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THE ELECTRIC HIGHWAY: AN INNOVATIVE PROJECT TO ABATE CO_2 EMISSIONS IN HEAVY-GOODS TRANSPORT

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Summary

Carbone 4 has studied the economic and environmental relevance of an innovative option to electrify long-distance heavy-goods transport: “electric highways”. They consist in a fleet of hybrid heavy-goods vehicles that can operate with distributed electricity while on a highway. The project could be profitable in the current economic conditions on high-traffic roads. A more ambitious deployment at a national level would allow significant reductions in CO_2 emissions. However such a deployment could not be done without a public support, that seems moderate as a abatement cost of approx. 100 € / tCO_2.

Keywords: dynamic charging, environment, heavy-duty, infrastructure, PHEV (plug in hybrid electric vehicle)

1 Context and presentation of electric highway concept

As recently stressed during the COP21, the case is made for the necessity to shift towards a low-carbon economy, by reducing greenhouse gases (GHG) emissions and fossil-fuels dependence in all economic sectors. Road transport (people and goods altogether), highly dependent on fossil fuels, is primarily concerned: it accounts for 30% of energy consumption and GHG emissions in France [1].

About half of these GHG emissions are due to passenger transport, for which various types of low-carbon alternatives appear (e.g. modal shift, hybrid or full-electric vehicles). The other half is due to transport of goods, one of the major components of our economy, and among which road freight is predominant (around 85% of modal share) because it is flexible, relatively cheap and it can cover long distances without reloading. Apart from modal shift from road to train, low-carbon solutions for freight capture less media attention, but they progressively take place in short-range and urban freight (e.g. electrification, gas, optimization of delivery rounds).

For long-range and heavy-goods transport, there are fewer low-carbon alternatives, rail freight being capital-intensive and well suited only for bulk freight of heavy industries (energy, steel, chemistry, cereals). There is much at stake: GHG emissions of heavy goods vehicles (HGVs) are approximately 5% of domestic GHG emissions and 3-4% of French energy consumption [1]. It can seem low, but considering that heavy goods vehicles represent only 5% of total road traffic, that is a very concentrated component of domestic emissions.

Full-electric heavy-goods vehicles are not likely to be deployed in the short term. In the current and foreseeable state of technologies, batteries cannot provide sufficient levels of autonomy to compete with liquid fuels. In addition, on-board storage with batteries implies significant additional weight and size, detrimental to the value of the cargo.

Carbone 4, on behalf of major stakeholders from road transport and energy sectors, studied an innovative option to electrify long-distance heavy-goods transport without massive on-board storage: "electric highways".

They consist in the setting up of a fleet of hybrid heavy-goods vehicles that can operate with distributed electricity while on a highway. Such hybrid vehicles would have no or little batteries, but would get their power from a dynamic charging infrastructure, while the lane would remain open to "conventional" traffic. These hybrid trucks would switch to a conventional internal combustion engine when outside the highway to cover first and last kilometres of their journey.

Such projects seem a good way to reduce the environmental impact of road freight transport while taking advantage of existing infrastructure (highways) with a relatively low need for adaptation from the actors of road freight transport (minimum training to adapt driving, no need to change vehicle when entering or leaving the highway, etc.)

Different forms of technology exist to distribute electricity along highways:

- Contact distribution from overhead contact lines. It requires installing pantographs on HGVs. This technology, inspired from the existing systems available for trains and tramways, is under active research and development by the German firm SIEMENS under the brand name of "eHighway";
- Contact distribution from rails built into the surface of the road. An electricity collector, "pick-up", is fixated at the bottom of the truck and slides along the power rail. This technology is under research and development by the French firm ASLTOM under the brand name of "APS", and by the Swedish company Elways;
- Induction distribution, through magnetic transfer between coils embedded in the road and a coil integrated into the truck. This technology had been under research and development, for instance by the Canadian firm BOMBARDIER.

Carbone 4 has studied the relevance of electric highways from an economic and climate perspectives, though during the study interviews were conducted with experts within different industries and among various business areas to assess if there were major caveat to limit the potential of these technologies from a technical perspective (e.g.: highway operations and maintenance, electricity transmissions). It turns out that at first glance these technologies of electricity distribution can all be used viably on existing highways, and they do not imply additional constraints for the electric grid for the vast majority of the highways network. Of course construction and maintenance costs, operational and physical constraints differ among these technologic options.

