KYBURZ Small Electric Vehicles: A Case Study in Successful Deployment

Erik Wilhelm, Wilfried Hahn, and Martin Kyburz

Abstract This paper is written from the perspective of a Swiss OEM which has been active in the small electric vehicle (SEV) market since 1991 and has put over 22,000 SEVs on the road around the world. KYBURZ Switzerland AG identified several important niche markets for SEVs and today sells vehicles to improve the mobility of senior citizens (e.g. KYBURZ Plus), to increase the efficiency of postal and logistics companies (e.g., KYBURZ DXP), and to imbue drivers with passion for electric vehicles (e.g., KYBURZ eRod). Most KYBURZ vehicles are currently homologated in the category L2e, L6e, or L7e. The company has also developed a Fleet Management product which gives its customers detailed insights into the performance of their electric as well as conventionally powered vehicles. Anonymized datasets from this Fleet Management system will be drawn upon in this paper to examine questions regarding their application, i.e., environmental and economic aspects. The unique feature which the authors from KYBURZ bring with this paper is that all their investigations are performed with real data gained from the field experience. The primary focus of this paper is on last-mile mobility services for postal organizations which help to increase efficiency and meet sustainability goals.

Keywords Electric postal vehicles · Large-scale deployment · Total cost

1 Introduction

The Swiss OEM KYBURZ offers a Fleet Management product which gives its customers detailed insights into the performance of their electric as well as conventionally powered vehicles. Anonymized datasets from this Fleet Management system will be drawn upon in this paper to examine the following questions:

E. Wilhelm (✉) · W. Hahn · M. Kyburz
Kyburz Switzerland AG, Solarweg 1, Freienstein-Teufen 8427, Switzerland
e-mail: erik.wilhelm@kyburz-switzerland.ch

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1. How do small electric vehicles (SEVs) compare against incumbents across a variety of environmental performance indicators based on real-world operating data?
2. What advantages do SEVs present considering increasing urbanization and e-commerce, particularly in terms of urban delivery vehicles?
3. Which economic indicators are decisive for fleet customers when considering the switch to SEVs, with an emphasis on total cost of ownership?
4. Do differences exist between different geographic markets for SEVs which should be considered, particularly regarding the electrical grid supply mix?
5. What can be done at the end of life for SEVs which further increase their economic value and reduce the demand for critical raw materials?
6. How can telematics data from SEVs be effectively collected, anonymized, and analyzed to maximize their impact?

2 Methods

KYBURZ Switzerland has developed the Fleet Management infrastructure shown in Fig. 1 which enables vehicle operators and managers to collect, process, store, and operationalize a wide variety of light as well as heavy-duty vehicle data. In this section, we will address question six: *How can telematics data from SEVs be effectively collected, anonymized, and analyzed to maximize their impact?*

The KYBURZ Fleet Management server infrastructure is protected by state-of-the-art approaches to ensure that user privacy is not compromised by maintaining high levels of cyber security (TLS everywhere), in addition to complying with the General Data Protection Regulation (DSGVO). We use several

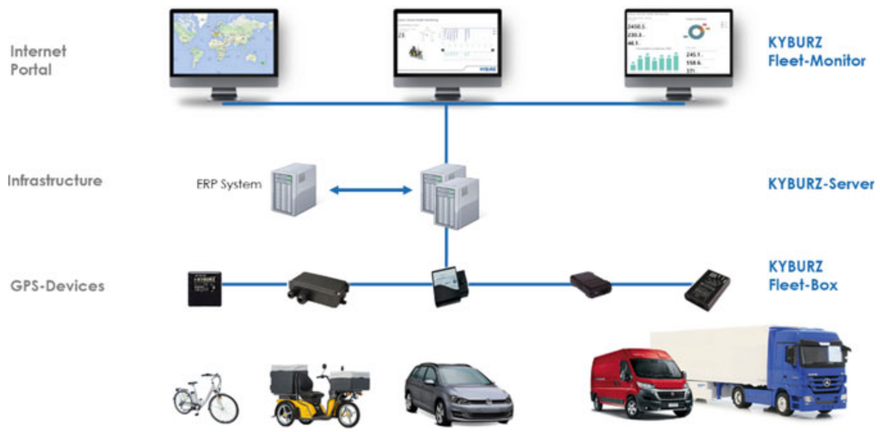


Fig. 1 KYBURZ Fleet management infrastructure for securely storing and processing data

