First Dutch Battery Flows Monitor – 2020

Commissioned by Stibat

STIBAT

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[1] https://www.stibat.nl/

Executive Summary

Executive Summary

This report delivers a baseline study for the portable battery waste flows, as described in the Battery Directive 2006/66, for the year 2019, using a replicable methodology that is consistent with the Dutch WEEE Flows 2020 study (Baldé et al. 2020). The goal is to provide well-evidenced information for investigating the collection rate of waste batteries and monitor other previously undocumented battery flows in the Netherlands.

This study shows that in 2019, a total of:

- 9.3 kilotons (kt) of batteries were Placed on the Market (POM) in the Netherlands,
- 24.2 kt of batteries were in use or hibernating in households, companies, and the public sector,
- 9.5 kt of batteries became waste.

This corresponds to approximately 500 Million units of batteries POM, 1,000 Million (1 Billion) units of batteries in use or in hibernation in households, companies, and the public sector, and 500 Million units of Battery Waste Generated. The generation of portable battery waste in the Netherlands has been increasing by 1.3 kt since 2016 with an average annual grow rate of 5%. The share of portable batteries in households is 90%, and 10% is calculated as existing in companies and in the public sector.

The battery waste flows show that, out of 9.5 kt of Battery Waste Generated in the Netherlands:

- 4.6 kt was compliantly declared in 2019:
    - 3.7 kt was separately collected by StiBat;
    - 0.9 kt was reported by recyclers and collectors apart from StiBat;
- 2.6 kt was disposed of in residual solid waste:
    - as loose batteries (1.8 kt);
    - embedded in WEEE (0.8 kt);
- 0.9 kt was embedded in WEEE not compliantly recycled and declared;
- 0.4 kt was embedded in exported used EEE (UEEE) and WEEE.

The fate of 1 kt of battery waste – with an overall uncertainty of ± 0.3 kt – in 2019 remains unknown.

Article 10 of the Battery Directive specifies that Member States shall achieve a 45% minimum collection rate by 26 September 2016. For 2019, the collection rate for the Netherlands is 50.6%, showing that the Netherlands is reaching the collection target set by the Battery Directive.

Nevertheless, this study reveals that 0.4 kt of batteries that were placed on the market are not becoming waste in the Netherlands, as they are exported as embedded in UEEE or WEEE. If those batteries are subtracted from the POM, similar to what the Netherlands does in the context of the WEEE Directive, the collection rate would increase from 50.6% to 53.2%.

Furthermore, it is expected that the collection rate would further increase if WEEE collection were to increase, as batteries would be diverted from unwanted flows (e.g. in residual solid waste, or in non-compliant recycling) to the compliantly declared collection. In a scenario in which batteries embedded in discarded WEEE in residual solid waste and non-compliant WEEE flows were to decrease by half, the collection rate of batteries would increase to 57%[2].

[2] This value does not take into account the deduction of batteries embedded in exported used EEE or WEEE from POMs.

Table of Contents

Table of Contents

Chapter 1:
Introduction

1. Introduction

On 6 September 2006, the European Parliament and the European Council approved the new directive 2006/66 on batteries and accumulators as well as waste batteries and waste battery accumulators (European Paliament 2006).

The Directive specifies restrictions on the use of mercury in all batteries and a restriction on the use of cadmium in portable batteries, with certain exemptions; collection requirements for all batteries and collection targets for portable batteries; the requirement that all batteries and accumulators collected must be properly treated and recycled; a ban on landfilling or incinerating automotive and industrial batteries; and the requirement that battery recycling processes must meet minimum levels of efficiency.

Article 10 of the Battery Directive specifies that Member States shall achieve the 45% minimum collection rate by 26 September 2016. The Directive distinguishes between portable/industrial and automotive batteries. This study addresses only portable batteries.

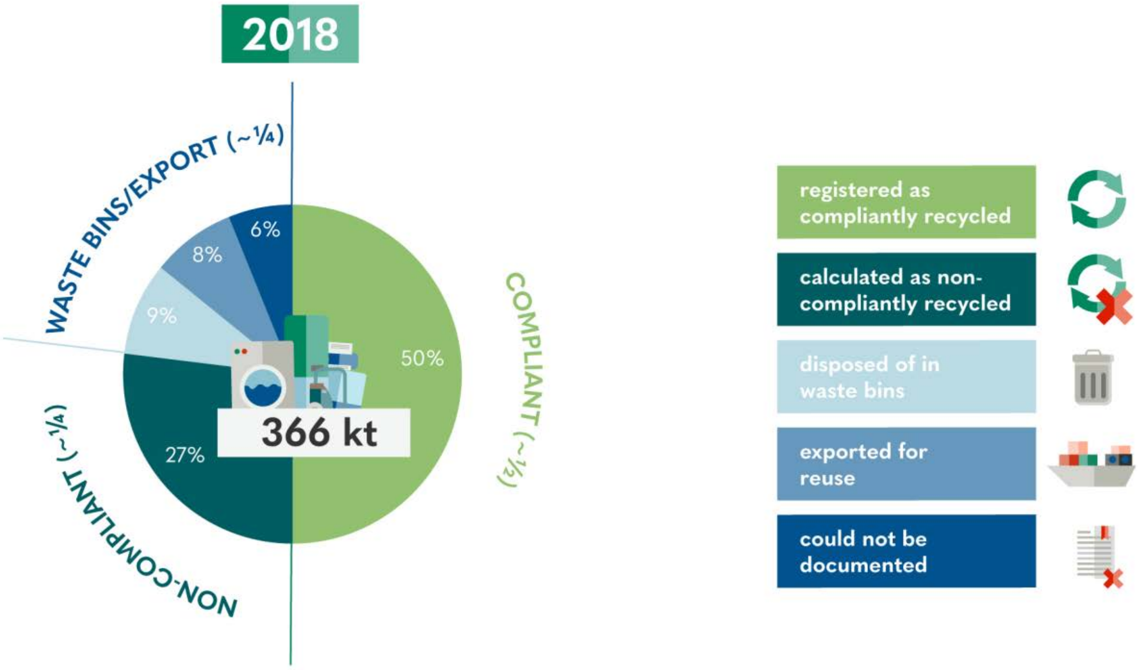
The overall objective of this study is to perform a baseline study for the year 2019, using a methodology that can be replicated in future years. The study also provides insights into all portable Battery Flows in the Netherlands, with the aim of quantifying Battery Flows that are fully consistent with The Dutch WEEE Flows 2020 study (Baldé et al. 2020), to investigate the collection rate of waste batteries and monitor other previously undocumented battery flow in the Netherlands.

The Dutch WEEE Flows 2020 study is directly related to this study because several EEE and WEEE items contain portable batteries. Such is the case for small equipment (such as clocks, food processing equipment, etc) or small IT equipment (such as keyboards, mice, phones, etc), screens (such as laptops, e-readers, etc), lamps, and other large equipment (such as toys or professional tools).

Similar to the Battery Directive, the WEEE Directive (European Paliament 2003) set collection, recycling, reuse, and recovery targets for WEEE. Since 2018, article 7 of the WEEE Directive states that the minimum collection rate to be achieved annually by a Member State shall be either 65% of the average weight of EEE POM in the three preceding years or 85% of WEEE generated on the territory of a Member State in 2018.

The Dutch WEEE Flows 2020 study (Baldé et al. 2020) presents the EEE POM, WEEE Generated, compliantly regulated WEEE Collection, and WEEE Flows outside of the regulated WEEE management system in the Netherlands. The methodology of the study followed an internationally recognised measurement framework for integrating all available statistical data, field studies, household and business surveys, internal data from compliance schemes, and data from the National (W)EEE Register (NWR) for the Netherlands. The main findings are shown in Figure 1.

Figure 1. WEEE Generated and WEEE flows in 2018 (Source: Baldé et al, 2020)



In 2018, the WEEE Generated was 366 kt, half of which was registered as compliantly recycled in the NWR. Approximately one quarter is calculated as being non-compliantly recycled (27%), and roughly another quarter was disposed of in waste bins, exported for reuse, or could not be documented.

Chapter 2: Methodology

2. Methodology

The methodology for the calculation of Battery Flows uses a mass balance approach and follows the same principles as developed in the Prospecting Secondary raw materials in the Urban mine and Mining wastes (ProSUM)[3] and further specified for the Battery Directive. The methodology is conceptually consistent with the internationally harmonised framework for measuring WEEE (Baldé et al. 2015 and Forti, Baldé, and Kuehr 2018). The methodology uses official data of batteries Placed on the Market (POM) from Stibat and lifetime data as a basis for the calculation of Battery Waste Generated. Data for Battery Flows were collected in part from official sources (e.g. battery waste collection from Stibat and other recyclers) and also derived from existing data sets on WEEE flows.

