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Generation of used lead-acid batteries in Africa – estimating the volumes

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ULAB	Used lead-acid battery
LAB	Lead-acid battery
OICA	Organisation Internationale des Constructeurs d'Automobiles / Organization of Motor Vehicle Manufacturers
UPS	Uninterruptible power supply
USGS	U.S. Geological Survey

1. Background

According to the International Lead Association, lead has one of the highest recycling rates of all material commonly used today, even higher than the recycling rate of glass or newspaper. Amongst other factors, this results from the high quality of recycled lead. There is basically no degradation in the recycled lead compared to the lead from primary mining (ILA, 2016). Nevertheless the inappropriate processing and recycling of lead can cause serious danger to human health and the environment.

In many African countries, the recycling of lead-acid batteries is economically attractive because of its high lead-content. Due to inappropriate practices in most parts of Africa, the recycling of lead-acid batteries is assumed to have a negative impact on human health and the environment. In field studies on the lead-acid battery recycling chain in Ghana for example, it was found that "persons involved in collecting and transport of lead-acid batteries drain the contained acid prior to transport by opening the plugs or punching holes into the case" (Manhart, A.; Schleicher, T. 2015) Due to the toxicity of lead and the sulfuric acid of the batteries, this causes massive lead contamination of soil and waterbodies. Besides, batteries are manually broken to extract the lead scrap which causes massive emissions of highly harmful lead-dust.[1]

Around 85 % of the total lead produced worldwide is consumed by lead-acid batteries (ILA, 2012). The most important application of lead-acid batteries is the use in motor vehicles. Further they are used in off-mains electricity systems (ITRI, 2011) such as Uninterruptible Power Supplies (UPS).

2. Introduction

This paper provides an estimation on the total annual generation of used lead-acid batteries (ULABs) in Africa. The derivation is based on data from the International Organization of Motor Vehicle Manufacturers OICA about the number of vehicles in use in Africa as well as sound assumptions about service live, weight and lead content of ULABs.

The African lead-acid battery market can be segmented in different ways. For example, it can be differentiated by the operating mode of the battery (engine starting, motive power, standby power and valve regulated lead-acid batteries) or by its application (industrial, automobile, commercial and residential power) (TMR, 2015). As this paper focuses on the overall generation of ULABs it distinguishes only between

- Used lead-acid batteries from use in vehicles and
- Used lead-acid batteries from stationary use.

[1] Find core findings of observations in Ghana and general considerations on lead-acid battery recycling in the paper "The recycling chain for used lead-acid batteries in Ghana" of Manhart, A.; Schleicher, T. 2015.

3. Used lead-acid batteries from use in vehicles

As in many African countries the availability of statistical data is difficult. Nevertheless, a consistent data base is needed. The OICA gives a consistent annual overview on the number of vehicles in use worldwide by continent and country. This paper applies the figures in “World Commercial Vehicle in use" by country and type 2005-2013 and “World Passenger Cars in use" by country and type 2005-2013 released by OICA in March 2015, retrieved in February 2016..

The term V*ehicles in use* composes all registered vehicles on the road. According to OICA, the figures are obtained from “national trade organizations, OICA members or correspondents, National Offices of Statistics or Ministries of Transport.” (OICA, 2016a). Two types of vehicles are distinguished:

- Passenger Cars: Passenger cars are road motor vehicle, other than a motor cycle, intended for the carriage of passengers and designed to seat no more than nine persons […], and
- Commercial Vehicles: Commercial vehicles include light commercial vehicles, heavy trucks, coaches and buses. (OICA, 2016a).

It is stated that data of buses or heavy trucks is not available in some countries. Besides, there is no data given for the following African countries: Cape Verde, Central African Republic, Chad, Comoros, Djibouti, Equatorial Guinea, Eritrea, Gabon, Gambia, Guinea, Guinea-Bissau, Lesotho, Namibia, Niger, Republic of Congo, Rwanda, Sahara, Sao Tome and Principe, Seychelles, Sierra Leone, Somalia, South Sudan, Swaziland and Togo.

Due to the given exclusions and the fact that only registered vehicles can be considered, the total amount of passenger cars and commercial vehicles in use can be regarded as conservative basis for the derivation of ULABs in use in vehicles.

