

## The Environmental Trinity — 20 June 2024<sup>1</sup>

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A century ago Gertrude Stein remarked profoundly that America was the oldest country in the world because it had been in the 20th century longer than any other country.<sup>2</sup> [The Breakthrough Institute](#) may now be the oldest environmental NGO because of its prescient founding Manifesto and subsequent [2015 Ecomodernist Manifesto](#).

This morning I would like to offer my own definition of environmentalism and explore briefly the vital signs in its trinity of components. My environmental trinity consists of Decarbonization, Dematerialization, and Land-sparing, the dynamic core of Ecomodernism.

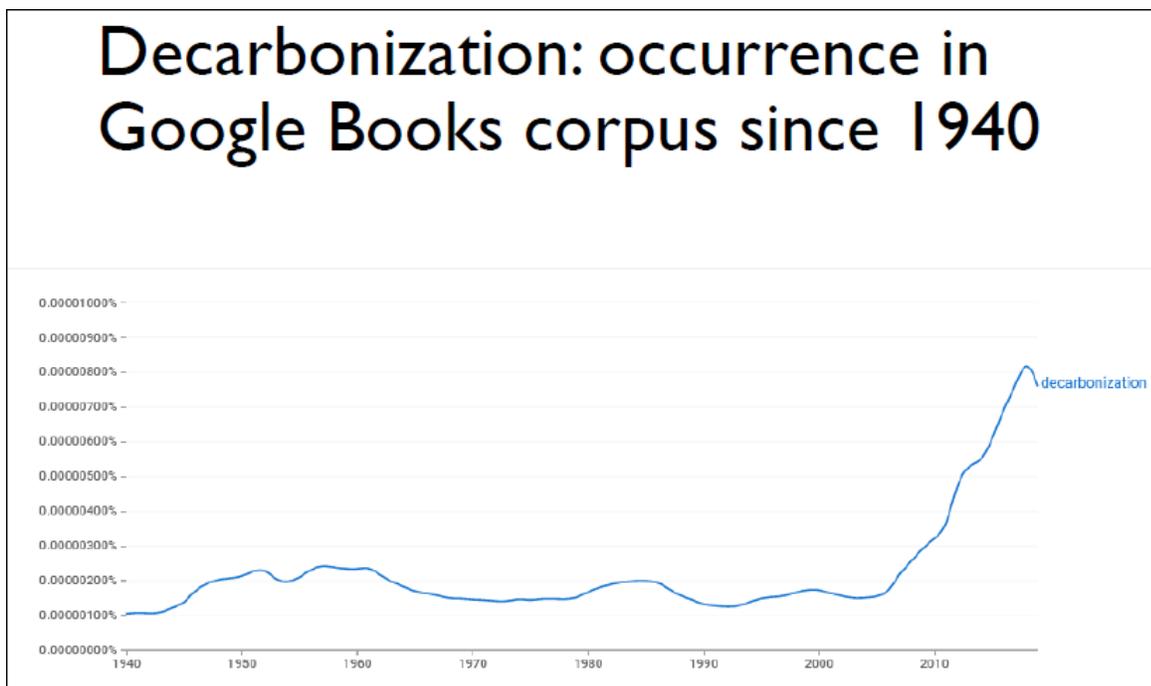
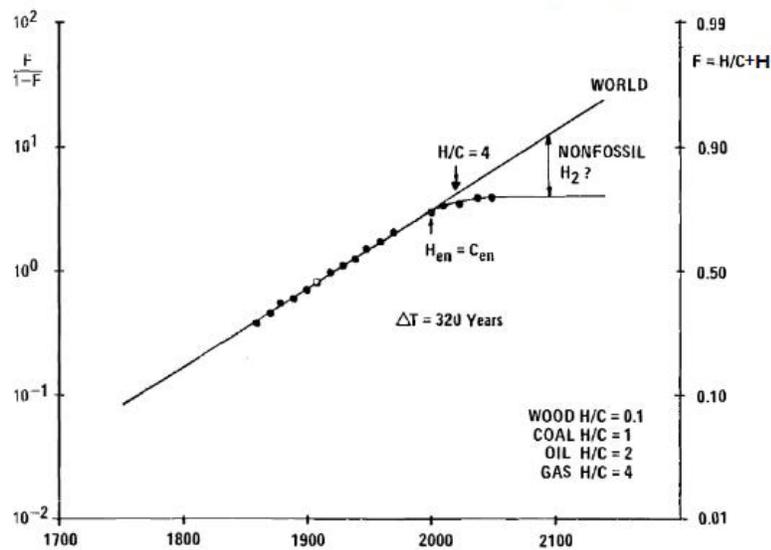


