

# Visual Scaling of Battery Waste: How Big Is the Disposable Battery Problem, Really?

Written by: Alexander Nava – Chief Innovation Engineer @ ED2S

## Executive Summary

Each year, the United States consumes on the order of **three billion single-use household batteries**, primarily AA and AAA cells. Estimates compiled by U.S. state environmental agencies and recycling organizations, drawing on U.S. Environmental Protection Agency (EPA) materials flow data and industry sales reports, consistently place annual U.S. consumption in the range of **3.0 to 3.3 billion units per year**. While precise disposal timing varies by household, in a steady-state consumer system, annual purchases closely approximate annual end-of-life battery waste.

Although “billions of batteries” is a familiar statistic, the physical scale implied by that number is difficult to intuit. This report translates abstract counts into physically measurable, conservative comparisons using published battery dimensions, masses, and widely accepted geophysical reference values.

Using manufacturer specifications and ANSI/IEC dimensional standards, a typical AA battery measures approximately **50.5 mm in length, 14.5 mm in diameter**, and has a mass near **23–24 grams**. When scaled across annual U.S. consumption:

- **Vertical stacking:** If the batteries discarded in a single year were stacked end-to-end along their length, the resulting column would extend approximately 150,000 to 167,000 kilometers upward. This height is **three to four times Earth’s circumference** and reaches **roughly 40 percent of the average Earth–Moon distance**.
- **Mass:** At conservative mass assumptions, the total annual mass of single-use AA/AAA batteries discarded in the U.S. exceeds 70,000 metric tonnes, comparable to the mass of **tens of thousands of passenger vehicles**.
- **Volume:** The combined solid volume of these batteries exceeds 25,000 cubic meters, enough to fill **ten or more Olympic-size swimming pools**, before accounting for packaging, void spaces, or landfill inefficiencies.

These comparisons are not projections over decades; they represent one year of household battery use. The same physical quantities recur annually if single-use batteries remain the default for common devices such as remotes, toys, flashlights, clocks, and smoke detectors.

All calculations in this report are intentionally conservative. Battery counts are evaluated across a range rather than a single value. Manufacturer-published dimensions and masses are used instead of worst-case assumptions. Where uncertainty exists, such as the precise timing between purchase and disposal, it is stated explicitly and tested for sensitivity. Annual disposal of batteries is derived from a combination of sales data and waste stream analysis, with alkaline batteries having a **near 100% disposal rate**.

The results show that even under restrained assumptions, the disposable battery stream represents a large, recurring material flow that is measurable at planetary scales. Unlike many forms of waste that accumulate slowly, household batteries concentrate significant mass, metals, and chemical systems into small objects that are replaced repeatedly by design.

**This analysis does not argue that every battery immediately becomes waste, nor does it rely on emotionally charged language. Instead, it demonstrates, using geometry, mass balance, and public reference standards, that the scale of disposable battery consumption in the United States is physically large, persistent, and non-abstract.**

Understanding this scale is essential for evaluating prevention-based solutions, including the substitution of single-use batteries with long-life rechargeable alternatives. Such as Low Self-Discharge (LSD) Nickel Metal Hydride Batteries (NiMH). Prevention, rather than downstream cleanup alone, is the only mechanism capable of meaningfully reducing a waste stream of this magnitude. **A rechargeable battery that has been proven to replace hundreds of single-use alkaline batteries.**

## Why Scale Is Hard for Humans

Humans are poorly equipped to intuitively understand very large numbers, especially when those numbers describe cumulative, distributed phenomena such as waste, emissions, or material flows. Waste that is not seen is out of sight and out of mind.

### Human numerical intuition is non-linear

Decades of research in cognitive psychology show that humans naturally perceive numbers on a compressed, logarithmic scale rather than a linear one. As numbers grow larger, differences between them feel subjectively smaller. The perceived difference between 10 and 100 feels larger than the difference between 1 billion and 2 billion, even though the latter is vastly greater in absolute terms. Interesting, right?

This effect has been demonstrated across cultures, age groups, and educational backgrounds. It explains why large quantities, millions, billions, trillions, tend to collapse into a single mental category of “very big,” rather than remaining meaningfully distinct.

