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An assessment of present and future competitiveness of electric commercial vans

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Abstract

As electric vehicles appear as a potential solution for cleaner deliveries, several constraints affect the attractiveness of electric light commercial vehicles (eLCVs). Our research aims at identifying these constraints as well as quantifying their respective weight. We investigate two types of constraints: operational and economic. Operational constraints determine if an electric vehicle is suitable for a given use; for example, the limited range of operation due to the necessity to recharge the battery. Economic performance, which we examine through Total Cost of Ownership (TCO) computations for electric and conventional vehicles, sheds light upon the trade-offs faced by business users when they have to choose between several technologies. We then present the results of a disaggregated constraints analysis made on a French database about light commercial vehicles, which assesses the proportion of vehicles that could be replaced by electric ones, and at what costs. This study shows that, today, eLCVs are competitive for some specific uses, but do not cover the needs of every freight transport operator. Our analysis also shows that even if fuel prices remain low and financial incentives decline, the competitiveness of electric vehicles could grow in the future.

Key-words: electric vehicles, light commercial vehicles, constraints analysis, total cost of ownership.

1 Introduction

The environmental impact of light commercial vehicles is high and freight transport, which represents a non-negligible proportion of road traffic, contributes significantly to the urban pollution – even more so than its mere physical presence in the streets, as shown by Dablanc (2008).

The use of alternative fuels brings good prospects for a more sustainable

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transport. In particular, battery electric vehicles raise a growing interest (Hanke et al. 2014), even if other alternative fuels are contenders. The environmental performance of electric vehicles is promising. Moreover, it raises interesting opportunities in interaction with the energy system and renewable energies (Held and Baumann 2011; Van Vliet et al. 2011; Helmers and Marx 2012).

Although electric vehicles have existed for more than a century, the last decade has witnessed a new enthusiasm, driven by the lithium-ion battery technology. Numerous carmakers have brought out several models, and new competitors have entered the market.

Light commercial vehicles (LCVs) seem to be good candidates to be replaced by electric vehicles, as most of them are used in built-up areas (IFEU 2012; Taefi et al. 2015). An urban use of LCVs, by freight companies for instance, seems particularly relevant (Lee et al. 2013; Macharis et al. 2013; CGDD 2014), since:

- They are driven at a low average speed.
- Driving conditions impose numerous slowdowns and stops. In these conditions, electric vehicles may take better advantage of regenerative breaking.
- Some delivery companies drive the same route every day.
- The driven distances may be relatively short.
- The frequent use of the vehicle allows a better profitability.
- Vehicles may return to company’s garage at the end of operation.
- Companies may benefit from a positive image.

It is interesting to notice that already in 1992, Brunel and Perillo (1992) identified business users as relevant early adopters for electric vehicles. However, the sales of Electric Light Commercial Vehicles (eLCVs) remain marginal in Europe, including in countries offering substantial financial incentives. In France for instance, despite a grant of 6300€ for the purchase of an electric vehicle, the market share of eLCVs in 2014 reached only 1.21%. There has been zero growth between the first semesters of 2014 and 2015 unlike the market for private cars. In Norway, a leading country in electromobility, eLCV market share is 1.87%, far behind that of passenger cars.

How can we explain this apparent lack of attractiveness? Is the LCV market an actual fertile ground for the development of electromobility?

The article is built as follows: in part 1, we discuss the methodology we use and present the database we worked with. In part 2, we examine and discuss the state of the art of operational and economic performance of electric light commercial vehicles. Part 3 looks at TCO computations for light commercial vehicles, and presents the numeric assumptions used for our computations. Our constraints analysis' results are exposed in part 4. Finally, we discuss the study's limitations in part 5, and conclude.

2 Objectives and methodology

The aim of this study is to quantify the impacts of operational and economic constraints of electric light commercial vehicles on business-type mobility. We put a special attention on freight transport operators. We assess the performance of vehicles currently on the market as well as the projected performance of vehicles in the future, taking into account expected rapid technological improvements. In this way, while not providing detailed market forecasts, we question the market development potential for electric commercial vehicles.

Approach

Our research relies on an agent-based disaggregated study. We do not target a comprehensive socio-economic evaluation. We investigate Light Commercial Vehicles (LCVs), i.e. commercial vehicles up to 3.5 ton gross weight. This corresponds to the N1 category of the European general classification of vehicle categories. The quantitative study will be limited to small vans, which we define as LCVs of less than 2.5 ton gross weight. This category is a rather common one within the car manufacturing industry, corresponding for instance to the market segment of the Renault Kangoo model.

We chose to compare conventional commercial vehicles (the most widely used internal combustion engine, or ICE vehicle), to the lithium-ion electric vehicles, mentioned as eLCV (for electric Light Commercial Vehicles) in the rest of the article. Switching from ICE to eLCV demands some operational adaptations that we will explore.

The spatial scale of our research is the use of commercial vehicles within France.