Figure 1

Let me begin with Decarbonization. A Google Books Ngram charts occurrences of the word Decarbonization since 1940 (Figure 1). Most occurrences before about 2005 referred to levels of bubbles in soda pop and other chemical processes. The energy roots date back to the early 1980s when my late mentor Cesare Marchetti first plotted the evolution of the ratio of hydrogen to carbon atoms in the global primary energy mix from 1860 to 1970.<sup>3</sup> Marchetti saw evolution as a series of replacements. He put all the hydrocarbons - wood, hay, coal, oil, and gas - that humans used each decade in an imaginary blender and charted the resulting substitution of Hs for Cs. During the 1980s, Nebojsa Nakicenovic and Arnulf Gruebler at IIASA in Austria, Japanese analysts Yoichi Kaya and Kenji Yamaji, and I began carefully measuring changing carbon intensities and using the term “decarbonization.” In about 2005 decarbonization entered the popular lexicon and its frequency multiplied 8-fold by 2019.

Consider Marchetti's placental figure (Figure 2). The time series of the ratio of Hs to Cs formed a straight line on semi-log paper, equivalent to a long S-curve in which hydrogen gradually takes share from carbon in the energy market. At a finer level, the monotonic line represented the successive dominance of wood (and hay), coal, and oil, and gave us great confidence to predict that hydrogen-rich CH<sub>4</sub> would govern the fuel mix of the next 50 years or more in an era when many believed in the geological scarcity of natural gas, before discovery of deep offshore gas deposits or fracking.

**Decarbonization as discovered ~1980**  
**Secular evolution of world H:C ratio in primary fuel mix**  
**Estimated decadal data for 1860-1970 and projected for 2000-2050**



On left, fraction of H divided by one minus the fraction of H;  
on right fraction of H+C that is H, so coal (one H to one C) is 0.50 (50%), methane (CH<sub>4</sub>) is 0.80 (80%)

Figure 2

Energy was on a marvelous trajectory, one might say in continuous transition, driven apparently by spatial density of energy consumption at the level of the end user. Marchetti envisioned the global journey from hay to hydrogen, from 10% H to 90% H, would take 320 years, from a shortly before 1800 to shortly after 2100. But what has happened?

It is somehow amusing that the outcome of all the huffing and puffing by politicians, diplomats, professors, investors, and protestors was perfect maintenance of the status quo. Energy was in transition until we began ogling it. Policy seems to act like fentanyl for the energy system.

Using the more detailed historical data on fuels now available and bringing the time series up to 2021 for the world and 2023 for the USA, we find disappointingly that, beginning about 1970, America and the world stopped the energy transition measured by our progressive indicator (Figure 3).

# Decarbonization: ratio of hydrogen to carbon The squandered half century

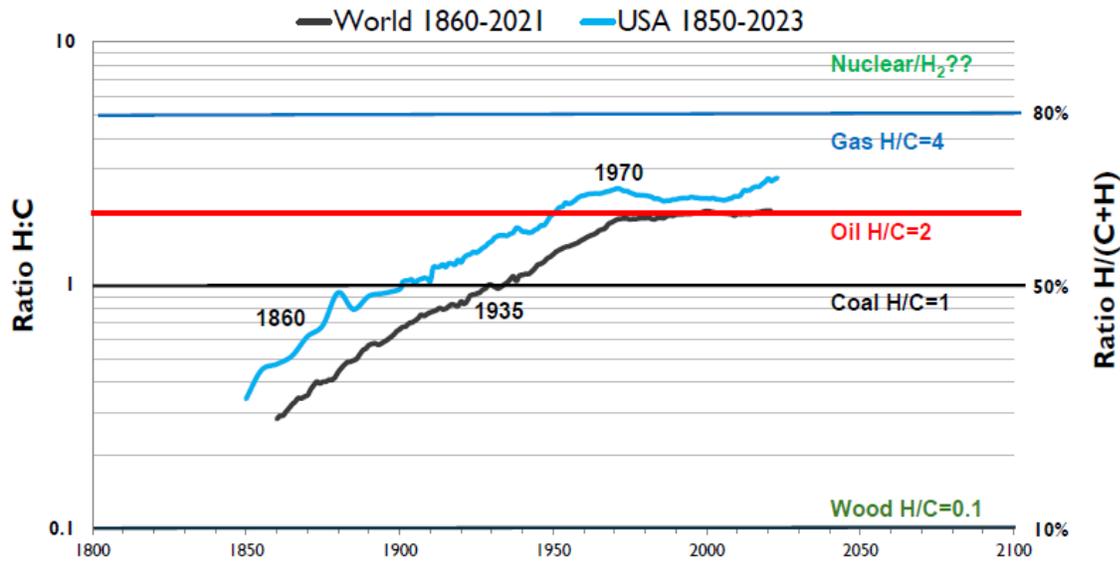


Figure 3

Concurrent with the growth of energy policy, ministries of energy, and academic centers for study of energy, humanity seems to have narcotized the energy system. A substitution process that had proceeded happily and unnoticed for about 200 years came to a halt, in fact slightly reversed in the USA and flatlined globally for about 50 years.

