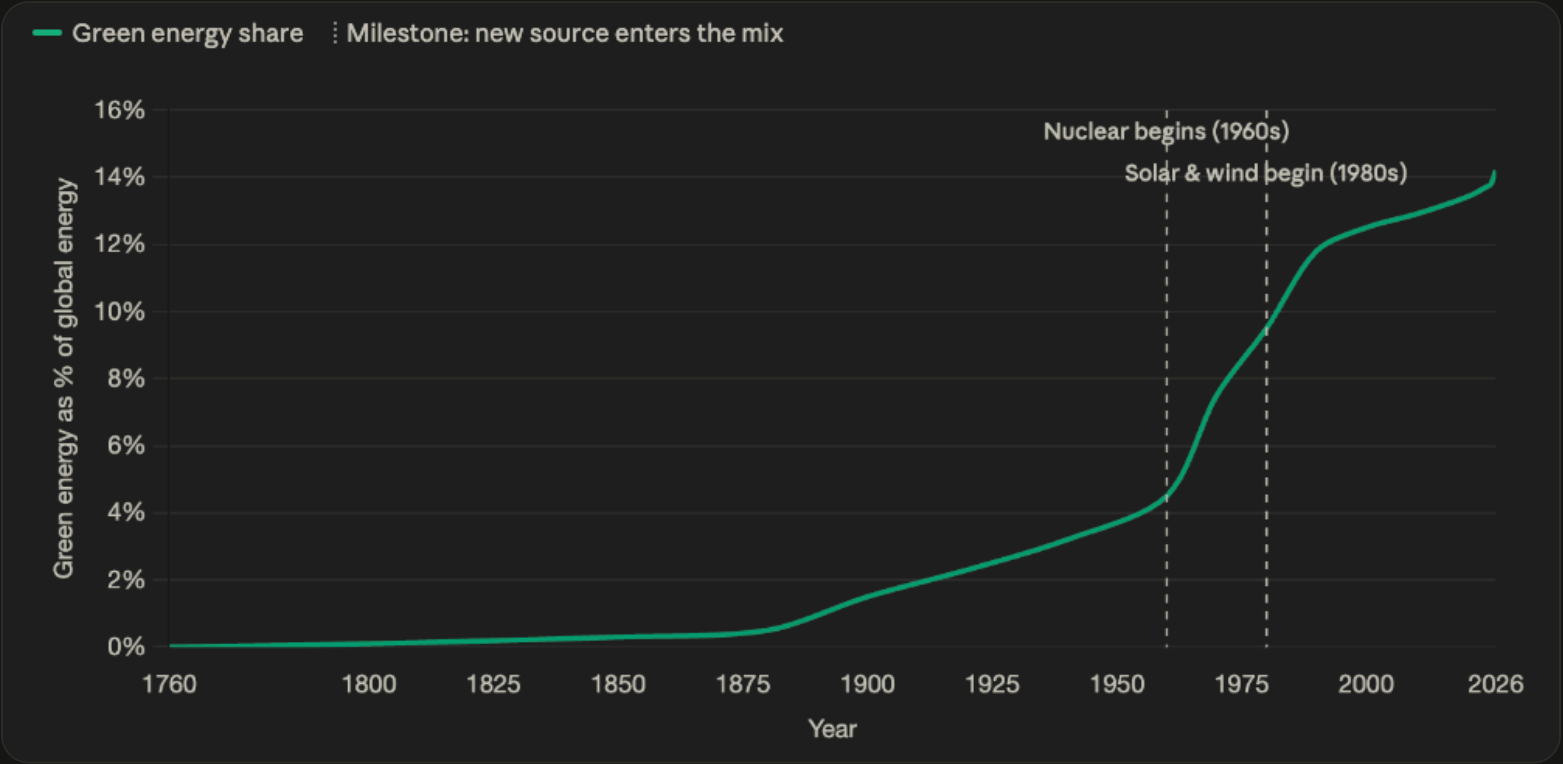


The search for clean energy

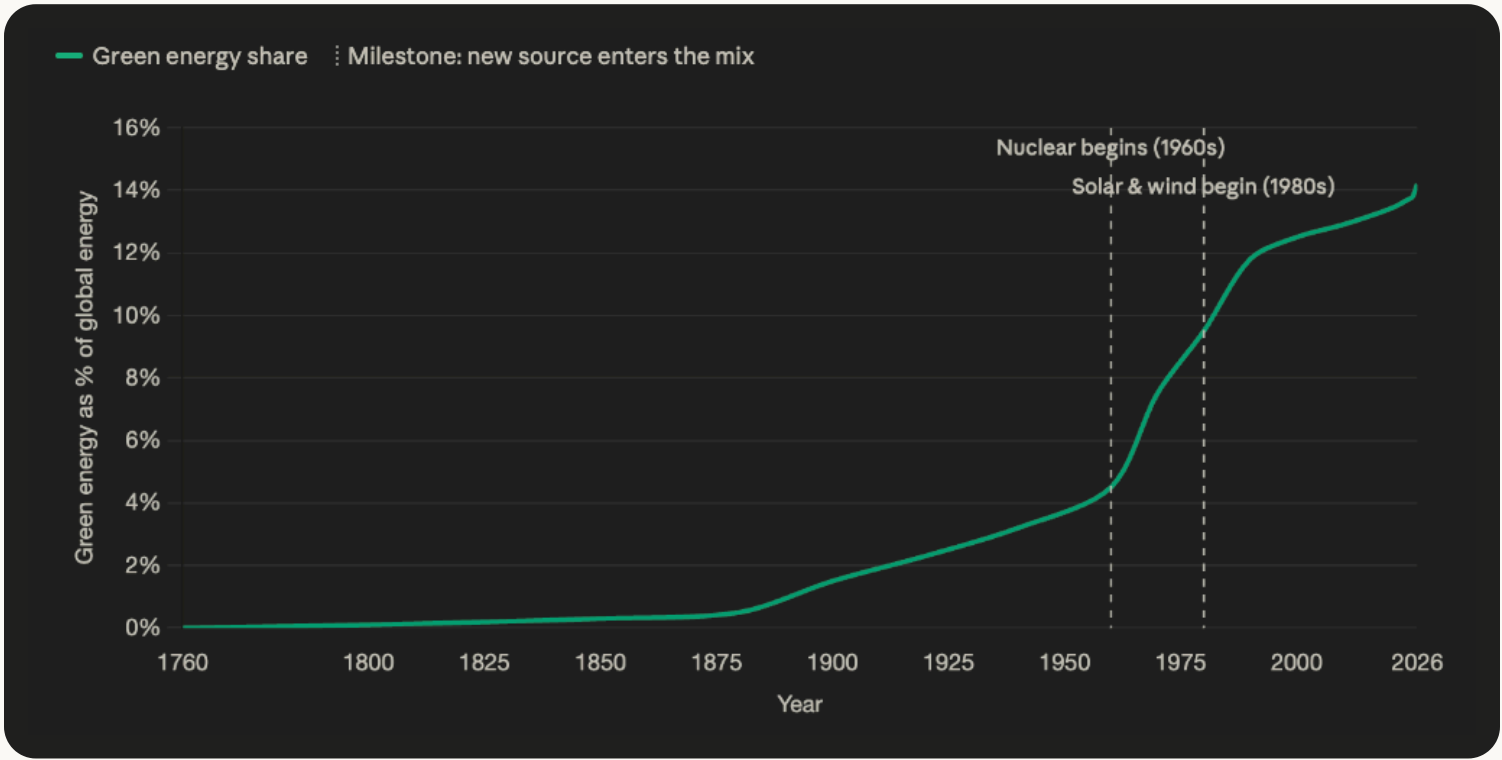
Why leaving fossil fuels is so hard, which clean options fit which job, and where the road leads.



From fossil dependence to a clean energy system

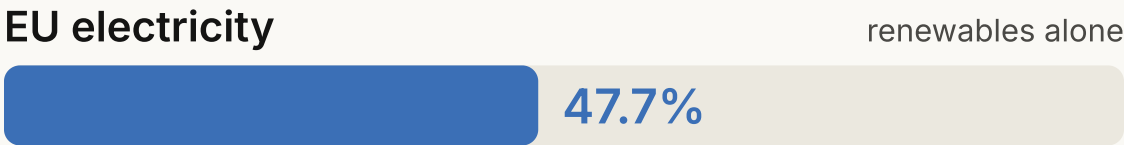
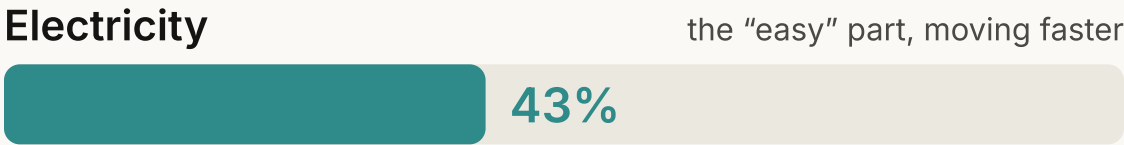
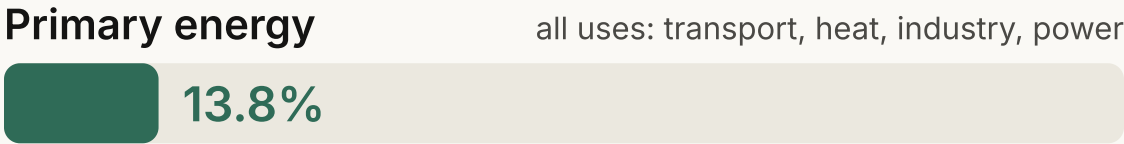
PART 1 · SLIDE 3 Our progress 03 Clean share so far	PART 2 · SLIDES 4-7 History of energy 04 What energy is 05 From muscle to fossil fuels 06 Why demand kept climbing 07 Energy per person	PART 3 · SLIDES 8-11 Our addiction to fossil fuel 08 Four jobs fossil fuels do 09 Why upstream matters 10 Sector by sector 11 Who is moving, who is stuck	PART 4 · SLIDES 12-17 Alternatives to fossil fuel 12 Two reasons for hope 13 The efficiency ladder 14 Options × sectors 15 A ranked answer per sector 16 Where I stand 17 The road to hydrogen
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Clean energy is 13.8% of the total, but the pace is speeding up.



