FABRIC

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

Feasibility assessment for applying Solution 1 to other use cases

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TABLE OF CONTENTS

LIST OF TABLES

No table of figures entries found.

LIST OF SELECTED ABBREVIATIONS

ABBREVIATION	DESCRIPTION
BCU	Base Charging Unit
DoW	Description of Work
DWPT	Dynamic Wireless Power Transfer
DXX.X	Deliverable XX.X
EMC	Electro-Magnetic Compatibility
EMF	Electro-Magnetic field
EV	Electric Vehicle
FABRIC	FeAsiBility analysis and development of on-Road chargIng solutions for future electric vehiCles
ICT	Information and Communication Technology
LDV	Light Duty Vehicle
OEM	Original Equipment Manufacturers
TX.X.X	Task X.X.X
UC	Use Case
VCU	Vehicle Charging Unit
WP	Work Package
WPT	Wireless Power Transfer

REVISION CHART AND HISTORY LOG

REV	DATE	REASON
1	10/06/2016	Document structured (VEDE)
2	16/06/2016	Latest Qualcomm input
3	27/06/2016	Submitted for review
4	21/07/2016	Final version
5	14/10/2016	Additions from VEDECOM

EXECUTIVE SUMMARY

The inductive on-road charging prototype developed by Qualcomm acting as a VEDECOM subcontractor within the FABRIC project has been assessed for its feasibility in application to essential use cases defined for FABRIC, i.e. the one which can be considered as relevant to technological research.

Potential adaptations of the system and possible limitations have been identified in this theoretical feasibility study and the overall results are summarised below in the following bullets:

- Further ITS functions could be developed (routing, billing, mapping …), however given the technological issues, the efforts were concentrated on the actual demonstration of the main use cases.
- Interoperability between static, stationary and dynamic wireless charging will be demonstrated
- A two vehicle demonstration is also scheduled
- Some theoretical considerations will be developed in order to cover “other “uses cases to the FABRIC project, i.e.
    - Adaptation to heavy vehicles
    - Higher speeds (greater than 60 km/h)
    - Compatibility with other road users (motorbikes, pedestrian …)
    - General safety (animals …)

1 INTRODUCTION

1.1 General

D36.5 has been added as a Confidential Report in the list of Fabric deliverables further to the first period review (first semester 2015). The version submitted in July 2016 contains elements supplied by the Solution 1 system provider, i.e. with Qualcomm acting as a VEDECOM subcontractor.

It is important to bear in mind the contract signed between VEDECOM and Qualcomm (December 2015, prior to the first period deliverable review) does not mention explicitly (and could not) any direct input of Qualcomm to FABRIC Reports. Qualcomm was indeed firstly a partner of FABRIC project. However this company decided to withdraw from the project as a direct partner for IP protection reasons. Qualcomm finally accepted to supply a wireless charge system as a VEDECOM subcontractor. Qualcomm showed only some "high level" cooperation providing comments on deliverables, in particular the first version of D36.5.

As a matter of fact, an extensive contribution from Qualcomm on feasibility assessment for applying Solution 1 to other use cases cannot be expected.

However, this deliverable aims to present a theoretical feasibility assessment of applying an inductive charging solution (referred to as "*Solution 1"* in the DoW) to the other than FABRIC use cases. It presents Qualcomm "high-level" considerations and VEDECOM point of view.

1.2 Contribution to FABRIC objectives

This deliverable contributes to the objectives of FABRIC by addressing directly the technological feasibility and economic viability of dynamic on-road charging of electric vehicles.

Responding to a need to assess the potential feasibility of more extensive integration of electric vehicles in the mobility and transportation system, with a primary focus on dynamic wireless charging, as this enables the perceived drawbacks of on-board battery packs to be avoided.

1.3 Deliverable structure

Chapter 1 – introduces and describes the background and goal of the deliverable.

Chapter 2 – explains the methodology used and the reason why this route was chosen. The link to the other key deliverables is also explained.

Chapter 3 - contains high level considerations from the original solution 1 provider (Qualcomm).

Chapter 4 - contains a prospective feasibility study from “solution 1” system integrator (VEDECOM)

Chapter 5 – summarises draws the final conclusions.

Chapter 6 – contains the appendix (a VEDECOM investigation)

Chapter 7 - References

2 METHODOLOGY

2.1 Introduction

During planning of the task the Work Package 36 team jointly decided that use cases such as cars and urban environments, as well as the ones defined in D4.3.1should be assessed. This complies well with the description of the task set out in the DoW:

In D36.1, the dynamic solution tested by VEDECOM based on the Qualcomm static wireless charging is described. This solution was trialled in London in 2013. The concept solution was originally created for dynamic charging for industrial applications such as materials handling and is actively used in many car factories. Therefore on-road charging of EVs is a natural development. The innovation lies in the extension of the technology to higher speeds and to a more uncertain environment with varying vehicle speeds, heights of vehicle coil above road level, vehicle energy requirements and vehicle alignment. In addition, the control technology must consider maximum grid network power limits, and power quality requirements. Finally, the system must have the capability to transfer data such as vehicle ID for electricity payment, and information to the car's computer for advanced services for the driver such as range prediction.

