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Electric cars: Back to the future?

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Abstract - The main objective of the paper is to evaluate the development of the EV in a couple of selected energy scenarios, to address the influence climate policy and the presence of nuclear energy can have on this development and to estimate the impact of different EV penetration rates on electricity demand. Throughout the paper, it becomes clear that, in the absence of specific, dedicated EV public programmes, policies and measures aimed at curbing climate change spark off the penetration of EVs, especially on a longer time horizon (up to 2030): with post 2012 climate policy in place, the pure EV penetration in 2020 attains approximately 2% of the road vehicle fleet while in 2030, around 5% of the road vehicle fleet will be electrically propelled. In the time span up to 2020, the electricity consumption of the EVs is rather small: it ranges between 0.4 and 0.5 TWh. It isn't until 2025 and 2030 that EVs start to have a more visible impact on electricity consumption, stretching out between 1.2 and 1.4 TWh which represents approximately 1% of the total final electricity demand in 2030. Nuclear energy can then be a modest incentive for EVs through, assuming perfect market functioning, a decrease in electricity prices, hence triggering a slightly higher EV penetration.

This paper assumes that no specific dedicated policies are in place to stimulate the upsurge of EVs. If policy makers decide they want to support and even intensify the expansion of EVs considering their positive impact on oil independency, climate change, transport efficiency and possibly job retention/creation, further policy measures (beyond climate policy) embedded in a long term national master plan are of utmost importance.

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Executive Summary

Even in the absence of specific, dedicated policies and measures, electric motorized vehicles (cars, busses, trucks and motorcycles) do have a future in the long term. To prepare this future, it is crucial to start laying the necessary building blocks already in the short and medium term. Not missing out on this opportunity is key since electric vehicles present a number of attractive solutions to modern challenges like climate change, energy security of supply and the economic crisis as they cut greenhouse gas emissions in the transport sector, reduce reliance on fossil fuels and may create (or maintain) employment in the national automotive industries.

According to the scenario analysis undertaken on two sets of scenarios, the first being the 20/20 target scenario of the WP21-08[1], the second a selection of scenarios taken from the Prospective Study on Electricity, we see that, in the absence of dedicated policies, two factors seem to have an impact on the resurrection of the electric vehicles in the medium to long term: first and foremost, the ambition of actions undertaken to halt climate change, second and to a far lesser extent, the presence of nuclear energy.

Following policies and measures aimed at curbing climate change, the penetration of EVs rises, especially on a longer time horizon (up to 2030). In the scenarios studied comprehending an enhanced climate policy post 2012, the pure electric vehicle penetration in 2020 attains approximately 2% of the road vehicle fleet[2] while in 2030, around 5% of the road vehicle fleet will be electrically propelled. In the time span up to 2020, the electricity consumption of the EVs is rather small: it ranges between 0.4 and 0.5 TWh. It isn't until 2025 and 2030 that EVs do seem to take off with an estimated electricity consumption between 1.2 and 1.4 TWh, representing approximately 1% of the total final electricity demand in 2030.

The availability of nuclear electricity can be a modest incentive for EVs through, assuming perfect market functioning, a decrease in electricity prices, hence triggering a slightly higher EV penetration.

According to a concise literature overview, several studies cite even higher penetration rates. Our analysis shows that the impact of higher penetration rates on electricity consumption is non-negligible: if pure EVs' penetration rates by 2030 will reach 20% (30%), additional electricity demand will turn out to be 3.8 (6.3) TWh, totalling an overall road transport electricity consumption of about 4.9 (7.4) TWh.

Important lesson to be drawn from the analyses then is that the impact of an enhanced post 2012 climate policy on EV development is, although not insignificant, rather minor. If policy

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[1] Bossier et al., *Impact of the EU Energy and Climate Package on the Belgian energy system and economy*, study commissioned by the Belgian federal and three regional authorities, WP21-08, Federal Planning Bureau, November 2008.

[2] The figures represented assume vehicles fully powered by an electrical motor. If plug-in hybrids are taken into account, these figures can increase significantly.

makers decide they want to support and even intensify the expansion of EVs considering their positive impact on oil independency, transport efficiency and possibly job retention/creation, further policy measures embedded in a long term national master plan are of utmost importance.

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Introduction

Nowadays, a lot of buzz is going on around motorized vehicles powered by electricity. Momentum was created by two recent events, being on the one hand the adoption of the legislative Energy/Climate package[1] by the European Parliament (December 17, 2008) and the Council of the European Union (April 6, 2009) including a renewable energy sources development target, comprehending a 10% renewable energy target in transport; on the other hand, the economic and financial crisis and its corollary EU Economic Recovery package[2]. The push to develop viable electric vehicles (EVs) is then initiated by the need to cut greenhouse gas emissions (in 2005, transport in the EU accounted for no less than 27% of CO_2 emissions[3]), reduce reliance on fossil fuels (in 2005, transport utilized no less than 72% of all oil consumed in Europe) as well as to create (or maintain) employment in the national automotive industries. These findings together with their subsequent EU undertaken actions create a substantial support to the development of the electric driven vehicle and consequently, an increased interest in its prospects.

