PROVOCATION

A Planetary Battery

THOMAS MAX TURNBULL
Max Planck Institute for the History of Science, Berlin, Germany

Abstract This article explores the trials and tribulations of various attempts to store energy from a broad historical and geographical perspective. It focuses on recent developments in and around Berlin but it extends into the deep past and distant stars. Taking in a wide-ranging sequence of historical events, it argues that certain dreams about unparalleled control over Earth's energy flows are unraveling. What if, rather than clinging to the vestiges of fossil-fueled existence or maintaining 24-7 lifestyles with banks of lithium-ion batteries, some decided to welcome the cycles and periodicities of the Sun back into their lives? It asks what we can learn from focusing on energy storage as a distinct point of exploitation, and what form resistance to new regimes of energy storage would take.

Keywords energy storage, batteries, caves, carbon footprint, life cycle analysis

Solar Sisyphus

Energy is always conserved. It just behaves that way. However, whatever is conserved—in words some might remember like a bedtime prayer—tends toward absolute entropy. Conserved energy becomes less and less useful; it degrades over time and with each act of conversion until we are left in a motionless universe, everything cooled to −273.15°C, absolute zero. That said, an astrophysicist recently explained to me that it is more likely the universe's gravitational expansion will eventually suck the estimated 10^{24} suns around us into black holes. Entropy is in a cosmic race with gravity to reach finality. Whatever lies ahead, energy isn't something we can save forever. It is an unfolding process, an event. We can't do much about black holes. But if we try hard, we can delay what we perceive as energy degradation in certain places and times. The fundamental problem in trying to save energy is that it is a Sisyphean task. We constantly fight against entropy, disorder, heat, friction, waste. We push ever-bigger boulders uphill and use ever-more energy to do so.

We can keep on pushing because Earth's energy supplies constantly get topped up by the Sun. This slowly dying orb of burning hydrogen, a million times larger than

Environmental Humanities 16:3 (November 2024)
DOI 10.1215/22011919-11327324

Earth, constantly beams around 173,000 terawatts of radiative energy onto our rotisserie planet.[1] This is equivalent to the energy of 17 trillion horses incessantly charging at Earth. Many get lost on their 150-million-kilometer journey, around a third hit Earth and are reflected back into space, and roughly a third of what remains powers Earth's atmospheric processes. The remainder is absorbed by whatever surface it meets, be it soil, water, or a golf course. This means a fundamental energy storage technology is, perhaps unexpectedly, the ground beneath us. On average, each square meter of Earth's surface receives about 1.366 kilowatts of energy, a figure known as the "solar constant."[2] The absorption of heat on Earth's surface and also in its atmosphere means Earth's average temperature is 14 degrees centigrade, while the space we float in is just 2.7 degrees above absolute zero. This differential tells us something: Earth and its atmosphere are a battery.[3] We live on a battery that orbits the Sun. A battery that, as the atmosphere changes, is becoming increasingly efficient at storing energy.

The German chemist Wilhelm Ostwald was enthralled by Earth's relation to the Sun. He developed an energetic theory of society (to the horror of some sociologists) in which processes of energy conversion and waste supposedly explained all aspects of life and culture. Ostwald wrote about the physical chemistry of this in a 1901 text titled *Vorlesungen über Naturphilosophie* (*Lectures on Nature Philosophy*). He described how Earth "assimilated" solar energy via innumerable processes of conversion and chemical energy storage.[4] The leaves of every plant, solar receivers, assimilate radiant energy and mobilize chemicals in soil, creating "mechanically resistant" and dense stores of chemical energy: plant matter. This feeds and sustains "higher" forms of life. However, living matter alone, given Earth's cyclical orbit, cannot provide the energy necessary for maintaining present societies.[5] As Earth rotates at a dizzying one thousand kilometers per hour, we get no sunlight at night, and due to its axial tilt, higher latitudes don't get much in winter. Luckily for those in northern climes, another source of stored energy has become useable, the ancient residues of hundreds of millions of years of assimilated radiant energy: fossilized plant matter.

There is arguably no better way to store energy than in these petrified residues of sunlight. The chemical energy of coal and petroleum remains usable for around five hundred million years, whereas biomass, without means of preservation, lasts a few weeks or months, perhaps centuries in the case of wood. However, while fossil fuels are a highly effective form of energy storage, their formation was wildly slow and inefficient. Of all the land-based photosynthesized matter on Earth, only 0.09 percent has become coal,

1. A watt is a unit indicating the power or rate of work in a given energy conversion process. Some lightbulbs do 40 watts of work; a horse is conventionally measured as having 746 watts of working power—hence we have a horsepower unit. A terawatt is a trillion watts (1^{12}), equivalent to over a billion working horses.

2. This figure fluctuates by about 0.2 percent when sunspots flare up during eleven-year solar cycles (Kleidon, *Thermodynamics of the Earth System*, 130–31).

