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Contribution of light and heavy vehicles to reduction of energy demand and CO_2 emissions by 2035 in the world

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Summary

To assess changes in CO2 emissions in the world by 2035 a model projecting running fleets volumes, sales and technological mixes of light vehicles and heavy vehicles has been created. This technical note, which presents the results of the model, is produced each year to incorporate recent changes in the various markets, and to take into account those changes in terms of regulations and technology, which are most up-to-date and most plausible for the period under analysis.

For the nominal scenario, in 2035, the total share of electro mobility in light vehicle sales is estimated at around 20% worldwide. In Europe, electro mobility will account for 35% sales in 2035 (including 25% BEV and 10%PHEV).

The 2018 version of the model's major hypotheses now includes stoppage, after 2030, of sales of 100% pure diesel and petrol internal combustion engine vehicles in Europe (ICE without hybridation technologies), the future appearance of a broader range of light vehicles powered by natural gas in this geographical area or, alternatively, the incorporation of regulations on a country-by-country basis (and in particular regulations specific to light commercial vehicles (LCV)).

1 Context and motivations

Following on from the decisions of COP21, most States throughout the world have committed themselves to limiting their greenhouse gas emissions to fight climate change. In 2015 road transport (private vehicles, light commercial vehicles and heavy vehicles) are responsible for 18% of CO2 emissions, compared to 15% in 1990. This sector is therefore called upon to attain the goals defined in Paris at COP21. At European level the energy-climate package has set ambitious goals for Europe which have been used as the basis for its international commitments. In the transport field the EU has set itself the goal of 10% of energy of renewable origin in 2020, and could determine on a goal of 14% in 2030.

The energy efficiency of sold vehicles has already substantially improved (26% of efficiency gains on average in Europe per new vehicle between 2005 and 2016), due to improvements with combustion engines, to the growth and sale of new powertrains (hybrid systems and electric vehicles) and improvements with vehicles (mass, aerodynamics and rolling resistance). But, simultaneously, motor vehicle volumes and usage continue to grow, propelled by the growth of a middle class in still-emerging markets (China, South America, ASEAN, etc.), and by the ever-increasing attraction of motor vehicle models of the SUV type. Faced with increasingly demanding regulations, the Motor Vehicle Industry must therefore come up with new efficiency gains by 2035.

In 2015 and 2016 the French motor vehicle sector initiated a working programme to assess the contribution of road transport to reduction in energy demand and CO2 emissions across the world. The analysis carried out has many goals:

- Producing a panorama of energy demand for each area and type of vehicle by 2035, with an analysis of risks and opportunities in relation to the variables
- Developing a reasoned and independent view of the energy future of road transport and its impact in terms of CO2 emissions
- Pooling and coordinating the research efforts of industrial companies for future technologies in the power chain field

To undertake this study the sector contacted BIPE, a research and consultancy firm, in order to devise a rational and independent view of changing motor vehicle volumes, the speed at which vehicles are renewed, and segmentation and distribution of them for each type of energy and powertrain. Similarly, changes to the production mix of the various energies were analyzed for each area and for certain countries. It was thus possible to create a model to project total energy demand; total CO2 emissions were deduced from it.

2 Methodology and scenarios

The model takes account of 15 geographical areas comprising all the world markets and 46 market segments (7 for PC, 4 for LCV, 35 for HV). 15 powertrain are analysed: petrol and diesel combustion engines (including start/stops and micro-hybrids), all combinations of hybridation (low-voltage mild, 12V and 48V, full, plug-in, range-extender), zero-emission vehicles (electric and fuel cell), gas-powered vehicles (NGV, LPG). The study relates to the period 2017-2035 for all segments of vehicles studied (light and heavy).

The general principle of the methodology is explained in below.

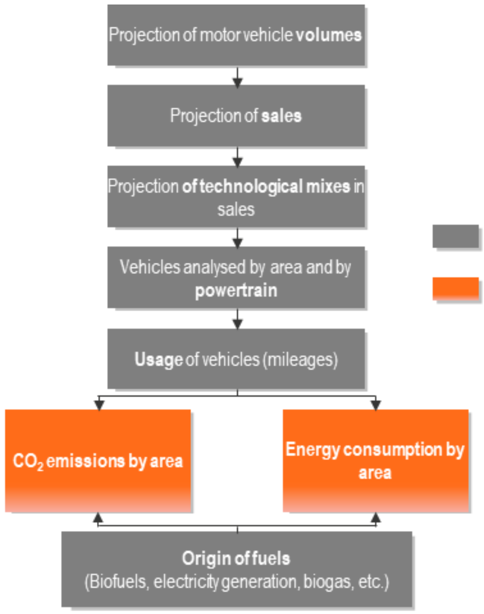

Figure 1 General outline of the projection approach

The motorisation rate (number of vehicles per 1000 inhabitants) as a function of GDP per inhabitant is an S-shaped curve which can be configured by a rate of saturation, a take-off GDP, and a take-off speed, which are specific for each area (see Figure 2). The ownership rate is very low for low GDPs per inhabitant; then from a threshold it starts to climb, and after that changes twice as fast as GDP. Its rise slows, reaching a threshold, and the rate will no longer change at the same speed as GDP, or may even decline. Due to growth hypotheses it is therefore possible to deduce the motorisation rate for each area and scenario, and therefore motor vehicle numbers by 2035. The scale of registrations and the structure of the volumes by age are then determined using a scrappage law.