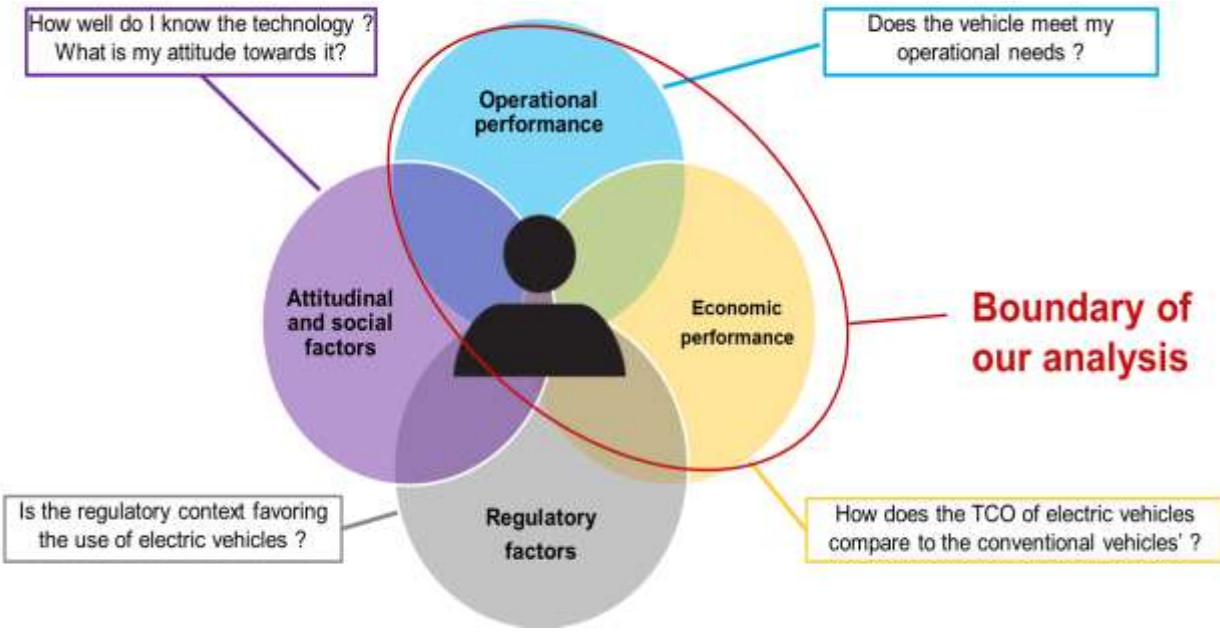

Figure 1: Schematic representation of the topics investigated (based on FREVUE project success factors (Nesterova et al. 2013))

Error! Reference source not found. presents four key factors (and briefly, some interrogations they raise) that impact the choice of a vehicle user to purchase an electric car. The choice of factors was based on Nesterova et al. (2013). We merged technical and operational factors. As shown on Figure 1, we only look at the economic and operational performances. Regulations vary a lot from one city to another, and they are difficult to take into account for a quantitative analysis at the scale of France. Cognitive perceptions cannot be quantified within a database either, and attitudinal and social factors will be researched further through interviews, and presented in a follow-up paper.

The uses of commercial vehicles are numerous and diverse. To comprehend this diversity, we started our research with a global understanding of the economic and operational performances of the lithium-ion technology. We explored constraints and opportunities of eLCVs through a literature review and state of the art, as well as preliminary interviews with several companies already operating them.

Economic performance is investigated through computations of Total Cost of Ownership (TCO). We use the Present Net Value method of computation for life costs analyses, presented for example in Tim Mearig et al. (1999):

$$PV = A_t . \frac{1}{(1+d)^t}$$

With:

PV: Present Value

A_t : Amount of costs at year t

d : Real discount rate

t : Time, in number of years

TCO can be computed over two different study periods: over the lifetime of the vehicle (with no residual value for the vehicle), or over a given length of time (the vehicle still has a residual value at the end of this period). The electric mobility system can be broken down to three independent systems, namely the vehicle without battery, the battery, and the charging infrastructure. As each has its own life cycle, we chose to make the analysis on a given period, which lasts four years. We took a real discount rate of 7%.

Nesbitt and Sperling (1998) had shown that the selection of a type of vehicle was largely driven by purchase costs, which is also the cost difference amongst vehicles which is the easiest to estimate. According to (OVE) cited in Boutueil (2015), more comprehensive assessments of the real costs, which take into account maintenance costs, fuel costs, tax expenses and vehicle resale value, are becoming more common. Though companies do not always have a precise knowledge of their costs, we also want to investigate how they are impacted if they switch to electric vehicles. Therefore, TCO comparisons seem to be a good method for the economic performance valuation.

Then, we tried to quantify how LCVs are impacted by the identified constraints with a *constraints analysis.* It is a disaggregated approach, applied on a database about uses of conventional LCVs. For each entry, we apply specific criteria to determine if the current vehicle could be replaced by an electric one, or in the words of Windisch (2014), if the use is *EV-qualifying*. If it is the case, we examine what would be the TCO comparison for this given use between conventional and electric vehicles. We obtain the proportion of vehicles that are impacted by one constraint or another. We can cross operational and economic performances. The same approach can be found for private car users, with a comprehensive literature review, in Windisch (2014).

Our analysis is not a market forecast: first, we do not look at all the constraints (for example, as mentioned earlier, cognitive and regulatory factors are left apart); non-monetary features are mentioned, but not integrated into the TCO computations. Taking only our indicators as market predicators would be strongly biased. TCO has its limitations, as it implies that agents have a perfect rational behavior. However, as stated for example in Nesbitt and Sperling (1998), companies do not always know precisely the cost structure of their vehicle fleet. In this article, or else in other words in Crane (1996), suitability and experience with the vehicle and technology are presented as two other important factors for pre-selection. Boutueil (2015) also underlines the complexity of decision-making processes for car fleet acquisition. Despite its drawbacks however, the constraints analysis gives a glimpse on the choices that are to be made by economic agents when faced with several technologies – ICE vehicles and EVs in the present case.

The disaggregated approach allows us to limit one drawback of TCO calculations when comparing two technologies, namely the difficulty of interpretation and generalization. Even when sensitivity analyses are conducted, it is not always easy to make a link between the results and the reality of LCV uses. This difficulty, and the fact that TCO varies from one country to another, justifies a multitude of computations, to confront several results with different assumptions. So we made our own assumptions for the TCO computations. The constraints analysis enables us to cross the operational and economic constraints and to have easier to interpret results: a result does not summarize a price difference between two technologies, but a price difference gradient for a big quantity of users.

We applied this methodology for two electric vehicles: a small van that is today on the market (based on the electric Renault Kangoo Z.E., on the market since 2011), and an imaginary comparable small van, projected in 2021 (in five years' time); and we compared both vehicles to a conventional small van (based on the non-electric Renault Kangoo), with only slight differences for 2021. All computations have been done under R.

Nature of the database

The database we worked with is a French "Survey on the uses of light commercial vehicles" ("Enquête sur l'utilisation de véhicules utilitaires légers"), conducted in 2010-2011 by the SOeS ("Service de l'Observatoire et des Statistiques"), the French environment ministry's statistics service. Light Commercial Vehicles are defined as vehicles of the N1 category according to the European general classification of vehicle categories. As such, private cars transformed into LCVs, usually by condemning the backseats and often for fiscal reasons, are integrated into the scope of the database.

The survey is vehicle-based and the answers are brought by the users (which are not always the owners) of the vehicles. Freight transport activities have been oversampled on purpose, to have a more accurate representation of this specific use. The same has been applied for recent vehicles, as they drive a great deal.

French LCVs represented approximately 5,800,000 vehicles in 2011. The database represents a subset of around 15,000 exploitable answers. We extracted from the database the vehicles of under 2.5 ton gross weight (small vans). As we are interested exclusively in business uses (as opposed to the use of commercial vehicles by households), we filtered vehicles that are only driven for private purposes, as well as the vehicles that were not driven at all in the year surveyed (2010). Thus, we used a database of around 7700 vehicles.