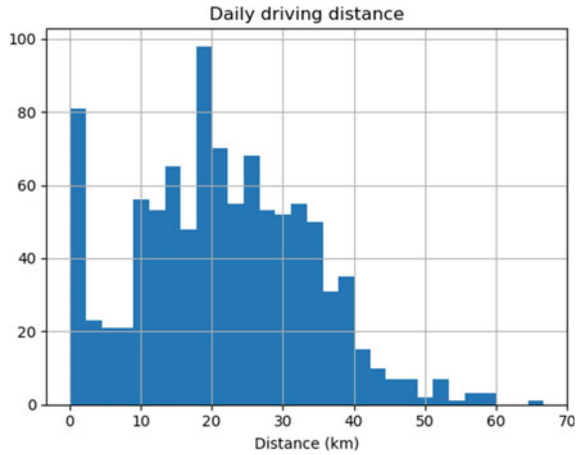


Fig. 2 Distribution of daily driving distance for the week of the 10th to the 14th of June 2019

approaches to minimize the risk while collecting telematics data. For example, we do not link datasets collected from vehicles to datasets containing personal or corporate information which is stored on the ERP server illustrated in Fig. 1, and we used hashed identifies where possible.

The Fleet Management infrastructure collects data from over 2,500 DXP vehicles in daily postal operation. For the analysis presented in this chapter, a subset of N = 394 was selected over the week of the 10th to the 16th of June 2019. These vehicles travel a mean of 22 km/day during their postal rounds, distributed as shown in Fig. 2. The vehicles typically finish their tours with over 50% of battery capacity remaining.

3 Environmental Impact and Geography

In this section, we propose answers to the questions: *How do SEVs compare against incumbents across a variety of environmental performance indicators based on real-world operating data? Do differences exist between different geographic markets for SEVs which should be considered, particularly regarding the electrical grid supply mix?*

Starting in early 2010, the Swiss Post began to replace their fleet of gasoline two-stroke delivery scooters with KYBURZ Switzerland's SEVs both shown in Fig. 4 and described in Table 1. The present deployment of roughly 6,000 SEVs is shown in Fig. 3 and resulted in a reduction in fleet size of over 1,500 fewer last-mile delivery vehicles which brought important economic and logistical efficiency gains [2]. A service network (shown as purple dots in the map) consisting of roughly 60 partners maintains and manages the fleet. The vehicles are serviced every 5,000 km, and the deployment has resulted in a diminished absolute total cost of fleet ownership for the Swiss Post.