Clean share of global primary energy, 1760 to 2025: coal rose from 1.7% (1800) to 47.2% (1900); hydro from the 1880s, nuclear the 1960s, solar and wind the 1980s.

CLEAN SHARE, 2025



+1.1 pts
renewables' gain, 2000–2010

+3.5 pts
the next decade: the pace tripled

Energy is the capacity to do work, and it takes six forms.

Kinetic
motion

Potential
position or configuration: dams,
springs, chemical bonds, nuclei

Thermal
jittering atoms: heat

Electromagnetic
light and radiation

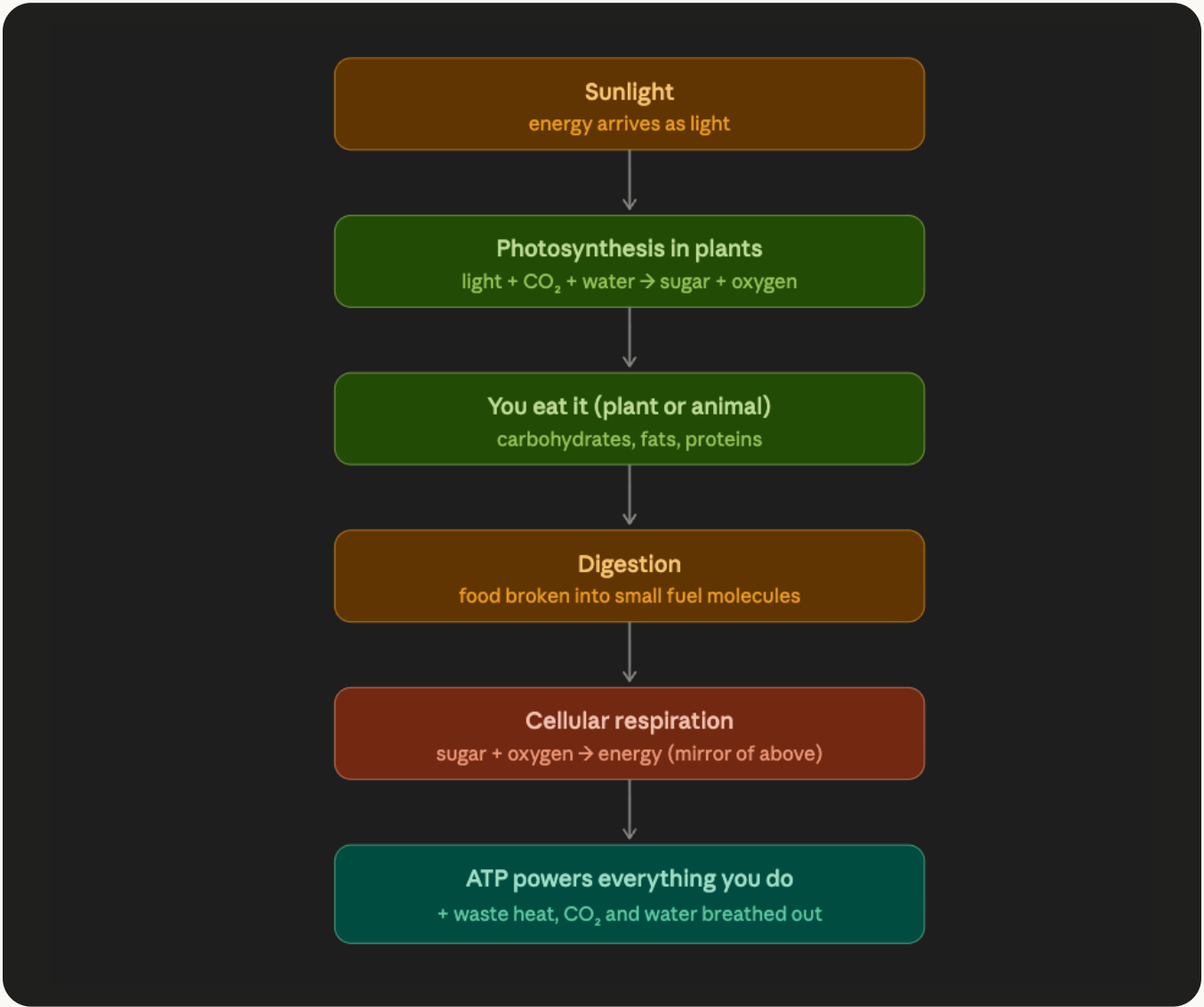
Electrical
organised, moving charge

Mass
 $E = mc^2$: why nuclear fuel is so dense

ENERGY VS POWER

Joules
the quantity: how much
a battery's capacity

Watts
the rate: how fast
a battery's output

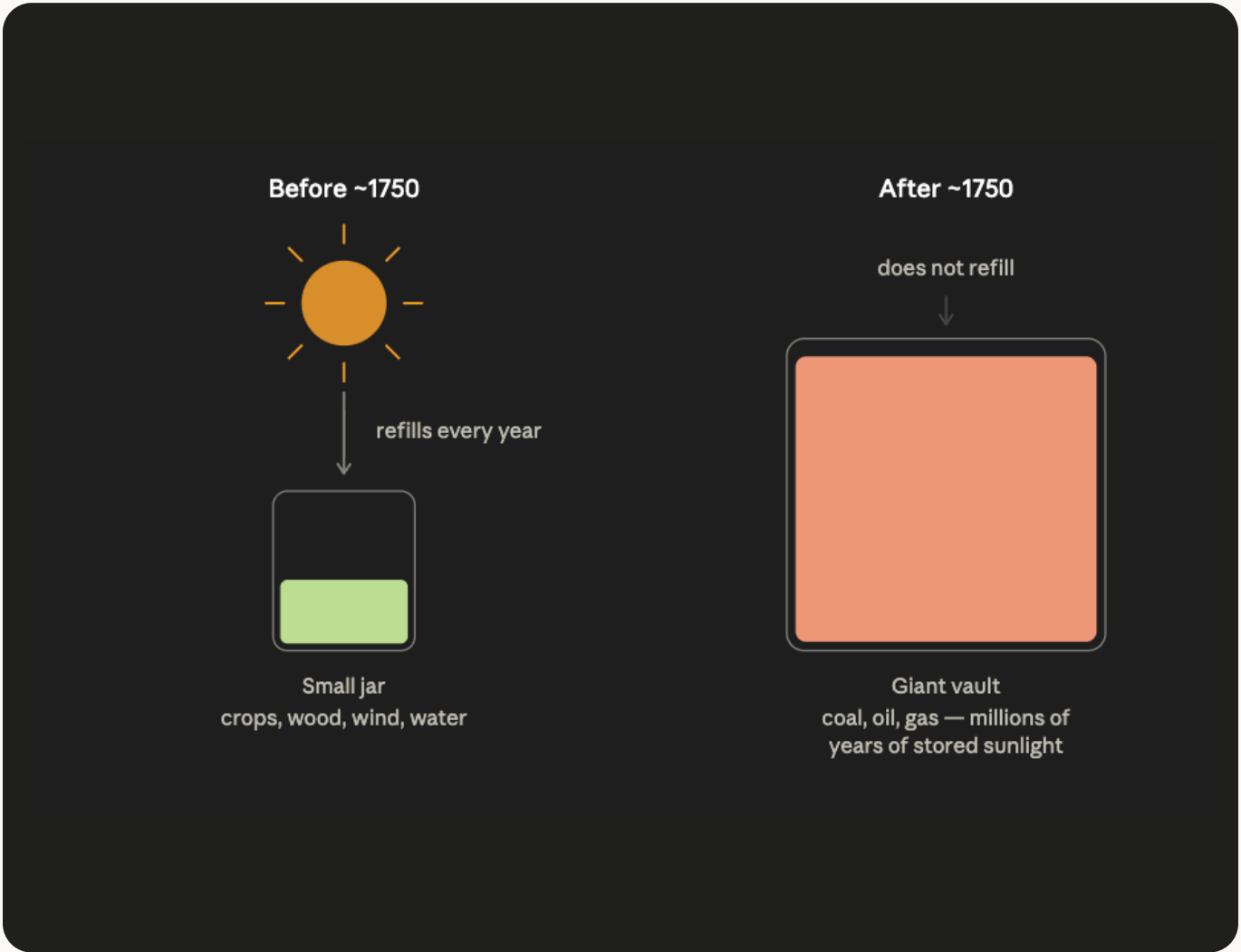


A body runs on sunlight: plant sugar becomes food becomes ATP. Being alive is a slice of the sun's energy passing through us.

From a jar of yearly sunlight to a vault of stored sunlight.

