Energy Predictions 2025

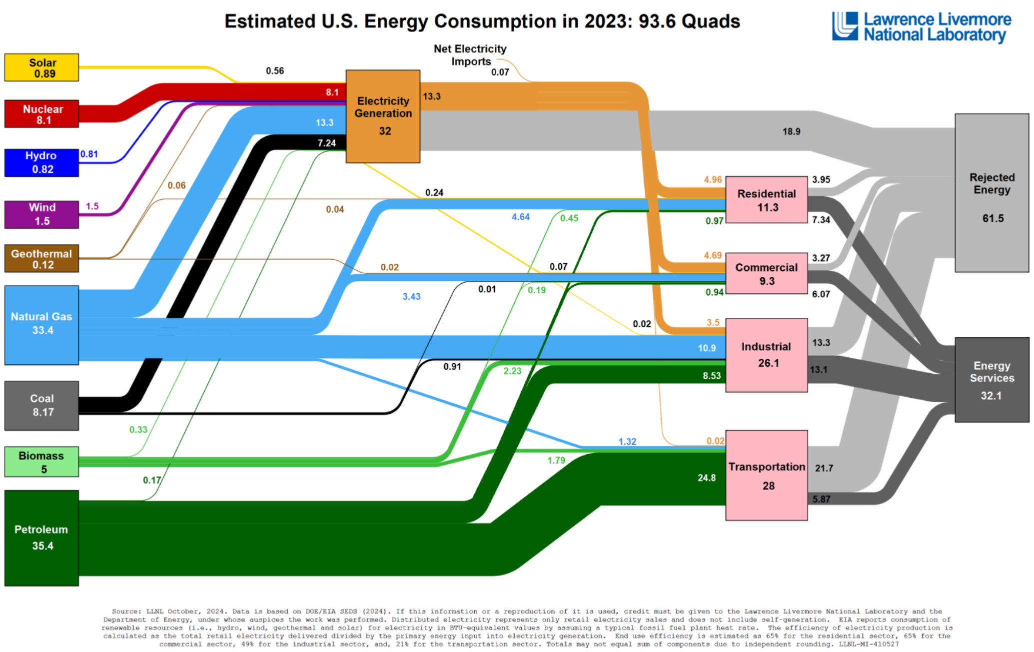
Casey Handmer

[Printable pdf.](#)

It's been a few years since I wrote a broad post on energy, so I'm providing an update in one easy to read place. More detailed specific posts on energy are here.

If you want to work on the future of energy, we're hiring for a wide range of opportunities at Terraform Industries.

Current fuel mix and uses



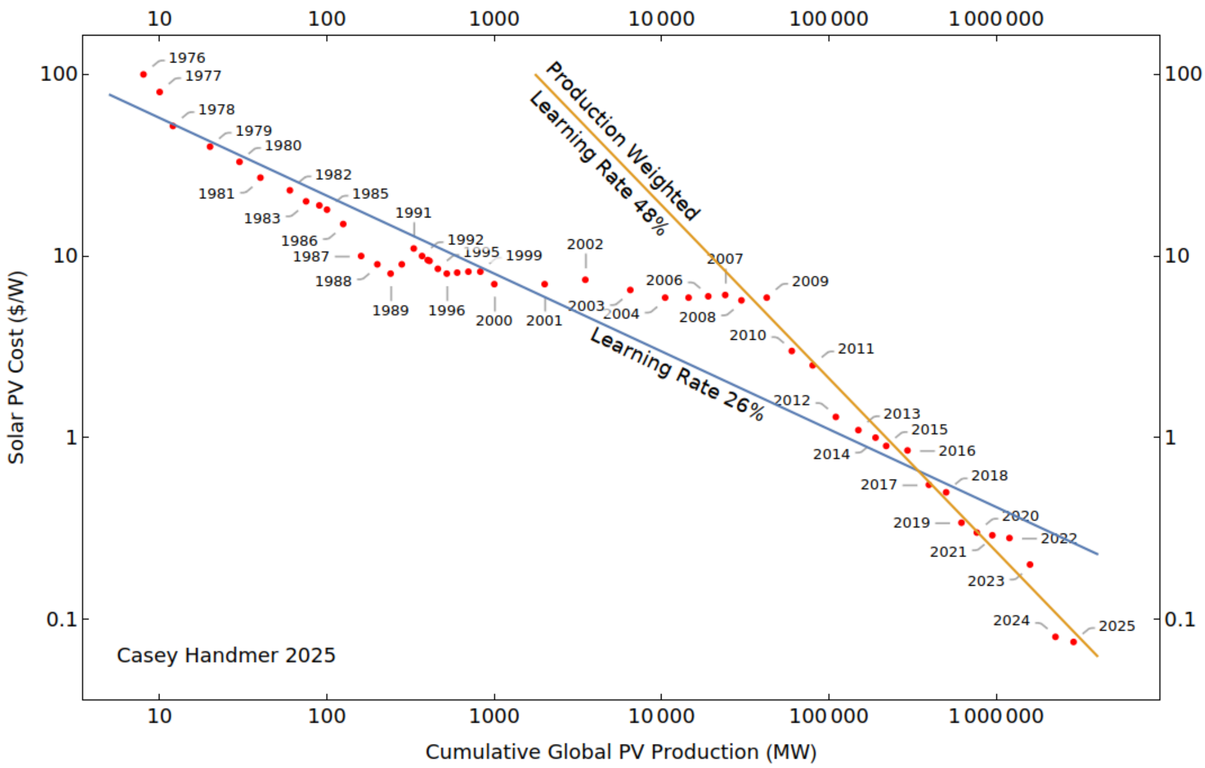
The US consumes about 100 quadrillion BTUs of energy per year. Of this, about 80 start life as coal, oil or gas, and roughly a third of the energy mix serves the electrical grid. Less than 1% is food, reflecting our enormous energy wealth in comparison to our pre-industrial forebears.

