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SUN2WHEEL: An Autarchic Concept for EV Charging

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Summary

The clean electricity supply of an EV is fundamental to maximize the reduction of green-house-gas emissions, compared to a mobility based on fossil fuels. In the places where the EVs are usually charged (houses, workplaces and so on), this can be achieved either purchasing certified clean electricity from the electricity distributor or by self-production of renewable energy. SUN2WHEEL is a system designed to pursue the latter option, combining together PV electricity production, second life battery storage and charging station. SUN2WHEEL aims to support the e-mobility in an environmental and economic sustainable way, satisfying the energy demand of one or more EVs using the PV electricity produced in the place where they are usually charged. Both the technical and the economic analysis have demonstrated the feasibility of SUN2WHEEL concept, therefore a first pilot system has been realized. The data coming from it are used to validate the design methods, to do the fine tuning of the system and to check the performances of second life batteries and to understand whether SUN2WHEEL has the potential to be offered on the market. The results show that this potential exists and therefore it has been decided to continue the development towards the market introduction.

Keywords: smart charging, photovoltaic, second-life battery, business model, sustainability

1 Introduction

The environmental benefits of electric mobility should be evaluated at least in a Well-to-Wheel (WtW) perspective [1]. Electricity production from renewables allows getting the best WtW results in terms of reduction of green-house-gas (GHG) emissions, compared to the fossil fuel based mobility. Power utilities offer products addressing this issue, i.e. certified clean electricity supply for electric vehicles (see for instance [2, 3] as typical examples for Switzerland, the reference market of this paper). The alternative solution is the PV based self-production of electricity, since it is the most suitable option at home, working places and so on, i.e. in the places where electric vehicles are typically charged.

Considering that:

- the use of renewables must be increased in the framework of Swiss energy strategy 2050 [4]
- second-life EV batteries are and will be more and more available for battery storage purposes [5]

Protoscar SA in cooperation with EVTEC AG, has decided to investigate the technical and economic feasibility of a system, named SUN2WHEEL (S2W). Its goal is to achieve the clean and independent energy supply of the electric vehicles, combining and integrating together the photovoltaic electricity production, second-life buffer batteries, regulated and/or bidirectional charging of the car and the connection to the house and to the grid for delivering excess electricity.

In this paper the results of the feasibility analysis, the first pilot system, the provisional results coming from the first months of data measurement on the pilot system and the possible future evolutions are presented.

2 Description of the system

Since the energy used for mobility with ICE vehicles often represents the most expensive position in a family energy bill, S2W aims to replace this fuel usage and the related cost with local solar energy (electricity for electric cars). The main components of the system are (Figure 1):

- second-life buffer battery storage with energy conversion devices (1, 2).
- Energy meters for the measurements required for the system regulation (3).
- A controller, with purpose developed SW to manage the system (4).
- Charging station (EVSE, 5)

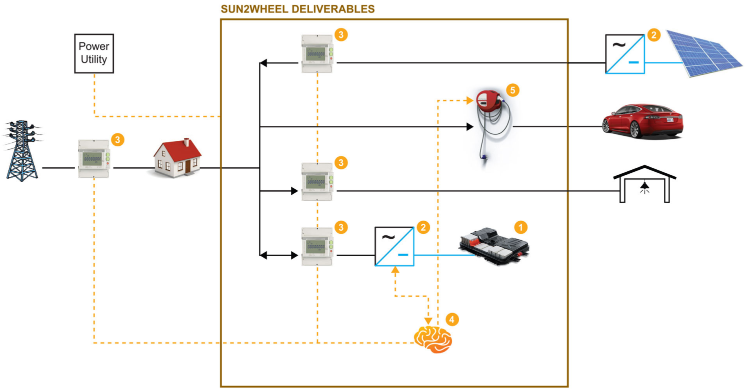

Figure 1: S2W system

S2W has to be tailored on specific requirements, since its goal is to fulfill the energy demand of one or more EVs using the PV electricity produced in the place where they are usually charged. Thus some general requirements have been introduced:

- S2W has to be independent from the hardware (PV panels, inverters, storage battery, EVSE), i.e. it must be possible to apply it to the widest possible range of HW;
- the HW have to fulfill only the minimum requirement to be externally controlled.