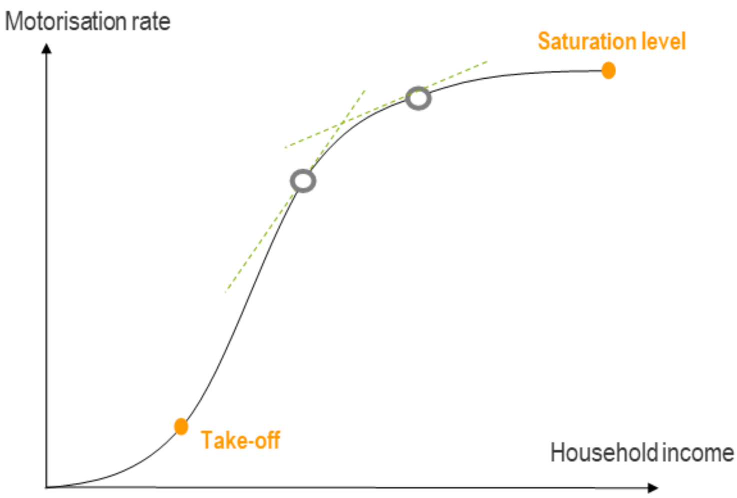

Figure 2 S-shaped curve for calculating volumes

After precise and exhaustive inventories of the costs for purchase and for usage of the various powertrains (TCO – Total Cost of Ownership), BIPE's models rely on formalising client purchase trade-offs. The models are predictive and are fed with explanatory variables (technological, fiscal, macro-economic, mobility habits, etc.) to project sales and volumes which are structured according to powertrain. From the projection concerning volumes, combined with usages (mileages) and unit consumptions, a demand for fuel and CO2 emissions is obtained.

To assess the impacts of the uncertainties relating to the context (macro-economic changes, regulations, etc.), 4 prospective scenarios were devised. Each of the scenarios makes reference to differentiated and consistent hypotheses concerning possible changes of the global environment and underlying factors of motor vehicle markets (cf. Figure 3).

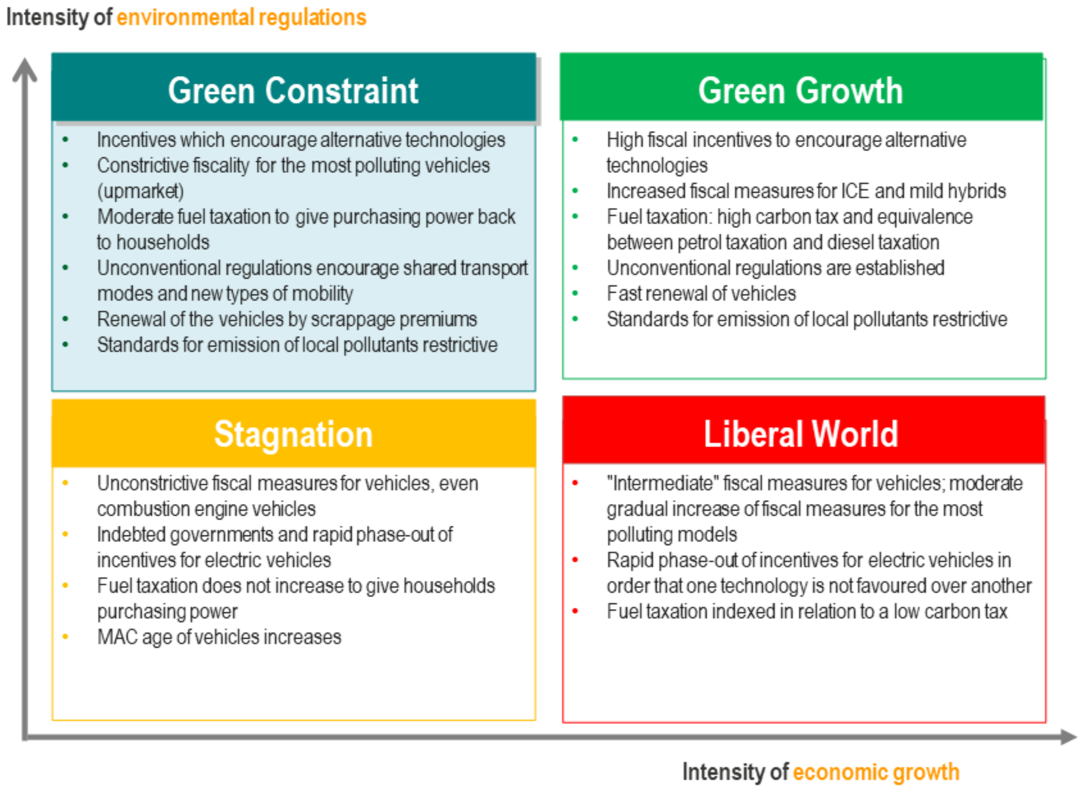

Figure 3 Projection scenarios

The results of technological mix and of total energy demand were projected in each of these scenarios, which will enable the most effective medium- and long-term measures to limit and then reduce CO2 emissions to be determined. The reference scenario is the Green Constraint scenario, with low economic growth and a high level of environmental regulation. Indeed, since the economic crisis world growth has stayed fragile (approximately 3% per year, compared to 4-5% before the crisis, with a substantial slow-down of the BRICS), and at the same time environmental conferences such as COP21 are succeeding in bringing together most of the world powers and in causing them to reach a consensus.