However, technical and logistical difficulties hamper the smooth development of an electric vehicle destined to mass market. Critics say electric cars do not have a long enough 'range' (meaning they are not well-suited to long-distance driving) and a major overhaul of power supply infrastructure will be indispensable to significant penetration of EVs in mass markets. Major technological breakthroughs in the field of high-density batteries next to regulatory, fiscal and financial incentives are of utmost importance on the road to battery-powered motorized vehicles.

This paper then zooms in on the energy side of the story. Although EVs can be approached from a variety of angles (employment, value added, corporate strategy, mobility management, ...), we chose to look at the subject from an electricity point of view, more specifically, at how future road transport electricity consumption will change and what share EVs will occupy in the total final electricity demand following a number of selected scenarios. Impact on load curves, on the other hand, is not dealt with in this publication.

In what follows, a summary of some relevant transport indicators is provided, next to a brief literature overview on the matter, complemented by a concise analysis on future prospects on the penetration and electricity consumption of EVs in Belgium according to a number of different scenarios.

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[1] http://eur-lex.europa.eu/JOHtml.do?uri=OJ:L:2009:140:SOM:EN:HTML

[2] In its Economic Recovery package released last year (2009), the EU earmarked €5 billion for its Green Car Initiative. The plan includes support for developing clean transport technologies, but is not solely dedicated to electric cars. The origin of the €5 billion is €4 billion in loans from the European Investment Bank and a further €1 billion in research funding coming from the Seventh Framework Programme for Research (FP7) and the private sector. Next to that, EU member states are encouraged to cut taxes on low-emission vehicles in order to incentivise customers to buy electric, hybrid or other green cars.

[3] CO_2 being the most prominent greenhouse gas, accounting for approximately 80% of all greenhouse gases.

1. Context

Electric cars are both a reminder of the past as a jump into the future. As early as 1884, the first electrical car was invented; in 1897, the first commercial application of electric vehicles was to be found on the streets of New York as NY taxis were equipped with an electrical motor; in 1899, the Belgian racing driver Camille Jenatzy, also known as "the red devil", drove an electrically propelled car (the Jamais Contente) at a dazzling speed of 105 km/h. Other electrical milestones were the seventies and eighties when the subsequent energy crises prompted renewed attention to the electric vehicle. Today, we witness another wave of interest and enhanced research into the EV technology thanks to the insertion of the 10% RES-T target in the legislative EU Energy/Climate package and the bending back of many industrial nations on their automotive industry as the perspective of job retention (creation) can ease the impact of the economic crisis.

However promising in terms of halting climate change, avoiding air pollution, contributing to security of supply, creating employment and even carrying in itself the possibility of transforming the entire electricity system as we know it today[4], battery-driven vehicles do have to deal with a number of flaws and obstacles. One major obstacle on the road to mass market EVs seems to be the battery range or the distance such vehicles can travel without needing to refuel or recharge. The full electric cars produced to date are suited for urban driving, but rather unfit for long journeys. This battery range issue is one of the main reasons why the first electric models did not achieve mass market penetration in the early 20th century, particularly compared to petrol engines. Hybrid engines, energy storage technology and hydrogen-based fuel cells have been touted as potential solutions. More recently, innovative developers have been working on using micro-jet turbine engines and supercapacity batteries to help energy-conscious consumers to prolong their electric journey.

Next to drastic improvements in the performance of batteries, grid infrastructure poses a problem as current distribution grids (as well as peak power plants) are not suited to adapt thousands of EVs waiting to be charged at the same moment of day. Preparing the electric grid to cope with a significant penetration of EVs is then of major importance to the viability of EVs. The long-awaited arrival of the smart grids, preferably extended to a vehicle-to-grid system[5], can break grounds in this perspective.

In addition, if electric vehicles are to live up to their green credentials, the electricity supplied to power these vehicles should be as CO_2 poor as possible, meaning a great presence of renewable energy sources in the national power production, hence another source of complicating the ex-

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[4] CREG, *De mogelijke impact van de elektrische auto op het Belgische elektriciteitssysteem*, Studie (F)100204-CDC-929, February 4, 2010.

[5] The *vehicle-to-grid system* supposes that an extended network of smart charging points is installed through which each non-driving EV is connected with the electricity grid and through which the vehicle can charge (upload on energy from the system) and discharge (supply energy back to the system) at times that are from an economic or security of supply perspective interesting. This discharge feature can alter the way the electricity system is conceived since EVs then act as giant back-up batteries for the system, even able to provide reserve services.

isting, in many cases obsolete, grid. Adapting the existing grid towards a vehicle-to-grid type system could solve that problem, since, according to CREG (2010), such a system can, through the vast presence of electric vehicles (in occurrence: one million vehicles), smoothen the integration of large intermittent energy sources like wind and solar without compromising the system security. Nuclear uptake in the power mix can also be viewed as bringing down the well-to-wheel emissions of EVs. Moreover, the presence of nuclear energy in itself is likely to have an effect on the penetration rate of EVs (see part 3.2.2).