3 Technical feasibility

The inputs for the technical feasibility are:

- the PV potential production of the site, evaluated with tools like [6, 7];
- the mobility needs (yearly mileage, daily range on workdays and weekends);
- estimated energy consumption of the BEV (kWh/100km);
- percentage of energy charged using S2W (in general the energy demand of a BEV can be partially covered by public EVSEs, EVSEs at work places and so on);
- daily charging profiles, i.e. when the EV is plugged-in and its maximum charging power.

The PV itself is not a part of S2W, but it has to be included in the computations because to get enough PV energy is the pre-requisite of S2W. Starting from these inputs, it is possible to compute:

- the size of PV panels and inverters;
- the number of buffer batteries;

and to check if the site offers the pre-requisites to allow the installation of such a system. In addition, the environmental benefits, in terms of avoided WTW GHG emissions are evaluated using the software Optiresource [8].

The computation of the required PV installation is done according to the mobility needs. Starting from the yearly mileage of the vehicle and its estimated energy consumption, the total amount of needed energy is defined and thus the amount of power (kWp) to install, according to the geographical photovoltaic modules electricity production.

Since a productivity loss is foreseeable, the photovoltaic installation is designed to address this limitation, i.e. the PV installation is oversized in order to cover the production losses in the years to come. Other elements, such as the losses due to self-consumptions and to the energy conversion steps through PV-buffer battery-BEV are included in the PV oversizing as well. Furthermore, the days with the car parked at home, have been considered.

In term of energy conversion losses, the energy used to charge directly the car without passing through the battery can ensure a saving of more than 20%.

According to different usage patterns, different scenarios of PV installation are considered:

Table 1: Comparison of different PV installation scenarios

km/year	PV Installation (kWp)	PV Daily Production (kWh)
10’000	2.1	5
20’000	4.2	11
30’000	6.4	16
40’000	8.5	22
50’000	10.6	27

The required storage energy is estimated taking the above daily production of the PV plant and considering the production average during the whole year. According to the environmental aspects pursued by the S2W approach, electric vehicle second life batteries are used, rated at nominal capacity of 17kWh (70% of their rated energy when new). The energy has been intentionally reduced at 12kWh to allow a longer lifetime of the battery. The battery has to be able to deliver the required energy until it reaches its end of life, therefore it must be oversized respect the values reported in Table 1. Details are provided in chapter 4.

S2W allows avoiding CO_2 WTW emissions. Their values depend on the fuel consumption of the ICE car replaced by a BEV and on the yearly mileage. The table 2 provides the avoided WTW CO_2 emissions, during the S2W system estimated life, for different values of yearly mileage and gasoline consumption.

Table 2: WTW avoided CO_2 equivalent emissions in Tons computed by Optiresource [8]

km/ year	Gasoline consumption (l/100km)			
	6.5	7	8	9
10’000	1.82	1.96	2.24	2.52
20’000	3.65	3.93	4.49	5.05
30’000	5.47	5.89	6.73	7.57
40’000	7.29	7.85	8.98	10.10
50’000	9.12	9.82	11.22	12.62

4 Economic feasibility

The business case behind S2W is based on the following idea: the investment to replace an ICE car with a 0 Well-to-Wheel emission individual mobility system (electricity generation with local RES + BEV) can be repaid through the avoided cost to refuel the ICE car.

The economic feasibility consists on:

- definition of the upper limit of the investment, given by the ICE car fuel costs in a 20 years time span, i.e. the estimated life of the PV plant;
- definition of the maximum investment compatible with an acceptable time of return;
- check whether the system can be sold at a price not greater than the above figure.

The maximum investment at the year 0 is repaid by the positive cash flow coming from the avoided fuel costs. A BEV has other advantages concerning its running costs when compared to an ICE car, but, to be conservative, only fuel costs are evaluated.

It has been chosen to use a gasoline ICE car for the computation of the investment, because:

- the average fuel consumption of the whole fleet of the new registered gasoline cars in Switzerland is lower than the diesel ones [10];
- gasoline is by far the most used fossil fuel in Switzerland [11];
- gasoline is a little bit cheaper than diesel in Switzerland.