To estimate the total amount of ULABs in use in vehicles the following formula will be applied:

$$\text{Generation of ULABs from vehicles [t/a]} = \frac{\text{Passenger Cars in use [n]} * \text{LABs per vehicle [n]} * \text{weight of LAB [t]}}{\text{Service life of LAB [a]}} + \frac{\text{Commercial vehicles in use[n]} * \text{LABs per vehicle[n]} * \text{weight of LAB[t]}}{\text{Service life of LAB [a]}}$$

Table 3-1 gives an overview on the number of Passenger Cars in use in Africa from 2007 to 2013 and the average annual growth rate of each country. The annual numbers are given by OICA. The average annual growth rate is calculated on the basis of the individual annual growth rates from 2007 to 2013.

Table 3-1: Passenger Cars in use in Africa [1000 units]

Country	2007	2008	2009	2010	2011	2012	2013	Avg. annual growth rate
	In thousand units							*In %*
Algeria	2,212	2,395	2,593	2,691	2,800	3,050	3,268	6.7
Angola	400	566	574	590	610	640	670	9.8
Benin	146	153	160	167	170	180	190	4.5
Botswana	105	121	135	177	180	190	210	12.6
Burkina Faso	105	109	112	116	120	130	140	4.9
Burundi	16	16	16	17	18	20	20	3.9
Cameroon	184	193	201	210	220	230	240	4.5
DR Congo	911	914	917	920	943	982	1,000	1.6
Egypt	2,400	2,546	3,000	3,437	3,600	3,800	4,000	9.0
Ethiopia	73	75	76	77	79	82	90	3.6
Ghana	370	500	440	450	470	490	510	6.4
Ivory Cost	298	312	326	340	350	370	390	4.6
Kenya	450	578	500	520	540	570	620	6.2
Liberia	16	13	13	13	14	15	20	4.9
Libya	1,400	1,420	1,430	1,436	1,500	1,600	1,700	3.3
Madagascar	110	146	141	150	160	170	180	9.1
Malawi	44	55	55	60	60	60	60	5.7
Mali	98	116	119	124	130	140	150	7.5
Mauritania	13	13	13	14	15	16	20	7.8
Mauritius	100	110	118	127	136	148	160	8.2
Morocco	1,644	1,721	1,798	1,875	2,000	2,100	2,200	5.0
Mozambique	156	156	204	233	240	250	270	10.0
Nigeria	2,200	2,250	2,288	2,400	2,500	2,600	2,700	3.5
Senegal	172	189	197	206	210	266	270	8.1
South Africa	5,161	5,276	5,411	5,596	5,832	6,111	6,377	3.6
Sudan	40	40	41	41	42	44	50	3.9
Tanzania	80	177	180	190	200	210	220	23.9
Togo	105	105	106	108	111	116	120	2.3
Tunisia	830	787	820	848	855	862	900	1.4
Uganda	91	94	97	101	110	120	130	6.2
Zambia	200	135	190	200	210	220	230	4.6
Zimbabwe	610	617	626	650	680	710	750	3.5
Africa	**20,740**	**21,898**	**22,897**	**24,084**	**25,105**	**26,492**	**27,855**	
Annual growth rate		5.6	4.6	5.2	4.2	5.5	5.1	5.0
	Estimated figures							
	Own calculation							

Source: Own compilation with data from OICA, 2016c. Annual growth rate and Average annual growth rate calculated.

With the calculated average annual growth rate at hand, the number of passenger cars in use is extrapolated until 2016. Table 3-2 shows this forecast for passenger cars in use in the indicated African countries for years 2014, 2015 and 2016. In total, it is estimated that in the indicated countries around 32.7 Mio. passenger cars are in use.