The refuelling system also causes bumps in the road to mass market penetration. A major requirement is that the EV refuelling system has to be at least as convenient as the current practice of filling up at petrol stations. Home charging stations or public service stations (e.g. at parking lots) can be a solution, but running into the constraints of the existing system as we know it today: completely recharging cars will take a period of several hours (estimated to be 8), making it suitable for urban commuters who recharge at night, but less attractive to long-distance drivers. Another option can be battery exchange sites where drivers could trade-in their empty batteries for new ones. From a practical point of view, electric vehicle chargers and sockets have to be standardised and uniform, preferably on a European level.

As to security of supply, EVs can contribute to a nation's energy supply security through its lack (or diminished need) of oil to propel the vehicle (see also part 5). On the other hand, batteries have to be produced and the resources to fabricate the batteries have to be available. Currently, nickel and lithium batteries are likely to prove most attractive. Although both are finite, there are believed to be considerable reserves of lithium in Bolivia, Chile, the US, Russia and China. Russia and Canada are believed to be the main source of nickel, but France, Australia and others also have some of the mineral.

Finally, mobility and safety issues regarding road transport close the deal. As to mobility, current congestion problems on heavy traffic roads will not be solved through the presence of EVs. Regarding safety, many of the safety issues arising from motorised transport also apply to EVs. One feature of the EV then is particular: the absence of noise due to the electric powered motor. Some electric cars are so quiet that they even are considered to be a danger to pedestrians and the visually impaired.

2. Transport is heading for ...

To start the analysis, an overview is given of the transport activity in 2005 and its evolution up to the horizon 2030 according to the WP21-08 (Bossier et al., 2008). Next to that, the impact of the transport activity is described in terms of final energy demand.

2.1. Evolution of the transport activity

Table 1 illustrates the evolution of the transport activity of passengers and freight which has served as the basis for the calculation of the evolution of the energy demand in the transport sector in the WP21-08 reference scenario (Bossier et al., 2008). This outlook was provided by the National Technical University of Athens and was calculated from the results of the European transport model SCENES. The SCENES model takes the extension projects of the different types of networks which are documented in the TEN-T into account as well as other projects foreseen by the Member States. However, the capacity of the secondary network is supposed to be constant over the period of projection.

Table 1: Evolution of the Belgian transport activity, 2005-2030, WP21-08 baseline

Baseline	2005	2020	2030	20//05	30//05	20/05	30/05
Passenger transport activity (Gpkm)	153	184	199	1.2%	1.0%	20%	30%
of which private cars	113	129	136	0.9%	0.7%	14%	20%
Average km/capita	13632	15285	15898			12%	17%
Freight transport activity (Gtkm)	61	75	86	1.4%	1.4%	23%	43%
of which trucks	44	56	67	1.6%	1.7%	28%	52%
Freight activity per GDP						-10%	-11%

Source: NTUA (hypotheses used in the WP21-08).

According to this outlook, the number of passenger-kilometres (pkm) augments with 20% between 2005 and 2020 and with 30% between 2005 and 2030. If transport by aeroplane, supposed to expand the fastest over the projection period, is excluded, the growth rates would become 16 and 23% respectively. The average distance travelled during a year by each inhabitant increases; it will be somewhat less than 16000 km in 2030 (compared to 13600 km in 2005).

Regarding freight transport, the number of ton-kilometres (tkm) increases with 23% between 2005 and 2020 and with 43% between 2005 and 2030. Freight transport is thus supposed to increase more than passenger transport. However, we observe a decrease in the freight transport activity per unit of GDP (around 10%).

According to the Planning Paper 107 (Hertveldt et al., 2009) which also contains passenger and freight transport activity forecasts, passenger transport will rise with 30% between 2005 and 2030 and freight transport with 60% over the same period. The latter is higher than the growth rate cited in Table 1. The model used to realise these projections (PLANET) nevertheless supposes that the capacity of the infrastructure remains unchanged. Not only differences in hypotheses and methodologies explain the gap between the two projections, but also differences in the coverage of transport activity (see Box below).

Box: Difference in transport activity definitions between WP21-08 and PP107

The two cited studies (WP21-08 and PP107), although originating from the same institution (the FPB), utilize different definitions of transport activity. These differences, especially in freight transport, contribute to variations in projected evolutions.

Large differences in road freight transport coverage can be observed between the two sources of data, being DG TREN/Eurostat (used for a.o. *European energy and transport: Trends to 2030, update 2007*) and DGSIE/FPS Mobility & Transport respectively. The definition used by DG TREN/Eurostat (as used in the WP21-08) incorporates national and international haulage by vehicles registered in the country, including cross-trade and cabotage, but only the haulage performed by heavy duty vehicles (>3.5 tonnes), whilst DGSIE/FPS M&T activity data (as used in the PP107) refers to transport activity on the Belgian territory and includes light duty vehicles.

As regards the passenger transport, definitions do not diverge much. Only deviation lies in that DG TREN/Eurostat includes the pkm by vehicles registered as light duty vehicles but used as personal cars, whilst the DGSIE/FPS M&T does not.

According to the PP107, the evolution of passenger transport is characterized by a higher increase in the number of trips for motives other than "home-work" or "home-school" and by a shift from peak to off-peak hours.