For provocation, I will offer the hypothesis of what sociologists call Reflexivity. Some flavors of reflexivity, making the system conscious of itself, lead to hardening of interests and stasis. Sociologists speak of reflexivity as a feature of modernity, and it certainly seems part of eco-modernity. Anyway, it is somehow amusing that the outcome of all the huffing and puffing by politicians, diplomats, professors, investors, and protestors was perfect maintenance of the status quo. Energy was in transition until we began ogling it. Policy seems to act like fentanyl for the energy system.

Where is our energy Narcan? How do we get beyond the difficulty of being both the subject and the object, and act? The needed actions have not changed in 50 years. We need to move up the line by substituting Hs for Cs, favoring natural gas over coal and oil. We need worldwide diffusion of large near-zero emission power plants, like those of the USA company Net Power, which [promises operating facilities in Texas in 2027](#).

And, to go beyond 80% H molecules, we need to build large nuclear power parks that make hydrogen as a flexible intermediate which stores nuclear heat as chemical energy. The abundant hydrogen can in turn reduce ores, heat homes and industries, synthesize chemicals, produce liquid fuels such as methanol and ammonia, run engines, and even provide feedstock for producing foods.

It's important to grasp that hydrogen is finally above all a way to store nuclear energy. Full stop. Abundant nuclear causes, indeed requires, abundant hydrogen.

Happily, the drowsy USA energy system seems to stir with the switching on of the two new Vogtle nuclear plants in Georgia. Tom Fanning, recently retired CEO of Southern Company to whom we are most indebted for the plants, was the rare CEO who did not succumb in the land of the Lotus Eaters. On 31 May in Georgia, the US Secretary of Energy rightly said, "Okay, two down, 198 to go," by 2050. Let's make a growing fraction of the 198 reactors high-temperature machines that can thermochemically make the hydrogen that sustain the USA on the track of Decarbonization on beyond methane.

If the monstrous contribution of dying old Environmentalism over the past 50 years was to refuse Decarbonization while accepting its rhetoric, what about Decarbonization's twin, Dematerialization? (Figure 4) Another Italian physicist, Umberto Colombo, fathered modern usage of Dematerialization.<sup>4</sup> Chair or director general of some of Italy's largest energy companies as well as an early member of the Club of Rome, Colombo was keenly interested in volumes of stuff, especially metals, and generation of waste, and around 1980 began to pose the question of whether an overall societal Dematerialization was possible.