A statistical adjustment was conducted on the database by the SOeS, by a marginal calibration, relying on several variables (energy used, vehicle gross weight, vehicle main use and vehicle age) to define 32 strata. 20 variables have been adjusted to make up for partial non-responses. The maximum partial non-response rates account for approximately 20% of the respondents, and affect the driven distance in 2010 and daily driven distance declarations, which are unfortunately important variables for our study. As a result, these two values are sometimes non consistent with each other, forcing to make choices on which one to choose.

The available data describes: the vehicles (gross weight and payload, year of purchase, age, etc.), the users (legal situation, main activity of the company they are working for, etc.), the driven distance (driven distance in 2010, typical daily driven distance, mileage at purchase, distribution of driven distances in city, on roads or highways, etc.) and the specific uses (frequency of uses, per distance brackets or weight of cargo brackets, category of use, etc.).

The size of the fleet of one company is unfortunately not available, although that would have been interesting to have. Geographic data is also missing, so there is no way to differentiate between a vehicle operated in the Paris region or in medium size cities, in the north or the south of France, etc.

To determine the annual driven distance for TCO calculations, we chose the declared driven distance in 2010 if the vehicle had been first sold in 2009 or before (as it is more accurate than what follows), else we multiplied the declared daily driven distance by 254, the number of working days in the year surveyed. In order not to have to cross the two most adjusted variables, which could give misleading results as mentioned before, we chose to stick to the previous choice when dealing with range constraints.

3 Barriers and opportunities for electric light commercial vehicles

Electric vans are not suited to every use that can be covered by ICE vehicles. Low driving range and long charging duration are considered in the literature the most restricting factors for the use of eLCVs (Frenzel 2016). However, eLCVs present other advantages compared with conventional LCVs. We discuss these barriers and opportunities in this section.

Range

Range is one of the most common constraints associated with battery electric vehicles. We make a distinction between the range that allows *most* everyday trips, which we define as covering the average daily driven distance; and the range that covers *all* the trips and that allows unchanged mobility patterns. It is clear that the latter is more demanding than the first one.

The range limitations are similar for the private use of a car by households. Based on GPS data, Pearre et al. (2011) show that even if most of the mobility needs are covered by electric vehicles, the possibility of adaptation (like charging during the trip / traveling by train / renting a car / sharing a car etc.) for a little amount of long trips in the year can multiply the potential for EVs (on the contrary, the absence of alternatives penalizes EVs heavily). To our knowledge, no such study has been conducted for business van users.

It is important to note that the range is not constant, because it varies with the consumption, dependent on many parameters, among which: (1) the driving profile, which depends both on the context (consumption in cities will be less than on highways), and the driving behavior (an aggressive driving style will consume more than a relaxed one); and (2) the temperature. The colder the weather is the higher the fuel consumption, compounded by the use of auxiliary equipment. The heater is by far the most consuming auxiliary component and is usually supplied by the power of the traction battery. Heater consumption depends on working time, not on distance (Helms et al. 2010). Solutions exist to minimize overconsumption and the lack of predictability of the range, for example an additional fuel heater or pre-heating scheduling as the vehicle is still charging (Taefi et al. 2015).

For regular delivery rounds, these seasonal range variations limit the maximal possible route to the minimal range (reached during winter, with the heater on, and with the worst driver). Frenzel (2016) shows that 18% of eLCV users who plan their trips try to exploit the range to its full extent.

Charging

Charging is another well-known constraint of using an electric vehicle. We will focus on charging facilities owned by companies, as it seems the most likely way companies deal with charging.

Indeed, in our opinion, it is unlikely that the use of electric vehicles develop if dependent on public charging infrastructure. In case of a problem (such as a charging station is down or occupied by somebody else), there are few alternatives. Frenzel (2016) calculated that, for commercial uses, only 5% of planned trips actually recharge during the trip, which is a small but not insignificant share. This raises the interesting question of the role of public charging stations for professional users.

In all cases, today, charging takes place essentially overnight and on company grounds (Nesterova et al. 2013), and we make the assumption that it will stay so.

In this configuration, charging might raise several problems:

- Vehicles are generally immobilized for a long duration. The time it takes to charge a vehicle depends on the power of the stations. If a charging problem occurs during night for instance, the vehicle is not usable for an appreciable length of time.
- Availability of overnight parking facilities is not systematic. Browne et al. (2007) indicate that almost two thirds of LCVs are taken home by drivers overnight, and one third are parked off-street at premises, as a result of a study conducted in 2005 in the London boroughs of Southwark and Lewisham. We expect that ad-hoc acquisition of facilities is unlikely. Observations in Frenzel (2016) tend to confirm this, as early adopters have mostly "trip-profiles which allow usage without any adjustments or adaptations regarding technical conditions."

  Counter-examples exist: for example "La Petite Reine," a French urban freight delivery company, which operates about 50 electric LCVs and 100 electric cargo bikes; also "Citylogin" (a collaboration of FM logistics and Mag.Di), which operates several electric LCVs and trucks in Rome (among other places). Both companies use proximity hubs where electric vehicles are parked overnight. However, it is not obvious that this solution can be applied to the majority of LCV users, and both examples are from companies trying out innovative logistics schemes.
- Implementation of charging stations is more expensive than the mere costs of the stations: extra costs can occur due to works, for example to bring electrical system up to standard. Companies willing to convert to electric vehicles often find themselves surprised in this regard (Van Amburg and Pitkanen 2012). Fire safety regulations can represent a significant financial burden too, especially when facilities are shared and considered as "establishment open to the public" (*Établissement recevant du public*, or ERP in French, such as underground car parks).

We will not discuss in details the possibility of charging the electric vehicles at the home of employees, but it seems to present several drawbacks: no guaranty that the installation of infrastructure is possible, the difficulty to assess the security of charge and to intervene in case of a flaw, the legal complexity to pay for electricity and infrastructure at the driver's home; or the turnaround of employees.

Constraints linked to the novelty of the electric vehicle market

Today's electric vehicle market is rather small and comparatively new (compared to the conventional vehicle market). Several drawbacks ensue:

- Existing eLCV market is relatively limited, especially for vans with higher payload (Frenzel 2016).
- Customer service and maintenance can be rather poor (Nesterova et al. 2013). Companies are used to put local garages in competition but cannot do so with electric vehicles, which can translate in an immediate monetary loss.
- Downtimes for repairs can be long, sometimes because of a lack of experience about electric vehicles by car mechanics, which goes along with the previous point.