The evolution of freight transport is characterized by a more pronounced increase in the international transport than in the national transport and thus by a prolongation of the average distance travelled per ton, as well as by a shift from peak to off-peak hours.

The PP107 also studies the impact of the projections on road congestion (impact on speed, externalities, etc.). The indicator fit to study congestion is the number of vehicle-kilometres rather than the number of pkm or tkm. For passenger transport, the number of vehicle-kilometres rises slightly more than the number of pkm on the road: +37% between 2005 and 2030 due to a decrease in the average occupation rate. As regards the freight transport, the opposite can be observed, the number of vehicle-kilometres augments less than the number of tkm on the road: +38% for trucks between 2005 and 2030 due to an increase in the average load rate.

Next to a baseline scenario detailing the evolution of the transport activity under unchanged policy, alternative scenarios can be envisaged that incorporate policies and measures to curb climate change and develop renewable energy sources, hence, act on the spectacular increase in transport activity. In the WP21-08 (Bossier et al., 2008), such a policy scenario is defined - the 20/20 target scenario - that mimicks as closely as possible the impact the EU Energy/Climate package has on Belgium's energy system. Through the installation of a carbon (and renewable) value[6], the system reacts to the constraints set at European level. Transport activity then responds to the introduction of a carbon value through the mechanism of price elasticities. This is shown in Table 2 illustrating the evolution of transport activity in the 20/20 target scenario. In that scenario, aviation (belonging to the ETS sector) is submitted to a carbon value of 33.5 €/tCO2 in 2020, while the other means of transport (belonging to the non-ETS sector) are submitted to a carbon value of 25 €/tCO2 in 2020.

Between 2005 and 2030, the number of pkm increases more moderately by 27% (compared with 30% in the baseline) as well as the number of tkm by 39% (compared with 43% in the baseline).

Table 2: Evolution of the Belgian transport activity, 2005-2030, WP21-08 20/20 target scenario

20/20 target scenario	2005	2020	2030	20//05	30//05	05-20	05-30
Passenger transport activity (Gpkm)	153	181	194	1.1%	1.0%	18%	27%
of which private cars	113	126	132	0.7%	0.6%	12%	17%
Average km/capita	13632	15065	15577			11%	14%
Freight transport activity (Gtkm)	61	73	84	1.3%	1.3%	21%	39%
of which trucks	44	54	64	1.4%	1.5%	23%	45%
Freight activity per GDP						-12%	-13%

Source: PRIMES, NTUA, WP21-08.

2.2. Evolution of the energy demand in transport

The significant development of transport activity, however, does not go hand in hand with a comparable increase in the final energy consumption of the sector. Between 2005 and 2020, the final energy consumption in transport increases by 17% (+11% without aviation). Between 2005 and 2030, it expands with 21% (+13% without aviation). These shares represent WP21-08 baseline figures.

In the 20/20 target scenario, the final energy consumption in transport progresses even less rapidly: +10% (+5% without aviation) between 2005 and 2020 and +9% (+3% without aviation) between 2005 and 2030.

Different explanations can be thought of: a decline in the transport activity (see supra), an uplift in the energy efficiency (in response to the carbon value) and the coming-to-market of other types of motorized vehicles like EVs.

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[6] For more information, see Bossier et al., 2008.

3. ... the future

Studies exist that estimate the share of EVs in road transport by 2020 and 2030 (at times even 2050). These estimations are useful because the development of EVs has an impact on the evolution of electricity demand. Most often, it concerns shares in relation to the total vehicle fleet (occasionally, the share relates solely to new vehicles at a given time, what tends to complicate the matter) or to the total number of passenger-kilometres travelled. These percentages sometimes relate to individual categories (hybrids type Prius, plug-in hybrids, entirely electric vehicles), sometimes to all categories. If one wants to estimate the impact the development of electric vehicles has on the electricity demand, only the last two categories are relevant.

The analysis that follows doesn't pretend to be either exhaustive or precise due to a lack of expertise and detailed information available. Its main objective is merely to evaluate the development of the EV in a couple of selected scenarios, to address the influence climate policy and the presence of nuclear energy can have on this development and to estimate the impact of different EV penetration rates on electricity demand.

3.1. Some key figures in recent studies

In a study of Eurelectric (Eurelectric, 2007), a sector association which represents the common interests of the electricity industry at pan-European level, it is written that plug-in hybrid vehicles (PHEV) can have a market share ranging from 8 to 20% in 2030. In the same study, several scenarios are scrutinized among which a scenario called *Role of electricity*, that estimates the share of plug-in hybrids at 11% in 2030 and at 23% in 2050.

In the Planning Paper 107 (Hertveldt et al., 2009), the assumption is made (based on a study of Logghe et al., 2006) that hybrid vehicles type Prius represent about 20% in 2020 and 30% in 2030 of the total number of vehicle-kilometres.

A study by ECN (2009) indicates that the share of light electric vehicles in 2030 can possibly reach 20%.

Conversations with experts indicate that reasonable EV penetration rates for Belgium boil down to 15% of the vehicle fleet by 2030.