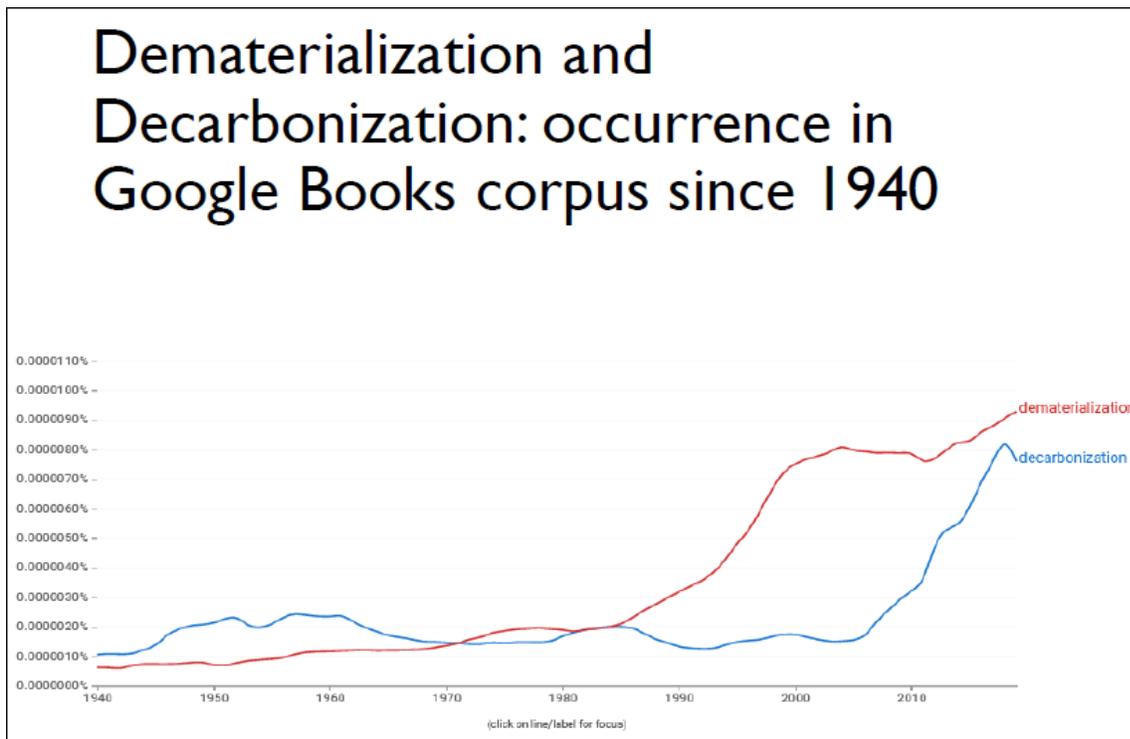
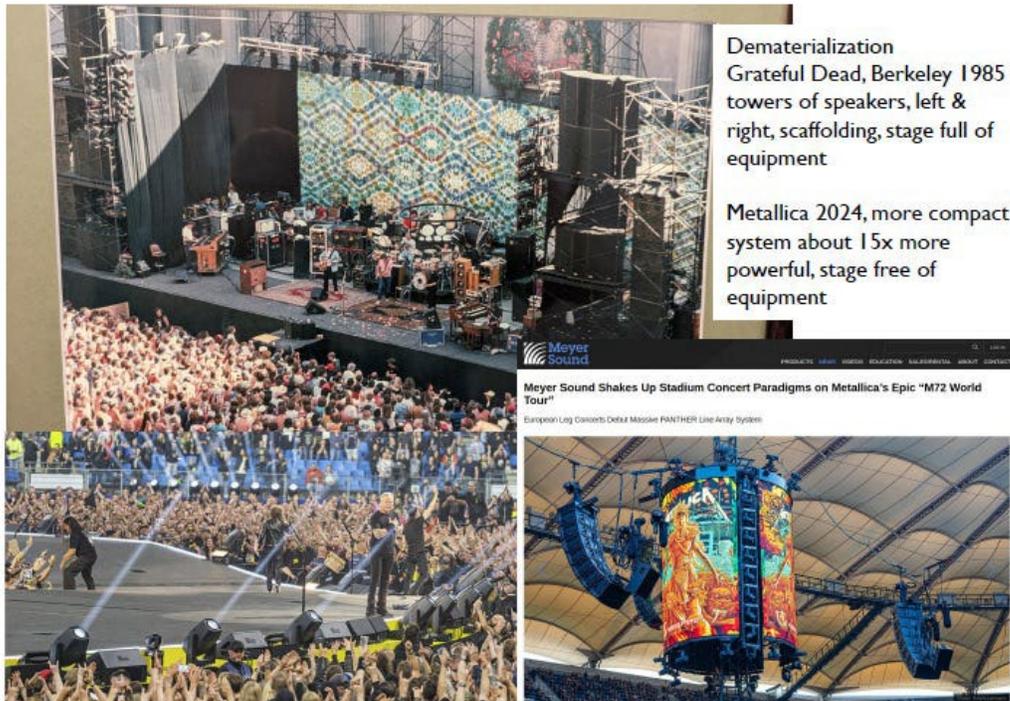


Figure 4

Iddo [Wernick] and I with another physicist, American Robert Herman, who shared in the discovery of the cosmic microwave background radiation that confirmed the Big Bang, had endless fun during the 1980s and 1990s exploring whether, for example, a typical car or building had become lighter and whether various technical and behavioral changes favored lessened use of materials. People giggled when we first talked about Dematerialization, but like Decarbonization, it came into vogue.

Let me begin with a loud, contemporary example of Dematerialization, made in California, indeed in Berkeley by the company Meyer Sound (Figure 5). Contrast a Grateful Dead 1985 concert with a 2024 Metallica concert, where one-third the loudspeakers cover an entire stadium five times larger than Berkeley's Greek theater. The Metallica system has 90% more energy efficient amplifiers built into the smaller boxes. Signals are sent from the mixing console to the loudspeakers over a slender fiber optic network instead of through heavy cables. The Metallica stage is also dematerialized, completely free of guitar and bass amplifiers; the guitar sounds travel wirelessly to receivers under the stage.

