops for charging, possibly to the point that they only coincide with the driver's own needs to stop (or mandatory breaks according to tachographs / regulations on drivers' hours).

Finally, for buses, compared to electric buses without dynamic charging capability, the benefits would first be cost and efficiency, second an increased potential route length (perhaps indefinite, as fixed-routes would be easy to equip sufficiently), and third, faster turnaround for top-up static charging.

5.5.1.1 Demand responses

In assessing the benefits of dynamic charging, it is necessary to make simplifying assumptions. The analyses in the FABRIC project have identified a set of assumptions appropriate for each of three infrastructure cases—motorway (LDVs & HDVs), peri-urban (HDVs only), and urban (buses only)—and for two stages of deployment corresponding to the years 2030 and 2050. These assumptions and their motivations have already been presented in Section 2, but in short, each scenario considers a fixed demand for DWPT-equipped vehicles, premised on the benefits outweighing the costs to the vehicle operator or private owner. These are then compared to an alternate scenario where no DWPT-capability is available, and under these circumstances the demand is also fixed.

In fact, the demand response to introducing DWPT will most certainly be sensitive to the costs and benefits that emerge. Therefore, the number of equipped vehicles will depend crucially on any subsidy used to ensure that DWPT is at least worthwhile for a target group. This demand sensitivity affects a social cost-benefit analysis by possibly diminishing, or inflating, the number of equipped DWPT vehicles, depending on the actual subsidy chosen.

There is also a demand response in the choice of how to absorb the benefits of dynamic wireless charging. In the business case analysis above, the agreed FABRIC assumptions lead to the benefits accruing from making an identical trip as previously, where the main benefit is estimated as the difference between the cost of refuelling by gasoline/gasoil and the cost of dynamic road charging. Contrarily, under the agreed FABRIC assumptions as shown above in Table 4, the base case used for comparison to the case of e-Corridors is one where DWPT-EVs replace non-DWPT EVs, not ICE vehicles. Hence the benefits would not be due to fuel costs, but rather due to the convenience of additional range. This convenience benefit is indeed included in the business case data inputs as in Tables 16, 14 and 18 as an "Autonomy range extension".

5.5.1.2 Static Charging Time Savings

The benefit of static charging time savings is not included in Tables 10, 15 and 19 in the calculations for required incentives for a business case.

This is because without assuming a more detailed travel preference structure of the users of this motorway, it is impossible to attribute this convenience to the correct combination of reduced vehicle investment costs, reduced stationary charging time, or increased destination value (from reaching further destinations). Perhaps more importantly, without knowing the detailed distribution of vehicles' overall trip distances and their respective charge capacities, it is impossible to determine what share of these vehicles are traveling under constrained range, thus requiring either static or dynamic charging, or traveling within range limits, thus making the mode of recharging irrelevant.

However, it is possible to establish a sort of benchmark for the value of static charging time savings, by attributing the whole convenience value to reduced charging time, then applying an appropriate value of time, and finally using this to calculate the value of time savings. We can then say that the realized benefits might be either below this level due to some vehicles either traveling well below their range constraints or stopping to charge for other reasons (stopping to eat, stretch legs, etc.), or alternatively the overall benefits could be greater than this level due to further optimization between purchase costs, battery size, and reduced charging time. In computing these benchmark values, here, as in later sections, we use values developed and agreed by the Swedish Transport Administration's latest standard for cost-benefit analysis, known as *ASEK 6.1*[6], and converted into Euros at an exchange rate of 10 SEK = 1 EUR.

5.5.1.3 Heavy-Duty Vehicles on Motorways

We start with heavy-duty vehicles in the motorway scenario. The estimated range extension is approximately 78 km. This is due to a charge of approximately 114 kWh over the 25 km length of motorway. To achieve an equivalent charge would require a stationary charging event, with a power transfer rate of 100 kW, would require about 68 minutes of charging time, although it would cost about €3.96 less (with subsidized tariff). Assuming an average load of 20 tonnes and an average travel time value of €4.80 per tonne-hour, the value of reduced charging time would be about €37.50 per traverse.

[6] Trafikverket (2016). "Analysmetod och samhällsekonomiska kalkylvärden för transportsektorn: ASEK 6.0" (Analysis method and social cost-benefit analysis values for the transport sector), Borlänge: Trafikverket, the Swedish National Transport Administration.

5.5.1.4 Light-Duty Vehicles on Motorways

Performing a similar calculation to light-duty vehicles, we can use a stand value of time per vehicle of €17 per hour for light-duty vehicles in the motorway scenario. To avoid a 15.63 kWh charging event, which would take 19 minutes at 50 kW, would save the driver a time value of €5.31 per traverse.