2.1 Classifications – Battery Keys

A classification system for batteries was developed for this study and formed the basis of the calculations. The battery classification is based on 12 main portable battery chemistries that are on the Dutch market (Table 1). The classification is based on the internal classification system at Stibat and was linked to the classification developed under the European projects: ProSUM, Optimising data collection for Primary and Secondary Raw Materials (ORAMA)[4] and the Raw Materials Information System (RMIS)[5]. The classification system is constructed in such a way that battery groups are compatible with classifications by chargeability type and battery recycling flows. Additionally, the classification is consistent with the scope and classification identified in the Battery Directive.

A correlation between the internal classification systems at Stibat and the ProSUM classification (Huisman et al. 2017) was created as indicated in Table 1. Some categories present in the Stibat classification are not present in the ProSUM classification; such is the case of alkaline-manganese, mercury oxide, and silver oxide batteries. Other chemistries such as Metal, Plastic, and N/A are also not present in the ProSUM classification but were analysed and are grouped in the "Other Batteries" category in this study.

Table 1. Correspondence list between the classification used in this study, the Stibat classification, and the ProSUM classification.

Classification used in this study	Stibat Classification	ProSUM Classification
Lithium	Lithium	battLiPrimary
Lithium-ion	Lithium-ion	battLiCoO2
		battLiNMC
		battLiMn
		battLiFePO4
Lithium-Polymer	Lithium-Polymer	battLiNMC/ battLiCoO2

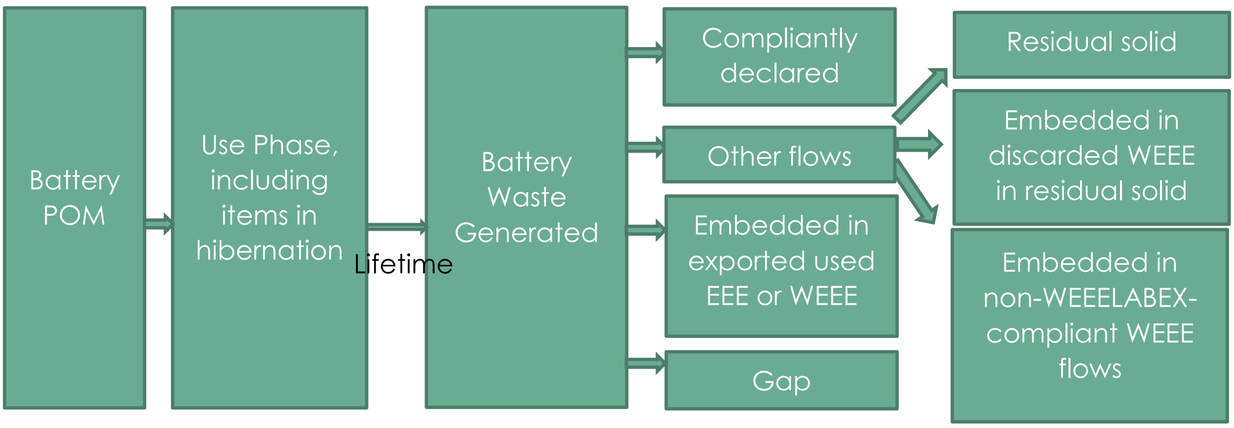
[3] www.prosumproject.eu
[4] https://orama-h2020.eu/
[5] https://rmis.jrc.ec.europa.eu/apps/bvc/#/p/methodology

Lead	Lead	battPbSealed
Nickel-Cadmium	Nickel-Cadmium	battNiCdSealed
Nickel-Metal Hydride	Nickel-Metal Hydride	battNiMHSealed
Zink	Zink	battZn
Zink-Carbon	Zink-Carbon	battZn
Alkaline-Manganese	Alkaline-Manganese	battZn
Zinc Oxide	Zinc Oxide	battZn
Silver Oxide	Silver Oxide	battOtherPrimary
Other Batteries	Plastic	battOtherPrimary
Other Batteries	Metal	battOtherPrimary
Other Batteries	Unknown	battOtherPrimary

2.2 Measurement framework

The measurement framework for calculating the Battery Flows uses a mass balance approach in which the entire life cycle is taken into account: from Placed on the Market (POM) and the use phase to Battery Waste Generated and battery waste collection. In the Battery Flows approach, all stages of the life cycle are mathematically related through mass balances (Figure 2). Datasets are created for weights, but calculations for Battery POM, use phase, and Battery Waste Generated were also performed for the number of units, through conversions of average weights per battery chemistry.

Figure 2. Measurement framework



The measurement framework starts with accounting the batteries **Placed on the Market (POM)** in the Netherlands. The market entry includes batteries placed on the market by households, businesses, and the public sector. Once the batteries have been sold, they remain either as loose batteries or as batteries embedded in Electric or Electronic Equipment (EEE) in households or businesses or as batteries in use in the public sector. This period is called the "use phase" and includes batteries embedded in EEE or loose batteries that are in hibernation or hoarded.

Data related to batteries POMs were provided by Stibat for the period 2009-2019, both in kg and in units for the chemistries listed in Table 1.

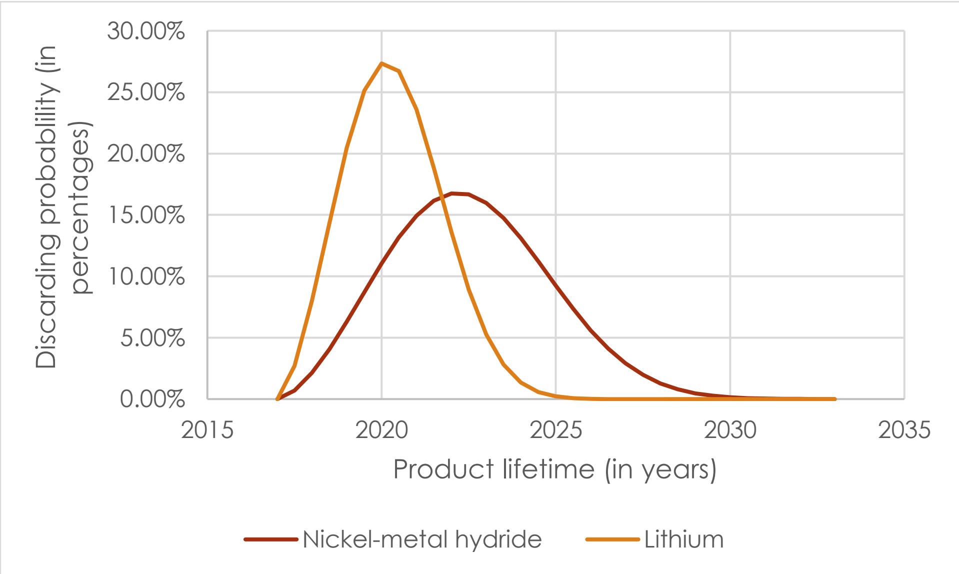
After a certain "**lifetime**" – which varies according to battery chemistry, but could be also related to the EEE products in which they are used – the battery is disposed of and becomes waste. The lifetime is the time from POM to waste and includes the hoarding time of the batteries. The lifetime can be mathematically described using several probability functions. This study uses the Weibull function, as it is considered to be the most suitable function for describing discarded behavior of EEE and batteries.

The Weibull function is defined by a time-varying shape parameter α (t) and β (t), a scale parameter as described in the equation [1]. The lifetime, $L^{(p)}$ (t, n), is the lifetime profile of an EEE sold in historical year t, which reflects its probable obsolescence rate in evaluation year n.

[1] $$L^{(p)}(t,n) = \frac{\alpha}{\beta^{\alpha}}(n-t)^{\alpha-1}e^{-[(n-t)/\beta]^{\alpha}}$$

An example of lifetime distributions for Nickel-metal hydride and Lithium batteries is presented below in Figure 3. The X axis represents years, while the Y axis represents the discarding probability of Nickel-metal hydride and Lithium battery POMs.

Figure 3. Nickel-metal hydride and Lithium battery Waste Generated per year in percentage of POM



From the moment the battery is disposed of, it becomes battery waste and is considered Battery Waste Generated.

Battery Waste Generated is defined as the battery waste generated within the Netherlands, either as separate batteries or as batteries embedded in WEEE, prior to the waste's collection. The amount of Battery Waste Generated was calculated from the time series of batteries POM from all historical years, taking into account their respective rates of obsolescence in the evaluation year n. The method is represented by Eq. [2].

[2] $$Batt\ Waste\ generated\ (n) = \sum_{t=t_0}^{n} POM\ (t) * L^{(p)}(t,n)$$

Where Batt Waste Generated (n) is the quantity of Battery Waste Generated in evolution year n, POM (t) is the product sales (Placed on the Market) in any historical years t prior to year n; t_0 is the initial year that a product was sold; $L^{(p)}$ (t, n) is the discard-based lifetime profile for the batch of batteries sold in historical year t.

The Battery Waste Generated can be collected and managed in different ways, and several **Battery Flows** are identified (see Figure 2):

1) **"Compliantly declared"** recycling of batteries. Formal collection activities fall under the requirement of the Battery Directive, in which battery waste is collected by Stibat or other designated recyclers or organisations in the Netherlands. Two battery waste flows can be identified:
   - "Separately collected by Stibat"
   - "Reported by recyclers/collectors other than Stibat or by third-party collectors"

   This data was obtained from Stibat's internal data.