3. Schramski, Gattie, and Brown, "Human Domination of the Biosphere," 9511.

4. Ostwald, *Vorlesungen*, 320–22. Thanks to Benjamin Steininger for the reference.

5. Ostwald, *Vorlesungen*, 320–22.

while only 0.00009 percent of the suitable organismic slime on land and sea became oil.[6] Nevertheless, this process has occurred for hundreds of millions of years, a time-scale over which concepts like inefficiency no longer mean much. Over very long time-scales, the slow pressure-cooking of Earth's photosynthesized dreck resulted in a vast subterranean stock of fossilized energy. These substances are far more concentrated than solar energy (broadly construed). We hew, extract, sell, and burn, satisfying our appetite for power with this highly improbable material.

Fossil energy was once seen as a Promethean gift to humankind (or to some at least), fire stolen from the gods that freed people from the limits and occasional tyranny of the solar system. Coal-rich western Europe is underlain by a band of ancient, fossilized forest known to geologists as the Hercynian Complex. With its use, wealth was no longer dictated by land ownership, the former means of assimilating solar energy, but via the use of the minerals that lay beneath the earth. Before the use of this subterranean forest freed up terranean land, human population growth was supposedly constrained by the limits of what we could derive from the Sun.[7] Worse, a proportion of whatever was gleaned from the Sun often had to be donated, often under duress, to armed aristocracies and their legitimating spiritual authorities.

There were earlier coal burners elsewhere. In the eleventh century, the city of Kaifeng in what is now modern China burned more coal than London would do until five hundred years later. This precocious fossil-fuel-using city only decarbonized when the area was sacked by Genghis Khan's army.[8] However, coal-fired life evolved distinctly in Europe. In the eighteenth century, when Europe lit its coal-powered Promethean fires, the capital generated by this subterranean form of productive and chemical power went to the few, not the many.[9] Vast amounts of accumulated fossil capital encouraged calls for the redistribution of wealth, an egalitarian impulse that encouraged a carbon-dependent kind of democracy.[10]

That said, even before widespread coal use, energy storage encultured distinct forms of political control. In the rich alluvium-filled river valleys of the Tigris and Euphrates, grains were grown and harvested. Some of the earliest evidence of agriculture is found in this so-called Fertile Crescent. With the Sun's intercession, sedimented soil became grain, nuggets of solar-derived protein and carbohydrates. Grain was not only a food but also a medium of conversion, something to be traded for objects or services considered of equivalent value. Grain could be transported and, if kept dry and free from rats, weevils, and thieves, it could be stored for years. Stored grains were a granular form of surplus solar energy, a unit of currency and exchange. Exchanging grain

6. Dukes, "Burning Buried Sunshine," 33–37.

7. Turnbull, "Energy, History, and the Humanities," 261–69.

8. Hartwell, "Cycle of Economic Change," 151–52.

9. Malm, *Fossil Capital*, 325–26.

10. Mitchell, *Carbon Democracy*, 4–11.

became a means for accumulating wealth and a target for taxation. The formation of states, armies, and bean-counting bureaucrats seemingly depended on a simple infrastructural means of storing solar energy, the raised granary.[11]

From Mesopotamia to the Senegal Valley, simple grain storage structures, like cereal temples, acted as "organic refineries" that allowed the concentration and storage of energy and helped protect societies from the uncertainties of climate, floods, bad harvests, war, drought, and other disruptions to calorific flow.[12] Grain could also be used to generate more concentrated energy sources. Fed on excess grain or spoiled food otherwise destined for the bin, pigs, chickens, cows, goats, and other domesticated animals are also batteries (though ones with feelings). These ambulant stores of energy get charged up during periods of abundance and are eaten in leaner times. Other simple techniques to ease the constraints of seasonality include salting, pickling, fermenting, drying, and smoking. Even immersing a gherkin in an electrolytic brine turns the energy of this perishable plant into an energy store.

The difference between these storage techniques and simply foraging for energy in the wild is the extra work involved. Hunter-gatherers supposedly had shorter working days than both the medieval peasant and today's software engineer.[13] So why did so many humans agree to work harder and longer? The pursuit of enrichment, enslavement, and other forms of state-sanctioned violence all had a role. Perhaps, for some, it was also the promise that energy flows could be turned into stocks, and that they could escape the tyranny of seasonality, at least for a while.

The anthropologist David Graeber and the archaeologist David Wengrow revised large parts of human history in their book *The Dawn of Everything* (2021). They did so by surveying the ever-more-detailed evidence the archaeological record contains. Their material testimony undermines broad-brush theories about societies having inevitably leveled up from hunting and gathering to farming. Societies instead ebbed and flowed in both their complexity and chosen modes of subsistence. In collating this evidence, they unsettle the idea that energy-storing states were bound to rule over those that lived more closely attuned to the vicissitudes of the Sun. The invention of steam engines, they argue, did not necessarily have to create a hegemonic fossil empire. Steam engines were invented in ancient Greece; there, rather than using them to conquer four-fifths of the world, as Britain later did, Greeks used them to create theatrical illusions such as temple doors that seemed to open of their own accord.[14]

Graeber and Wengrow also argue that new archaeological methods, not least isotope analysis, the study of trace radioactivity, reveal a human history far more complex

11. Scott, *Against the Grain*, 111, 175.

12. Cropper, "Sparrow Loves Millet," 49.

13. The anthropologist Marshall Sahlins argued that hunting and gathering was a four-hour-per-day assignment ("Notes," 85–89). Others argue that such a life of comparative leisure was in fact exceptional among so-called prehistoric people (Graeber and Wengrow, *Dawn of Everything*, 139–40).