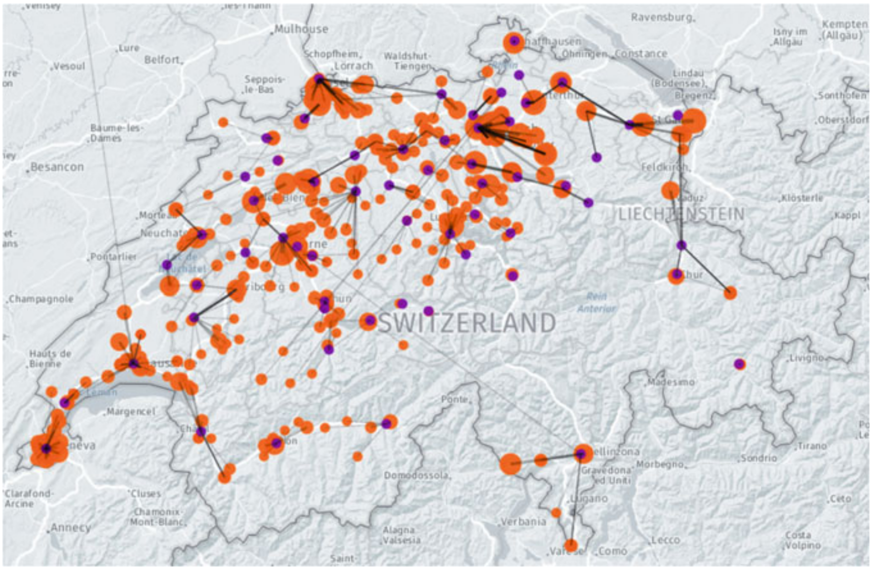


Fig. 3 Deployment of DXPs in Switzerland

Fig. 4 Piaggio Liberty 125 cc internal combustion engine (ICE) incumbent delivery vehicle (left) and the KYBURZ DXP electric delivery vehicle (right)

Table 1 Physical characteristics of the delivery vehicles

Parameters	Internal combustion	KYBURZ DXP SEV
Empty weight (kg)	95	210
Maximum load capacity (kg)	89	270

Using the input data and methodology from Sacchi [6] and Cox [3] as well as the input assumptions summarized in Table 2, we obtain the results in Table 3. Here, it can be clearly seen that the DXP SEVs offer substantial benefits over the incumbent

Table 2 Life cycle modeling inputs for the DXP SEV

	Best case	Mean case	Worst case
Lifetime (in km)	40,000	35,000	30,000
Lifetime (in years)	7	7	7
Mass driver (in kg)	70	70	70
Mass cargo (in kg)	125	198	270
Curb mass (in kg)	210	210	210
Of which, glider mass	138	138	138
Of which, electric motor mass	20	20	20
Of which, battery mass	52	52	52
Battery change during lifetime	No	Yes	Yes
Driving mass (in kg)	478	405	550
Motor peak power (in kW)	2.4	2.4	2.4
Electricity consumption (in Wh/km)	69.4	88.8	111.1
Battery capacity (in kWh)	4.5	4.8	5.2
Max discharge rate (in % of capacity)	80	80	80
Range (in km)	59	43	33
Swiss electricity CO_2 intensity (gCO_2-eq./kWh)	106	106	106

Table 3 Life cycle modeling results for the DXP SEV, compared to the incumbent ICE the DXP exhibits far superior performance

gCO_2-eq./km	Glider	Powertrain	Energy storage	Maintenance	Energy chain	Direct emissions	Road	Total
Best case EV	28	10	16	4	8	0	6	71
Mean case EV	32	11	36	4	10	0	6	100
Worst case EV	37	13	42	5	12	0	6	116
ICE	11	9	0	11	42	217	6	296

internal combustion engine (ICE) delivery vehicles, even when considering a conservative estimate of the electrical grid CO_2 intensity of 106 g CO_2/kWh. As expected, the major penalty incurred by the incumbent ICE is during the use-phase.

The results of analyzing the on-road energy use of the DXPs in various geographical markets under both summer and winter conditions is shown in Fig. 5, where it is clear that the electrical delivery vehicles offer over 8× efficiency advantages versus the internal combustion engine incumbents, which as previously discussed in the LCA analysis drives the substantially lower total emissions. In postal delivery applications with a high loads and large number of starts and stops, the real-world ICE consumption is typically much higher than when tested to standardized cycles. In postal applications, the inherent efficiency of SEVs is a strong advantage.