2 Methodology

2.1 Model overview

To evaluate the economic relevance of electric highway projects, we have modelled the cash flows for two major stakeholders:

- A SPV, Special-Purpose Vehicle: a dedicated company that builds and operates the additional infrastructure to distribute electricity along the highway. For overhead-wire technology, the SPV would need to invest roughly 1.5 million euros per kilometre of highway for both ways of circulation (taking into account physical connexion to the electric grid). This is the value that was considered to calibrate the model. The initial investments of construction and the operational costs are to be paid back by tolls paid by the hybrid trucks that would come on top of the usual toll of the highway. Such a SPV can be a totally independent company, or bound to the highway concession company;

- Road carriers: with hybrid vehicles, road carriers have to pay an extra cost for detaining the truck through leasing, and the additional toll while on the highway, but they save money by running on electricity instead of gasoil. Additional costs of hybrid HGVs is assumed to be about half the price of conventional HGVs.

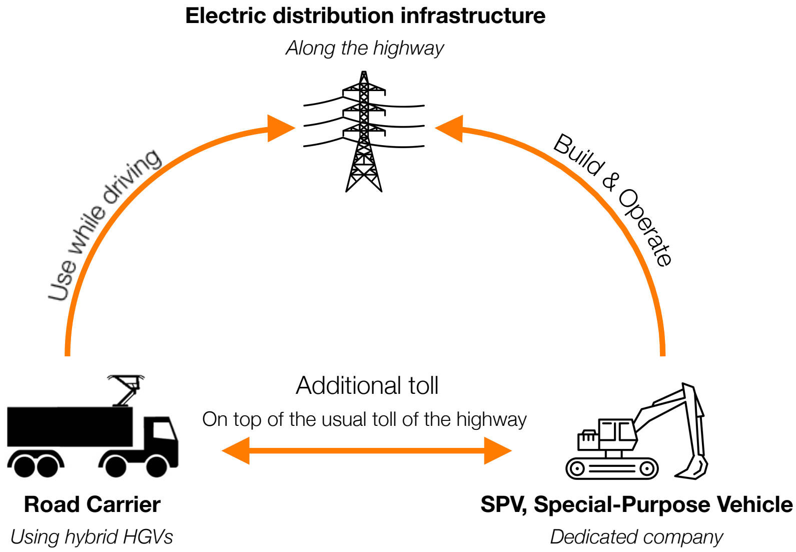

Figure1: Overview of the model considering two types of actors linked by the infrastructure

Since the infrastructure costs is split upon the users, through the intermediation of the SPV, the more carriers convert to hybrid HGVs, the cheaper the additional toll. Thus the incentive for road carriers has to be strong enough to impulse massive conversion; in the model, we assume that conversion occurs if it generates profits for road carriers from year one. Given the distribution of distances that carriers travel on a highway, the necessity of economic profit translates into a maximum portion of the highway flows that can be converted to hybrid HGVs. This potential of conversion is supposed to be reached in 6 years after the construction of the electric distribution infrastructure, which corresponds to the average owning period of a HGV for long-distance road carriers.

Regarding the SPV, we have assumed that the profitability constraint is a positive net present value of free cash flows generated by the project, over a twenty-year period, at a 4.5% p.a. discount rate above inflation.

2.2 Main hypotheses regarding major parameters in the central scenario

The economic viability is assessed with cautious hypotheses on exogenous parameters:

- Constant price of gasoil for road carriers at € 1.00 per litre, which is a conservative hypothesis and a cautious assumption given the uncertainty on future oil prices and tax levels;
- Increasing electricity price from € 80 to € 130 per MWh (in 20 years), which is robust with recent trends in price for French industry consumers from 2010 to 2014 [2];
- 1.5% p.a. increase of HGV traffic, which corresponds to the compound annual growth rate of HGV traffic on highways from 2009 to 2015 [3];
- Future efficiency gains of energy consumption of HGV limited to the prolongation of historical trends: -1% p.a. of unitary consumption of conventional HGV, in the trend of the evolution from 2007 to 2014 [4]. Hybrid HGVs are assumed to improve efficiency quicker: -1.3% p.a.

3 Results

3.1 Electric highways are profitable on high-traffic roads

With cautious hypotheses on exogenous parameters, electric highway projects' viability is reached on highways with high traffic if at least one of these conditions is met:

- if the price of diesel goes up to € 1.15 per litre;
- if freight operators adapt their courses to drive dedicated travels on electric highways.

Ceteris paribus, € 1.15 per litre of diesel corresponds to an oil price of $ 80 per barrel by 2020 and beyond, which is a prediction commonly used in scenarios of the International Energy Agency for instance. In such conditions, the projects are profitable for highways with high flow rates without any special adaptation of flows by road carriers.

In order to achieve significant impacts on CO_2 emissions, we have investigated the implementation of electric highways everywhere as soon as there are more than 5,000 heavy-duty vehicles per day. It means that one third of the total highway network would be equipped with electric distribution. For such an ambitious deployment, the project would be profitable if both of the previous conditions are met: € 1.15 per litre of diesel and an adaptation of courses by road carriers.