The *Pathways to a low-carbon economy* by McKinsey & Company (2009) calculate the impact of three distinct scenarios on the total road transport abatement opportunities. The penetration of EVs fluctuates according to the chosen scenario: in the *ICE World scenario*, no EVs are in the picture (all new cars are supposed to be ICE[7] cars); in the *Mix Technology World* scenario, hybrids

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[7] The ICE or internal combustion engine is an engine in which the combustion of a fossil fuel occurs with an oxidizer in a combustion chamber. In an ICE the expansion of the high temperature and pressure gases, which are produced by the combustion, directly applies force to a movable component of the engine and by moving it over a distance,

type Prius account for 22% of new sales and plug-in electric vehicles (PHEVs) for 16% in the period 2026-2030; in the *Hybrid/Electric World* scenario, 25% of sales are hybrids type Prius, 24% are PHEVs and 9% are full EVs in 2026-2030.

Finally, a study from Clement et al. (2008) specifies that by 2010 7% of the market will be populated by hybrid electric vehicles, by 2030 this share will grow into 30% (of which 35% diesel vehicles and 30% gasoline).

3.2. Estimation of the share and consumption of EVs

First, it is important to note that the analysis that follows only concerns electric vehicles of which the power supply is assured through the grid. The development of hybrids type Prius do not bring about any additional electricity demand since their battery is charged by the drive cycle of the vehicle (e.g. regenerative braking[8]). Also, the available results do not allow to make a distinction between the two other categories of EVs (plug-in and full electric[9]). Finally, we only have results in terms of energy consumption, not in function of technology used. One can then understand why the estimation can only be rough at best.

3.2.1. Impact of climate policy

In a first analysis, the impact of a post 2012 enhanced climate policy is evaluated by means of an assessment of a number of scenarios. The selected scenarios are taken from the WP21-08 on the one hand, the Prospective Study on Electricity (PSE) on the other. The simulated climate policy relates to the adoption of the EU Energy/Climate package for Belgium in the first case, while in the second case several scenarios comprehending an enhanced climate effort in the period after the Kyoto engagement was simulated[10].

a. WP21-08

In the WP21-08 baseline, the share of electricity in the energy consumption of road transport (cars, busses, trucks and motorcycles) remains marginal up until 2030. In the 20/20 target scenario on the other hand, the electricity consumption of road transport increases regularly: in 2020, it represents 0.4% of the total energy consumption of that type of transport; in 2030, the percentage reaches 1.1%. These figures may seem negligible, but if one takes into account that a

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generates useful mechanical energy.

[8] A regenerative brake is an energy recovery mechanism that reduces vehicle speed by converting some of its kinetic energy and/or potential energy (due to elevation) into a useful form of energy instead of dissipating it as heat as with a conventional brake. The converted kinetic energy is stored for future use or fed back into a power system for use by other vehicles.

[9] Plug-in hybrid vehicles (PHEVs) differ from battery-electrical vehicles ((B)EVs) or pure electrical vehicles in that the former have an electrical next to an internal combustion engine (ICE) whilst the latter solely possess an electrical motor.

[10] No exact copy of the package was simulated in the PSE, since the quantitative part of this study was drafted prematurely to the adoption (or even disclosure) of the package (for more information, see Box: Climate and renewable policies in the PSE).

(full) electric vehicle consumes up to 4 times less energy per 100 kilometres than a 'normal' car (weighted average of consumption of gasoline/diesel/LPG confounded), the outlook becomes completely different: the share of (full) electric vehicles would then become 1% in 2020 and 4% in 2030. If we make the assumption that the increase in the electricity consumption is mainly caused by plug-in hybrids, the share of these vehicles in the total vehicle fleet should even be more elevated because they only partly function on electricity.

In terms of electricity consumption, these shares translate into 0.4 TWh in 2020 and 1.1 TWh in 2030, representing 0.4 and 0.9% of the total final electricity demand respectively.

Table 3: EV electricity consumption (TWh) and share of electric road transport in total final electricity demand (%), 2005-2030, WP21-08 baseline and 20/20 target scenario

	TWh			Share	
	2005	2020	2030	2020	2030
Baseline	0,00	0,01	0,01	0,0%	0,0%
20/20 target	0,00	0,35	1,10	0,4%	0,9%

Source: own calculations.

The average annual growth rate of the final electricity demand in the 20/20 target scenario reaches 1.65% between 2005 and 2030. In that scenario, the share of EVs in the total road vehicle fleet is estimated to be 4% in 2030. Starting from there, we have evaluated how the average annual growth rate of the final electricity demand would evolve if the share of EVs would be higher in 2030. The results of these estimations are stated in Table 4. Given the 'rough' outset of the estimation, these results are to be considered with caution and demand to be further investigated.

Table 4: Estimation of the impact of EV penetration on the average annual growth rate of final electricity demand, 2005-2030

Share of EVs in the road vehicle fleet by 2030	Average annual growth rate of final electricity demand (2005-2030)
4%	1.65%
10%	1.69%
20%	1.77%
30%	1.85%

Source: own calculations.