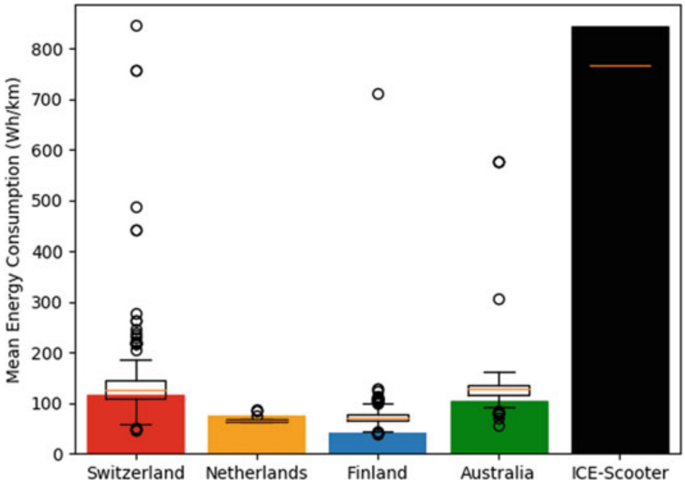


Fig. 5 Measured on-road energy consumption of the DXP in various markets compared with the ICE incumbent, showing a significant: energy-saving potential by switching to electric delivery vehicles

In a further analysis, we evaluated the CO_2 intensity of the electricity grid mix, and conclude that the DXP will either cut the CO_2 emissions by one third over its lifecycle, or in the best case reduce them by 50% depending on whether the primary energy comes from a natural-gas intensive grid or from the Swiss grid mix. Other recent studies have arrived at similar conclusions, for example, the work of Edwards [4].

4 Urban Space Implications

In this section, we answer the question: *What advantages do SEVs present considering increasing urbanization and e-commerce, particularly in terms of urban delivery vehicles?*

The shrinking volume of letter mail leaves a Post two choices: either reduce the mail network ("downward spiral") or maintain the network by adding items from other areas (e.g., small parcels). The mail network typically shows significant lower cost per item delivered compared to a parcel delivery van. Further, with the increase in e-commerce, the last-mile parcel delivery hits capacity limits. Going from door to door with a delivery van brings additional traffic congestion and emissions to city areas, whereas the mail network already uses small vehicles in cities. With SEV like the KYBURZ DXCargo, the mail network can easily be extended to deliver small parcels on a postman's letter route, keeping the cost per item delivered to a minimum. On the other hand, the parcel van can operate more efficiently focusing on bigger items with higher single value and less e-commerce packets.

Fig. 6 Compare the KYBURZ DXCargo with conventional panel delivery trucks

To examine the potential for SEVs such as the KYBURZ DXCargo to solve pressing urban logistics problems presented by conventional panel trucks (both shown in Fig. 6), we perform a simple line calculation to examine the space used by both delivery vehicles in this section.

The DXCargo has a maximum carrying capacity of 200 kg and occupies a footprint of 2.4 m^2. The conventional cargo van has a carrying capacity of 1,100 kg and occupies a footprint of 16.8 m^2. As such, to carry the same number of parcels by weight a postal service would require six DXCs with an aggregated footprint of 14.4 m^2. If six DXCs are deployed to deliver the same number of packages as one cargo van, cumulatively they use almost 100 m^2 less urban area over the course of driving a single route with an average of 50 stops relative to when a cargo van is used. Occupied surface per route is calculated by multiplying the number of stops times the footprint of the vehicle (fleet). Considering that 247,000 cargo vans were sold in 2016 [7], this sums to a traffic-reducing space saving of over 20 km^2 per day if all of the cargo vans sold in 2016 were replaced by SEVs like the DXCargo. Put in other terms, 2,869 soccer field sized areas would be saved in urban spaces through this swap. This is a conservative estimate, since it is likely more than 250,000 cargo vans are deployed for daily deliveries. A geospatial study of urban deliveries found that the distance walked to delivery packages was almost equivalent to the distance driven. Hence, we are comfortable making this head-to-head comparison [1].