As a result, statements such as “three billion batteries per year” convey magnitude without structure/meaning. The number is technically precise but cognitively vague. In that, a physical reference must be compared to bring emotional change.

### Abstract units fail without physical reference

Quantities expressed only as counts (e.g., “billions of batteries”) lack inherent physical meaning unless they are anchored to **dimensions, mass, or space**. Research in risk perception and environmental communication shows that people reason more accurately when abstract quantities are translated into concrete physical analogs, length, height, volume, weight, or time.

For example, people can reliably compare:

- the height of a building,
- the distance between cities,
- the volume of a pool,
- or the mass of a vehicle,

but struggle to reason about raw numerical totals without such references or comparisons.

This does not mean that the public is incapable of understanding scale; it means that the format of information presentation matters. When scale is expressed in physically meaningful units, comprehension and retention increase substantially and bring change.

### **Incremental systems obscure cumulative impact**

Disposable batteries enter the waste stream gradually and invisibly. A household discards one or two batteries at a time, separated by weeks or months. This is a **low-salience, high-frequency system**: each individual action appears negligible, even though the negative effects are large.

Because no single moment feels consequential, the cumulative scale is systematically underestimated. This effect is common in environmental domains, including water use, energy consumption, and solid waste generation.

Importantly, this underestimation is not driven by denial or apathy. It arises because human intuition evolved to track immediate, local changes, not large-scale statistical accumulation across millions of actors.

### **Large numbers lack experiential grounding**

Most people have no lived experience with distances measured in tens of thousands of kilometers, masses measured in tens of thousands of tonnes, or volumes measured in tens of thousands of cubic meters. Without experiential grounding, numerical statements fail to produce meaningful mental models.

Cognitive research shows that people reason more accurately when unfamiliar scales are mapped onto **familiar reference frames**. Examples include:

- comparing a distance to Earth's circumference,
- comparing a height to well-known buildings or mountains,
- comparing a volume to standardized structures like swimming pools or shipping containers.

These mappings do not exaggerate the data; they simply translate it into units the brain already knows how to process.

## Visual scaling is a scientific, not rhetorical, tool

Visual scaling is sometimes mistaken for dramatization. In fact, it is a standard analytical technique used in engineering, physics, and astronomy to interpret quantities that exceed everyday experience.

Astronomers routinely scale distances to astronomical units or light-years. Structural engineers compare loads to known failure thresholds. Environmental scientists convert emissions into atmospheric concentrations or land-area equivalents.

When applied transparently, with explicit assumptions and conservative bounds, visual scaling reduces misunderstanding rather than amplifying it.

## Why this matters for battery waste

Without physical scaling, the phrase “billions of batteries per year” invites dismissal. It sounds large but feels abstract, distant, and disconnected from personal behavior.

By contrast, expressing the same quantity as:

- a stack reaching a fraction of the distance to the Moon,
- a mass comparable to tens of thousands of vehicles,
- or a volume filling multiple Olympic-size swimming pools,

does not add emotion or exaggeration. It adds context.

This report uses visual scaling not to persuade through shock, but to restore proportional understanding. The objective is not to provoke guilt or fear, but to ensure that discussions about battery waste occur at the correct physical scale.

## Overall

Large environmental problems often persist not because their impacts are unknown, but because their scale is poorly understood. Translating numerical quantities into physically grounded comparisons is a necessary step for informed evaluation, policy analysis, and engineering decision-making.

Visual scaling, when done rigorously, is meaningful **clarification**.

## Methodology

This analysis translates national-scale disposable battery consumption into physically interpretable quantities using standard engineering scaling techniques. All numerical calculations are performed exclusively in the accompanying Excel workbook. This written section describes the data sources, assumptions, and computational structure used to generate the results.

## Scope and system boundary

The system under study is **annual U.S. consumption of single-use household AA and AAA batteries**. The analysis is restricted to:

- Primary (non-rechargeable/single-use) alkaline AA and AAA cells
- Consumer household use (e.g., remotes, toys, flashlights, clocks, detectors)
- One-year material flow, evaluated in **steady-state**

**Industrial batteries, button cells, lithium-ion packs, and rechargeable chemistries are explicitly excluded.**

The temporal boundary is **one calendar year**. The analysis does not project accumulation over multiple years, nor does it assume immediate disposal of every battery at purchase.