3 Results

3.1 Demand for mobility

Demand for mobility is an essential result of the model (cf. Figure 4 and Figure 5). In mature motor vehicle markets total numbers have reached a level of saturation (500 LV per 1000 inhabitants in Europe, 800 in the United States), which depends on the specific features of each country (e.g. urban organisation, public transport, geography), and changes to motor vehicle volumes and usages (unit mileages) are now no longer correlated with economic growth in these areas. In addition, demands for mobility (persons and goods) are subject to drastic optimisation against a background high energy price volatility.

Conversely, in the Emerging countries (e.g. China, India, Brazil and Russia) a high degree of dependency is observed between economic growth and growth of total demand for mobility. Initially, economic growth is accompanied by a sudden rise in the numbers of utility vehicles (light and heavy) which enable the industrial fabric and the economy in general to grow. The growth in incomes is then accompanied by the emergence of a middle class which purchases private vehicles.

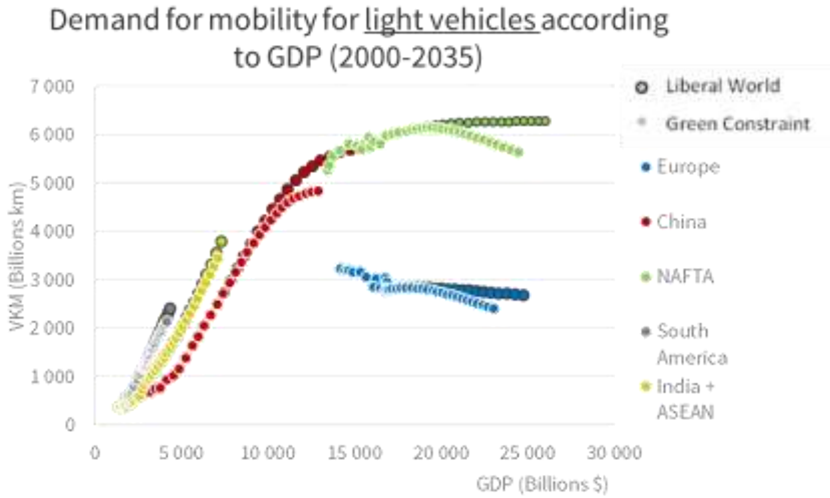

Figure 4 Demand for mobility for LV for each area in the Green Constraint and Liberal World scenarios

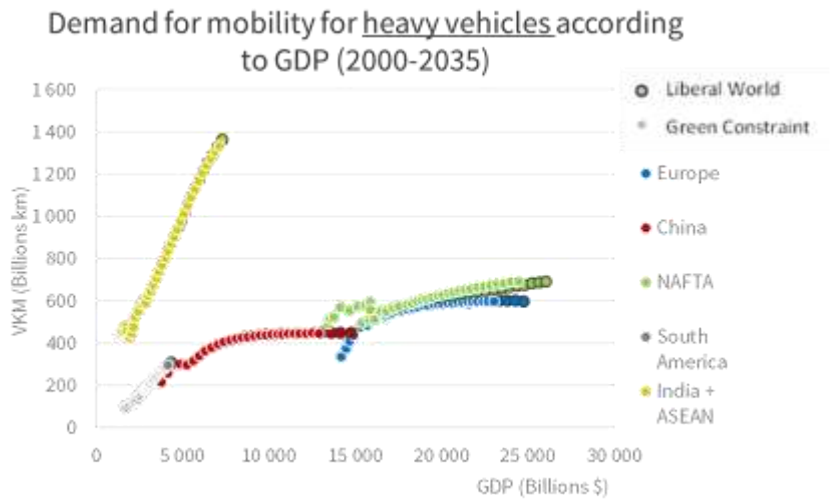

Figure 5 Demand for mobility for HV for each area in the Green Constraint and Liberal World scenarios

The scenarios are therefore highly differentiated (cf. Figure 6): in scenarios where there is strong growth the total LV (Light Vehicles) motor vehicle number is close to 2.1 billion vehicles (compared to 1.2 billion currently), with markets of over 150 million sales of new vehicles per year in 2035 (compared to 95 million in 2017); in the Stagnation and Green Constraintscenarios total world numbers are close to 1.9 billion vehicles, with a market of close to 130 million in 2035. In these scenarios world growth is highly subdued and total demand for mobility declines as a result. The impacts of new forms of mobility (e.g. car-sharing and ride-sharing) are included (reduction of motor vehicle numbers by approximately 10% by 2035), with a reduction of total numbers in the mature areas (Europe, Japan), and stable in the United States. These emission reductions are even more substantial if governmental regulations are stronger, as in the green scenarios.

Figure 6 Total number and annual sales of LV (PC & LCV) in 2035

3.2 Mix of sales of light vehicles for each technology and for each area

Table 1 **Erreur ! Source du renvoi introuvable.**shows the changes of the powertrain split in sales of new light vehicles at world level in the Green Constraint scenario by 2035.