The investments are computed with the formula:

$$INV = \sum_{t=1}^{n} \frac{\frac{YM}{100} \cdot L \cdot FC}{(1+DR)^t} \tag{1}$$

where n is the number of years, YM is the yearly mileage in km, L the fuel consumption in l/100km, and FC the fuel (gasoline) cost. The cash flow is actualized using the discount rate DR.

Several scenarios have been investigated, according to the following combinations of inputs:

- YM = 10’000, 20’000, 30’000, 40’000 and 50’000 km/year.
- L = 6.5, 7, 8, 9 l/100km; these values have been selected because they allow getting a feasible level of the investments. The whole gasoline car fleet in Switzerland [12] shows that 13% of cars has a displacement between 1’800 and 1’999 cm^3, 4% between 2’000 and 2’499 cm^3 and 9% ≥ 2’500 cm^3. From [10], the NEDC fuel consumption of the new registered car belonging to the above displacement classes are 6.08, 6.4, 7.57 l/100km (2’500 and 2’999 cm^3), hence the above values are representative of real life consumption both of the average gasoline car (NEDC = 5.88l/100km [10]) and of 25% of the whole gasoline cars.
- FC = 1.48 CHF/l (average gasoline price in Switzerland, [14]) constant over 20 years or linearly increasing to 2, 3, 4 or 5 CHF/l after 20 years.
- DR = 3%.

The results are reported in the following figures for the two cases L=6.5 and L=9 l/100km. Each diagram shows the available investments after 10 to 20 years for each mileage and final gasoline price.

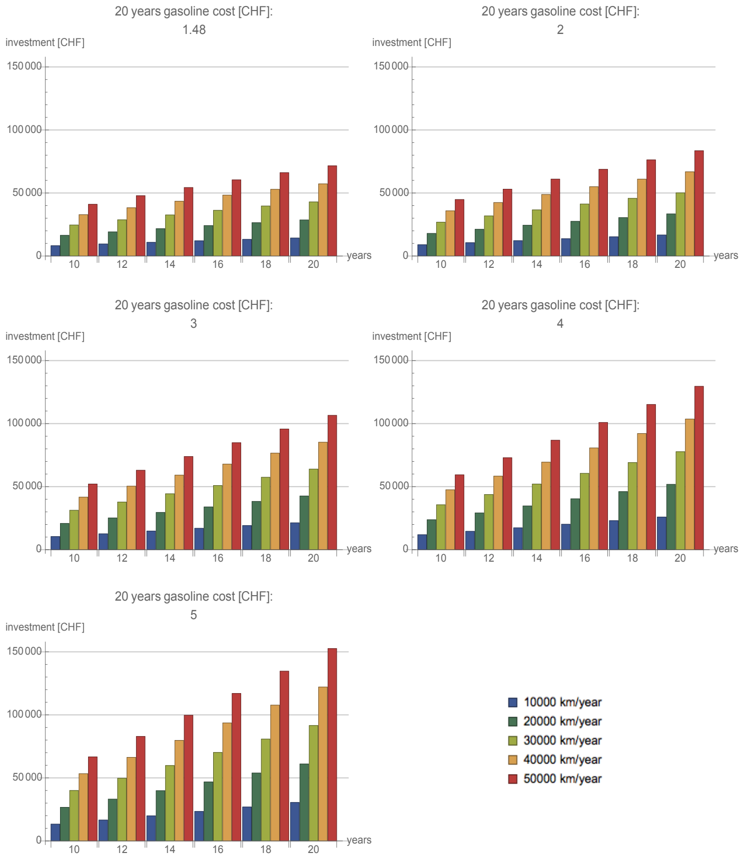

Figure 2: available investments replacing an ICE car with a fuel consumption of 6.5l/100km