2) **"Embedded in exported used EEE or WEEE".** This notation refers to all batteries that are embedded EEE and shipped to another country as second-hand goods or for recycling purposes (see Annex 2 for the steps on how this was quantified).
   This data was calculated from the detailed data from the Dutch WEEE Flows 2020 study. See Annex 2 on how the data was quantified.

3) **"Other flows"** consist of batteries:
   - Disposed of in **"residual solid waste as loose batteries"**
     This data was obtained from sorting analysis from Eureco (Stibat 2019)
   - **"embedded in discarded WEEE in residual solid waste"**
     This data was calculated from the detailed data from the Dutch WEEE Flows 2020 study. See Annex 2 on how the data was quantified.
   - **"embedded in non-WEEELABEX-compliant WEEE flows"** consists of batteries embedded in WEEE that is most likely recycled with metal scrap.
     This data was calculated from the detailed data from the Dutch WEEE Flows 2020 study. See Annex 2 on how the data was quantified.

4) **"Gap"** is the difference between the total Battery Waste Generated and the total of the Battery Flows; it provides an indication of the data gap.

The total Battery Waste Generated is thus the sum of all flows (Eq. 3):

[3] $$Battery\ Waste\ Generated = Compliant\ Declared + Other\ Flows + Embedded\ in\ exported\ used\ EEE\ or\ WEEE + Gap$$

The Gap was calculated by deducting all Battery Waste Flows from the modelled Battery Waste Generated (Eq. 4):

[4] $$Gap = Battery\ Waste\ Generated - Compliant\ Declared - Other\ Flows - Embedded\ in\ exported\ used\ EEE\ or\ WEEE$$

The battery collection rate is calculated as described in the Eq. 5:

[5] $$Collection\ rate\ in\ 2019 = \frac{Battery\ Waste\ Compliantly\ Declared\ in\ 2019}{Average\ Battery\ POMs\ in\ 2017\text{–}2018\text{–}2019}$$

The collection rate for 2019 is thus derived by dividing the weight of portable battery waste and accumulators collected in a calendar year (2019) by the average weight of portable batteries and accumulators put on the market during that calendar year and the preceding two calendar years (2017, 2018, and 2019).

The **Batteries in use or hibernation** can be calculated from Battery Waste Generated. The Batteries in use or hibernation, S(n), were calculated as the summation of all Batteries Placed on the Market in historical years, POM (t), minus the summation of Battery Waste Generated in the historical years Batt Waste Generated (n) as described in Eq. [6]:

[6] $$S(n) = \sum_{t=to}^{n} POM(t) - \sum_{t=to}^{n} \text{Batt waste generated } (n)$$

Where n is the evolution year and t_0 is the initial year that a battery is sold.

However, in this study, the number of batteries in use or hibernation was also determined with empirical data. The alternative data sources and methods for the calculation of batteries in use or hibernation in Dutch households and companies/the public sector are:

1) Batteries in use or hibernation in households, source: (Panteia 2013);
2) Batteries in use or hibernation in companies in the public sector, source: (GFK 2009), integrated with calculations;
3) Share of batteries embedded in EEE in use or hibernation in households, source: SCYCLE internal databases;
4) Share of batteries embedded in EEE in use or hibernation in companies/the public sector, source: SCYCLE internal databases;
5) Theoretical number of batteries embedded in EEE in use or hibernation in the Netherlands, source: SCYCLE internal databases.

Empirical data on batteries in use and hibernation was used as a basis for the consolidation of the modelled data (calculated with Eq. 5) and for the calculation of batteries' lifetime.

In this study, as a first step, the lifetime data from ProSUM (Huisman et al. 2017 and EUCOBAT 2017) was used to model batteries in use and hibernation S (n), and in a second step, the lifetimes were adjusted so that the empirical number of batteries in use and hibernation match with the modelled one. The adjustments were made by reverting Eq. [2] as it is shown in Eq. [7]. A more detailed description of all steps undertaken can be found in Chapter 3.

[7] $$L^{(p)}(t,n) = 1 - \frac{S(n)}{\sum_{t=to}^{n} POM(t)}$$

The aforementioned datasources for the estimation of batteries in use or hibernation (specifically 1, 2, 3, and 4) were also used to calculate the share (in %) of the batteries by households vs. companies/the public sector.

Chapter 3: Results and Discussion

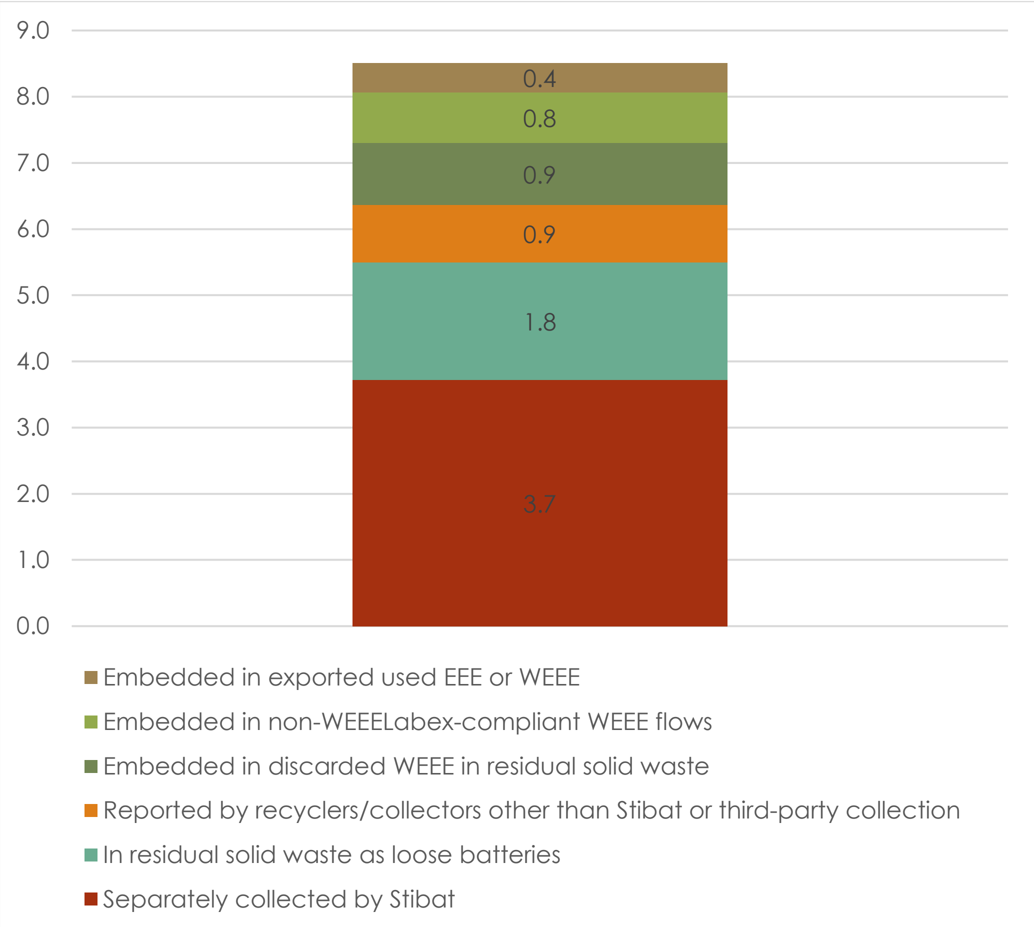
3. Results and Discussion

The Batteries-in-Use-Flow model is used in this study for the calculation of Battery Waste Generated. Such a model strives for consistency between battery POM, in use/hibernation and lifetimes, and for consistency between the calculated Battery Waste Generated and battery waste flows.

3.1 Quantification of the Battery Waste Flows

All Battery Waste Flows were first analysed and accounted for to generate a first order of magnitude of the Battery Waste Generated (Figure 4).

Figure 4. Measured Battery Waste Flows in kt



The analysis shows that the majority of the quantifiable battery waste was collected by Stibat 3.7 kt; 1.8 kt was found to be in residual solid waste bins as loose batteries, and half of that amount (0.9 kt) was estimated to be embedded in discarded WEEE in residual solid waste. A similar amount (0.9 kt) was reported to be collected by recyclers or collectors other than Stibat. 0.8 kt of batteries was estimated to be embedded in non-WEEELABEX-complaint WEEE flows. The rest, 0.4 kt, was estimated to be embedded in exported used EEE or WEEE.

The batteries found in exported used EEE or WEEE are mainly embedded in:

1) Cat 2: Screens and Monitors (0.05 kt)
2) Cat 4: Large Equipment (0.01 kt)

3) Cat 5: Small Equipment (0.06 kt)
4) Cat 6: Small IT and telecommunication equipment (0.3 kt)

The total of quantifiable Battery Waste Flows in the Netherlands in 2019 is 8.5 kt. This amount represented the lower boundary of the bandwidth of Battery Waste Generated and, as such, was used as background information in the Use-Flow model.