In activity 3.6.1, the system has been adapted to meet the specifications agreed in WP3.4 and using the architecture determined in WP3.5. Since the vehicles will not have been designed to incorporate an induction pad, it may be necessary to consider more than one pad size to meet available mechanical package. (Full electrical integration will be performed in SP4.) Prototype systems will be manufactured for rig testing in WP3.7. These will not contain the power control required by the vehicle, but will be suitable for powering a dummy electrical load and for measurement of EMF emissions on a suitable rig.

In Activity 3.6.5 (D 36.5), VEDE and Qualcomm have:

- Recalled the uses cases to be demonstrated in the framework of FABRIC project
- Performed a feasibility analysis to extend solution 1 to other vehicles and use cases than the ones covered by the FABRIC project

2.2 Methodology for Feasibility Analysis

2.2.1 Use cases for the charging solution in the FABRIC scope

A collaborative approach was initiated by VEDECOM from M13 (Jan 2015) to M16 (April 2015) to complement the work undergone at very early stages of the project in T4.3 activities.

A wide consensus between the main involved stakeholders i.e. POLITIO, CRF, HITACHI, TUB and Qualcomm was reached on the definition of the most technological research relevant FABRIC use cases to be demonstrated. The common position can be summarized in the table here below:

UC No.	Use case ID	Use case name
8.	#1.8	Assisted charging – static
9.	#1.9	Assisted charging - stationary
10.	#1.10	Assisted charging - dynamic

Table 1 Essential use cases to be demonstrated.

These priorities actually match the priorities given by the DG RTD in the call FP7-SST-2013-RTD-1.

These use cases have been collaboratively reviewed by partners involved in the physical demonstration mentioned above in order to prioritize the relevance, optimize the complementarity of the demonstrations between test sites as well as resources available.
The other use cases were judged as “nice to have” developments, however not on the same level of research priority. These tests are proposed to be treated in the limit of available resources by each test site.

The reasons for this lower level of prioritization can be summarized in the table here below:

UC No.	Use case ID	Use case name	Reasons	Comment
1.	#1.1	Driver-owner registration	Already included in other EU funded projects (ELVIRE, ECOFEV …)	This feature will be fully implemented in the Italian test site
2.	#1.2	Logging in to the FABRIC interfaces – end users	Already included in other EU funded projects (ELVIRE, ECOFEV …)	This feature will be fully implemented in the Italian test site
3.	#1.3	User account management	Already included in other EU funded projects (ELVIRE, ECOFEV …)	This feature will be fully implemented in the Italian test site
4.	#1.4	Planning of a trip	Low priority in terms of research relevance	This feature can be done through the Web (not through the HMI)
5.	#1.5	Guidance to a charging facility	Low priority in terms of research relevance	This feature will be fully implemented in the Italian test site
6.	#1.6	Emergency charging	Already included in other EU funded projects (ECOFEV …)	This feature will be fully implemented in the Italian test site
7.	#1.7	Guidance to destination	Low priority in terms of research relevance	This feature will be fully implemented in the Italian test site
11.	#2.1	EV charging supply management – high level	Interfaces will be developed on the Italian test site. However this complex Implementation is not scheduled in the framework of the project. Already treated in other European projects (e-dash)	This task can be emulated. Some connection with e-dash project could be made
12.	#3.1	Energy supply tarif modulation	This task can be simulated from EV side	What has been done in ECOFEV is the measure of energy that has been delivered/received in static charging. The problem arises with dynamic solution if many vehicles get recharged at the same time (how much energy goes to whom). This a specific question for FABRIC. Not so trivial. Demo on the French test site will include two vehicles.
13.	#4.1	Integration of	Low priority in terms of research	

UC No.	Use case ID	Use case name	Reasons	Comment
		FABRIC with UTMC (Urban Traffic Management and Control)	relevance	
14.	#4.2	EV identification	Already included in other EU funded projects	This use case could be interesting with the two car scenarios Could be different from static to dynamic For Qualcomm it might not be difficult to have this feature for the dynamic. This could be the base for another project.
15.	#4.3	Charging or road infrastructure availability status updating (scheduled)	To be confirmed that this UC could be demonstrated on project time scale	This is already is developed in POLITO. Communication with Com station operator is available (Done in terms of software and management). **This could be nice to have on the French test site.**
16.	#4.4	Charging or road infrastructure availability status updating (unscheduled)	To be confirmed that this UC could be demonstrated on project time scale	Same as UC 4.3
17.	#5.1	Logging in to the FABRIC interfaces – operators	Not necessary for demonstration	
18.	#5.2	Messaging to FABRIC platform – operators	Not necessary for demo	OK
19.	#6.1	Dynamic route and booking management		Not research relevant
20.	#7.1	Charging management and load balancing - static	Already treated on wired charges systems. Low Interest and not so Specific to dynamic charging.	It could become more complex to have a load balancing system. The required power from the grid does not have a nice shape. This point should be looked in depth... Maybe not in the framework of the project

UC No.	Use case ID	Use case name	Reasons	Comment
				ICSS/CIRCE proposes to integrate photovoltaic power station a storage system. POLITO proposes to keep the system open for future implementation. POLITO/VEDE agree on the need to realize something which allows these activities. **This should be discussed with partners during further meeting.** This is very important for future viability of the system (succession to power peaks is no good for the grid) An intermediate question might be to estimate the actual accumulator/super capacitor capacity
21.	#7.2	Charging management and load balancing – dynamic and stationary	Hypothesis TBD guarantee energy mode of best effort basis?	Same 7.1
22.	#8.1	Billing	This is a complex development subject, however with lower research priorities	The project should focus on complete characterization of the energy chain and quantification of energy transfer

Table 2 Explanations justifying the selected use case to be demonstrated on the French test site.