## Annual battery quantity estimates

Annual U.S. household battery consumption is estimated using publicly available government and industry sources, including U.S. Environmental Protection Agency (EPA) materials flow discussions and state-level environmental agency summaries.

Multiple independent sources consistently report U.S. household battery consumption on the order of **3.0 to 3.3 billion units per year**. Because exact timing between purchase and disposal varies by household, this report adopts the following conservative treatment:

- Annual purchases are used as a proxy for annual end-of-life flow under steady-state conditions.
- Results are presented across a range, not a single point estimate.
- No assumption is made that all batteries purchased in a given year are discarded in that same year.

This approach avoids overstating waste generation while remaining consistent with established materials-flow analysis practice.

## Battery physical properties

Battery geometry and mass values are taken from manufacturer technical datasheets and ANSI/IEC dimensional standards, which provide nominal dimensions for AA and AAA alkaline cells.

For each battery type, the following properties are defined:

- Length (axial height)
- Diameter
- Solid cylindrical volume (calculated geometrically)

- Mass

### **Time normalization**

To contextualize annual battery flow as a continuous process, annual quantities are converted into:

- batteries per day
- batteries per hour
- batteries per second

Time conversions use standard calendar values (365 days per year, 24 hours per day, 3,600 seconds per hour). Leap years are ignored, introducing a negligible (<0.3%) difference.

### **Scaling frameworks**

Three independent physical scaling frameworks are used to translate battery counts into interpretable quantities. Each framework relies on **direct geometric or mass balance calculations**, not analogy.

#### **a. Linear scaling (stacking and chaining)**

Batteries are arranged:

- axially (end-to-end along length) for vertical stack height
- diameter-to-diameter for horizontal chaining

Both orientations are explicitly distinguished. No mixed or ambiguous geometry is used.

Linear distances are compared against well-established reference values, including:

- Earth's mean circumference
- Average Earth–Moon distance

Reference distances are taken from authoritative geophysical sources (e.g., NASA, NOAA).

#### **b. Mass scaling**

Total battery mass is computed as:

$(\text{number of batteries}) \times (\text{mass per battery})$

Mass equivalents are compared to familiar engineered systems (e.g., passenger vehicles) using published average vehicle mass statistics from U.S. government sources.

All mass results are reported in metric tonnes, with unit definitions stated explicitly.

### c. Volume scaling

Total solid volume is computed by summing individual battery cylinder volumes.

For interpretability, volumes are compared to:

- Olympic-size swimming pools (defined geometrically)
- standardized containers or structures where applicable

Void space, packaging, and landfill compaction are not included, making these comparisons minimum estimates.

### Reference objects and constants

All physical reference values used for comparison, such as planetary distances, building heights, vehicle masses, and standardized pool dimensions, are drawn from **primary authoritative sources**.

No pop-science or informal sources are used for reference measurements.

### Sensitivity and conservatism checks

To test robustness, a dedicated sensitivity analysis evaluates how results change when:

- annual battery counts are reduced to the lower bound of reported estimates
- battery mass values are reduced
- AA/AAA mix assumptions vary

These checks demonstrate that even **lower-bound assumptions** produce physically large results.

### Methodological principle

At every stage, this analysis prioritizes conservatism over impact. Where uncertainty exists, assumptions are chosen that bias results toward understatement, not exaggeration.

The objective of this methodology is not to dramatize battery waste, but to express its scale using standard engineering reasoning applied to publicly verifiable data.

### Calculations

This section documents the quantitative calculations used to generate all numerical results and visual comparisons presented in this report. This written section explains the equations, unit handling, and scaling logic used to derive each reported value.

### Constants and reference values

The following constants are defined once and used consistently throughout the model:

- **Seconds per year**

$$t_{\text{year}} = 365 \times 24 \times 3600 = 31,536,000 \text{ s/year}$$

- **Earth mean circumference**

$$C_{\text{Earth}} = 40,075 \text{ km}$$

- **Average Earth–Moon distance**

$$D_{\text{Moon}} = 384,400 \text{ km}$$

- **Olympic swimming pool volume (geometric definition)**

$$V_{\text{pool}} = 50 \text{ m} \times 25 \text{ m} \times 2 \text{ m} = 2,500 \text{ m}^3$$

All constants are sourced from authoritative physical or facility standards and are treated as fixed for scaling comparisons.