Energy mix and outlook

We're in the middle of a period of rapid transition. Much will be much clearer in retrospect. This is how I think it will shake out.

Primary production will be mostly solar

Solar is decosting at an accelerating rate.



The production-weighted learning rate is 48%! Module cost falling up to 20% per year, twice what it was five years ago.

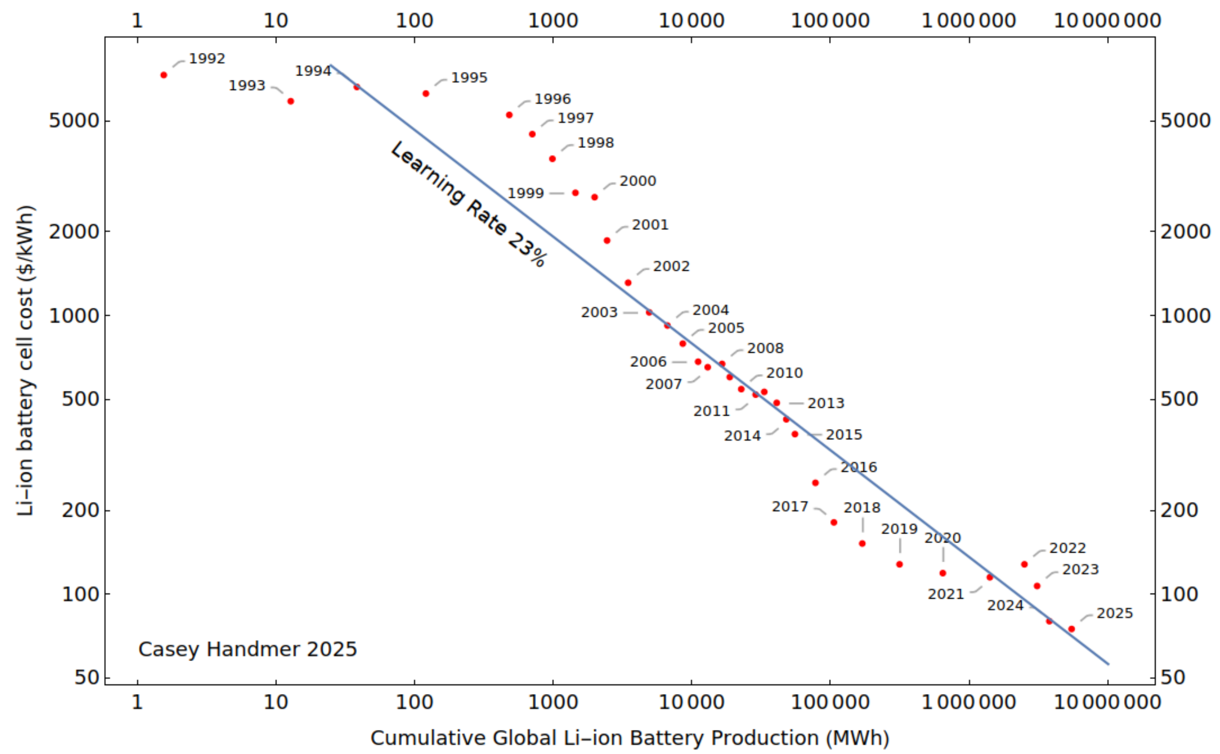
Coal is shrinking. Nuclear is flat. It doesn't take Sherlock Holmes to see which way the wind is blowing.