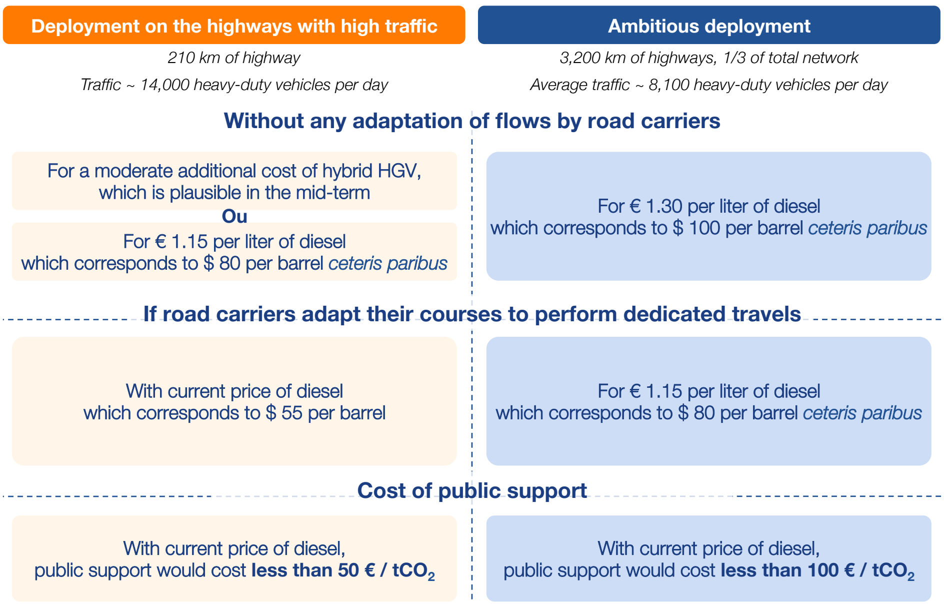

Figure2: Domains of economic relevance for two types of deployment

3.2 Cost-effectiveness to tackle climate change

In the case of an ambitious deployment over one third of the highway network, and with conservative assumptions (current price of diesel and no adaption of routes by road carriers), the "global SPV" (covering all the eligible highways) would generate a negative present value of approximately € 3 Bn over the 20-year period (the costs of initial investment – around € 5 Bn – are partially, but not totally, compensated for). If public authorities covered the losses of the project, on behalf of its positive externalities (mainly reduction of CO_2 emissions by 30 $MtCO_2$ over the twenty-year period, but also reduction of noise, fine particles and NOx pollution), it would represent a subsidy of roughly € 100 per avoided ton of CO_2. This figure is in the low range of the bracket when compared to costs of other mitigation measures, such as subsidies to renewable electricity (from € 100 to 4,000 per avoided ton of CO_2), or the implicit cost of strengthening efficiency requirements on new buildings (from € 500 to 10,000 per avoided ton of CO_2).

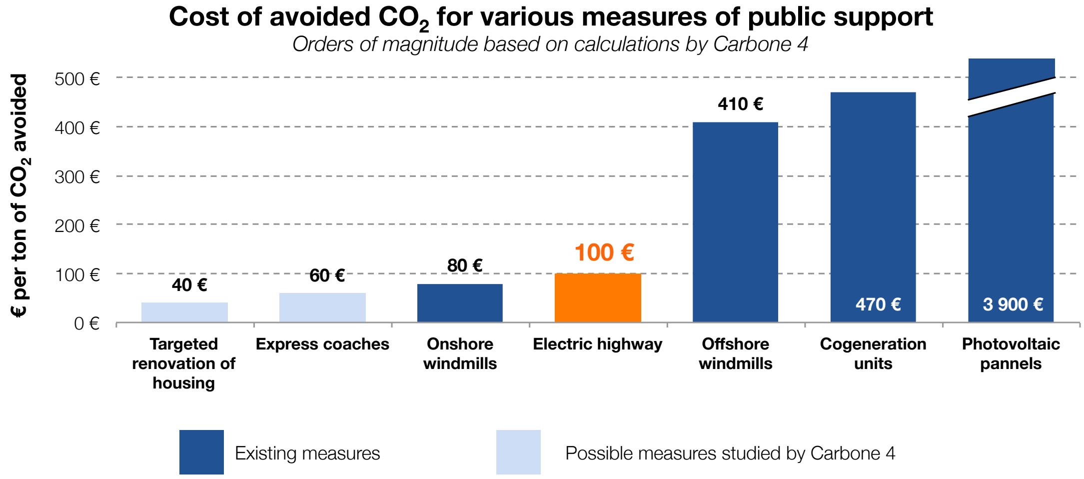

Figure3: Mitigation costs of several measures in France [5]

In other words, the project is cost-effective in terms of cost per ton of CO_2 avoided, relatively to other measures that are already implemented in France.

