SCelecTRA

Scenarios for the Electrification of Transport

Final report

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Contenu

This why you should read SCelecTRA reports!

Do you want to know how many Electric Vehicles and Plug-in Hybrid Vehicles could be on the road in 2030?

*You should read our **D4.1a Policy scenarios to sustain EV deployment** or go to section 5 of this report*

Do you want to know what are the drivers of the European passenger mobility?

*You should read our **D2.1a Econometrical study** or go to section 2 of this report*

Do you want to know how to support EV deployment in Europe and which public policy tools are the most efficient?

*You should read **D2.2 Policy scenario definition** and **D4.1a Policy scenarios to sustain EV deployment** or go to section 3 of this report*

Do you want to explore the system effects & impacts on the EU energy & transport sectors?

*You should read **D4.2 Energy systems analysis of electromobility deployment scenarios in Europe: a 2030-2035 perspective** and go explore SCelecTRA results on **http://vedaviz.com/Portal/Playground.aspx?p=Scelectra02Jun15&g=1a3c15** and **http://vedaviz.com/Presenter/Presenter.aspx?p=Scelectra02Jun15&g=3918c6***

Do you want to know what could be the environmental impacts of Electric Vehicles?

If you want to have the benefit of one Electric Vehicle compared to conventional vehicles *you should read **D3.1 Attributional Life Cycle Analysis report** or go to section 1 of this report*

*If you want to know what could be the benefits associated with the electrification of passenger fleet in Europe, you should read **D3.2 Environmental assessment of e-mobility deployment scenarios in climate policies***

Do you want to assess the costs of the deployment of Electromobility?

*You should read **D3.3 Externality repot and D4.2 Cost Benefit analysis section** or go to section 8 of this report*

PROJECT DESCRIPTION AND OBJECTIVES

SCelecTRA – Scenarios for the electrification of Transport is a collaborative project under the ERANET – Electromobility+ call for project and aims at:

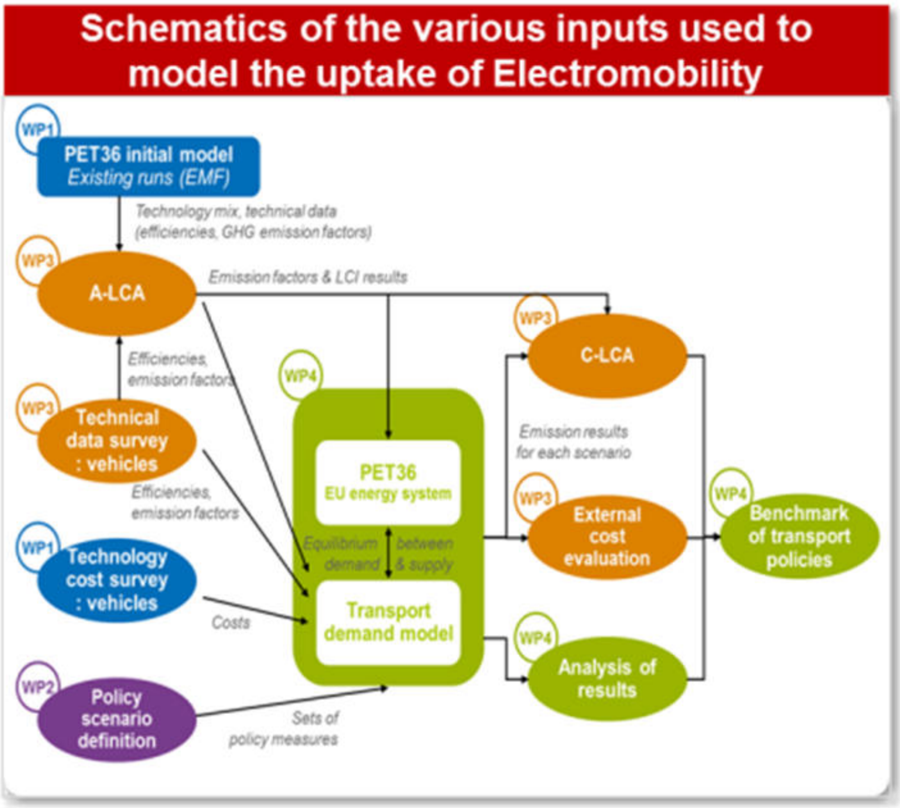
- identifying the conditions and public policies actions to develop road passenger electromobility in Europe for 2030,
- assessing the environmental impacts of such policies via consequential Life Cycle Analysis as well as their external costs.

SCelecTRA has issued scenarios of the potential size of Plug-in hybrid vehicles (PHEVs) and Electric Vehicles (EVs) market for the 2030 horizon.

The question of Public Policies is tackled by reviewing the different legislative and economic tools for promoting Electromobility and evaluating their efficiency and assessing their overall cost both on the economic and environmental levels. It has assessed the energetic and environmental benefits of Electromobility by investigating the “Well to wheel” impact of PHEVs and EVs by integrating the diversity of Europe’s countries energy-mix profiles and evaluating the CO_2 reduction impacts of the introduction of such vehicles in the European fleet and by proposing a comparison between two distinct Life Cycle Analysis methodologies.

Objectives of the project

SCelecTRA is about depicting the future of Electromobility in Europe. As represented in Figure 1 the project has gathered different approaches : economic, environmental, political and technical and their associated databases to figure out the best ways to promote the arrival of electrified vehicles such as electric and hybrid vehicles.



Source : SCelecTRA

Figure 1: data interaction within the project

The main objective and the core of the project is to model the interactions between the transport sector with a focus on passenger cars and the other energy sectors and to impulse the arrival on a large scale of the electrified vehicles in the PET36 model, a TIMES model specific to Europe.

SCelecTRA aims at investigating several questions around Electromobility (also addressed by the Key dimension of ERANET – Electromobility+: socio-économic issues) which are:

- What are the relevant conditions for EVs & PHEVs deployment ?
- What are the impacts on the EU energy & transport sectors?
- What are the environmental impacts related to Electromobility deployment ?
- What are the costs related to Electromobility deployment in EU ?

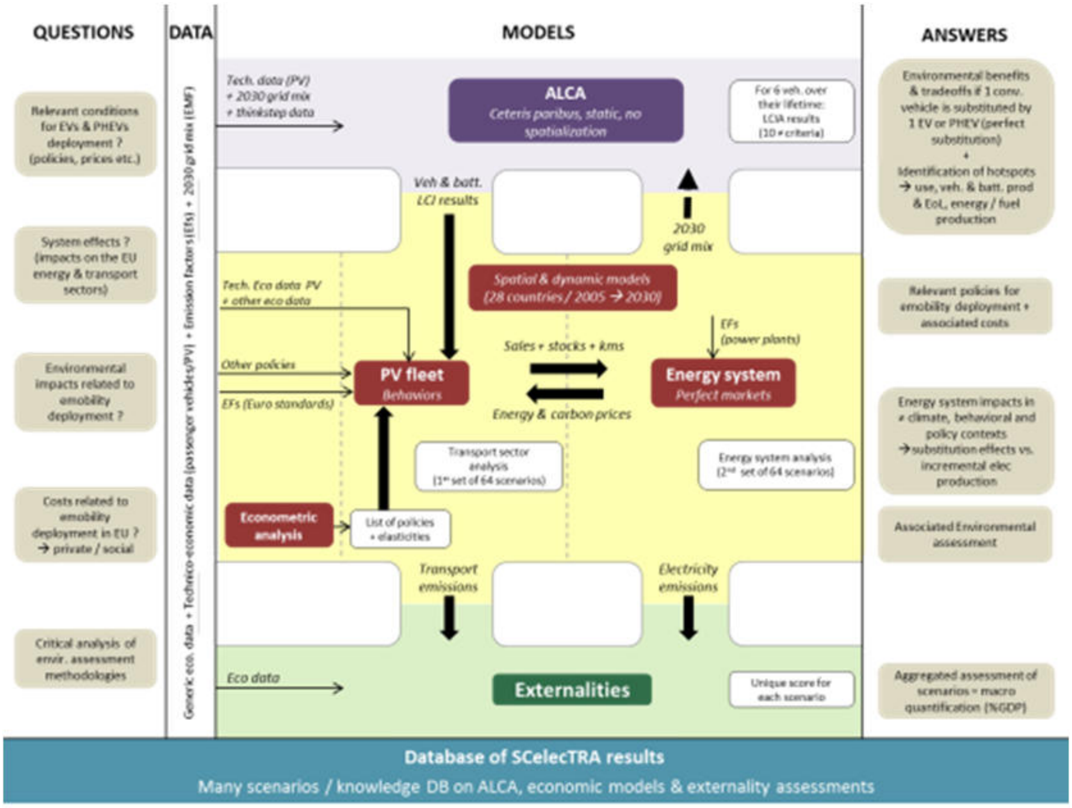


Figure 2: Objectives of SCelecTRA

This unique mix of approaches has allowed us :

- to assess what the drivers of EU mobility are,
- to study the public policies which have been used in the past in order to know which would be the most efficient in the future,
- to model as accurately as possible the different conditions to create a market for electrified vehicles,
- to assess the impacts they will have on the energy sector and how they will help us to move towards a more environment friendly transport sector not as individual solutions but as a mix of solutions as a whole,
- draw a clear roadmap of the actions which should be used in order to create as soon and as effectively as possible a mass-market Electromobility in Europe.

Pan-European Times PET model

The Pan European Times (PET) Model is a multi-regional partial equilibrium model of Europe built with MARKAL/TIMES, the technical economic model of IEA-ETSAP.

The PET36 model represents the energy system of 36 European regions and its possible long term evolution and was developed following a series of European Commission funded projects (NEEDS, RES2020, REACCESS, REALISEGRID, COMET, Irish-TIMES…).
The model was developed and is maintained by the KanLo team. The actual system encompasses all the steps from primary resources in place to the supply of the energy services demanded by energy consumers, through the chain of processes which transform, transport, distribute and convert energy into services.

PET36 is an optimization techno-economic TIMES model covering EU27 countries + Norway, Iceland, Switzerland and the Balkan countries. The Balkans were added during the REALISEGRID project, which was mainly an electricity sector study. The non-electric parts for the six additional regions were not really tested and further, recent developments have been done only for the 30 countries. Thus, the EU27+3 version (i.e. without the Balkan countries) has been used in this project.

In this 30 multi-region model, country energy systems are linked through trade of the main energy forms and most of its national energy systems were validated by national teams. The model runs from 2005 to 2050 with 5 years interval.

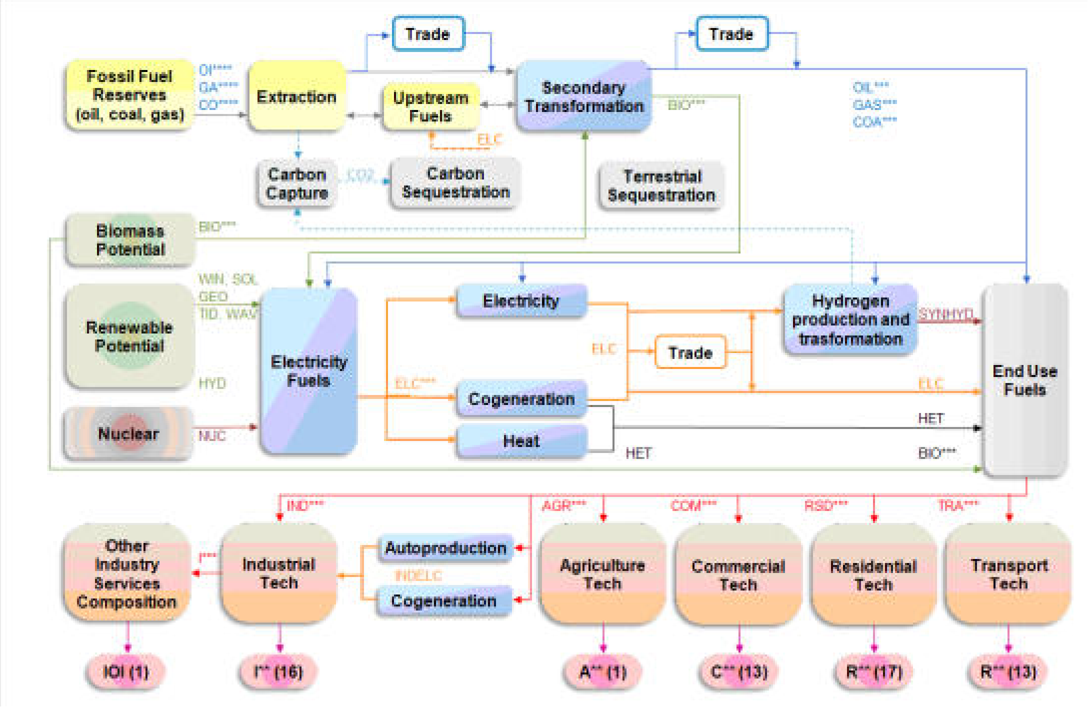


Figure 3: High level reference energy system of the PET country single models (http://www.kanors.com/Index.asp, 2010)

For each region, the model describes and models the following sectors: the region's supply sector (fuel mining, primary and secondary production, exogenous import and export), its power generation sector (including also the combined heat and power production and the heat production by district heating plants), and its demand sectors (residential, commercial, agricultural, transport, industrial).

Solving the model means finding for each time period the optimum Reference Energy System by selecting the set of technologies and fuels that maximize the total surplus, which in the simplest case is equivalent to minimize the total system cost over the entire planning horizon (i.e. the optimal energy-technology pathways). Thus, the model determines the optimal mix of technologies and fuels at each period, the associated emissions, mining and trading activities and the equilibrium level of the demand.

More details on http://www.kanors.com/Index.asp

PROJECT RESULTS

1. Environmental benefits of xEVs

1.1 Introduction to Life Cycle Assessment

Life Cycle Assessment (LCA) is a tool for analysing and assessing the environmental impacts resulting from the production, use and disposal/recycling of products.
Life-cycle assessment represents a standard method to assess environmental impacts associated with all product's life cycle stages from-cradle-to-grave (i.e., from raw material extraction to materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling). Attributional LCAs seek to establish the burdens associated with the production and use of a product, or specific service or process, at a point in time (typically the recent past).

1.2 Scope and boundaries

Six technologies for C-segment vehicles (middle class vehicles) are considered for the study;

- Gasoline vehicle
- Diesel vehicle
- Compressed natural gas (CNG) vehicle
- Gasoline HEV
- Plug-in gasoline HEV
- Electric vehicle

	Gasoline vehicle	Diesel vehicle	CNG vehicle	Gasoline HEV	Plug-in gasoline HEV	Electric vehicle
Approximate Weight (kg)	1450	1450	1560	1550	1650	1640
ICE power (kW)	75	70	75	70	70	
Electric motor power (kW)				50	50	70
Type of fuel injection	Gasoline Direct injection	Diesel High pressure injection	CNG injection	Gasoline Direct injection	Gasoline Direct injection	
Turbocompressor	yes	yes	yes	yes	yes	no
Stop&Start	yes	yes	yes	no	no	no
High Voltage Battery	no	no	no	yes	yes	yes
Type of high voltage batteries				Li-ion	Li-ion	Li-ion
Battery capacity (kWh)				3	10	20
Fuel tanks	Gasoline	Diesel	Gasoline + CNG	Gasoline	Gasoline	
Post-treatment	3 way catalyst	DOC + DPF + SCR	3 way catalyst	3 way catalyst	3 way catalyst	
Particulate filter	yes	yes	no	yes	yes	no

Table 1: Vehicle configurations

The system under study is a cradle-to-grave system covering process steps from the manufacture of the vehicle, to its end of life:

- Extraction of raw materials;
- Car production including automobile coating;
- All fuel transformation processes upstream to fuel consumption (Well to Tank);
- Electricity production process upstream to power consumption (Well to Tank);
- Fuel and electricity consumption for car driving (Tank to Wheel);

- Use phase of vehicle over a defined lifetime;
- End of life of vehicle (according to the EU EoL Vehicle directive including shredding process);
- Recovery and recycling of battery/battery pack components, metal compo-nents and electronic equipment

1.3 The Functional Unit

The functional unit (FU) quantifies the performance/function of a product system for use as a reference unit. It is very much linked to the type of question which is addressed and resulting choices regarding system boundaries.

- One vehicle-life time taking into account the average life time of a vehicle (between 12 and 15 years) of 150,000 km.

1.4 Results & Life cycle interpretation

According to the analysis carried out and presented in deliverable D3.1 of SCelecTRA, the use phase dominates the impact associated with conventional vehicle types referring to most of the CML categories. As the use phase for electric vehicles shows lower values than for conventional ones, the production phase gains importance in the life cycle analysis of electric vehicles. Their production phase certainly includes higher impacts due to the manufacturing of the lithium ion cell representing the main driver in this context.

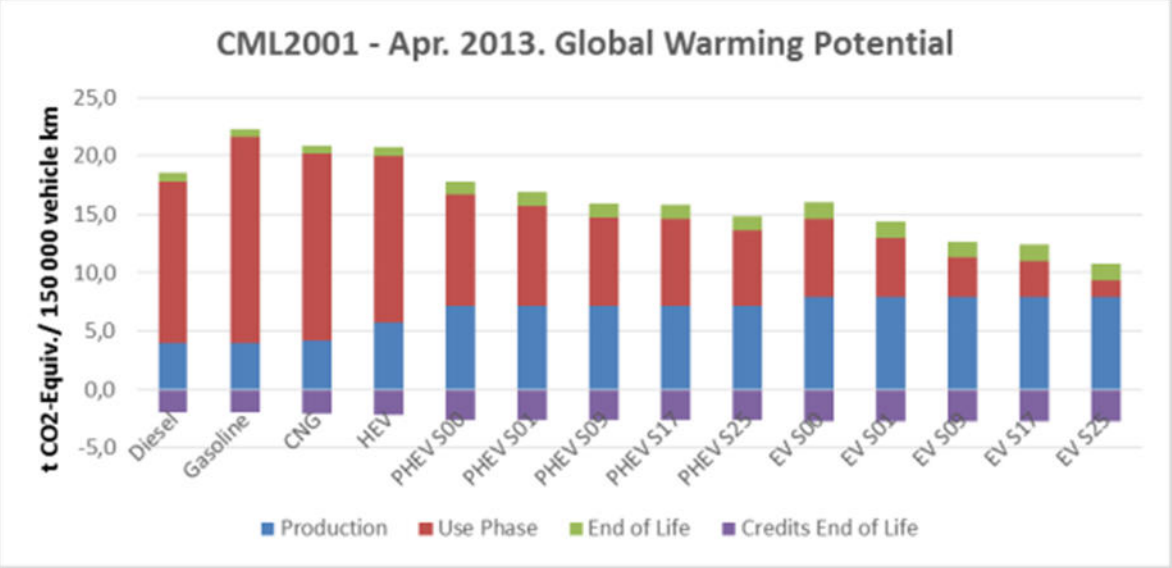


Figure 4: Global warming potential generated over the life cycle phases of different vehicle types (CML 2001-2013)

As a result, the production of lithium ion cells and their implications in terms of environmental impacts represent significant issues throughout the life cycle of electric vehicles. A more detailed analysis of the impacts associated with the lithium ion battery shows the predominance of the cathode material. This study assumes lithium iron phosphate batteries to be the cell type widely used in 2030. Nevertheless, other cell types could be of importance at that time due to the uncertainty associated with the development of innovative approaches such as exemplary the lithium air cell.

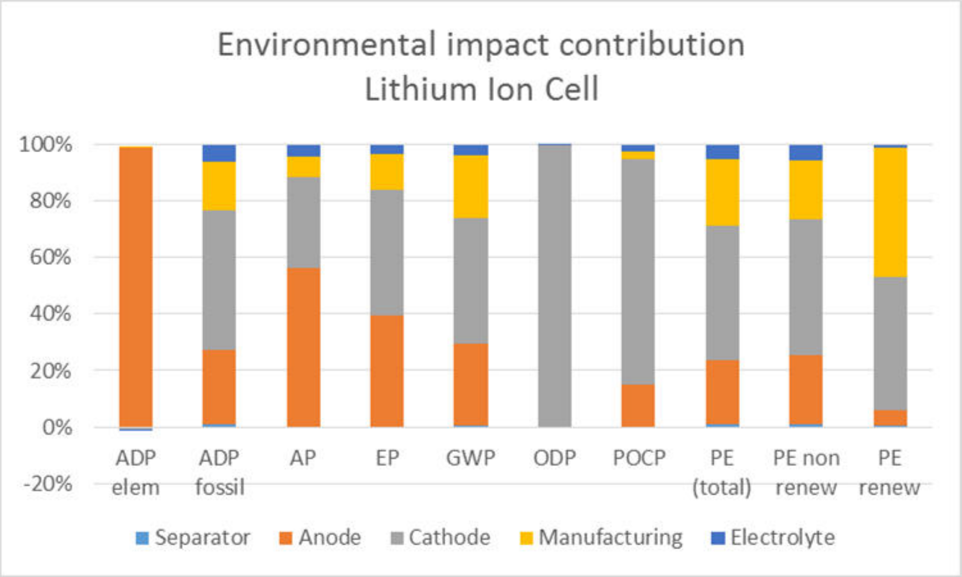


Figure 5: Environmental impact contribution of 1 kg of Lithium Ion Cell

The investigation of five different electricity grid mix scenarios for the future render the projection of various energy supply alternatives possible and shows the implications of ‘environmental’ policies (nuclear phase out, cap of GHG emissions) on the environmental performance of electric vehicles as shown in Figure 6.

Figure 6: Environmental impacts of 1 kWh of electricity from the grid referring to different policy scenarios (S00, S01, S09, S17, and S25)

In order to further investigate the direct effects of different approaches for the calculation of consumption patterns of vehicles, this study evaluates ARTEMIS driving cycles compared to NEDC. The integration of ARTEMIS cycles renders the analysis of fuel consumption with regard to different driving situations differentiating between urban, road and highway driving cycles possible. In general, fuel consumption of ARTEMIS driving cycles compared to NEDC shows higher values except for road transport. As a result, environmental impact associated to the use phase are higher assuming ARTEMIS instead of New European driving cycles.