2.2.2 Other use cases to be analysed

Some theoretical considerations are developed below in Chapter 3 in order to cover “other“ use cases to the FABRIC project, i.e.

- Adaptation to heavy vehicles
- Higher speeds (greater than 60 km/h)
- Compatibility with other road users (motorbikes, pedestrian …)
- General safety (animals …)

3 FEASIBILITY ANALYSIS AND RESULTS (QUALCOMM HIGH LEVEL CONSIDERATIONS)

3.1 Introduction

This chapter covers theoretical considerations regarding the feasibility of Solution 1 application to “other” than FABRIC use cases described in the previous chapter (these considerations were provided directly by Qualcomm. They can be considered as “high-level” and limited due to IP concerns)

3.2 Adaptation to heavy vehicles

Concerning the charging system, this could be feasible with some design changes, in particular power levels. Note that the power installed in the Satory test track is 200 kVA and that more powerful systems could be tested on this experimental track.

3.3 Higher speeds

For speed ranges greater than 80 km /h, this could be answered after test done in Satory for Solution 1. The current design could work to speeds up to 100 km/h. Some issues linked with communication speed might be found. This is one of the questions the FABRIC project might address on all tested solutions.

3.4 Compatibility and safety issues with other road users (motorbikes, pedestrians …)

The QC system is designed to minimize emissions leaking out from under the vehicle therefore minimizes, in design principle, the exposure to others road users.

3.5 Adaptation to the autonomous vehicle and benefits for the dynamic wireless transfer efficiency and EMC issues

One interesting benefit of integrating a charging system in an autonomous car would be that the centering of the car could be done in a more precise way (+/- 5 cm seems a realistic objective), therefore:

- The architecture of the coils system could be done differently and optimized for better efficiency
- Less emissions would leak out of the car

3.6 Other considerations regarding the charging system

The power distribution architecture of future will influence strongly the charging system architecture in the future. The Qualcomm system should by architecture take into account distance between access points

3.7 Other considerations regarding the experimental track

The experimental track is a heavy VEDECOM investment (more than 500 k€). Its design will enable cost effective reconfiguration for future systems testing.

4 FEASIBILITY ANALYSIS AND RESULTS (VEDECOM POINT OF VIEW)

4.1 Introduction

Here below are some additional elements provided by VEDECOM in a prospective exercise. Note: the tables issued from “Review and Evaluation of Wireless Power Transfer (WPT) ([2]for Electric Transit Applications” from FTA report number 0060 provide an interesting overview of research topics for heavy vehicles.

4.2 Adaptation to heavy vehicles

The design changes needed to adapt solution 1 concept for heavy vehicles would consist in reviewing all factors of influence of a wireless charging system in particular power increase, efficiency increase, energy management from grid, EMF emissions control, EMC control for the vehicle …

Concerning:

- Power increase up to 100-200 kVA: this will need further basic technological study which would define optimized wire loops configurations (in terms of material, geometry and induction mode for a power target...)
- Efficiency increase: The more power will be transferred, the more efficiency will become a critical factor. Two axis of research could be further investigated , i.e. :
    - Leakage flux reduction between primary and secondary side of coupler. One idea would be to use improved magnetic materials and reviewed design (higher magnetic permeability). Heavy vehicle could bear higher weight for the embedded system.
    - Intercoil distance optimized control : heavy vehicle automation research should provide efficient automated systems to reduce the air gap during charging.
- Energy management from grid will become necessary: it will require the use of local storage systems at the grid connection.
- EMF emissions control:

  - One important effect of leakage reduction (linked to efficiency increase) would be to confine better the magnetic emissions, therefore to limit the risks of exposure in zones which could be occupied by pedestrians, or other road users). This could be considered as the most important axis of research.
  - One mitigation of exposure risk could be obtained by modulating the power transmitted in particularly at low speeds in order to respect applicable regulations and recommendations.
  - Some additional consideration should be added depending on the kind of transportation (from busses with low floor carrying passengers to delivery trucks)
- EMC concerns:
  - The design of protection shield could be revisited to optimize the energy loss (due to counter reactive shielding concept used in Solution 1)
  - One other investigation to conduct would be to make sure high power emissions will not harm other functions of the vehicles (safety in particular)

4.3 Higher speeds

As shown in a prospective study in Appendix for today's vehicle (Nissan Leaf), there could be an optimum speed range (between 30-70 km/h)

- maximizing the economic interest for wireless charging (more car per km respecting safety distances without reducing too much the car flow per lane)
- minimizing the safety issues (speeds greater than 30 km/h would diminish likeliness of pedestrian /vulnerable road users presence)
- enable autonomous vehicle deployment

As shown in curve A-4, higher speeds (> 70 km/h) may not necessarily be the first priority for future research. As shown in figure here below; indeed the additional energy/km transfer benefit of an increased charging power is much greater at "urban speed range"(30-70 km/h) than at "highway speeds" (80-130 km/h):

- at # 50 km/h if charging power per car were doubled (100-200 kW) it would enable approximately an additional 2000 Wh/km (with homogeneous traffic flows)
- However, at 120 km/h a doubling in charge power would only result in an additional 750 Wh/km.

