# Brain energy

Main energy units

- Joule (J): The SI unit of energy; brain energy use in biophysics and neuroscience is often expressed in joules or joules per second (watts) when talking about power.
- Calorie / kilocalorie (cal / kcal): In nutrition and whole-body energy balance, the brain's daily energy consumption is often given in kilocalories, as part of total dietary energy intake.

Power and metabolic units

- Watt (W): When describing how fast the brain uses energy, power is expressed in watts, which are joules per second; an adult human brain typically uses on the order of tens of watts.
- Metabolic units: In detailed research, brain energy metabolism can also be expressed in units like micromoles per gram per minute (μmol/g/min) for glucose, oxygen, or ATP usage, which quantify chemical energy turnover in tissue.

**1. Power Consumption: Brain vs. Mobile Phone**

**Human Brain**

- **Average power consumption:** ~20 watts (W) ≈ **20 joules per second**.
- This is **≈ 20% of total resting metabolic energy** of the **whole human body.**
- Even when resting or sleeping, the brain's consumption remains high because:
  - it continuously processes signals,
  - maintains ionic gradients,
  - coordinates the internal body state,
  - and supports ongoing consciousness, memory, and prediction.

👉 **The brain never goes "offline."** Its "antenna" is always active.

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**Mobile Phone**

- **Typical power consumption while idle or background mode:** 0.1–0.5 W
- **During calling, data transfer, or video:** 1–3 W
- **Peak when gaming or high brightness:** 4–7 W (flagship devices can spike higher)

👉 A smartphone spends most of its time **asleep**, and its maximum power draw is **still lower than a continuously active brain**.

**Conclusion:**

Even a top smartphone will rarely exceed **7 W**, while the brain continuously draws **20 W**.


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**2. Total Daily Energy Budget**

Energy is power × time:

**Energy (joules) = Power (watts) × Time (seconds)**

or in daily units: **kilojoules (kJ) or kilocalories (kcal)**

**Brain**

At 20 W, over 24 hours:

- **20 W × 24 h = 480 watt-hours**
- Convert:
  - 480 Wh ≈ **1,728,000 joules (1.7 MJ)**
  - ≈ **400 kilocalories** (food calories)

This is **roughly a small meal per day exclusively for brain activity.**

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**Mobile Phone**

Let's assume:

- Idle background: 0.2 W for 20 hours = 4 Wh
- Active usage: 3 W for 4 hours = 12 Wh

**Total per day = 16 Wh**

= **57,600 joules (0.058 MJ)**

**≈ 14 food calories**

So:

**The brain consumes ≈ 30× more energy per day than a smartphone.**

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So, in rough terms, the brain's continuous energy use is higher than, the power of a phone while it is charging, and over a whole day it consumes the energy equivalent of charging a smartphone many times.

For a single text/IM message, the energy used by the phone's communications hardware (radio, CPU, etc.) is tiny – on the order of microjoules to millijoules – and is usually much smaller than the energy for the screen.

Reasonable back-of-the-envelope estimate:

- Modern phone Wi-Fi radios can use on the order of tens to hundreds of nanojoules per bit.
- A short message (say a few hundred bytes including protocol overhead, roughly 2–3 kilobytes = about 20,000 bits) at 100 nanojoules per bit would cost around $20{,}000 \times 10^{-7}$ joules ≈ 0.002 joules (2 millijoules) to send or receive.
- Even if cellular data is somewhat less efficient than Wi-Fi, you are still likely talking about at most a few millijoules per message for the radio plus some similar order of magnitude overhead in the modem/CPU.

- A typical smartphone battery stores around 15,000–20,000 joules, so a 0.002–0.01 joule cost per message is effectively negligible for battery percentage.
- Studies that measured instant-messaging energy usage over minutes show that the total device energy rises with message count, but the per-message contribution (excluding the display) is still very small compared with screen and background activity.

Step-by-step rough estimate (Daily energy in joules)

- Brain: Running at around 20 watts over 24 hours gives about 480 watt-hours per day, which is about 1.7 million joules per day.
- Phone: If a phone needs about 19 watt-hours for a full charge, that is about 68,000 joules per full charge, so the brain uses on the order of 20–30 times more energy per day than one typical phone charge.
- A single short message (a few kilobytes including overhead) was estimated at about 0.002–0.01 joules (2–10 millijoules) for radio + processing, ignoring the screen.
- "Constant" messaging could mean, for example, on the order of 1 message per second. Over 24 hours that is about 86,000 messages.
- At 0.002 joules per message, that gives about 172 joules per day: at 0.01 joules per message, about 860 joules per day.