## Dematerialization of Heavy Metal

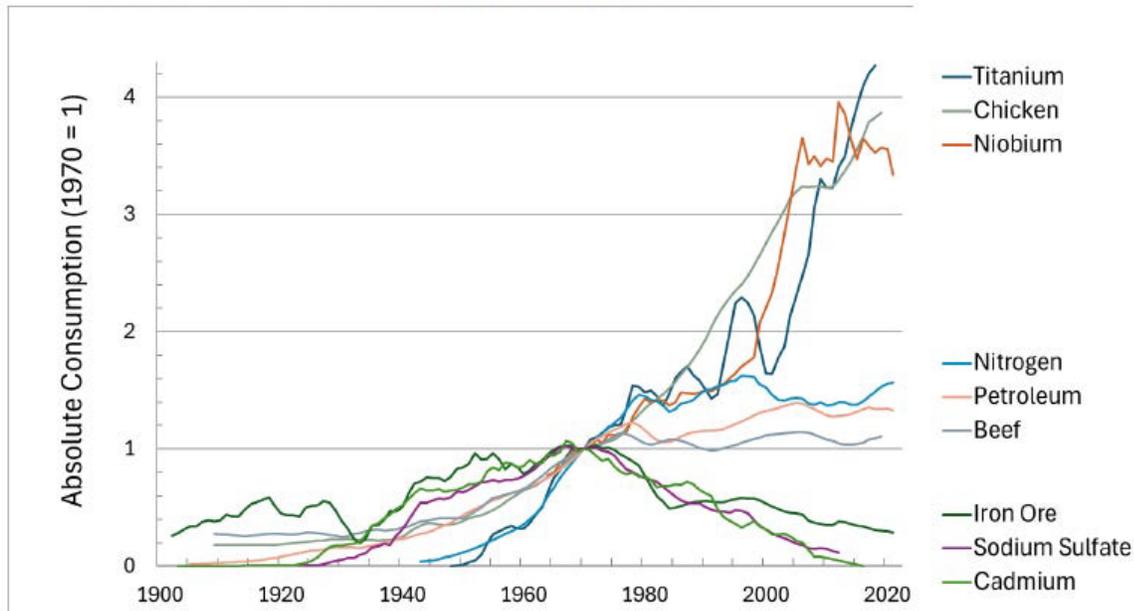


Source: Meyer Sound

Figure 5

To our surprise, in a study of use of 100 commodities in the USA from 1900 to 2020 Iddo and I found Dematerialization occurring extensively, both in absolute terms (of weight or volume) and in relative terms where the weight or volume is compared to gross domestic product. First consider trends in absolute consumption for nine representative commodities (Figure 6). Cadmium, sodium sulfate, and iron grew to 1970 but then absolutely dematerialized. Interestingly, we found that 1970, year of the first Earth Day, was the American year of Peak Materialization, when use of many of the 100 commodities either began to fall or plateau. Iron ore, beef, and petroleum plateaued since 1970. Meanwhile, niobium, chicken, and titanium have dramatically materialized, with amounts roughly quadrupling.

# Dematerialization: USA 9 commodities



Source: Wernick I, 2024, Is America dematerializing? Trends and tradeoffs in historic demand for one hundred commodities in the United States. Submitted to PlosOne

Figure 6

The list of the 100 commodities we considered spans an overwhelming fraction of the stuff of the USA or any economy (Figure 7). The 41 items in blue, from asbestos to water to cropland, have dematerialized in both absolute and relative terms. The 51 in green from sulfur to silver to sand & gravel, are dematerializing by one measure and materializing by another. Only the 9 in red, from chickens to gallium and rhenium, are materializing in both absolute and relative terms.

The 100 Commodities Study:  
 Materialization and Dematerialization in the USA 1900-2020  
 Group 1: Dematerialization; Group 2: Mixed; Group 3: Materialization