More generally speaking, the novelty of the market generates big uncertainties, on the reliability of the technology in the long term, on the residual value of used vehicles… Prospects on improvements in the technology can also cause wait-and-see behaviors, and residual value deterioration due to obsolescence.

Other constraints

To what is described above, we can add some other potential problems: as the weight of battery and electric engine widely exceeds the weight of the internal combustion engine and fuel tank, payload can be affected; especially for the heaviest of LCVs (near 3.5t gross weight), whose overall weight cannot exceed 3.5t without changing their regulatory category. It looks like in Europe a regulatory solution already exists for heavier trucks, which can benefit from a weight overrun of up to one ton compared with conventional ones, if they are equipped with a heavier technology using alternative energies (EU, 2015).

If reliability has been a recurring problem in the past, with the newest vehicles, it seems to be less so, because the vehicles are no longer trial products but mass-produced (Nesterova et al. 2013).

Opportunities

Electric LCVs are not only about new constraints. Opportunities can be numerous too.

- Electric vehicles are subsidized in many countries. In France today, each vehicle benefits from 6300€ from the state.
- They can be a mean of communication: the image associated with an electric vehicle is very positive. Brand image is one of the main drivers of the adoption of electric vehicles today (Boutueil 2015).

- They free the user from refueling the vehicle, which simplifies the shared use of the vehicle.
- Comfort of electric vehicles, due to less noise and vibrations (at low speeds), is very appreciable for drivers who use their vehicle intensively. EVs are more responsive when the vehicle starts, and they have no gearbox, which is valuable when activities include numerous stops and urban trips.
- Less maintenance overall is necessary compared with a conventional LCV.
- Paradoxically, conventional vehicles have their own uncertainties too: the fuel, which can be a big expenditure item, has a very unforeseeable price. EV users have more visibility on this expenditure item and are able to have a more resilient planning (McMorrin et al. 2012).

The constraints taken in our constraints analysis

We considered the following constraints in our quantitative analysis:

- A first range constraint for the vehicles which daily driven distance is higher than the calculated range (given the driving profile and the mean consumptions in city environments, on roads and on highways). We will call this constraint “insufficient range for daily use”.

- A second constraint will be on the declared frequency of long trips. The constraint will be called “insufficient range for peak use”. For the current eLCVs, we will consider that any trip exceeding 80 kilometers is a limiting factor. For the future eLCVs, the data is insufficient to do the same, as in the upper bracket for the frequency of trips is 150 kilometers and more. So when the range is more than 150 kilometers, we can’t determine if the trip is feasible or not. Therefore, we chose to add a constraint called “Uncertainties on peak use”.

- A third and last constraint affects the vehicles used for daily commute. For reasons exposed before, we consider that this is an important obstacle for the use of electric vehicles.

We warn that even if we try at the most to personalize the treatment of each vehicle, we are necessarily restricted by the availability of data in the database. Some assumptions necessarily average the real use.

One example is the number of working days: some professions use the vehicle more than the 254 working days used in the computations, and this affects greatly the economic results. For example , post activities can use the vehicle more than 300 days a year (Infini-drive, 2015), but this will not be taken into account in our analysis, the number of working days being fixed at 254 for every vehicle.

To conclude this section, we see that the use of electric vehicle requires careful planning and anticipation. However, electric vehicles have also non-monetary benefits that can possibly outweigh disadvantages. The question of the TCO is an important arbitrator: if it costs more, how much (if any) are users ready to pay extra for the benefits of EVs? If on the contrary, eLCVs cost less, are the companies ready to shift their habits despite the complexity of the change? We do not answer these questions, raised only to underline the importance of the TCO difference between the two technologies, but we calculate these TCO for each vehicle of the database, in order to shed light upon the trade-offs faced by users.

4 TCO computations and numerical assumptions

Several TCO analyses have been conducted to compare the costs of ICE and EVs, which range from small LCVs to medium size trucks.

Lee et al. (2013), Van Amburg and Pitkanen (2012) and Davis and Figliozzi (2013) have investigated the US case for medium-sized trucks (around 7t gross weight). Lee et al. (2013) use a statistical distribution of numerical hypotheses to take into account uncertainty, and find (in the baseline) a TCO distribution around zero, which shows that electric vehicles might be competitive in some scenarios. Van Amburg and Pitkanen (2012) insist on the potentially surprising high costs that can occur for installation of infrastructure and the need to carefully plan in advance the deployment of further vehicles. Hidden costs linked to the infrastructure seem to affect large fleets in particular. Davis and Figliozzi (2013) use modeling and optimization to evaluate input assumptions for the TCO. The final conclusion is that even if at the time of the study, electric vehicles are not competitive in most scenarios, "it is highly plausible that a confluence of rising energy costs and falling battery costs will create an environment where EVs will prevail in most scenarios."

There are European studies as well. Lebeau et al. (2015) consider a wide range of different light commercial vehicles. TCO calculations are made for the Belgian market. In general, the results put electric vehicles between their diesel counterpart (cheaper) and their petrol counterpart (more expensive). In France, Crist (2012) studies the TCO and socio-economic impact of three vehicles, including one LCV (the Renault Kangoo). The research shows that TCO is more suited for a business rather than a private use, with almost comparable TCO between conventional and electric LCVs after only three years. However, assumptions are rather optimistic for the professional user given the range of the vehicle (90km/day for 260 days a year). It also finds unfavorable societal costs, with an additional cost over the vehicle life of almost 7000€.

Infini-drive (2015) makes a review of a French experimentation of small electric vans by La Poste (the French postal operator) and ERDF (network manager of electricity distribution in France). Almost 100 vehicles were tested for 20 months, in about 15 locations. The study focuses mainly on charging and infrastructure optimization, but real life TCO are computed as well. Three results caught our attention: a possible gain of 3 to 7% for mixed fleet optimization (i.e. use of both ICE and electric vehicles); an estimation of 3% savings made possible by charging optimization in the most favorable case; and as in Van Amburg and Pitkanen (2012), a high variability of infrastructure costs, that range from 5% to 15% of the vehicle TCO.