For information, the scenario *Role of electricity* in the Eurelectric study that simulates a high penetration of electric uses (plug-in hybrids, heat pumps) in the final demand sectors and mobilises nuclear and CCS in the power sector, notes an average annual growth rate of electricity demand of 2.2% between 2005 and 2030, against 1.5% in the scenario *Baseline*. Our estimations and this result are, however, not directly comparable since the Eurelectric study relates to all 27 MS of the EU and the *Role of electricity* scenario covers other policies and measures than solely those who aim at promoting the development of EVs.

EVs in RES-T target

Finally, to grasp the importance of EVs in the legislative Energy/Climate Package, more specifically, in the RES-T target which stipulates that every Member State has to reach a 10% share of renewable energy sources in its transport mix by 2020, a quantitative analysis was performed based on the 20/20 target scenario. When the EU share of renewable energy sources in electricity production by 2020 is set at 31%[11], the Belgian RES-T target is reached by both use of biofuels and renewable electricity in transport. Biofuels take care of the biggest part of the objective (9.3%), the balance is made up of renewable electricity used in EVs (0.3%) and in rail transport (0.5%).

b. Prospective Study on Electricity

Next to the WP21-08 sketching the impact of the EU Energy/Climate package on the Belgian energy system, another insightful study is the Prospective Study on Electricity (FPS Economy, FPB, 2009). This study finds its roots in the June 1, 2005 law in which its objective is stated to be the analysis of the evolution of electricity supply and demand in the medium to long term and subsequently the derivative needs for the future power generation park. In the PSE a wide range of scenarios is analyzed, diverging on three uncertainties. These uncertainties relate to 1) the evolution of the electricity demand, 2) the implementation of a post 2012 climate policy and its impact on the price of emission permits (or carbon value), 3) the retention of the law on nuclear phase out, or the possibility to prolong the functional lifetime of the existing nuclear power plants beyond 40 years.

In October 2009, further to the publication of the GEMIX report on the ideal energy mix for Belgium towards 2020 and 2030, the federal government decided to reconsider the 2003 Act concerning the gradual phase out of Belgian nuclear energy and to postpone the retirement of the three oldest nuclear power plants Doel 1, Doel 2 and Tihange 1 to 2025. These three power plants, instead of being closed after 40 years of service, will see their operational lifetime extended with another 10 years. No decision on the newest reactors was taken, so all things being equal, the entire nuclear power production park (about 6000 MW) will close its doors between 2022 and 2025, the last nuclear kWh being generated in 2025.

To include the changed outset on nuclear power production, only the PSE-scenarios in which the nuclear extension is taken into account, are scrutinized in this part. These are all the scenarios with the 'Nuc' suffix in Table 5 (highlighted in grey). Table 5 depicts the entire spectrum of alternative scenarios analyzed in the PSE (11 in total[12]).

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[11] Capros et al. (2008), *Model-based Analysis of the 2008 EU Policy Package on Climate Change and Renewables, Appendix 5: EC Proposal with JI/CDM & with RES trading.*

[12] For more information, see FPS Economy, FPB (2009), *Studie over de perspectieven van elektriciteitsbevoorrading 2008-2017.*

Table 5: Definition of the alternative PSE-scenarios

	Reference electricity demand	Higher electricity demand	Lower electricity demand	Nuclear option	Reference CV	Higher CV
Base_Nuc	x			x	x	
Base_HiCV	x					x
LoGro			x		x	
HiGro		x			x	
LoGro_HiCV			x			x
HiGro_HiCV		x				x
LoGro_Nuc			x	x	x	
HiGro_Nuc		x		x	x	
LoGro_HiCV_Nuc			x	x		x
HiGro_HiCV_Nuc		x		x		x
Base_HiCV_Nuc	x			x		x

Source: PSE (2009).

When we then turn to the in-depth analysis of the relevant PSE-scenarios, more specifically the penetration rate and electricity consumption of EVs in the different scenarios[13], the difference between two types of scenarios becomes apparent: on the one hand, the scenarios with enhanced climate policy after 2012, on the other scenarios without any climate action other than what was already decided end of 2006. The scenarios without post-Kyoto climate action (Base_Nuc, LoGro_Nuc, HiGro_Nuc) experience a seemingly insignificant penetration of electric motorized vehicles (cars, busses, motorcycles and trucks) against the horizon 2020 and 2030 with an electricity consumption of 0.01 and 0.02 TWh respectively. The lowest road transport electricity consumption is identified in the LoGro_Nuc-scenario, a scenario in which no climate policy strengthening is combined with low overall energy demand (due to low economic activity and stringent energy efficiency actions). The overall transport activity in the LoGro_Nuc-scenario is also lower than in the Base_Nuc-scenario.

The scenarios that do make a difference are the scenarios with post 2012 climate policy implementation (HiCV). This climate policy is no exact reflection of the Energy/Climate package as adopted by the Parliament and the Council (2009) since that information was not available at the time of the PSE scenario analysis (mainly Fall 2007). Nevertheless, it supposes an enhanced engagement in climate policies and measures that results from a carbon price of 54 €/TCO_2 in all sectors (ETS as well as non-ETS).

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[13] The figures represented in this section assume vehicles fully powered by an electrical motor. If plug-in hybrids are taken into account, these figures can increase significantly.