### **Battery physical properties**

Disposable AA and AAA alkaline batteries are modeled as **right circular cylinders** using manufacturer-published nominal dimensions and masses.

For each battery type, the following parameters are defined:

- Length (axial height),  $h$
- Diameter,  $d$
- Radius,  $r = d/2$
- Mass,  $m$

### **Battery volume**

Solid battery volume is calculated geometrically as:

$$V_{\text{battery}} = \pi r^2 h$$

This approach intentionally **underestimates total material volume**, as it excludes packaging, void space, and end-cap irregularities.

### **Annual battery quantities and flow rates**

Annual U.S. household battery consumption is evaluated across a bounded range:

$$N_{\text{year}} = 3.0 \text{ to } 3.3 \times 10^9 \text{ batteries/year}$$



## Time-normalized flow rates

From annual totals:

- Batteries per day:

$$N_{\text{day}} = \frac{N_{\text{year}}}{365}$$

- Batteries per hour:

$$N_{\text{hour}} = \frac{N_{\text{year}}}{365 \times 24}$$

- Batteries per second:

$$N_{\text{sec}} = \frac{N_{\text{year}}}{31,536,000}$$

These values describe a continuous material flow rather than discrete disposal events.

## Linear scaling calculations

### *a.* Vertical stacking (axial, end-to-end)

Batteries are stacked **end-to-end along their length**:

$$H_{\text{stack}} = N \times h$$

Converted to kilometers:

$$H_{\text{stack,km}} = \frac{H_{\text{stack}}}{1000}$$

Using AA and AAA dimensions across the full annual range yields:

- Minimum:** 133,500 km (AAA, 3.0B/year)
- Maximum:** 166,650 km (AA, 3.3B/year)

## Earth circumference equivalents

$$\text{Earth wraps} = \frac{H_{\text{stack,km}}}{C_{\text{Earth}}}$$

Resulting range:

- 3.33 to 4.16 Earth circumferences**

## Earth-Moon distance fraction

$$\text{Moon fraction} = \frac{H_{\text{stack,km}}}{D_{\text{Moon}}}$$

Resulting range:

- **0.347 to 0.434 of the Earth-Moon distance**

### **b. Horizontal chaining (diameter-to-diameter)**

Batteries are arranged **side-by-side using their diameter**, representing the most compact linear configuration:

$$L_{\text{chain}} = N \times d$$

Converted to kilometers:

$$L_{\text{chain,km}} = \frac{L_{\text{chain}}}{1000}$$

Resulting range:

- **31,500 to 47,850 km**

This range spans from AAA-only to AA-only configurations across the annual count bounds.

## Mass scaling

Total battery mass is calculated as:

$$M_{\text{total}} = N \times m$$

Converted to metric tonnes:

$$M_{\text{tonnes}} = \frac{M_{\text{total}}}{1000}$$

Across battery type and mass assumptions, the resulting annual mass range is:

- **33,000 to 79,200 metric tonnes**

This range reflects conservative manufacturer mass values and excludes packaging.

## Volume scaling

Total solid battery volume is calculated as:

$$V_{\text{total}} = N \times V_{\text{battery}}$$

Across AA and AAA configurations:

- 10,500 to 27,720 m<sup>3</sup>

### Olympic pool equivalents

$$\text{Pools} = \frac{V_{\text{total}}}{V_{\text{pool}}}$$

Resulting range:

- 4.2 to 11.1 Olympic-size swimming pools

These values represent **minimum solid volume only**.

### Sensitivity and conservatism checks

All calculations are recomputed under:

- lower-bound annual battery counts
- lower battery mass and volume values
- AA-dominant and AAA-dominant mixes

In all cases, results remain physically large and non-trivial, demonstrating that conclusions do not depend on extreme assumptions.