Solar power production will locally feed the grid, but also provide power behind the meter, and beyond the meter in off-grid developments.

Batteries everywhere, the grid will shrink

Do we need to drastically expand the grid in order to metabolize renewables? No.

[Batteries have been winning](#) for about a decade and the gap is only increasing.



Battery production is growing while costs continue to plummet.

Will we build more batteries? Yes. Per capita allocation of batteries has already increased from a few grams to a few tonnes in a single generation. It will only continue up and to the right. Demand will not saturate until after it stops being induced.

Democratized battery ownership is good for freedom

Will batteries be deployed behind the meter, at the point of generation, or within the grid?

Yes.

Batteries at solar arrays allow higher utilization of offtake grid connections, matching evening power consumption. Batteries behind the meter allow granular, independent assurance of power continuation. Batteries in devices and vehicles. Batteries in houses. Batteries on power poles. Batteries at substations. Batteries in schools. Batteries in appliances. More!

Already we are seeing adoption of behind the meter batteries such as the Tesla Powerwall for individual consumers who can justify the expense relative to the hassle of utility power cuts. In a world where every consumer can choose the size of their battery, it doesn't make sense to spend 10x the money trying to keep the distribution grid at 99.9% production. Less developed markets are pointing the way - Pakistan has cut most domestic power consumption over to solar and batteries in about two years. This is analogous to the growth of cell phones in developing countries that never ran copper phone lines to every house. This trend puts more value and market power in the hands of individual consumers. In the limit, market power will shift from the monopoly electricity utility to amorphous confederations of illegible behind-the-meter demand in the form of networked batteries.

Datacenters will be the nexus of electricity production growth

In 2025, headlines scream that datacenters are pushing prices up and consuming all the power. I think datacenters are exposing the rot in a moribund power generation and delivery industry which has proven unable to meet demand in recent years. But it is a moot point.

Datacenters are already building their own captive power plants. As AI demand outstrips production of gas turbines, hyperscalers will turn to offgrid solar+battery power systems, which are already competitive with pure gas or gas+solar in the sunnier parts of Earth.

Depending on location, 10x overbuild of solar and batteries are sufficient to hit >99.5% uptime for the GPUs.

Datacenters will be net power sources for their communities

On the flip side, these captive solar power plants will be curtailing approximately 75% of their generated power and will be able to provide net power on all but a few days per year. That is, 99% of the time, which is substantially higher utilization than any conventional thermal power plant.

Within the next five years, market power between utilities and datacenters will flip, with DCs becoming the preferred load growth power generation partner.

To spell out the implications, this means that consumers will get access to extremely competitive (cheap) power most of the time, and some combination of utility-owned and privately owned batteries will be needed to smooth out the gaps, as they would be anyway.

Solar datacenters will ultimately be pure DC constant voltage systems

Solar PV modules are approximately constant current sources. Lithium ion batteries are approximately constant voltage sources. GPU power consumption scales like the cube of token production. Why fill the entire thing with DC-DC converters and inverters? In the limit, it’s all a single piece of silicon.

Substantial cost improvements are needed to make space AI competitive

If SpaceX or a competitor can ship inference compute to a 560 km unshaded sun-synchronous orbit which is 80% 1 kg/m^2 solar arrays by mass and 80% compute by cost, then it should be possible to make money. Otherwise, we can expect to see compute being developed on the ground.

Electricity power markets should evolve toward real time and local prices

Real time matching of supply and demand will require responsive time- and location-based pricing. Different regulatory regimes are already experimenting with versions of this. In general, regulatory insistence on *unphysical* pricing schemes are a choice to socialize the costs of pathological markets. Almost by definition, capital allocation in opaque or non-existent markets with unresponsive prices will be less optimal, driving costs higher and increasing the value of the available price arbitrage.

I pre-register my belief here that electricity governance markets will bifurcate. On one side, we'll see those that embrace a steady cadence of pricing reforms, allowing effective competition between many private operators of generation, storage and transmission assets, pushing prices down. On the other side, increasing prices for consumers will drive increasingly desperate governance measures that allow far less competitive storage operators to extract vast rents from the difference between real world power conditions and the conditions approximated by some legal framework.

