

King of Dumbs

Level: ♦ Intermediate

Joules, watts or calories? Energy and power without fear

Energy is how much; power is how fast. Joules, watts, kcal and kWh explained with a bathtub, why fast means hot and how to compare scales, in three levels.

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Scan to open the interactive lesson

<https://kingofdumbs.com/en/lessons/joules-watts-or-calories>

What you'll learn

- Energy and its units: joule, kilocalorie and kilowatt hour
- Power and the watt
- The difference between energy and power
- Heat versus temperature
- Comparing powers on a log scale

Before this lesson

If something sounds like gibberish, these lessons explain it from scratch:

1. [How much is \$7 \times 10^{27}\$? Huge numbers without fear](#)

Symbols you'll meet

Δ change: how much it moved (♦♠) · E_a subscript: the label underneath (♠) · $\bar{x}$ bar on top: the average (♠) · $\approx$ approximately equal (♦♠) · $\equiv$ is defined as (♠) · $\cdot$ dot: multiply (or dot product) (♠) · 10^{-3} negative exponent: divide (♠) · e the number e (≈ 2.718) (♠) · $\log$ logarithm: how many times do I multiply? (♠) · σ sigma: depends on the lesson (♠) · τ tau: a characteristic time (♠) · ϵ epsilon: something tiny (♠) · dE/dt derivative: the rate of change (♠) · $\int$ integral: adding up slivers (♠)

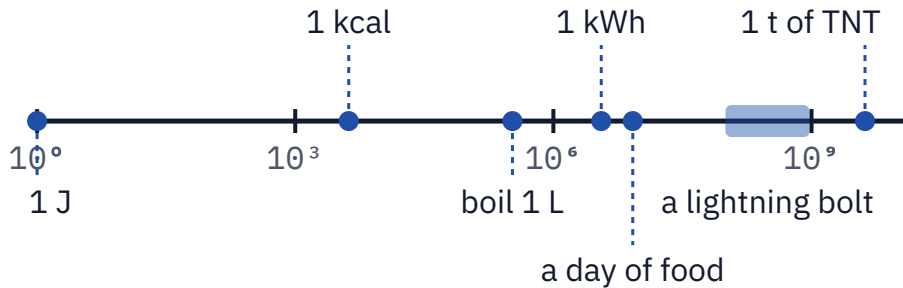
A kettle's label says **2,000 W**. An electricity bill talks about **kW** and **kWh**. A yoghurt, about **kcal** and **kJ**. And the dumb question of this lesson is: **do all of those measure the same thing?**

Almost. There are two different questions in there: **how much** energy you need, and **how fast** it's delivered. The first is measured in joules (or calories, or kWh); the second, in watts. Mixing them up is so common that education research finds it even among future physics teachers. Pulling them apart clears up more doubts than you'd think, especially the "is that even possible?" kind.

Pick your card: ♠ if you're starting from zero, ♦ if a simple formula doesn't scare you, ♠ if you want the notation. You can switch at any time.

Energy: how much

joules (log scale: each tick $\times 1000$)



Energy is what you have to supply to change something: lift it, speed it up, heat it or break it. It has two very useful properties. It is **conserved**: it neither appears nor disappears, it only passes from one form to another. And all its forms are measured with the same unit, the **joule** (J).

A joule is the energy of pushing with a force of one newton over one metre. In practice, lifting a 100 g apple by one metre costs almost exactly one joule: $0.1 \text{ kg} \times 9.8 \text{ m/s}^2 \times 1 \text{ m} \approx 0.98 \text{ J}$.

The other units are the joule in a different size:

Unit	In joules	Where you see it
Kilocalorie (kcal), the food "Calorie"	4,184 J	Food labels, which in the EU must give kJ and kcal
Kilowatt hour (kWh)	3,600,000 J	Electricity bill
Electronvolt (eV)	0.000 000 000 000 000 16 J	Atomic physics
Tonne of TNT	4,184,000,000 J	Explosions

