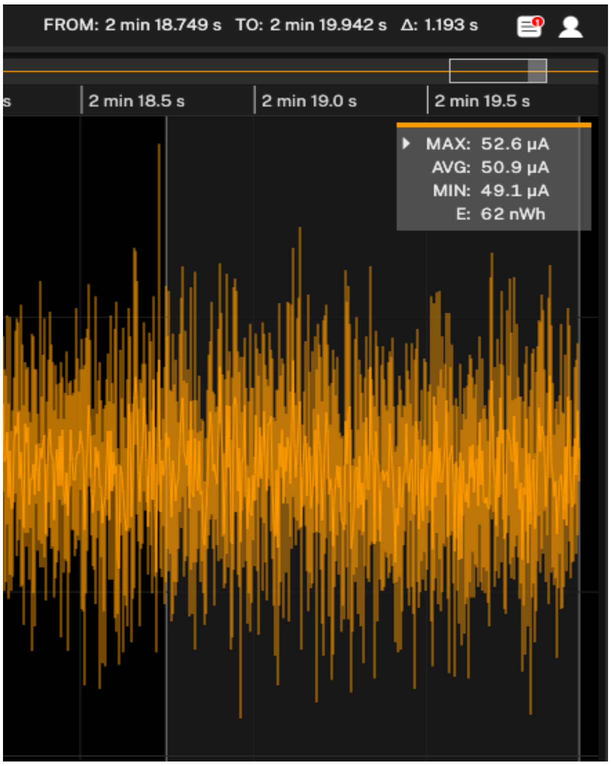
Battery Life analysis for Aqua-Scope Rain Gauge (RANWIE01)

ESP32 power profile measured with OTII Arc — powered by 2 × Bevigor LFB AAA ($LiFeS_2$, equivalent to Energizer Ultimate Lithium AAA / L92)

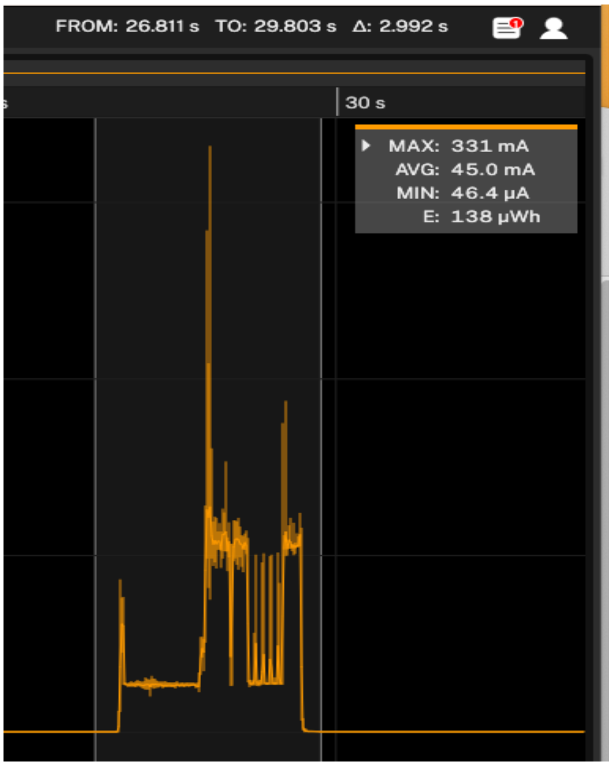
Date: 2026-05-12

1. Measured power profile

The current draw of the ESP32-based device was measured with an OTII Arc battery analyser. Two operating modes were captured:



__Deep sleep__ — avg 50.9 µA (min 49.1 / max 52.6 µA)



__Wi-Fi wake-up__ — avg 45.0 mA over 2.99 s (peak 331 mA)

Parameter	Value	Source
Sleep current (average)	51.0 µA	OTII screenshot 1
Wi-Fi wake current (avg)	45.0 mA	OTII screenshot 2
Wi-Fi wake duration	3.00 s	OTII screenshot 2
Wake-ups per day	5	every 6 h ⇒ 4/day + 1 extra
Pack cut-off voltage	2.9 V (1.45 V/cell)	ESP32 brown-out

2. Battery: Bevigor LFB AAA ($LiFeS_2$)

The rain gauge is powered by two **Bevigor LFB AAA** lithium iron-disulfide ($LiFeS_2$) cells in series, giving a nominal pack voltage of 3.0 V (1.5 V per cell). The LFB AAA is chemically and mechanically equivalent to the Energizer Ultimate Lithium AAA (L92), so its datasheet values are used for this analysis:

Property	Value
Form factor	AAA (LR03 / R03 size)
Chemistry	Lithium iron-disulfide (LiFeS2)
Nominal voltage	1.5 V per cell / 3.0 V pack
Open-circuit voltage	≈ 1.8 V per cell (fresh)
Rated capacity	1250 mAh to 1.0 V/cell at 25 mA, 21 °C
Operating temperature	–40 °C … +60 °C
Self-discharge	≤ 0.5 % per year (>90 % after 20 a)
Internal resistance	90 … 250 mΩ
Weight	≈ 7.5 g per cell

Discharge / voltage relationship. $LiFeS_2$ cells have an unusually flat discharge curve: under light loads the cell voltage stays between 1.55 V and 1.45 V for the vast majority of its capacity, then drops rapidly past the "knee". The ESP32 brown-out for the rain gauge is set to 2.9 V (i.e. 1.45 V per cell), so the device runs almost to the knee of the discharge curve before shutting down. At the very low average load of this design (≈ 0.06 mA), the cell stays above 1.45 V for roughly the first **1200 mAh** of its 1250 mAh rated capacity.

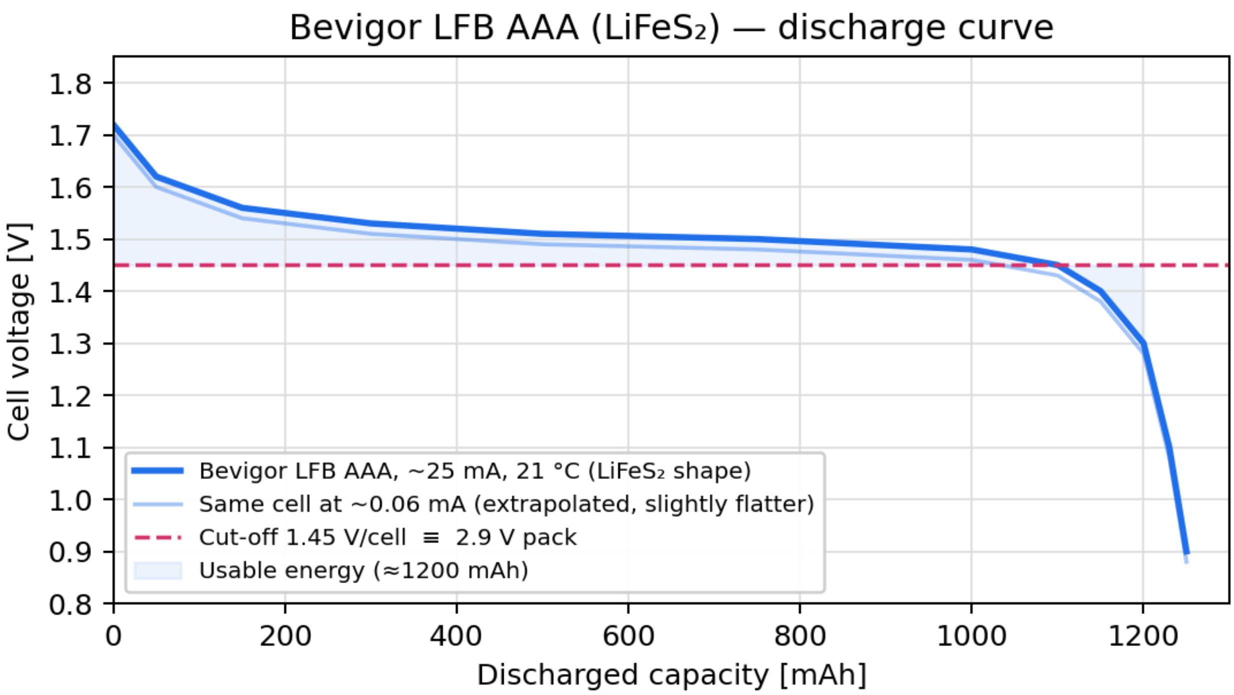


Fig. 1 — Representative L91 single-cell discharge curve. The blue-shaded area is the energy usable before the 3.0 V pack cut-off is reached.