Just remember, the universe does not care about how we encode our opinion as to how we think the world should work. It has given us an infinitely powerful sun and a planetary crust composed largely of silicon. What we do with that is up to us.

Seasonal load variation - summer

Hot climates see increased loads due to air conditioning during the summer. Solar power systems also produce more power during the hottest days of summer, so this is a complete non-issue. Essentially all suburban houses can easily run their own ACs off rooftop solar, so we don't even need an expansion of power distribution capacity. As an exercise, figure out how cold a standard issue suburban house could be made with a rooftop system.

Seasonal load variation - winter

Nearly all winter load increase occurs in cold climates which also suffer a reduction of solar power in winter. This load is for heating.

Current battery technology is marginal for seasonal power storage. Conventional wisdom would dictate that we either need radically cheaper batteries, greatly expanded overbuild of solar or wind generation, continued burning of fuel for heat in winter, or a bunch of winter-only power plants that will have the same terrible utilization economics as seasonal-only batteries.

These ideas overlook one important fact. Storing electricity for months is economically difficult, but storing heat is easy. Austin Vernon has been building ultra-low-cost thermal energy storage at [Standard Thermal](). Essentially a giant hair dryer blows hot air into a large pile of sand during the summer months with abundant cheap power. In winter, the fan switches direction, extracting heat. The storage medium can be made almost any size and is self-insulating. You can think of it as artificial geothermal power storage - in fact it has several strengths that geothermal lacks, like the ability to cheaply build and renew stored power.

While heat pumps can achieve higher efficiency, consumer uptake has been much lower than expected because fundamentally, a heat pump is a 20 year bet on future power prices that most homeowners are unwilling to make.

Synthetic fuel is our path to chemical energy abundance

At Terraform Industries, we're pioneering the technology to convert cheap solar power, air, and water into synthetic natural gas and other hydrocarbons. Within the next five years, solar cost reductions will drive our process to be cost-preferred in all hydrocarbon import markets, and geological sources of oil and gas will never again be able to compete. Our grandchildren will be swimming in copious cheap energy and wondering what all that drilling was for.

We believe that the path forward is lime-calcite captured CO_2 + electrolyzed H_2 to make CH_4 and CH_3OH (methanol). Methanol can be upgraded via a wide variety of existing petrochemical processes to make DME, ethylene, propane, gasoline, kerosene, and almost anything else you can imagine.

Hydrocarbon usage patterns will change a lot

In 2025, most gas is used for electricity generation, while most oil is used for cars, trucks, ships, and aircraft.

Solar is going to continue to displace all other primary electricity generators. And electric cars and trucks will continue to dominate growth in ground transportation.

By 2045, natural gas will be used as LNG primarily for high performance supersonic aviation, shipping, and industrial heat.

Methanol will be used as the universal industrial chemical precursor for plastics, paints, fertilizers, adhesives, as well as specialty fuels. Kerosene will service the legacy aviation fleet. Internal combustion piston engines will ultimately go the way of the piston steam engine.

The United Kingdom needs wind

The only highly populated industrial country unable to trivially meet its electricity and synthetic fuel needs with solar alone is the United Kingdom, due primarily to a high population density and high latitude. The Nordic and Baltic countries are tiny by comparison.

Among other problems, the UK needs to decide if it wants the future where energy is cheap and it is rich, or the future where energy is expensive and it is poor.

If the former, it is time to get serious about large scale deployment of wind power, using home-grown vertically integrated technology at prices as low as $10/MWh. It is not forbidden by the laws of physics.

Ultracheap solar power will eventually change mining

They don't want you to know this, but rocks are made of metal oxides, and infinitely abundant commonly occurring rocks such as basalt contain basically every metal you could ever want.

With sufficiently cheap power, we no longer need to travel to the ends of the Earth to build mines. Instead, build a solar powered rock refinery at your local gravel pit.

Coastal deserts will be irrigated with desalinated water

Israel already does this at scale. But much of the coast of Australia, Chile, Peru, Namibia, South Africa, Mexico, Saudi Arabia and other gulf states have essentially infinite quantities of cheap land, free solar power, and sea water. Democratized solar desalination technology can turn any and all these areas into arbitrarily lush paradises with <1% of the available land under solar arrays.

What have I missed?

I'll add topics here.