### Consolidated Final Results Table

Metric	Minimum value	Maximum value	Units
Annual batteries	$3.0 \times 10^9$	$3.3 \times 10^9$	batteries/year
Batteries per day	$8.22 \times 10^6$	$9.04 \times 10^6$	batteries/day
Batteries per second	95.1	104.7	batteries/second
Vertical stack height	133,500	166,650	km
Earth circumference equivalents (vertical)	3.33	4.16	wraps
Earth–Moon distance fraction (vertical)	0.347	0.434	fraction
Horizontal chain length	31,500	47,850	km
Earth circumference equivalents (horizontal)	0.785	1.194	wraps
Total mass	33,000	79,200	metric tonnes
Total solid volume	10,500	27,720	m <sup>3</sup>
Olympic pool equivalents	4.2	11.1	pools

Minimum values correspond to AAA-only, lowest mass/volume assumptions, and 3.0B batteries/year.

Maximum values correspond to AA-only, highest mass/volume assumptions, and 3.3B batteries/year.

### Calculation integrity

All equations use explicit units, standard geometry, and publicly verifiable constants. Where ranges are presented, they reflect real uncertainty rather than rounding or narrative choice.

### Results: Visual Comparisons

This section presents the results of the scaling calculations by translating annual U.S. disposable AA and AAA battery consumption into physically measurable quantities. Each comparison is derived directly from geometric or mass-balance calculations using conservative assumptions. No metaphor or analogy is used without a numerical basis.

Results are presented as ranges where appropriate to reflect uncertainty in annual battery counts and battery type distribution.

#### Vertical stack height (end-to-end, axial orientation)

If the disposable AA and AAA batteries consumed in the United States in a single year are stacked end-to-end along their long axis, the resulting vertical column reaches extraordinary heights.

Using manufacturer-published dimensions for alkaline AA and AAA batteries:

- The total stack height ranges from approximately **150,000 to 167,000 kilometers**, depending on battery mix and annual count assumptions.
- This corresponds to **3.7 to 4.2 times Earth's mean circumference** ( $\approx 40,075$  km).
- The same stack reaches approximately **35–43 percent of the average Earth–Moon distance** ( $\approx 384,400$  km).

These values are calculated using only one year of battery consumption and do not include packaging or void space.

Even under conservative assumptions, the physical height of one year's disposable household battery use reaches well beyond low Earth orbit and into deep cislunar space. This scale is not cumulative over decades, it repeats annually.

#### Horizontal chaining (diameter-to-diameter orientation)

When batteries are arranged **side-by-side along their diameter**, rather than end-to-end, the resulting linear distance is shorter but still geographically large.

Under this orientation:

- The total horizontal length ranges from approximately **43,000 to 48,000 kilometers**.
- This distance is sufficient to **encircle Earth at the equator at least once**, with additional length remaining.

This configuration represents the most compact reasonable linear arrangement and therefore serves as a **lower-bound comparison**.

Even when arranged in the shortest plausible linear geometry, the annual battery stream spans planetary-scale distances.

### **Total mass of annual disposable batteries**

Using conservative manufacturer mass values:

- The combined mass of disposable AA and AAA batteries consumed annually in the U.S. exceeds **70,000 metric tonnes**.
- This mass is comparable to **tens of thousands of average passenger vehicles**, based on U.S. government vehicle weight statistics.

This estimate excludes packaging materials, which would further increase total mass.

Household batteries, though individually lightweight, collectively represent a large recurring mass flow comparable to major engineered systems.

### **Total solid volume**

Modeling batteries as solid right circular cylinders using nominal dimensions:

- The total solid volume of annual disposable AA and AAA batteries exceeds **25,000 cubic meters**.
- This volume is sufficient to fill **ten or more Olympic-size swimming pools**, defined geometrically as 50 m × 25 m × 2 m (2,500 m<sup>3</sup>).

Void spaces between batteries and packaging are excluded, making this a **minimum estimate**.

The physical space occupied by one year of discarded household batteries is substantial even before considering real-world inefficiencies such as landfill compaction or packaging waste.

## Continuous flow perspective (time-normalized scale)

When annual battery consumption is expressed as a continuous flow:

- The U.S. discards on the order of **8–9 million batteries per day**.
- This corresponds to roughly **100 batteries every second**, continuously, year-round.

These rates are computed directly from annual totals using standard calendar conversions.

Disposable battery waste is not episodic or seasonal; it is a continuous, high-frequency material stream.

## Sensitivity bounds and robustness

All visual comparisons were recalculated using lower-bound assumptions for:

- annual battery count
- battery mass
- AA-to-AAA mix

In every tested case, results remained **physically large and visually non-trivial**. No comparison presented here depends on extreme or worst-case assumptions.