Some studies focused on companies. The Observatory of Company Vehicles (*Observatoire du Véhicule d'Entreprise*, (OVE 2015)) presents a TCO study for France, mainly about conventional LCVs, but with a section about electric vehicles. At last, we can mention tools available online for businesses willing to calculate TCO within their own operational conditions: the tool from Van Amburg and Pitkanen (2012) where a user can enter their own data, or the I-Cvue decision

support model (I-Cvue n.d.), which has preloaded data for several European countries and several car models, including LCVs, and which gives also other information, such as reduced CO_2 emissions for instance.

We can conclude from these studies that electric vehicles can be, according to the cases, in the same price range as ICE vehicles, or a bit more expensive. This applies to different countries and different sizes of LCVs or trucks. There is a general agreement over the following: the more intensive the use, the more competitive the electric vehicle. All in all, this seems to us a rather positive signal, as the lithium-ion electric vehicle market development seems to be in its early stages, even if we have to keep in mind that the current financial incentives will perhaps not last forever.

For each period of time (2016 and 2021), we investigate two equivalent LCVs, one with an ICE and one full electric with a lithium-ion battery. In **Error! Reference source not found.** and **Error! Reference source not found.**, we present the numerical assumptions taken for the computations. Sources and short discussions are presented after.

Vehicle Data	Small ICE Van	Small ICE Van 2020	Small Van EV 2016	Small Van EV 2020

Table 1: Numerical assumptions for the vehicle data

	2016			
Purchase price (excluding VAT) [1]	17450 €	17950 €	21850 €	20350 €
Incentives [2]	0	0	6300 €	3300 €
Battery Size [3]	-		22 kWh	40 kWh
Battery Rental (excluding VAT) [4]	-		From 79€/month (less than 10000km/year) to 106€/month (more than 20000km/year)	The same, with a quadratic interpolation for higher mileages
Infrastructure [5]	-		2500 € amortized on 8 years + 200€/year maintenance and supervision	
Mean consumption city [6]	7,4 L / 100 km		17,5 kWh/100km	
Mean consumption road [6]	6,4 L / 100 km		19,5kWh/100 km	
Mean consumpt. Highway [6]	7,4 L / 100 km		24 kWh/100km	
Worst heating power [6]	-		2.5 kW (energy consumption depends on time driven)	
Residual Value [7]	Identical in €			
Maintenance [8]	3,77c€/km		1,885c€/km	

Table 2: Numerical assumptions for the contextual data

Contextual Data	**Diesel**	**Electricity**

Fuel prices in 2016 (excluding VAT) [9]	84,88 c€/L	8,936 c€/kWh
Fuel prices in 2021 (excluding VAT) [9]	84,88 c€/L	8,936 c€/kWh
Study period	4 years	
Discount rate	7%	
Number of working days [10]	254	

Assumptions:

1. Purchase price: the small ICE van is inspired from a Renault Kangoo Express Confort dCi 90 model, and the EV is based on the Renault Kangoo Z.E. Confort model. Assumptions for future projections are, that ICE will cost 500€ more due to more demanding air-pollution treatment devices, and that electric vehicles (without battery) will benefit from a decrease of 1500€ in purchase prices, thanks to economies of scale and technologic advances.
2. Incentives: 6300€ is the current bonus from the French administration for the purchase of an electric vehicle. Other subsidies exist from local governments, but they are different from one place to another, so we did not include them. Incentives cannot remain as high as they are today if the market takes off and the vehicle technology improves (Fearnley et al. 2015), so our baseline's assumption is a 3000€ cut into the incentives by 2021.
3. EV battery sizes: for the current eLCVs, we take the battery size of the Kangoo Z.E. model. For the projected battery size, our baseline takes the more conservative battery's cost decrease of 6% from Nykvist and Nilsson (2015). From this, we assume that for the same price, we will have a progress of 80% in 10 years over the battery of the 2011-brought-out Kangoo Z.E., which results in a 40 kWh battery. This is in line with announcements that have been made by carmakers, even if there is no mention of the price (LesEchos.fr 2015).
4. EV battery rental: we base our analyses on a Renault-like battery rental business model. This has benefits and drawbacks. The main benefit is that we don't have to care about battery ageing, second life and residual value,

which are all very uncertain. The major drawback is that we have to rely on the carmakers' outlooks. We have no visibility on their evolution nor on the factors which impact rental rates. Today's rental prices are based on Kangoo Z.E. prices, projected prices are the same for low driven distances, and we make a quadratic interpolation of today's prices to determine the rental for higher annual driven distances.

5. Infrastructure costs: Values have been taken in line with the order of magnitude given by our preliminary interviews.
6. Mean consumptions: for the conventional LCV, we corrected NEDC consumption in cities and on roads to account for real driving conditions. Based on findings of ICCT (2015), we increased them by 37%. Consumption on highway is assumed equal to consumption in cities. For eLCVs, we take the mean consumptions of Helms et al. (2010). When computing worst range, we assume a 10% increase of consumptions due to cold temperature, and take into account the heating consumption separately, based on data from Kavalchuk et al. (2015). We assume an 85% charging efficiency rate.
7. Residual values: they are a great unknown today. As the purchase price of electric vehicles is higher, and under the assumption of the same life span of electric and conventional vehicles, we could make the hypothesis that residual values will be greater for eLCVs than for conventional vehicles. However, residual values might be affected by obsolescence of the technology, and uncertainties on the ageing of the vehicle. By lack of evidence and of quantitative data, we choose to put residual values equal, in euros, for conventional and electric vehicles. So we do not have to take them into account in the comparison. For illustrative purposes, residual values in Figure 1 and Figure 2 are respectively 33.8% and 19.7% of the ICE purchase price to calculate vehicle depreciations.
8. Maintenance: The ICE maintenance costs are proportional to the driven distance. We make the assumption that it is constant over our study period. The value is an average of 28 declared real-use costs on (entretien-auto.com). Moreover, we assume savings of 50% of maintenance costs for electric vehicles, in accordance with Lee et al. (2013) and with our preliminary interviews.
9. Energy prices: in our baseline, we consider energy constant over the 10 next years. As many expect the fuel prices to raise in the future, this may be a conservative assumption. Changes in electricity prices are less crucial as the part of costs for electricity represents a more marginal proportion of the TCO. We take the fuel and electricity prices of January 2016 as baseline (MEEM 2016; SOeS n.d.).