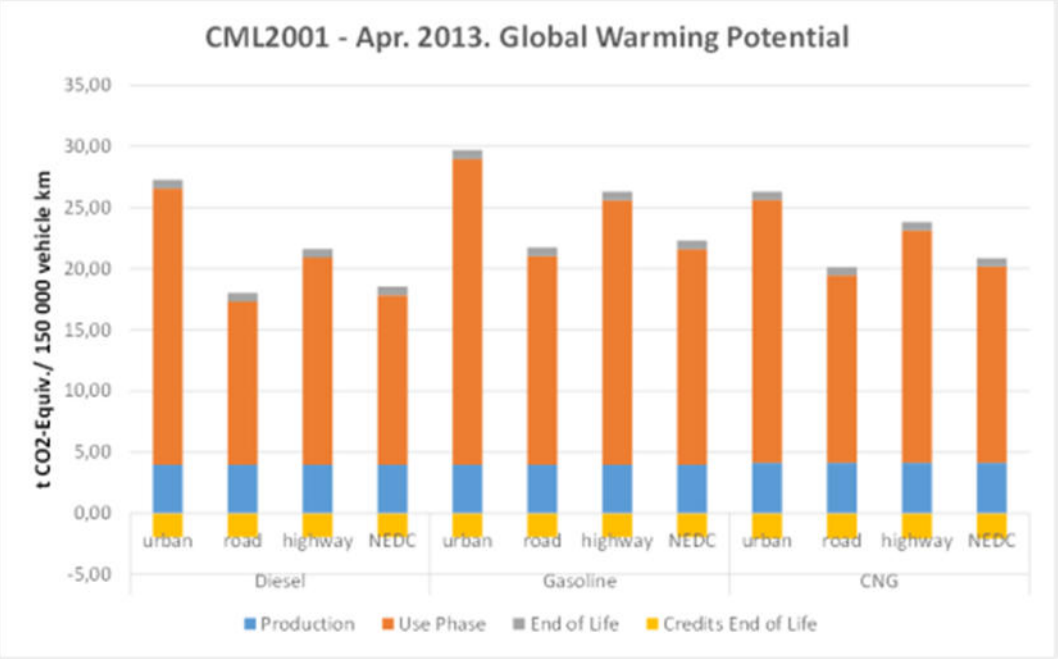


Figure 7: Global warming potential of different vehicle types assuming ARTEMIS driving cycles

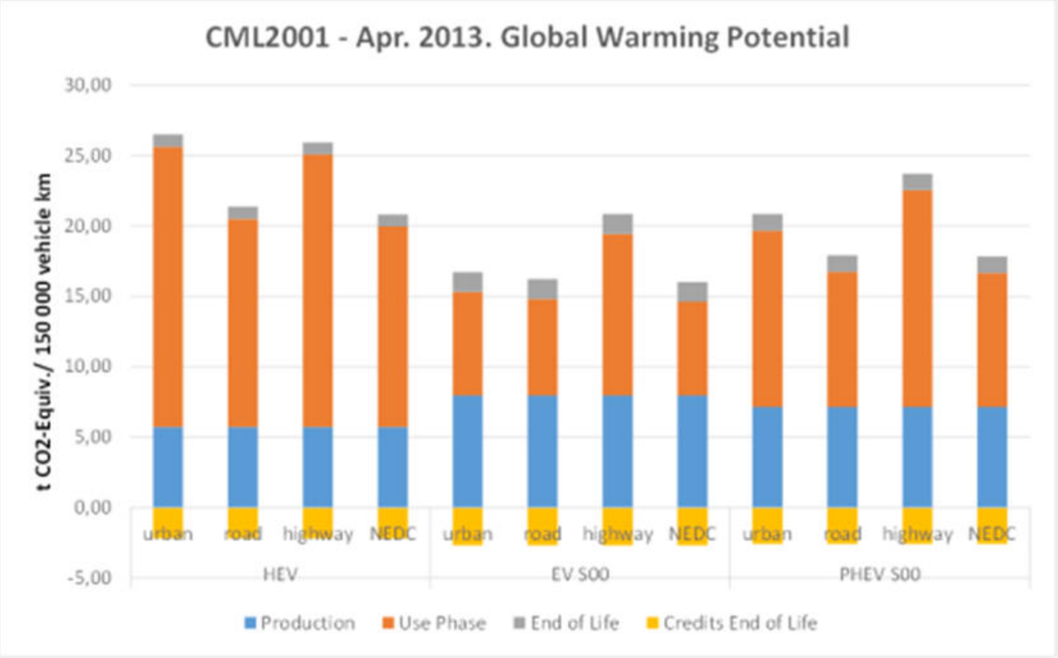


Figure 8: Global warming potential of different vehicle types assuming ARTEMIS driving cycles

1.5 Lessons learned from the A-LCA

To sum up, electric vehicles represent the more environmental friendly alternative for some of the impact categories in focus, mainly those dominated by fossil energy supply (non renewable primary energy demand, ADP fossil and GWP). In general, it is worth to note that conventional and electric vehicles cannot be fully compared as a comparison of life cycle impacts needs to take into account the functionality of the systems under study. At the moment, electric vehicles do not show the same functionality in use as conventional vehicles do, due to the fact that electric vehicles show significant restrictions concerning range, charging infrastructure and charging time. As a result, the analysis presented in the study must be used with caution accentuating its limitations of comparability.

2. Mobility drivers and public policies in the European Union

2.1 Grouping of countries

For a more realistic description of reality, we decided to take into account the heterogeneity of the countries under consideration. According to the descriptive statistics and a principal component analysis[1], it seems relevant to separate the countries studied into three groups. This classification may seem oversimplified, yet it does accurately reflect observed differences. The countries differ in many ways, including: the market for passenger cars, "macro-drivers" and transportation policies; as explained in our Deliverable D2.1 Econometrical study. The composition of these three groups is shown in **Table 2** and **Map 1**; the split is based on their characteristics and factors influencing vehicular mobility:

i) economic development (as measured by *GDP per capita*),

ii) the automotive market maturity (as measured by *the amount of cars per 1000 inhabitants*),

iii) previous transport policies (as measured by *the price of gasoline including taxes*).[2]

Group	Countries
G.1	Bulgaria, Estonia, Hungary, Latvia, Lithuania, Poland, Romania
G.2	Cyprus, Czech Republic, Greece, Malta, Portugal, Slovakia, Slovenia, Spain
G.3	Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Norway, Sweden, United Kingdom

Table 2: Grouping of countries

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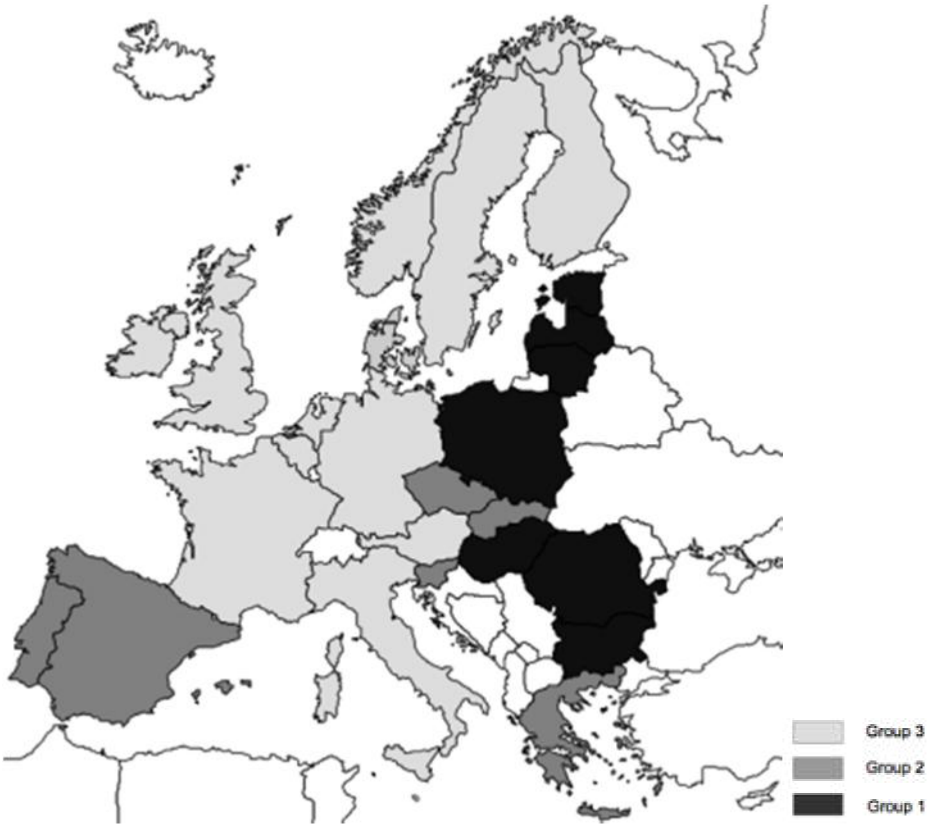
[1] Available upon request.

[2] This split has been confirmed by an econometric study. See D2.1 Econometrical study



Map 1: Grouping of countries

2.2 Differences in the market for passenger cars

In Europe, the market for passenger cars is split between a mature zone (Western Europe) and an emerging zone (Eastern Europe). The majority of eastern countries lie at the lower end of the scale in terms of number of passenger cars per 1,000 inhabitants. In most of the recent EU Member States (*i.e.* Eastern Europe), the domestic car market has not yet reached the maturity of the Western European market.

As regards socioeconomic variables, the most important drivers of road transport demand appear to be:

- GDP per capita (positive effect) and population changes (size and composition between urban and non-urban areas).

- The price of fuel always has a negative influence on road transport demand, regardless of whatever the model we used to approximate the EU mobility : vehicle sales, vehicle fleets or transport demand.

- Scrappage policies also appear to exert a positive impact on road transport demand, but this is limited to new registrations. The other policies (e.g. a CO_2-based car tax, "feebate" systems) do not appear to have any influence.

- Lastly, dynamic panel data modeling leads us to conclude that the influence of these road transport demand drivers differs from one country to the next and those individual correlations have been implemented in SCelecTRA transport module (see D4.1a Policy scenarios to sustain EV deployment).

Public policy tools at hand

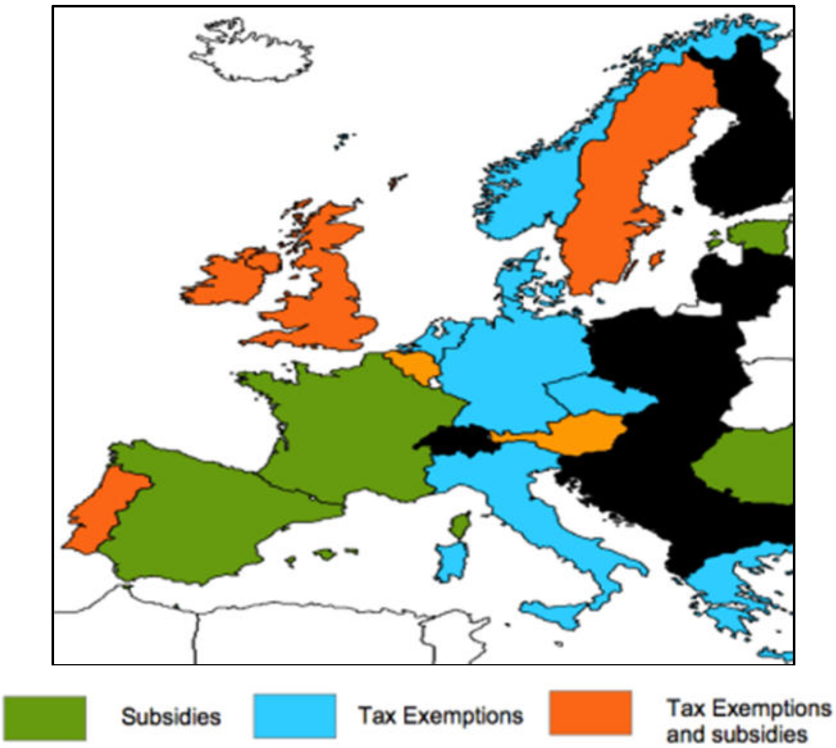
Public policy tools are generally classified according to their modes of application and the more or less binding nature of the requirements they impose on road transport players. A distinction is usually drawn between binding regulatory measures (emissions standards and speed limits for example) on the one hand, and economic incentive type tools (such as taxes or feebate schemes) on the other. These different types of policy are not all aimed at the same uses or the same players in the transport sector, and are not taken by the same public decision makers. Depending on the circumstances, these tools may therefore tend to be associated with road transport supply or demand policies and may be applied at different levels (urban, inter-urban, national, international).

Table 1 summarizes the different public policy tools in road transport in Europe.

Command and Control	**Demand-side**	. Speed limit
		. Low Emission Zones
		. High-Occupancy Vehicles lanes
		. Parking access management
	Supply-side	- Related to CO$_2$ emissions :
		. CO$_2$ emissions standards for new passenger cars and light-duty-vehicles
		- Related to biofuels :
		. Minimum of biofuel content in fuels
		- Related to EV charge plug :
		. Norms on publicly accessible infrastructures
		. Obligation of EV charge plug in buildings
Economic Instruments	**Demand-side**	- Automobile purchase pricing schemes :
		. Bonus-malus
		. Scrapping premium
		. VAT and income tax reduction
		. CO$_2$-tax for used pollutant passenger cars
		- Automobile ownership fiscal schemes :
		. Annual tax for company vehicles,
		. Annual tax for pollutant vehicles
		- Automobile use pricing schemes :
		. Fuel pricing (Fuel tax, Tax exemption for biofuel, Carbon tax)
		. Road user charge (Urban toll, Major roads and highways toll)
		. Parking pricing
		. Free access to public transport
	Supply-side	. Investment in R&D
		. Investment in infrastructures

Table 3: Summary of different road transport policies in Europe (Source: Extract from Papaix and Meurisse (2013) and Leurent and Windisch (2011))

Eastern European countries lag far behind their Western counterparts in terms of promoting and supporting electric vehicle use and, more broadly, in terms of supporting clean vehicles (at both the national and municipal levels). Only three Eastern countries have adopted a CO_2-based taxation system and only two offer purchase subsidies.



Map 2: EV incentives applied in Europe (Zehner, 2013)[3]

To complete this step, we identified policies that have already been implemented in a few countries and that are considered a viable option for supporting the development of electric and hybrid vehicles and/or favoring vehicle renewal programs. Combining these with the results depicted in section 2.2 and with the possibility for our model to simulate them (for example, our bottom-up Times model could not take into account urban toll policies and/or speed limitations which are to specific) the selection of viable and efficient transport policies is as follows :

- scrappage program;
- higher fuel taxes and discounts on electricity rates;
- purchase incentive.

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[3] Zehner O. 2013 Unclean at Any Speed. Electric car don't solve the automobile's environmental problems. IEEE spectrum. (http://spectrum.ieee.org/energy/renewables/unclean-at-any-speed)

Scrappage Program

The scrappage program (also known as fleet renewal scheme or "bangers-for-cash" system) consists of awarding a cash premium to motorists who trade in their older cars for a new vehicle. Eligibility for such a trade-in is conditional on the car's age and (sometimes) on emissions requirements. A scrappage program may stimulate the auto manufacturing industry, though it brings many other impacts as well.

Car scrappage programs have not yet been implemented at the level of the European Union. As highlighted in Table 4 however, over the past two decades, such programs have gained broader support in many countries. These national systems differ by the incentive amount and by certain requirements (minimum age of the replaced vehicle, new vehicle emissions standard

Country	Incentive	Age requirement	Emissions requirement
France	€1,000 (scrapping bonus called « *Superbonus* »)	>10 years old	<160g CO_2/km
Germany	€2,500 (environmental bonus for car scrapping called « *Umweltprämie* »)	>9 years old	
Ireland	Vehicle Registration Tax (VRT) relief up to €1,500	>10 years old	<140g CO_2/km
Italy	Financial contribution of €700 (€1,500 in case of replacement of 'special categories ' of EURO 0 and EURO 1).	>10 years old	EURO 4 + <130g CO_2/km (diesel) or <140g CO_2/km (other fuels)
Portugal	Reduction in the vehicle tax of : €1,000 €1,500	 >10 years old >15 years old	
Romania	€700 (scrapping premium)	>12 years old	
Slovakia	€2,000	>10 years old	
Spain	Discount amounting to €480 of the normal registration tax.	>7 years old	
United Kingdom	£2,000	>10 years old	

Table 4: Comparison of car scrappage programs across EU countries (source: MURE)[4]

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[4] MURE (Mesures d'Utilisation Rationnelle de l'Energie) provides information on energy efficiency policies and measures that have been carried out in the Member States of the European Union (http://www.measures-odyssee-mure.eu/).

In some countries, the scrappage scheme may be combined with other incentives. In Italy for example, an extra contribution of €1,500 can be added if the purchased vehicle runs (either partially or completely) on LPG or methane.

Higher fuel taxes and Discount on electricity rates

As previously described in 2.2, fuel taxes play a major role in reducing fuel consumption and curbing CO_2 emissions in Europe. Thus the following actions have been considered :

- Increase fuel taxes by 20% over and above the current maximum tax level: Europe will be fully committed to ecological policy and to an increase in the excise rates on gasoline and diesel.

- Elimination of the tax bias favoring diesel: Over the medium term, it is most likely that diesel and gasoline will be equally taxed.

- A discounted charging rate for electric vehicles (-20%): It is assumed that the electricity used to charge electric and hybrid vehicles is paid at a lower rate than the consumer rate for regular domestic power. This explanation lies in the fact that the electricity used to charge vehicles may be billed through a meter tracking vehicle electricity use separately from the rest of household consumption, as well as by the fact that energy companies offer specific "Electric Vehicle Charging Tariffs".

Purchase incentives

One of the main current challenges with electrified vehicles (EV and PHEV) pertains to price. Future electrification of the European vehicle fleet (i.e. more extensive deployment of electric vehicles) will depend in part on the competitiveness of electric vehicles compared to other technologies (namely conventional technologies). Offering cash rebates directly to consumers when purchasing a new car is the most common type of car-based incentive; it narrows the gap between prices for conventional and electric vehicles. This scenario focuses on a generalization of electric vehicle purchase incentives.

Since electric and hybrid vehicles are both seen as potential means to decrease CO_2 emissions from road transport, many European countries have introduced strong incentives for the purchase of such types of vehicles.

In these countries, electric vehicles and plug-in hybrid vehicles are exempt from the registration tax and/or circulation tax (e.g. Austria, Belgium, Czech Republic, Germany, Denmark). Furthermore, some countries have implemented specific purchase incentives (Table **5**).

Country	Incentives
France	Bonus-penalty scheme: premium award of €6,300 (< 20 g CO_2/km), €4,000 (20-60 g CO_2/km). The incentive amount cannot exceed a given percentage of the vehicle purchase price. Hybrid vehicles (< 110 g CO_2/km): premium award of €3,300.
Ireland	Electric vehicles: *Vehicle Registration Tax* relief up to €5,000. Plug-in hydrids: a maximum relief of €2,500. Conventional hybrid vehicles and other flexible fuels: a maximum relief of €1,500.
Luxembourg	Premium award of €5,000 for the purchase of electric or plug-in hybrid vehicles (< 60 g CO_2/km). The purchaser must buy electricity from renewable energy sources.
Sweden	Super green car premium (*Supermiljöbilspremie*): 40,000 SEK for purchasing a new car emitting less than 50 g CO_2/km.
United Kingdom	Electric and plug-in hybrid vehicles (< 75 g CO_2/km): premium award of £5,000 (max) or 25% of the value of the new car.

Table 5: Examples of purchase incentives for Electric Vehicles in the EU (source: ACEA, 2014)

3. Building the scenarios

In order to assess the future uptake of electric vehicles In Europe, several scenarios have been built. They describe different situations Europe might face in the next decades (i.e. plausible and reasonable future) and will be used to simulate vehicle sales and vehicle stock evolution in Europe. This section describes scenarios suitable for estimating the effect of policies directed at promoting electric vehicles. They rely on many sources of information including, in particular, government announcements, expert and consultant reports, academic literature, institutional documents. Compared to the different policy tools presented in Section 1, it should be noted that given the structure and the purpose of the TIMES PET model some specific policy instruments cannot be considered (speed limit, toll, low emission zone,…).

Seven policy scenarios have been chosen : three "*supply side policy*" *scenarios*, named "*contextual scenarios*", and four "*demand side policy*" *scenarios*.

3.1 The three Contextual scenarios

Three contextual scenarios have been chosen. They rely on the evolution on *i)* the number of charging points, *ii)* the energy prices and *iii)* the efficiency progress for ICEs. The following sub-sections describe these scenarios.

Charging infrastructures

Even if charging infrastructure is not the only criterion to determine a market development of the electric vehicles market in the European Union, there is a strong link between the former and the latter, as recalled by the Clean Power for Transport Report (EU, 2013)

As explained in Deliverable 2.2., the number of electric charging points currently varies greatly across the European Union (see Figure 9). The leading countries are Germany, France, the Netherlands, Spain and the UK (62% of the total).

In the favorable scenario, we assume that the public charging infrastructure at a constant speed over 15 years vehicles (~13 points / 1000 vehicles / year), to reach a density of 200 points /1000. In the pessimistic scenario, the charging infrastructure does not develop.

Figure 9 EV charging stations in Europe in 2014 (chargemap.com, 06/01/15)

Energy prices

Fossil fuel prices are linked to the oil price. In the low scenario, it is assumed that the oil price remains constant at 70$/bbl until 2030. While it is difficult to project such energy prices (especially falls) by 2030-2035, this assumption is based on the observation of current (2015) energy prices. They provide a lower bound on energy prices and on the impact of energy price for the choice of alternative mobility technologies. In the high scenario, the price goes up to 110$/bbl in 2030. This assumption puts it between the last IEA New Policies and 450 scenarios (123$/barrel and 100$/barrel in 2030 respectively; IEA, 2014). Diesel and gasoline price are derived from the oil price with constant mark-ups.

Efficiency progress for ICEs

The main hypothesis about technical progress for Internal Combustion Engines (ICEs) vehicles is based around the improvement made on the specific fuel consumption of the considered vehicles. Table 2 sums up our basic assumptions for gasoline and Diesel vehicles but each configuration has been modeled and owns a specific progress roadmap based on:

- its current state of the art (i.e. the average fuel consumption of vehicles sold in 2013/2014),
- technical improvements in the following :
  - Vehicle mass reduction,
  - Aerodynamic and tire resistance reduction,
  - Engine improvement.