Table 3-2: Passenger Cars in use in Africa Forecast 2014 - 2016

Country	2014	2015	2016
	In thousand units		
Algeria	3,488	3,723	3,974
Angola	736	808	886
Benin	199	207	217
Botswana	236	266	300
Burkina Faso	147	154	162
Burundi	21	22	22
Cameroon	251	262	274
DR Congo	1,016	1,032	1,048
Egypt	4,360	4,753	5,181
Ethiopia	93	97	100
Ghana	542	577	614
Ivory Cost	408	427	446
Kenya	658	699	742
Liberia	21	22	23
Libya	1,756	1,815	1,875
Madagascar	196	214	234
Malawi	63	67	71
Mali	161	173	186
Mauritania	22	23	25
Mauritius	173	187	202
Morocco	2,310	2,424	2,545
Mozambique	297	327	360
Nigeria	2,794	2,891	2,992
Senegal	292	316	341
South Africa	6,606	6,844	7,089
Sudan	52	54	56
Tanzania	273	338	419
Togo	123	125	128
Tunisia	913	926	939
Uganda	138	147	156
Zambia	241	252	263
Zimbabwe	776	804	832
Africa	**29,362**	**30,975**	**32,704**
Annual growth rate	5.4	5.5	5.6
	Own calculation		

Source: calculated figures based on data of table 2-1

Table 3-3 provides an overview on the number of commercial vehicles in use in selected African countries from 2007 to 2013 and the average annual growth rate of each country. The annual numbers are given by OICA. The average annual growth rate is calculated on the basis of the individual annual growth rates from 2007 to 2013.

Table 3-3: Commercial vehicles in use in Africa [1000 units]

Country	2007	2008	2009	2010	2011	2012	2013	Avg. annual growth rate
	In thousand units							*In %*
Algeria	1,100	1,150	1,254	1,290	1,330	1,483	1,567	6.1
Angola	90	124	126	130	130	130	133	7.5
Benin	20	38	39	40	41	40	41	16.3
Botswana	106	114	118	120	120	120	120	2.1
Burkina Faso	44	46	49	51	52	50	52	2.9
Burundi	30	34	34	35	36	40	41	5.5
Cameroon	63	67	69	71	73	80	82	4.5
DR Congo	704	708	709	711	726	741	760	1.3
Egypt	750	931	940	954	980	1,010	1,030	5.7
Ethiopia	55	56	57	58	59	60	61	1.7
Ghana	200	280	270	280	290	300	310	8.4
Ivory Cost	373	403	414	424	440	450	470	3.9
Kenya	280	237	396	400	410	420	440	10.4
Liberia	40	38	39	40	41	40	41	0.5
Libya	400	410	420	430	440	450	470	2.7
Madagascar	160	365	370	380	390	400	420	23.7
Malawi	50	68	69	70	72	70	73	7.2
Mali	30	28	29	30	31	30	31	0.6
Mauritania	19	20	21	21	22	20	20	1.0
Mauritius	41	42	43	43	44	43	45	1.6
Morocco	512	553	569	582	600	620	730	6.2
Mozambique	57	57	72	82	84	90	94	9.0
Nigeria	660	670	679	690	710	730	740	1.9
Senegal	229	259	266	273	280	290	300	4.7
South Africa	2,642	2,741	2,810	2,876	2,962	3,057	3,149	3.0
Sudan	50	50	52	53	54	55	57	2.2
Tanzania	80	135	137	140	140	140	140	12.1
Togo	48	49	49	50	51	52	54	2.0
Tunisia	220	390	400	411	414	417	430	14.5
Uganda	212	219	259	265	270	280	300	6.1
Zambia	80	83	108	110	110	110	113	6.4
Zimbabwe	90	93	95	97	100	100	103	2.3
Africa	**9,435**	**10,458**	**10,962**	**11,207**	**11,502**	**11,918**	**12,417**	
Annual growth rate		10.8	4.8	2.2	2.6	3.6	4.2	4.7
	Estimated figures							
	Own calculation							

Source: Own compilation with data from OICA, 2016d. Annual growth rate and Average annual growth rate calculated.

With the calculated average annual growth rate the number of commercial vehicles in use is extrapolated until 2016. Table 3-4 shows the forecast for commercial vehicles in use in the indicated African countries for 2014, 2015 and 2016. This sums-up to around 14.7 million commercial vehicles for all of the African countries analysed in 2016.