3.2 Consolidation of Battery POMs

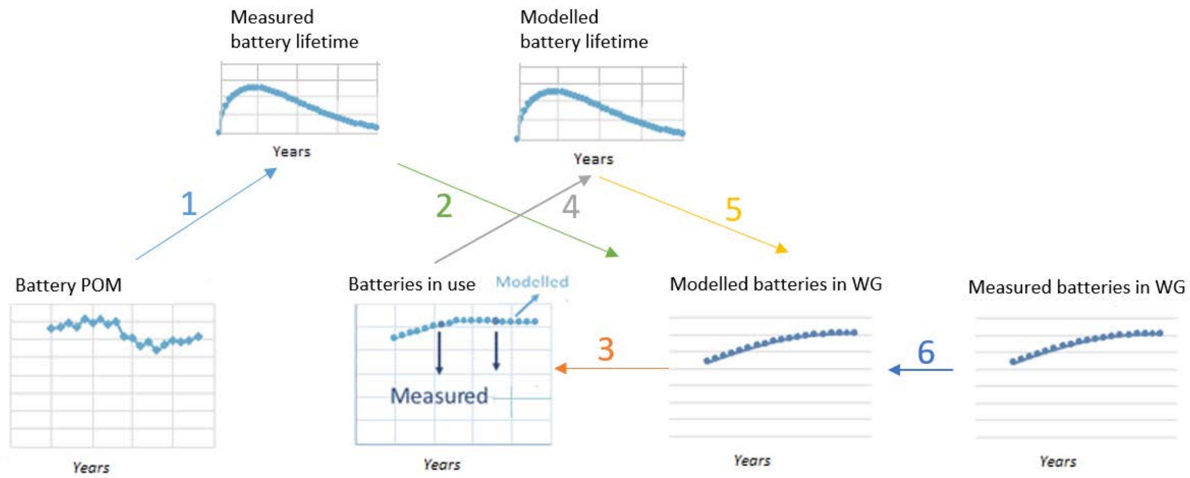
The second step was to analyse POM data obtained from Stibat. Since POM data were provided both in weight and in number of pieces, the average weight was calculated by chemistry. The change of weight over time was then analysed for all chemistries and corrected for outliers. Once the average weight was adjusted, the POM value, either in weight or in pieces, was corrected. When necessary, POM data in pieces were adjusted by multiplying the POMs in weight by the consolidated average weight per chemistry.

Additionally, POM data of lead batteries have been adjusted from 0.06 kt to 0.6 kt, as the POM of lead batteries is underestimated in the POM data of Stibat. The increase of POM data of lead batteries was essential to match the amount that is reported as compliantly declared in the Netherlands. Given the positive value of spent lead batteries, they are not subject to the recycling fee and thus are not well-declared.

3.3 Calculation of the Batteries-in-Use-Flow model

Consolidated battery POM data and lifetime distributions (Step 1 in Figure 5) were used in the model to calculate Battery Waste Generated and, consequently, the batteries in use or in hibernation in the Netherlands in 2019 (Step 2).

Figure 5. The mathematical model for the calculation of batteries POM, in use, or in hibernation and Waste Generated



The total number of batteries in use or hibernation calculated with this model was then compared to empirical data obtained from the literature (Panteia 2013).

The Panteia study calculated that, on average, a Dutch household has approximately 118 batteries in use or in hibernation. Multiplying this value by the number of households in the Netherlands in 2019 (7.9 Million), as obtained from Statistics Netherlands (CBS), results in approximately 0.9 Billion units of batteries in use. The calculated total number of batteries in use or hibernation was very high (1.7 Billion units) and far greater than the calculated batteries in use in households obtained from the literature (0.9 Billion units). It was concluded that the model needed to be adjusted in order to create outputs more aligned with reality.

The next step was to closely analyse POM data and compare it to data reported to Eurostat in order to ensure the reliability of POMs provided by Stibat. The analysis of Eurostat data[6] shows that battery POM per capita in the Netherlands (0.57 kg/capita) is very close to the values reported by many neighbour countries, such as Germany (0.63 kg/capita), Denmark (0.74 kg/capita), Ireland (0.48 kg/capita), France (0.46 kg/capita), and the UK (0.59 kg/capita). However, the battery POM per capita for Belgium is considerably lower (0.22 kg/capita). The average POM per capita for all neighbour countries, including Belgium, is thus 0.52 kg/capita with a standard deviation of 0.2. This analysis demonstrates that POM data calculated in this study is comparable to data reported to Eurostat by most neighbour countries.

The last step was to calculate batteries in use or in hibernation. Batteries in use was analysed using several different methods and data sources. Priority was given to adjusting batteries in use over correcting lifetimes because data related to batteries in use were more representative and reliable than lifetime data.

Method 1) consists of using the GFK study as a basis for the calculation of batteries in use or hibernation in companies in the Netherlands. The GFK study conducted surveys addressed to small enterprises with less than 10 employees and found that there are, on average, 39 batteries in use or in hibernation per company. Additional calculations were conducted in the present study to estimate the number of batteries in use or in hibernation in companies/the public sector in the Netherlands for organisations with more than 10 employees. Data on the number of companies or institutions in the Netherlands, information on the size, and number of employees were obtained from the CBS. In addition, the following assumptions were made, in companies/institutions with 11 to 100 employees, with each employee having 45% of the number of batteries per employee in a small company (1-10 employees). In companies/institutions with more than 101 employees, this percentage decreases to 25%, as shown in Table 2.

Table 2. Number of batteries in use or in hibernation in companies/institutions per employee by company size.

Company size (employee number)	Number of batteries per employee	Source
1-10	23	GFK
11-100	11	Assumption (45% of 1-10)
>101	6	Assumption (25% of 1-10)

These percentages are based on the assumption that smaller companies/institutions might have a higher concentration of EEE products and batteries per employee than

[6] http://appsso.eurostat.ec.europa.eu/nui/show.do?p=ad4d7d6b-9265-4596-9ecd-7ba8b7b4a80f-1600335927478_

larger companies, as small companies operate mainly in the service (or similar) sectors. Based on these assumptions, an average of 11.5 batteries per employee are calculated to be in use or in hibernation in the Netherlands, which equates to a total of 0.1 Billion units of batteries.

Totaling the number of batteries in use in companies and the number of batteries in use in households (0.9 Billion) equates to a total number of batteries in use in the Netherlands of 1 Billion units.

$$Total\ batteries\ in\ use = in\ households\ + in\ companies\ and\ the\ public\ sector$$

$$1\ Billion\ units = 0.9\ Billion\ units\ (Panteia)\ +\ 0.1\ Billion\ units\ (GFK)$$

Method 2) is based on SCYCLE internal data on EEE in use or in hibernation in households and in companies/the public sector. The share of batteries in use or in hibernation in households and in companies/the public sector obtained from the model was compared to SCYCLE internal data. In the case of households as well as for companies/the public sector, methods lead to a similar result: 90% of are in use or hibernation in households and 10% in companies/the public sector. Nevertheless, it should be noted that SCYCLE's dataset presents data gaps – particularly in the case of households, where data are available for only 34% of the UNU-KEYS, while for companies, data are available for 42% of the UNU-KEYs.

From methods 2 and 3, one can conclude that 90% of the batteries in use or in hibernation in the Netherlands are in households, and 10% are in companies or in the public sector. This result corroborates the results obtained from method 1.

Method 2:

$$Total\ batteries\ in\ use = in\ households\ + in\ companies\ and\ the\ public\ sector$$

$$100\% = 90\%\ \ (SCYCLE\ internal\ data) +\ 10\%\ (SCYCLE\ internal\ data)$$

The number of batteries used in households is 0.9 Billion, representing 90%, according to these outcomes. Thus, the total number of batteries in use is 1 Billion units.