The following table summarizes the key assumptions.

	2010	2030
Weight	**1360**	**1130**
S Cx (aerodynamic)	0,7	0,5
Tyre rolling resistance factor	0,008	0,006
		Stop and Start
Engine efficiency improvement		-15%/2010
Engine inertia	0,15	0,1
Cold start overconsumption	1,4	1,1

Table 6 Hypothesis for efficiency progress of ICEs

All of these have served as an input for fuel consumption simulations run by SCelecTRA team and using the simulation tool developed by IFPEN in the Hi-CEPS project (http://www.hi-ceps.eu/fe/Site/t02/Home/1). As a result fuel consumptions of the different configurations and forecasts for 2020, 2025 and 2030 have been assessed within SCelecTRA and are illustrated for gasoline and Diesel vehicles in Figure 10.

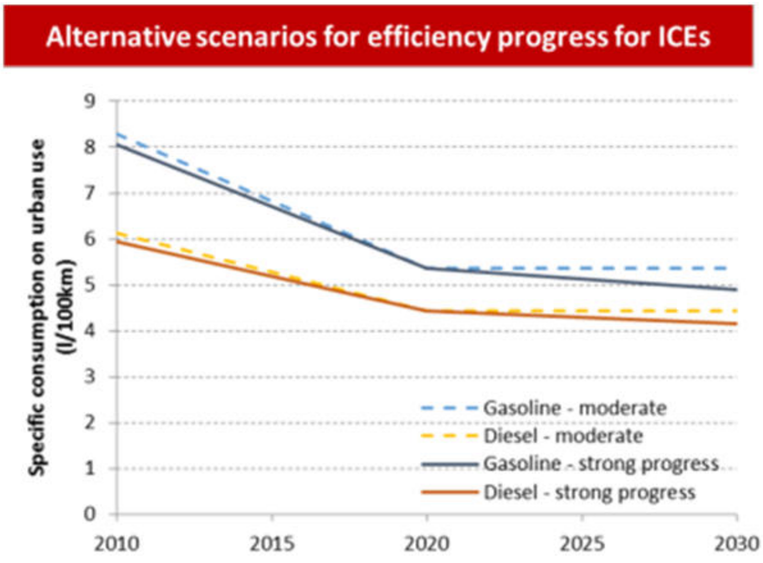


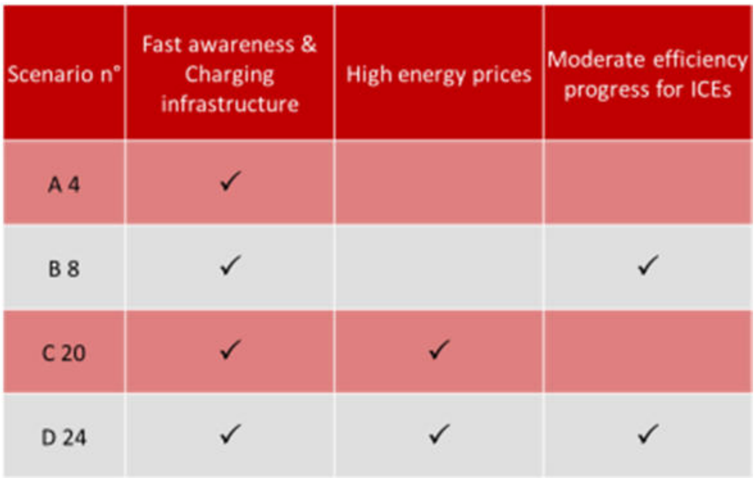
Figure 10 Alternative scenarios for efficiency progress for ICEs

Furthermore, this roadmap has been made consistent with major milestones for the European transport sector: the reduction of CO_2 emissions from passenger cars. EU legislation sets mandatory emission reduction targets for new cars. This legislation is the cornerstone of the EU's strategy to improve the fuel economy of cars sold on the European market:

- The law requires that the new cars registered in the EU do not emit more than an average of 130 grams of CO_2 per kilometer (g CO_2/km) by 2015.
- By 2021, phased in from 2020, the fleet average (with all vehicle technologies mixed together thus plug-in hybrid, hybrid and electric vehicles lowering the consumption of ‘pure’ ICE vehicles as mentioned in Figure 10) to be achieved by all new cars is 95 grams of CO_2 per kilometer.

Summary

Table 7 summarizes the characteristics of the three main contextual scenarios.



Scenario n°	Fast awareness & Charging infrastructure	High energy prices	Moderate efficiency progress for ICEs
A 4	✓		
B 8	✓		✓
C 20	✓	✓	
D 24	✓	✓	✓

Table 7 Contextual scenarios

3.2 The four Demand policies scenarios

This section describes the main characteristics and figures from the four demand policies scenarios: i.e. *i)* scrappage program, *ii)* purchase incentive, *iii)* carbon taxes and *iv)* specific action on fuel taxes.

Scrappage program

The scrappage program (also known as fleet renewal scheme) consists of awarding a cash premium to motorists who trade in their older conventional cars for a new electric vehicle. A scrappage program may stimulate the auto manufacturing industry, though it brings many other impacts as well. We consider that Group 1 countries offer smaller purchase incentives than Groups 2 and 3 countries.

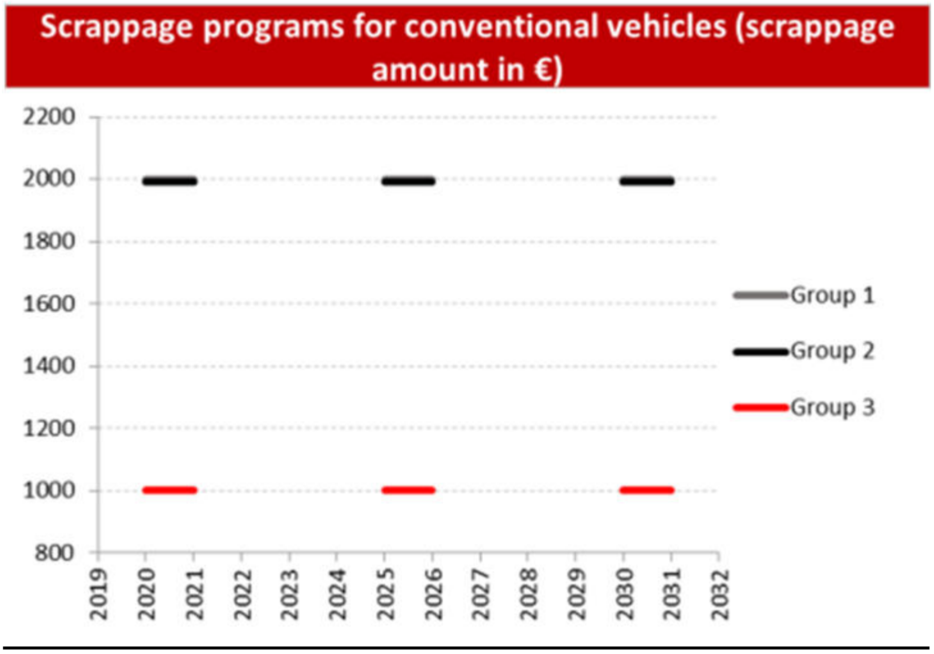


Table 8 Scrappage programs for conventional vehicles

Purchase incentive

According to this scenario, European policymakers are lowering the relative cost of alternative fuel vehicles. To accomplish this, they must implement large incentives for electric vehicles in order for their purchase price to be comparable with that of conventional vehicles. In taking into account the differences in budget limitations and infrastructure development required to charge plug-in electric vehicles, let's consider that Groups 1 and 2 countries offer smaller purchase incentives than Group 3 countries. Subsidies are planned to be phased out smoothly after the alternative fuel vehicles market has emerged.

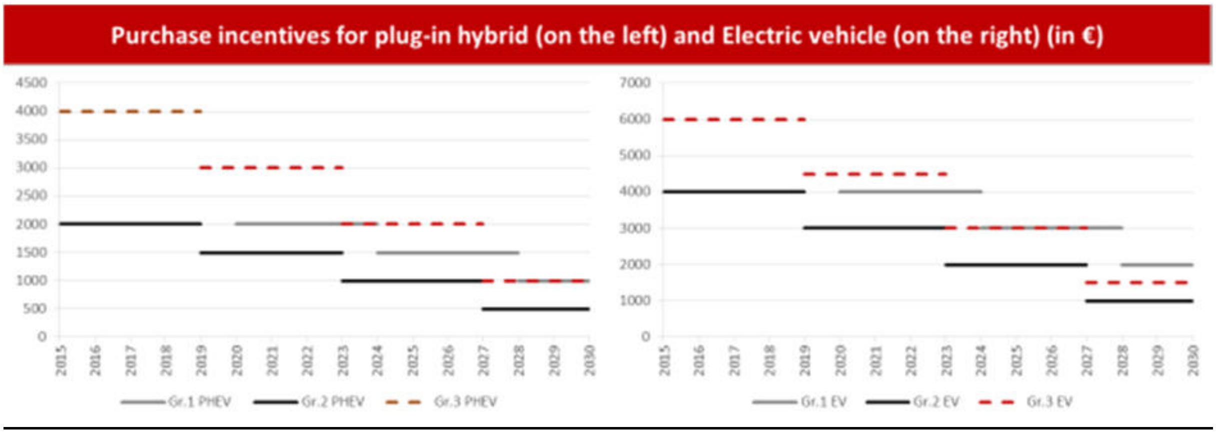


Table 9 Purchase incentives for xEVs

CO$_2$ tax

Two scenarios have been elaborated regarding the evolution of the carbon tax in European countries: i) the *low carbon tax* and *ii)* the *high carbon tax scenarios*.

In the *low carbon tax scenario,* we specify a level of 10 € per ton for all countries at the beginning and no evolution.

In the *high carbon tax scenarios*, the carbon tax is supposed to be equal to 10 € per ton for all countries at the beginning and increase linearly to achieve a level of 100 € per ton for all countries in 2030.

Specific action on fuel taxes

A specific action on fuel taxes has been specified to promote the *electromobility* in European countries. This scenario specify *i)* a decrease of 20% of the electricity tax on electric vehicles and *ii)* an increase of tax to diesel until it reaches the level of tax to gasoline in order to annihilate the pump price differential between gasoline and diesel noted in the most part of European countries.

Summary

Considering the possible coexistence of demand policies, 16 scenarios simulate the range of demand policy measures available to help launch the "*Electromobility*" market (Table 10).

Scenario n°	Scrappage	Subsidies to Evs	Specific action on fuel taxes	High C0$_2$ Tax
1				
2				✓
3			✓	
4			✓	✓
5		✓		
6		✓		✓
7		✓	✓	
8		✓	✓	✓
9	✓			
10	✓			✓
11	✓		✓	
12	✓		✓	✓
13	✓	✓		
14	✓	✓		✓
15	✓	✓	✓	
16	✓	✓	✓	✓

Table 10 Demand policies scenarios

4. Tree of possible scenarios

We have previously presented the three contextual scenarios and the four demand policies scenarios retained in the SCelecTRA project to study the development of low-carbon vehicles in Europe, and electric vehicles (i.e. HEV, PHEV and EV) in particular.

Considering the possible coexistence of demand policies and contextual scenarios many scenarios simulate the range of policy measures available to help launch the "*Electromobility*" market and their various combinations (Figure 11).

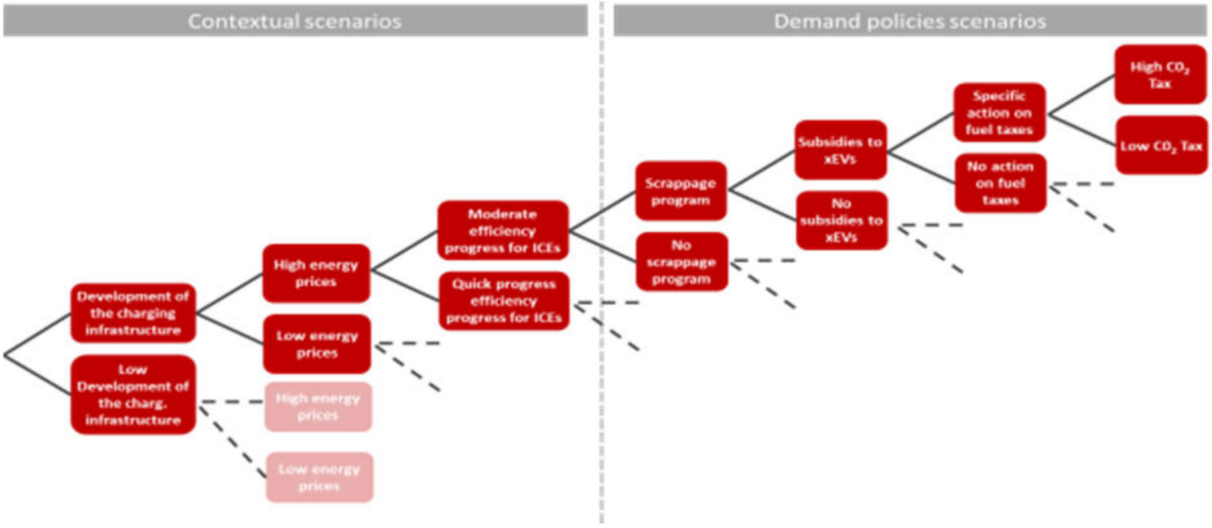


Figure 11 Tree of all possible scenarios within SCelecTRA analysis

In all, the combination of the three contextual scenarios and the four demand scenarios yield to 64 scenarios. Note that the upper path in the tree represents the most optimistic scenario for Electromobility and the lower path after considering the development of charging infrastructure will be the pessimistic scenario.

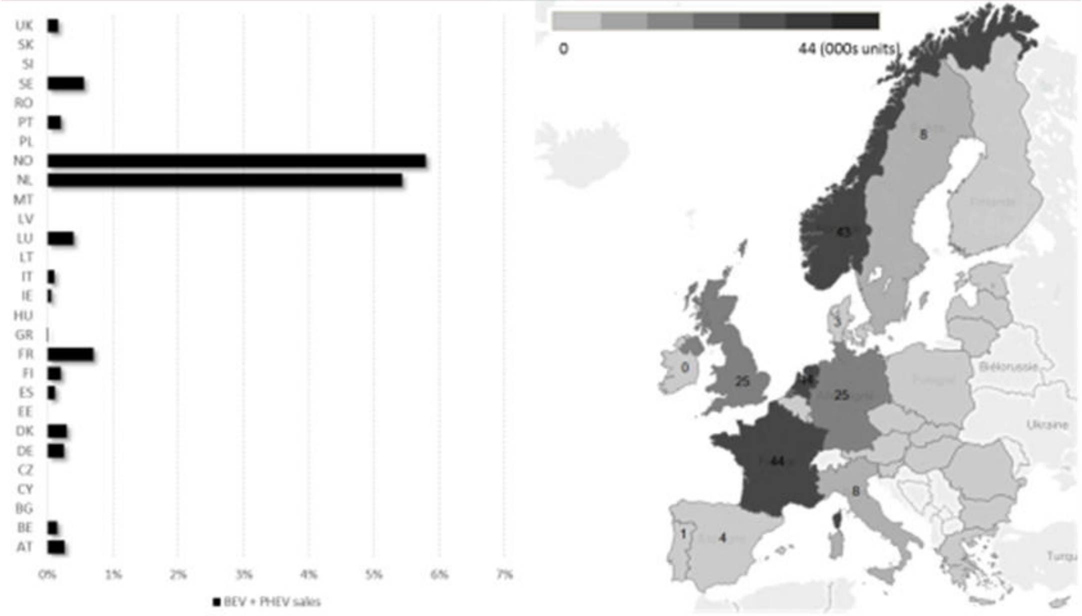
The more detailed results of our simulations (see **D4.1a Policy scenarios to sustain EV deployment**) have led us to conclude that even if charging infrastructure is not the only criterion to determine a market development of the electric vehicles market in the European Union, there is a strong link between the former and the latter. Without a strong involvement to deploy such an infrastructure, no EVs appear. So we can say that the number of charging point is a necessary, but not sufficient, condition to the development of electromobility.

5. Results for the transport sector

5.1 Deployment of electromobility

Currently the European electromobility market is not a mature market : a few thousands electric vehicles are on the road with highs in France (44 000 units), Norway (43 000 units), UK (25 000 units) and Germany (25 000 units) and very low pretty much everywhere else throughout the European Union.

Current situation (as of End of 2013) for EV+PHEV penetration : market share (left) and resulting EV+PHEV vehicle stock (right in 000s units)

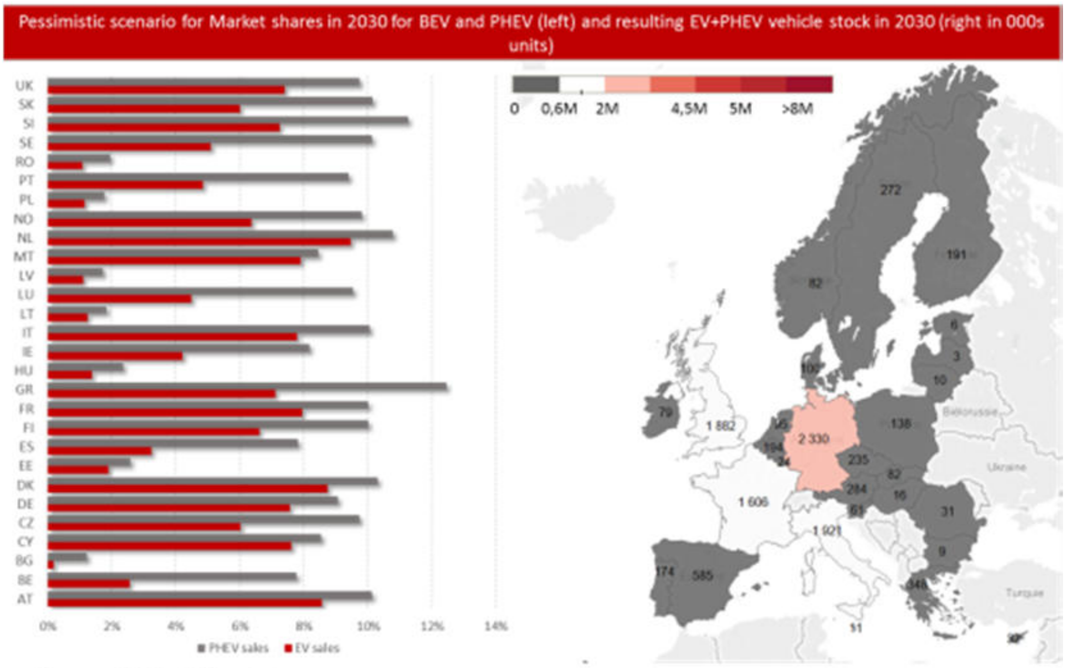


Sources : ICCT pocketbook 2014, IEA Global EV Outlook 2015

Figure 12: Current status of electromobility

According to our scenarios, there will be great differences in electric vehicle stock among countries in 2030. These differences can be both explained by difference in EV penetration rate and difference in vehicle stock size (in absolute terms). As one would expect, the five largest EV fleets by 2030 will be: Germany, France, Italy, UK, and Spain.

As previously mentioned, significant differences in EV market penetration are expected across the European Member States. These differences reflect the difference of national situations (present vehicle fleet composition, market maturity, GDP per capita, urban and spatial planning, density of population in urban areas…)[5]. As previously seen, we differentiate the orientation of policies with respect to country characteristics and generating more realistic assumptions.


Pessimistic scenario for Market shares in 2030 for BEV and PHEV (left) and resulting EV+PHEV vehicle stock in 2030 (right in 000s units)

Sources : SCelecTRA project

Figure 13: Pessimistic scenario for electromobility in 2030

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[5] See WP2 D2.2

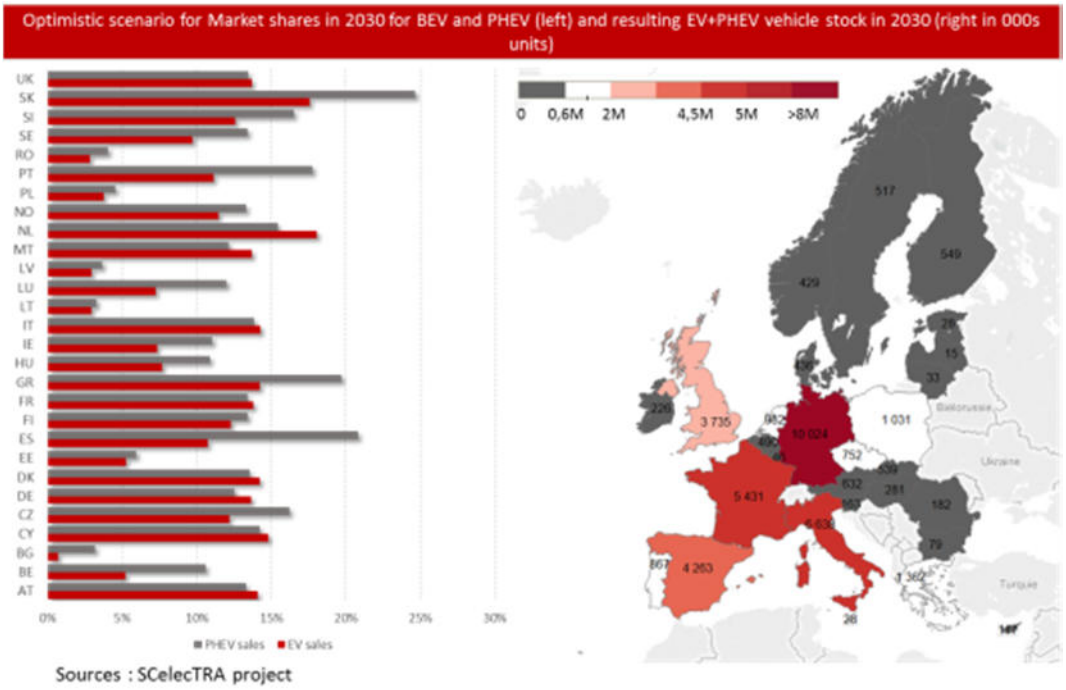


Figure 14: Optimistic scenario for electromobility in 2030

According to our different scenarios, Germany will be Europe's largest market for electric vehicles over the next 15 years, with electrified vehicle (xEV) fleet ranging from 2.3 million units (Figure 13) to 10 million units by 2030 (Figure 14). Close behind will be Italy, followed by France, Spain and United Kingdom.