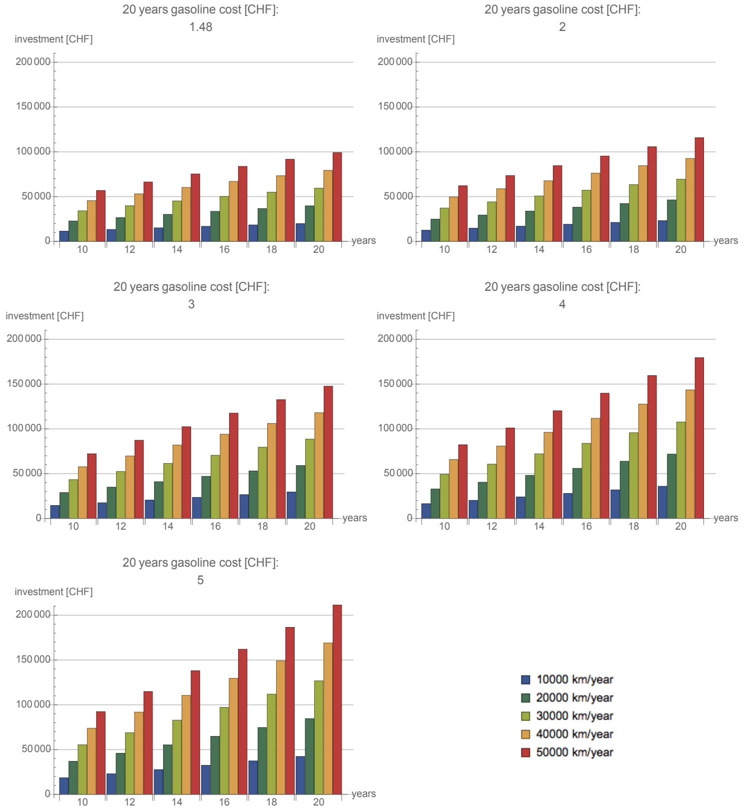

Figure 3: available investments replacing an ICE car with a fuel consumption of 9l/100km

The above investments must cover the cost of the components of the S2W system and allow an acceptable return of the investment. As explained in the chapter 3, S2W itself could not include the PV system, but, since PV is a part of the whole investment required to let the system work, it has been included in the feasibility analysis.

The cost are given by:

$$S2WCOST = PV + SSCD + SS + OC \tag{2}$$

Where PV is the cost of the photovoltaic plant, SSCD the cost of the conversion devices of the storage system, SS the cost of the storage system (battery + BMS) and OC are other costs (controller, wiring, charging station, installation etc.).

Two simulations are done, using either the prototype or the optimized costs. The inputs are:

- PV: it is used the average installation cost in Switzerland, i.e. 3'000 CHF/kWp up to 10 kWp (for larger installation the actual price is about 1'800 CHF/kWp) [9]. No further optimizing is introduced.
- SSCD: the prototypes costs are used, i.e. 400 CHF/kW (cost of the prototypes). For the optimized system, a reduction of 25% is introduced.
- SS: the prototype costs are used, i.e. 500 CHF/usable kWh. For the optimized system, a reduction of 40% is introduced.
- OC: the prototypes costs are used. For the optimized system, a reduction of 25% is introduced.

The storage system has been sold by the car manufacturer at a cost per kWh corresponding to the 50% of the estimated cost of a new battery (this cost was not disclosed), as reported in the literature (see, for instance [13]). Since the battery is used at half its rated capacity, the cost per kWh is basically the same of the one of a new battery. Considering that [13] the costs of the automotive batteries are quickly moving down to 200 $/kWh, assuming that also in the future they will be sold us at 50% the cost of a new battery, the computation of the optimized system uses a cost of 200 CHF/kWh (exchange rate CHF – USD is around 1:1). But SS depends on the life of the batteries as well. Introducing a battery degradation rate (BDR), i.e. the ratio actual capacity / initial capacity (as delivered to us, i.e. after the usage on a car), if BL represents the battery life, then in 20 years 20/BL batteries will be needed. Thus, the storage system cost is, being kWhC the cost per kWh and PVDL the daily average production of the PV system (Table 1):

$$SS = \frac{20}{BL}\frac{PVDP}{1-BDR\,BL}kWhC \tag{3}$$

The first results, after 1 and a half year of tests of the same batteries in other our applications but with the same DODs, have shown a degradation rate of about 8%. This degradation rate means that the estimated life could be 5 years. Due to these uncertainties, simulations have been done considering a battery life of 4, 5 and 6 years. The Figure 4 shows SS (prototype), for the PVDP values corresponding to 10'000, 20'000, 30'000, 40'000 and 50'000 km/year.