Such a project also has a positive impact on the country's trade balance, through the saving of oil imports, therefore resulting in a positive macroeconomic impact, which legitimates the initial investment. At current value of oil price, the project would save € 5 Bn on the French trade balance over the twenty-year period.

Finally, such a project would profit to road carriers since it is a prerequisite in the model that conversion to hybrid occurs only if it results in net savings. Thus, the electrification of highways with more than 5,000 heavy-duty vehicles per day would alleviate huge economic constraints on the sector by generating a net present value of € 1 Bn savings for road carriers.

4 Conclusion

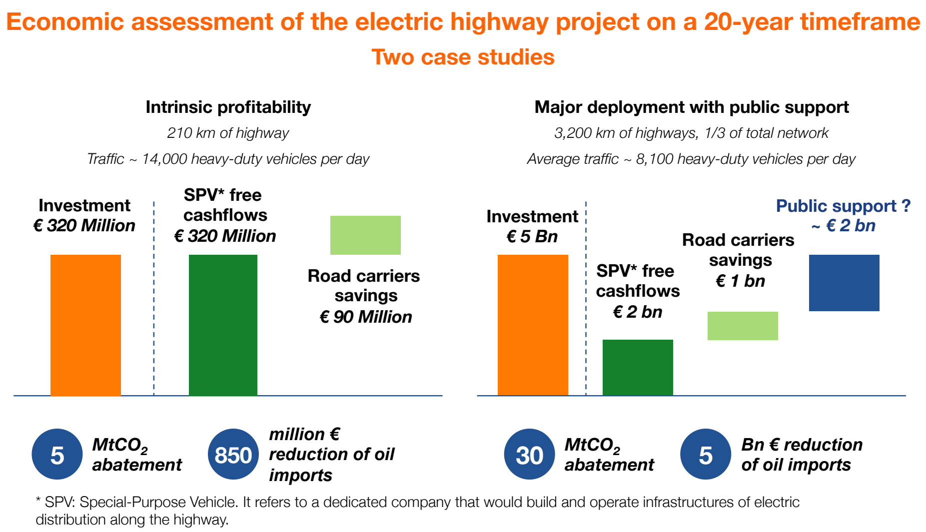

Figure4: Economic and climate assessment for two types of deployment

Electric highways deserve public authorities' deep consideration (local authorities, governments and European Union): in some cases of high-traffic highways and provided carriers adapt their courses, the profitability of the electric highway is reached in the current market conditions, but to have a significant impact on CO_2 emissions, a financial support of € 3 Bn would allow abating cost-effectively a large amount of CO_2, while generating macroeconomic positive externalities in the meantime. It is worth noting that

€ 3 Bn is comparable to the annual investment in the total rail network in France, or similar to the amount of the recently launched recovery plan for the highways in France (“Plan de Relance Autoroutier” that began in 2015). The projects could be supported in different manners, other than through direct economic assistance to stakeholders: some of them are given in the following section.

The implementation of projects on the most frequented highways would result in:

- € 5 Bn reduction of oil imports at current value of oil price;
- The alleviation of economic constraints by generating savings worth € 1 Bn for road carriers at present value;
- The abatement of 30 MtCO_2 over 20 years at a cost of € 100 per avoided ton of CO_2;
- Other positive impacts on environment such as reduction of noise, fine particles and NOx pollution.

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- And a major truck-manufacturer in Europe.

References

[1] Analysis by Carbone 4 based on data from CCFA, CITEPA and SOeS

[2] IEA, *Electricity information*, 2015

[3] According to ASFA, Association des Sociétés Françaises d’Autoroute

[4] CGDD, *Accounts of the Nation’s transport*, 2015

[5] Carbone 4, *4ème Lettre du Carbone - L'État au secours de la décarbonation de l'économie : combien ça coûte ?,* 2016, https://bit.ly/2HyKB7b

Authors

A graduate of École Polytechnique and a Master of Economics from CEA and IFP-School specializing in the energy and climate sectors, Aurélien has been working at Carbone 4 for three years. Aurélien is a member of the Mobility practice within the firm. He carried out several technico-economic forward-looking studies, in particular in the field of electric vehicles. Expert in French public energy policies, Aurélien also conducts studies about the energy system, across all sectors, to evaluate the efficiency of various energy transition measures. Before joining Carbone 4, Aurélien worked for one year in The Shift Project, a think-tank on the energy transition. He has conducted forward-looking studies with full modeling of the energy system. He has also designed a serious game for economic policymakers, based on European energy infrastructures.