Looking at market penetration in 2030 in the five largest markets, in the most optimistic scenario xEV sales share in the total sales is 34% in Germany, 32% in Spain, 27% in Italy, 26% in France and 28% in UK. In the pessimistic-realistic scenario these shares are respectively 20%, 11%, 18%, 18% and 17%. Note that while the shares of BEV and PHEV are close in Italy, France and UK, PHEV "dominate" the xEV market in Germany and Spain.

5.2 Impacts on the CO_2 emissions

All the scenarios have a dramatic effect on the tailpipe CO_2 emissions of the European passenger vehicle sector with reduction of at least by 30% by 2030 from the 2010 level and this despite a growing mobility (+17% between 2010 and 2030) and a growing vehicle fleet (+17% between 2010 and 2030).

Figure 15 and Figure 16 show the evolution of direct CO_2 emissions of the European passenger cars for two contextual scenarios: C.20 (fast awareness & charging infrastructure and high energy prices) and D.24 (fast awareness & charging infrastructure, high energy prices and moderate efficiency progress for ICEs). As expected, the reduction of CO_2 emissions are greater in C.20 than in D.24. The explanation lies in the better performance of conventional vehicles (ICEs) in terms of energy consumption. According to our forecasts, in 2030, direct CO_2 emissions of the European passenger cars will be reduced at least by 30 per cent by 2030 from the 2010 level.

Figure 15 Direct CO_2 emissions of passenger cars in the EU, scenarios 24.1 to 24.16 (source: SCelecTRA project)

Figure 16 Direct CO_2 emissions of passenger cars in the EU, scenarios 20.1 to 20.16 (source: SCelecTRA project)

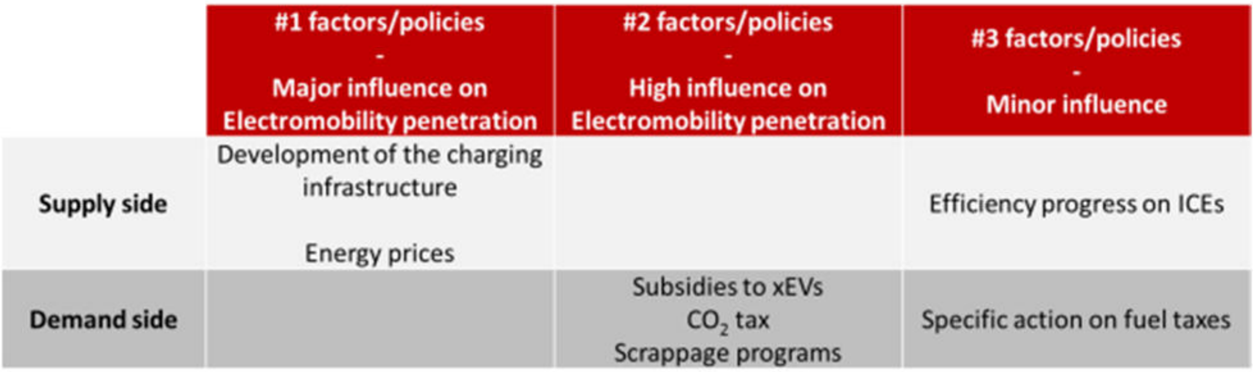
Thus the most EV-optimistic scenario is not necessarily the one producing the most CO_2 emission reductions in the European transport sector. So if the overall objective is to reduce the CO_2 emissions of the transport sector, electromobility is not the only - and sometimes not the most – efficient way to go forward. Inducing fuel consumption improvements for the conventional vehicles combined with a reasonable deployment of EVs yields to even greater CO_2 emission reductions than only focusing on a much higher electromobility deployment.

5.3 Policy tools to support electromobility

In parallel on studying the potential xEv fleets in Europe, the simulations run in SCelecTRA could highlight the individual impact of each factor. Going back to our scenario tree it means one could assess which public policy tool is the most efficient to promote the development of electromobility in Europe.

Regarding the conditions to create a European-scale EV market, charging infrastructure is not the only criterion but our simulations made it clear that without charging points no EVs appear. So we can say that the number of charging point is a necessary, but not sufficient, condition to the development of electromobility. It should also be noted, that policies are not necessarily additive, i.e. the sum of the effects of two policies is not equal to the effect of the combination of the two policies.

Another interesting point is to rank the influence of all the factors. And if the charging infrastructure is of prime importance not all factors weight the same in the deployment of electromobility. Those effects are summed up in Table 11 below. Focusing on public policy tools, member states should focus on scrappage programs to accelerate the renewing of their vehicle fleets, subsidies to lower the purchase costs of xEVs and ease their arrival on the market and a high CO_2 tax to even further penalize high-CO_2 emitting vehicles. On the other hand, a specific action on fuel taxes appear to be less efficient.



	#1 factors/policies - Major influence on Electromobility penetration	**#2 factors/policies - High influence on Electromobility penetration**	**#3 factors/policies - Minor influence**
Supply side	Development of the charging infrastructure Energy prices		Efficiency progress on ICEs
Demand side		Subsidies to xEVs CO_2 tax Scrappage programs	Specific action on fuel taxes

Table 11: Impacts of supply and demand side factors

6. Impacts on the energy sector

The next step in our assessment of electromobility is to include the energy infrastructure and flows themselves, but also policies and political organizations, social values and norms etc… The main objective of this study is thus to undertake a system-level analysis of electromobility to identify the potential impacts of electric mobility futures on the energy "technological" systems.

For this systems assessment, the two models (PET and the fleet model described above) are soft-coupled. To this purpose, the private passenger transport sector from PET was shut down, and replaced by outputs from the fleet model (mileage driven, sales) at the technology level. Compared to a pure optimization model, we wish to use this simulation model to introduce some behavioral elements within the European energy system model (PET): demand-side choices generally lack realism because important processes affecting consumer choice are absent from optimization models (Schäfer, 2012). The penny-switching nature of optimization, technology-rich models can be mitigated by (in the present case) a soft-coupling procedure linking the demand model (Girod et al., 2012; Girod et al., 2013; Cayla and Maïzi, 2015) with the energy supply model.

The integration procedure is performed in one step, and consists in a standard prices-quantities coupling between the two models. The technology selection and mileage driven depend on fuel and carbon prices, which are derived endogenously as shadow prices of the corresponding demand or emissions constraints (see D4.2 for specifics on the method).

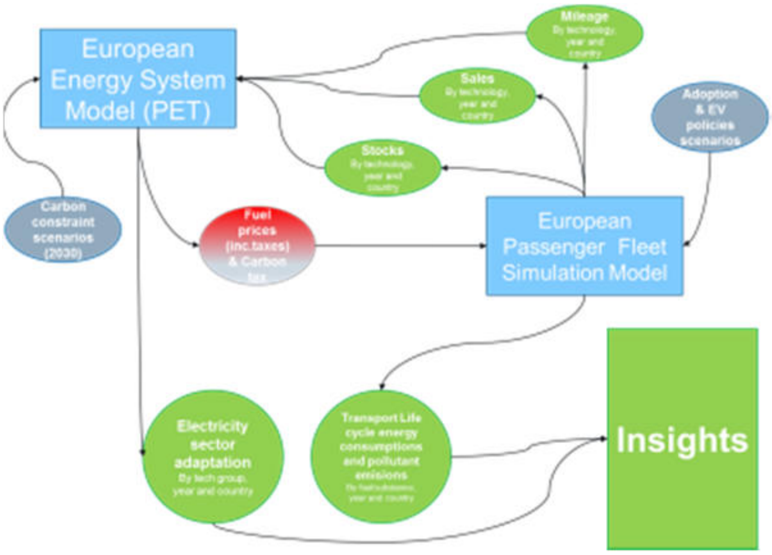


Figure 17: Soft-coupling PET and the fleet simulation model

While the development of electric mobility for passengers is subject to a great deal of uncertainty (technological, political, behavioral or even social), the analysis conducted in this report was meant to represent a sufficiently large set of scenarios to elaborate a relevant systems exploration. This implies, overall, the identification of upwards and downwards tendencies, as well as potential shifts (in short, non-monotonic phenomena). Thus, sampling through scenarios is a key elements. The considered variables have been:

- European, economy-wide CO_2 emissions reductions targets Therefore, we defined **four carbon scenarios consisting in -20, -30, -35 and -40% cuts in 2030.**
- Consumer's attitude towards new EV technologies – the adoption dynamics We retain four adoption dynamics, namely **reference, dynamic, high and instantaneous**, as shown in Figure 18.

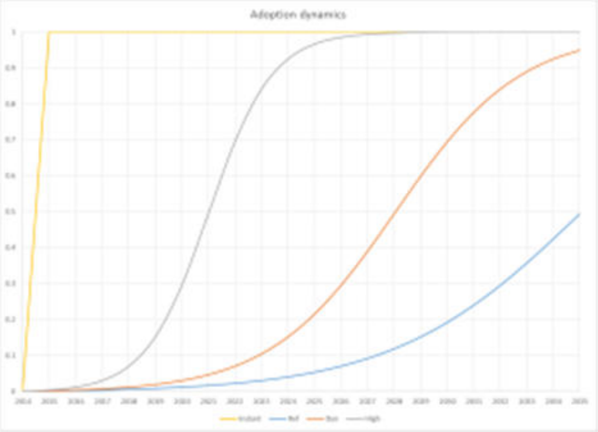


Figure 18: Adoption dynamics scenarios

- Public policies in favor of EVs with 4 policy scenarios: no policy, scrappage only, subsidies and taxes, and scrappage plus subsidies and taxes.

The final scenario tree is presented in Figure 19. All combinations of the four scenarios in the three dimensions are simulated and optimized, hence a final set of 64 scenarios which differ from the 64 scenarios analyzed in the previous section.

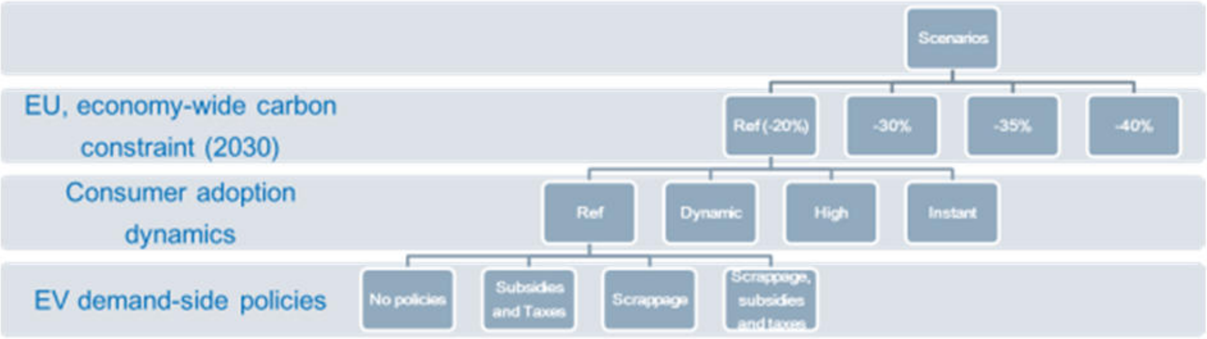


Figure 19: Scenario tree

In general S1 will be the reference case and S64 will be the most favourable case for electromobility deployment. For a complete description of the 64 scenarios, report to Table 15 in the annexes.

Concerning the transport sector, the scenarios considered consist in substituting conventional and (to a lesser extent) hybrid vehicles for plug-in hybrids and electric vehicles. In the most optimistic scenarios, PHEVs and EVs can reach shares as high as one third of the total mileage driven in Europe in 2030. One conclusion is that the evolution of the passenger fleet structure weakly depends on the climate target set for 2030 as seen in Figure 20 :

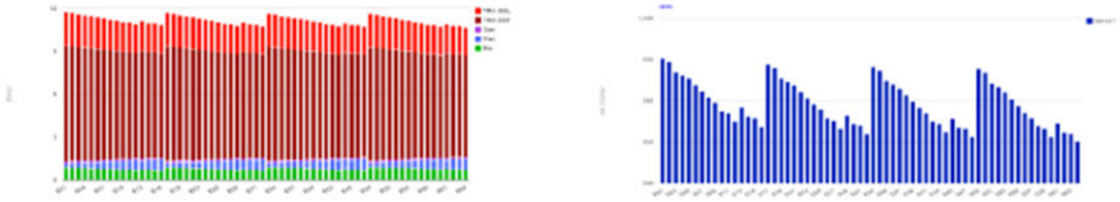


Figure 20: 2030 transport fuel consumption and CO_2 emissions, all scenarios

While the climate objective impacts energy and carbon prices, it turns out these price have little impact on the consumer’s purchase decision. There are several reasons for that. First, the standard cost-of-use structure of a vehicles is dominated by the investment and fixed cost, while energy represents a minor part. The anticipated technical progress reduces this part further, so that these increases in fuel prices do not compensate the increases in fuel efficiency: consumers become less responsive to prices as the share of variable expense in the ownership cost goes down. This has an important implication for policy purposes: public policies and R&D affecting the fixed costs of new technologies such as purchase subsidies should play a bigger role in the short term.

If carbon-constraint-driven fuel prices are not the main drivers for the development of electromobility in the short to mid run, then consumers’ attitudes with respect to the adoption of new technologies will play a crucial role. It is also through this channel that policies will gain in effectiveness. In the end, energy intensity trajectories show some dependence on the rate of electrification (Figure 21), but incremental gains are small compared to the effect of fuel efficiency increases for conventional technologies by 2030.

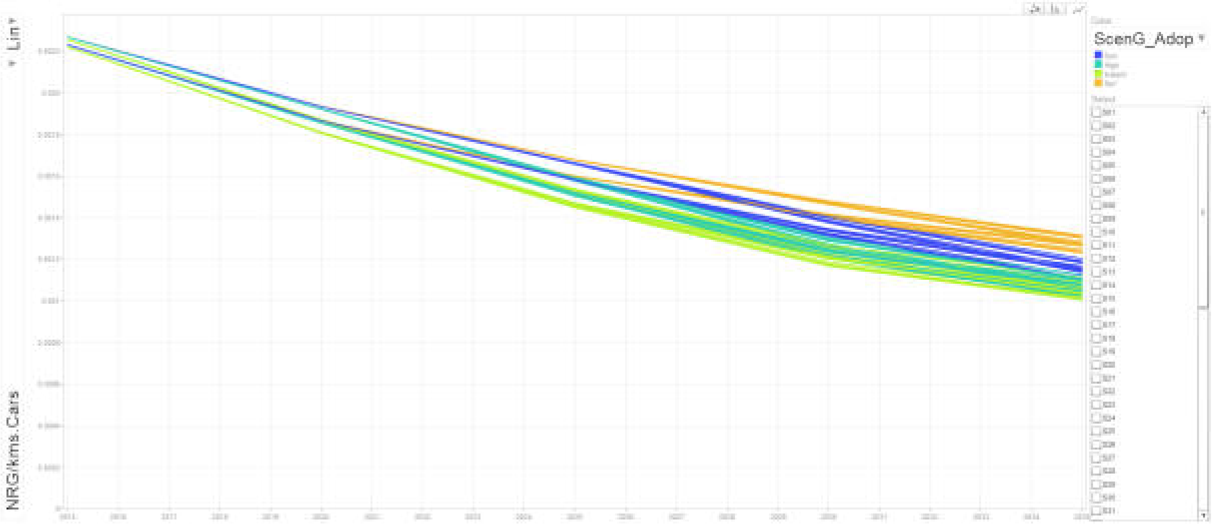


Figure 21: Passenger vehicles energy intensity, all scenarios, 2015-2035

As for energy demand, the substitution dynamics in the transport sector reflects the relative fuel efficiencies of electrified vehicles compared to conventional. Because of the advantage of PHEVs and EVs, it turns out that the additional electricity demand due to passenger electric mobility represents a small share of the 2030 final energy mix of transport, as well as a small proportion of the final electricity demand compared to other sectors.

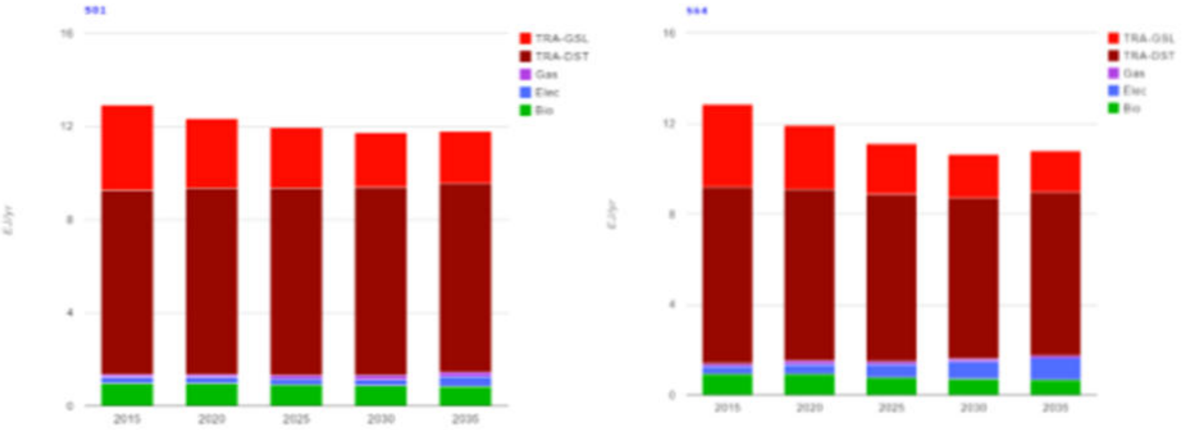


Figure 22: Total transport energy consumption by fuel, 2015-2035, S01 & S64

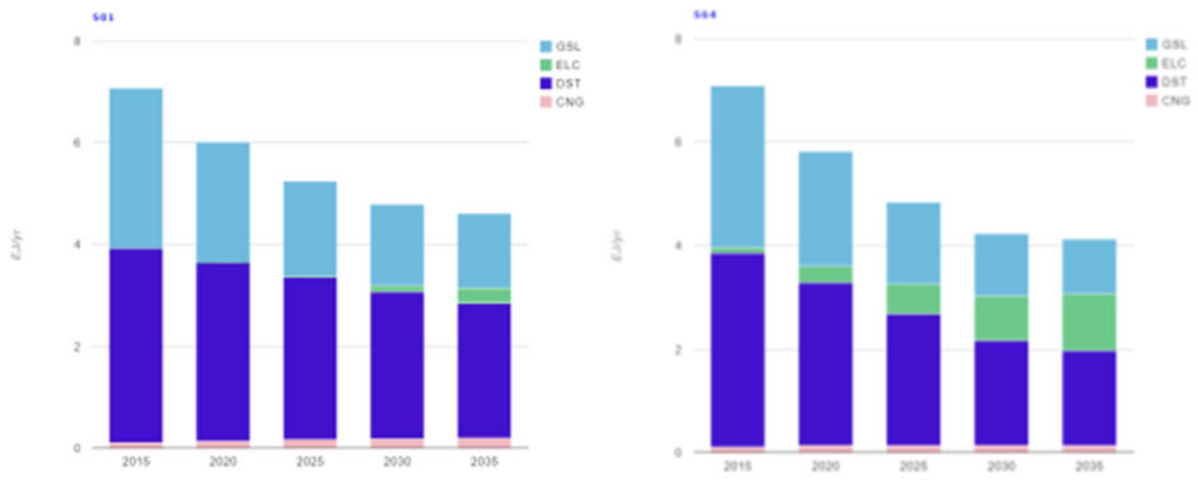


Figure 23: Private transport energy consumption by fuel, 2015-2035, S01 & S64

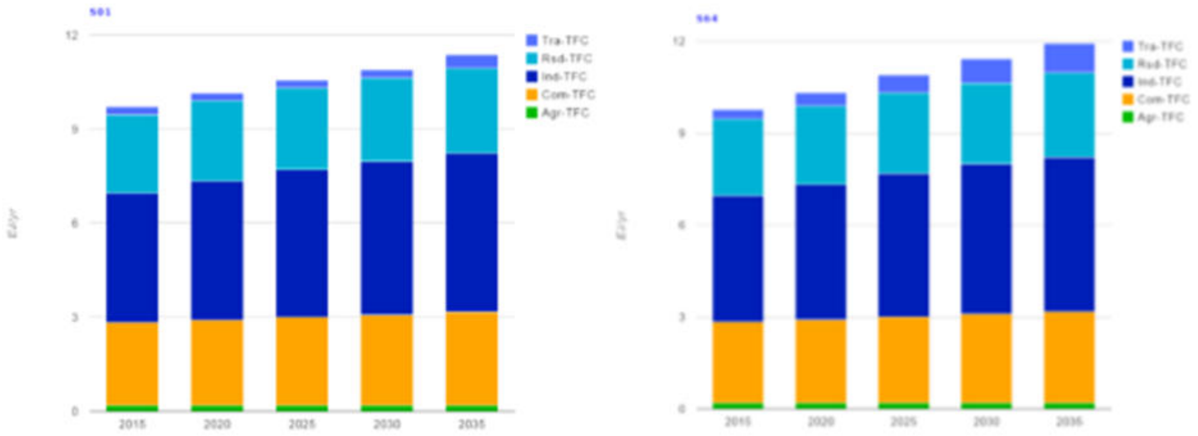


Figure 24: Final electricity consumption by sector, 2015-2035, S01 & S64

This implies that in relative terms, the electrification for passenger vehicles may have a large/larger impact on the fuels production sector, than on the electricity system (1 additional MJ of electricity substitutes to 2~2.5MJ of liquid fuel). Although this effect could not be analyzed in detail in this project, we would recommend to investigate this issue with more appropriate frameworks. It could bring in side-benefits to electrification, in terms of changes in the crude and fossil products balance, hence on the European energy trades bill. Others costs may occur, due to changes in the use of the fuels production capacities. We also show that in the carbon-constrained worlds described in these scenarios, the additional electricity to be supplied to transport comes from additional electricity production rather than reduced uses in residential, commercial or industrial sectors, and basically no changes occur in the electricity consumption of these other sectors.

