Photovoltaics, Buildings and Electric Mobility: What Synergies?

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Introduction

Based both upon real and statistical behaviors' data [1], evaluations were carried out on the technical, economic and environmental feasibility and advantages of the innovation which consists in creating a synergy between the building and the transport of people. For the first two case studies, the photovoltaic installation covers all of the annual electricity requirements, for the third case, we take into account the available roof areas. A first case modeled the interactions between consumption of a corporate building, photovoltaic production and recharging of 20 Twizy electric vehicles made available to employees of the CEA Grenoble site. A second case modeled a fleet of car-sharing vehicles deployed by the company Clem', without interaction with a building. These first two cases also analyzed the technical and economic valuation associated with primary frequency adjustment (vehicule-to-grid services). Finally, a third case modeled the French residential park: characteristics of buildings, equipment, socioeconomics of occupants, cars. Three EVs recharging strategies have been identified: average behavior (upon returning home), smart behavior, and based on market prices. The environmental benefit was assessed too.

Results

SmartCharging for a corporate fleet and a carsharing fleet

In Europe, France is responsible for 700 MW network management as soon as frequency deviates from 50Hz due to excess production or consumption. This primary frequency reserve must be available in a few seconds. An aggregator will be responsible for optimizing local and global systems. The exchanges were from the network to the battery, and vice versa.

In the case of the corporate fleet, each Twizy is connected to its charging point from 8 p.m. to 5 a.m. and on weekends, and constantly exchanges with the aggregator thanks to its specific characteristics and constraints.

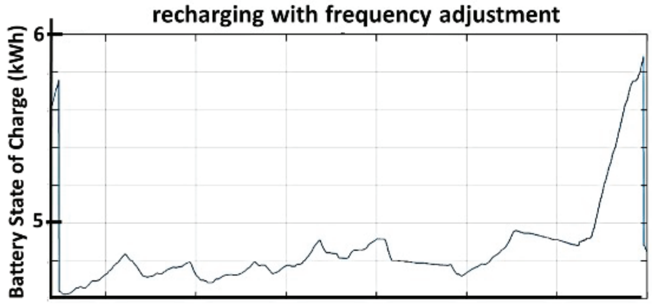

Fig.1: Actual realization of the states of charge for a given EV

For the entire fleet of 20 Twizys, the model gives an annual remuneration ranging from € 15 to € 150 per vehicle. For the car-sharing fleet, the monthly revenues for the average of the most representative stations in eastern Paris are higher, around € 60 / month per station and vehicle. The difference is mainly related to the lower power of the terminal for the Twizy, and the lower capacity of its battery (6.1 kWh against 24 kWh).

Refilling Stations	Average Monthly Income (Euro)	Number of Yearly Bookings
Bienvenu	57.87	336
Bussy RER	63.92	238
Montevrain	66.14	174
Einstein	65.80	142
CSTB	66.23	95
Galilee	64.42	138

Tab. 1: Average annual monthly income per station and vehicle for the car-sharing fleet

Assessment of the TCO associated with each of the cases studied

The TCOs of photovoltaic installations connected or not to the network have been calculated with an hourly basis dedicated tool, as well as those of the modes of mobility: EVs (electric vehicles), TVs (thermal vehicles), as well as fuel cell electric vehicles (EV H2) and hydrogen + battery range-extender vehicles (EV-Re H2) [2]. We took into account subsidies for the purchase of EVs and the installation of systems, as well as the electricity buy-back tariffs, and we characterized self-consumption.

For the corporate fleet case 1, according to 2015 – 2017 ADEME's PV cost assumptions [3], the average cost of electricity from the PV + grid system is significantly higher than using the grid alone. But there are margins: R&D (recent significant progress), organization of the system (curtailment) and discount rate (the financial cost of capital represents 50% of the total cost). We reach a self-consumption rate of 48%. The cost of grid connecting when using PV for the sole purpose of recharging EVs represents the major part of the cost of electricity (little energy in total, a lot of power demand). Thus, the synergy [Building + VE] is

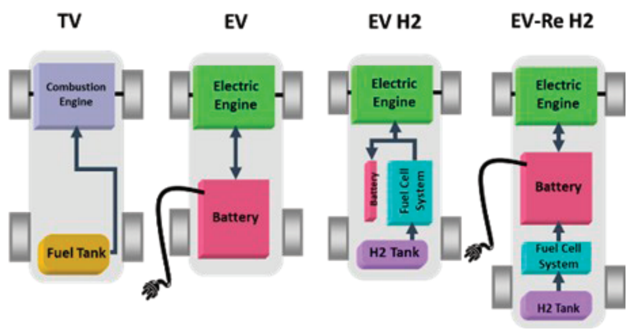

Fig.2: Vehicles studied

valuable, more precisely as long as the use of EV leads to less or equal power than the building one.

The full cost per km of battery EVs is the lowest, slightly lower than hydrogen Evs: 0.643€/km vs. 0.654€/km. It is however much better than that of the TV. The impact of the price of electricity, PV or network, is negligible in the TCO.