- In this scenario the proportion of electric vehicles (e.g. BEV, hybrids) accounts for a majority of the world market by 2035. The market share of Mild 12V and 48V hybrids is thus respectively 20% and 13%, and 2% for Full hybrids. There are even nearly 8% PHEV and 12% battery electric vehicles.
- The proportion of 100% pure ICEs vehicles falls greatly, reaching 38%, 3% of which diesel, by 2035, at world level.
- Diesel (include hybrids) declines in all world areas (5% of the market in 2035 compared to 17% in 2017, and nearly 20% before "Diesel Gate"): very strict pollution reduction standards and regulations in urban areas which are penalising residual values in Europe, deregulation of prices of fuels in India, and growth of small segments in ASEAN countries.
- Gas grows significantly in Europe, increasing from less than 1% to over 10% between 2017 and 2035. However, this market share is subject to the hypothesis that 100% ICEs vehicles will cease being sold in Europe, which would not affect CNG vehicles. Over the same period it grows more moderately in certain growth markets, particularly in India, rising from 5% to nearly 10%, and at world level CNG will increase from 1 to 4%.
- As for electrification, low-hybridation engines (mild hybrids) are ahead of the pack, and can be seen as the natural development for start/stop systems. They account for 32% of the world market in 2035. Full hybrids are stable and will have 2% of the market in 18 years, due in particular to the American and Japanese markets.

- Finally, highly electrified vehicles (BEV and PHEV) are growing in areas which impose severe regulation of CO2 emissions for new vehicles (Europe, USA, China and Japan). Electromobility (BEV and PHEV) will account for 20% of sales by 2035 in the reference scenario. In total, PHEV take 8% of the market, supported by the United States and Europe, while BEV become well-established in China (20%) and Europe (24%). The latter benefit in particular from changes in regulations (e.g. policies to remove 100% ICEs vehicles in Europe by around 2030, and toughening of CO2 emissions standards). The proportion of BEV at world level reaches 12% in 2035. VE will still be limited by a number of restraints, in particular the perception by consumers of vehicle recharging times in certain geographical areas; however, these should gradually dissipate by 2035 due to positive developments in terms of autonomy, charging times and the cost of batteries.
- In Europe the anticipation of the toughening of CAFE regulations after 2025 is leading to a gradual removal of 100% petrol and diesel combustion engine vehicles, and from 2020 town centre access restrictions will be put in place for the most polluting vehicles. The effects of these two mechanisms are an acceleration of declines of market shares of diesel for the area, and increased interest in gas technologies for LV segments which could satisfy consumers who are most sensitive to purchase prices, and whose usage patterns are less compatible with BEV.
- The results of the market shares of CNG, which are 11.7% in 2035 in Europe, are obtained by considering that this technology would not be affected by future restrictions for combustion engine vehicles.

Technology	World		China		Europe		NAFTA		India	
	2017	2035	2017	2035	2017	2035	2017	2035	2017	2035
Gasoline 100% Combustion Engine	76.3%	35.8%	87.4%	29.9%	45.6%	0.0%	92.0%	25.6%	51.0%	50.7%
Electric Gasoline*	3.4%	41.4%	3.0%	47.0%	3.0%	57.2%	4.4%	60.3%	0.0%	24.1%
Diesel 100% Combustion Engine	17.2%	2.5%	8.0%	0.8%	49.8%	0.0%	1.5%	2.3%	43.1%	3.2%
Electric Diesel*	0.3%	2.6%	0.4%	2.2%	0.1%	5.4%	0.2%	3.4%	0.0%	2.4%
CNG	1.2%	4.0%	0.0%	0.0%	0.5%	11.7%	0.6%	0.5%	5.2%	8.7%
LPG	0.9%	1.7%	0.0%	0.0%	0.6%	1.1%	0.5%	0.2%	0.5%	1.9%
BEV	0.6%	11.9%	1.2%	20.1%	0.5%	24.4%	0.8%	7.6%	0.0%	9.1%
Hydrogen	0.0%	0.1%	0.0%	0.0%	0.0%	0.2%	0.0%	0.1%	0.0%	0.1%

* Including low hybridation technologies (mild 12V and 48V hybrids), full hybrids and plug-in hybrids

3.3 Energy and CO_2 emissions efficiency: “from the well to the wheel”

In the Stagnation and Liberal World scenarios world energy demand in 2035 increases respectively by 13% and 17% (basis 2017, cf. Figure 7). In the Green Growth and Green Constraint scenarios demand declines by 3%. In terms of CO2 emissions relating to energy use by road transport (cf. Figure 8, excluding figures for vehicle production), these increase by over 10% in the Stagnation and Liberal World scenarios, stabilise in the Green Constraint scenario and decline by 3% in the Green Growth scenario. The introduction of electric vehicles and the growth of gas-powered vehicles enable the emissions curve to be levelled off in the green scenarios, but do not compensate sufficiently for the large increase in world vehicle numbers in the other two scenarios. This reflects 2 opposing effects: high growth of motor vehicle numbers in Emerging countries, compensated partially by efforts made in relation to efficiency of combustion engine vehicles and the introduction of low-emission vehicles. However, this type of progress takes time to become widely adopted, and to modify consumption, given that a given pool of vehicles is renewed only every 17 years on average. It is therefore to be expected that the substantial efforts made by the manufacturers from 2000 onwards should only bear fruit several years later.