Finally, adaptations in the electricity generation sector were investigated. While the main driver for changes in the electricity mixes relates to the carbon objective, we show how economic-optimal variations happen due to the incremental electricity transport demand. With a global carbon cap design, additional reduction efforts realized in the transport sector provide an additional “carbon budget” to be spent elsewhere. This allows to relax the abatement level especially in the electricity sector, where the additional demand is satisfied by a mix of coal, gas and nuclear electricity as illustrated in Figure 25 with various adaptations depending on the country as shown in Figure 26.

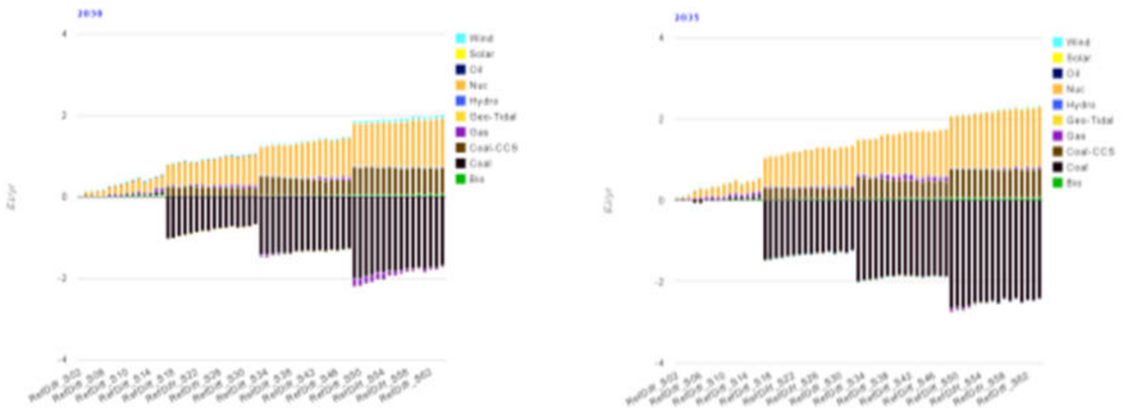


Figure 25: Electricity generation by type, variations over S01, all scenarios, 2030-2035

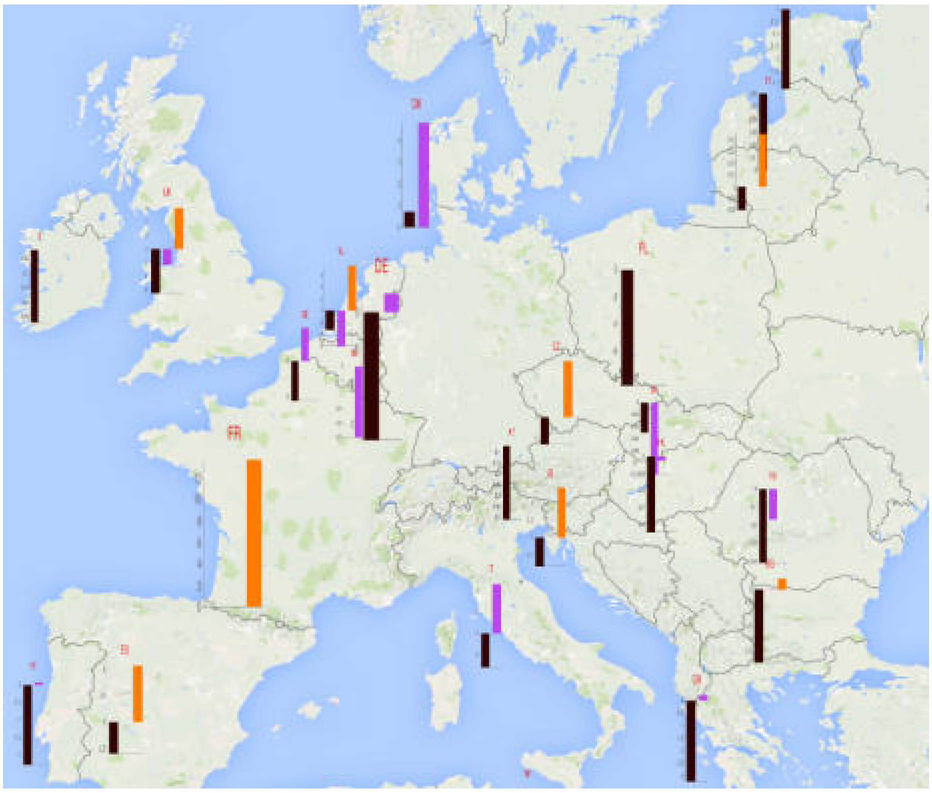


Figure 26: Coal, gas and nuclear generation capacities by country, S64 difference over S01, 2030

These economic choices results from the adaptation of the electricity sector by a balance of low-cost and carbon-free technologies. From a policy perspective, this questions the relevance of policy designs to reach global abatement targets. If a global cap seems more efficient from a perfect market perspective, sectoral targets may avoid some cross-sectoral transfers, although we somehow show that these are not necessarily undesirable.

On top of that, we observe that the electricity provided in addition is produced by a mix of two strategies, consisting in additional investments in new production capacities (for nuclear, where upfront costs are high enough to prevent investments made at low loads), and increases in the utilization rates of existing capacities (coal and gas) as the carbon cap becomes more stringent. This last strategy is the most economically rational. Lastly, we highlight how cross-border trades are impacted by these electricity demand shifts.

Figure 27: Coal, gas and nuclear electricity generation, incremental capacities versus load rate, all scenarios, difference over S01, 2030

Overall, and putting the question of electromobility in a longer-term perspective (e.g. 2050) then we shall consider that the 2030 horizon is an upscale, maturation phase for later periods where electric vehicles may be an unavoidable technology shifts to reach ambitious climate-compliant targets. If the demand-side inertia of behaviors can hardly be anticipated, we can still argue that the short-term benefits (e.g. in terms of CO_2 emissions) of electric pathways could be partly transfers to other sectors, which contribute to their upscale through additional costs of energy supply. This intertemporal and cross-sectoral burden sharing perspective is economically rational, and probably highlights the sense of global targets.

7. Assessment of environmental impacts

In the SCelecTRA project, we have implemented several methodologies to assess the impacts of electromobility in passenger cars fleets. The attributional LCA detailed in section 1 provides detailed results (for 2030) concerning the environmental benefits and costs associated to the replacement of one conventional vehicle by one PHEV or EV. But it turns out this is where the ALCA comes to a certain limit. While assessing environmental impact for a pathway, it makes most of the assumptions on energy supply etc… static and independent of any economic context. Beyond that, one can argue that results obtained for one vehicle of each category cannot be extrapolated for a whole vehicle fleet. In short, ALCA becomes hardly practicable when it comes to assessing the impact of full-scale EV fleet (Querini 2015, Del Duce 2013) , including its potential impacts on the energy supply system.

Determining such consequences is essentially an economic question; therefore, we proposed to rely on the economic modeling framework used in SCelecTRA to perform an extended environmental analysis of the global electromobility scenarios. This analysis endogenously includes the identification and environmental emissions due to changes in the energy sector (focusing on electricity: new investments, changes in grid mix etc…) compared to those occurring in the whole passenger transport sector.

7.1 The life cycle emissions of passenger fleets: CO_2 emissions and GWP

Figure 28 below presents the evolution in tailpipe CO_2 emissions over time for each scenario taking into account overall respective passenger fleet. As previously noticed in WP4 analyses, highest reductions of tailpipe CO_2 emissions towards 2035 are reached when electrification rate is higher thanks to null or lower emissions associated with electrified vehicles (reduction of carbon intensity and increase of the overall energy efficiency of the fleet). An increasing spreading of such technologies generates a small rebound effect (as previously explained in D.4.2 report and in the previous section) but the induced increase in overall mobility demand does not change the trend: the highest the EVs/PHEVs penetration rate is, the highest the reduction in CO_2 tailpipe emissions is.

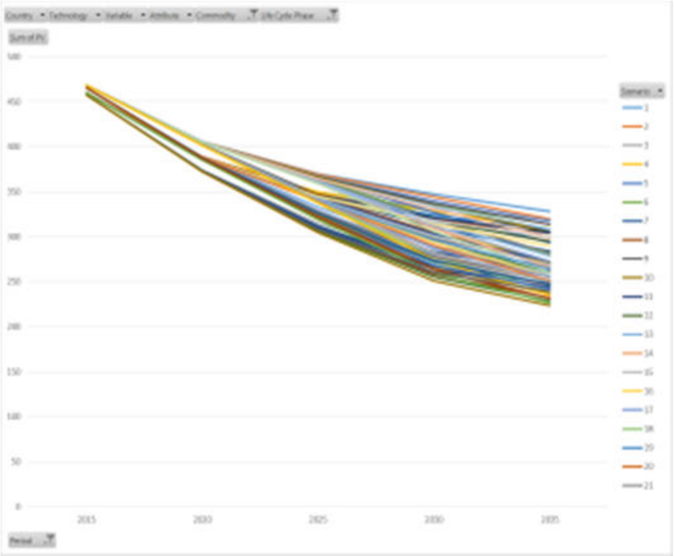
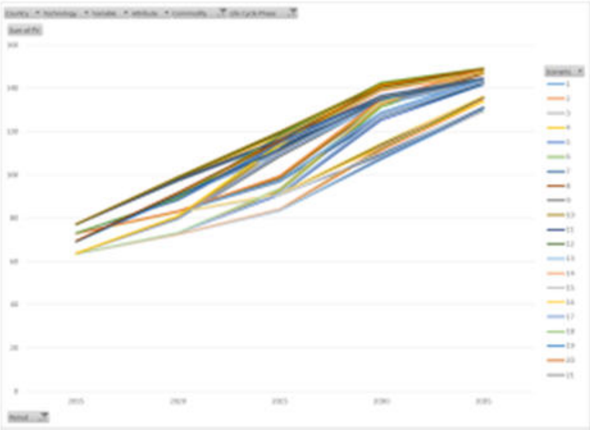


Figure 28 - CO_2 emissions of the passenger fleet: tailpipe emissions over time (64 scenarios)

On the contrary, CO_2 emissions related to the production phase (vehicles and cells) as well as CO_2 emissions credits related to the end of life phase (negative values) go up over time (replacement of vehicles) and highest production emission / credit emission levels correspond to scenarios with highest electrification rates (Figure 29 and Figure 30). However, tailpipe emission trend and dynamics prevail so that total CO_2 emissions of the fleet decrease over time (Figure 31). In other words, the emission increase related to the production phase does not offset the reduction of tailpipe emissions due to improvements in terms of energy efficiency and carbon intensity of the fleet.



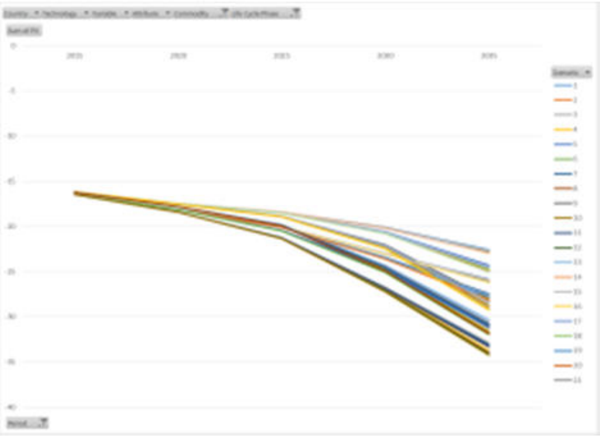


Figure 29 - CO_2 emissions of the passenger fleet: emissions related to the end of life of vehicles and cells (64 scenarios) (left)

Figure 30 - CO_2 emissions of the passenger fleet: emissions related to the production of vehicles and cells (64 scenarios) (right)

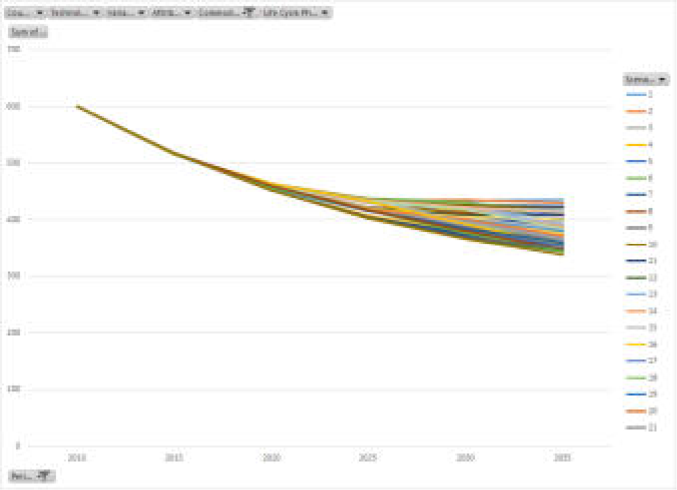


Figure 31 - CO_2 emissions of the passenger fleet: total emissions (64 scenarios)

Owing to the fact that tailpipe CO_2 emissions decrease from 41% (S1) up to 74% (S64) by 2030 (compared to 2005 level) and that production emissions increase in the same time (+160% in S1 and + 260% in S64), the respective contributions of production, use and end of life emissions in total CO_2 emissions of the fleet greatly vary over time (Figure 32). While the sum of emissions related to production and end of life phases represent around 8% of total CO_2 emissions in 2005, corresponding contribution in 2030-2035 ranges from 22% up to 38%. These are meaningful results to demonstrate the relevance of the inclusion of production and end of life emissions in such analysis and therefore confirm at the passenger fleet scale (for the purpose of comparing several technological scenarios) what A-LCA results have previously highlighted at the individual vehicle scale (for the purpose of comparing environmental impacts of individual vehicles).

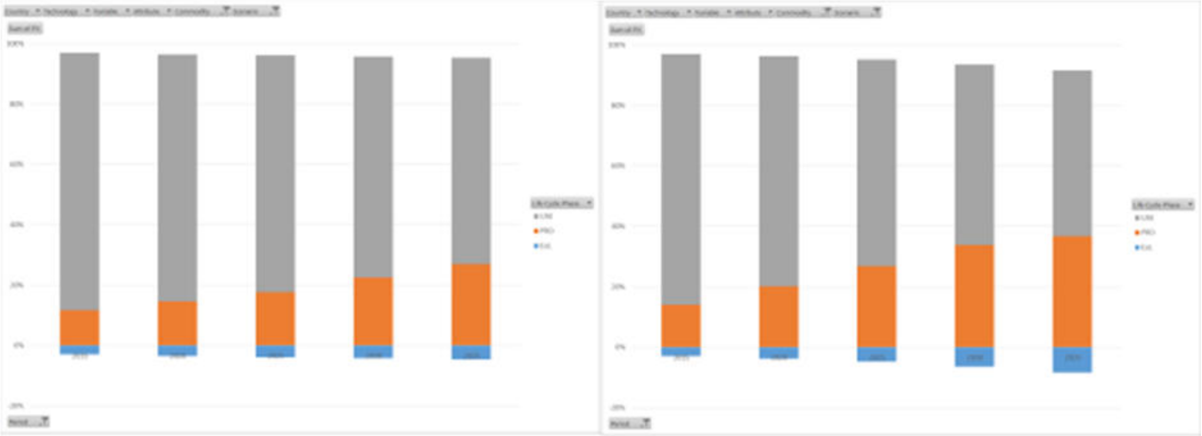


Figure 32 - CO_2 emissions of the passenger fleet: relative contributions in total emissions over time (S1 on the left, S64 on the right)

In order to better reflect impacts of the different policies on total CO_2 emissions, relative results are presented in Figure 33 standing for the difference between results got for a given scenario in 2035 with those associated to reference scenario S1. Several effects can be appraised on this basis. First, these results highlight the respective dynamics characterizing the evolution of tailpipe emissions and production/end of life emissions across scenarios: **while effect of policies on tailpipe emissions is cumulative, their effect on production and end of life emissions is rather instantaneous.** This is due to the fact that tailpipe emissions depends on vehicle stocks (and therefore on technological choices made during past periods as a result of policies) whereas production emissions depend on sales (and therefore only on technological choices made at the considered time period). Then, other valuable outcomes can be drawn from such results about the effect of economics on CO_2 emissions of the fleet. Indeed, the increase in energy and carbon prices (resulting from carbon constraint) generates higher CO_2 emission benefits due to larger reductions in tailpipe emissions: penetration rates of electrified vehicles are slightly higher and the increase in mobility demand (small rebound effect) is reduced. Besides, subsidies and taxes also have significant effect on CO_2 emissions: higher reduction in tailpipe emissions and higher credits due to end of life emissions that are partially offset by an increase in emissions related to production of vehicles and cells.

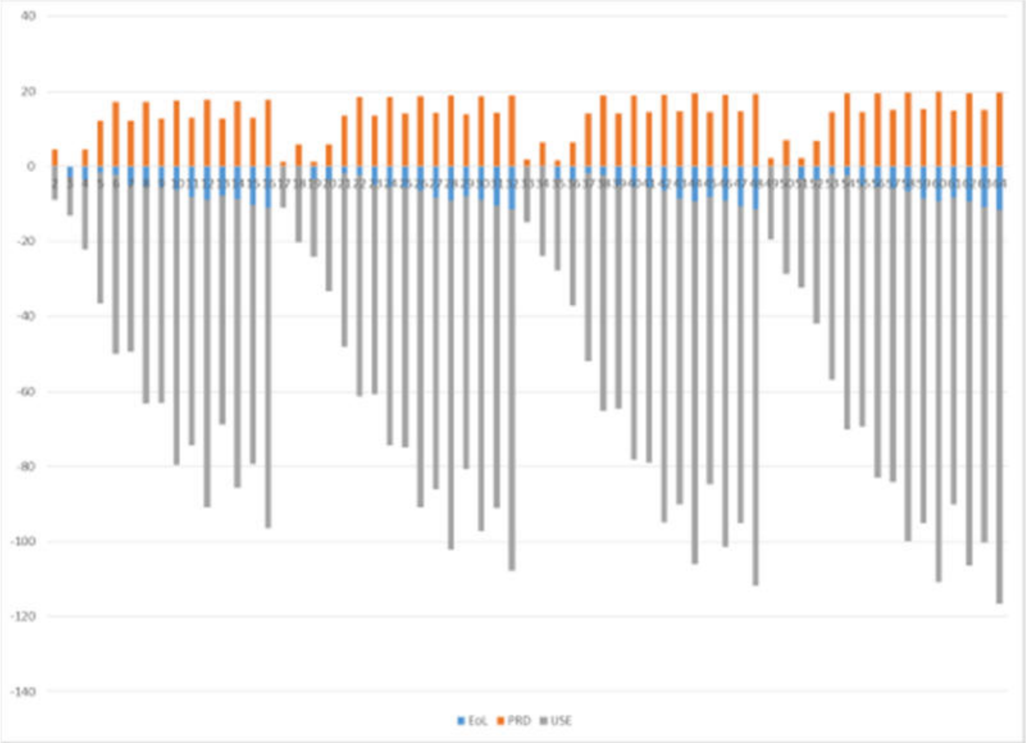


Figure 33 – Difference in total CO_2 emissions of the fleet in 2035 vs. reference scenario S1 (63 scenarios)

Looking at cumulative emission results for the time period 2005-2030 (sum of CO_2 emissions occurring each year over this time period) leads to a different picture (Figure 34). Trend is obviously similar (cumulative CO_2 emissions are lower for policy scenarios inducing highest electrification rates) but results do not much differ among considered scenarios (- 3.8% for S64 compared to S1). This is due to the facts that total CO_2 emission trajectories especially differ at the end of time period (starting from 2020) when CO_2 emission levels are greatly lower compared to the early period (2005-2020). Therefore, the significant discrepancies between scenarios noticed at the end of time period (see Figure 31) are considerably reduced by larger emission amounts released in early periods (quite similar amounts for all scenarios). Similar comments can be made on cumulative GWP results (Figure 35). The differences between cumulative GWP results are even smaller since considered characterization factors lead to discount GHG emissions and give more weight to emissions released in early periods and less to those occurring closer to the end of the time period. The difference between cumulative GWP results associated to S64 and S1 is then reduced to 2.5%.

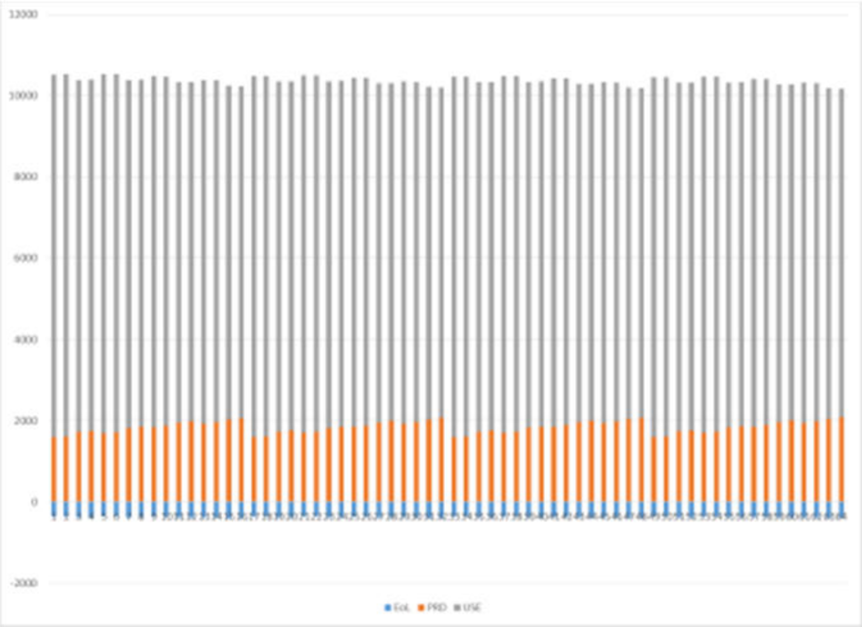


Figure 34 – Cumulative CO_2 emissions (2005-2030) of the fleet (64 scenarios)

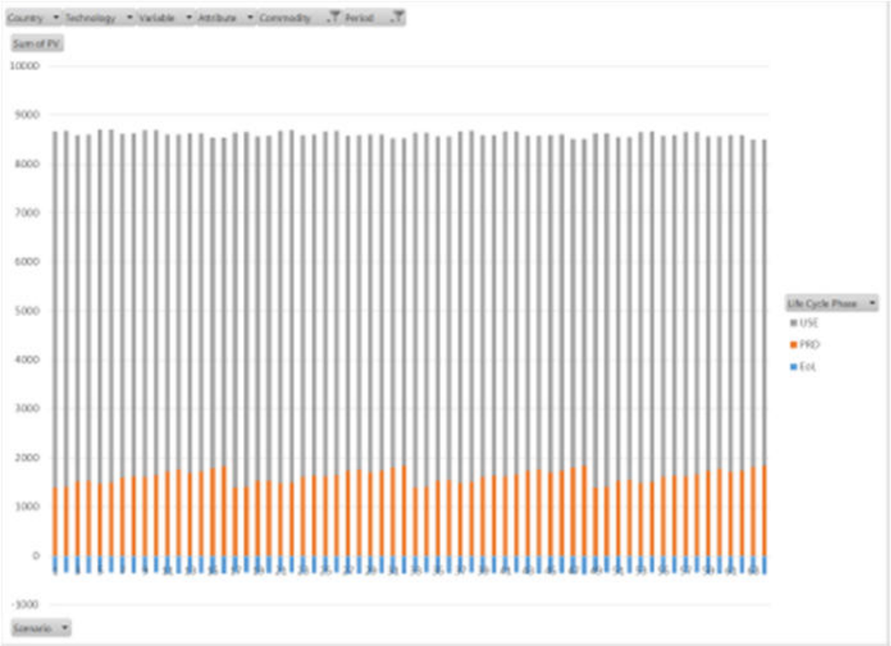


Figure 35 – Cumulative GWP (2005-2030) of the fleet (64 scenarios)

7.2 The life cycle emissions of passenger fleets: other pollutant emissions

Analyses similar to the one presented in previous section can be conducted on other pollutant emissions (CO, NOx, SOx, PM).