Electricity costs are taken for off-peak hours, for the “blue rate” (*Tarif bleu),* which power is limited at 36 kW. This assumption suits better to small businesses than to big fleets. If it is necessary to switch from the “blue rate” to the “yellow rate“ because of an increased need in power due to charging stations, extra-costs can be penalizing (920€/year according to Infini-drive (2015). This might encourage ‘smart’ recharge management.

10. The number of working days chosen is the number of working days of the year surveyed (2010). Even if we are well aware that the vehicles are not necessarily used every working day or on the contrary can be driven on non-working days, daily driven distances are computed as if it were the case.

No taxes and insurance differences have been taken into account, so we can leave them out for our comparison. Business users get important commercial discounts when they buy new vehicles. We do not take any commercial discount rate. This is the same as considering they are identical in euros for both vehicle technologies.

Several scenarios are investigated from this baseline.

5 Main results of the constraints analysis

As previously stated, this section will only cover the market of small vans (<2500kg gross weight). On Figures 2 and 3 the TCO for two specific vehicle uses are represented, for illustrative purposes. The first one illustrates a daily driven distance of around 50 kilometers; the second one of 160 kilometers a day.

Based on Figure 1, we can make the following statements:

- For small driven distances, the main expenditure item of the TCO is the vehicle’s depreciation. Therefore, the current 6300€ state incentives enable to have less depreciation on the electric vehicle than on the conventional one. This is still the case in 2021, despite the lower incentives, thanks to the purchase price decline.
- Electricity expenses are much lower than ICE fuel expenses. But as diesel prices are currently very low, electricity and rental expenses together exceed by far these fuel expenses.
- Maintenance cost savings are rather significant, as are infrastructure costs, and should not be neglected.
- All in all, TCO of conventional and electric vehicles are comparable in 2016, and eLCVs slightly more expensive in 2021 for moderate driven distances (which are the only ones which we consider as being covered by eLCVs

today). If there is a 3000€ cut in incentives as in our baseline, tomorrow's projected eLCVs may be more expensive than the current eLCVs for this user's profile.

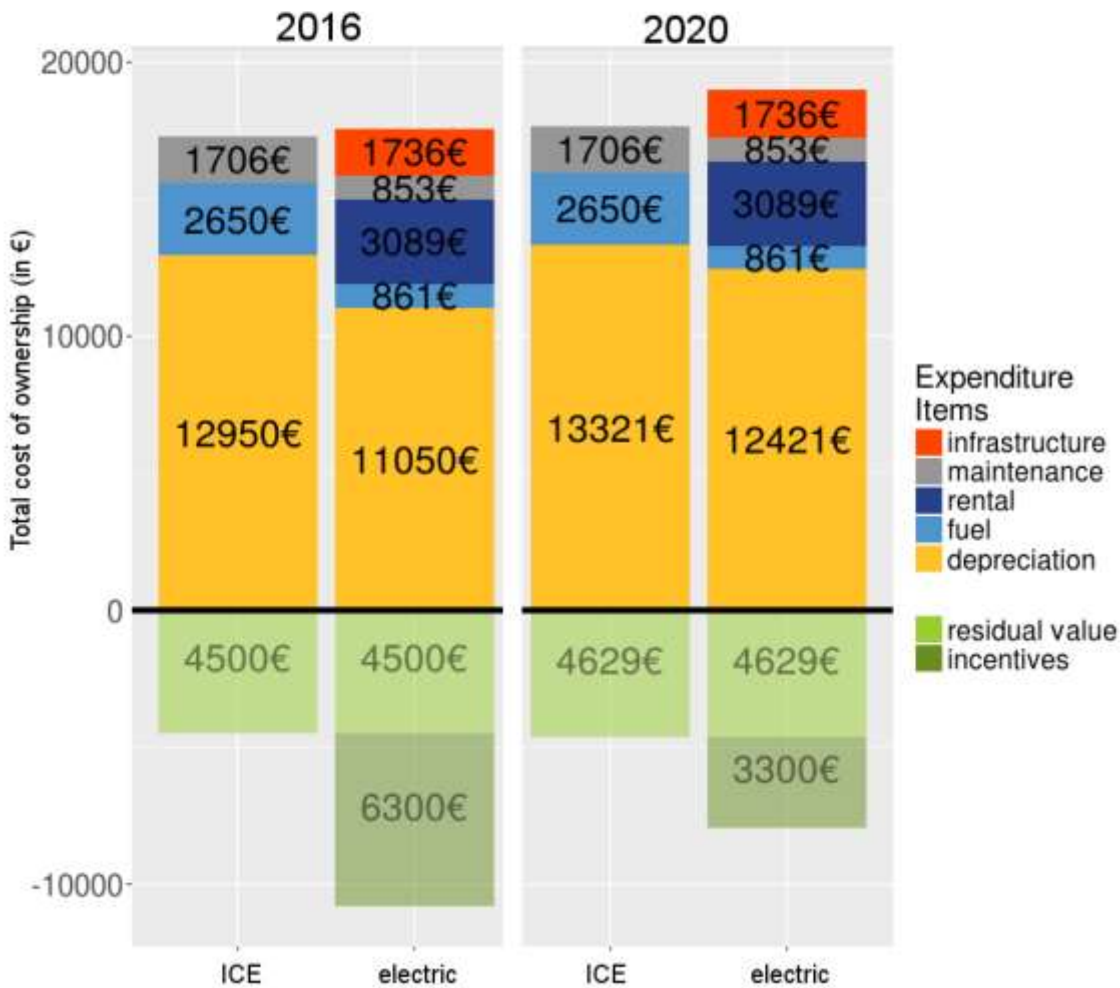

Figure 1: Current and projected TCO comparisons between electric and conventional LCVs in 2021, for a specific use, driving in average 50 kilometers a day.

Figure 2Figure **2** represents the projected TCO for a user who drives 160 kilometers every day. The following can be said:

- Today's eLCVs have a range that doesn't fit this user's needs. However, the projected eLCVs will be adequate.
- Fuel costs represent a much more important proportion of the TCO than in

the first case.

- With our assumptions, the electric vehicle is competitive with the conventional one in this case. However, we also see that with our projected battery prices and if diesel prices remain as low as today, it may lead to smaller fixed costs and higher operational costs for eLCVs, even for higher mileages. Indeed, we can see that battery rental and electricity account for one third more than fuel expenses.

This being said, how many business users resemble the first user presented, and how many the second user?