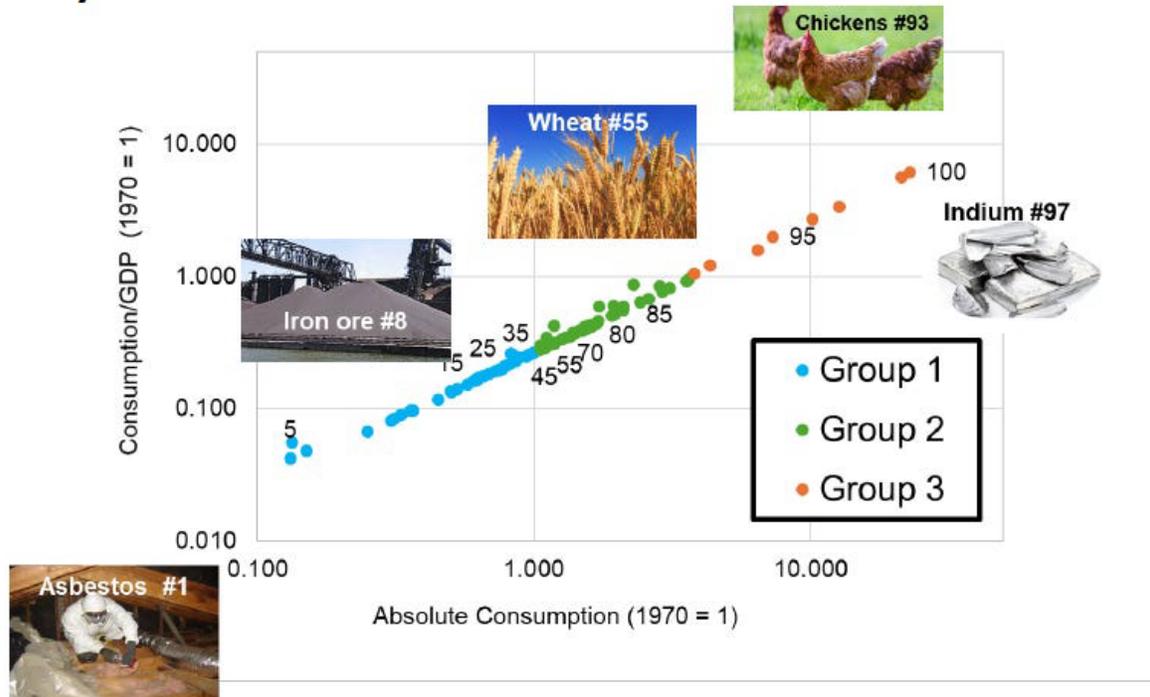
Group 1		Group 2		Group 3	
20 Tin*	41 Cropland	66 Cotton	92 Sand & Gravel (I)	100 Rhenium*	
19 Iron & Steel Scrap	40 Antimony*	65 Nitrogen (Ammonia)	91 Soybeans	99 Diamond (Industrial)	
18 Beryllium*	39 Lime	64 Pork	90 Natural Gas liquids	98 Garnet (Industrial)	
17 Mica	38 Strontium*	63 Natural Gas	89 Niobium*	97 Indium*	
16 Mg Compounds	37 Copper*	62 Iodine	88 Platinum-Group Metals*	96 Stone (Dimension)	
15 Iron & Steel Slag	36 Chromium*	61 Perlite	87 Corn	95 Gallium*	
14 Arsenic	35 Water	60 Potash	86 Gypsum	94 Titanium Metal	
13 Clays	34 Lithium*	59 Cement	85 Electricity	93 Chicken	
12 Alumina*	33 Selenium	58 Aluminum*	84 Helium		
11 Fluorspar*	32 Soda Ash	57 Potatoes	83 Hafnium*		
10 Pig Iron	31 Graphite (Natural)	56 Petroleum	82 Feldspar		
9 Zirconium	30 Rare Earths*	55 Salt	81 Fish		
8 Iron Ore	29 Lubricants	54 Lead*	80 Diatomite		
7 Bauxite*	28 Asphalt & road oil	53 Titanium Dioxide	79 Tungsten*		
6 Sodium Sulfate	27 Zinc*	52 Wheat	78 Stone (Crushed)		
5 Mercury*	26 Pumice & Pumicite	51 Boron*	77 Bromine		
4 Cadmium*	25 Talc & Pyrophyllite	50 Silicon	76 Barite		
3 Thallium	24 Phosphate Rock	49 Cobalt*	75 Nickel*		
2 Thorium	23 Abrasives	48 Sand & Gravel (C)	74 Paper & Board		
1 Asbestos	22 Gold	47 Magnesium Metal	73 Tantalum*		
	21 Manganese	46 Coal	72 Gasoline		
		45 Molybdenum*	71 Silver		
		44 Beef	70 Bismuth*		
		43 Timber	69 Uranium		
		42 Sulfur	68 Vanadium*		
			67 Germanium*		

Source: Wernick I, 2024, Is America dematerializing? Trends and tradeoffs in historic demand for one hundred commodities in the United States. Submitted to PlosOne

Figure 7

One can align all 100 commodities on a chart that has absolute use on one axis and relative use (or intensity) on another (Figure 8). The outcome offers a material definition of Ecomodernism, which I like to summarize as “chickens and gallium.” The quartet of population, affluence, consumer taste (or behavior), and technical change all impact Materialization,<sup>5</sup> as does trade, but it’s clear the USA economy is in a very different phase than before 1970, the time of America’s ecological Big Bang. Since then, I would summarize by saying more bits and bytes and fewer liters and kilos, though still a lot. Newly popular materials like Gallium one can think of as vitamins – or information – that allow the bulky elements to stay lean.

