Energy transition: electric Vehicles, smartgrids and PV

Feedback of 19 month using of a small electric car

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Context of this ongoing study

Replacing common fossil fuelled vehicles by electric cars is considered by many as a solution for the urban air pollution and eventually the energy transition [1, 2]. Some people are more circumspect spotlighting the carbon emission and the pollution due to mining and manufacturing, the share of world electric production by coal burning (40 percent), the urban traffic congestion [3]...

Even if we do not confuse an example as the general reality, some orders of magnitude may be extracted from this experiment. Here we do not present an LCA (life cycle analysis) but the production, consumption and CO_2 impact resulting from the use. From more than 19 month of consumption monitoring of a small electric car, for private and business use, we deduce the specific final and primary energy consumption and its seasonal variation as well as the carbon content of 1km. Based on our expertise on photovoltaic modules in outdoor conditions [4] and taking into account nine years of PV production measurements 25km south of Paris, we show that it is easy to offset the car consumption by the production of a limited area of PV module. Moreover we address the question of the potential benefits of adding PV cells on the car roof.

The electric car

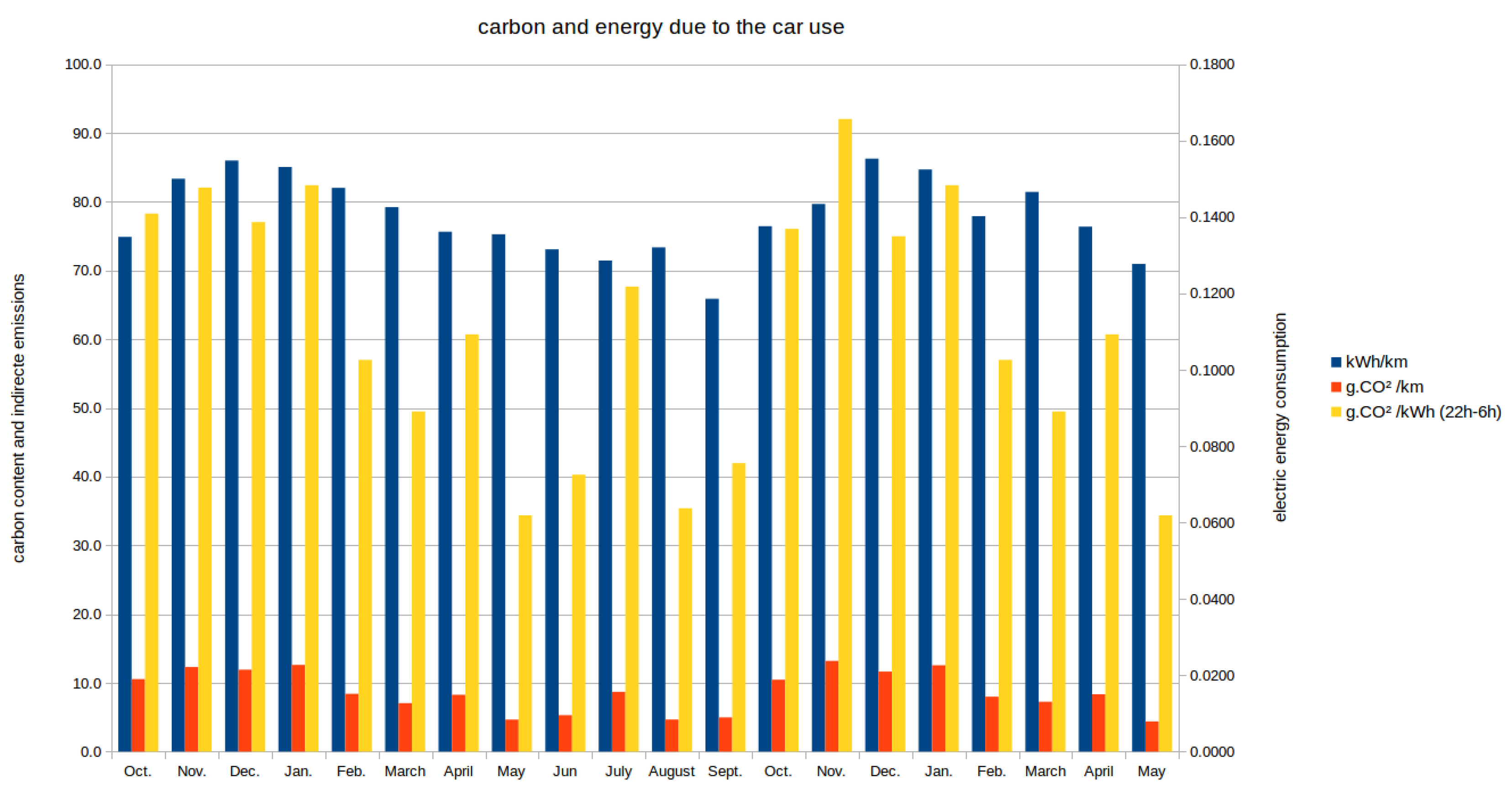
The car of this study has the following characteristics. It is a four places car propelled by a permanent Nd magnets synchronous motor.