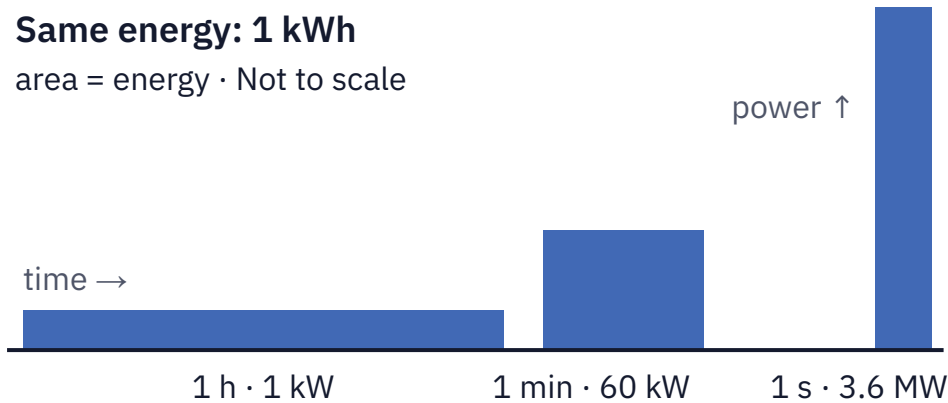
A kilocalorie is also almost exactly what it takes to warm a litre of water by one degree: 4,184 J against about 4,180 J.

On the ruler above, each tick multiplies by a thousand. That's how an apple and a tonne of TNT fit in the same drawing.

Power: how fast

Same energy: 1 kWh

area = energy · Not to scale



Power is energy divided by time: $P = E / t$. A **watt** (W) is one joule per second. The other way round, energy is power times time: $E = P \cdot t$.

That's where the kilowatt hour comes from: 1,000 W for 3,600 s is 3.6 million joules. A 2,000 W kettle on for 3 minutes uses $2,000 \times 180 = 360,000$ J, which is 0.1 kWh.

If you draw power going up and time going across, energy is the **area** of the rectangle. The same energy fits in a long, low rectangle or in a narrow, very tall one: 1 kWh is 1 kW for an hour, 60 kW for a minute or 3.6 megawatts (MW, millions of watts) for a second.

Some reference powers:

What	Power
A person at rest	68–87 W
Tour de France cyclist, average over a stage	218–234 W
The same cyclist, best 30-minute average	342–394 W
The same cyclist, best 15-second average	836–895 W
A typical nuclear reactor, in electricity	1,000,000,000 W (1 GW)

Look at the cyclist: the shorter the effort, the more power they can hold. Power isn't only how much you can do, but for how long.

Lightning is the extreme case. A typical bolt carries about 950 million joules, about 260 kWh (other estimates go as low as 100 million): the same as a 2,000 W kettle running for about 130 hours. It isn't a huge amount of energy. What makes it terrible is that it releases it in a fraction of a second.