# 100 commodities aligned by absolute & relative dematerialization



Source: Wernick I, 2024, Is America dematerializing? Trends and tradeoffs in historic demand for one hundred commodities in the United States. Submitted to PlosOne

Figure 8

Now let us shift attention in the odd couple of Gallium and Chickens to the poultry. Already having great fun with Decarbonization and Dematerialization,<sup>6</sup> about 1990 agronomist Paul Waggoner and I asked the question “How Much Land Can Ten Billion People Spare for Nature?”<sup>7</sup> Conventional wisdom held that all the planet’s arable land would be used, remaining forests would be shaved, that the prospects for land-sparing or a great restoration of Nature were essentially nil. The prospect was so unlikely that no one needed to use the phrase land-sparing (Figure 9).

# Land-sparing: occurrences in Google Books corpus since 1940

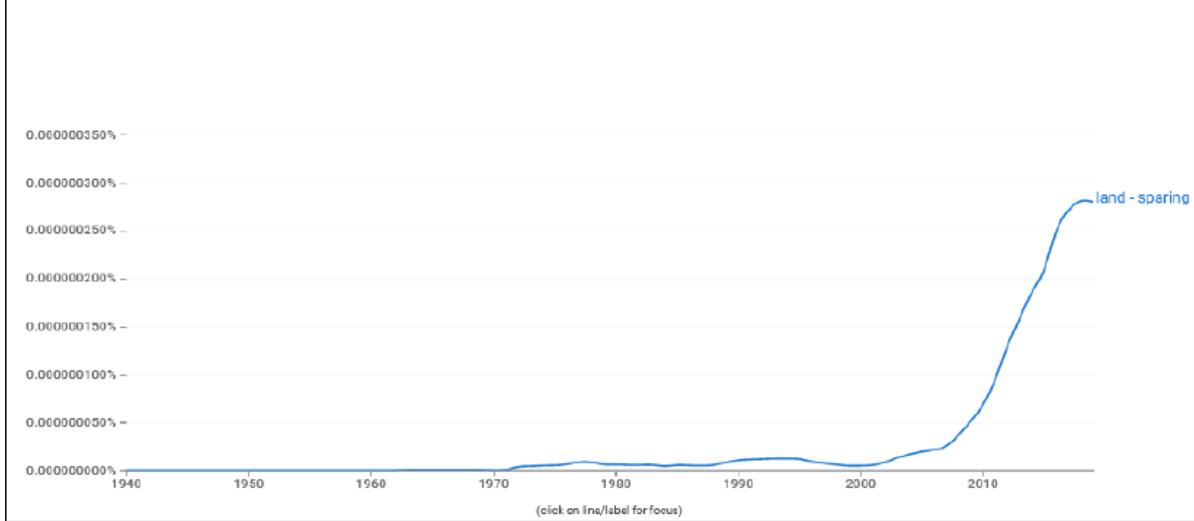
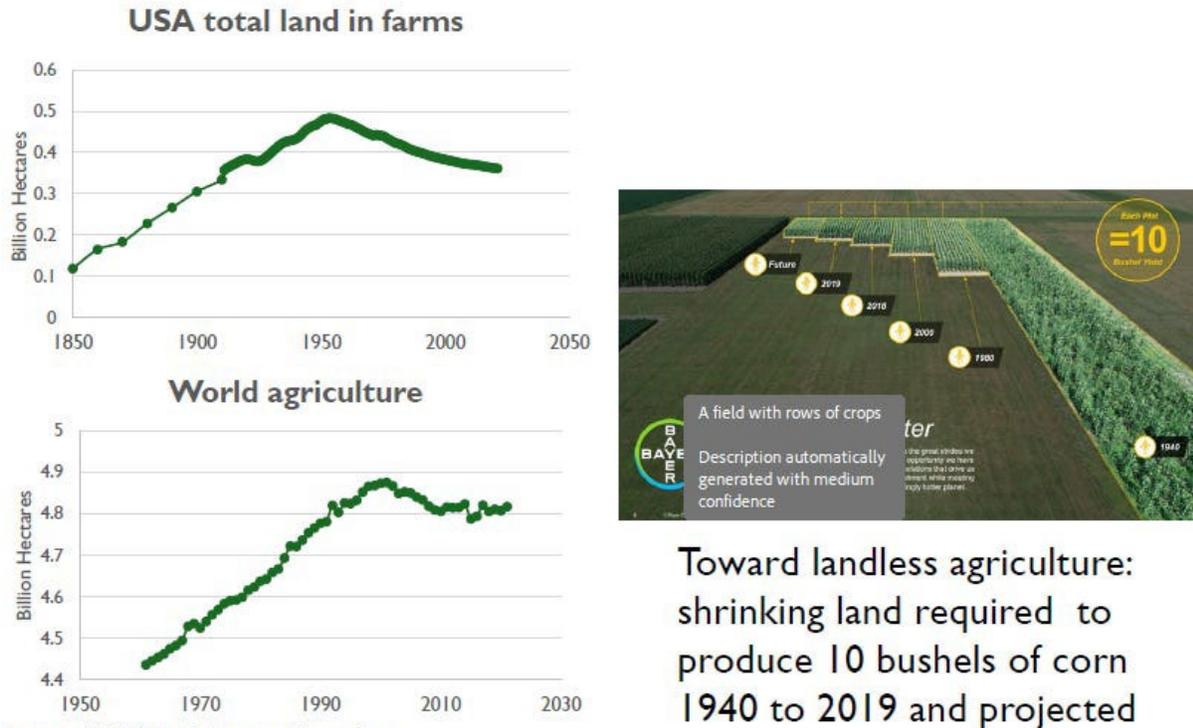