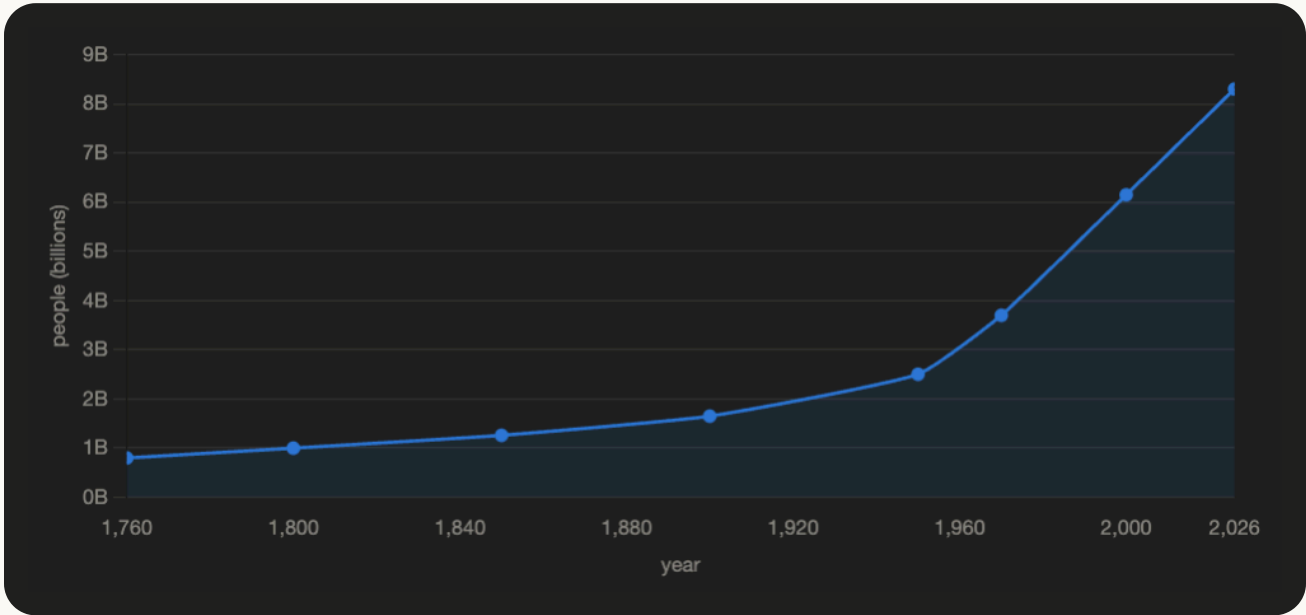


Energy eras, from ~100 W of muscle to today. Green: solar-powered eras; brown: fossil eras.

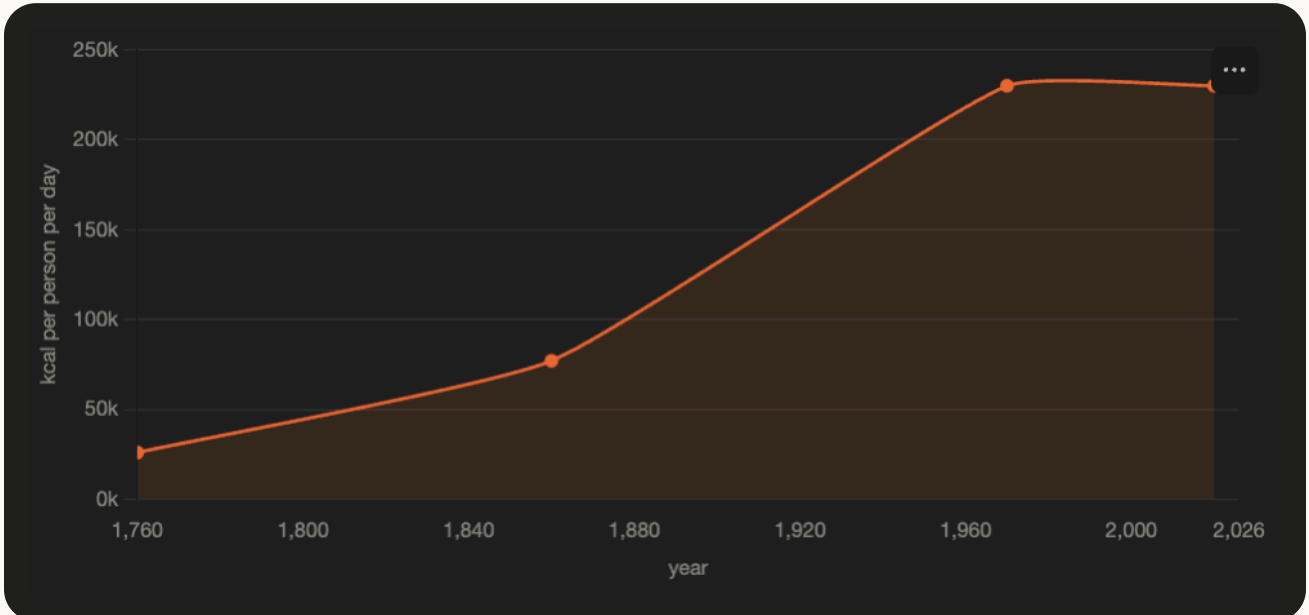


Before 1750, a small jar refilled every year (crops, wood, wind, water). After, a vault that never refills on a human timescale.

Demand kept climbing: more people, each using far more.



×



1 → 8 billion
people, 1800 to today

~60×
energy per person: ~4,000 → ~230,000 kcal a day, hunter-gatherer to rich industrial

A modern industrial life runs on ~60× a forager’s energy.

CONTINUOUS POWER PER PERSON, ALL USES



Sources: Earl Cook (1971), extended by Ian Morris. A human body alone runs on about 100 W.

Fossil fuels do four different jobs for us, not one.