14. Graeber and Wengrow, *Dawn of Everything*, 500.

than once assumed. *Homo Sapiens* have existed for two hundred thousand years, for which we have only five thousand years of written records, beginning with Sumerian cuneiform tablets. We know less about the other 97.5 percent of human history, and that which we do know is largely based on decaying radioactivity. Such traces reveal that energy storage has a very long history.

Take an example from Cap Sizun, Brittany, on the western edge of France. There, in 1985 an archaeologist, Bernard Hallégouët, discovered a cave, Menez Dragan, which had been sealed by a rockfall. Inside were shards of knapped flint and cut pebbles, traces of human agency. Eight stones had been neatly arranged in a circle, within which were traces of charcoal and fire-reddened flint. This would have been unremarkable were it not for the fact that since this fire was lit, the cave had been periodically inundated with seawater. This indicated the hearth had experienced dramatic sea level rises, dramatic fluctuations in environmental conditions, which suggested it had first been lit long before the last ice age. Hallégouët and colleagues subjected a hearthstone, a lump of burnt quartz, to electron spin resonance, a dating method that measures how much of Earth's trace radiation a crystalline object has absorbed. This indicated that a flame had been struck around 465,000 years earlier. Fire would have illuminated the cave's dark recesses, and some of its radiating heat would have been absorbed into the walls, warming the air within the cave a little. Though imperfect—given the absence of a door—in lighting a fire in a cave, someone had tried to save energy. Pyroarchaeologists consider this site one of the oldest "preserved anthropic combustion structures."[15] On this evidence, it appears that we've been trying to store energy in specific places and specific times for at least a quarter of our species' existence.

As we have become better at storing energy, we've arguably become more profligate. While methods have improved, we don't tend to store energy for posterity but to consume at a later point. Fossil fuel conservation is actually intended future fossil fuel use. As a result of our past successes in this endeavor, gases emitted by burnt fuels are blanketing Earth in increased concentrations, inadvertently improving the atmosphere's ability to store the Sun's energy. One way to stop this is to try and return to something like a solar system. To do so would return the industrialized world to intermittency, to seasons, to diurnal fluxes, to early and dark nights, to feasts and fasts. Critics of defossilization like to emphasize the risks of intermittency. How can server farms or life-support machines run on intermittent power?

Such assertions ignore the great efforts that have been made to ensure that fossil fuels deliver continuous power.[16] Previously, it was James Watt's rotary steam engine and Thomas Edison's electrical grid that created reliability. Today, it is online payment transfer baron Elon Musk who claims he can overcome the intermittency of the Sun. In 2016 he purchased SolarCity, a firm conveniently run by his cousins. This was the start

15. Monnier et al., "New Regional Group."

16. Sovacool, "Intermittency of Wind," 289.

of the company's annoyingly named "Secret Tesla Motors Master Plan," a long-term strategy to move, so it claims, from a "mine-and-burn hydrocarbon economy towards a solar electric economy."[17] Lithium-ion "power-wall" batteries and electric vehicles will become a planet-spanning storage and use network, a rhizomatic and automobile capacitor that can tame the Sun.[18]

We appear stuck between a rock and a hard place. Do we have to supplicate before Musk, the world's (intermittently) richest man, to allow us to store solar energy? Wouldn't it be nice if we could find alternative ways of using energy that do not line the pockets of the world's most (reliably) self-important man? To avoid this situation, do we need to go back into the cave, or are less austere ways of living without new energy dependencies possible? What about slowing down instead, living with those intermittencies, with fluctuations, cycles, seasonality, fasts and feasts? We might turn out to enjoy shorter working days, longer and more restful nights.[19] Fossil fuel use has not freed us from toil but has increased the length and tempo of working time. For many, the result has been subjugation and fatigue rather than liberation and leisure. What if, rather than trying to tame the Sun, trying to force it to replicate the tempo of fossil-fueled systems, we instead allow ourselves to be tamed by it?[20]

The vast, burning orb could once again be something to be feared, worshipped, and perhaps even supplicated before. A resacralization of the Sun, at least in fossil-fueled cultures like my own, could involve recognizing it as the entity that ultimately governs the passage of time, the seasons, agricultural yields, atmospheric processes, climate, even the gravitation that keeps us in orbit. Don't we already acknowledge the Sun's power every time we say good morning to each other, each greeting an unwitting mantra to the Sun?[21] What would a more conscious re-sacralized relationship to the Sun look like? The philosopher Oxana Timofeeva notes that sacrifices made in honor of the Sun should mirror its exuberant and excessive benevolence.[22] Rather than bloodshed, a beneficent kind of sacrifice could involve humility and the undertaking of clear steps toward achieving more equal societies.[23] Naively idealistic, no doubt. But is it less realistic than thinking everything can stay the same?

17. Musk, "Secret Tesla Motors Master Plan."

18. The technology will no doubt be profitable. One estimate is that just the United States' energy-storage needs alone would require 37.8 billion Tesla "Powerwall 2.0" home energy-storage systems (Sivaram, *Taming the Sun*, 225).