3. Daily energy budget

Phase	Current	Time / day	Charge	Share
Deep sleep	51.0 µA	86385 s (23.996 h)	1.2238 mAh	86.7 %
Wi-Fi wake-ups (5/day × 3 s)	45.0 mA	15 s	0.1875 mAh	13.3 %
TOTAL per day	**—**	**86400 s (24 h)**	**1.4113 mAh**	**100 %**
Average current	**58.80 µA**	**—**	**—**	**—**

Observation. Even though a Wi-Fi wake draws ~880 × more current than sleep, it only runs for 15 s out of 86 400 s. The deep-sleep current still dominates the daily charge by a factor of ≈6.5.

4. Expected battery life

The pack delivers two cells in series, so its capacity is that of a single AAA cell. Three scenarios are computed for the usable capacity down to 1.45 V per cell (= 2.9 V pack cut-off):

Scenario (cut-off 2.9 V pack ≡ 1.45 V/cell)	Usable capacity	Lifetime (ideal)	Lifetime (incl. 0.5 %/a self-d
Conservative (1050 mAh to 1.45 V/cell)	1050 mAh	2.04 a (744 d)	2.02 a (737 d)
Typical (1200 mAh to 1.45 V/cell)	1200 mAh	2.33 a (850 d)	2.30 a (841 d)
Optimistic (1250 mAh to 1.0 V/cell)	1250 mAh	2.42 a (886 d)	2.40 a (875 d)

Expected lifetime ≈ 2.3 years

(typical: 1200 mAh usable to 2.9 V pack, 5 wake-ups / day, including self-discharge)

5. Assumptions & remarks

• Constant ambient temperature near 21 °C. At < 0 °C the L91 still delivers most of its capacity, but the voltage plateau drops slightly, which may shorten the usable capacity above 3.0 V pack.

• Pulse currents during Wi-Fi wake (peak 331 mA) are well below the AAA $LiFeS_2$ cell's continuous rating (1.5 A) and pulse rating (2 A), so no extra voltage sag is expected.

• The two cells are assumed matched. With unmatched cells the weaker one hits 1.5 V earlier and limits the pack.

• Self-discharge is modelled as a constant 0.5 % of the remaining capacity per year, which is the typical figure quoted by Energizer (20-year shelf life, ≥ 90 % retained).

• The 1200 mAh "typical" capacity is the energy available above 1.45 V per cell at sub-mA loads. At higher loads (or higher cut-off) this number would be lower.

• If lifetime needs to be extended further, the sleep current is the biggest lever: dropping from 51 µA to 10 µA would extend lifetime to roughly 7.7 years.

6. Circumstances that can shorten battery life

Two real-world conditions can noticeably reduce the calculated lifetime:

Poor Wi-Fi connectivity. The base calculation assumes a 3-second wake to associate with the access point and push a measurement to the cloud. If the Wi-Fi connection is slow (weak signal, busy router, DHCP delays, DNS retries) and the wake takes twice as long — say **6 seconds** instead of 3 — then the active-mode charge doubles from **0.188 mAh/day** to **0.375 mAh/day**. The daily energy budget grows from 1.411 mAh to 1.599 mAh, shortening the expected lifetime by about **12 %** — from 2.30 years down to roughly **2.03 years** (≈97 days less).

Aged or degraded battery. As the cells age (or run cold), their internal resistance rises and the voltage plateau is pulled down. The pack voltage then crosses the 2.9 V brown-out threshold earlier in the discharge curve, leaving usable capacity stranded above the cut-off. A degraded pack may yield only 800–1000 mAh of usable charge instead of 1200 mAh, reducing the lifetime proportionally (e.g. from 2.30 years to ~1.92 years at 1000 mAh usable).

7. Ways to increase battery life

The base calculation assumes 5 wake-ups per day (every 6 h + 1 extra). The device only really needs to phone home when something has to be reported:

• **365 rain-event reports per year** (1/day on average — in dry seasons fewer, in wet seasons more).

• **Daily heartbeat reduced from 2 to 1 per day** (365/year). The 6-hourly schedule is overkill for a sensor whose only job is to confirm "still alive".

That gives 730 wake-ups per year ≈ **2 wake-ups per day** on average, instead of 5/day. The new daily budget is:

- Active: 45 mA × 6 s = **0.075 mAh/day**
- Deep sleep: 51 µA × 86394 s = **1.224 mAh/day**
- **Total: 1.299 mAh/day** (vs 1.411 mAh/day in the 5-wake baseline)

Expected lifetime in this scenario rises to about **2.50 years** (1200 mAh / 1.315 mAh/day incl. self-discharge), an improvement of **9 %** over the 5-wake baseline (≈72 extra days).

Extended lifetime ≈ 2.50 years

(2 wake-ups/day instead of 5, 1200 mAh, incl. self-discharge)