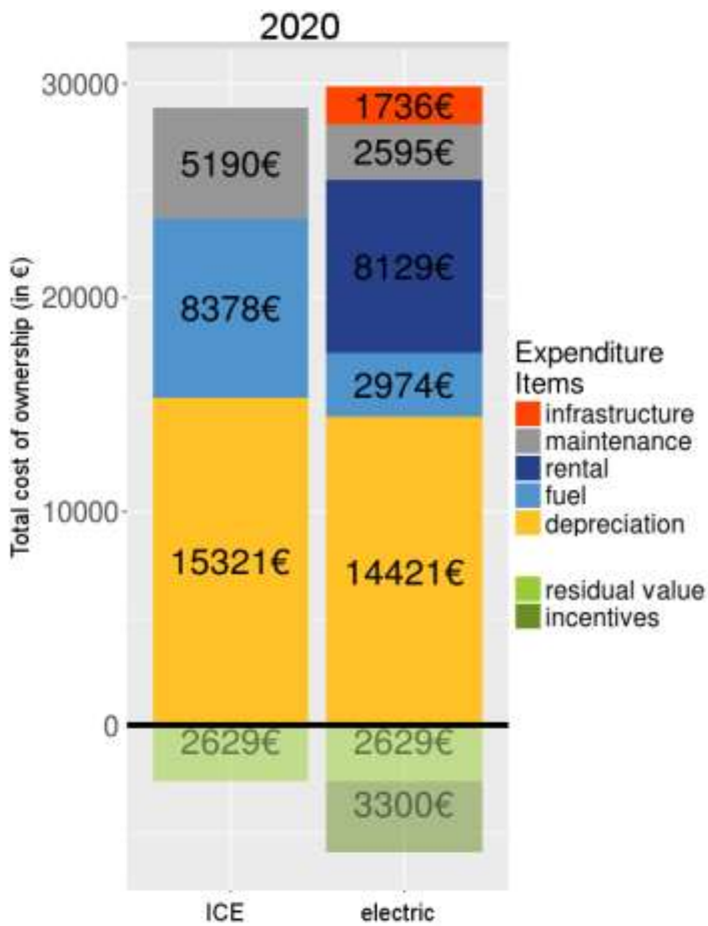

Figure 2: Projected TCO comparison between electric and conventional LCV in 2021, for a specific use, driving in average 160 kilometers a day.

The constraints analysis

Figures **Error! Reference source not found.** show the constraints analysis as we described it in the previous section, for today and for a 2021 projection. The sum of percentages does not always reach 100% due to rounding-off errors. For each, the first line represents the operational constraints and the second the distribution of TCO comparisons between EV and ICE. A positive TCO difference favors eLCVs. TCO differences are given by ranges of 50€. Results can be interpreted as follows: percentages in yellow have comparable TCO for conventional and electric LCVs, orange shades represent extra-costs for the use of an electric vehicle (the darker the greater the extra-costs). In **Error! Reference source not found.**, we identified 26% of the vehicles that are used for the drivers' commute. We consider this as a negative constraint, due to the difficulties to install charging infrastructure at the driver's home. When we look at the range issues, we see that more than 35% of them would be constrained by the use of electric vehicles, a majority of them on a regular basis, and a bit more than a third at least on a monthly basis. All in all, 38% of the vehicles seem to be EV-qualifying. Among these EV-qualifying vehicles, a bit more than half (19% of the total) could be replaced by an electric vehicle at no additional costs, according to our computations. The other half would be penalized by around 50€ monthly extra-costs per vehicle.

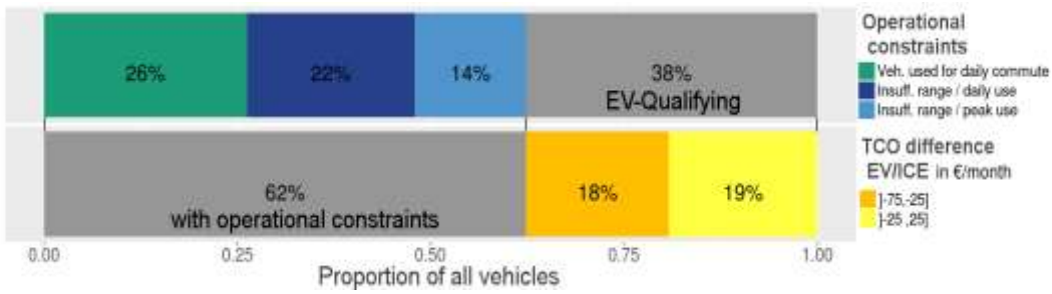

Figure 4: Constraints analysis for eLCVs compared to conventional LCVs, in 2016

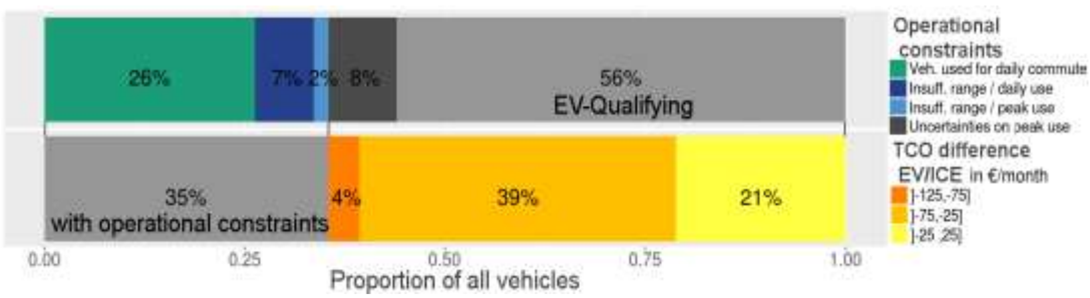

Figure 5: Projected constraints analysis for eLCVs compared to conventional LCVs, in 2021

In Figure 5, which represents the same analysis with our projected vehicles in 2021, we can see that the operational constraints are less stringent. The charging constraint remains identical, but the range constraint impacts only 7% of the vehicles in their daily use. From 2% to 10% of vehicles may have a range problem during peak uses, but the data we have don’t allow us to decide. Indeed, 8% have a range of more than 150 kilometers, and all we know is that they make regularly trips of over 150 kilometers, but we do not have further details about the exact distance of these trips.

All in all, between 56% and 64% of vehicles could be electric without changing operators’ organization.

Among these EV-qualifying vehicles, our pessimistic baseline assumptions give an extra-cost of more than 25€/month per vehicle for 43% of the total, and a comparable TCO for 21%.