Table 3-4: Commercial Vehicles in use in Africa Forecast 2014 - 2016

Country	2014	2015	2016
	In thousand units		
Algeria	1,663	1,765	1,873
Angola	143	154	165
Benin	48	55	64
Botswana	123	125	128
Burkina Faso	53	55	57
Burundi	43	46	48
Cameroon	86	90	94
DR Congo	770	780	790
Egypt	1,089	1,151	1,217
Ethiopia	62	63	64
Ghana	336	364	395
Ivory Cost	489	508	528
Kenya	486	536	592
Liberia	41	41	42
Libya	483	496	510
Madagascar	520	643	796
Malawi	78	84	90
Mali	31	31	32
Mauritania	20	20	21
Mauritius	46	46	47
Morocco	775	824	875
Mozambique	102	112	122
Nigeria	754	769	784
Senegal	314	329	344
South Africa	3,243	3,339	3,438
Sudan	58	60	61
Tanzania	157	176	197
Togo	55	56	57
Tunisia	492	564	646
Uganda	318	338	358
Zambia	120	128	136
Zimbabwe	105	108	110
Africa	**13,104**	**13,855**	**14,679**
Annual growth rate	5.5	5.7	5.9
	Own calculation		

Source: calculated figures based on data of table 2-3

In order to estimate the annual generation of ULAB in Africa on basis of the number of vehicles in use the following information and assumptions are taken into account (Table 3-5 and Table 3-6):

Table 3-5: Information on weight and required units of lead-acid batteries

Lead-acid battery	For use in Passenger Cars	For use in Commercial Vehicles
Weight	20 kg	50 kg
Required units per vehicle	1	2

Source: Buchert, B.; Manhart, A.; Recycling global – Best-of-two-Worlds Projekt und Recycling von Blei-Säure-Batterien in Afrika. In: Thomé-Kotmiensky, K.J.; Goldmann, D.: Recycling und Rohstoffe Band 9. TK Verlag, Neuruppin, 2016

Table 3-6: Assumptions on service life and lead content of lead-acid batteries

Lead-acid battery	For use in Passenger Cars	For use in Commercial Vehicles
Service life	2 years	2 years
Content of lead per battery	65 %	65 %

Source: own estimations

Expected service life of a lead-acid battery is assumed to be 3 years. However, certain conditions do affect the service life. In the case of most African areas, the lead-acid battery market is dominated by inexpensive batteries with a limited life-time. Furthermore, high temperatures and bad road conditions affect the lifetime of batteries negatively. Due to this, the service life of a lead-acid battery in use in Africa is assumed to be around two years.

A lead-acid battery contains 20 to 30 % metallic lead and 35 to 45 % lead paste (Lehmann, C., 2013). Thus, the content of lead per battery is assumed to be 65 % of the total weight.

Table 3-6 shows the calculated estimation of the total weight of ULABs per year and country. ULABs generated by *Passenger Cars in use* in Africa in 2016 have a weight of about 330,000 tons. The *Commercial Vehicles in use* in Africa in 2016 are estimated to generate ULABs weighing round about 730,000 tons. In total, the generation of ULABs from the use in vehicles sums up to more than 1 million tons in 2016.

Table 3-7: Total annual generation of ULABs from vehicles in Africa 2016 [t/a]

	Passenger Cars			Commercial Vehicles			
	PCs in use 2016 [1.000 units]	Generation of ULABs [1.000 units]	Weight of ULABs [t/a]	CVs in use 2016 [1.000 units]	Generation of ULABs [1.000 units]	Weight of ULABs [t/a]	Total weight of ULABs [t/a]
Algeria	3,974	1,987	39,744	1,873	1,873	93,637	**133,382**
Angola	886	443	8,865	165	165	8,256	**17,121**
Benin	217	108	2,168	64	64	3,224	**5,392**
Botswana	300	150	2,999	128	128	6,391	**9,390**
Burkina Faso	162	81	1,618	57	57	2,831	**4,449**
Burundi	22	11	224	48	48	2,404	**2,628**
Cameroon	274	137	2,741	94	94	4,682	**7,423**
DR Congo	1,048	524	10,480	790	790	39,488	**49,968**
Egypt	5,181	2,591	51,811	1,217	1,217	60,863	**112,674**
Ethiopia	100	50	1,000	64	64	3,212	**4,213**
Ghana	614	307	6,137	395	395	19,751	**25,888**
Ivory Cost	446	223	4,462	528	528	26,393	**30,856**
Kenya	742	371	7,423	592	592	29,608	**37,032**
Liberia	23	12	231	42	42	2,078	**2,309**
Libya	1,875	938	18,751	510	510	25,476	**44,226**
Madagascar	234	117	2,336	796	796	39,780	**42,116**
Malawi	71	35	708	90	90	4,498	**5,207**
Mali	186	93	1,862	32	32	1,580	**3,442**
Mauritania	25	13	250	21	21	1,030	**1,280**
Mauritius	202	101	2,024	47	47	2,359	**4,383**
Morocco	2,545	1,273	25,452	875	875	43,750	**69,202**
Mozambique	360	180	3,596	122	122	6,093	**9,689**
Nigeria	2,992	1,496	29,917	784	784	39,181	**69,097**
Senegal	341	171	3,414	344	344	17,201	**20,615**
South Africa	7.089	3,545	70,894	3,438	3,438	171,900	**242,794**
Sudan	56	28	561	61	61	3,044	**3,604**
Tanzania	419	209	4,187	197	197	9,853	**14,040**
Togo	128	64	1,283	57	57	2,864	**4,148**
Tunisia	939	469	9,387	646	646	32,297	**41,684**
Uganda	156	78	1,555	358	358	17,917	**19,473**
Zambia	263	132	2,635	136	136	6,807	**9,442**
Zimbabwe	832	416	8,319	110	110	5,510	**13,830**
Africa	**32,704**	**16,352**	**327,036**	**14,679**	**14,679**	**733,960**	**1.060,996**