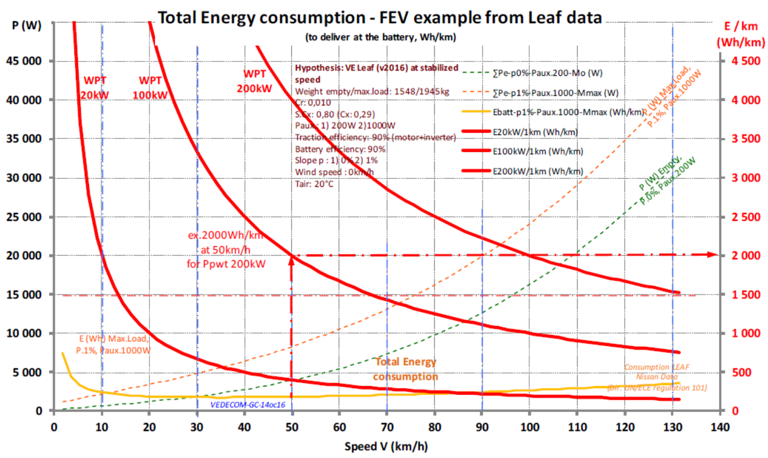

Figure A-0: Maximal vehicle number & traffic versus driving speed on 1000m length road

4.4 Compatibility and safety issues with other road users (motorbikes, pedestrians …) and

Future intelligent wireless charging system should be connected to smart perception systems (which could use the sensors of an autonomous vehicle) so wireless charge induced bad effects (EMF leaks) are well controlled and confined in a manner that safety is guaranteed. This is of particular importance for urban environment (cross sections for example).

4.5 Adaptation to the autonomous vehicle and benefits for the dynamic wireless transfer efficiency and EMC issues

The autonomous vehicle capability to follow a line with small deviation (+/- 5 cm) would be a very useful feature enabling new electric design options for WPT system with even more confined and concentrated magnetic flux. Further research would be needed to set the limits of maximal acceptable transfer flux density in wireless contactless charging conditions. At 0 speed the systems functionality could be extended to full contact charging (0 mm air gap) with maximum power and efficiency in total respect of EMF. The technical feasibility of such devices remains to be assessed.

4.6 Other considerations regarding the experimental track

The experimental track implemented by VEDECOM is an investment of more than 500 k€. Its design will enable cost effective reconfiguration for testing future systems.

5 CONCLUSIONS

Applying Solution 1 concept to other than FABRIC use case is a challenging task from a prospective first approach. This study has conducted us to identify some new paths and priorities for future research on future wireless charging solutions. Amongst them, breakthroughs in autonomous vehicle research and technology (in which VEDECOM is also involved) could be of great benefit. What is done for light vehicle could also be of great interest for heavy vehicle.

6 APPENDIX 1: TECHNICAL CONSIDERATIONS FOR FUTURE WIRELESS POWER CHARGE INFRASTRUCTURE COMBINING SPEED, POWER AND GRID ASPECTS

6.1 Analysis of traffic data for sizing power requirement for future wireless power systems

The following inputs are presented to determine the sizing requirements for the power supply connected to the grid of a PWT charging for automotive

First data are established taking account of the road traffic. Figure 1 presents the maximal traffic on one lane road versus the speed of the vehicles taking account the usual safety rule "2s between vehicle". It is shown that the maximal number of car reached around 1700 cars or vehicles per hour (4m car length).

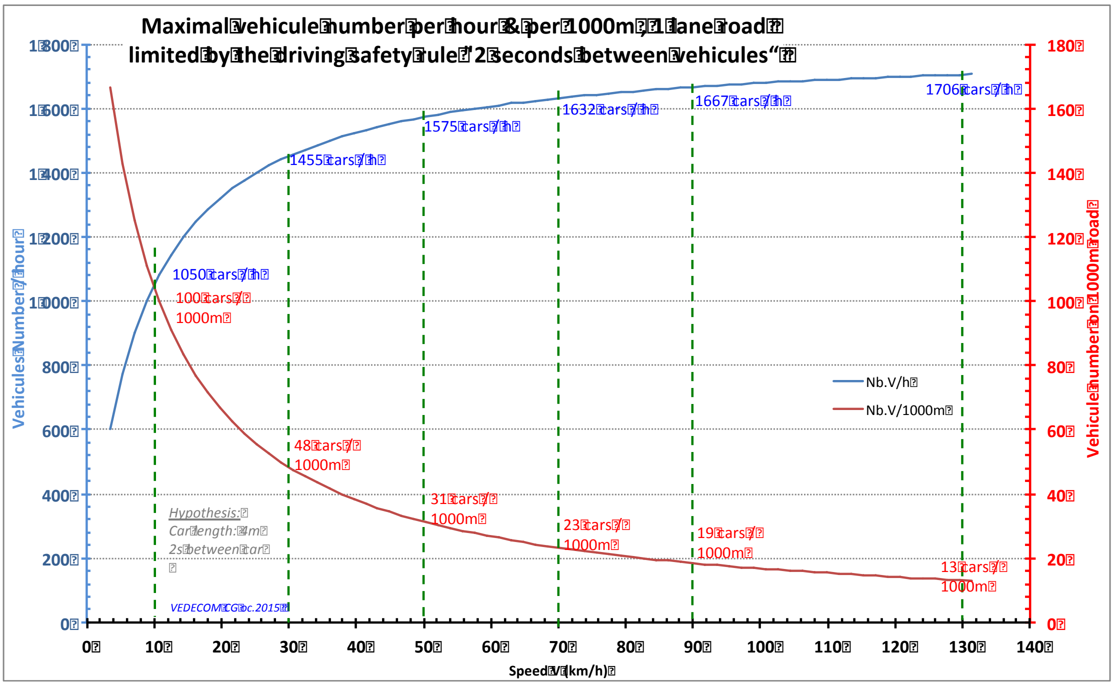

Figure A-1: Maximal vehicle number & traffic versus driving speed on 1000m length road

These corresponding numbers of cars on a 1000m road length decreases from 106 cars running at 10km/h, to 13 cars running at 130km/h, respectively the traffic density increases from 1050 cars per hour, to 1706 cars per hour.