Box: Climate and renewable policies in the PSE

Although a further strengthening of the post 2012 climate policy – which, in April 2009, was translated into the adoption of the legislative Energy/Climate package that, amongst others, comprehends a European specified target of reducing greenhouse gases in 2020 in the ETS sector as well as national GHG emission reduction targets in 2020 in the non-ETS sector - was simulated in the PSE in the alternative scenarios with suffix 'HiCV', the target specifying the development of renewable energy sources was not studied in an explicit way.

In particular, in the PSE, the development of renewable energy sources for the electricity production results from the minimisation of the costs for the power sector, taking into account the relative costs of the different production means (capital, operation and maintenance, fuel), the evolution of the policies and measures to back the RES, the average annual utilisation rate of the different types of power plants, etc.

As regards the strengthening of the climate policy after 2012, the PSE scenarios with suffix 'HiCV' integrate an increase of the carbon value that, in 2020, is supposed to equal 54 €/tCO_2 in all sectors, against 22 €/tCO_2 in the non-HiCV-scenarios and solely in the ETS sector. This hypothesis is higher than the one made in the framework of the study on the impact of the Energy/Climate package on the Belgian energy system and its economy, the WP21-08 (Bossier et al., 2008), being 33.5 €/tCO_2 in the ETS sector and 25 €/tCO_2 in the non-ETS sector.

These HiCV-scenarios then show a road transport electricity consumption of around 0.5 TWh in 2020 and a bit less than 1.4 TWh in 2030, while the EV penetration rates in the total fleet oscillate around 2% and 6% respectively. The scenario showing the highest EV electricity consumption is the HiGro_HiCV_Nuc-scenario, a scenario combining an enhanced climate policy effort with a higher economic growth (2.3% per year on average between 2005 and 2020 instead of 2.1% in the Base_Nuc-case), inducing a higher overall electricity demand. The HiGro_HiCV_Nuc-scenario can also be seen as a scenario that induces a further electrification of the energy landscape[14], giving way to for example heat pumps and battery-driven vehicles.

Table 6: EV electricity consumption (TWh) and share of electric road transport in total final electricity demand (%), 2005-2030, different PSE-scenarios

	TWh			Share	
	2005	2020	2030	2020	2030
Base_Nuc	0,00	0,01	0,02	0,0%	0,0%
Base_HiCV_Nuc	0,00	0,44	1,31	0,4%	1,0%
HiGro_Nuc	0,00	0,03	0,04	0,0%	0,0%
HiGro_HiCV_Nuc	0,00	0,47	1,37	0,4%	1,0%
LoGro_Nuc	0,00	0,00	0,00	0,0%	0,0%
LoGro_HiCV_Nuc	0,00	0,40	1,25	0,4%	1,2%

Source: own calculations.

3.2.2. Impact of nuclear energy

Next to climate policy, we also investigate the impact nuclear produced energy can have on the consumption and penetration rate of EVs. Since the PSE is the only recent study that includes both post-Kyoto climate policy and a nuclear lifetime extension, only a selection of PSE-scenarios is serviceable in this regard. The scenarios under evaluation are then scenarios that include both post-2012 climate policy (with suffix 'HiCV', since, corollary to 3.2.1.b, only the HiCV-scenarios

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[14] It is inspired on Eurelectric's *Role of electricity* scenario (see supra).

do show a noticeable EV penetration) combined with the (no) prolongation of the operational life span of all nuclear power plants (with suffix 'HiCV(_Nuc)' since we want to study the effect nuclear energy has on EV occurrence).

Table 7: EV electricity consumption (TWh) and share of electric road transport in total final electricity demand (%), 2005-2030, different PSE-scenarios

	TWh			Share	
	2005	2020	2030	2020	2030
Base_HiCV	0,00	0,42	1,21	0,4%	1,0%
Base_HiCV_Nuc	0,00	0,44	1,31	0,4%	1,0%
HiGro_HiCV	0,00	0,45	1,26	0,4%	1,0%
HiGro_HiCV_Nuc	0,00	0,47	1,37	0,4%	1,0%
LoGro_HiCV	0,00	0,39	1,12	0,4%	1,1%
LoGro_HiCV_Nuc	0,00	0,40	1,25	0,4%	1,2%

Source: own calculations.

Table 7 then teaches us that nuclear energy has a small, yet visible influence on the development of EVs. In 2020, the Nuc-scenarios experience an EV electricity consumption that is on average 4% higher than the no Nuc-scenarios. In 2030 the difference attains 9% (12% in the LoGro_HiCV-case). The reason for the higher presence of electric-driven vehicles in scenarios in which the lifetime of nuclear power plants is prolonged up to 60 years, has to be sought in the lower cost to produce electricity. Since fully amortized nuclear power plants can be used to produce electricity up to 2030 in the Nuc-scenarios, the average electricity production cost is lower. This lower production cost is then translated into a more appealing electricity price (through the Ramsey-Boitteux pricing mechanism used in PRIMES) and, hence, influences the relative competition between the different types of fuel utilized to propel motorised vehicles, thereby giving a boost to electric-driven vehicles.