5.5.1.5 Heavy-Duty Vehicles on Periurban Roads

The calculation for heavy-duty vehicles in the periurban road scenario is similar to the calculation on motorways. A range extension of 21 km over the 10-km length of e-Launcher would be equivalent to about nine minutes of static charging, which for a 20-tonne load and a value of tonne-time of €4.80/tonne-hour would be worth approximately €15.00 per traverse.

5.5.1.6 Buses in Urban Areas

Finally, in the urban scenario, buses are outfitted with dynamic charging capability, which is used in relatively short stretches to minimize the need for static charging during constant use on a fixed route. The potential travel time savings are due to increased refuelling turnaround, and hence greater route frequency and shorter waiting times. Here, we do not calculate the value of time savings, since the valuation is substantially more complex than for the previous cases, but instead we summarize qualitatively the propagation of value through to public transport users.

A reduced turnaround time is important for bus operations because it enables more frequent service using the same number of vehicles. While this is a necessary condition for greater frequency, it is not sufficient: driver time need also be allocated for higher frequency, which could be achieved through either shorter breaks or an increase in allocated shifts. (Alternatively, an operator could choose to use shorter turnaround times to reduce vehicle operating costs while maintaining the same shift allocation and bus service frequency.) If an increase in frequency is achieved, then the benefits to travellers are firstly through reduced waiting time, the average of which can be computed as the difference between one-half the headway minus one-half the previous headway between bus arrivals.

There are also several possible secondary benefits. Firstly, reduced waiting time can lead to a slight increase in demand for buses, which, in turn, can improve the economic efficiency of the route and enable further improvements to service (the so-called Mohring effect[7]). Secondly,

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[7] Mohring, H. (1972): "Optimization and Scale Economies in Urban Bus Transportation", American Economic Review, 62, 591–604.

increased frequency can help to reduce the common phenomenon of “bus bunching”, leading to enhanced reliability for all users[8].

Overall, the user benefits of dynamic charging for buses will depend on the scale of infrastructure. For a small distance of dynamic charging per route cycle, the benefits are likely to be quite small, and the secondary effects negligible. It is entirely possible that the greater share of benefits would be borne out in reducing battery size and improving vehicle energy efficiency, rather than reducing static charging time, and that operators would choose to do so. Alternatively, if dynamic charging were deployed sufficiently widely that no static charging was necessary, and if this coupled with autonomous driving so that driver shifts were not an issue, then frequency could be increased substantially and user benefits would be large. To quantify the benefits under these conditions, a specific case would be needed where the travel demand, and its responsiveness to travel time reductions, is well-understood.

5.5.2 External Effects: Emissions Reductions

In evaluating the emissions effects of dynamic road charging, it is essential to be clear about the base case. In most of the projected scenarios for dynamic road charging, it is seen as a potential replacement for static-charged electric vehicles. The main exception is long-distance transport on motorways, where internal combustion engines are likely to maintain a competitive advantage, although this advantage is also likely to be gradually eroded through improvements in battery capacity and electric engine efficiency.

Here, we assess the potential emissions reductions in comparison to the newest technology of internal combustion engines, which serves as a benchmark for what savings could be achieved. It is important to be aware, however, that by choosing this base case, the results represent the benefits of electric vehicles in general, provided they are sufficient for the scenario under consideration, and not necessarily dynamic charging in particular. For example, the results for motorways are applicable not only to dynamic-charged electric vehicles, but also to static-charged electric vehicles to the extent that they can be seen as viable on motorways.

5.5.2.1 Local Air Quality

The value of direct, local-area emissions reductions depends strongly on the exposure level of populations to the roadway of concern. As such, for inter-urban roadways, the exposure (per km

[8] Daganzo, C.F. (1990). “A headway-based approach to eliminate bus bunching: Systematic analysis and comparisons”, Transportation Research Part B: Methodological, 43(10), 913-921.

of roadway) will generally be the lowest, with the larger part of motorway alignments avoiding population centres. Emissions-reductions are likely to have a greater benefit in periurban and urban areas, where shifts in heavy-duty vehicle and bus technology can reduce direct exposure of populations to especially the emissions of particulate matter (PM) and of sulphur dioxide (SO_2). PM is associated with a wide variety of serious health risks, especially fine particulates (less than 2.5 microns in diameter). Volatile organic compounds (VOCs) and nitrous oxides (NO_x) are also a concern but lesser so at this level.