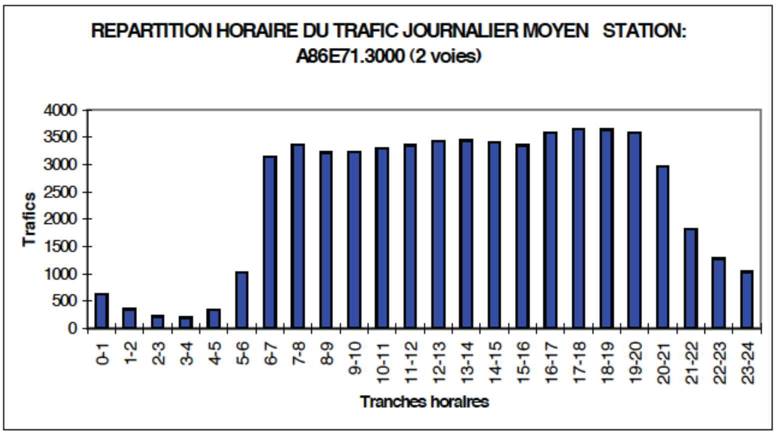

Figure A-2: Hourly average distribution of the working day daily traffic on A86 highway close to Paris urban area, maximal reach 3200 cars/hours for 2 lanes (1600 cars/hours/lane).

6.2 Theoretical estimation of e electrical consumption of FEV (Full Electrical Vehicle), data input from the best EV sales "LEAF" EV.

The next figure presents the energy consumption evaluation established at stabilised speed for the Nissan Leaf EV. Some parameters increase the electrical consumption: speed, auxiliary power for inside comfort, slope, load on board,

Only 2 limits study case are presented by 2 curves:

- minimal consumption with 200W low Paux., no slope, only driver no passengers,
- maximal consumption with 1000W Paux., slope 1%, maximum load

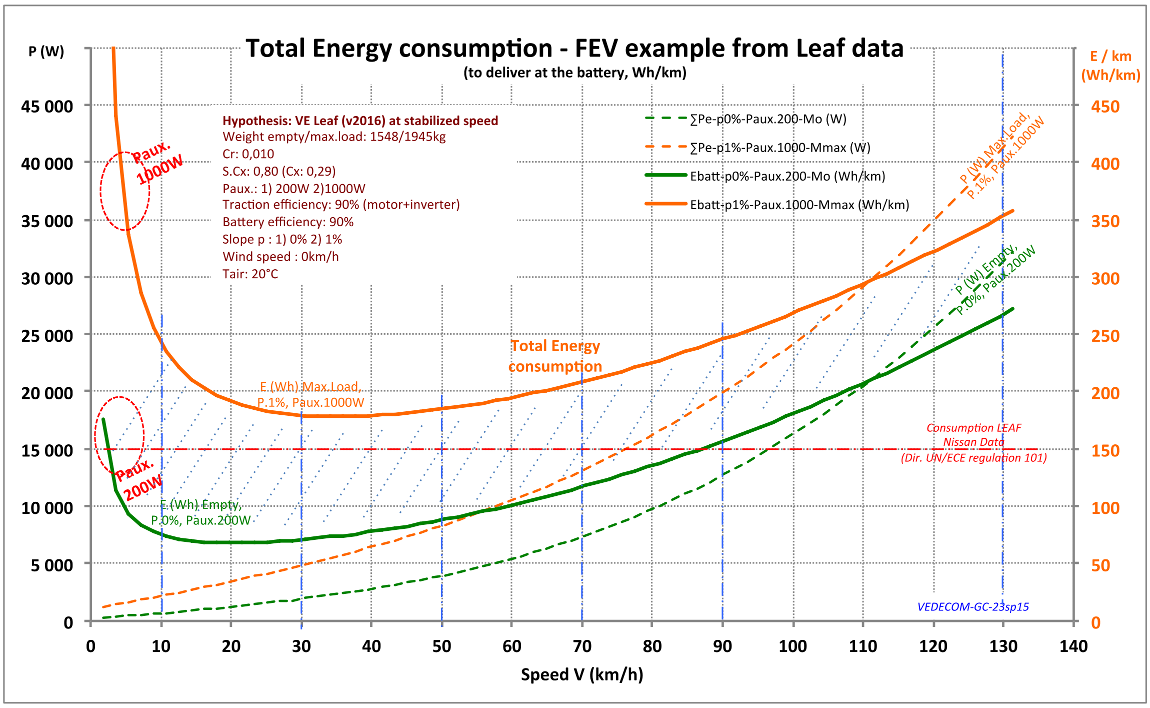

Figure A-3: Electrical energy consumption to be delivered at the battery established for the Nissan Leaf EV

We note the strong influence of the auxiliary power at low speed and of the load at medium and higher speed.