6 Discussion

The important amount of operational constraints shows that today, electric vehicles are not appropriate for all commercial fleet operators, if we make the assumption that use patterns stay identical. Peak uses seem almost as constraining as average uses: this shows that it is important not to take into account only the average daily driven distance to assess the relevancy of electric vehicles. Peak uses, that we considered disqualifying, are peak trips made with at least one occurrence per month. We have no data on rarer events, so the constraint could be greater than identified here. On the contrary, it would be interesting to investigate mixed fleet uses – i.e. with vehicles of both technologies. Then, rare longer trips could be covered by conventional vehicles and would not stop the operational use of electric vehicles for a portion of the fleet. This would minimize the range constraint for peak uses.

Electric vans are still a bit more expensive in average than conventional ones. 19% of vehicles present comparable costs, which represents an important proportion, far more than the actual market shares. This is not surprising, as switching from one technology to another requires careful preparation, and a change in operational habits, which can discourage some operators. Moreover, these operators do not have a detailed knowledge of the technology and of its costs. Operators who value their image, have a specific environmental commitment or want to be at the leading edge of innovation, and/or have specific uses, are more inclined to be favorable to EVs. Moreover, with relatively moderate ranges (less than 80km in worst conditions for current LCVs), even if the vehicle’s range apparently covers all the needs of the user, the mere hypothetical possibility that they could need more range one day can prevent them from buying an electric vehicle (even if costs are comparable).

If we project ourselves into 2021, this cognitive barrier will be partly reduced as the average range potential grows. And even if diesel prices remain low and with a decrease in incentives, there is some potential for competitive electric vehicles. To specify this interpretation, a comprehensive sensitivity analysis is necessary, but is still in progress. Instead, Table 3 shows the variation in the potential market for EVs, depending on two varying parameters: fuel prices and fixed costs. The number presented is the proportion of vehicles for which operating an EV would cost as much or less than a conventional vehicle, the number in the parentheses represents the proportion that would potentially save money by operating an eLCV.

Table 3: Potential for the economic competitiveness of eLCVs, according to two varying parameters: fuel prices and fixed costs. Numbers in the parentheses represent the proportion of electric vehicles saving more than 25€ per month and vehicle.

		Fuel prices scenarios (without VAT)		
		0.85€/L (base.)	1€/L	1.15€/L
Fixed costs scenarios	+1500 €	1% (0%)	8% (0%)	21% (1%)
	baseline	21% (0%)	34% (1%)	40% (9%)
	-1500 €	53% (2%)	55% (18%)	57% (29%)

Fixed costs variations can be interpreted as one, or any combination, of the following factors:

- Different financial incentives (3300€ for the baseline, 1800€ or 4800€ incentives from the state, or other incentives such as local ones).
- Different purchase prices (if economies of scale are lower or higher than expected from the baseline for example).
- Different residual values than for conventional LCVs (to be weighted by the discount rate as the revenue is four years after the purchase).

In this table, we see that more optimistic assumptions (for the electric vehicle) give much more potential for the electric vehicle in 2021 than our baseline. Some scenarios give even a significant amount of vehicles which could lead to savings, which would certainly give a real boost to the EV market.

We can see that high fuel prices could make it possible to reduce the incentives without penalizing the eLCVs market's growth. If fuel prices remain low, the decrease in incentives would be possible without penalizing eLCVs, but with a constant potential (which is not inconsistent with a growing market). Lowering the amount of financial incentive too fast (from 6300€ in 2016 to 1800€ in 2021 for example) would impact the EV potential market very much. On the contrary, if we have a combination of increasing fuel prices and decreasing vehicle prices, we could see an actual breakthrough for the electric commercial vehicle market, even with cuts in subsidies.

All this brings a rather positive signal for electromobility in the freight transport business: if the financial incentives are carefully adapted to the economic context, there is a huge development potential. Still, there will be a certain amount of costs to absorb to be competitive without incentives. This will probably slow down the expansion of electric vehicles, but history gave us many examples of rapidly falling costs for new technologies, more rapidly than we assumed in this paper.

There are some limitations to our approach. First, we considered only one type of vehicle, whether for conventional or electric vehicles. This is a great restriction, as results might be different depending on the specific needs of each operator (one operator can favor volume while another can favor weight). This is even more penalizing for tomorrow's projections, as we could imagine a more diverse supply of electric vehicles: several battery sizes, but also several business models, with the battery either leased or sold.

Another limitation is that the vehicles we considered represent only a portion of all light commercial vehicles, as we didn't account for medium-sized and larger vans.

The constraints analysis is inevitably limited by the availability of data. That is why we tried to give a broader qualitative picture of constraints and opportunities associated to electric vehicles, which are important to keep in mind. Charging might be the real constraint of tomorrow, as batteries grow and as this constraint may remain the same in the future, unlike range. Charging difficulties are rather hard to account for given the available data of the database we are working on.

The quality of the results is also strongly linked to the quality of data, and partial adjustments made on the database might introduce some discrepancies.

Cognitive and regulatory factors have not been examined in this study, but can have great effects on the rise of freight transport electromobility.

7 Conclusion

Examining the potential market for electric vehicles in the freight sector is relevant when looking at the future sustainability of our communities. Light commercial vehicles are among the most rapidly expanding types of vehicles on roads, especially in urban areas. A significant proportion of them are used for freight and delivery activities, and this trend is growing as consumer demand for e-commerce and home deliveries is increasing at a fast rate in metropolitan areas around the world. Another interesting characteristics of the urban freight market is that, currently, the vehicles used are rather old, more so than in the longer haul freight sector. Freight commercial vehicles' environmental impact in terms of global (CO2) and local (NOx, particulate matters) emissions is therefore poor, and their share in total emissions is growing.

This study focused on the market development potential for small electric commercial vans. We were able to use a comprehensive database of light commercial vehicles in France with very detailed characteristics of their uses and users for year 2010. Current users and their operating attributes constituted the baseline of our analysis, which makes our research rather close to the reality of the current market. From that basis, and taking into account that our analysis misses important issues, as discussed in the methodology section, our results are - from a mostly economic point of view - somewhat positive towards the market potential of electric vans. Even if fuel prices in 2021 remain as low as they are today, which is a realistic assumption given that oil production continues to increase faster than oil demand, a rather small decrease in EV fixed costs (including purchase prices), which could be brought by several factors many of them being realistic today, could translate into a significant market potential for freight electric vans.

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