JOB 1

Dense, portable energy



fuel tank



battery, same mass

about 50× the energy per kilo of a battery: what planes, ships and trucks need

JOB 2

Fierce, concentrated heat

1,450 °C · 1,600 °C



heat pump



cement

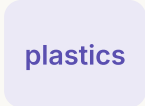


steel

kilns and furnaces at 1,450–1,600 °C

JOB 3

A chemical raw material



plastics



fertiliser



lubricants

the fuel is the material

the actual matter some things are made of

JOB 4

Always-ready fuel



fuel: always full



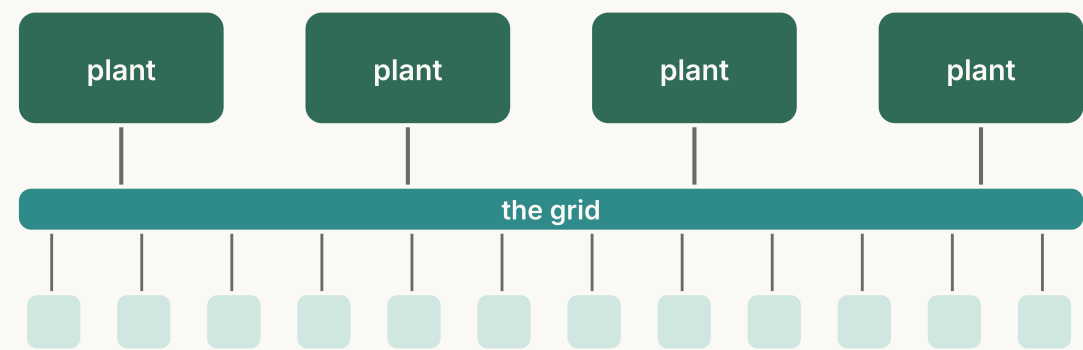
sun: day by day

sits at full charge until the moment we light it

A sector can drop fossil fuels quickly only when **its particular job** can be handed to something clean, far enough upstream that the rest of the system barely notices.

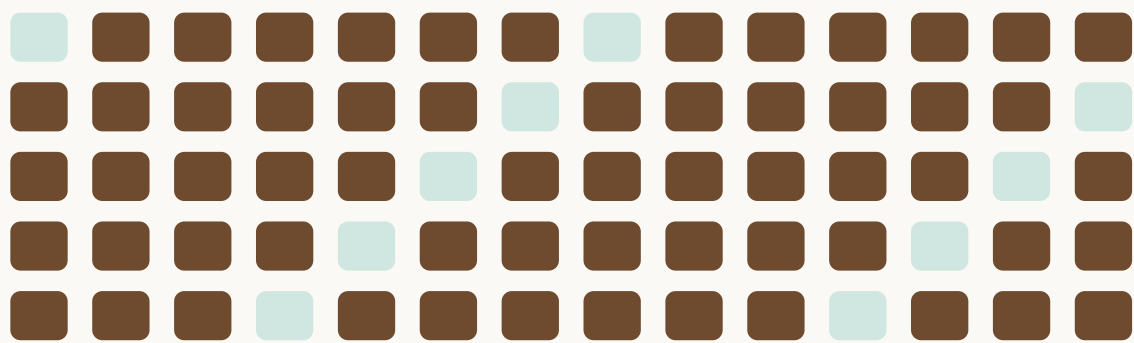
Upstream is the hinge: clean the source, or replace every machine.

Electricity is a carrier



clean a few thousand plants →
every device downstream is clean, unnoticed

Fuel burned at the point of use



no upstream to clean →
replace a billion engines, furnaces and boilers, one owner at a time

How far upstream?

Can the swap happen at the source, or only at the end machine?

How few hands?

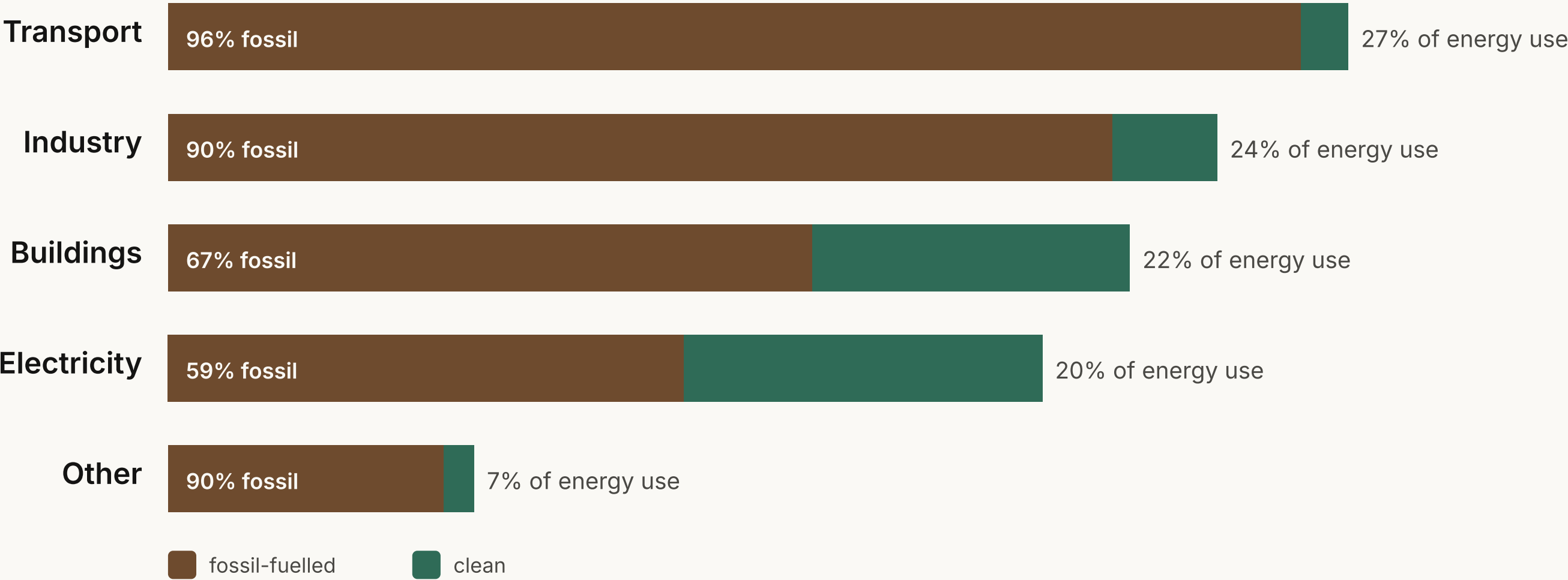
A few utilities, or billions of separate owners?