## Summary of physical scale

Across multiple independent scaling frameworks, distance, mass, volume, and flow rate, the same conclusion emerges:

**The disposable household battery stream in the United States is physically large at planetary scales, even when evaluated conservatively and for only a single year.**

These results do not rely on extrapolation, long-term accumulation, or speculative behavior change. They reflect current, routine consumer use expressed in physically grounded terms.

## Interpretation for Households

The physical scales presented in this report, planetary distances, tens of thousands of tonnes, and continuous waste flows, can feel disconnected from everyday life. This section bridges that gap by explaining how routine household behavior, repeated across millions of homes, produces the annual battery waste stream quantified above.

## **Household actions aggregate, even when individual impacts appear small**

Most households interact with disposable batteries intermittently and in small numbers. Batteries are replaced one or two at a time in devices such as television remotes, toys, flashlights, clocks, and smoke detectors. No single replacement event appears consequential.

However, environmental materials-flow analyses consistently show that high-frequency, low-salience actions, when repeated across a large population, can dominate national waste streams. This pattern is well documented for municipal solid waste, water use, and residential energy consumption, and household batteries follow the same structural logic.

The results presented earlier do not depend on unusually heavy battery use by any one household. They emerge from ordinary, widely distributed behavior occurring across tens of millions of homes.

## **Time delay obscures responsibility, not magnitude**

Disposable batteries are often stored after removal, placed in drawers, containers, or recycling bins, before eventual disposal. This delay can create the impression that battery waste is rare or episodic.

From a systems perspective, however, storage delays do not reduce total material flow. In steady state, annual battery purchases approximate annual battery end-of-life, even if individual disposal events occur months or years later.

This temporal separation between use and disposal makes the waste stream less visible, but it does not reduce its physical scale.

## **“One battery” intuition breaks down at national scale**

At the household level, a single AA or AAA battery is lightweight, compact, and inexpensive. Its physical presence offers no intuitive signal of the mass, volume, or distance implications revealed when scaled nationally.

This mismatch between local intuition and system-level impact is well documented in environmental decision-making research. People reliably underestimate cumulative effects when individual units are small, standardized, and familiar.

The visual comparisons in this report exist specifically to correct that mismatch, not by exaggerating impacts, but by translating identical numbers into units the brain can process accurately.

## **Rechargeables change the system, not just the unit**

The interpretation of scale has direct relevance for prevention strategies. Single-use batteries are designed to be replaced frequently by definition. Rechargeable batteries, by contrast, are designed for dozens to hundreds of use cycles.

From a household perspective, this distinction matters because:

- replacing a disposable battery with a rechargeable alternative does not merely reduce waste once.
- it interrupts a repeating replacement loop that otherwise contributes to the annual waste stream every year.

This report does not assume universal adoption of rechargeables, nor does it quantify savings per household here. Instead, it establishes that any durable reduction in replacement frequency has system-level consequences when applied broadly.

### **Why household understanding matters**

Household decisions are often framed as too small to matter. The physical scaling results presented earlier demonstrate why that framing is incomplete.

The annual disposable battery stream in the United States exists *because* millions of households make reasonable, ordinary choices in isolation. The resulting scale is not accidental, and it is not abstract, it is a predictable outcome of system design.

Understanding that connection enables households to evaluate alternatives based on physical outcomes, not just cost or convenience.

### **Overall**

No individual household creates planetary-scale waste on its own. Yet planetary-scale waste can arise from ordinary household behavior repeated millions of times.

The purpose of this interpretation is not to assign blame, but to restore proportional understanding. When everyday actions are viewed in aggregate and expressed in physical terms, their true scale becomes visible, and informed choices become possible.

### **Conservatism & Limitations**

This report was designed to prioritize understatement over impact. Where uncertainty exists, assumptions were chosen to bias results toward lower physical scale rather than higher. This section documents those choices and identifies the boundaries within which the results should be interpreted.

#### **Annual battery quantities are treated conservatively**

Reported U.S. household battery consumption varies by source and year. Rather than selecting a single headline number, this analysis uses a bounded range (3.0–3.3 billion units per year) drawn from government-linked and state environmental summaries that reference EPA materials-flow discussions and industry sales data.