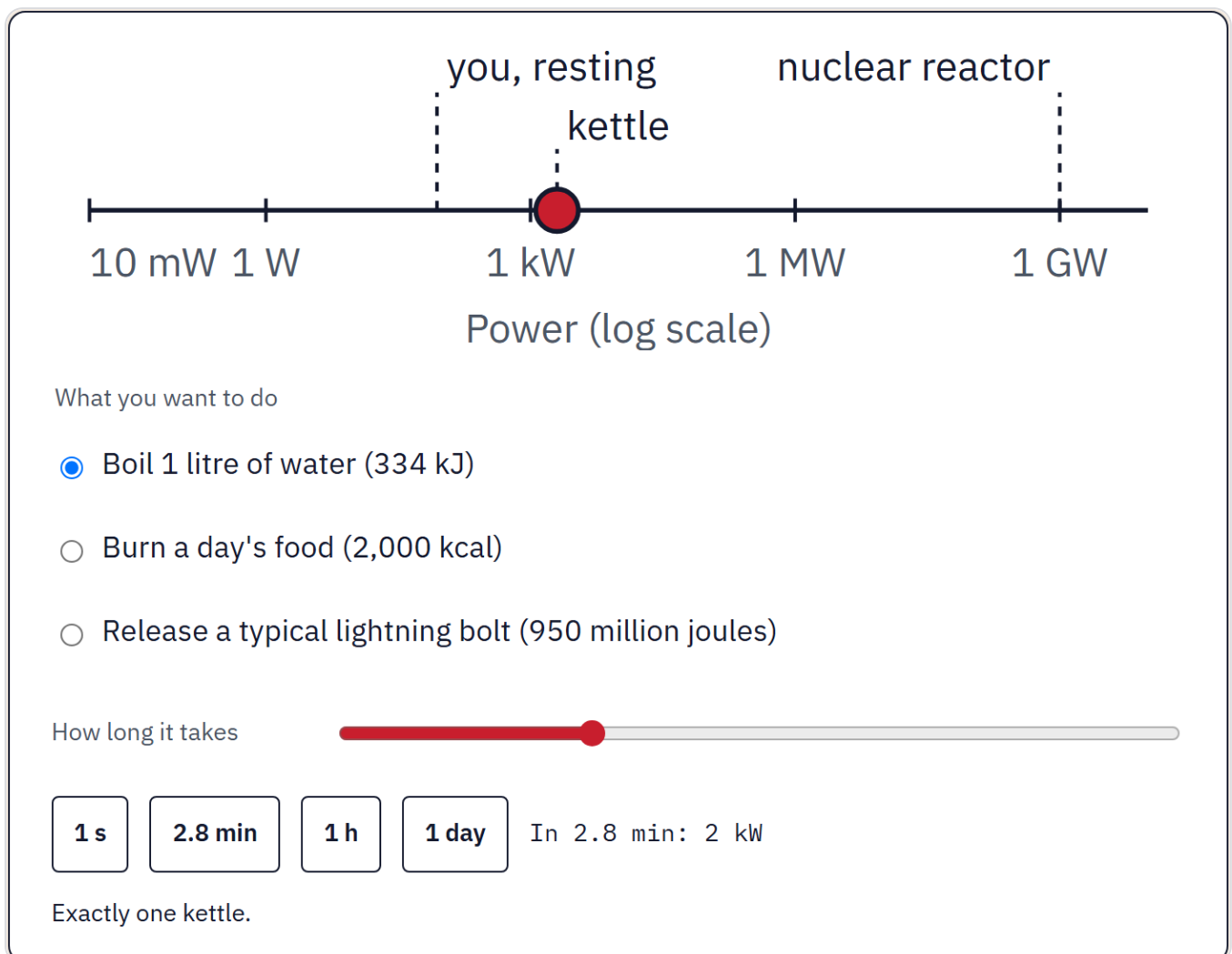
The King of Dumbs says:

Saying a kettle “uses 2,000 watts” is like saying a car “uses 120 km/h”. That’s how fast it goes, not how much it uses.



Try it: same energy, different pace

Choose what you want to do and how long it takes. The energy of each task doesn’t change; watch how the power shoots up as you shorten the time, and what it compares to.



Interactive widget. Try it on the web: <https://kingofdumbs.com/en/lessons/joules-watts-or-calories>

Heat and temperature: why fast means hot



what stays: $\Delta T = Q / (m \cdot c)$

water: $c \approx 4.18 \text{ J/(g} \cdot \text{K)}$

Temperature measures how agitated the particles of a body are. **Heat** is energy that passes from one body to another because they're at different temperatures, always from hot to cold. Heat is measured in joules; temperature, in degrees Celsius or in **kelvin** (K). A degree Celsius and a kelvin are the same step, and $0^\circ\text{C} = 273.15 \text{ K}$.

How much the temperature rises depends on the energy that stays (Q), the mass (m) and the **specific heat** (c), which is what it takes to raise one gram of that substance by one degree: $\Delta T = Q / (m \cdot c)$.

Water has a high specific heat, about 4.18 J per gram per degree. Boiling a litre from 20°C costs $1,000 \text{ g} \times 4.18 \times 80 \approx 334,000 \text{ J}$. With a 2,000 W kettle and no losses that's 167 seconds, about 2 minutes 47. In real life it takes a bit longer, because some heat escapes in the meantime.

Heat leaves in three ways: by **conduction** (contact), by **convection** (a fluid, like air or blood, carrying it away) and by **radiation** (infrared light, no contact). At rest, your body gives off its 68–87 W mostly by radiation, around 60%.

The rule that explains why fast means hot is a balance: what comes in minus what goes out is what stays, and that raises the temperature. A kilo of water receiving 1,000 W without losing any rises about 0.24 degrees per second: 14 degrees per minute.



From a person to the Sun: comparing scales

watts (log scale)



To fit a person and the Sun in the same drawing you use a **log scale**: each equal step along the axis multiplies by the same amount, here by a thousand (watt, kilowatt, megawatt, gigawatt). The prefixes help: kilo is a thousand, mega a million and giga a billion.