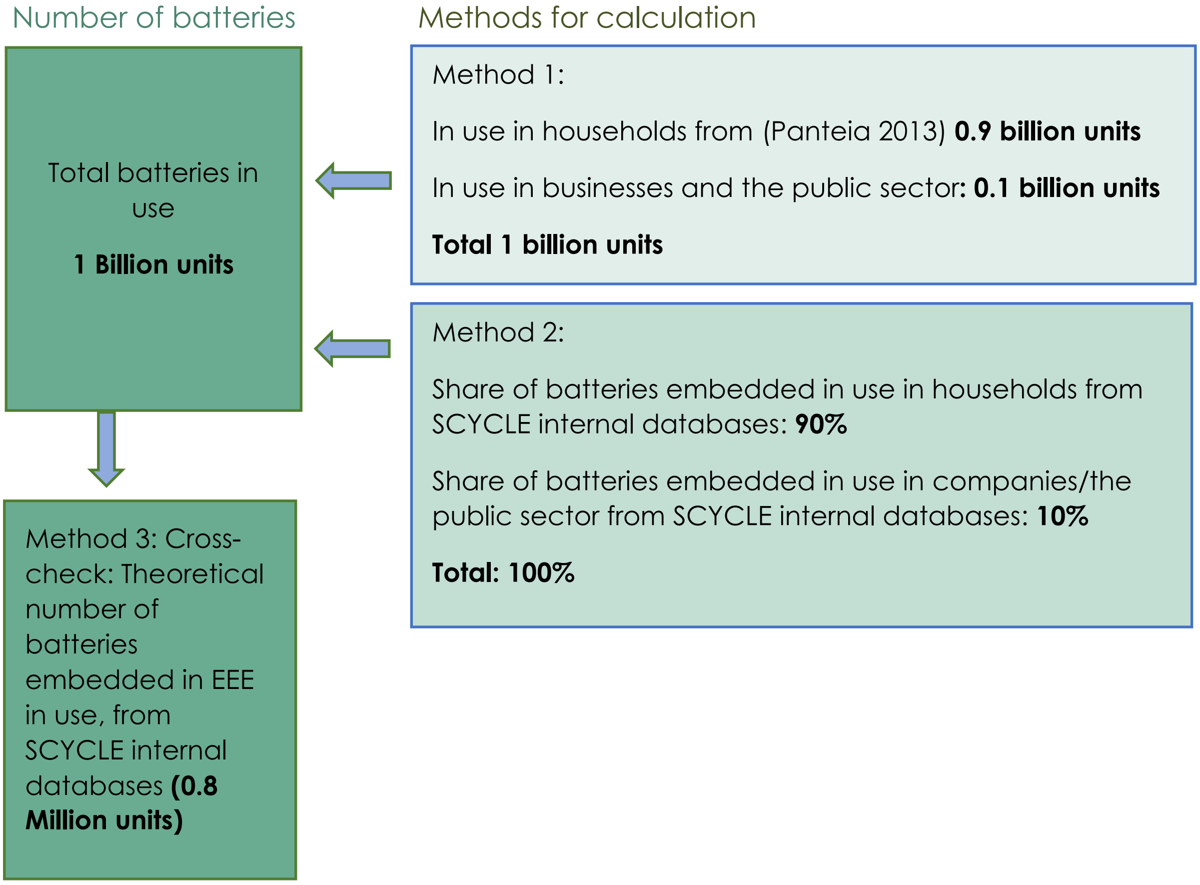
Method 3), which is actually more of a cross-check, determines the total number of batteries embedded in EEE in use or in hibernation in the Netherlands in 2019 from EEE data obtained from the Dutch WEEE Flows 2020 study. In order to determine the theoretical number of batteries embedded in EEE in use or in hibernation in the Netherlands, two assumptions were made:

- Share of products within the UNU-KEY that might contain one or multiple batteries
- Number of batteries per typical appliance in each UNU-KEY

The combination of the two assumptions resulted in a factor that was multiplied by the data of EEE in use or in hibernation in the Netherlands in 2019 from SCYCLE internal datasets. The conclusion is that approximately 0.8 Billion units of batteries are calculated to be embedded in EEE in the Netherlands (Figure 6). Besides the fact that this is a rough calculation, the result is comparable to the total number of batteries in use or in hibernation, as calculated in Method 1 (1 Billion units). It must be noted that method 4 can only capture batteries embedded in EEE, not loose batteries in use.

The results of all methods are illustrated in Figure 6.

Figure 6. Results of the calculation of number of batteries in use



The different methods demonstrate that the estimation of the total number of batteries in use or in hibernation in the Netherlands is reliable and is representative of the Dutch situation.

3.4 Calculation of Battery Lifetimes

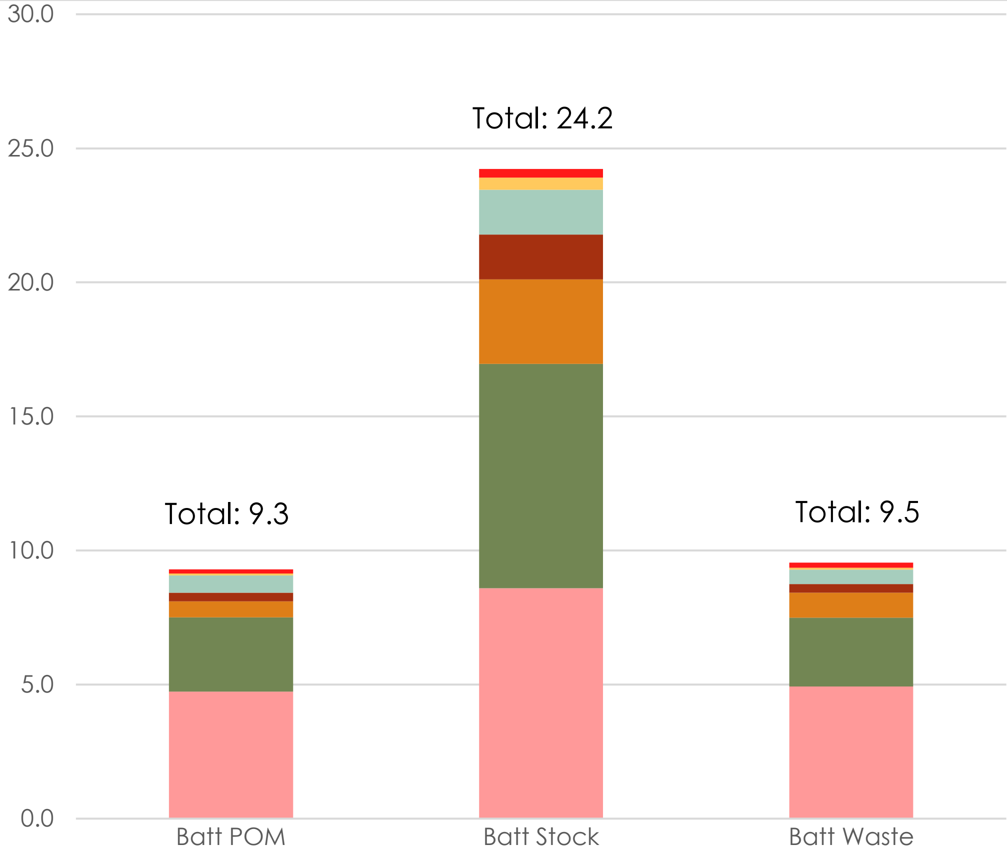
Once the number of batteries in use and in hibernation has been consolidated, lifetime values were derived (Step 4 in Figure 5) in order to match the number of batteries in use from the previous step. The calculated weighted average (based on the market size per chemistry) of all batteries analysed in this study is 3.3 year. In particular, Alkaline-Manganese batteries are calculated to have an average lifetime of 2.6 years, Lead batteries of 4.5 years, Lithium batteries of 3.4 years, Nickel-metal hydride batteries of 5.6 years, and Nickel-Cadmium batteries of 6.4 years.

These results were compared to lifetime data obtained from ProSUM (Huisman et al. 2017 and EUCOBAT 2017). The general observation is that modelled lifetimes are, on average, approximately 64% lower than the empirical lifetime values. The discrepancy between these outcomes is probably related to the methodology. In the EUCOBAT and ProSUM lifespans, the lifespans have been determined with household surveys, in which the respondents had to remember when they purchased batteries or had to remember how old a particular battery in the household was. The outcomes heavily rely on respondents' memories and can very often be biased. Thus, a methodology for calculating battery lifetimes using POM and Stock data, as conducted in this study, is considered to be more representative, as such memory bias does not exist.

3.5 Results of the Batteries-in-Use-Flow model

Consolidated battery POMs data and calculated lifetime distributions were used for the calculation of Battery Waste Generated (Step 5 in Figure 5). Battery POM data per chemistry from 2009 to 2019 was multiplied by the average lifetime of batteries of the corresponding chemistry group in order to calculate Battery Waste Generated and batteries in use or in hibernation. The results of the model are illustrated in Figure 7.

Figure 7. Battery POM - in use or in hibernation - Waste Generated in kt in 2019



	Batt POM	Batt Stock	Batt Waste
Other Niche Batteries	0.2	0.3	0.2
Nickel Cadmium	0.1	0.5	0.1
Lithium	0.6	1.7	0.5
Nickel-Metalhidride	0.3	1.7	0.3
Lead	0.6	3.2	0.9
Other Batteries	2.8	8.4	2.6
Alkaline-Manganese	4.7	8.6	4.9

As a result of the Battery-in-Use-Flow model, in the Netherlands in 2019, 9.3 kilotons (kt) of batteries were placed on the market, 24.2 kt were in use or in hibernation in households or in companies/the public sector, and 9.5 kt became Waste Generated. These amounts correspond to 487 Million (M) units of batteries POM, 1024 M units of batteries in use or in hibernation in Dutch households or in companies/the public sector, and 481 M units of Battery Waste Generated.