We can distinguish 2 typical driving conditions:

- urban driving: energy consumption is in the rang 100 to 200 Wh/km
- inter-urban or highway driving: energy consumption is in the rang 150 to 300 Wh/km

6.3 Theoretical approach for sizing of the power supply for the grid connection for 1km road equipped with a WPT system.

If the hypotheses are based on the FABRIC requirements for WPT systems, then the useful power transmitted on board each car is fixed at 20kW, total system efficiency has to be at least 80%.

The FEV energy consumption is estimated by using the LEAF-Nissan car characteristics, the calculation use the rolling resistance and aerodynamic characteristics published, wind speed is zero, no road slope, the driving speed is constant.

The electrical consumption of auxiliary systems (electronic sub-system, comfort…) are a very important part of the car consumption at low speed, and affect autonomy performance, results are presented for 2 values: 200W and 1000W.

<u>Solution 1</u>: estimation of the absolute maximal power supply to be delivered by the grid

The next table 1 or 2 show the results of the calculations of the maximal power supply to be installed and to be connected to the grid. The hypothesis is to supply all the cars driving on the 1000 meter road section equipped with a WPT systems from 10km/h to 130km/h.

V (km/h)	d between car 2s safety rule (m)	**Nb Cars /1000m**	∑Pch max. (kW)	t-1000m/car (s)	∑Ech1000m/car (Wh)	**∑Pgrid (kVA) (cosø=1)**	Ec-Leaf*/km (Wh) Paux.200W	**Ech/E-Leaf (km saved)**
10	5,6	**106**	2120	360,0	2000	**2650**	78	**26**
30	16,7	**48**	960	120,0	667	**1200**	71	**9,4**
50	27,8	**31**	620	72,0	400	**775**	89	**4,5**
70	38,9	**23**	460	51,4	286	**575**	117	**2,4**
90	50,0	**19**	380	40,0	222	**475**	157	**1,4**
130	72,2	**13**	260	27,7	154	**325**	266	**0,6**

Table A-1: Maximal grid power supply estimation based on 20kW transferred to car, Leaf consumption estimation based on 200W permanent auxiliary power

V (km/h)	d between car 2s safety rule (m)	**Nb Cars /1000m**	Pch max. (kW)	t-1000m (s)	Ech1000m (Wh)	**∑Pgrid (kVA) (cosø=1)**	Ec-Leaf*/km (Wh) Paux.1000W	**Ech/E-Leaf (km saved)**
10	5,6	**106**	2120	360,0	2000	**2650**	255	**8**
30	16,7	**48**	960	120,0	667	**1200**	179	**3,7**
50	27,8	**31**	620	72,0	400	**775**	185	**2,2**
70	38,9	**23**	460	51,4	286	**575**	209	**1,4**
90	50,0	**19**	380	40,0	222	**475**	246	**0,9**
130	72,2	**13**	260	27,7	154	**325**	352	**0,4**

Table A- 2: Maximal grid power supply estimation based on 20kW transferred to car, Leaf consumption estimation based on 1000W permanent auxiliary power

Taking account of these results, the maximal grid power requested for 1 kilometre of road equipped with a WPT system, should be 2 650 kVA with the all 106 cars supplied at 10 km/h.

The global efficiency is fixed to 80% and the useful on board instantaneous power is 20 kW.

The auxiliary power has a strong influence on the Leaf consumption at low speed, using 1 kilometre of dynamic WPT charge, at 10km/h the gain on autonomy is reduced from 23 kms to 11kms by increasing this average auxiliary power from 200 W to 1000 W. If we focus on the

more realistic hypothesis of 1000W auxiliary power, the gain on autonomy reach 6 kms at 30km/h, 3,4 at 50, 1,3 at 90, and only 0,6 at 130.

<u>Solution 2</u>: estimation of the power supply to be delivered by the grid by using the Qualcomm PWT system which is limited at 20kW / 25m road

The difference with the previous calculation is the on board transferred power limitation at 20 kW for a 25 m section length, that means a total power of 1000 kW for 1000 m.

We kept the 2 scenarios about the average auxiliary power, 200W and 1000W.

The tables 3 and 4 present the results of the calculation.

V (km/h)	d between car 2s safety rule (m)	**Nb Cars /1000m (1car/25m section)**	Pch max. (kW)	t-1000m (s)	Ech1000m (Wh)	**∑Pgrid (kVA) (cosø=1)**	Ec-Leaf*/km (Wh) Paux.200W	**Ech/E-Leaf (km saved)**
10	5,6	**40**	800	360,0	2000	**1000**	78	**26**
30	16,7	**40**	800	120,0	667	**1000**	71	**9,4**
50	27,8	**31**	620	72,0	400	**775**	89	**4,5**
70	38,9	**23**	460	51,4	286	**575**	117	**2,4**
90	50,0	**19**	380	40,0	222	**475**	157	**1,4**
130	72,2	**13**	260	27,7	154	**325**	266	**0,6**

Table A-3: Grid power supply estimation based on Qualcomm PWT 20kW transferred to car, Leaf consumption estimation based on 200W permanent auxiliary power