Another important consideration is the time saved during delivery stops. A typical delivery route recorded using the KYBURZ Fleet Management system is shown in Fig. 7. Although it does not seem like much time, the eight seconds saved using three-wheeled SEVs like those produced by KYBURZ illustrated in Fig. 9 can sum to major cost savings [5]. The eight seconds of efficiency exist because the letters can be gathered while the brake is being applied, there is no need to extend or retract a side stand, forward, and reverse directions can be controlled simply and easily with a simple button click, and the DXP has improved agility (Fig. 8).

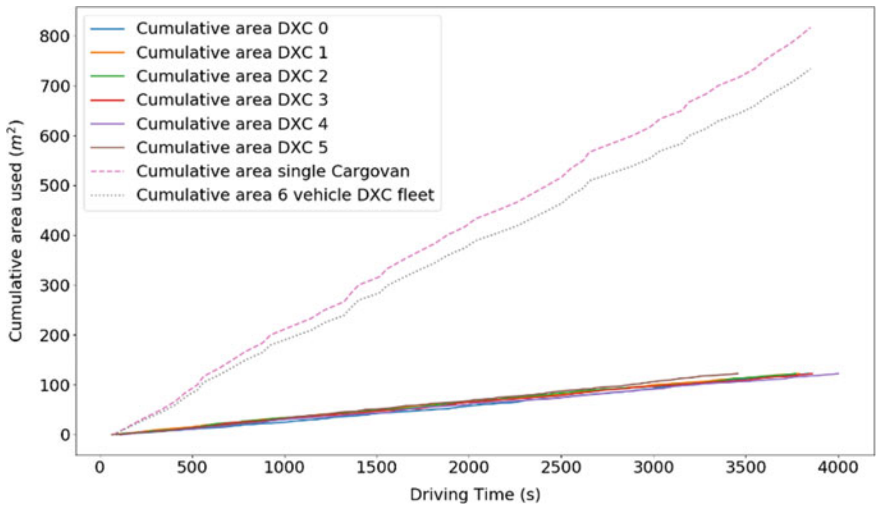


Fig. 7 Cargo van-based deliveries occupy almost 700 m^2 area per route versus DXC-based deliveries with one vehicle. A DXC fleet with six vehicles, capable of delivering the same amount of cargo as one big van, would save 100 m^2 per route

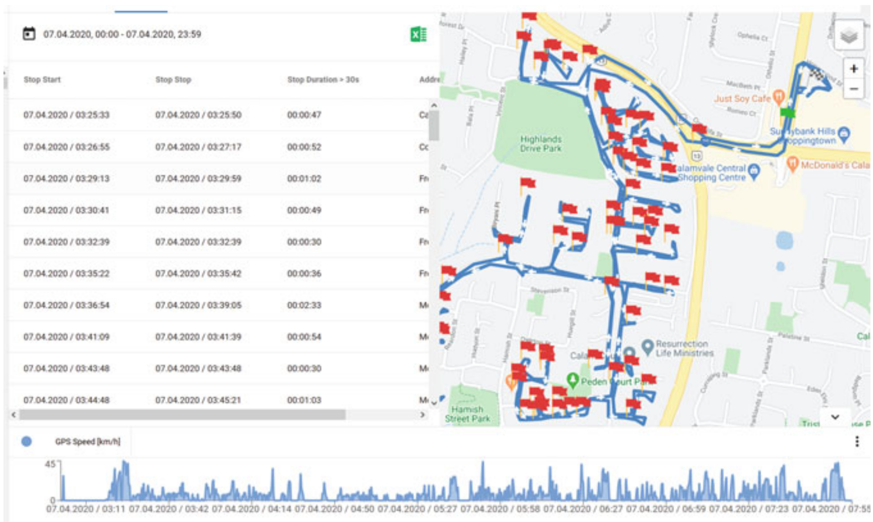


Fig. 8 A typical delivery route shows over 50 stops in postal service per day

Based on the daily summary of April 6th, 2020, one DXP fleet consisting of 1,124 vehicles made an average of 57 stops per day as can be seen in Fig. 10. On this basis, this fleet operator saves 4,528 working days per year for this relatively modest fleet of 2,000 vehicles.