- mass = 1 140 kg
- height = 1,608 m
- width = 1,475 m

The Li-ion batteries are always charged at low rate (8 A), during the off-peak hours (22h-6h), in a garage (not under 10°C). Consumption of the auxiliaries is included in the energy balance. The line resistance (obtained by an indirect method) is less than 4.7Ω, most probably much less (<0.3 Ω including the contacts). The charging line consumes therefore less than 0,8% of the total energy.

Methods and results

The car electricity consumption has been measured for each charging of the batteries. For the first year (after the first 3 months of the car) it lead to an average consumption of **0.1384 kWh/km** equivalent 0.45 kWh/km of primary energy. As a comparison a gasoline small vehicle with the same conductor and in the same conditions consumes roughly 0,65 kWh LHP (+43%). This gain of efficiency come principally from the kinetic energy recovery permitted by electric cars and in a less extant by hybrids cars.



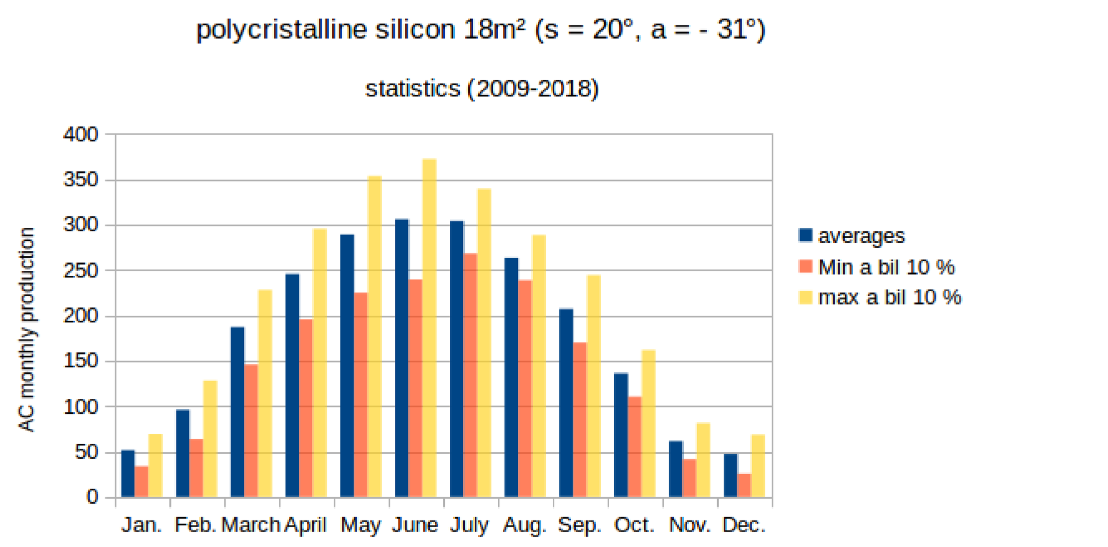
It must be noted that the efficiency is seasonal being lower in winter. This is due to the increased serial resistance in the batteries at low temperature, and to a less extant to the more frequent use of the headlights and the air conditioning. The mean carbon content of the off-peak (22h – 6h) kWh of electricity has been evaluated for each month of year 2017 by sorting randomly 6 days for each month from RTE Data 'Eco2Mix' and making the average.