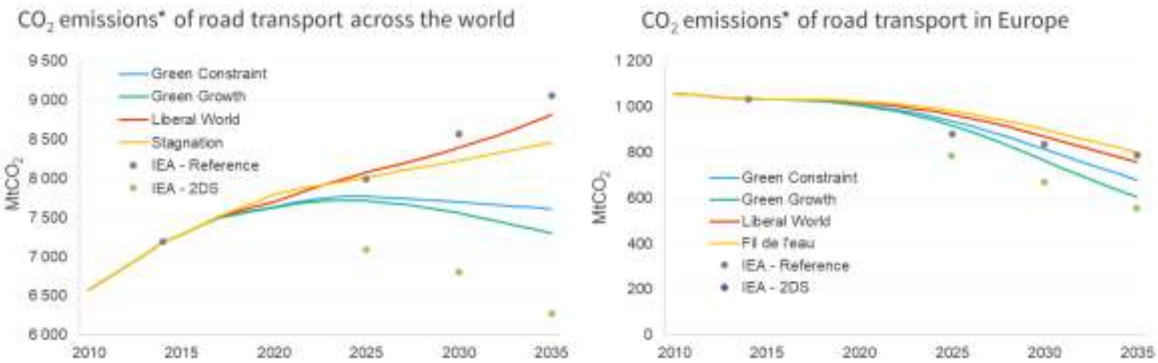

Figure 7 CO_2 emissions of road transport throughout the world and in Europe

(excluding figures for vehicle production)*

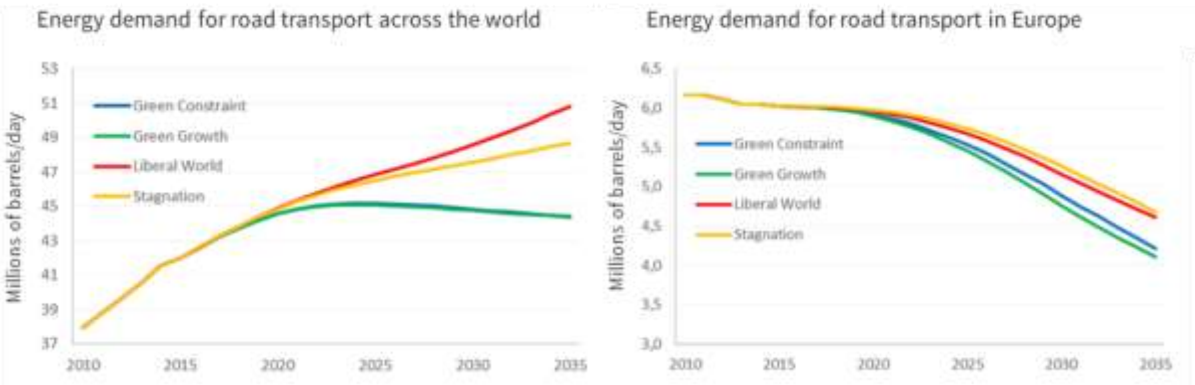

Figure 8 Road transport energy demand in the world and in Europe

The finding for world CO2 emissions is differentiated by category of vehicles (cf. Figure 9):

- Rise in emissions for heavy vehicles (17-19% growth in 2035 compared to 2017), due to an increasing demand for mobility,
- In the "green" scenarios emissions for light vehicles (LV) decline (between 8% for Green Constraint and 13% for Green Growth). LV emissions increase by 7% to 15% respectively in the Stagnation and Liberal World scenarios.

In Europe CO2 emissions from road transport fall in the four scenarios under study (from -23% to -40% over the period 2017-2035, cf. Figure 8). In this area the maturity of the total pool of LV and the great potential for electrification of LV and HV enable the increased demand for mobility arising from HV to be compensated, and therefore a more than significant improvement of road transport sector emissions.

The differentiation of the effects presented in the following figures allows comparisons of the figures for gains of CO2 emissions between two years of a given scenario, or between two scenarios for a given year. The contribution to changes of emissions for four types of effect can therefore be seen below:

- Changes in vehicle mixes: The effect of changing volumes and mileages is measured for a given vehicle mix
- ICE and electrification efficiency: For a set of vehicles of the same size and the same usages, the combined effect of improving unit consumption of vehicles is measured, together with the change of mix by power train.

- Incorporation of biofuels: For a given energy demand the effect greater or lesser incorporation of biofuels is measured
- Carbon intensity effect: For a given fuel consumption the effect of changing their carbon content is measured (e.g. zero emission of the energy mix relating to electricity generation)