The higher share (52%) of Battery Waste Generated is represented by Alkaline-Manganese Batteries (4.9 kt or 246 M units); indeed, 4.7 kt (or 237 M units) are reported by Stibat to be placed on the market in the Netherlands in 2019.

The second largest share (27%) of Battery Waste Generated in 2019 is represented by Other Batteries (2.6 kt or 150 M units); this category is comprised of Lithium-ion, Lithium-polymer, Zink, Zinc-carbon, Mercury-oxide, and Silver-oxide.

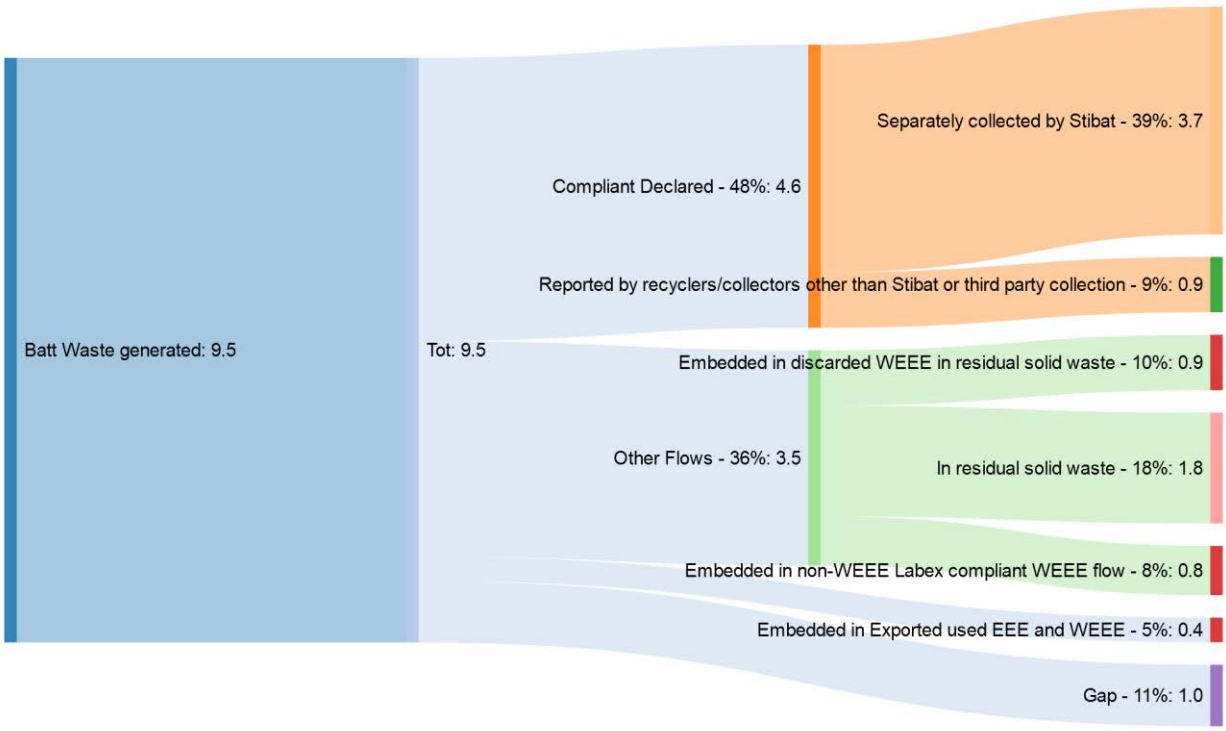
Lead batteries found in Battery Waste Generated in the Netherlands in 2019 totalled 0.9 kt (0.7 M units), Lithium batteries totalled 0.5 kt (54 M units), Nickel-metal hydride batteries totalled 0.3 kt (14 M units), and Nickel Cadmium batteries totalled 0.1 kt (1.4 M units). Other niche batteries totalled 0.2 kt, or 14 M units.

The total amount of modelled battery waste (9.5 kt) is coherent with the total quantifiable battery waste, shown in Figure 4, which is 8.5 kt; nevertheless, a data gap of 1 kt can be observed. A closer analysis of Battery Waste Flows and of the size of the gap is presented in the following section.

3.6 Overview of the Battery Waste Flows

The results of the analysis of the Battery Waste Flows are illustrated in the Sankey diagram below. The values are expressed both in kt and in percentages of the total Battery Waste Generated.

Figure 3. Battery Waste Flows



The diagram illustrates that Batteries Compliant Declared in 2019 in the Netherlands were 4.6 kt (48% of the total Battery Waste Generated), of which 39% (3.7 kt) was "separately collected by Stibat" and 9% (0.9 kt) was "reported by recyclers/collectors other than Stibat or third-party collection".

It should be noted that collected batteries resulting from WEEELABEX recycling were not added to the total "Batteries Compliant Declared" because the former are already reported in the flow, "separately collected by Stibat". This flow corresponds to 0.5 t (source: Stibat).

"Other flows" represent 36% (3.5 kt) of the total Battery Waste Generated, which is comprised of batteries "Embedded in discarded WEEE in residual solid waste" (10% or 0.9 kt), "In residual solid waste" as loose batteries (18% or 1.8 kt), and "Embedded in non-WEEELABEX-compliant WEEE flows" (8% or 0.8 kt).

It is calculated that in 2019, 5% or 0.4 kt of the Battery Waste Generated in the Netherlands was "embedded in exported used EEE or WEEE", and most batteries (0.3 kt) are embedded in category 6 (small IT and telecommunication equipment).

The "Gap" is calculated to be 11% or 1 t, which means either that other Battery Flows are underestimated or that it was not possible to track part of the Battery Waste Generated in 2019 in the Netherlands. The gap may be related to batteries illegally exported either as loose batteries or as embedded in WEEE, or it may be related to underestimated batteries in residual solid waste or an underestimated number of batteries embedded in non-WEEELABEX-compliant WEEE flows.

3.7 Sensitivity Analysis

This report uses a variety of methodologies for the calculation of Battery Waste Generated and the accounting of Battery Waste Flows. For instance, the battery POMs came from Stibat registers, households, and business surveys, and waste sorting was based on samples, with some data being converted using share of batteries in electronics. Due to the lack of information from underlying data sources and the variety of methodologies, it was difficult to perform an uncertainty analysis that considered all uncertainties. Therefore, a sensitivity analysis has been performed on the parameters most sensitive to the outcomes.

Battery POM data from the registers of Stibat are reported by the producers, validated by Stibat, and simply added together. The data on battery waste compliantly declared as provided by Stibat also came from declarations from recyclers in a register and are added together. Therefore, those data from registers are not sensitive to methodological choices and were not considered in the sensitivity analysis.

The households or business surveys used a representative sample and were then extrapolated to the national level. As an example, the household survey sampled 1,303 households in stratified groups, which were extrapolated to the 7.9 Million households in the Netherlands, and the bandwidth related to the sample was not published for both household and business surveys. Since the number of batteries used in households and businesses correlates with the lifetime, it was chosen to provide fluctuation in the lifetime of ±10% in the sensitivity analysis.

The amount of battery waste found in residual solid waste was determined by sorting the residual waste according to the Eureco study (Stibat 2019). The share of batteries represents a small fraction of the total residual solid waste sampled – of merely 0.06% of the total mass of residual solid waste. Extrapolation to the national level was completed by stratifying the sample to the level of urbanisation in five different classes. However, the Eureco study did not provide a bandwidth of the outcomes. Therefore, it was assumed that the number of batteries in residual solid waste varies by ± 5% in the sensitivity analysis.

The share of the weight of batteries in EEE products was determined per UNU-KEY (see the UNU-KEYs in ANNEX 1). These shares were used to convert the WEEE flows into battery waste flows. Due to the large variety of battery types, shapes, chemistries, and applications, identifying an average weight of batteries is a complex process. The possible variation of the share of batteries embedded in EEE/WEEE was reflected in all variables derived from WEEE statistics (batteries embedded in discarded WEEE in residual solid waste, batteries embedded in exported used EEE and WEEE, and batteries embedded in non-WEEELABEX-compliant WEEE flows). Unfortunately, real spreads in the results of the average weights were not available and were assumed to be ± 10%.

Table 3 presents a summary of the results of the model for the calculation of batteries POM, batteries in use or in hibernation, Waste Generated, and the calculation of Battery Flows. Data are split into batteries in households or batteries in companies/the public sector where possible. Additionally, an indication of the sensitivity is provided for each variable affected by the sensitivity of the model.