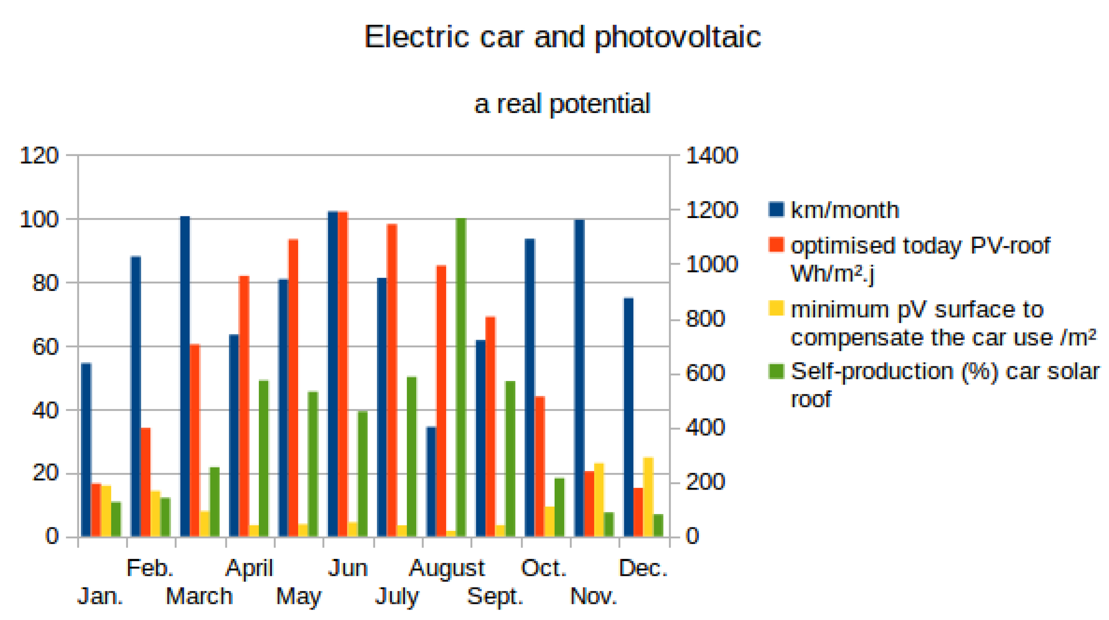
Taking into account the monthly distance of travel we deduced carbon indirect emission of the small electric car. The 2017 value for french off-peak mix is **8,4 g.CO2/km**. With electricity coming respectively from today "Euromix" (535g/kWh), from a high efficiency (62%) gas combined cycle power plant, from a conventional coal plant, it would have been respectively **95.2, 45.7** and **101 g.CO2/km.**

As a comparison a gasoline small vehicle in the same conditions emits **116 g.CO2/km** (15 % more than the coal plant-electric car case to 14 times more than for french off-peak hours mix case). It must be noted that the indirect emissions of electric car are seasonal being higher in winter for two reasons : the higher electric consumption of the car and the higher carbon content of the electricity.

Nine years of roof top photovoltaic production at 25km south of Paris with 18 m2 of Solar Fabrik poly crystalline panels (tilt: 20º, azimuth: 31º West) are used for the study. The figure on the right shows the mean, and the 5% and 95% percentiles of monthly production.

Based on the performance experience of high-ranked PV modules we estimate the production of an optimised PV installation per m², shown in red in the figure. From the km/month data (in blue) we estimate the minimum area high-ranked panels needed to meet the consumption from the electrical vehicle (yellow). Finally, considering the available area on the roof of the car, we calculate the seasonal self-production rate that could be achieved: 7 to 100% (green).





Conclusions

This study lead us to the following conclusions:

- It is possible to compensate the electricity consumption by the PV production of a house roof of rather limited area (< 25 m²),
- A PV roof on the vehicle itself may contribute substantially to electric power and, as a second advantage, that may also increase the car autonomy,
- Seasonality of the battery efficiency has been demonstrated,
- When it is used reasonably, and due to the exceptional efficiency of electrical motors and combined cycles of electrical thermal plants, an electric car is very efficient for energy saving and for emission reduction (particularly on the French grid but not only).

References

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