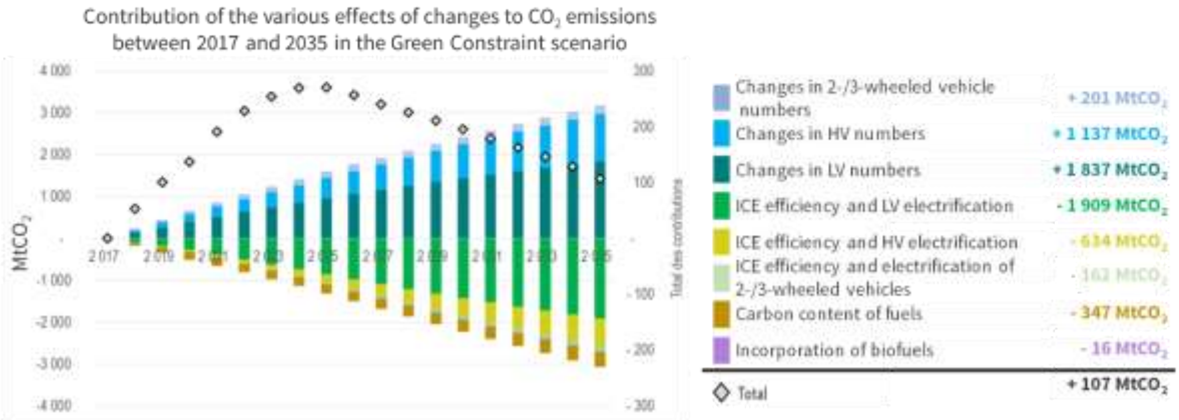

Figure 9 Contribution of the various effects on CO_2 emissions relating to road transport between 2017 and 2035 in the Green Constraint scenario

Biofuels (1G+2G) account for 10% of world fuel consumption in energy terms in 2035, compared to 6% in 2017 (cf. Appendix 10).

Thus, despite the strong emergence of a middle class in certain countries, which is tending to increase vehicle numbers, the efforts made by the entire value chain for LV bears fruit for both "green" scenarios. The significant improvements in combustion engine consumption, coupled with changes to the powertrain mix overall, counterbalance the growth of light vehicle numbers (cf. Figure 10), which is not the case for the Liberal World and Stagnation scenarios.

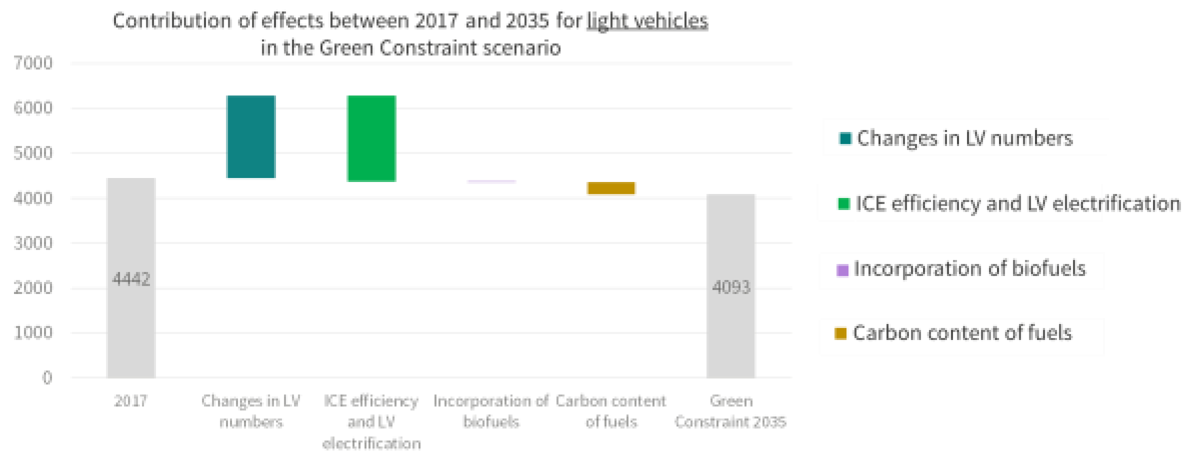

Figure 10 Contribution of the various effects on CO2 emissions for light vehicles between 2017 and 2035 in the Green Constraint scenario

Thus, in OECD areas, where vehicle numbers are relatively stable, electrification of vehicles and improved efficiency of combustion engines are the main mechanisms for reducing emissions.

This is not the case with heavy vehicles, where the less significant progress made with efficiency of new vehicles does not enable to high rise in vehicle numbers to be compensated (cf. Figure 11). Indeed, unlike LV, where technological progress enables to emissions to be reduced despite the growth in numbers, gains made with HV enable only some 56% of the growth of emissions relating to the increased number of HV in use to be absorbed, despite a strong emergence of electric in certain HV segments such as buses.

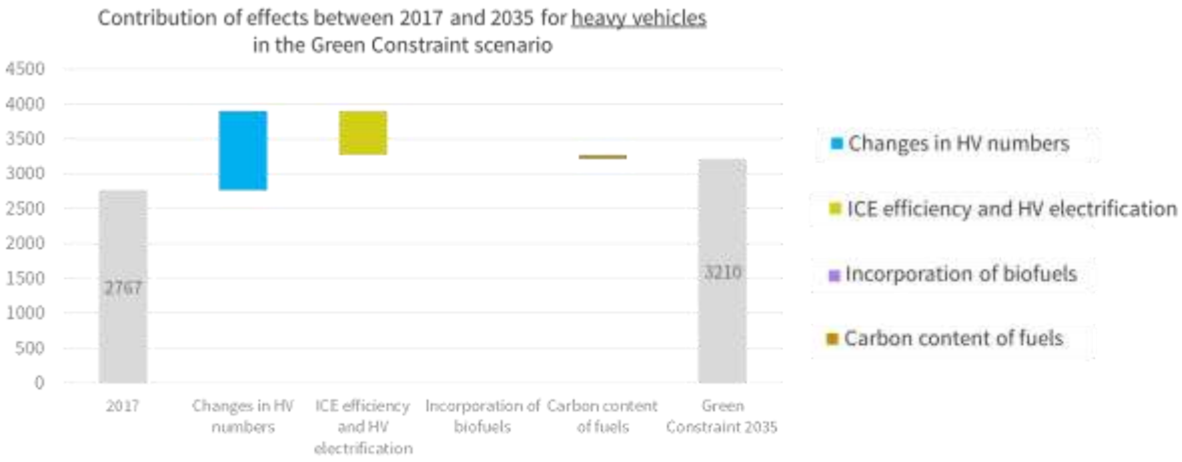

Figure 11 Contribution of the various effects on CO_2 emissions for heavy vehicles between 2017 and 2035 in the Green Constraint scenario