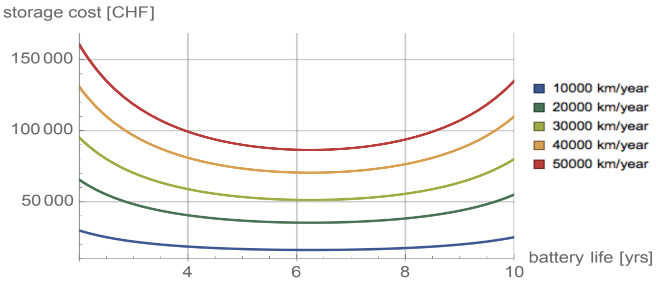

Figure 4: cost of the storage system for different estimated battery life and yearly mileages

The Figure 4 shows that the optimal battery life is around 6 years and that the storage cost is a relevant part of the SUN2WHEEL system, as shown also in the Figures 5 and 6.

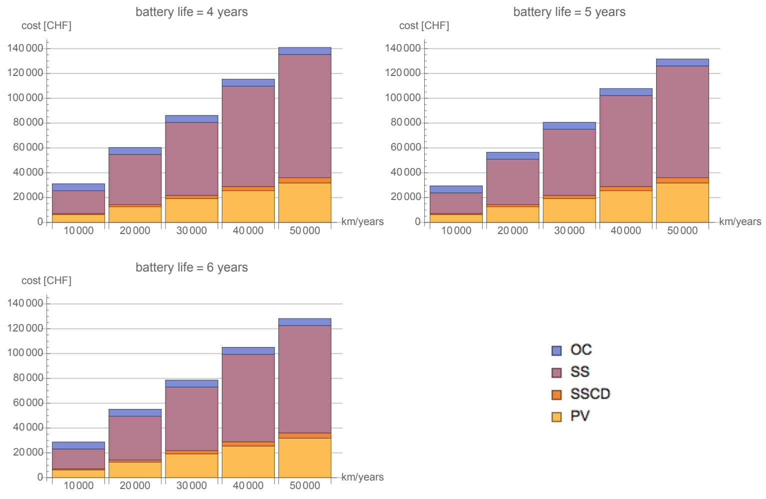

Figure: 5: costs of whole system (prototype costs)

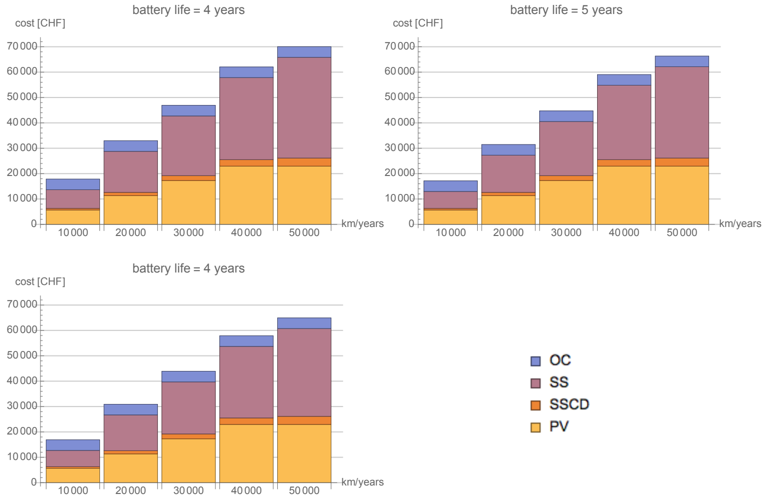

Figure: 6 costs of whole system (optimized costs)

The economic feasibility is reached if the margin, i.e. (INV – SS)/INV is ≥ 20% and it is reached after no more than 15 / 16 years.

At prototype cost, there are no combinations allowing to reach the economic feasibility.

With an optimized battery cost, there are some feasible combinations, reported in the Tables 3, 4, 5 and 6, where the columns refer to the gasoline price after 20 years. The symbol "√" is used to mark the feasible conditions.