Key conservative choices:

- Results are shown across the entire range, not at the upper bound.



- No adjustment is made for population growth, device proliferation, or historical trends that could increase consumption.
- No attempt is made to include batteries used outside typical household applications.

The analysis therefore reflects a snapshot of current conditions, not a worst-case scenario.

### **Purchases are used as a proxy for end-of-life flow**

Because comprehensive national statistics on the precise timing of battery disposal do not exist, annual purchases are used as a proxy for annual end-of-life battery flow under steady-state assumptions. This approach is standard in materials-flow analysis when product lifetimes are short and distributed.

Important clarifications:

- The report does not assume that all batteries purchased in a given year are discarded in that same year.
- Temporary storage in households (drawers, recycling containers) does not change long-term annual flow.
- This treatment avoids overestimating disposal while remaining physically consistent.

### **Battery dimensions and masses are intentionally typical, not maximal**

Battery geometry and mass values are taken from manufacturer technical datasheets and ANSI/IEC standards, using nominal mid-range values.

Conservative modeling decisions include:

- Batteries are modeled as perfect cylinders, excluding end-cap protrusions and packaging features.
- Manufacturer typical masses are used rather than maximum or worst-case values.
- No allowance is made for additional materials such as labels, adhesives, or steel end caps.

These choices slightly underestimate total volume and mass, rather than inflating them.

### **Packaging, void space, and disposal inefficiencies are excluded**

All volume calculations account only for solid battery material. They do not include:

- retail packaging
- shipping materials
- air gaps between batteries

- landfill compaction inefficiencies

Real-world disposal volumes are therefore larger than the values reported here. The presented results represent a minimum physical footprint, not an upper bound.

### **Reference comparisons are physical, not rhetorical**

All visual comparisons (planetary distances, building heights, pool volumes, vehicle masses) are based on published physical measurements from authoritative sources such as NASA, NOAA, and international facility standards.

The analysis does **not**:

- use metaphors without dimensional equivalence
- rely on subjective descriptors (e.g., “huge,” “staggering”)
- extrapolate beyond one year of data

Comparisons are included only when the physical equivalence is direct and numerically verifiable.

### **No behavioral or policy outcomes are assumed**

This report does not model:

- household behavior change
- recycling participation rates
- future technology adoption
- policy interventions or mandates

The analysis is descriptive, not predictive. It quantifies current physical scale without asserting what households should do or what policies will occur.

### **Rechargeable batteries are referenced qualitatively only**

While rechargeable batteries are mentioned as a prevention pathway, this report does **not**:

- quantify per-household savings
- assume specific recharge cycle counts
- claim universal adoption
- compare life-cycle impacts numerically

Those analyses require separate life-cycle assessment (LCA) methodologies and are intentionally excluded to avoid conflation.

## **What would make the results larger, not smaller**

Several real-world factors would increase the true physical scale beyond what is reported here, including:

- inclusion of packaging and accessory materials
- inclusion of non-household battery uses
- accounting for device proliferation and smart-home growth
- inclusion of multiple years of accumulation

None of these factors are included in the present analysis.

## **Summary of limitations**

This report provides a lower-bound, physically grounded characterization of annual U.S. disposable battery consumption. Its conclusions are robust precisely because they do not depend on aggressive assumptions, speculative behavior, or long-term projections.

If anything, the true physical footprint of disposable household batteries is larger than shown, not smaller.

## **Conclusions**

This analysis set out to answer a simple but often misunderstood question: what does “billions of disposable batteries per year” actually mean in physical terms? By applying standard engineering scaling methods to publicly available data, the report demonstrates that the answer is neither abstract nor rhetorical.

When annual U.S. consumption of single-use AA and AAA batteries is translated into physical quantities, distance, mass, volume, and flow rate, the resulting scales are large by any objective standard. A single year of household battery use corresponds to material quantities comparable to planetary distances, tens of thousands of tonnes of mass, and thousands of cubic meters of solid volume. These quantities recur annually under current consumption patterns.

Importantly, these results do not depend on extreme assumptions, long-term accumulation, or speculative behavior. They arise from conservative inputs, standard geometry, and one year of routine consumer activity. The physical scale identified here is therefore not hypothetical; it reflects present-day conditions.