First, Figure 36 presents contributions in total pollutant emissions in 2035 for scenarios S1 and S64. This enables to appraise the respective contributions of tailpipe, production and end of life emissions as well as the effect of a larger spreading of electrified vehicles on this type of values. Regarding NOx and PM emissions, results demonstrate that tailpipe emissions clearly prevail over production and end of life emissions. A large electromobility deployment does not change the picture, even if NOx and PM emissions related to the production of an EV can be three times higher than those of a conventional diesel or gasoline vehicle. The same cannot be said with respect to SOx and CO emissions. Indeed, production and end of life emissions have significant contributions in total emissions but still lower than those associated with tailpipe emissions. A large electrification of the passenger fleet leads to higher shares in total emissions due to production and end of life of vehicles and battery cells, especially regarding SOx emissions (as a reminder, SOx emissions related to the production of an EV can be up to 6 times higher than those of a conventional vehicle).

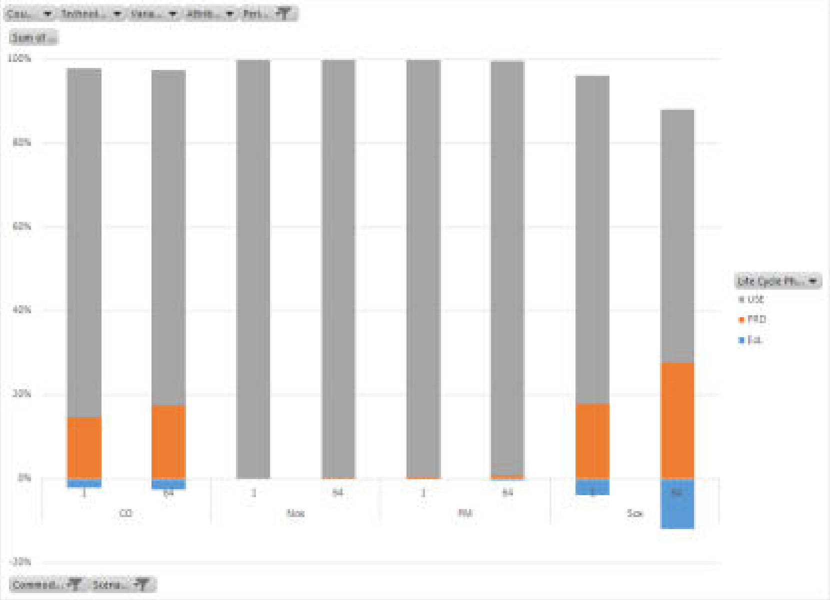


Figure 36 - Pollutant emissions of the passenger fleet: relative contributions in total emissions in S1 and S64 (2035)

Total emission profiles of the fleet are driven by the evolutions of tailpipe emissions (dominating contribution) and therefore total emissions naturally decrease over time (Figure 37). The reduction in NOx, PM and CO emissions is especially due to increasingly stringent standards for new vehicles put on the market (lowering emission limits). These emissions limits decrease until 2015 and then remain constant by 2035; continuous emissions decrease after 2015 being due to fleet renewal (replacement of Euro 4 / Euro 5 vehicles). Tailpipe SOx emissions are correlated to fuel consumption and sulfur content of gasoline and diesel fuel. Considerable decrease in SOx emissions at the beginning of the period is mainly due to the change in gasoline and diesel specifications (sulfur content lowered from 50 ppm to 10ppm starting from 2010) while further reductions by 2035 result from improvement in vehicle energy efficiencies.

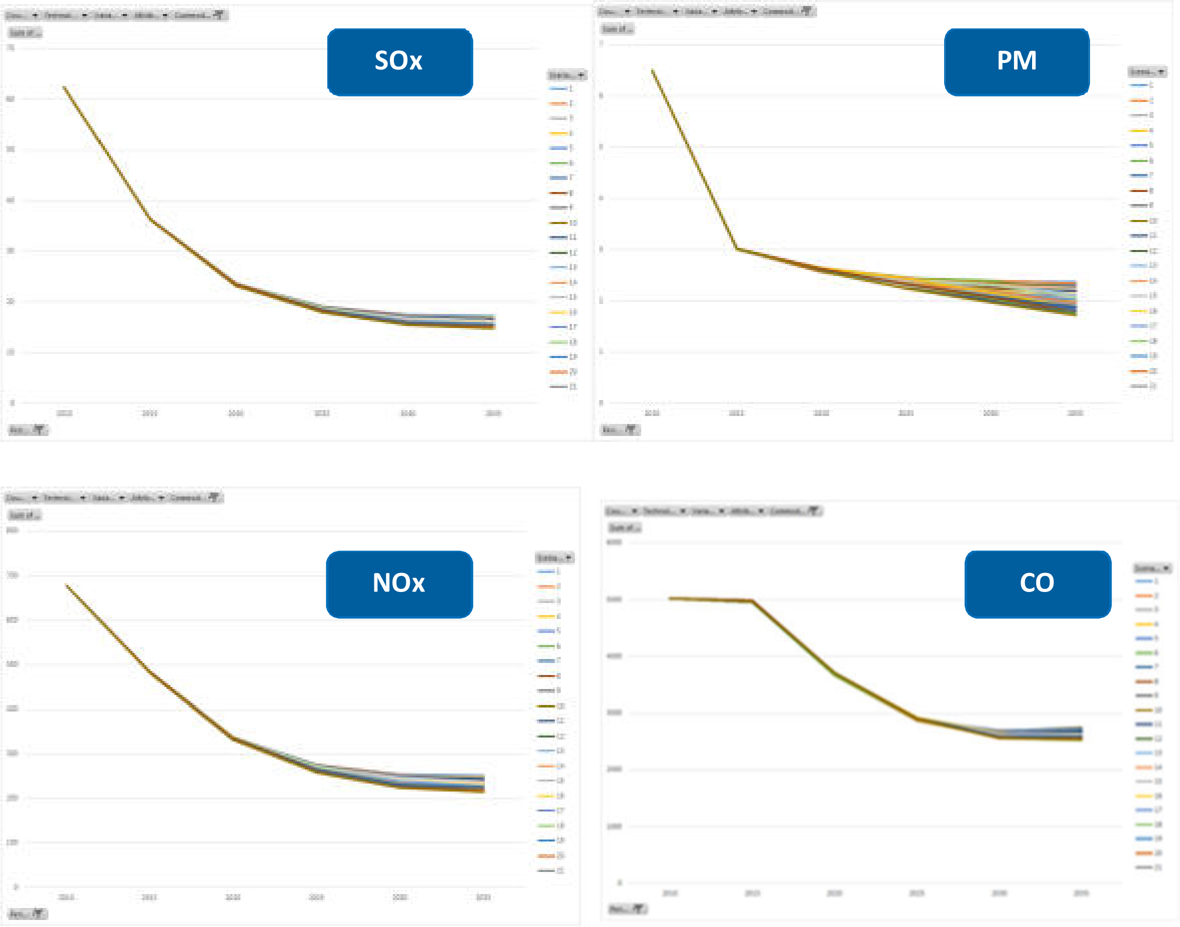


Figure 37 – Evolution of total pollutant emissions of the fleet over time (64 scenarios)

Spreading of electric vehicles leads to higher decrease in such pollutant emissions (Figure 38). In 2035, the decrease in total PM and CO emissions is around 15% higher for S64 compared to reference scenario S1. Regarding CO emissions, the additional benefits due to electromobility deployment is smaller (around 8% in 2035) since it is reduced by an increase in emissions related to PHEVs and EVs production (this increase even offset temporarily the decrease in tailpipe emissions).

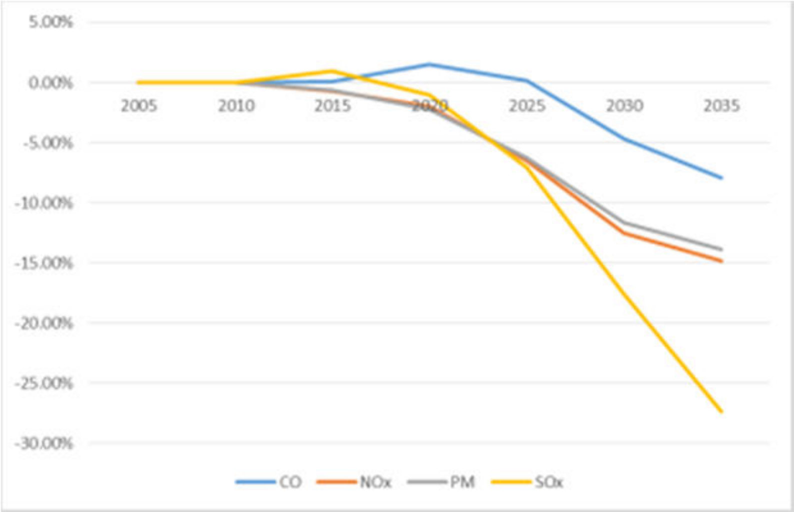
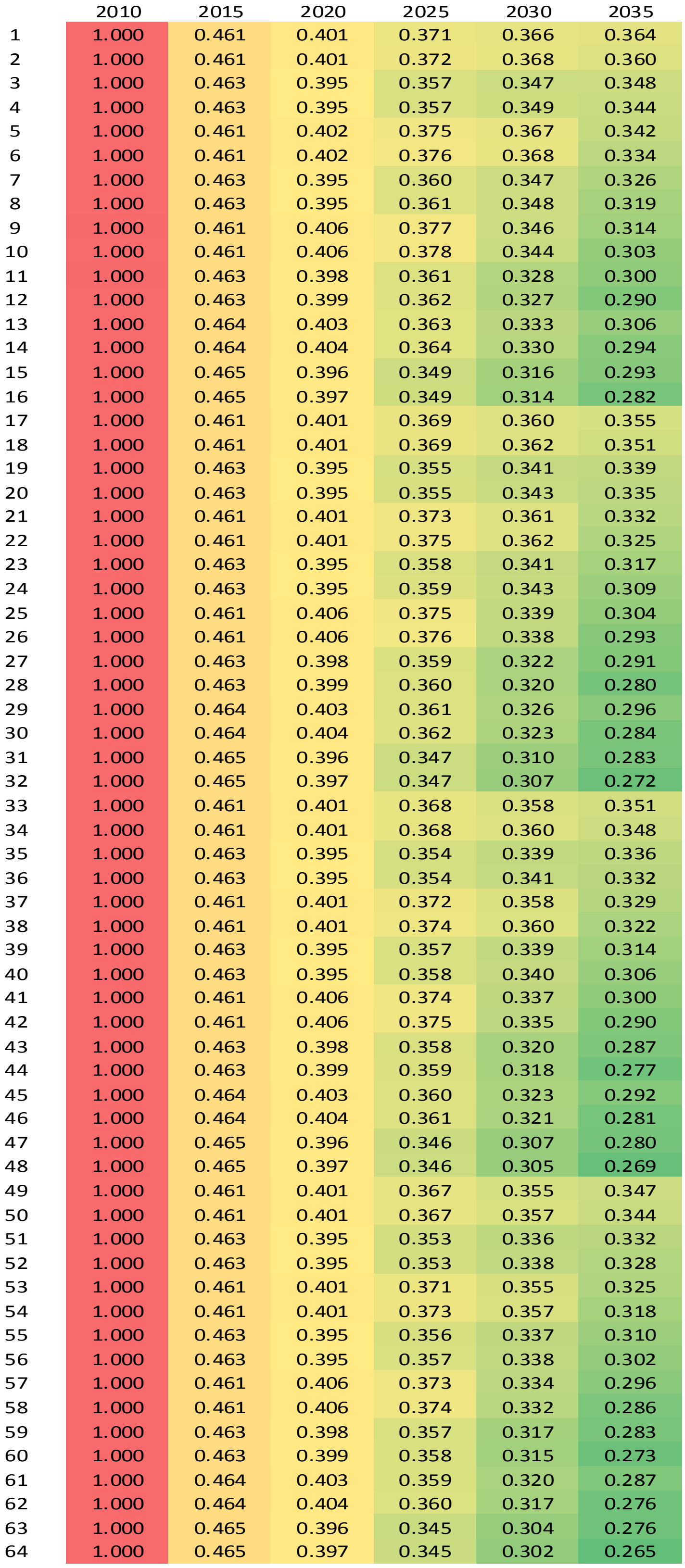


Figure 38 – Difference in total pollutant emissions of the fleet over time (S64 vs. S1)

Additional savings in SOx emissions (S64 vs. S1) are more significant (around 27% in 2035) because of a decrease in gasoline and diesel consumption. This effect is only partially offset by increasing production emissions and overall mobility demand (small rebound effect). Looking at the evolution of total SOx emissions over time across all scenarios enables to highlight respective impacts of considered policies (Table 12): rather small effect of the climate constraint and more substantial effect related to behavioral shifts (adoption) and public policies (subsidies, scrappage and taxes).



	2010	2015	2020	2025	2030	2035
1	1.000	0.461	0.401	0.371	0.366	0.364
2	1.000	0.461	0.401	0.372	0.368	0.360
3	1.000	0.463	0.395	0.357	0.347	0.348
4	1.000	0.463	0.395	0.357	0.349	0.344
5	1.000	0.461	0.402	0.375	0.367	0.342
6	1.000	0.461	0.402	0.376	0.368	0.334
7	1.000	0.463	0.395	0.360	0.347	0.326
8	1.000	0.463	0.395	0.361	0.348	0.319
9	1.000	0.461	0.406	0.377	0.346	0.314
10	1.000	0.461	0.406	0.378	0.344	0.303
11	1.000	0.463	0.398	0.361	0.328	0.300
12	1.000	0.463	0.399	0.362	0.327	0.290
13	1.000	0.464	0.403	0.363	0.333	0.306
14	1.000	0.464	0.404	0.364	0.330	0.294
15	1.000	0.465	0.396	0.349	0.316	0.293
16	1.000	0.465	0.397	0.349	0.314	0.282
17	1.000	0.461	0.401	0.369	0.360	0.355
18	1.000	0.461	0.401	0.369	0.362	0.351
19	1.000	0.463	0.395	0.355	0.341	0.339
20	1.000	0.463	0.395	0.355	0.343	0.335
21	1.000	0.461	0.401	0.373	0.361	0.332
22	1.000	0.461	0.401	0.375	0.362	0.325
23	1.000	0.463	0.395	0.358	0.341	0.317
24	1.000	0.463	0.395	0.359	0.343	0.309
25	1.000	0.461	0.406	0.375	0.339	0.304
26	1.000	0.461	0.406	0.376	0.338	0.293
27	1.000	0.463	0.398	0.359	0.322	0.291
28	1.000	0.463	0.399	0.360	0.320	0.280
29	1.000	0.464	0.403	0.361	0.326	0.296
30	1.000	0.464	0.404	0.362	0.323	0.284
31	1.000	0.465	0.396	0.347	0.310	0.283
32	1.000	0.465	0.397	0.347	0.307	0.272
33	1.000	0.461	0.401	0.368	0.358	0.351
34	1.000	0.461	0.401	0.368	0.360	0.348
35	1.000	0.463	0.395	0.354	0.339	0.336
36	1.000	0.463	0.395	0.354	0.341	0.332
37	1.000	0.461	0.401	0.372	0.358	0.329
38	1.000	0.461	0.401	0.374	0.360	0.322
39	1.000	0.463	0.395	0.357	0.339	0.314
40	1.000	0.463	0.395	0.358	0.340	0.306
41	1.000	0.461	0.406	0.374	0.337	0.300
42	1.000	0.461	0.406	0.375	0.335	0.290
43	1.000	0.463	0.398	0.358	0.320	0.287
44	1.000	0.463	0.399	0.359	0.318	0.277
45	1.000	0.464	0.403	0.360	0.323	0.292
46	1.000	0.464	0.404	0.361	0.321	0.281
47	1.000	0.465	0.396	0.346	0.307	0.280
48	1.000	0.465	0.397	0.346	0.305	0.269
49	1.000	0.461	0.401	0.367	0.355	0.347
50	1.000	0.461	0.401	0.367	0.357	0.344
51	1.000	0.463	0.395	0.353	0.336	0.332
52	1.000	0.463	0.395	0.353	0.338	0.328
53	1.000	0.461	0.401	0.371	0.355	0.325
54	1.000	0.461	0.401	0.373	0.357	0.318
55	1.000	0.463	0.395	0.356	0.337	0.310
56	1.000	0.463	0.395	0.357	0.338	0.302
57	1.000	0.461	0.406	0.373	0.334	0.296
58	1.000	0.461	0.406	0.374	0.332	0.286
59	1.000	0.463	0.398	0.357	0.317	0.283
60	1.000	0.463	0.399	0.358	0.315	0.273
61	1.000	0.464	0.403	0.359	0.320	0.287
62	1.000	0.464	0.404	0.360	0.317	0.276
63	1.000	0.465	0.396	0.345	0.304	0.276
64	1.000	0.465	0.397	0.345	0.302	0.265

Table 12 – Evolution of total SOx emissions of the fleet over time and across scenarios (64 scenarios)

7.3 Extending the analysis to the EU electricity and transport sectors

In this section, the scope of the environmental assessment is extended to assess pollutant emission transfers across sectors. While a global view of transfers between supply and demand sectors is presented regarding CO_2 emissions, the analysis is focused on transport and electricity sectors for other pollutant emissions.

Figure 39 presents total CO_2 emissions variations of the EU energy system in 2030 for all considered scenarios, compared to reference scenario S1. These results show that the effect of carbon constraint prevails on the evolution of total CO_2 emissions and that most emission abatements are made in the energy supply sector (Esup). The industry sector also reacts to carbon cap but to a lesser extent (Ind).

The electrification rate of the transport sector has a positive impact on CO_2 emissions of industry and energy supply sectors because of the global climate constraint: the same target has to be met with lower transport sector emissions, allowing for an emission increase in other sectors. Residential (Rsd) and commercial (Com) sectors are not really reactive to both carbon cap and electromobility deployment.

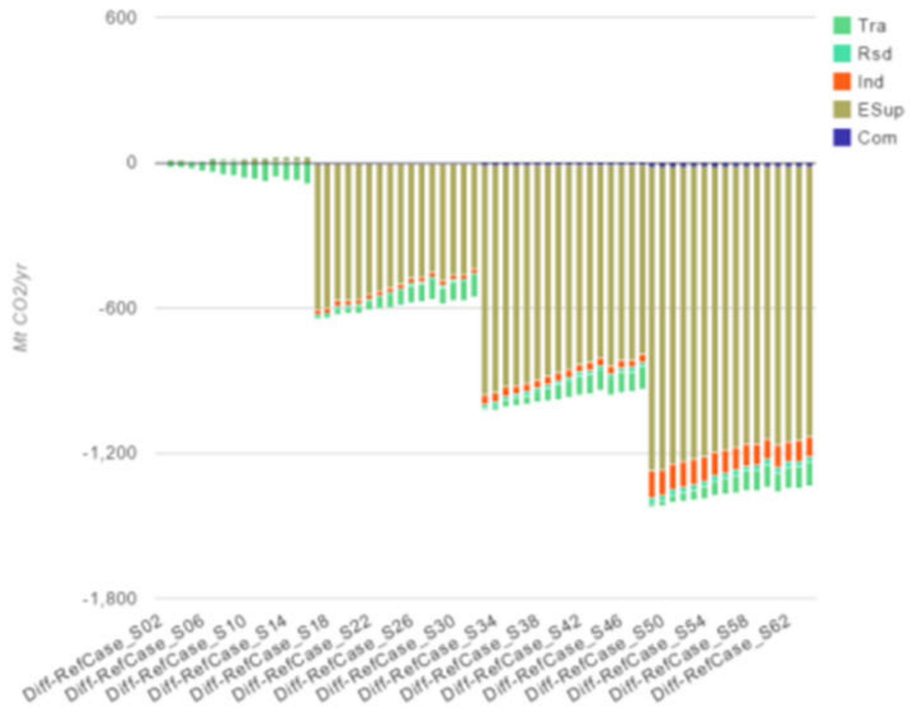


Figure 39 – Supply and demand CO_2 emissions abatements: Difference in total CO_2 emissions of the energy system in 2030 vs. reference scenario S1 (63 scenarios)

Figure 40 provides more detailed information on the reaction of energy supply and shows that abatements due to higher carbon constraints are mainly made in the electricity, upstream and “other” sectors (fuel production, energy transport and distribution). Besides, for a given carbon cap, both emissions from electricity and “other” sectors vary upwards with the increase of transport electrification rate. As previously mentioned, this is because carbon cap is global so that reducing emission of transport sector allows for increased emissions elsewhere. For modeling reasons (see D4.2 report), further analyses are focused on the electricity sector.