19. Powys Whyte and Buck, "Geoengineering and Indigenous Climate Justice," 79; a distinct liberationist "solarity" can be read about in Boyer, "Revolution and Revellion," 33; and Szeman, "On Solarity," 137.

20. While I agree with most of Oxana Timofeeva's excellent case for a liberationist solar politics, I don't think the Sun is our "comrade" so much as our higher power. Timofeeva, *Solar Politics*, 96–97, 119.

21. Sanskrit scholar Max Müller has often been derided for seeing "solar myths" in almost all cultures, but the derision only sharpens their everyday ubiquity. Dorson, "Eclipse of Solar Mythology," 399.

22. Timofeeva enlists Georges Bataille's thinking on the Sun (Timofeeva, *Solar Politics*, 62).

23. Moreover, as Imre Szeman notes, in 1949, as Western-run developmental organizations were poised to take a neo-Malthusian turn, Bataille had called for a solar-like "transfer of American wealth to India without reciprocation," just as the Sun asks nothing of Earth for its beneficence (Szeman, "On Solarity," 137).

That said, without humility, turning toward the Sun does not necessarily mean humankind will use less energy. Currently our species uses around 18 terawatts of energy. Bold calculations suggest we could generate between 500 and 1,000 terawatts of electrical energy using current photovoltaic technologies.[24] There are a number of violent abstractions behind such numbers. They are predicated on the assumption that vast swaths of Earth, in this case its deserts, can be carpeted with silicon cells. This ignores that deserts are rich ecosystems and home to around 6 percent of humanity. A sort of neo-orientalism encourages these solar cornucopians to ignore the existence of these people and to imagine deserts as uninhabited and barren places that can be readily transformed into giant energy assimilators.[25]

No less hubristic is the physicist Freeman Dyson's hypothetical megastructure, the "Dyson sphere," in which a nearby star is encased in an artificial biosphere that captures its radiating energy for human use, potentially giving humankind (or part of it) the energy to explore and colonize an extraterrestrial "*lebensraum*."[26] The tech bros' favorite solution inverts this logic. In their imagination, a caged ball of burning hydrogen, a miniature sun, achieves small-scale nuclear fusion and grants them previously undreamed amounts of electrical energy at little cost.[27] The problem with solar accelerationist fantasies is that, if successful, the energy made available could transform the planet's metabolic processes at a magnitude that would make the changes some term "Anthropocene" seem mild.[28] Should we trust the technological elite with such amplified agency? Knowing their foibles, the tech-solutionists' solar future is likely to be more James Dyson than Freeman Dyson.[29]

Pocket-Sized Entropy Delayers

Most humans walk around with a battery in their pocket, around their neck, or in a belt-fastened holster. It is estimated that 91.54 percent of the world's population own a mobile phone, 7.26 billion of us. In doing so, we each carry a little box of conserved energy with us, a pocket-sized demonstration of the principles that simultaneously enable and constrain the universe's innumerable conversion processes. Each battery transforms electrical energy into a charged chemical solution, which we can choose to convert into information, be it emoticons, selfies, or the old-fashioned and increasingly unwelcome

24. Bardi, "What Future for the Anthropocene?," 5.

25. Bengezi, "New Constructions of Environmental Orientalism."

26. This is an unfortunate use of the term. In fact, the sphere was first intended simply as a thought experiment, a way of imagining what form extraterrestrial life might take (Dyson, "Search for Artificial Stellar Sources," 1667). On subsequent visions of extraterrestrial colonialism, see Timofeeva, *Solar Politics*, 101–2.

27. OpenAI boss Sam Altman is a big investor in fusion (Hiller, "Tech Billionaires Bet on Fusion"). Thanks to Adam Wickberg for enlightening me on this point.

28. Ugo Bardi terms this new age the "Stereocene" in acknowledgment of the role that the physics of solid-state silicon cells would play in this transformation ("What Future for the Anthropocene?," 7).

29. The British inventor James Dyson invented a popular jet-driven hand dryer for public toilets that research shows can launch a cloud of fecal viruses into the air (Kimmitt and Redway, "Evaluation").

phone call. Like almost all technologies, batteries allow us to briefly and advantageously delay entropy.

When the battery runs out, we plug it into two or three small holes in the wall. In doing so we achieve a process of electrochemical polarization. We channel current, a flow of charged particles, into the battery, until its electrolyte can't take more—it becomes resistant. This occurs because there is a finite solution of electrons in the battery's electrolytic solution. Often the battery gets warm. In doing so, we can observe entropy.

The US Vietnam War veteran and historian of science Richard Schallenberg wrote a history of the battery in the eighties called *Bottled Energy*.[30] He recounted how, in eighteenth-century German-speaking Europe, the Bavarian chemist Johann Ritter took batteries as a demonstration of the principles of *Naturphilosophie*, a blend of scientific and romanticized ideas about nature. Its central tenet was *Weltseele*, a spiritual force believed to pervade the universe and animate all human and nonhuman entities. This dynamism is composed of opposing forces: life/death, north/south, up/down, positive/negative. His world was a gigantic pile of substances with either positive or negative relations to each other that constantly underwent innumerable processes of attraction and repulsion. For Ritter, batteries embodied the vital elan dynamizing all earthly processes. The experimental battery from which he derived such lofty thoughts consisted of six hundred layers of saltwater-soaked cardboard and copper assembled in his home, apparently "a vile and dismal room in which everything possible: books, instruments, wine bottles—lay indiscriminately about." Amid this debased mess, Ritter engaged in brutal acts of self-experimentation, attaching wires to his eyelids and even his testicles to try and better familiarize himself with electricity. He died at thirty-three.[31]