A conversion from internal combustion technology is likely to essentially eliminate emissions of NO_x, VOCs, and SO_2. However, while PM emissions will be substantially reduced, some will remain due to the continuing wearing of tires and brakes.

5.5.2.2 Regional Air Quality

At the regional level, the relative importance of the different emissions types shifts from PM and SO2, to NO_x and VOCs, which react to generate Ozone (O_3). The generated ozone is more mobile than PM and SO_2, and hence its effects are less localized to the points of NO_x and VOC emission. Reductions in ozone concentrations can lead to lowered levels of lung-related health risks, especially for those with pre-existing conditions such as asthma.

5.5.2.3 Global Greenhouse Gas

The detrimental effects of greenhouse gas emissions on global climate, and its secondary effects on ecosystems in general, are widely recognized. In the FABRIC project, the potential reductions in CO2 emissions from dynamic charging, compared to internal-combustion vehicles, have been estimated and reported above in Sections 5.1 to 5.4. How to value these savings, in practice, is complicated by the variety of policies already in place to reduce carbon emission. For example, many European countries place a carbon tax on industries consuming petroleum-based products, while at the EU-level, all countries participate in a cap-and-trade system where a natural price emerges dynamically from the trading of a limited amount of emissions-rights.

One option to set a value at the implicit value emerging from these policies (the Swedish ASEK method, for example, uses the Swedish Carbon Tax as such a proxy[9]). However, an overview by

[9] Trafikverket (2016). “Analysmetod och samhällsekonomiska kalkylvärden för transportsektorn: ASEK 6.0” (Analysis method and social cost-benefit analysis values for the transport sector), Borlänge: Trafikverket, the Swedish National Transport Administration.

the OECD[10] has found most carbon policies to set too low of a value (mostly around €30/tonne) to fully capture carbon costs. These costs have been found instead to be closer to €40/tonne[11] or €50/tonne[12]. Further, emissions compensating costs are likely to increase toward the future years chosen for the FABRIC analyses. Hence, we choose here to adopt a price at the upper end of these prices, €50/tonne, or €0.05/kg.

5.5.3 Wider aspects of e-Road deployment

In the context of this final assessment of the potential of e-Roads for deployment in society, it is important to link the discussion to wider effects that have been mentioned in assessments of results and insights gained during the FABRIC project. Most of these are of a qualitative nature, and listed to provide context, rather than definitive quantified effects.

5.5.3.1 DWPT synergies with Autonomous Driving

Within FABRIC, the focus has been on the use of DWPT with vehicle types as we know them at the time of the project. However, over the course of the project, the advancement of autonomous driving has been very significant.

While the two technologies are in principle unrelated, there is one intersection that repeatedly recurred in discussions are the deployment scenarios.

Autonomous driving in a scenario where mobility-as-a-service (MaaS) is offered in a wide societal deployment is relatively independent on the exact route taken. Particularly in large metropolitan areas, travellers are known to be more and more open to quickly switching modalities, depending on real-time travel advice (for reference, please consult the final reports of the EU FP7 projects PETRA and MyWay). Particularly the PETRA project (www.petraproject.eu) proved that the addition of planning under uncertainty to travel planners suddenly makes shared, public and service-based transportation an attractive alternative over the own car.
A known discussion point for autonomous vehicles in MaaS is the need for replenishment of energy for which it needs to travel to a destination with either charging or refuelling infrastructure. This takes valuable time out of the duty cycle of the vehicle, particularly when slower charging

[10] OECD (2016), *Effective Carbon Rates: Pricing CO_2 through Taxes and Emissions Trading Systems*, OECD Publishing, Paris.

[11] Smith, S. and N.A. Braathen (2015). "Monetary Carbon Values in Policy Appraisal: An Overview of Current Practice and Key Issues", *OECD Environmental Working Papers*, No. 92, OECD Publishing, Paris.

[12] Alberici, S. et al (2014), "Final Report and Annex 3" in *Subsidies and costs of EU energy, Ecofys by order of the European Commission*.

techniques are used for electric vehicles. In such a scenario, one could foresee a demand for DWPT deployments from future operators of MaaS autonomous vehicles in taxi-like duty. This is different from regular taxis with a driver since the autonomous character of the vehicle is likely to put constraints on charging and refuelling options.
The magnitude and scale of such demand is however fully unpredictable at this point in time, as companies like Uber and Ola are experimenting with MaaS-like taxis and first fully autonomous vehicles at the same time, but demand patterns from the public are highly instable, as are the regulatory systems across Europe and the globe

5.5.3.2 Changing ownership models

The success of car-sharing and collective car models across Europe has earned these models a small but significant place in the vehicle fleet. The use pattern of shared cars is typically for short trips within the region of the car sharing community or service. This provides a very specific opportunity for deployment of wireless charging, both static at reserved parking spots for shared vehicles and dynamic within a region. It is unlikely that shared cars are numerous enough to justify DWPT deployment, but it could provide a very specific niche that could serve as an accelerator on top of one of the deployment scenarios that come out positive from the FABRIC analysis. Particularly inner-city options could benefit from piggy-backing of car-sharing use of DWPT infrastructure.