In Developing and Emerging countries the increased vehicle numbers are not compensated, but at world level the major efforts made in Europe and North America enable the global emissions curve to level off, as the patterns of growth of LV numbers are weakening in China (cf. Figure 12) in both "green" scenarios. Emission reductions are to be found in the OECD countries, which now account for 49% of total emissions. The increase in numbers allowed by economic growth in Emerging countries explains the increase in emissions between 2017 and 2035. The latter will be the sources of nearly 60% of global CO2 emissions in 2035.

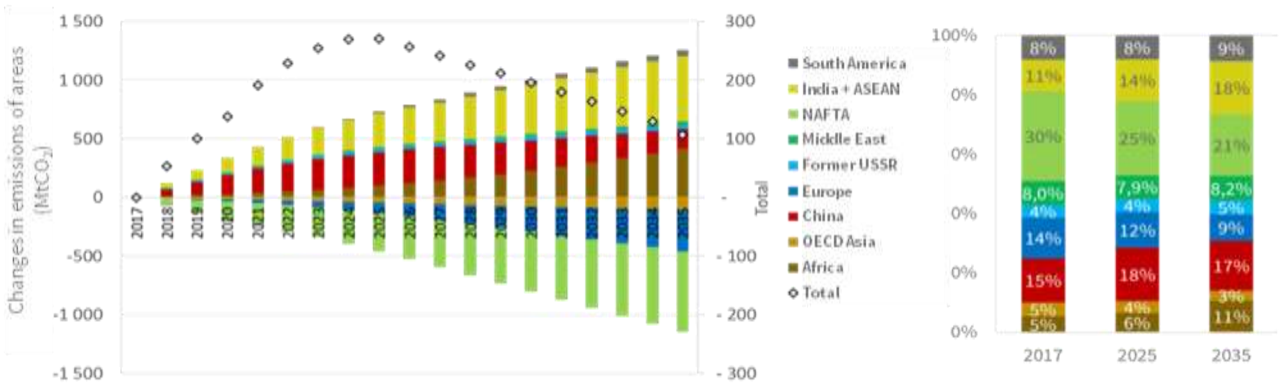

Figure 12 Changes in CO_2 emissions relating to road transport for each area between 2017 and 2035 and proportion of the area in CO_2 emissions in the Green Constraint scenario

3.4 Changes of CO2 emissions by 2035

As shown in the previous part, improving the energy efficiency of engines and promoting electric powertrains are some of the principal measures to reduce CO2 emissions relating to transport. This process has been established for light vehicles. In respect of heavy vehicles, city buses, for example, are also seeing major changes of the power train mix in sales, which are tending towards all-electric across the world.

The effects of policies established in the medium term to reduce CO2 emissions can also be measured by comparing two scenarios with equal growth, one "green" and one not "green". In both scenarios the impact of the manufacturers' efforts to reduce consumption of combustion engines is the same, and only the rate of electrification changes the results substantially over the period 2017 – 2035.

In 2035 reduced carbon intensity of alternative energy sources (biofuel, electricity, biomethane and hydrogen), the development of new types of mobility (e.g. car-sharing and ride-sharing), and access restriction measures are much more effective in lowering the emissions curve than toughening of CO2emissions standards (cf. Figure 13).

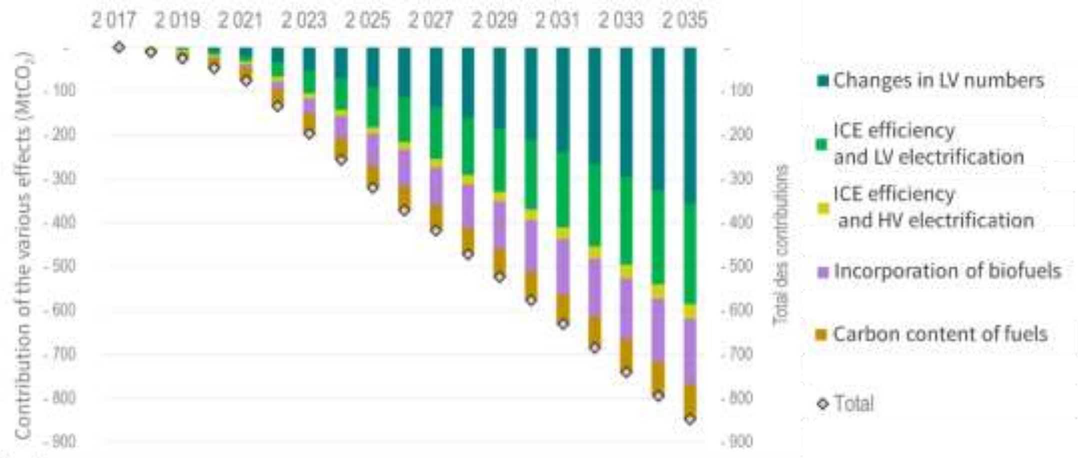

Figure 13 Contribution difference of the various effects to reduction of CO_2 emissions relating to road transport between 2017 and 2035 in the Green Constraint and Stagnation scenarios