We understand electricity not as a source of energy but as a means for transferring power over space and time, a kind of currency. We've replaced an enchantment with batteries with the generalization of their form, and the result has been a kind of terrestrial accountancy. The Sun's energy drives Earth's hydrological and atmospheric cycles. In doing so, the formation of lakes, glaciers, and snowfall above sea level become a landscape technology for energy storage. The potential energy of frozen or dammed water is stored by our planet's undulating topography. Reservoirs, for example, store the energy of raised water. Just how much is stored depends on the water's mass, its gravity, and the height at which it is constrained. If sluices are raised or apertures opened, these liquid batteries flow, driving water wheels or electromagnetic turbines. What was once sacred has been profaned, elemental transubstantiation has taken place, and—in return—we get to charge our phones.

Some people are vaguely aware and mildly guilty about the geological composition of the battery in their pocket. In most phones there's a lithium-ion cell. These were first

30. Schallenberg sadly died of a diabetic seizure before his book was published (Schallenberg, *Bottled Energy*, 6).

31. Strickland, "Ideology of Self-Knowledge."

invented by the chemist Stanley Whittingham, who worked at ExxonMobil during the 1970s, a period marked by oil price spikes. Once prices settled, the company lost interest in his invention. Interest only resurfaced with the rise of handheld electronics—the Walkman, portable computer, and mobile phone.[32] Today most handheld devices contain a bottle or bottles of lithium (perhaps mined in Chile, the Congo, Cornwall, or even Saxony), cobalt (most likely from the Congo), and oxygen (from the atmosphere). This creates a mixture called lithium cobalt oxide.

Lithium is a strange element. It forms when a dwarf star draws hydrogen from older nearby stars. A pulse of energy is created as a result, explosive events called *classical novae*. This makes the star eject lithium and other elements into space.[33] In Berlin, for instance, suitably stored, this stellar ejaculate can be plugged into the grid. In doing so, we connect it to forms of energy generated elsewhere, perhaps from Lusatian lignite in a Jänschwalde power plant, or maybe, if the Sun is shining, a solar farm in Werneuchen, Brandenburg.

Current flows through this electrolytic cocktail, triggering a reversible reaction that negatively charges lithium ions. As we charge the battery, current potentiates the latent energy in this chemical solution. Imagine the ions as dominos. In charging, it is as if we stand each domino on its end, upright. If we actually did this, we would use our bodies' energy to raise and line up each domino. We would be like the current. Some of the energy we expended in standing the dominos upright is now stored in the potential energy of their raised position. When we use a battery, it is as if we tip the dominos over and use the energy generated as they fall. Unfortunately, it always takes more energy to pile up dominos than we get from knocking them down. This differential demonstrates energy's tendency toward absolute entropy. In a closed system, a change in state always results in a net loss of energy.

Great losses occur as we harness the various energies of our terrestrial battery, and as we do so, we are often contributing to accelerating climate change. At the moment, around 30 percent of Germany's electrical energy still comes from burning coal. Under the rubric of the *Energiewende* (energy transition), a widely accepted plan is to generate energy in a manner that reduces the carbon emissions of Europe's largest economy to "zero" by 2045. To do so will require a means to store noncarbon energy in a manner that assures both stability and security of supply.[34] Security hasn't always been such a concern. However, since Russia invaded Ukraine in 2022, we learned that Germany's strategic gas reserves are partly owned by Russia's fossil fuel outfit Gazprom.

A problem with moving away from fossil fuels is that the energy density of the lithium-ion batteries is pretty low. Though rechargeable, they can store far less energy

32. Turner, *Charged*, 211–13.

33. Kemp et al., "Novae as Sources of Galactic Lithium."

34. Appunn, Eriksen, and Wettenengel, "Germany's Greenhouse Gas Emissions"; Nandita Badami notes that "zero" implies both nothingness and infinitude ("Counting on Zero").

than the same mass of fossil fuels.[35] Moreover, making batteries requires large amounts of water. Hence ecologists have argued battery manufacturing is a bad idea in water-scarce Brandenburg, where Tesla's new "Gigafactory" lies.[36] Despite lacking full clearance, the factory was completed in 2022 and now produces electric vehicles. However, it has been suggested the plant may expand and produce batteries. The rhetoric, as before, is that a teeming planetary fleet of vehicles will eventually run on the Sun's energy. The arrival of this factory shows that "solarity" is not necessarily liberatory or egalitarian when mediated via a societal and technological system that continues to allow certain individuals to monopolize the Sun's beneficence.[37] History shows those controlling the means of energy storage can attain an authority that exceeds that of elected sovereigns and certainly their citizens. As Musk himself has said, "Batteries suck."[38]