Does a clean machine exist?

Sometimes it still has to be invented.

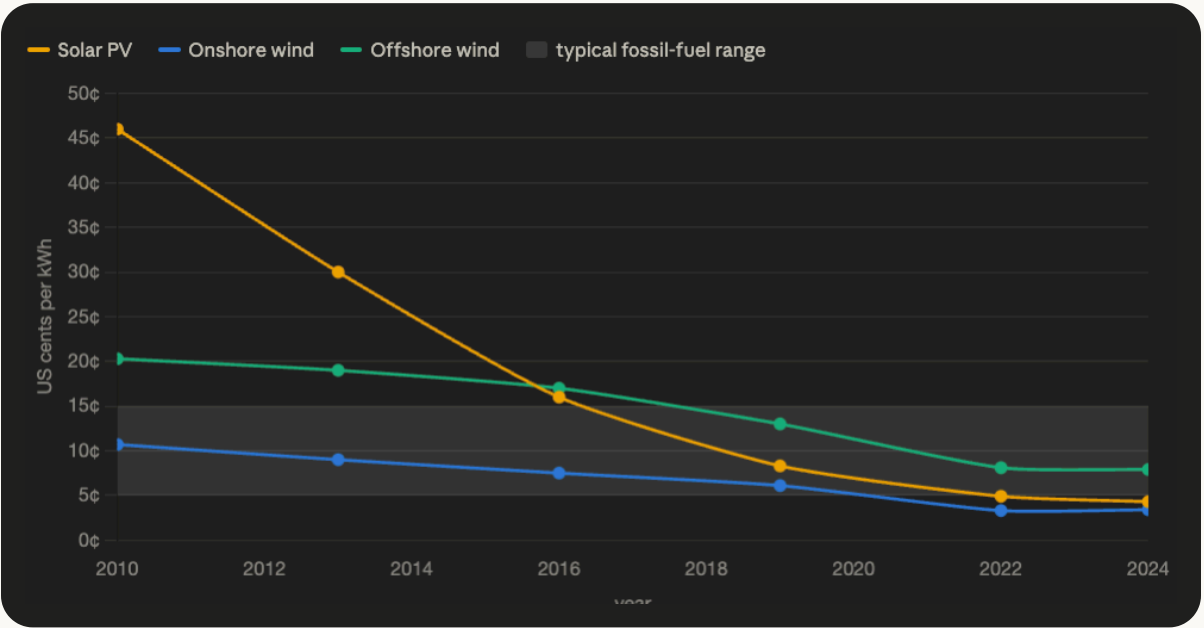
Clean wires solve only about a fifth of the problem.

GLOBAL ENERGY USE BY SECTOR · BAR LENGTH = SHARE · FILL = HOW MUCH IS STILL FOSSIL



Two sectors are moving; two are stuck.

Electricity	MOVING	Solar ~46¢ → ~4¢/kWh, 2010–2024: below fossil. Clean sources >40% of power.
Buildings	SLOW	Heat pumps deliver 3–4 units of heat per unit of power, but buildings last a century.
Light transport	MOVING	EVs ~25% of new-car sales in 2025, but 1.5 billion vehicles turn over slowly.
Heavy transport	STUCK	Liquid fuel carries ~50× a battery’s energy per kilo: planes and ships need density.
Industry	STUCK	Cement kilns ~1,450 °C, steel ~1,600 °C, and limestone releases CO ₂ by itself.



Cost of electricity from solar, onshore and offshore wind, 2010–2024: a tenfold drop for solar.

Whoever builds an era's energy system is rewarded like no one else.