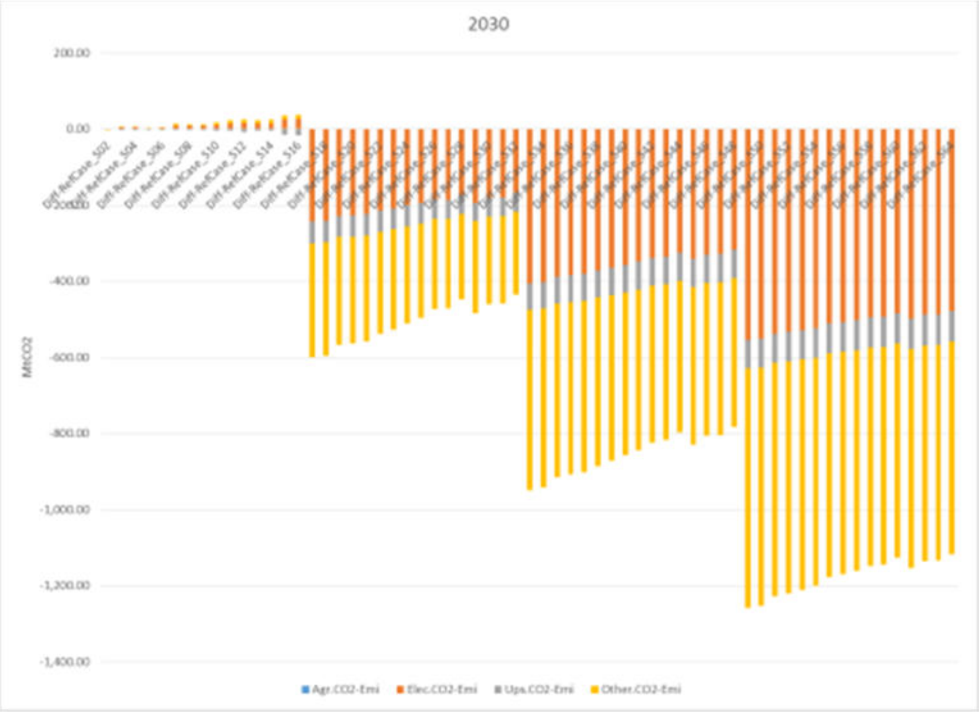


Figure 40 – Detailed CO_2 emissions abatements in the energy supply: Difference in total CO_2 emissions in 2030 vs. reference scenario S1 (63 scenarios)

Then, Figure 41 below presents the evolutions over time of electricity sector emissions. Carbon constraint proves to be the first order effect since results for sets of scenarios corresponding to same climate policy are quite similar. Indeed, to satisfy higher carbon constraint, evolution of the electricity mix is driven by substituting production from coal with other technologies that enables to lower CO_2 emissions while also reducing other pollutant emissions. This results in overall decrease in pollutant emissions along the time period. Regarding CO emissions, results corresponding to different carbon caps are much closer than for other pollutants but same downward trend is noticed when raising this constraint. Unlike other pollutants, CO emissions levels in 2030 are slightly higher than current ones in some scenarios corresponding to lowest carbon constraints.

The increase of the transport electrification rate is a second-order driver that tends to raise pollutant emissions of electricity sector due to additional electricity demand which is partly satisfied by additional production from gas and coal power plants (see D4.2 report for further details). A comparison of scenarios within each carbon block enables to better highlight such effects and shows that large spreading of electrified vehicles can generate significant relative increase in emissions of electricity sector, especially when carbon constraint is high (Figure 42). Such outcomes result from the difference between carbon blocks in marginal grid mix (grid mix corresponding to additional electricity production to satisfy transport demand) and average grid mix in corresponding reference scenario:

- the share of combustion power plants is smaller in grid mix associated to more stringent carbon constraint (e.g. in S49 compared to S1),
- For a similar additional transport demand in S16 and S64 compared to respective reference scenario (S1 and S49), additional production from coal and gas is higher when carbon constraint is high whereas nuclear production is lower (Figure 43).

It is worth noticing that the same analysis at the national scale would lead to different findings because of strong country differences in marginal grid mix.

Figure 41 – Evolution of emissions of the electricity sector over time (64 scenarios)

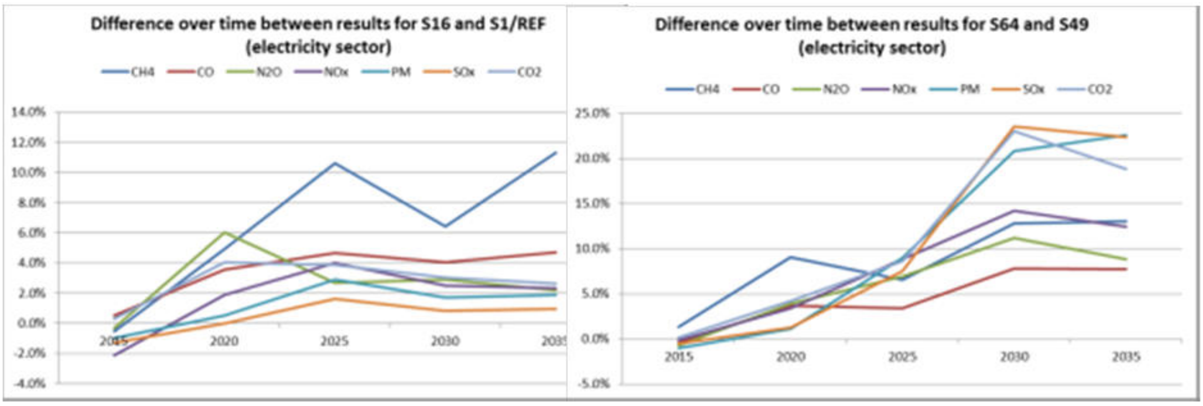


Figure 42 – Impact of transport electrification on emissions of electricity sector: comparison of scenarios based on same climate policy and corresponding to most differing electrification rates

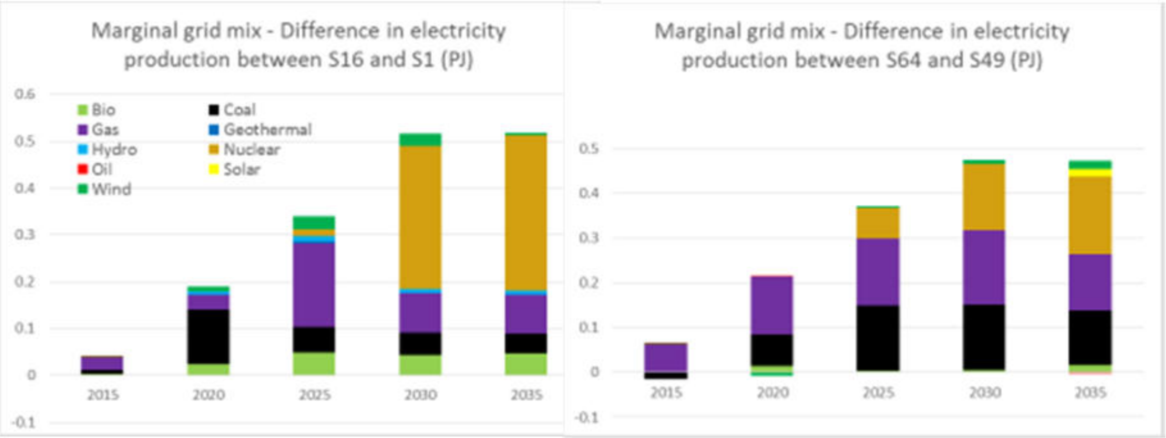


Figure 43 – Impact of transport electrification on electricity sector : Marginal grid mix depends on climate policy

Looking at the sum of emissions of transport and electricity sectors enable to appraise how effects in these two sectors can compensate each other (see Figure 44 for 2030 results). Regarding SOx, NOx and PM emissions, carbon constraint is still the first-order driver of emission profiles. CO emission results prove to be significantly different: the effect of carbon cap is balanced with electrification since the share of road transport sector in total CO emissions is much higher than electricity generation.

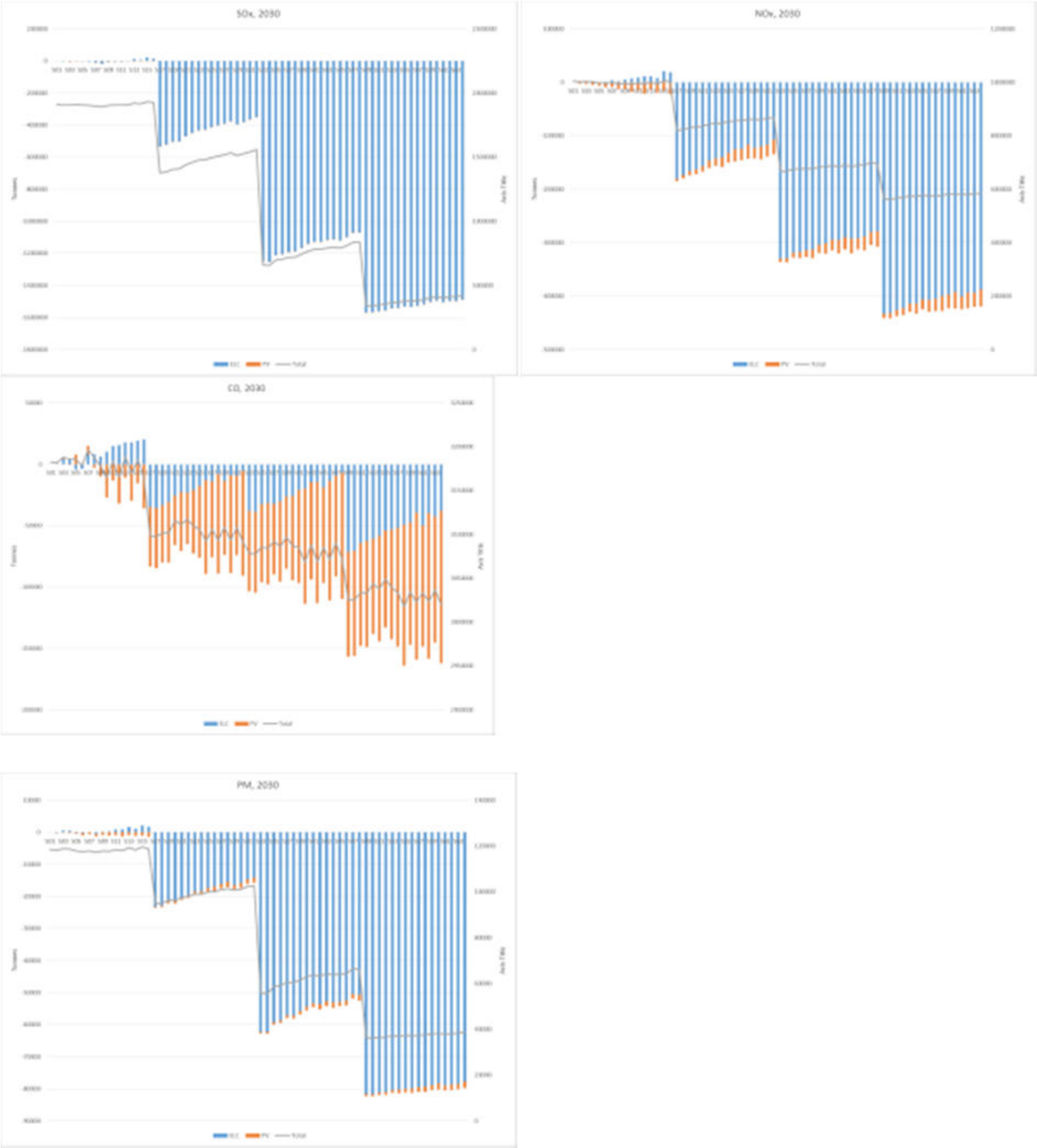
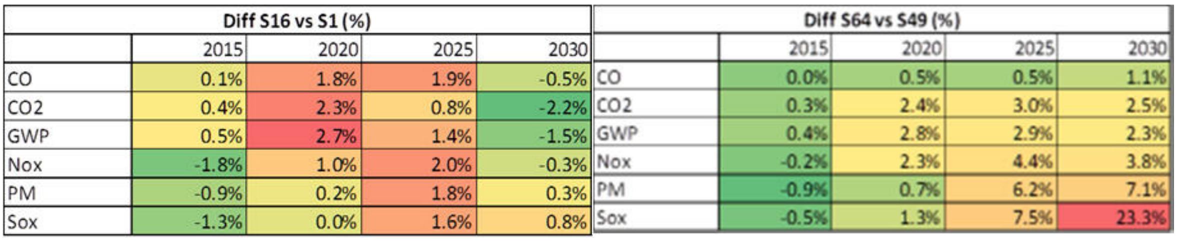


Figure 44 – Balancing effects in electricity and transport sectors (63 scenarios): difference in 2030 emissions compared to reference scenario S1 (left axis) and total emission levels (right axis).

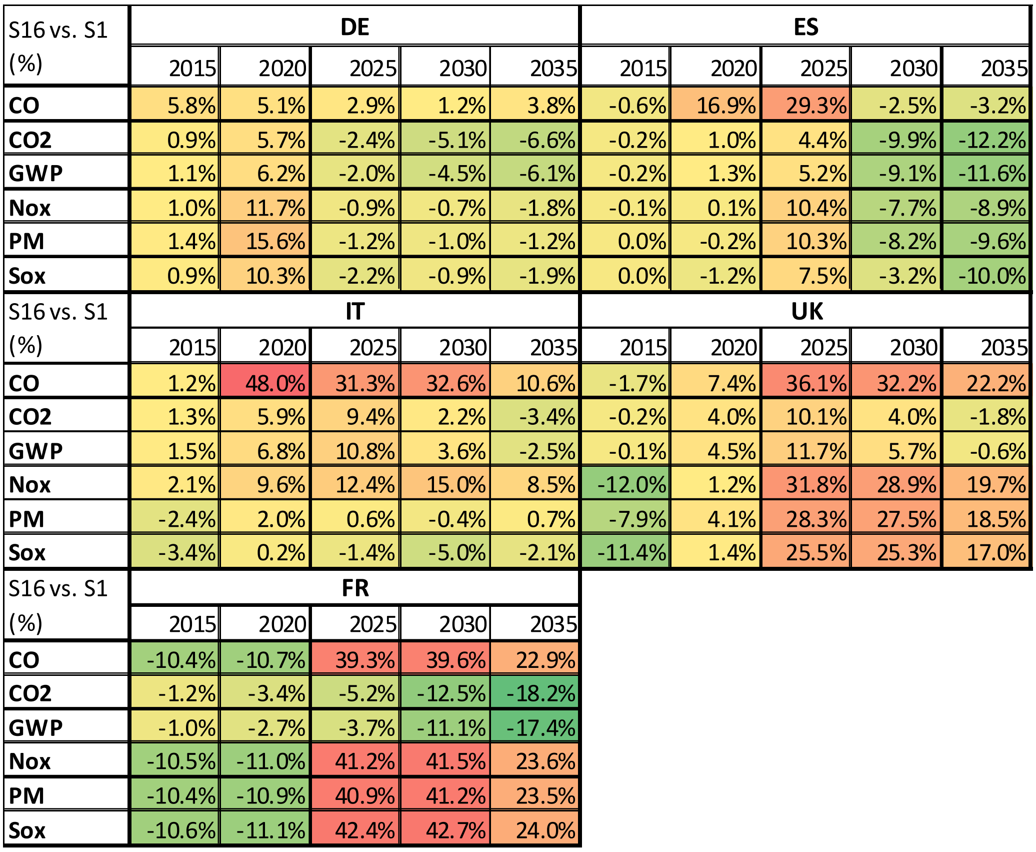
Then, comparing results associated to a similar climate policy (Table 13) reveals that emission increase in the electricity sector due to fleet electrification can prevail over the emission reduction in transport, especially when carbon constraint is high because of larger additional capacities in combustion power plants. Hence, for a given carbon constraint, total emission levels tend to raise with electrification rate except when carbon cap is fairly low (limited positive impact on CO, CO_2 and NOx emissions). Therefore, overall effects due to electrification are not clear-cut and depend on climate policy. Again, as shown in Table 14, analyses at national scale lead to different findings because of strong country differences in marginal grid mix. For France, relative increases in pollutant emissions (CO, NOx, PM, SOx) are high because of very low emission levels compared to other countries (little increase in production from coal, gas or biomass lead to huge increase in pollutant emissions due to small contribution of thermal generation in French grid mix).



Diff S16 vs S1 (%)				
	2015	2020	2025	2030
CO	0.1%	1.8%	1.9%	-0.5%
CO2	0.4%	2.3%	0.8%	-2.2%
GWP	0.5%	2.7%	1.4%	-1.5%
Nox	-1.8%	1.0%	2.0%	-0.3%
PM	-0.9%	0.2%	1.8%	0.3%
Sox	-1.3%	0.0%	1.6%	0.8%

Diff S64 vs S49 (%)				
	2015	2020	2025	2030
CO	0.0%	0.5%	0.5%	1.1%
CO2	0.3%	2.4%	3.0%	2.5%
GWP	0.4%	2.8%	2.9%	2.3%
Nox	-0.2%	2.3%	4.4%	3.8%
PM	-0.9%	0.7%	6.2%	7.1%
Sox	-0.5%	1.3%	7.5%	23.3%

Table 13 – Impact of transport electrification on total emissions (electricity sector + transport sector): comparison of scenarios based on same climate policy and corresponding to most differing electrification rates (EU level)



S16 vs. S1 (%)	DE					ES				
	2015	2020	2025	2030	2035	2015	2020	2025	2030	2035
CO	5.8%	5.1%	2.9%	1.2%	3.8%	-0.6%	16.9%	29.3%	-2.5%	-3.2%
CO2	0.9%	5.7%	-2.4%	-5.1%	-6.6%	-0.2%	1.0%	4.4%	-9.9%	-12.2%
GWP	1.1%	6.2%	-2.0%	-4.5%	-6.1%	-0.2%	1.3%	5.2%	-9.1%	-11.6%
Nox	1.0%	11.7%	-0.9%	-0.7%	-1.8%	-0.1%	0.1%	10.4%	-7.7%	-8.9%
PM	1.4%	15.6%	-1.2%	-1.0%	-1.2%	0.0%	-0.2%	10.3%	-8.2%	-9.6%
Sox	0.9%	10.3%	-2.2%	-0.9%	-1.9%	0.0%	-1.2%	7.5%	-3.2%	-10.0%

S16 vs. S1 (%)	IT					UK				
	2015	2020	2025	2030	2035	2015	2020	2025	2030	2035
CO	1.2%	48.0%	31.3%	32.6%	10.6%	-1.7%	7.4%	36.1%	32.2%	22.2%
CO2	1.3%	5.9%	9.4%	2.2%	-3.4%	-0.2%	4.0%	10.1%	4.0%	-1.8%
GWP	1.5%	6.8%	10.8%	3.6%	-2.5%	-0.1%	4.5%	11.7%	5.7%	-0.6%
Nox	2.1%	9.6%	12.4%	15.0%	8.5%	-12.0%	1.2%	31.8%	28.9%	19.7%
PM	-2.4%	2.0%	0.6%	-0.4%	0.7%	-7.9%	4.1%	28.3%	27.5%	18.5%
Sox	-3.4%	0.2%	-1.4%	-5.0%	-2.1%	-11.4%	1.4%	25.5%	25.3%	17.0%

S16 vs. S1 (%)	FR				
	2015	2020	2025	2030	2035
CO	-10.4%	-10.7%	39.3%	39.6%	22.9%
CO2	-1.2%	-3.4%	-5.2%	-12.5%	-18.2%
GWP	-1.0%	-2.7%	-3.7%	-11.1%	-17.4%
Nox	-10.5%	-11.0%	41.2%	41.5%	23.6%
PM	-10.4%	-10.9%	40.9%	41.2%	23.5%
Sox	-10.6%	-11.1%	42.4%	42.7%	24.0%

Table 14 – Impact of transport electrification on total emissions (electricity sector + transport sector): comparison of scenarios based on same climate policy and corresponding to most differing electrification rates (national level)

8. Cost benefit analysis of such deployments

The differences of external costs between the reference scenario and different policy scenarios have to be assessed in order to perform a cost-benefit-analysis.

Within this section the quantifiable external and internal costs for the transport sector (passenger cars) and the energy sector (power generation) within European EU28 countries for the 64 scenarios, have been calculated and compared on the basis of the methodology developed for the SCelecTRA project and described in deliverable D 3.3 Externality report.

8.1 Externality

The methodology to calculate the external costs of the considered sectors is based on activity data with their resulting pressures on the one hand, and corresponding unit damage factors (UDFs) on the other hand. The applied UDFs have been derived from various literature sources. They are in principle based on the Impact Pathway Approach (European Commission, 2005).

For 64 scenarios the inventory data of operating passenger cars and power plants in Europe until 2030 (air pollution, greenhouse gas emission, mileages of passenger cars) has to be evaluated and expressed as external costs €$_{2005}$.

The evaluation of classical air pollutants and GHG is based on country specific unit damage cost factors derived from state-of-the-art recommendations found in literature. Air pollution due to operation of power generation technologies are evaluated according to factors derived within the NEEDS project by Preiss et al. (2008). Air pollution emission due to operation of passenger cars are differentiated to urban and non-urban road types and evaluated based on recommendations by Korzhenevych et al. (2014a). The evaluation of GHG is based on a meta-analysis of avoidance costs conducted by Kuik et al. (2009). The estimation of external costs of passenger cars due to noise and accidents is based on generic average damage factors found e.g. in Schwermer et al. (2012) and Korzhenevych et al. (2014a).

The details will not be described in this final report but all the UDFs used in this section and the associated sources are described in deliverable D3.3 Externality report.

8.2 Cost-Benefit Assessment methodology

A comprehensive set of data has been gathered in the course of the project as exposed in deliverable D3.3 Externality report.

As input for each scenario S_i we have the discounted

- quantified external costs (greenhouse gases and air pollutants)

- the internal costs supported by car owners for energy carriers and purchase, as well as costs for electricity generation after having balanced for the corresponding revenues for member states.