Energy and Information

The North American mathematician Norbert Wiener is known for popularizing the term *cybernetics*, the science of information and control. Working at MIT's electrical engineering laboratory during and after World War II, he came to argue that at a certain level of abstraction, information was the same thing as energy. A lump of coal was like a book or an orderly cluster of bits. Entropy, on the other hand, is as if someone put a book through a shredder and let the paper ribbons blow around like autumn leaves. Wiener believed energy and information had a causal relation to one another. Computers, recently invented, could be used to organize information, and information could be used to work against entropy. One example he gave was the thermostat, a simple computer that allows humans to program the temperature of a room and thereby minimize unnecessary energy use.[39] In his second book, *The Human Use of Human Beings* (1950), Wiener argued that our ability to use information, and to use it to impose control on Earth's energetic fluxes, drove civilizational progress. The control of information has allowed the establishment of "local and temporary islands of decreasing entropy in a world in which the entropy as a whole tends to increase."[40] That said, not all information is created equally. At a certain level of abstraction, it doesn't matter if information is energy or entropy, it's all just bits. Information can be used to increase as well as decrease the entropy of a system.

One way to use information to increase entropy is to persuade us that the problem is not the energy industry but us, the consumers. In a sense, these industries are right. Many of us have evolved, culturally at least, into a species that requires a continuous

35. Lithium-ion batteries store around 265 watt hours per kilogram, which equals less than 1 megajoule (MJ) per kilogram, whereas the density of bituminous coal has 29 MJ/kg, and crude oil can be as high as 43 MJ/kg (Turnbull et al., "Quantifying Available Energy," 295).

36. Goldhammer et al., "Berlin Brandenburg Region."

37. After Oil Collective, Vemuri, and Barney, *Solarities*, 6.

38. Jacobs, "Elon Musk."

39. Wiener, *Cybernetics*, 96–97.

40. Wiener, *Human Use*, 36.

input of exogenous energy to sustain our existence. One estimate is that the richest 0.54 percent of our species consume a third more fossil fuels than the poorest half; another is that the richest 1 percent have a carbon footprint 175 times larger than the poorest 10 percent.[41] In the Congo, where Tesla intends to source lithium, the average carbon footprint is just 0.08 tons per person per year. The average Berliner emits 5,000 times more carbon dioxide emissions than a Congolese person; the average German, double again.[42] Such differences demonstrate ecologically unequal colonial relations. In the case of electric vehicles, the rich will get battery-powered "living rooms on wheels," while a few people in Manono, the Congolese mining region, will get temporary jobs as security guards.[43]

Tesla's Berlin-made "Model Y" electric car is part of a growing range of products that promise customers all the pleasures of fossil-fueled lifestyles with none of the carbon footprint, or at least far less of it. What is this informational metric and why is it significant? The carbon footprint, a method for allocating responsibility for fossil energy use, was not dreamed up on the front lines of climate change activism but by the public relations company Ogilvy and Mather in the late 1990s. Their client? British Petroleum. They took an existing environmental metric, the "ecological footprint," and applied it to the consumer.[44] Now the primary driver of climate change was not the oil industry but its customers. The obligation to deconstruct the largest infrastructural network ever created—the planet-spanning apparatus for fossil fuel extraction and use, built over the last century—was now placed on energy consumers' shoulders.[45] Despite differing levels of responsibility, our species' survival strategy is that we keep on shopping but buy different things: electric cars, solar panels, oat milk, pea protein "chicken" nuggets. The energy revolution has been commodified.

If the solution to excessive consumerism is more consumerism, who is keeping tabs on how much energy is used to make the things we are supposed to buy? Rest easy, industrial ecologists and sustainability gurus tell us; to fight atmospheric limits to growth, manufacturers can use a cutting-edge form of accounting called life-cycle analysis (LCA) to ensure that their consumption of energy and resources is minimized as sales are maximized. Tesla has made sure to publicize the fact that its electric vehicles exact a less severe "lifetime environmental impact" than that of its rivals.[46] From resource extraction to fabrication and end-of-life disposal, information on the impact of the company's productive processes on various Earth parameters is carefully recorded and strategically communicated.

41. Malm, *How to Blow Up a Pipeline*, 127.

42. Ritchie and Roser, "Democratic Republic of Congo"; Smee, "Energy Use."

43. This point was made by Jack Wolf during the Driving Factor event (Wolf, *Money Tree*); Jolly, "Living Room"; on the maintenance of underdevelopment via relations of ecologically unequal exchange, see Bunker, *Underdeveloping the Amazon*.

44. Doyle, "Where Has All the Oil Gone?"

45. Seto et al., "Carbon Lock-In," 426.

46. Tesla Inc., *Impact Report 2020*, 10–19.

LCA originated with the Coca-Cola Company. In the late 1960s, the soft drink executive Harry Teasley Jr. commissioned the Midwest Research Institute (MRI) to develop a method for measuring the energy and resources consumed and the emissions and waste created if the company adopted various kinds of bottle.[47] Termed "resource and environmental profile analysis," or REPA, the method offered a means for large corporations to demonstrate fealty to the environmental regulations that had begun to appear in the United States in the 1970s, while also helping them find ways to cut costs at different stages of production. Coca-Cola's research remained secret, but one publicized outcome was that this analysis persuaded the company to shift from glass to lighter, more easily transported and thereby "energy efficient" plastic bottles. Today, Coke sells two hundred thousand plastic bottles of sugar water each minute and has been voted "world's biggest polluter" for the last four years.[48]