V (km/h)	d between car 2s safety rule (m)	**Nb Cars /1000m (1car/25m section)**	Pch max. (kW)	t-1000m (s)	Ech1000m (Wh)	**∑Pgrid (kVA) (cosø=1)**	Ec-Leaf*/km (Wh) Paux.1000W	**Ech/E-Leaf (km saved)**
10	5,6	**40**	800	360,0	2000	**1000**	255	**8**
30	16,7	**40**	800	120,0	667	**1000**	179	**3,7**
50	27,8	**31**	620	72,0	400	**775**	185	**2,2**
70	38,9	**23**	460	51,4	286	**575**	209	**1,4**
90	50,0	**19**	380	40,0	222	**475**	246	**0,9**
130	72,2	**13**	260	27,7	154	**325**	352	**0,4**

Table A-4: Grid power supply estimation based on Qualcomm PWT 20kW transferred to car, Leaf consumption estimation based on 1000W permanent auxiliary power

The grid power, requested for 1 kilometre of road equipped with the Qualcomm WPT system, should be 1250 kVA taking account of a global efficiency of 80% to get 20 kW on board of electrical car, and the number of cars is limited to 50. From 30 km/h, the results are the same as the first solution.

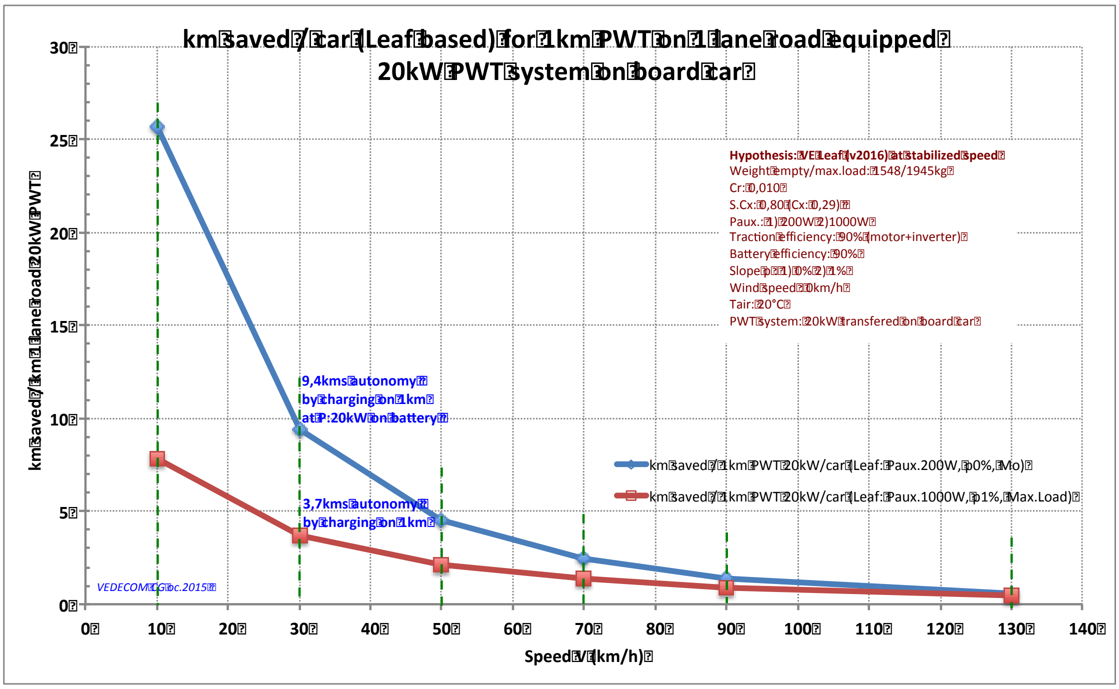

Figure A- 4: Estimation of the number of km saved based on a 20kW PWT system (P on board) at stabilised speed for a Leaf-Nissan energy consumption with 2 extreme hypothesis: very low and high consumption.

From these basic data it is possible to establish different scenarios for the choices: charging area locations (urban, sub-urban highway, inter-urban highway,…), power level of the WPT,…

But it is clear that the low speed WPT solution will be more efficient.

6.4 Electrical power supply sizing, discussion of the FEV traffic taking account of the FEV fleet ratio.

The sizing estimation, 2650 kVA and 1250 kVA are established for a continuous FEV traffic on the dedicated lane equipped with a PWT system.