Table 3: conditions for economic feasibility with optimized battery cost and investment based on gasoline consumption = 6.5 l/100km

km/ year	Battery life 4 years					Battery life 5 years					Battery life 6 years				
	1.48	2	3	4	5	1.48	2	3	4	5	1.48	2	3	4	5
10’000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20’000	-	-	-	-	-	-	-	-	-	-	-	-	-	√	√
30’000	-	-	-	-	-	-	-	-	√	√	-	-	-	√	√
40’000	-	-	-	-	-	-	-	-	√	√	-	-	-	√	√
50’000	-	-	-	√	√	-	-	-	√	√	-	-	-	√	√

Table 4: conditions for economic feasibility with optimized battery cost and investment based on gasoline consumption = 7 l/100km

km/ year	Battery life 4 years					Battery life 5 years					Battery life 6 years				
	1.48	2	3	4	5	1.48	2	3	4	5	1.48	2	3	4	5
10’000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	√
20’000	-	-	-	-	-	-	-	-	√	√	-	-	-	√	√
30’000	-	-	-	√	√	-	-	-	√	√	-	-	-	√	√
40’000	-	-	-	√	√	-	-	-	√	√	-	-	-	√	√
50’000	-	-	-	√	√	-	-	-	√	√	-	-	-	√	√

Table 5: conditions for economic feasibility with optimized battery cost and investment based on gasoline consumption = 8 l/100km

km/ year	Battery life 4 years					Battery life 5 years					Battery life 6 years				
	1.48	2	3	4	5	1.48	2	3	4	5	1.48	2	3	4	5
10’000	-	-	-	-	√	-	-	-	√	√	-	-	-	√	√
20’000	-	-	-	√	√	-	-	-	√	√	-	-	-	√	√
30’000	-	-	-	√	√	-	-	√	√	√	-	-	√	√	√
40’000	-	-	√	√	√	-	-	√	√	√	-	-	√	√	√
50’000	-	-	√	√	√	-	-	√	√	√	-	-	√	√	√

Table 6: conditions for economic feasibility with optimized battery cost and investment based on gasoline consumption = 9 l/100km

km/ year	Battery life 4 years					Battery life 5 years					Battery life 6 years				
	1.48	2	3	4	5	1.48	2	3	4	5	1.48	2	3	4	5
10’000	-	-	-	-	√	-	-	-	√	√	-	-	-	√	√
20’000	-	-	√	√	√	-	-	√	√	√	-	-	√	√	√
30’000	-	-	√	√	√	-	-	√	√	√	-	-	√	√	√
40’000	-	-	√	√	√	-	-	√	√	√	-	-	√	√	√
50’000	-	-	√	√	√	-	-	√	√	√	-	√	√	√	√

The feasibility conditions are never met for the lower gasoline prices (1.48 and 2 CHF/l). For gasoline price up to 3 CHF/l after 20 years, the BEV must replace an ICE car with fuel consumption of 8 to 9 l/100km to get a positive feasibility. When the fuel consumption is 6.5 l/100km the feasibility is rather limited.

In the tables 7, 8, 9 and 10 there are the results with the full optimization.

Table 7: conditions for economic feasibility with optimized costs and investment based on gasoline consumption = 6.5 l/100km

km/ year	Battery life 4 years					Battery life 5 years					Battery life 6 years				
	20 year gasoline price					20 year gasoline price					20 year gasoline price				
	1.48	2	3	4	5	1.48	2	3	4	5	1.48	2	3	4	5
10’000	-	-	-	-	-	-	-	-	-	√	-	-	-	-	√
20’000	-	-	-	-	√	-	-	-	√	√	-	-	-	√	√
30’000	-	-	-	√	√	-	-	-	√	√	-	-	-	√	√
40’000	-	-	-	√	√	-	-	-	√	√	-	-	-	√	√
50’000	-	-	-	√	√	-	-	-	√	√	-	-	-	√	√

Table 8: conditions for economic feasibility with optimized costs and investment based on gasoline consumption = 7 l/100km

km/ year	Battery life 4 years					Battery life 5 years					Battery life 6 years				
	20 year gasoline price					20 year gasoline price					20 year gasoline price				
	1.48	2	3	4	5	1.48	2	3	4	5	1.48	2	3	4	5
10’000	-	-	-	-	√	-	-	-	-	√	-	-	-	√	√
20’000	-	-	-	√	√	-	-	-	√	√	-	-	-	√	√
30’000	-	-	-	√	√	-	-	-	√	√	-	-	√	√	√
40’000	-	-	-	√	√	-	-	-	√	√	-	-	√	√	√
50’000	-	-	-	√	√	-	-	√	√	√	-	-	√	√	√