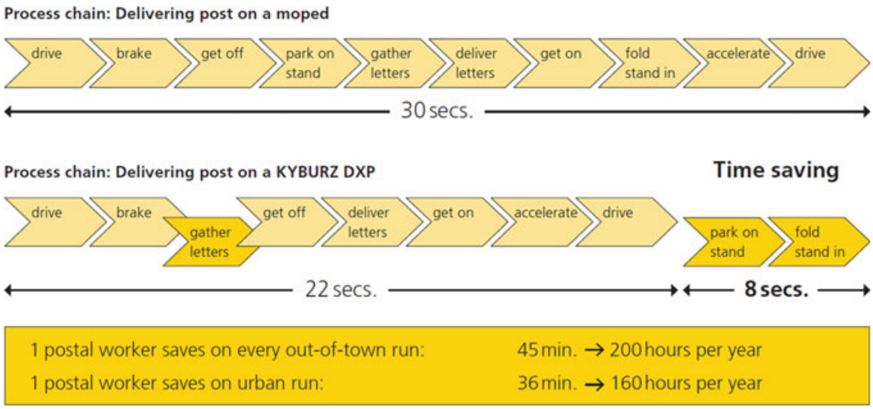
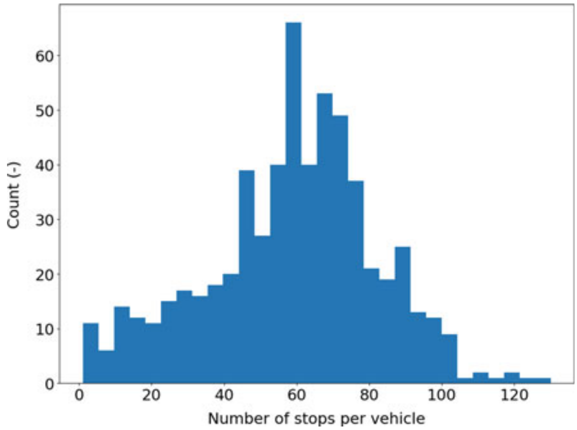


Fig. 9 Average time savings recorded for real postal routes between services using conventional versus three-wheeled SEVs for delivery

Fig. 10 DXP vehicles stop an average of 57 times per route, resulting in substantial time and cost savings



5 Commercial Efficiency

Here, we examine the question: *Which economic indicators are decisive for fleet customers when considering the switch to SEVs, with an emphasis on total cost of ownership?*

Considering only purchase, maintenance, fuel, and disposal costs based on the assumptions illustrated in Table 4, we analyze the total cost of ownership for last-mile delivery fleets. We assume that both types of vehicles must travel the same km per year, although it is likely that the internal combustion engine (ICE) vehicles would be required to travel further due to their diminished load capacity. We also include a positive residual value of 700 € for the SEV due to SecondLife considerations described in Sect. 5.

Table 4 Assumptions for calculating the total cost of ownership comparison

	Electric delivery vehicle	ICE incumbent
Purchase price CHF	10,000	3,000
7 year replacements	1	2.5
Carrying capacity kg	270	89
Km/year	5,000	5,000
Fuel cost CHF/L-eq	0.65	1.49
Maintenance cost CHF/km	0.29	0.24
End of life disposal cost	−700	100
Total cost of ownership CHF/km	0.57	0.59