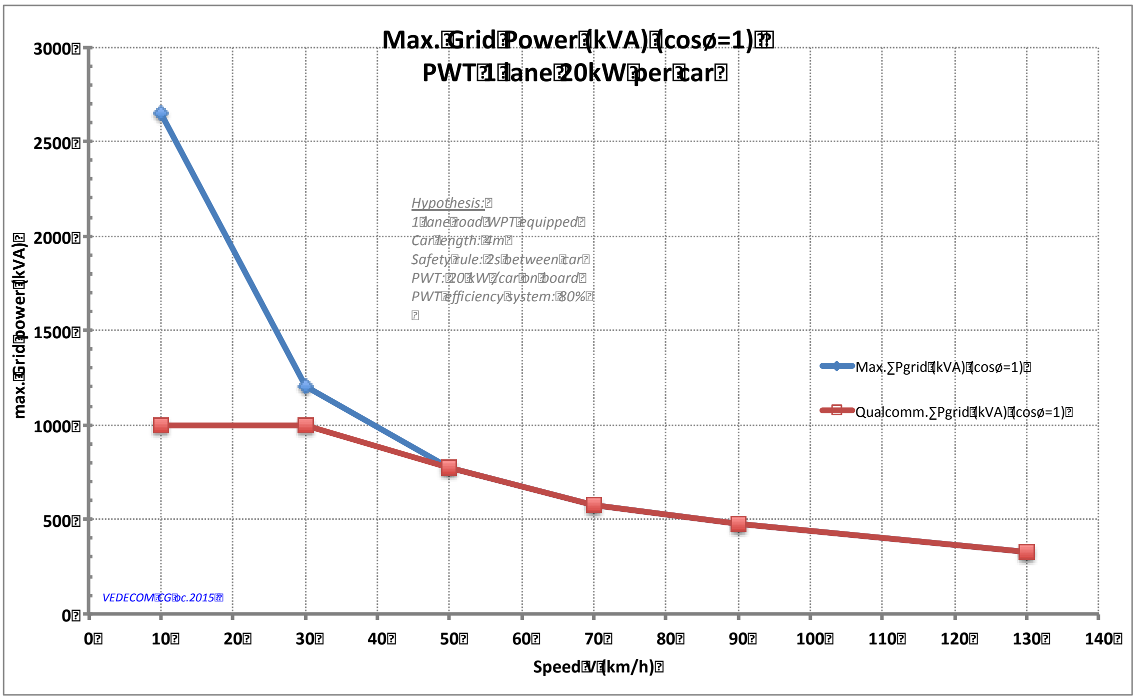

Figure A-5: Max Grid Power to be connected for 1 kilometre to assume PWT system 20kW/car for the maximum traffic possible on 1 lane road.

While we know that the FEV fleet ratio is now ≤1%, it could be 5% in 2020-30 (reference to France & Germany prospective towards 1 million FEV in 2020), and perhaps 10% in 2030-50.

This ratio can be use as reference to evaluate the number of FEV among the total traffic of the road which is limited at about 1700 cars /hour, and to estimate the maximal power grid to be connected in order to assume the charging of any FEV car at the traffic maximal.

FEV Traffic ratio				1%			
V (km/h)	Max. Trafic Cars/hour	Max. cars nb/1000m	Ech1000m/ car (Wh)	Av.Nb. FEV/ hour	Pmax. (trafic ratio) (kVA)	Ech.grid/ hour (kWh)	∑Pch.Av-Grid (kVA)
10	1050	100	2000	11	263	26	7,3
30	1455	48	667	15	364	12	3,4
50	1575	31	400	16	394	8	2,2
70	1632	23	286	16	408	6	1,6
90	1667	19	222	17	417	5	1,3
130	1706	13	154	*17*	427	3	0,9

Table A-5: Grid power supply estimation based on the FEV traffic ratio 1%

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FEV Traffic ratio				5%			
V (km/h)	Max. Trafic Cars/hour	Max. cars nb/1000m	Ech1000m/ car (Wh)	Av.Nb. FEV/ hour	Pmax. (trafic ratio) (kVA)	Ech.grid/ hour (kWh)	∑Pch.Av-Grid (kVA)
10	1050	100	2000	53	1313	131	36,5
30	1455	48	667	*73*	1200	61	16,8
50	1575	31	400	*79*	775	39	10,9
70	1632	23	286	*82*	575	29	8,1
90	1667	19	222	*83*	475	23	6,4
130	1706	13	154	*85*	325	16	4,6

Table A-6: Grid power supply estimation based on the FEV traffic ratio 5%

FEV Traffic ratio				10%			
V (km/h)	Max. Trafic Cars/hour	Max. cars nb/1000m	Ech1000m/ car (Wh)	Av.Nb. FEV/ hour	Pmax. (trafic ratio) (kVA)	Ech.grid/ hour (kWh)	∑Pch.Av-Grid (kVA)
10	1050	100	2000	105	2625	263	72,9
30	1455	48	667	146	1200	121	33,7
50	1575	31	400	158	775	79	21,9
70	1632	23	286	163	575	58	16,2
90	1667	19	222	167	475	46	12,9
130	1706	13	154	171	325	33	9,1

Table A-7: Grid power supply estimation based on the FEV traffic ratio 5%

These tables show the impact of the 2 criteria for the sizing of the electrical power grid connection:

- to satisfy any car on the PWT charging area, then the full power is requested in order to reach 20 kw on board for each car,
- to satisfy the average energy to transfer, then it is needed to take account of the traffic ratio of the electrical car and the number of total lane (only one lane for PWT).

6.5 Sizing of the power supply for the grid connection for 1km road equipped with a WPT system.

Such hypotheses have to be confirmed taking account of the total traffic of the road and the ratio of electrical vehicles by this traffic, but it appears a technical interest to manage the

electrical energy using an energy storage system localised close to the road which can use do deliver the peak power requested and offer to reducing the power of the grid connection line.

Such systems offer real efficiency opportunities to be coupled to any renewable energy generation.

Then the methodology to sizing the power to be requested to the grid is based on:

1. The maximal power corresponding to the total energy consumption requested during a high traffic period;
2. An energy storage system must be designed in order to offer the complementary energy;
3. The maximal power deliver to the car via the PWT system at the maximal traffic conditions is the sum of the power delivered by the grid connection and from the energy storage system installed close to the on ground PWT system.

REFERENCES

[1] FABRIC D4.3.1 “Final use cases definition”

[2] “Review and Evaluation of Wireless Power Transfer (WPT) for Electric Transit Applications” - FTA report number 0060