Table 9: conditions for economic feasibility with optimized costs and investment based on gasoline consumption = 8 l/100km

km/ year	Battery life 4 years					Battery life 5 years					Battery life 6 years				
	1.48	2	3	4	5	1.48	2	3	4	5	1.48	2	3	4	5
10’000	-	-	-	√	√	-	-	-	√	√	-	-	-	√	√
20’000	-	-	√	√	√	-	-	√	√	√	-	-	√	√	√
30’000	-	-	√	√	√	-	-	√	√	√	-	-	√	√	√
40’000	-	-	√	√	√	-	-	√	√	√	-	-	√	√	√
50’000	-	-	√	√	√	-	-	√	√	√	-	-	√	√	√

Table 10: conditions for economic feasibility with optimized costs and investment based on gasoline consumption = 9 l/100km

km/ year	Battery life 4 years					Battery life 5 years					Battery life 6 years				
	1.48	2	3	4	5	1.48	2	3	4	5	1.48	2	3	4	5
10’000	-	-	√	√	√	-	-	√	√	√	-	-	√	√	√
20’000	-	-	√	√	√	-	-	√	√	√	-	-	√	√	√
30’000	-	-	√	√	√	-	√	√	√	√	-	√	√	√	√
40’000	-	-	√	√	√	-	√	√	√	√	-	√	√	√	√
50’000	-	√	√	√	√	-	√	√	√	√	-	√	√	√	√

As expected, a full optimized system increases the conditions where the economic feasibility is met. When the fuel cost is 2 CHF/l after 20 years, it is possible to get a positive business case, at least for the higher mileages, when the fuel consumption is 9 l/100km. When the fuel cost is 3 CHF/l, some positive cases are met even when the fuel consumption is 7 l/100km, at least for higher mileages and battery life. When the fuel cost is higher (4 – 5 CHF/l), there is the widest feasibility, also for the lower fuel consumption and battery life. Again, with a constant gasoline price, there is not any feasibility.

5 Pilot system

The first pilot plant has been implemented in a garage of a household in Rovio, Switzerland, close to the Protoscar office.

Figure 7: S2W Pilot Installation in Switzerland. On the left it is possible to see the second-life battery and, on the wall, the inverters and the controller

The goal of the pilot system is to validate the technical and economic feasibility methods, to do the fine tuning of S2W software, to check the performances of second life batteries and finally to understand whether S2W can be a reliable and cost-effective product to be offered in the market. The design conditions foresee two batteries, but in the first testing phase it was decided to install only one battery.

The first demo site is in service since October 2016 with a photovoltaic installation of 52 m^2 (94% of the available roof surface), and a nominal power of 7,68 kWp with a yearly energy production of 7’150 kWh able to about 35’000 km per year. Energy meters have been provided to measure the PV production, the charged energy, the energy exchange with the grid and the energy used by the whole garage, given by the charged energy, the self-consumption of S2W system, the garage lightning and other loads.

6 First results from the pilot system

The data recording started on October 1st 2016. At the end of May 2017 the total PV production was 3’846 kWh. The electric vehicles charged 4’776 kWh, equivalent to 27’293 km. The whole garage consumed 5’003 kWh. The difference between PV production and whole garage consumption was provided by the grid (1’157 kWh). The minimum PV production was in January (199 kWh) and the Maximum in May (988 kWh). In May PV production exceeded by 425 kWh the garage consumption: this surplus was supplied to the house. The battery behaviour is aligned with the expected 8% yearly degradation

7 Conclusion

S2W concept is technically and economically feasible. From a technical point of view there are not critical aspects. The conditions for the economic feasibility are realistic because:

- the cost of the second-life batteries will decrease, pushed by the trend of the cost of the new batteries.
- The economic feasibility strongly depends on the expected gasoline price in a 20 years period: most of the positive business cases need that the gasoline price be ≥ 3 CHF/l, which is a realistic condition. Moreover, for mileages ≥ 30’000 km/year and battery life of at least 5 years, the feasibility is possible at 2 CHF/l as well.
- In the S2W business model, the available investments are deeply influenced by the fuel consumption of the ICE cars that will be replaced by a BEV. Most of the scenarios giving a positive economic feasibility, correspond to the replacement of ICE cars with real life fuel consumption of 8 - 9 l/100km. But about 25% of the ICE cars in Switzerland have such fuel consumption, resulting in a large potential market in Switzerland.
- A market analysis conducted in the framework of a Master Thesis at the University of St. Gallen (CH) highlighted a potential market of several thousands of installations in a 10 years perspective.