On that scale you can see the reactor is seven steps of ten above you, and the Sun nearly eighteen steps beyond the reactor.

The method for judging any claim has three steps:

1. Work out the energy needed.
2. Divide it by the time.
3. Compare with the table of references.

If it comes out around a kettle, it's a household thing. If it comes out around a reactor, it's a power-station thing.



Final challenge

1. A kettle's label says 2,000 W. What does that number tell you?

- a. How much energy it stores inside
- b. How fast it turns electricity into heat
- c. How much you'll pay each month

2. You boil a litre of water in a 1,000 W kettle and another litre in a 2,000 W one, with no losses. What changes?

- a. The 2,000 W one uses twice the energy
- b. They use the same energy; the 2,000 W one takes half the time
- c. The 1,000 W one can't bring it to the boil

3. A spark from a bonfire is very hot, yet you barely feel it if it lands on your hand. Why?

- a. It's so small it carries very little energy, even though its temperature is high
- b. Sparks are cold inside
- c. Skin can't feel temperature



In three sentences

1. Energy is the how much (joules, kcal and kWh are the same thing in a different glass) and power is the rate (watts, joules per second).
2. The same energy in less time takes more power, and almost all of it ends up as heat: if it comes in faster than it goes out, the temperature rises.
3. To judge whether something is possible, work out the energy, divide it by the time and compare it with references: a person (about 80 W), a kettle (2,000 W) and a reactor (1 GW).



Sources

- Unit conversions (calorie, kWh, tonne of TNT, horsepower): [NIST SP 811, appendix B.8](#). Electronvolt: [NIST CODATA](#). Joule and watt in the SI: [BIPM, SI Brochure](#).
- Kelvin and the Boltzmann constant: [IUPAC Gold Book](#) and [BIPM, kelvin appendix](#).
- Food labels in kJ and kcal: [Regulation \(EU\) 1169/2011](#), Annex XV. Power and energy terms on the Spanish bill: [IIT Comillas](#) (in Spanish). Automatic cut-off above contracted power: [Royal Decree 1955/2000, art. 92](#) (in Spanish).

- Specific heat of liquid water: [NIST WebBook](#) ($C_p \approx 75.4 \text{ J}/(\text{mol}\cdot\text{K})$ at 25°C , divided by 18.015 g/mol) and [OpenStax, College Physics 2e, table 14.1](#) ($4186 \text{ J}/(\text{kg}\cdot^\circ\text{C})$).
- Basal metabolic rate (68 W and 87 W): [Harrison, University of Toronto](#), cross-checked with [OpenStax, College Physics 2e, table 7.4](#) (85 W). Routes of body heat loss: [OpenStax, Anatomy and Physiology 2e, 24.6](#) and [OpenAnesthesia](#).
- Power of Tour de France cyclists: Vogt et al., *Int J Sports Med* 28, 756 (2007), [doi:10.1055/s-2007-964982](#).
- Power of a typical nuclear reactor: [US DOE](#). Energy of a lightning bolt: Cooray, *J. Geophys. Res.* 102 (1997), [doi:10.1029/96JD01917](#), and [EPA AP-42, ch. 14.3](#).
- Nominal solar luminosity and total solar irradiance: IAU 2015, Resolution B3, [arXiv:1510.07674](#).
- Confusion between energy, power and force among future physics teachers: Sağlam-Arslan and Kurnaz, *Asia-Pacific Forum on Science Learning and Teaching* 10(1), 2009, [conclusions](#). Heat versus temperature: [IOP Spark](#).

How this lesson was made: researched and written with help from Claude from the sources above, checked and cross-checked against a second source on 13 October 2026, and translated from Spanish by Claude. Figures without their own link are calculations based on them. The drawings are my own.

Answers

1. **b)** How fast it turns electricity into heat. That's it: watts are a rate. What you use depends on how long you leave it on.
2. **b)** They use the same energy; the 2,000 W one takes half the time. Exactly: same water, twice the tap.
3. **a)** It's so small it carries very little energy, even though its temperature is high. Good. Temperature says how hot; energy, how much. A spark has lots of the first and little of the second.

A King of Dumbs lesson, kingofdumbs.com. Offline version; the original, with widgets you can play with, is at: <https://kingofdumbs.com/en/lessons/joules-watts-or-calories>

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