Environmental metrics that emerge as an aspect of corporate strategy, like carbon footprints or LCAs, can, in the wrong hands, be a means to engage in misleading accounting practices. A given process can be shown to be significantly less energy intensive than another, depending on how you set the boundaries of measurement. Do you factor in the energy needed to fly Tesla execs from the United States to Brandenburg, or that needed to educate their kids at Berlin's best international schools? Maybe not. But if not, why not? In making such measurements, the choice of a system's boundaries can have a decisive effect on whether a given process or product can be shown to be more or less environmentally impactful than others.[49] At the same time, the implied certainties of measurement have a kind of antipolitical effect, allowing companies to pay for and conspicuously demonstrate regulatory compliance and to publicly communicate these supposed indicators of their altruism, all the while avoiding the more important question of whether the company's very existence is a good idea.[50]

Brandenburg, where Tesla's Gigafactory is located, contains Germany's largest desert: Lieberoser Desert (*Lieberoser Wüste*) lies ninety kilometers southeast of Berlin. In 1942 a forest fire and then the soil-churning tracks of the tanks and incendiary weapons of the occupying Soviet army created a desert. The removal of foliage and topsoil revealed glacier-ground sand from the last ice age. This strange place, a *Panzerwüste*, or tank desert, gradually adopted the dynamics of a naturally changing desert. In its five square kilometers, gusts of wind form and reform rippled sand dunes, migrating birds supposedly land in confusion, mistaking the place for Africa, and rare desert lichens grow between footpaths that wind between unexploded munitions.[51] Germany's largest desert experiences temperature extremes unlike those of the forests that

47. Hunt and Franklin, "LCA."
48. Break Free from Plastic, *Brand Audit Report 2021*, 17.
49. Cederlöf and Hornborg, "System Boundaries."
50. Barry, "Anti-political Economy," 272.
51. Brunk et al., "Der ehemalige Truppenübungsplatz Lieberose."

surround it. The environmental idiosyncrasies of this place have led to its designation as a nature protection site, a place of special ecological interest. As average global temperatures rise and Brandenburg becomes increasingly arid, the wider region may become more like Lieberoser Desert than the lake-filled forests of the past.

Water will likely become increasingly scarce. Tesla's factory is expected to use as much water as a town of forty thousand people. It will tap Berlin's primary water source, Lake Müggel (Müggelsee). The 3.6 million cubic meters of water it will use—more if the site makes batteries—will likely become sulphate contaminated before being discharged back into the lake.[52] When asked about the implications of the plant (set to double in size) for the city and region's water supply, Musk replied, "We're not in the desert"![53] No, not yet.

In March 2024 the forest next to Brandenburg's Tesla factory was occupied by activists in an attempt to block its expansion. Hammocks were strung and tree houses erected in surrounding pine trees. Educational events were organized and statements of solidarity made with activists in lithium-rich Chile and Congo. Another group calling themselves Vulkangruppe (Volcano Group) burned one of the factory's grid transformers, melting cables, cutting power, halting production, and causing damage to the factory. The group published a statement terming the increasingly right-wing Musk as a "techno-fascist" and dismissing his company's green credentials as a "dirty ideological magic trick."[54] A newer generation are refusing to accept the bromides of green capitalism. Musk, in response, on the social media platform he bought, described the Vulkangruppe as the "dumbest ecoterrorists on Earth." Strong words from a man who once launched one of his company's cars into space.

Cave People

As strange as it seems, some people still store energy in caves. In the village of Etzel, Lower Saxony, deep in a subterranean mountain of salt, Europe's energy history is being decided. Since 1971, this geological formation has been used as a strategic gas reserve. It lies near Wilhelmshaven, a port town where North Sea petroleum is brought onshore and a network of gas pipelines converge, connecting this sleepy corner of northwest Germany by land and sea with not only the refineries of Abadan and Isfahan, but once also the dank and ancient methane reservoirs of the Siberian steppe, and now, increasingly, with Texas and the Gulf of Mexico.[55] Aboveground there is little to see, just a few warehouses. Below these unremarkable structures lie seventy-three deep vertical caves. Beginning in the 1970s, soil and rock were drilled through to reach the salt mountain. Water was pumped down these holes, dissolving some of the mineral into

52. Goldhammer et al., "Berlin Brandenburg Region."
53. Blankennagel, "'We're Not in the Desert.'"
54. Agua de Pau, "Vulkangruppe Tesla abschalten!"
55. Ahmed, "Qatar Gas Shipments to Germany."

a saline solution. This saltwater was then pumped out. Repeated solution-extraction carved deep cavities in this ancient salt dome, each around three hundred meters long and around sixty meters wide. A promotional website explains that each of the seventy-three voids are large enough to fit an Eiffel-Tower-size object inside.[56]

Gas is pumped into these caves via the same aperture by which water entered. The salt's strength means gas can be stored at a pressure of 200 bar (racing bike tires run at around 8 bar). Given the caves' size, over 4.5 billion cubic meters of gas can be stored within these voids. This constitutes around a quarter of Germany's entire strategic reserve and a proportion of that of the Netherlands and Belgium. However, having once been West German government property, between 1986 and 1993 the Etzel gas storage caves were gradually privatized. This meant that there were now three companies running the strategic gas reserve: British Petroleum; the Danish energy company Ørsted (formerly DONG Energy); and Gazprom Germania, Russia's state-owned energy company.[57] What had once been state owned was now something that could be owned by anyone who could invest in some shares.