The battery is one of the key component of the system. There are uncertainties concerning its residual life: even if the partial results show an expected life of 5 years, this value is based on 1.5 years tests on 2 batteries and 8 months with another battery, further tests are needed to confirm that value. Nevertheless, the results of the feasibility analysis and of the tests from the pilot plant have suggested to Protoscar SA and EVTEC AG to continue the development in order to be able to offer the S2W on the market, as soon as enough confidence about the battery life will be achieved and its costs will further decrease.

The next steps will be the implementation of other pilot systems in cooperation with power utilities or other organizations willing to add S2W to their e-mobility offer. The economic feasibility will be further investigated including the elaboration of a leasing proposal for final customers including the risk assessment due to the uncertainties on battery life. On the technical side, the next steps will focus on a pure DC system, removing the losses related to the energy conversion (AC/DC) and on the integration of BEVs V2H/V2G capability.

References

[1] JEC – Joint Research Center-EUCAR-CONCAWE collaboration, WELL-TO-WHEEL Report Version 4.a, Report EUR 26237 EN, ISBN 978-92-79-33887-8, Luxembourg: Publications Office of the European Union, 2014

[2] EKZ *Naturstrom für Elektrofahrzeuge*, http://www.ekz.ch/de/private/strom-kaufen.html#vignette, accessed on 2016-10-19

[3] AMB, *Ordinanza relativa alle tariffe per la fornitura di energia elettrica in vigore dal 1. gennaio 2016,* accessed on 2015-11-05

[4] Bundesamt für Energie BFE, *Die Energieperspektiven für die Schweiz bis 2050*, Basel 2012-09-12

[5] Bloomberg, *Used Electric Car Batteries Get Second Life as Home Storage*, https://www.bloomberg.com/news/articles/2016-08-25/used-electric-car-batteries-will-get-second-life-as-home-storage

[6] Joint Research Center (JRC), *Photovoltaic Geographical Information System (PVGIS)*, http://re.jrc.ec.europa.eu/pvgis/, accessed on 2015-11-05

[7] Osservatorio ambientale della Svizzera Italiana, *Mappatura solare - Potenziale della produzione di energia solare*, http://www.oasi.ti.ch/web/catasti/mappatura-solare.html, accessed on 2015-11-05

[8] Optiresource.org, *Optiresource Experts Version*, http://www.optiresource.org/en/software/for_experts.html, accessed on 2016-10-21

[9] Swiss Confederation, *Verifica dei prezzi di costo e dei tassi di rimunerazione per gli impianti RIC*, May, 2016

[10] Bundesamt für Energie BFE, *Energieverbrauch und Energieeffizienz der neuen Personenwagen 2016*, Bern 2017-06-12

[11] Bundesamt für Statistik BFS, *STAT-TAB interactive Tabellen*, https://www.pxweb.bfs.admin.ch/Table.aspx?layout=tableViewLayout2&px_tableid=px-x-1103020100_104%5cpx-x-1103020100_104.px&px_language=de&px_type=PX&px_db=px-x-1103020100_104&rxid=0dbeec4c-6bfd-4070-897d-239c0f4160be, on-line query accessed on 2017-04-12

[12] Bundesamt für Statistik BFS, *STAT-TAB interactive Tabellen*, https://www.pxweb.bfs.admin.ch/Table.aspx?layout=tableViewLayout2&px_tableid=px-x-1103020100_104%5cpx-x-1103020100_104.px&px_language=de&px_type=PX&px_db=px-x-1103020100_104&rxid=0dbeec4c-6bfd-4070-897d-239c0f4160be, on-line query accessed on 2017-04-12

[13] Ernest Basel und Partner (EBP), *Szenarien der Elektromobilität in der Schweiz – Update 2016*, Zollikon, 2016-10-31

[14] TCS, *Durchschnittliche Benzinpreise in Europa*, https://www.tcs.ch/de/camping-reisen/reiseinfos/fahrkosten-und-gebuehren/benzinpreise.php, accessed on 2017-06-12

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