5.5.3.3 Health

As stated in the early feasibility study at the start of the FABRIC project (D5.2.1), the health concerns of DWPT extend beyond the beneficial reductions in CO2, NOx and PM10 emissions.

Within FABRIC, the solutions tested have all been wireless, but the general e-Road concept also includes conductive solutions. For conductive solutions, the particles generated from the contact between a pantograph and overhead wire or integrated rail in the road need to be assessed. This is currently ongoing in the Swedish e-Road project at Arlanda airport near Stockholm. Initial tests in laboratory conditions have shown very little fine particles to be generated, but this needs confirmation on size, nature and spreading patterns from real world deployment. Results are expected in 2019.

For wireless solutions, the spreading of EMF and EMC is a very relevant question due to its potential health risks for humans. As described in FABRIC D5.2.1, several countries have

introduced limits for human body exposure[13]. The fact that wireless charging also needs to comply with the standard defined by the International Commission for Non-Ionization Radiation Protection (ICNIRP) is also very relevant[14]. The HEMIS project[15] has however showed that "The current situation regarding automotive EMC standards is lacking in test limits and methodology to fully account for the different electromagnetic environment generated by a fully electrical vehicle (FEV)" (p. 43). Regarding EMF, the same report concludes that there is a general recommendation, but at the time of the study (2013) were "no relevant product standards that specify how to measure in-vehicle field levels and interpret the results in terms of the recommended exposure limits" (p.44), but that a proposal was recently submitted, "however, methods for assessing electromagnetic field exposure will be required for both vehicle occupants and bystanders." (p.44).

Within FABRIC, measurements have been done on EMF and EMC exposure, as well as earlier in the SLIDE-IN project. None of these show levels in the direct environment that exceed boundary levels for direct exposure, however there is still a lack of clarity on standardization of measurement methods and their relation to regulations and laws in the EU.

Furthermore, as expressed by experts from the Swedish radiation agency (Strålsäkerhetsmyndigheten) in preparation for FABRIC D5.2.1 and D5.2.2, the accumulated exposure over time, and the accumulation of EMF /EMC in an urban context with highly increased levels of wireless power transfer on roads leads to new questions for research on the health consequences. Particularly vulnerable groups and patients with implants (a rapidly developing segment in health care) need to be assessed.

[13] Musavi, F., Edington, M., & Eberle, W. (2012, September). Wireless power transfer: A survey of EV battery charging technologies. In Energy Conversion Congress and Exposition (ECCE), 2012 IEEE (pp. 1804-1810). IEEE.

[14] Suh, I-S; Kim, J (2013) Electrical Vehicle On-Road Dynamic Charging System with Wireless Power Transfer Technology, http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6556258, accessed Aug. 9, 2015

[15] HEMIS consortium (2013) D5.1-2 Current EMC standards and gaps detected regarding FEVs http://www.hemis-eu.org/HEMIS_314609_D5-1_v2.pdf, accessed Aug. 10, 2015

5.5.3.4 Comfort and driver behaviour

FABRIC's research on ICT solutions and driver support systems focused on technical verification of the systems.

Victoria Swedish ICT and VTI have done a driving simulator study to assess whether it is possible for truck drivers to follow the alignment needed for different e-Road solutions and to assess their driver behaviour on e-Roads in general. A demonstration environment in a driving simulator was developed in order to test and evaluate e-Roads concepts and electric vehicles driving on e-Roads. A user study was conducted, where 25 drivers drove a 40 km long route, both with a hybrid truck on e-Roads and with a conventional truck.

Driving on e-Roads showed no remarkable difference on driver's experience of safety and aesthetics or the driving behaviour compared to no e-Roads. The exception was average speed which was 2 km/h higher when driving on e-Roads. The energy consumption decreased 35 per cent on e-Roads [16].