4. Conclusion

On the journey throughout this paper, it has become obvious that electric motorized vehicles (cars, busses, trucks and motorcycles) do have a future, slowly taking off in the medium term to gain weight in the long term. Electric vehicles present a number of attractive solutions to modern hurdles like climate change, energy security of supply and the economic crisis as they cut greenhouse gas emissions in the transport sector, reduce reliance on fossil fuels and may create (or maintain) employment in the national automotive industries. To secure these advantages, it is of utmost importance to start laying the necessary building blocks already today through explicit policy measures (beyond climate policy) embedded in a comprehensive national master plan.

According to the scenario analysis undertaken on two sets of scenarios, we see that, in the absence of specific dedicated policies, two factors seem to have an impact on the resurrection of the electric vehicles in the medium to long term: first and foremost, the ambition of actions undertaken to halt climate change, second and to a far lesser extent, the presence of nuclear energy.

Following policies and measures aimed at curbing climate change, the penetration of EVs rises, especially on a longer time horizon (up to 2030). In the scenarios studied comprehending an enhanced climate policy post 2012, the pure electric vehicle penetration in 2020 attains approximately 2% of the road vehicle fleet[15] while in 2030, around 5% of the road vehicle fleet will be electrically propelled.

In the time span up to 2020, the electricity consumption of the EVs is rather small: it ranges between 0.4 and 0.5 TWh. It isn't until 2025 and 2030 that EVs do seem to take off with an estimated electricity consumption between 1.2 and 1.4 TWh, representing approximately 1% of the total final electricity demand in 2030.

The availability of nuclear electricity can be a modest incentive for EVs through, assuming perfect market functioning, a decrease in electricity prices, hence triggering a slightly higher EV penetration.

According to a concise literature overview, several studies cite even higher penetration rates. Our analysis shows that the impact of higher penetration rates on electricity consumption is non-negligible: if pure EV's penetration rates by 2030 will reach 20% (30%), additional electricity demand will turn out to be 3.8 (6.3) TWh, totalling an overall road transport electricity consumption of about 4.9 (7.4) TWh. If penetration rates like these are desirable for reasons mentioned, the analysis has made clear that climate policy alone will not suffice: other specific policy efforts are then required.

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[15] The figures represented assume vehicles fully powered by an electrical motor. If plug-in hybrids are taken into account, these figures can increase significantly.

5. Annex

Next to the scenario analyses performed with the PRIMES model, some additional evaluations were made 'outside the model'. Based on a number of hypotheses and distinct sources (FPB, 2009, Clement et al., 2008, McKinsey, 2009), the impact of the EV penetration is estimated in terms of energy consumption and money saved. If the analysis performed in 3.2 is rough, this evaluation is even rougher.

Following an average annual growth rate of the Belgian vehicle fleet of 1% up to 2030, an assumption coherent with Clement et al. (2008) and lower than the average annual growth rates we experienced in Belgium between 1991 and 2007 (1.5%), and assuming the *Mix Technology World* scenario 2 of the McKinsey study[16], we arrive in 2020 (2030) at 183000 (674000) electric vehicles (representing 3 (11)% of the total vehicle fleet in 2020 (2030)).

The estimated consumption of the total Belgian road vehicle fleet then turns out to be 5083 ktoe in 2020 and 4300 ktoe in 2030. Although the total number of vehicles increases by almost one quarter between 2007 and 2030, energy consumption declines by 15%. This seemingly opposing movement can be attributed to two elements: the first being advances and improvement measures in internal combustion engines' (ICE) efficiency, the second the presence of EVs that are up to 4 times more efficient than ICEs.

Table 8: (Estimated) consumption of total car fleet with EVS (ktoe), 2007-2030

	2007	2010	2020	2030
ICE cars	5062	5216	5037	4163
(PH)EV hyp2	0	0	46	137
Total	5062	5216	5083	4300

Source: own calculations.
ICE stands for internal combustion engine.

Supposing that the EVs did not materialise, but that they were replaced by diesel cars, the estimated consumption then would be 3% higher in 2020, whilst by 2030, the consumption would grow by 11%.

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[16] Based on the concise literature overview cited in 3.1, scenario 2 seemed most in accordance to the other studies.

Table 9: (Estimated) consumption of total vehicle fleet without EVS (ktoe), 2007-2030

	2007	2010	2020	2030
ICE cars	5062	5216	5037	4163
Additional diesel cars	0	0	209	624
Total	5062	5216	5246	4788

Source: own calculations.

In other words, taking the extra diesel vehicles off the road and replacing them by electric-powered vehicles would save 163 ktoe in 2020 and 488 ktoe in 2030 in energy consumed. In practical terms, this represents 233 million liters of diesel in 2020 and 695 million liters of diesel in 2030 replaced by 0.5 TWh and 1.6 TWh respectively.

For the sake of the argument, suppose that the price paid at the pump for diesel reaches 1€/l in 2020 (2030) and the consumer price of electricity 0.24 €/kWh for both years, one could then save up to 45% in fuel cost. If by then the price at the pump would have doubled (2€/l) and the price of electricity would reach 0.3 €/kWh, the saving would even mount to 66%.

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