So, a very rough but reasonable range for intense, continuous messaging traffic is around $10^2$–$10^3$ joules per day just for sending/receiving (no screen), which is still well below the 15,000–20,000 joules stored in a typical smartphone battery.

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**3. Why the Units Matter**

**Electrical devices**

- Measured in **power (W)** and **energy (Wh or joules)**

**Biological systems**

- Equivalent physics units apply,
- But biology adds:
  - **kilocalories (kcal)** from metabolism
  - **oxygen consumption (mL/min)** as an energy proxy
  - **ATP turnover rates** (molecules/sec)

So, for clarity:

| Context | Power units | Energy units |
|---|---|---|
| Engineering (phone) | watts (W) | watt-hours (Wh), joules (J) |
| Biology (brain) | watts (W) | joules (J), kilocalories (kcal), or oxygen use |

All are compatible through standard conversions.

**4. Signaling Efficiency: The Brain as an Antenna**

**Mobile Device Signals**

- Radiate:
  - **RF energy in milliwatts (mW)**
  - A receiver needs only **picowatts to nanowatts**
- Antennas are explicitly designed to:
  - detect, filter, amplify, decode, and store external information

**Brain Signals**

- The brain:
  - maintains electric potential across membranes
  - fires synapses
  - produces electromagnetic oscillations
  - is massively parallel
- Power needed per bit of internal neural computation is **astonishingly low**:
  - estimated **$10^{-14}$ joules per synaptic event**
  - For comparison, computers are millions of times less efficient

**Yet in terms of radiated, broadcast energy to the outside world**, the brain is extremely conservative. The EM fields measured outside the skull are tiny (fT to pT), which is why **MEG**, **EEG**, or **SQUID** detectors are needed.

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**5. Efficiency of Information Processing**

**Brain**

- (very rough scientific consensus)
- **$10^{15}$ synaptic operations per second**
- **20 watts**
- So:
  **$10^{14}$–$10^{15}$ operations per joule**

**Mobile Phone CPU**

- **$10^{7}$–$10^{8}$ operations per joule**

So, the brain is **Millions to billions of times more energy-efficient** than silicon.

This is the deepest reason the brain IS a good biological antenna:

- It extracts meaning from extremely weak and noisy signals
- With almost no excess energy
- And integrates huge context from past experience

Phones need towers and amplification.

Brains rely on **distributed resonance and learning**.



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### 6. The "Antenna Metaphor" Revisited

Our philosophical framing is now easier to ground scientifically:

- **A smartphone antenna** receives a clean digital signal from a powerful transmitter, then decodes it via silicon logic, powered by a battery.
- **A brain-antenna**, if we expand the metaphor beyond simple EM coupling, receives:
  - sensory inputs (photons, air vibrations, chemical signals),
  - emotional and social signals,
  - memory and predictive context,
  - and possibly subtle environmental fields and **decodes them into meaning, consciousness, and adaptive behavior** using only **20 watts** and a vast distributed biological network.
- ❖ Phones are signal receivers.
- ❖ Brains are **signal receivers, predictors, interpreters, creators, simulators, narrators, and meaning-makers**.

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### 7. Final Numbers Summary Table

| System | Continuous Power | Daily Energy | Daily Energy Source |
|---|---|---|---|
| **Brain** | 20 W | 480 Wh ≈ 1.7 MJ ≈ 400 kcal | Food metabolism |
| **Smartphone** | 0.1–7 W (usage-dependent) | ~16 Wh ≈ 0.058 MJ ≈ 14 kcal | Lithium battery |

**Ratio (Daily):**
**Brain ≈ 30× total energy usage of smartphone**
**Brain per operation $\gg 10^6\times$ efficiency of smartphone computing**

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### Final Insight

From an **informational perspective**:

- A brain can **perceive**, **synchronize**, **interpret**, and sometimes **radiate** its states with **orders of magnitude less energy** per unit of information than any man-made device.
- Its continuous operation is a signature of a **biological quantum-level antenna and decoder**, intertwined with:
  - metabolism,
  - memory,
  - meaning,
  - emotion,
  - and consciousness.


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