Figure 9

Yet, a great reversal of land use was already underway. Let's set aside discussions about exactly how to measure land use and land cover and their changes, which abound in both agriculture and forestry. The big picture, recently well-summarized by Hannah Ritchie in her book<sup>8</sup> and the site [Our World In Data](#), is firm. About 1960 a great reversal in land-use in the USA occurred as land in farms began to peak (Figure 10).

# Land-sparing: USA and global



Sources: UNFAO; US Dept. of Agriculture

Figure 10

A cluster of technologies spanning ways to plant, seeds, weather forecasts, and sensors of many kinds, which we bundle under the rubric Precision Agriculture, allowed outputs of crops to grow while land and most other inputs (except information) stayed level or even shrank. USA farmers again achieved record average corn yields in 2023, about 12 tons per hectare, 50% more than a generation ago. The winner of the National Corn Growers Contest, David Hula of Charles City VA, grew an astounding record of 42 tons per hectare, while the top grower in the competition with strict nitrogen fertilizer limits grew about 21. (A Hula hectare produces enough calories to feed more than 130 people for a year, while an American hectare in 1900 produced enough for only four people.) The global land-sparing pattern seems to follow the USA pattern by about 30 years.

In conclusion, where have America and the world come since [the Death of Environmentalism?](#)

On Decarbonization, not far. America and the world wasted several decades, but perhaps finally America is resuming the light path of natural gas and nuclear and hydrogen. America has passed peak CO2 emissions, and globally Peak C may be in sight.

On Dematerialization, some surprising successes, at least in America. “Peak stuff” may not be as crazy an idea as it seemed, though the total infrastructure to satisfy the virtual, immersive, and autonomous desires of humanity will be very large. Large parts of the world will materialize for decades to come, though more efficiently than the early materializers.<sup>9</sup>

On Land-Sparing, Peak Farmland is past or now. While regional tragedies of land use and deforestation persist, the global prospect for land-sparing is bright. Let's hope that sea-sparing follows, but so far we observe mainly continuing industrialization of the oceans.

We could speak of Peak Baby, which also seems to have occurred (2007 in USA and 2012 globally), but perhaps more striking is the extraordinary penetration of the trio of memes, Decarbonization, Dematerialization, and Land-Sparing, that I have discussed and that Breakthrough has advanced in many ways. We need all three for environmental salvation. Regrettably, wind, solar, and biomass fail badly on Dematerialization and Land-Sparing. If we agree with Plato that things begin first in the mind, then perhaps the Death of Environmentalism will be followed now by large collective movements, often quiet, to implement Ecomodernism, that, is decoupling from carbon, materials, and land.

In closing, I recur to a variation on Gertrude Stein's question, "What is the oldest country in the world?" Let us try to learn by asking "Who has been longest in the 21st century?" Shanghai? Florida? The LNG-powered cruise ship Icon of the Seas carrying almost 10,000 passengers and crew? Perhaps for the next two days the answer is Sausalito.

## References

- [1](#) Thanks to Ted Nordhaus, Alex Trembath, and The Breakthrough Institute team for the honor to participate in the Breakthrough Dialogue 2024 and to open today's session as we revisit, after 20 years, "The Death of Environmentalism." Thanks to Iddo Wernick, my long-time partner in studies I will report.
- [2](#) Stein, G. (1933). **Autobiography of Alice B. Toklas**. Chap. 4.
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- [5](#) Waggoner, P. E., & Ausubel, J. H. (2002). [A framework for sustainability science: a renovated IPAT identity](#). *Proceedings of the National Academy of Sciences*, 99(12), 7860-7865.
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- [7](#) Waggoner, P. E. (1996). [How much land can ten billion people spare for nature?](#) *Daedalus*, 125(3), 73-93.
- [8](#) Ritchie, H. (2024). **Not the End of the World: How we can be the First Generation to Build a Sustainable Planet**. Hachette UK.
- [9](#) Ausubel, J.H. (2004) [Will the Rest of the World Live Like America?](#) *Technology in Society* 26:343–360.