Table 3. Summary of the results of the model for the calculation of Battery POM, batteries in use or hibernation, Waste Generated, and the Battery Flows in 2019

		Total Portable Batteries in kt	**Total Portable Batteries in % of the Battery Waste Generated**
Battery POM	Stibat	8.8	
	This Study	9.3	
	Of which are in households	8.4	
	Of which are in companies/the public sector	0.9	
Batteries in use or hibernation	In use	24.2 ± 5	
	Of which are in households	21.8 ± 4	
	Of which are in companies/the public sector	2.4 ± 0.5	
Battery Waste Generated	This Study	9.5 ± 0.2	
	Of which are in households	8.5 ± 0.2	
	Of which are in companies/the public sector	1 ± 0.02	
Batteries Compliantly Declared	Separately collected by Stibat	3.7	39%
	Reported by recyclers/collectors other than Stibat or third-party collection	0.9	9%
Other Battery Waste flows	Embedded in discarded WEEE in residual solid waste	0.9 ± 0.1	10%
	As loose batteries in residual solid waste	1.8 ± 0.2	18%
	Embedded in non-WEEELABEX-compliant WEEE flow	0.8 ± 0.1	8%
Battery Exports in used-EEE	Embedded in exported used EEE or WEEE	0.4 ± 0.1	5%

GAP		1 ± 0.3	11%

The result of the sensitivity analysis on the share of batteries in households and in companies/the public sector led from an 80%-20% spread to a 97%-3 % spread. However, the share of 3% in Dutch companies and in the public sector is regarded as being unrealistic and not aligned with reality.

Thus, the sensitivity analysis of the gap is ± 0.3 kt, or from 0.7 kt to 1.3 kt.

Chapter 4: *Battery Flows and Collection Targets in the Battery Directive*

4. Battery Flows and Collection Targets in the Battery Directive

According to the Battery Directive[7], Member States needed to achieve a 45% collection rate by 26 September 2016. This study calculated the collection rate as described by the Battery Directive: *The percentage obtained by dividing the weight of waste portable batteries and accumulators collected in a calendar year by the average weight of portable batteries and accumulators put on the market during that calendar year and the preceding two calendar years*.

$$Collection\ rate\ in\ 2019 = \frac{Battery\ Waste\ Compliantly\ Declared\ in\ 2019}{Average\ Battery\ POMs\ in\ 2017-2018-2019}$$

The result of this analysis is that the Netherlands reached the minimum target in 2019 with a collection rate of 50.6% by compliantly collecting 4,595 kt of battery waste in 2019.

For WEEE, as described in the WEEE Directive of 2019, the WEEE minimum collection rate becomes:

65% of EEE put on the market, calculated on the basis of:

- *the total weight of WEEE collected; and*
- *the average weight of EEE put on the market in the three preceding years*.

In the Netherlands, exports of used-EEE are, in the context of the WEEE Directive, subtracted from the POM in the target calculation. A similar approach for the 437 t of batteries embedded in the used-EEE could be envisioned. The average batteries POM for 2017–2018–2019 would have to be adjusted from 9,077 t to 8,693 t, which would lead to an increase of the collection rate from 50.6% to 53.2%, as indicated in Table 4.

Table 4 shows the Battery Waste Flows and relates the collection rates calculated in this study with the collection target of the Battery Directive.

[7] Directive 2006/66/EC of the European Parliament and the Council of 6 September 2006 on batteries and accumulators, waste batteries and accumulators, and repealing Directive 91/157/EE

Table 4. Interlinkage collection targets in the Battery Directive and in collection rates calculated in this study for Battery Flows

Battery Flows description (2019)	Battery Flows (kt)	Collection rate calculated in this study *(compliant with methodology in the Battery Directive)*	Collection rate calculated in this study *(deducting batteries embedded in exported used EEE or WEEE from the Battery POM)*	Collection target in the Battery Directive
Compliantly Declared	4,6	50.6%	53.2%	45%

Other than the batteries compliantly declared, this study's research analysed the quantities of other flows, and the study provides suggestions for improving the collection rate. A considerable amount (3,474 t) is calculated to be non-compliantly recycled because batteries either end up in residual solid waste as loose batteries or as embedded in electronics or are embedded in WEEE that are not compliantly recycled and declared. The Netherlands realised a 48% collection rate (compared to EEE POM), whereas the target is at 65% (Nationaal (W)EEE Register, 2020). Thus, the Netherlands did not reach the collection target for WEEE in 2019. Therefore, it is expected that the collection rate of WEEE will increase in the forthcoming years, which will, in turn, also positively impact collection rates of batteries.

In a scenario in which batteries embedded in discarded WEEE in residual solid waste and in non-WEEELABEX-compliant WEEE flows decreases by half as a consequence of the efforts of reaching the 65% collection rate of EEE POM, the collection rate of batteries would increase to 57%[8]. In conclusion, if the Netherlands reaches or comes closer to reaching the collection target as defined in the WEEE Directive, it will increase the collection rate for batteries as well.

[8] This value does not take into account the deduction of batteries embedded in exported used EEE or WEEE from POMs.

Chapter 5: *Conclusions*

5. Conclusions

The batteries POM-in use or hibernation-Waste Generated model is reliable, and results are consistent with data obtained from various other sources. Battery POM data are considered to be reliable, but they might be slightly underestimated because of the presence of free riders who trade batteries within and outside of the Netherlands.

This study calculated that the battery POM in 2019 in the Netherlands was 9.3 kt, Battery Waste Generated was 9.5 kt, and 24.2 kt are in use or in hibernation in Dutch households or in companies/the public sector.

The POM reported to Stibat is 8.8 kt, whereas the Battery Flows model calculates that the POM is 9.3 kt. This is an indication that the official POM is probably 0.5 kt low, due to free riders and the related, unreported lead Battery Flows.

Approximately 90% of the batteries in use or hibernation in the Netherlands are calculated to be found in Dutch households, while 10% are calculated to be in companies/the public sector.

Nearly half (48%) of the Battery Waste Generated is compliantly declared. This represents a 50.6% collection rate (compliant with methodology in the Battery Directive), and the Netherlands are thus reaching the collection target as defined by the Battery Directive, which is set to 45% of the batteries POM. The collection rate could increase to 53.2% if the target is corrected by subtracting UEEE exports from the POM, as they do not become waste in the Netherlands.

More than one quarter, (28%), is non-compliantly recycled because batteries either end up in residual solid waste as loose batteries or as embedded in electronics. Nevertheless, it should be noted that the mass of loose batteries reported to end up in residual solid waste represents only 0.06% of the total residual solid waste generated in the Netherlands.

Nearly one quarter (24%) is comprised of batteries embedded in WEEE that are not compliantly recycled and declared (8%), batteries embedded in exported used EEE and WEEE (5%), and batteries in unknown flows (11%).

Chapter 6: Recommendations

6. Recommendations

Recommendation 1: Expand monitoring of Battery Flows

The Battery Flow Model in this report is based on a variety of different sources and studies, such as POM data, collection and recycling data, household and business possession data, batteries in residual waste, etc. However, these studies are usually not integrated with each other, as they use different classification systems or different scope and extrapolation methods. As well, battery and WEEE statistics are very interrelated, but they are not interlinked in the national monitoring. To improve and expand the monitoring of Battery Flows, it is therefore recommended to:

- expand the national monitoring to all Battery Flows – from POM, in use phase, to discard phase – and to ensure consistency between all flows;
- enhance the integration between battery and WEEE Statistics, as illustrated in this report;
- enhance the registration of the weight of batteries embedded in electronics per product category (ideally using the UNU-KEYs classification) to allow the calculation of average weights of the battery per UNU-KEY. A possible source of information could be the data reported from producers to Stibat;
- perform regular checks and validation routines on the reporting of battery sales and batteries embedded in EEE to ensure that flows are not double-reported or under-reported;
- perform additional checks on the data reported by collectors, which could be foreseen and maybe supported by integrated reporting tools. More accurate collection data can be used to quantify the impact that free riders have on POMs, which will simultaneously help to improve POM data.

Recommendation 2: Improve accuracy for batteries in use or in hibernation in companies and in the public sector

- Follow-up studies could focus more on getting more recent and empirical data on batteries in use or in hibernation in companies/the public sector and on getting information about their discarding behavior. In particular, companies with more than 10 employees should be included in the scope of the surveys in the future. Such studies may be useful for further improving the quality of battery lifetimes and have a better indication of the share of batteries in use or in hibernation in households vs. in companies and the public sector.

Recommendation 3: Reduce the number of batteries found in the mixed residual waste

- The largest leakage are batteries in mixed residual waste (28%), which are discarded as loose batteries (18%) or embedded in WEEE (10%). Thus, more consumer awareness is needed to divert the largest leakage of batteries. Future studies may focus on assessing the number of batteries discarded in the residual solid waste by companies/the public sector, as this data was currently not available.

Recommendation 4: Accounting for batteries exported in EEE in the battery collection target

- Approximately 5% of batteries are exported as embedded in UEEE, and as a consequence, they do not become waste in the Netherlands. Improving the sampling methodology is recommended; doing so will measure this flow and take the phenomenon into account in the calculation of the collection rate by, for instance, subtracting the exported batteries from the batteries POM.

Literature

Literature

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Annexes

Annex 1- UNU-KEYs

Detailed description of the UNU product classification and its correlation to other WEEE classification.