Since the fall of the Soviet Union, Gazprom has sought ever-closer relations with gas-consuming nations, their distribution networks, storage infrastructures, consumers, and politicians. Particularly so in the case of former German chancellor Gerhard Schröder. The semi-privatized Gazprom, long the post-Soviet *Siloviki* strongmen's most profitable grift, now ensured the steady supply of billions of moles of gas via the Nord Stream pipelines spanning the Baltic Sea.[58] Gazprom had a majority share in Gascade, a company that oversaw a number of domestic German pipelines, not least that connecting Eztel to Lubmin, a coastal village near Greifswald where Russian gas first came ashore. Moreover, since privatization, in an act of blind faith in the regulatory capacity of markets, Astora, a Gazprom Germania subsidiary, had run parts of Germany's natural gas storage facilities. As Russia's all-out war against Ukraine unfolded, on September 26, 2022, Nord Stream 1 and 2 were bombed by an as-yet-unidentified saboteur. After the explosion, half a million tons of methane bubbled up through the water. Who stood to benefit from cutting this link?

This improbable pipeline infrastructure once fed ancient methane from Siberia's Urengoy gas field into the productive maw of Europe's leading industrial economy, a fragile interconnection that has lined pockets at both ends of the pipeline.[59] Gas helped fund Russia's invasion. In response, Germany took meek retaliatory conservation measures, such as lowering the temperature of municipal swimming pools and closing municipal saunas. This move, as one avid swimmer told me, simply encouraged longer post-swim warm showers.

56. Storag Etzel, "Energiespeicher."
57. Socor, "Gazprom Accumulates Storage Capacities."
58. Belton, *Putin's People*, 123.
59. Balmaceda, *Russian Energy Chains*, 82.

Irrespective, Russia's war crimes, geopolitical ambitions, and anti-Western rhetoric have meant that Gazprom's continued involvement in Germany's strategic gas supply was, to put it lightly, no longer tenable. In April 2022, Gazprom Germania was placed under the receivership of Germany's federal government, a move that meant the company was not allowed to decide on day-to-day nor strategic operations. That said, shareholders will still receive profits in what will likely prove to be windfall years for fossil fuel companies.[60]

The German-Texan petroleum economist Erich Zimmermann once described gas as the most "fugacious" of all fuels. It tends to disperse.[61] Without the caves, Germany's methane would dissipate into the atmosphere. But does any of this make sense? Should we have turned the subsurface into a cellar for sustaining fossil fuel use? The caves imitate the salt domes and capped fissures in which gas from the distant Gulf of Mexico was cooked and trapped hundreds of millions of years ago.[62] The United States is now the world's largest natural gas supplier, and liquified gas is now brought onshore in Wilhelmshaven on Germany's west coast.[63] The tentacular structure of fossil capitalism has realigned itself. Should we have transformed Earth like this to warm our houses and cook pasta? Should we make subterranean voids to control the price we pay for fossilized remains of biota from long-forgotten primordial oceans? Should gas be pumped at high pressure under a sleepy North West German village? Time and winter were supposed to tell. However, the winter of 2022 was the warmest on record. Presumably as a consequence of the improved efficiency of the solar-planetary battery, gas demand was lower than predicted. A crisis averted, perhaps.

To take energy storage seriously is to recognize that stocks of accumulated energy allow great profit to be made and acts of control to be imposed. To step outside extant and emerging energy storage regimes will require imagination, new kinds of political relationships, and no doubt great hardship. However, the alternative is to continue at this exhausting pace, enriching a few at the expense of the many, and upholding unequal relations of ecological exchange. However, if we allow excessive harnessing of the Sun by a few energy storage oligopolists, as we seem to be doing, we may swap one ultimately damaging system of extraction for another, one of potentially far greater magnitude. Perhaps the answer is for some to instead engage in a kind of sacrifice. Maybe some of us should approach the Sun, the preeminent source of energy, with humility, and with awe rather than avarice.

THOMAS MAX TURNBULL is a historical geographer who is interested in energy in all its forms. He is a researcher at the Max Planck Institute for the History of Science in Berlin.

60. Oien, "Berlin Nationalizes Gazprom Germania."
61. Turnbull, "Toward Histories of Saving Energy," 10.
62. Turnbull, "Mississippi," 21.
63. Plumer and Popovich, "How the U.S. Became the World's Biggest Gas Supplier."

Acknowledgments

This essay was presented as a talk at an event called The Driving Factor in June 2022 (https://thedrivingfactor.net/). The text was then recycled and expanded as part of Fusion Festival's Universal University later that month, held at Flugplatz Müritz. The organizers' and audiences' thoughtful responses and reflections fed back into the piece. Thanks also to the helpful and encouraging readers and reviewers. Very special thanks to Jamie Allen for inviting me to *The Ledger of the Sun* in Oslo in October 2022 and for our inspiring chats.

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