Source: Calculated figures based on data of Table 3-6

4. Used lead-acid batteries from stationary use

More noteworthy applications of lead-acid batteries in stationary use are Uninterruptible Power Supply (UPS) systems.

A UPS supplies energy stored in batteries in case the input power of a grid system fails. For example, mains power supply is generally not straight-lined – in practice the voltage level alternates slightly. These slight alternations include voltage peaks which can damage the sensitive electronic components of IT equipment. Besides, they allow to bridge outages of the grid power supply. A UPS stores the energy and delivers a straightened voltage to the system so that no electronic components are damaged. Furthermore, it delivers a backup power in any case of power supply outage, either to allow IT equipment to shut down orderly or to keep required loads until a generator comes online. Thus, the loss of important data can be avoided (Loeffler, C.; Spears, E., 2015). It is mostly used in data centres or in off-grid household power systems.

There is no statistical data available on the number of UPS in use in Africa. According to the industrial technology research institute the share of market applications for lead-acid batteries is as follows:

- 61 % in automobile and transportation,
- 21 % in other vehicles including motorcycles and electric bicycles,
- 10 % in UPS, and 8 % in other applications (ITRI, 2011).

In the following, it is assumed that this share of UPS would also hold for African countries. Accordingly, with an annual generation of ULABs from vehicles in Africa of 1,060,996 tons, there is a generation of ULABs from UPS of 173,934 tons.

A further important application of lead batteries is off-grid electrification, which is becoming an increasing political priority globally. Nevertheless, there are no data on this segment available for Africa. Thus, this segment was not taken into account in this estimation.

5. Total annual generation of ULABs in Africa

With an annual generation of ULABs from vehicles in Africa of more than 1 million ton and a generation of ULABs from UPS of around 170,000 tons the total annual generation of ULABs in Africa is estimated to sum up to more than 1.2 million tons.

This estimation can be regarded as conservative due to fragmentary data about buses and heavy trucks in Africa and due to a lack of information about vehicles in use in certain countries of Africa (see exclusions in chapter 3). Besides, the derivation is not taking into account all applications of Lead-acid batteries such as off-grid electrification.

Table 5-1: Total annual generation of ULABs in Africa 2016 [t/a]

Total annual generation of ULABs from vehicles [t/a]	Total annual generation of ULABs from stationary use [t/a]	Total annual generation of ULABs [t/a]
1,060,996	173,934	1,234,930

Source: Calculated figures based on data of Table 3-6 and assumption given in chapter 4.

Assuming that each ULAB contains around 65 % of lead, there are more than 800,000 tonnes of lead from batteries available for recycling in per year.

According to the U.S. Geological Survey (USGS) the annual production of refined lead summed up to 10.5 million tons worldwide in 2013 (USGS, 2015). Thus, the annual volumes of lead from ULABs in Africa are quite considerable in global terms. Assuming that world refined lead production in 2016 is equal to those of 2013, the lead from African ULABs would equal to 8 % of the worldwide refined lead production.

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