UNU KEY	Description	EEE category under EU-6
0001	Central Heating (household installed)	Large equipment
0002	Photovoltaic Panels (incl. inverters)	Large equipment
0101	Professional Heating & Ventilation (excl. cooling equipment)	Large equipment
0102	Dishwashers	Large equipment
0103	Kitchen equipment (e.g. large furnaces, ovens, cooking equipment)	Large equipment
0104	Washing Machines (incl. combined dryers)	Large equipment
0105	Dryers (washer-dryers, centrifuges)	Large equipment
0106	Household Heating & Ventilation (e.g. hoods, ventilators, space heaters)	Large equipment
0108	Fridges (incl. combi-fridges)	Temperature exchange equipment
0109	Freezers	Temperature exchange equipment
0111	Air Conditioners (household installed and portable)	Temperature exchange equipment
0112	Other Cooling equipment (e.g. dehumidifiers, heat pump dryers)	Temperature exchange equipment
0113	Professional Cooling equipment (e.g. large air conditioners, cooling displays)	Temperature exchange equipment
0114	Microwaves (incl. combined, excl. grills)	Small equipment
0201	Other small household equipment (e.g. small ventilators, irons, clocks, adapters)	Small equipment
0202	Equipment for food preparation (e.g. toasters, grills, food processing, frying pans)	Small equipment
0203	Small household equipment for hot water preparation (e.g. coffee, tea, water cookers)	Small equipment
0204	Vacuum Cleaners (excl. professional)	Small equipment
0205	Personal Care equipment (e.g. tooth brushes, hair dryers, razors)	Small equipment

0301	Small IT equipment (e.g. routers, mice, keyboards, external drives, accessories)	Small IT
0302	Desktop PCs (excl. monitors, accessories)	Small IT
0303	Laptops (incl. tablets)	Screens and monitors
0304	Printers (e.g. scanners, multifunctionals, faxes)	Small IT
0305	Telecommunication equipment (e.g. [cordless] phones, answering machines)	Small IT
0306	Mobile Phones (incl. smartphones, pagers)	Small IT
0307	Professional IT equipment (e.g. servers, routers, data storage, copiers)	Large equipment
0308	Cathode Ray Tube Monitors	Screens and monitors
0309	Flat Display Panel Monitors (LCD, LED)	Screens and monitors
0401	Small Consumer Electronics (e.g. headphones, remote controls)	Small equipment
0402	Portable Audio & Video (e.g. MP3, e-readers, car navigation)	Small equipment
0403	Music Instruments, Radio, Hi-Fi (incl. audio sets)	Small equipment
0404	Video (e.g. Video recorders, DVD and Blu-Ray players, set-top boxes) and projectors	Small equipment
0405	Speakers	Small equipment
0406	Cameras (e.g. camcorders, photo & digital still cameras)	Small equipment
0407	Cathode Ray Tube TVs	Screens and monitors
0408	Flat Display Panel TVs (LCD, LED, Plasma)	Screens and monitors
0501	Small lighting equipment (excl. LED & incandescent)	Small equipment
0502	Compact Fluorescent Lamps (incl. retrofit & non-retrofit)	Lamps
0503	Straight Tube Fluorescent Lamps	Lamps
0504	Special Lamps (e.g. professional mercury, high & low pressure sodium)	Lamps
0505	LED Lamps (incl. retrofit LED lamps)	Lamps
0506	Household Luminaires (incl. household incandescent fittings & household LED luminaires)	Small equipment
0507	Professional Luminaires (offices, public space, industry)	Small equipment
0601	Household Tools (e.g. drills, saws, high-pressure cleaners, lawnmowers)	Small equipment
0602	Professional Tools (e.g. for welding, soldering, milling)	Large equipment

0701	Toys (e.g. car racing sets, electric trains, music toys, biking computers, drones)	Small equipment
0702	Game Consoles	Small IT
0703	Leisure equipment (e.g. sports equipment, electric bikes, juke boxes)	Large equipment
0801	Household Medical equipment (e.g. thermometers, blood pressure meters)	Small equipment
0802	Professional Medical equipment (e.g. hospital, dentist, diagnostics)	Large equipment
0901	Household Monitoring & Control equipment (alarm, heat, smoke, excl. screens)	Small equipment
0902	Professional Monitoring & Control equipment (e.g. laboratory, control panels)	Large equipment
1001	Non-cooled Dispensers (e.g. for vending, hot drinks, tickets, money)	Large equipment
1002	Cooled Dispensers (e.g. for vending, cold drinks)	Temperature exchange equipment

Annex 2 – Conversion of WEEE Flows to Battery Flows

The battery classification can be linked to the internationally recognised WEEE classification, the so called UNU-KEYs. The classification was developed by UNU (Wang et al. 2012) and categorises products by similar function, comparable material composition (in terms of hazardous substances and valuable materials) and related end-of-life attributes. Additionally, products within the same category have a homogeneous average weight and lifetime distribution. The EEE is classified into 54 different UNU-KEYS, which are grouped into six general categories that refer to the new reporting categories for the recast of the WEEE Directive (Forti, Baldé, and Kuehr 2018). The full list of the UNU-KEYS is presented in Annex 1.

The following steps were undertaken to calculate the battery fractions within the UNU-KEYs:

1) selecting the UNU-KEYS that contain one or multiple batteries (listed in Table 6)
2) accounting for the number of batteries embedded in the most representative product per UNU-KEY
3) researching the average weight of batteries per application or per chemistry
4) calculating the relation of the weight of batteries compared to the weight of the UNU-KEYs.

Table 6. UNU-KEYs that contain one or multiple batteries

UNU-KEY	Description
0201	Other small household equipment (e.g. small ventilators, irons, clocks, adapters)
0202	Equipment for food preparation (e.g. toasters, grills, food processing, frying pans)
0205	Personal Care equipment (e.g. tooth brushes, hair dryers, razors)
0301	Small IT equipment (e.g. routers, mice, keyboards, external drives & accessories)
0303	Laptops (incl. tablets)
0305	Telecommunication equipment (e.g. [cordless] phones, answering machines)
0306	Mobile Phones (incl. smartphones, pagers)
0401	Small Consumer Electronics (e.g. headphones, remote controls)
0402	Portable Audio & Video (e.g. MP3, e-readers, car navigation)
0403	Music Instruments, Radio, Hi-Fi (incl. audio sets)
0404	Video (e.g. Video recorders, DVD and Blu-Ray players, set-top boxes) and projectors
0405	Speakers
0406	Cameras (e.g. camcorders, photo & digital still cameras)
0501	Small lighting equipment (excl. LED & incandescent)
0505	LED Lamps (incl. retrofit LED lamps)
0601	Household Tools (e.g. drills, saws, high-pressure cleaners, lawnmowers)
0602	Professional Tools (e.g. for welding, soldering, milling)
0701	Toys (e.g. car racing sets, electric trains, music toys, biking computers, drones)

0702	Game Consoles
0801	Household Medical equipment (e.g. thermometers, blood pressure meters)
0901	Household Monitoring & Control equipment (alarm, heat, smoke, excl. screens)

As a next step, the calculated battery fractions were multiplied with the internal detailed dataset of the Dutch WEEE Flows per UNU-KEY, and the following Battery Flows were calculated:

1) discarded WEEE in residual solid waste
2) non-WEEELABEX-compliant WEEE
3) exported used EEE or WEEE

Thus, it was necessary to convert the WEEE Flows into Battery Flows:

- The conversion was made only for the UNU-KEYS that contain one or multiple batteries;
- The type of battery was researched, as was its average weight for at least 3 representative products (EEE) per UNU-KEY. The average weights of the batteries per product were collected from SCYCLE internal databases. The battery's average weight was, in most cases, indicated by application in the EEE. However, sometimes the weight was expressed by size of battery (e.g. AA, AAA, 9V etc); in such cases, the battery's average weight was multiplied by the calculated number of batteries embedded in each EEE. An example of the assessment is presented in Table 7;

Table 7. Example of the assessment of average weight of batteries in UNU-KEY 0402 (Small Consumer Electronics)

EEE	Type of battery	Source Table	Size/application	Calculated number of batteries per EEE	Grams/unit
E-readers	Li-ion	by size	pouch 1300 mAh	1	30
Car navigation	Li-ion	by size	pouch 1300 mAh	1	30
MP3	Li-ion	by size	pouch 300 mAh	1	5.2

- Next, the average weight of batteries per UNU-KEY was calculated;
- The share of the weight of batteries out of the weight of the UNU-KEYs was calculated and used to convert WEEE Flows into Battery Waste Flows.
- In conclusion, the final result of the share of batteries per UNU-KEY was corrected by applying the condition that up to 33% of batteries POM are embedded in EEE. The source for this information is Stibat's internal calculations from data reported by producers in national registers. This condition was integrated into the model and used to adjust the share of batteries in EEE/WEEE.

It is important to note that battery quantities resulted from the conversion of WEEE Flows (Balde et al, 2020) and refer only to batteries embedded in EEE/WEEE; these quantities do not include loose batteries.