The Cost-Benefit Assessment is done in the following way for each scenario:

- By accounting all relative benefits for a scenario i when compared to the reference scenario

Δ Benefit 1): external costs (scenario i - reference < 0)

Δ Benefit 2): internal costs (scenario i - reference < 0)

- By accounting all relative costs for a scenario i when compared to the reference scenario

Δ Cost 1): external costs (scenario i - reference > 0)

Δ Cost 2): internal costs (scenario i - reference > 0)

The final index is that if relative benefits outbalance the relative costs then the policy measures and CO_2 emission reduction target should be considered as efficient within the limits we have defined in this analysis, i.e. transport sector limited to passenger cars and the power generation sector.

As a reminder, scenarios have been built with growing carbon constraints, fastening consumer adoption for EVs and EV demand-side policies. This is depicted in Figure 19.

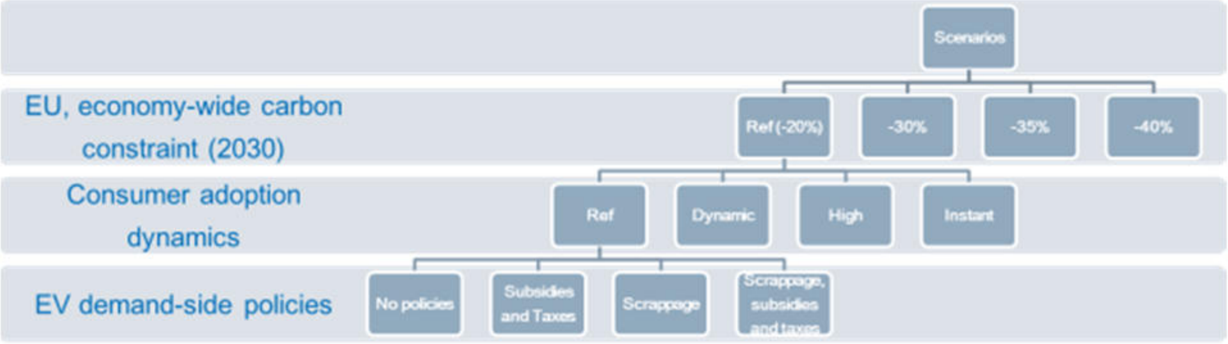


Figure 45: Scenario tree | Source: D 4.1

The results of subtracting the costs from the benefits, corresponding to the deltas of internal and external costs for each scenario are displayed in Figure 46. If a value is lower than zero, as it is in most of the cases, this means that the delta costs are higher than the delta benefits.

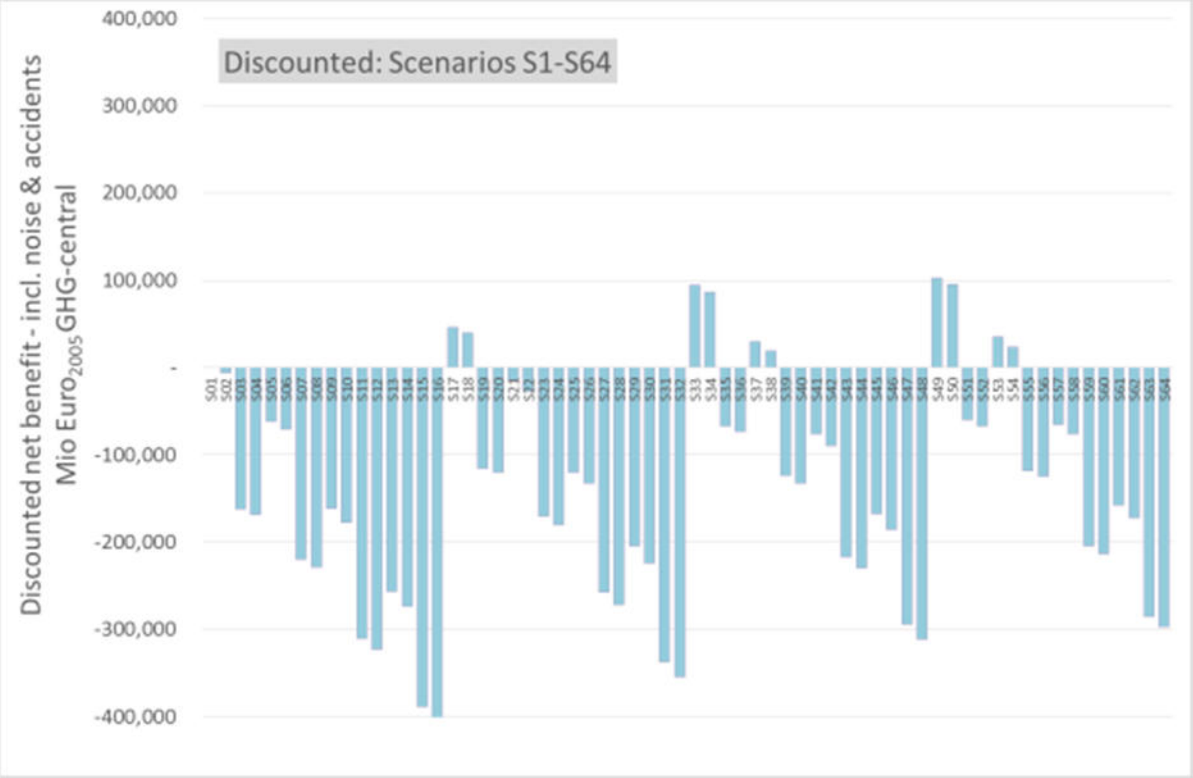


Figure 46: Discounted results of costs and benefits regarding internal and external costs for power plant and passenger cars of scenario S1- 64 compared to the reference scenario S1 (including greenhouse gases based on central value for GHG valuation, air pollutants, noise & accidents; accounting for costs of ETS certificates for the power plants) – [million €2005]

8.3 Discussion

From the results shown in Figure 46 the conclusion is that for the scenarios S17, S18, S33, S34, S49 and S50 the policies may have a net benefit for the society. Those scenarios are the ones with the least electrified vehicles millage for a given CO_2 constraint.

Meanwhile the carbon constraint has a slight positive impact on the internal cost as the higher the constraint the higher the internal costs. Inside these CO_2 constraints the first observation is the higher the EV deployment, the higher the costs.

We observe a difference for example between scenarios 33-34 which are beneficial, scenarios 35-36 which show a cost and scenarios 37-38 which again are beneficial. The difference between 33-34 and 35-36 are the policies implemented:

- A scrappage program costs a lot and accounts for the difference between scenario 34 and 36

- Fuel taxes and subsidies appear to have a lesser impact on the costs. But this could also be due to the fact that these measures have already been identified as being less efficient in developing the EV market.

It should be born in mind that the change of external costs of noise and accidents is only depending on the total mileages driven. Hence, the substitution of ICE vehicles by EV does have no effect. However, the policies of some scenarios can lead to an increase of total mileages due to high penetration of EV. Moreover, the impacts related to noise and accidents being even more situation-dependent than those due to air pollutants, their macro analysis is therefore also more uncertain.

Nonetheless, the "sensitivity assessment" of excluding noise and accidents show, that there is nearly no difference. This can be explained by

- a larger share of external costs is caused by power plants
- hence, a larger share of external costs differences is caused by CO_2 emission reduction by power plants
- most of the EV substitute ICE car vkm; hence there is nearly no difference between the scenarios regarding noise and accidents.

One should consider that this analysis only take into account the costs of driving passengers cars for the customers and the cost of power plants. EV are more expensive for the consumers than ICE cars (at least for now). Therefore, the results do not show an overall advantage of scenarios with a higher share of EV.

Indeed our analysis have not taken into account some benefits of a large deployment of EVs. These can be e.g. certain OEMs would sell more expensive cars and therefore increase their margins, creating wealth and jobs. Another effect would be that utilities sell some more electricity creating wealth and jobs. Of course, manufactures of ICE cars would maybe sell less cars and gasoline and diesel suppliers would sell less fuel with the opposite consequences. Hence, from a European perspective a cost-benefit assessment would also need to take into account domestic economic added value, energy supply security and independents from imports (energy, other resources, and other products, e.g. batteries for EV).

Furthermore as this analysis is mainly based on the costs supported by automotive consumers one should not forget that driving a car is not a beneficial activity if one only takes into account the economic balance. On top of that electromobility is in its infancy and will deploy. In this CBA analysis we have only looked at the deployment of electromobility (from 2013 to 2032) which in general always relates to the higher costs (equivalent to the investment phase for an industrial project) whereas one should hope that these new mobility technologies will last and will bring benefits for future decades.

CONCLUSIONS

At the early stages of the project SCelecTRA had identified the main questions it should answer to address the challenges of electromobility.

What are the relevant conditions for EVs & PHEVs deployment ?

SCelecTRA has shown that electromobility has a great potential in Europe for the passenger cars sector. In the most optimistic scenario xEV sales share in the total sales are close to 30% in 2030 in the big automotive markets: Germany, France, Italy, UK, and Spain. Note that while the shares of BEV and PHEV are close in Italy, France and UK, PHEV dominate the xEV market in Germany and Spain.

Regarding the conditions to create a European-scale EV market, charging infrastructure is not the only criterion but our simulations made it clear that without charging points no EVs appear.

It should also be noted, that policies are not necessarily additive, i.e. the sum of the effects of two policies is not equal to the effect of the combination of the two policies.

Another interesting point is to rank the influence of all the factors. And if the charging infrastructure is of prime importance not all factors weight the same in the deployment of electromobility. Regardin public policy tools, member states should focus on scrappage programs to accelerate the renewing of their vehicle fleets, subsidies to lower the purchase costs of xEVs and ease their arrival on the market and a high CO_2 tax to even further penalize high-CO_2 emitting vehicles. On the other hand, a specific action on fuel taxes appear to be less efficient.

What are the impacts on the EU energy & transport sectors?

As for energy demand, the substitution dynamics in the transport sector reflects the relative fuel efficiencies of electrified vehicles compared to conventional. Because of the advantage of PHEVs and EVs, it turns out that the additional electricity demand due to passenger electric mobility represents a small share of the 2030 final energy mix of transport, as well as a small proportion of the final electricity demand compared to other sectors.

ScelecTRA also showed that in the carbon-constrained worlds described in these scenarios, the additional electricity to be supplied to transport comes from additional electricity production rather than reduced uses in residential, commercial or industrial sectors, and basically no changes occur in the electricity consumption of these other sectors.

While the main driver for changes in the electricity mixes relates to the carbon objective, we show how economic-optimal variations happen due to the incremental electricity transport demand. With a global carbon cap design, additional reduction efforts realized in the transport sector provide an additional “carbon budget” to be spent elsewhere. This allows to relax the abatement level especially in the electricity sector, where the additional demand is satisfied by a mix of coal, gas and nuclear electricity depending on the countries

These economic choices results from the adaptation of the electricity sector by a balance of low-cost and carbon-free technologies. From a policy perspective, this questions the relevance of policy designs to reach global abatement targets. If a global cap seems more efficient from a perfect market perspective, sectoral targets may avoid some cross-sectoral transfers, although we somehow show that these are not necessarily undesirable.

What are the environmental impacts related to Electromobility deployment ?

The highest reductions of tailpipe CO_2 emissions towards 2035 are reached when electrification rate is higher thanks to null or lower emissions associated with electrified vehicles (reduction of carbon intensity and increase of the overall energy efficiency of the fleet) even accounting for a small rebound effect of the passenger car mobility.

The electrification rate of the transport sector has a positive impact on CO_2 emissions of industry and energy supply sectors because of the global climate constraint: the same target has to be met with lower transport sector emissions, allowing for an emission increase in other sectors.

Then, comparing results associated to a similar climate policy reveals that emission increase in the electricity sector due to fleet electrification can prevail over the emission reduction in transport, especially when carbon constraint is high because of larger additional capacities in combustion power plants. Hence, for a given carbon constraint, total emission levels tend to raise with electrification rate except when carbon cap is fairly low (limited positive impact on CO, CO_2 and NOx emissions). Therefore, overall effects due to electrification are not clear-cut and depend on climate policy.

What are the costs related to Electromobility deployment in EU ?

Our simulation results come from economic choices, and traduce the complexity of transfers of flows (economic, environmental) across sectors – for a given carbon cap, scenarios have the same global CO_2 outcome. Differences are due to changing, yet interdependent, technology choices in the different sectors. The evaluation of external costs reveals another difficulty, because cross-sectoral “leakages” may occur for pollutants not covered by specific policy objectives. And the cost-benefit analysis showed that due to the high costs of abatement in transports, an ambitious electromobility policy faces difficulties to cover its costs and should therefore be considered on a higher scale to account for all its indirect benefits.

PROJECT RESULTS DISSEMINATION

Date	Location	Name of the event or publication	Partner
13/09/12	Paris	Electromobility + launching seminar	Simon Vinot (IFPEN)
06/02/14	Copenhagen	Electromobility+ Mid-term Event	Simon Vinot (IFPEN)
21/05/2015	Berlin	Electromobility+ Final Event	Simon Vinot (IFPEN)
30/10/14	Rome	Presentation of WP2 results to **IAEE**, session 28 : EU transport policy to reduce CO_2 emissions. Title of presentation: Measuring The Impact of Existing Environmental Regulations and Fiscal Legislations on the European Road Transport Demand: a Dynamic Panel Data Econometric Analysis	Pascal Gastineau (IFSTTAR), Benoit Chèze (IFPEN)
17/11/14	Copenhagen	Presentation of SCelecTRA first results in the **EV-step regional workshop** during **66th Semi-annual ETSAP meeting**	Stephane Tchung-Ming (IFPEN)
2015		**Papers to be submitted to** Journal of Transport Economics and Policy**,** Transportation Research Part A**,** Transportation Research Part B**.**	Pascal Gastineau (IFSTTAR), Benoit Chèze (IFPEN)
2015	Bordeaux	**Presentation of WP3 results in** LCM 2015 http://lcm2015.org/	EIFER
2015	USA	**Presentation of WP3 results in the** CRC workshop on LCA of transportation fuels	IFPEN
2015		**Papers to be submitted by WP3 to :** Energy Policy Renewable & Sustainable Energy Reviews Energy The International Journal of Life Cycle Assessment	IFPEN

ANNEXES

Case#	Description
1	CO2 Ref | Adop Ref | EVPol-Scrap N | EVPol-Subs N | EVPol-Tax N
2	CO2 Ref | Adop Ref | EVPol-Scrap N | EVPol-Subs Y | EVPol-Tax Y
3	CO2 Ref | Adop Ref | EVPol-Scrap Y | EVPol-Subs N | EVPol-Tax N
4	CO2 Ref | Adop Ref | EVPol-Scrap Y | EVPol-Subs Y | EVPol-Tax Y
5	CO2 Ref | Adop Dyn | EVPol-Scrap N | EVPol-Subs N | EVPol-Tax N
6	CO2 Ref | Adop Dyn | EVPol-Scrap N | EVPol-Subs Y | EVPol-Tax Y
7	CO2 Ref | Adop Dyn | EVPol-Scrap Y | EVPol-Subs N | EVPol-Tax N
8	CO2 Ref | Adop Dyn | EVPol-Scrap Y | EVPol-Subs Y | EVPol-Tax Y
9	CO2 Ref | Adop High | EVPol-Scrap N | EVPol-Subs N | EVPol-Tax N
10	CO2 Ref | Adop High | EVPol-Scrap N | EVPol-Subs Y | EVPol-Tax Y
11	CO2 Ref | Adop High | EVPol-Scrap Y | EVPol-Subs N | EVPol-Tax N
12	CO2 Ref | Adop High | EVPol-Scrap Y | EVPol-Subs Y | EVPol-Tax Y
13	CO2 Ref | Adop Instant | EVPol-Scrap N | EVPol-Subs N | EVPol-Tax N
14	CO2 Ref | Adop Instant | EVPol-Scrap N | EVPol-Subs Y | EVPol-Tax Y
15	CO2 Ref | Adop Instant | EVPol-Scrap Y | EVPol-Subs N | EVPol-Tax N
16	CO2 Ref | Adop Instant | EVPol-Scrap Y | EVPol-Subs Y | EVPol-Tax Y
17	CO2 30 | Adop Ref | EVPol-Scrap N | EVPol-Subs N | EVPol-Tax N
18	CO2 30 | Adop Ref | EVPol-Scrap N | EVPol-Subs Y | EVPol-Tax Y
19	CO2 30 | Adop Ref | EVPol-Scrap Y | EVPol-Subs N | EVPol-Tax N
20	CO2 30 | Adop Ref | EVPol-Scrap Y | EVPol-Subs Y | EVPol-Tax Y
21	CO2 30 | Adop Dyn | EVPol-Scrap N | EVPol-Subs N | EVPol-Tax N
22	CO2 30 | Adop Dyn | EVPol-Scrap N | EVPol-Subs Y | EVPol-Tax Y
23	CO2 30 | Adop Dyn | EVPol-Scrap Y | EVPol-Subs N | EVPol-Tax N
24	CO2 30 | Adop Dyn | EVPol-Scrap Y | EVPol-Subs Y | EVPol-Tax Y
25	CO2 30 | Adop High | EVPol-Scrap N | EVPol-Subs N | EVPol-Tax N
26	CO2 30 | Adop High | EVPol-Scrap N | EVPol-Subs Y | EVPol-Tax Y
27	CO2 30 | Adop High | EVPol-Scrap Y | EVPol-Subs N | EVPol-Tax N
28	CO2 30 | Adop High | EVPol-Scrap Y | EVPol-Subs Y | EVPol-Tax Y
29	CO2 30 | Adop Instant | EVPol-Scrap N | EVPol-Subs N | EVPol-Tax N
30	CO2 30 | Adop Instant | EVPol-Scrap N | EVPol-Subs Y | EVPol-Tax Y
31	CO2 30 | Adop Instant | EVPol-Scrap Y | EVPol-Subs N | EVPol-Tax N
32	CO2 30 | Adop Instant | EVPol-Scrap Y | EVPol-Subs Y | EVPol-Tax Y
33	CO2 35 | Adop Ref | EVPol-Scrap N | EVPol-Subs N | EVPol-Tax N
34	CO2 35 | Adop Ref | EVPol-Scrap N | EVPol-Subs Y | EVPol-Tax Y
35	CO2 35 | Adop Ref | EVPol-Scrap Y | EVPol-Subs N | EVPol-Tax N
36	CO2 35 | Adop Ref | EVPol-Scrap Y | EVPol-Subs Y | EVPol-Tax Y
37	CO2 35 | Adop Dyn | EVPol-Scrap N | EVPol-Subs N | EVPol-Tax N
38	CO2 35 | Adop Dyn | EVPol-Scrap N | EVPol-Subs Y | EVPol-Tax Y
39	CO2 35 | Adop Dyn | EVPol-Scrap Y | EVPol-Subs N | EVPol-Tax N
40	CO2 35 | Adop Dyn | EVPol-Scrap Y | EVPol-Subs Y | EVPol-Tax Y
41	CO2 35 | Adop High | EVPol-Scrap N | EVPol-Subs N | EVPol-Tax N
42	CO2 35 | Adop High | EVPol-Scrap N | EVPol-Subs Y | EVPol-Tax Y
43	CO2 35 | Adop High | EVPol-Scrap Y | EVPol-Subs N | EVPol-Tax N
44	CO2 35 | Adop High | EVPol-Scrap Y | EVPol-Subs Y | EVPol-Tax Y
45	CO2 35 | Adop Instant | EVPol-Scrap N | EVPol-Subs N | EVPol-Tax N
46	CO2 35 | Adop Instant | EVPol-Scrap N | EVPol-Subs Y | EVPol-Tax Y
47	CO2 35 | Adop Instant | EVPol-Scrap Y | EVPol-Subs N | EVPol-Tax N
48	CO2 35 | Adop Instant | EVPol-Scrap Y | EVPol-Subs Y | EVPol-Tax Y
49	CO2 40 | Adop Ref | EVPol-Scrap N | EVPol-Subs N | EVPol-Tax N
50	CO2 40 | Adop Ref | EVPol-Scrap N | EVPol-Subs Y | EVPol-Tax Y
51	CO2 40 | Adop Ref | EVPol-Scrap Y | EVPol-Subs N | EVPol-Tax N
52	CO2 40 | Adop Ref | EVPol-Scrap Y | EVPol-Subs Y | EVPol-Tax Y
53	CO2 40 | Adop Dyn | EVPol-Scrap N | EVPol-Subs N | EVPol-Tax N
54	CO2 40 | Adop Dyn | EVPol-Scrap N | EVPol-Subs Y | EVPol-Tax Y
55	CO2 40 | Adop Dyn | EVPol-Scrap Y | EVPol-Subs N | EVPol-Tax N
56	CO2 40 | Adop Dyn | EVPol-Scrap Y | EVPol-Subs Y | EVPol-Tax Y
57	CO2 40 | Adop High | EVPol-Scrap N | EVPol-Subs N | EVPol-Tax N
58	CO2 40 | Adop High | EVPol-Scrap N | EVPol-Subs Y | EVPol-Tax Y
59	CO2 40 | Adop High | EVPol-Scrap Y | EVPol-Subs N | EVPol-Tax N
60	CO2 40 | Adop High | EVPol-Scrap Y | EVPol-Subs Y | EVPol-Tax Y
61	CO2 40 | Adop Instant | EVPol-Scrap N | EVPol-Subs N | EVPol-Tax N
62	CO2 40 | Adop Instant | EVPol-Scrap N | EVPol-Subs Y | EVPol-Tax Y
63	CO2 40 | Adop Instant | EVPol-Scrap Y | EVPol-Subs N | EVPol-Tax N
64	CO2 40 | Adop Instant | EVPol-Scrap Y | EVPol-Subs Y | EVPol-Tax Y

Table 15: Scenarios nomenclature

PROJECT CONSORTIUM

SCelecTRA consortium gathered 5 partners from 3 countries (France, Germany and Austria)

http://www.thinkstep.com/

www.ifsttar.fr

http://www.kanors.com/Index.asp

https://www.eifer.kit.edu/

www.ifpen.fr

More information can be found at the following web address:

http://projet.ifpen.fr/Projet/jcms/xnt_79165/fr/scelectra

All simulation results are available to explore on

http://vedaviz.com/Portal/Playground.aspx?p=Scelectra02Jun15&g=1a3c15

and

http://vedaviz.com/Presenter/Presenter.aspx?p=Scelectra02Jun15&g=3918c6