BUILDERS OF THE FOSSIL ERA

OIL

John D. Rockefeller

still the richest man in modern history, by most inflation-adjusted measures

STEEL

Andrew Carnegie

one of the great fortunes

THE PETROL CAR

Henry Ford

an empire built on it

FERTILISER FROM AIR

Haber & Bosch

Nobel Prizes; changed how the planet eats



REASON FOR HOPE 1

Builders of the clean era: wide open

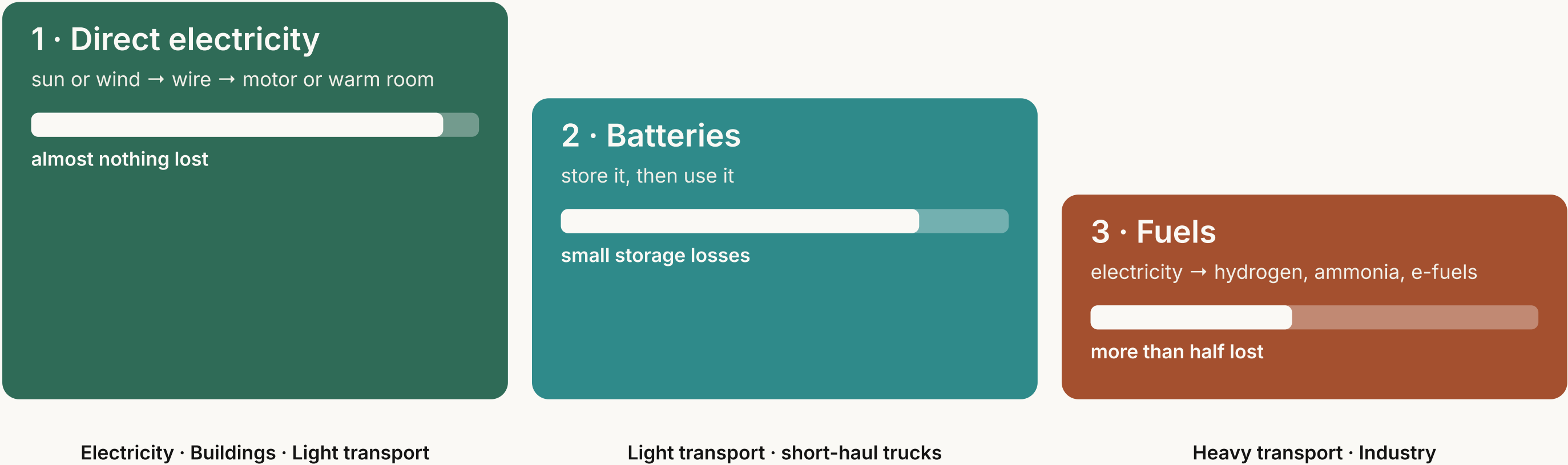
An opportunity of exactly that size, in wealth and in legacy.

REASON FOR HOPE 2

We are already making good progress

The clean options, sector by sector, follow.

The efficiency ladder: direct electricity, then batteries, then fuels.



bars are illustrative: the energy you keep falls at every conversion

Every conversion wastes energy. **How far down the ladder a sector is forced to reach decides how hard it is to go clean.**

No single technology fits every sector.

	Electricity	Buildings	Light transport	Heavy transport	Industry	Other
Solar & wind	strong	strong	strong	partial	partial	partial
Firm clean power	strong	strong	strong	partial	partial	partial
Batteries & storage	strong	partial	strong	partial	poor	partial
Heat pumps	poor	strong	poor	poor	partial	poor
Green hydrogen	partial	poor	poor	partial	strong	partial
Ammonia, e-fuels, SAF	poor	poor	poor	strong	partial	partial
Sustainable bioenergy	partial	partial	partial	partial	partial	partial
Carbon capture	partial	poor	poor	partial	strong	partial

Firm clean power: nuclear, geothermal, hydro. Read rows: solar and wind cover the top three sectors; hydrogen shines where nothing else works.

A ranked answer for each sector.

Electricity

ESSENTIALLY SOLVED

- 1 Solar & wind backbone
- 2 Firm power: nuclear, geothermal, hydro
- 3 Batteries & long storage

Buildings

GATED BY RENOVATION

- 1 Heat pumps on a greening grid
- 2 Electric lighting & appliances
- 3 District heat, solar-thermal

Light transport

SOLVED

- 1 Batteries & EVs
- 2 Biofuels as a fading blend

Heavy transport

UNSOLVED

- 1 Trucks: batteries, then H₂ fuel cells
- 2 Ships: green ammonia, methanol
- 3 Planes: SAF, e-kerosene

Industry

THE HARDEST

- 1 Heat: electric arc, induction
- 2 Steel: green-H₂ reduction
- 3 Cement: carbon capture

Other

MIXED

- 1 Machines: batteries, biofuels, H₂
- 2 Plastics: bio-feedstock, recycling

Match the solution to the land: harvest what is locally abundant, then link grids across borders to trade the surplus.

Where I stand: a personal view of the trade-offs.

Excited	Cautious	Narrow use only
Geothermal limitless heat; reuses oil and gas rigs, talent and supply chains Sodium batteries no lithium mining, at a small cost in density	Nuclear safe per unit, Onkalo is opening, but waste lasts up to hundreds of thousands of years Large hydro use sparingly: dams disrupt rivers	Carbon capture for cement's chemistry, yes; on fossil plants, an excuse to keep burning Direct air capture CO₂ is 0.04% of air: too costly today, maybe later

For two centuries, every new fuel had more hydrogen and less carbon.



Hydrogen-to-carbon ratio of each fuel (bar height illustrative). Pattern named by Cesare Marchetti; developed as decarbonisation by Jesse Ausubel.

bottom step

of the ladder is where heavy transport and industry land: only a clean fuel will do

<1%

of the ~100 Mt of hydrogen made each year is low-emission today

THE SHORT VERSION

Ask what job the fossil fuel does and how far upstream it can be swapped. Where clean electricity plugs straight in (power, heating, cars), the technology already exists: the work is **building it fast enough**. Where only a clean fuel will do (steel, cement, ships, planes), it doesn't yet: the work is **making it work at a viable cost**, and that is where the next era's fortunes will be made.

READ huyentran.tech/writings/the-search-for-clean-energy