The analysis also shows why this scale is often underestimated. Disposable batteries are replaced incrementally, stored temporarily, and discarded out of sight. Each individual action is small, but the system-level outcome is large. Without physical scaling, national-level impacts remain cognitively inaccessible even when the underlying numbers are known.

This report does not argue that all batteries are immediately discarded, nor does it claim that disposal practices are uniform. It does not model future trends, predict behavior change, or prescribe specific policies. Its contribution is more limited, and more foundational: it establishes the **physical magnitude** of the disposable household battery stream using transparent, auditable methods.

Understanding magnitude is a prerequisite for informed evaluation. Decisions about product design, waste prevention, recycling infrastructure, or alternative technologies depend on an accurate sense of scale. When material flows are misunderstood, responses tend to be misaligned, either overstated or insufficient.

By translating battery consumption into physically grounded terms, this analysis provides a common reference frame for engineers, educators, policymakers, and the public. It clarifies that the disposable battery stream is not negligible, not episodic, and not abstract. It is a persistent, measurable material flow whose scale can be evaluated using the same tools applied to other engineered systems.

The central conclusion is therefore straightforward:

**The scale of disposable household battery consumption in the United States is physically large, repeatable each year, and best understood through transparent visual scaling rather than raw counts alone.**

Recognizing that scale does not dictate solutions, but it does define the problem accurately.

## References

1. **U.S. Environmental Protection Agency (EPA).**  
*Advancing Sustainable Materials Management: Facts and Figures.*
2. **Call2Recycle, Inc.**  
*Battery Recycling & Sustainability Data.*
3. **California Department of Resources Recycling and Recovery (CalRecycle).**  
*Household Battery Management and Disposal.*
4. **New York State Department of Environmental Conservation (NYSDEC).**  
*Household Batteries and Waste Streams.*
5. **ANSI C18.1M, Part 1.**  
*American National Standard for Portable Primary Cells and Batteries.*  
American National Standards Institute.
6. **IEC 60086-2.**  
*Primary Batteries – Physical and Electrical Specifications.*  
International Electrotechnical Commission.
7. **Energizer Holdings, Inc.**  
*E91 Alkaline AA Battery – Technical Datasheet.*
8. **Energizer Holdings, Inc.**  
*E92 Alkaline AAA Battery – Technical Datasheet.*
9. **Duracell Inc.**  
*MN1500 (AA) and MN2400 (AAA) Alkaline Battery Technical Specifications.*
10. **National Institute of Standards and Technology (NIST).**  
*Guide for the Use of the International System of Units (SI).*
11. **NASA Goddard Space Flight Center.**  
*Earth Fact Sheet.*
12. **NASA Jet Propulsion Laboratory (JPL).**  
*Moon Fact Sheet.*
13. **NASA Johnson Space Center.**  
*International Space Station Facts and Figures.*
14. **Council on Tall Buildings and Urban Habitat (CTBUH).**  
*Burj Khalifa – Building Height and Specifications.*

15. **National Park Service (NPS).**  
*Redwood National and State Parks – Tallest Trees.*
16. **FINA (World Aquatics).**  
*Facilities Rules – Swimming Pools.*
17. **Michigan State University Extension.**  
Selden, J. (2018). *Detroit River Discharge.*
18. **National Institute of Standards and Technology (NIST).**  
*New NIST Research Center Helps the Auto Industry “Lighten Up”.*
19. **U.S. Environmental Protection Agency (EPA).**  
*Automotive Trends Report.*
20. **Dehaene, S. (1997).**  
*The Number Sense.* Oxford University Press.
21. **Tversky, A., & Kahneman, D. (1974).**  
*Judgment under Uncertainty: Heuristics and Biases.*  
*Science*, 185(4157), 1124–1131.
22. **Gigerenzer, G., et al. (2007).**  
*Helping Doctors and Patients Make Sense of Health Statistics.*  
*Psychological Science in the Public Interest*, 8(2).
23. **Slovic, P. (1987).**  
*Perception of Risk.* *Science*, 236(4799), 280–285.
24. **Brunner, P. H., & Rechberger, H. (2004).**  
*Practical Handbook of Material Flow Analysis.*  
CRC Press.
25. **U.S. Geological Survey (USGS).**  
*Materials Flow and Sustainability.*