32% of the difference in emissions of light vehicles between the Stagnation scenario and the Green Constraint scenario, i.e. a difference of 229 tonnes, derives from differences in penetration of more efficient (low hybridation) and highly electrified vehicles (cf. Figure 14).

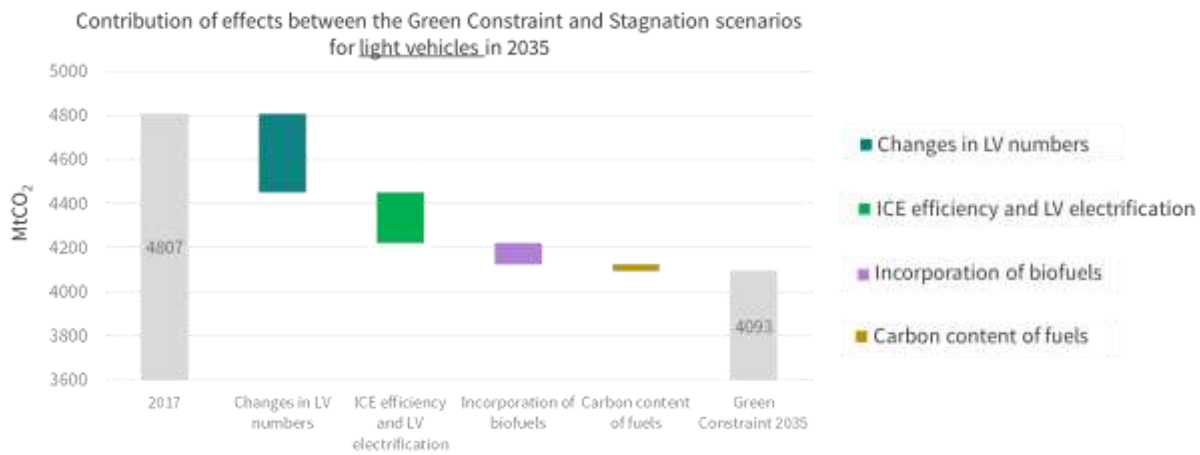

Figure 14 Comparison of CO_2 emissions of road transport of the Green Constraint and Stagnation scenarios in 2035, by type of effect

Electric technologies will be the main contributors to reduction of CO2 emissions over the period 2030-2040. These technologies have sufficiently high market shares only in scenarios in which incentive mechanisms are maintained or established between 2020 and 2030. In addition, the establishment of very severe CAFE standards after 2025 would make the attainment of these targets highly dependent on the short- and medium-term development of a recharging infrastructure which is capable of getting the market to accept vehicles with very low emissions rapidly, and on a large scale. This would also presuppose significant breakthroughs in terms of research and development relating to battery technologies, to make electrification economically accessible.

4 Conclusions of the study

1. A downward trend of CO2 emissions in the road transport sector at world level can be achieved, firstly, due to increased electrification of power chains of light vehicles (LV), and secondly due the expected

slow-down of the patterns of growth of LV vehicles in China. After 2023 these two effects combined will enable the effect of the substantial increase of volumes of LV and Heavy Vehicles (HV) at world level to be compensated.

2. Over the period 2017-2035 Europe and North America are responsible for 90% of the reduction of CO2 emissions, and Africa and Asia for most of the increase.

3. Electric technologies will be the main contributors to reduction of CO2 emissions after 2025. These technologies have sufficiently high market shares only in scenarios in which incentive mechanisms are maintained or established between 2020 and 2035.

4. In 2035 reduced carbon intensity of alternative energy sources (biofuel, electricity, biomethane and hydrogen), the development of new types of mobility (e.g. car-sharing and ride-sharing), access restriction measures and the gradual cessation of sales of 100% combustion engine vehicles in Europe are much more effective in lowering the emissions curve than toughening of CO2 emissions standards.

5. In 2030 and 2035 the proportion of electromobility of light vehicles is estimated, respectively, at 17% and 20% of BEV and PHEV at world level (including 7% and 8% of PHEV) and at 29% and 35% in Europe (including 9% and 10% of PHEV in 2030 and 2035).

Authors

Jean-Luc Brossard Ecole des Mines (57), started his career in Matra Automobile in 1986. He was successively head of the Testing Department, Project Manager and Technical Director. In 2003, he joined Ferrari as Coupe-Spider Project Manager, and Maserati in 2005 as Technical Director and Product Development Director. In 2007, he became Vice-President Engineering of Pininfarina. In late 2008, he returned to France to integrate PSA Peugeot Citroen, as Advanced Engineering Director and Innovations Manager. Since January 2015, he assumes the role of R & D Managing Director at the PFA (Automotive Industry Platform) and Program Director for the Low Environmental Footprint Vehicle.