[16] http://vti.diva-portal.org/smash/get/diva2:860686/FULLTEXT01.pdf

6 CONCLUSIONS

FABRIC project has studied dynamic wireless power transfer (in motion) to electric vehicles and findings show that it is a technically possible option, although with a current limitation in relation to the maximum level of power transmitted. This level of power at present for light vehicle rounds 20 kW, however, the consensus of the technicians ensures that by 2030, this figure may perhaps rise to 50 kW. For heavy vehicles (HDV), the figure stands at 100 kW as the expected average value. Based on these initial criteria, three scenarios were selected in FABRIC where technology could make sense; the "Motorway" scenario, for light and heavy vehicles, with dynamic corridors of 25 km in length on general highways, the "Periurban" scenario for heavy vehicles on freeways in the periphery of cities or between two nearby cities with dynamic corridors of 10 km, and the “Urban” scenario which aimed at a complete fleet of city buses using dynamic chargers of only 25 m on all bus stops.

Without these indicated power levels, the extension of the autonomy in a corridor for example of 25 km will not be sufficiently interesting to justify the investment. According to the calculations made, this extension of autonomy would be approximately 50 km for light vehicles traveling at 100 km/h and 50 kW power transfer and 21 km for heavy vehicles traveling at 80 km/h and 100 kW power transfer level. In the periurban scenario, the extension of the autonomy will be about 14 km for heavy vehicles at 60 km/h. The range of autonomy obtained depends not only on the power transfer, but also on the time that the vehicle is charging in the e-Road and this time depends on the speed. The paradox is that to increase autonomy we need to go slower, but in that case, we lose the valuable time we want to recover by not stopping at a static charger. This is the main threat to the technology. If the ultra-fast static charging technology evolves to reach 150 kW or 350 kW through cooling, it will be more cost-effective to stop and charge than to run through an electric corridor, because in the end, you will load more in less time, and infrastructure costs will be avoided.

Another big problem for the technology is the need to have a critical mass of electric vehicles that run daily through the e-Corridors or otherwise the e-Corridors will not be profitable. The analyses carried out have been based on an estimate of a number of vehicles equipped with dynamic charging technology in the years 2030, 2040 and 2050 (based on an estimate of the penetration of electric cars in the market). Results show that only in the year 2050 with the expected amount of DWPT-EVs on road, may the public subsidies be withdrawn. It is therefore, as on many occasions, a "chicken and egg” problem; the non-existence of charging infrastructures will discourage users to transform their vehicles (already adapted to the static charging) to the dynamic charging (no matter how small the cost is) and the non-existence of vehicles equipped with this technology will discourage owners from investing in charging infrastructures (e-Roads).

To avoid this problem, at least with the heavy vehicles of the periurban scenario, pre-established contracts should be foreseen between the promoter and the users with commitments of passage and daily load. In general, an electric highway corridor can range between 2.5 and 4 times (between 2.5 and 4 million € / km) the cost of a conventional lane.

Regarding emissions, analysing the complete life cycle and comparing vehicles driven by fossil fuels and vehicles equipped with the DWPT system, there is a gain of around 30% in CO_2 emissions in light vehicles and 20% in heavy vehicles. This is rather low in the motorway and periurban scenarios since the size of the battery is the maximum possible. However, the scenario of urban buses is different, since what is sought in it is to reduce the size of the battery to the maximum (battery shrink strategy), whose capacity is replaced by the extension of the autonomy generated in the e-trenches. In this case, the emission reduction is 70%. Generalised, this means that DWPT is mostly relevant for vehicles that can utilize e-Roads through the majority of the route(s) travelled, and this fits special purpose vehicles and heavy vehicles more than general passenger cars.

Finally, the urban scenario is the most promising. It is based on replacing the entire fleet of conventional urban buses with DWPT-buses reducing the battery to the maximum and extending the range of autonomy through small electric trenches of 25 m, located in all bus stops. The analysis of this scenario shows that the TCO (Total Cost of Ownership) compared between a purely electric bus, a conventional one and a DWPT is favourable to the latter with a cost reduction of around 35% compared to its adversaries. However, if we add the cost of the infrastructure to the account, with the forecast made, the overall TCO would be higher than its competitors, (with similar costs) around 20%. However, this figure could be reduced with the experience curve over time.

In conclusion, dynamic charging is a technically viable technology, still with some uncertainties but it is threatened by competing technologies (ultra-fast chargers and cheap batteries). However, since the transition from plug-in to the static / stationary charging is highly probable and the transition between static and dynamic is relatively affordable, it is not a case that the technology can be ruled out in specific niches. The evolution of the cost of copper (main material of the coils) and fossil fuel will also influence the evolution of compared costs, and consequently, the potential ramp up.

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