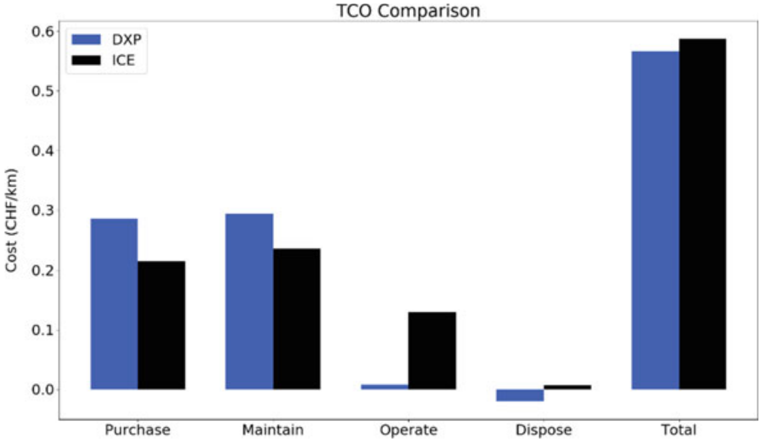


Fig. 11 Total cost of ownership for the DXP is 0.02 CHF lower than for the ICE

The result of the total cost of ownership modeling can be seen in Fig. 11. Although a savings of 0.02 CHF/km does not seem like an impressive margin, our conservative assumption is that a typical small national postal fleet drives 150,000 km/day (roughly what the Swiss Post is travelling), then over the vehicle fleet's seven year lifetime, we estimate savings of 5,561,729 CHF from switching to SEVs. However, the more significant effect results from the increased payload efficiency of SEVs compared to ICE vehicles. We could estimate roughly a 3× higher payload for SEVs, saving 3× the number of replenishment trips and reduced overall number of vehicles, which leads to substantial cost reductions.

6 Circular Economies

In this final section, we describe our answer to the question: *What can be done at the end of life for SEVs which further increase their economic value and reduce the demand for critical raw materials?*

In 2019, we received 1,153 vehicles back from the Swiss Post as part of a buy-back agreement. To improve the ecological benefit of our vehicles, we created a refurbishment production line that we call KYBURZ SecondLife. To date, we sold 198 refurbished vehicles, and 63 in as-is condition, representing an overall net economic loss, but at substantial ecological gain. The economic benefit of battery recycling is not presently known, but as part of this project KYBURZ has also commissioned a battery recycling line to handle the recycling in-house (Fig. 12).

Details of the scheme and the material balance and flows are shown in Fig. 13. Although the overall economic benefit of the SecondLife project is presently not positive, and the outlook is uncertain, KYBURZ will continue the project since the ecological benefits are clear, such as the advantage of being a family-owned and operated business.

Fig. 12 KYBURZ SecondLife project refurbishment hall and production line

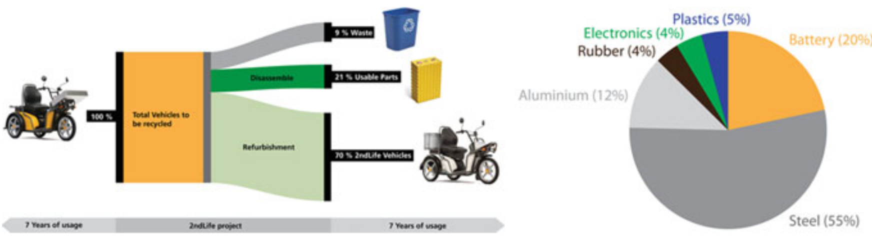


Fig. 13 Majority of the KYBURZ DXPs are refurbished, and those which are recycled result in good yields

7 Summary and Conclusions

To conclude, in this short chapter, we describe our successful deployment of SEVs in the form of the KYBURZ DXP, and draw the following conclusions:

1. Telematics data is extremely valuable for companies in the SEV market wishing to better understand their products,
2. SEVs are at least one third, and perhaps as much as 50% less CO_2 emitting than their ICE-based competitors,
3. The use of SEVs in package delivery operations in urban environments could easily save over 20 km^2 per operation day, reducing congestion and point-source emissions,
4. The total cost of SEV ownership is lower than ICE-based competitors due to reduced replacement rates, greater carrying capacity, and increased operational efficiency,
5. Though it is presently economically irrational, the ecological advantages from refurbishing SEVs for second life deployments means KYBURZ will pursue this approach.

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