In case 2 of the car-sharing fleet, we observe low rates of self-consumption: from 13 to 21%, because there is a real gap between PV production and the need for EV recharging, and the network satisfies the electricity consumption peaks. As the installation is small and considering the assumptions done, the cost with PV system remains higher (*196€/MWh)* than that of the grid alone *(121€/MWh)*, including with governmental incentives which are useful but do not promote self-consumption. For such an installation, the total cost of the installed PV should reach 1.57 €/Wp to reach the network parity, a value that can be achieved in the short term by the sole effect of the R&D and financial margin (discount rate 0%).

In a similar way to case 1, the cost of electric power supply for EVs, with or without PV, suffers from a very low rate of use of the grid electricity to which the installation subscribes: disproportionate connection compared to the energy consumed. Such an EV power supply system should be connected to a quite different demand, for example, a building for professional or domestic use (see case 3). The very high underuse of vehicles leads to a very high cost per km for each solution, and places the TV in the lead. EVs, with battery and range extender, again become the least expensive when the annual mileage regains the values of conventional rentals, the purely hydrogen electric vehicle being the least attractive today (purchase costs still too high).

Case 3 differs from the other two in one major point: we are in the prospective, at the level of individuals, both of the deployment of PV solar energy, but also, in coupled mode, of individual electric mobility.

The overall French housing energy coverage reaches 93.5% with the PV, and the self-consumption rate stands at 42.2% in the event of a recharging strategy upon returning home (average behavior). The EV recharging situation based on market prices drops the self-consumption rate to 34%, while this value reaches 52% in the case of smart behavior («Local optimum»).

The cost of electricity is always in favor of PV (145€/MWh vs. 160€/MWh), and the public support does not value self-consumption resale. The latter can be reduced by a factor of 2 if the cost of the installed PV goes from 2.86 to 2.25 €/Wp, a completely reasonable development, with a system with PV cost equal to that of the network alone. The combined use of PV for the building and EV systematically leads to an increase in profitability. The accumulation of Building + EV recharging slightly increases the maximum power of connection to the network and we can see once again the advantage of recharging EVs in «local optimum» mode, as well than to associate buildings and EVs. In addition, in the event of a PV surplus sale to the network, a reasonable PV cost progress makes the State aid no longer necessary: 2.12 €/Wp (installed) instead of 2.86 €/Wp, which is achievable in the short term.

Regarding actual mobility and for the next decades, the EV is already competitive compared to the TV, despite a much higher CAPEX, with a bonus of € 6,000 and thanks to the very low cost of its «fuel» (electricity): ca.3€/100 km. The EVs using hydrogen are not out of the running, if production becomes massive, and the EV-Re H2 is already a real alternative, thanks to the bonus too. All EVs TCOs converge over time, and are identical in 2040 and lower than that of TV; all costs

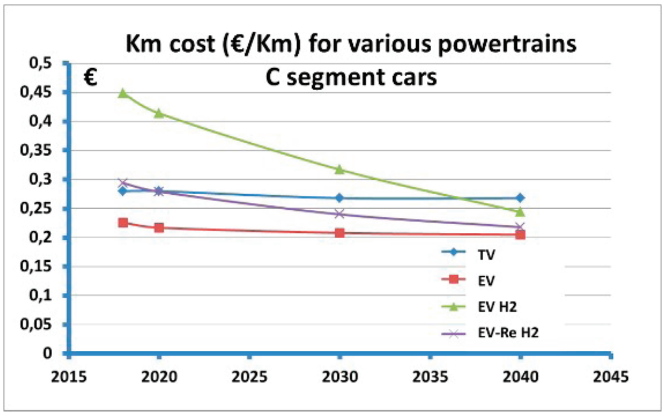

Fig.3: Km costs of the various powertrains for the next decades, 6,000€ bonus included

would be equivalent if the bonus disappears.

Environmental balance sheet estimates: CO_2 avoided due to the use of PV

Concerning the PV systems, the CO_2 emissions avoided [4] are, overall in France, of the order of magnitude of the PV manufacturing emissions: the solar systems are thus practically neutral in terms of CO_2 balance, even in situation of Asia countries manufacturing (mainly China)[5]. The difference is however visible depending on the regions, it would be interesting to be able to "pump up PV energy" from the south (surplus) to the north in order to compensate for

(continued on page 30)

Le Duigou (continued from page 26)

emissions due to kilometers traveled in France is very low compared to the total from well to wheel (8g vs. 40gCO_2 / km), it increases by 2.25gCO_2 / km in Hauts de France and drop of 2.7gCO_2 / km in the PACA region.

Conclusions and Perspectives

There is a real synergy between mobility and housing in the context of solar photovoltaic (PV) equipment. This is valid both from real consumption data and on the construction of scenarios from behavioral statistics. The margins of progress that exist today on PV systems, allow us to envisage the massive deployment of competitive PV systems without public incentives, and this in the short term.

Mobility will benefit from organizing EV recharging periods in line with the electrical consumption already in place. Massively produced, battery and hydrogen EVs are today, or at least in the short term, competitive with TVs. The EV and EV-Re H2 can also contribute to the network primary frequency adjustment, in the short term. The environmental benefits in terms of CO_2 emissions are hardly visible.

Acknowledgments

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