In Chips We Trust? Remembering the Environmental Impacts of Hardware Manufacturing

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"God decided where the oil reserves are. Let's put the fabs where we want them."

— Pat Gelsinger, Intel CEO

With the passing of the US CHIPS and Science Act in 2022, semiconductor fabrication plants ("fabs") became the subject of significant business and political attention. Through the legislation's composite parts, the "Endless Frontier Act" and the "CHIPS for America Act," the United States Congress implicitly acknowledged that offshoring strategies pursued by American businesses over several decades had rendered local silicon manufacturing uncompetitive. In response, patriotism and pioneer mythology converged in the bill to deliver an historic bipartisan infrastructure investment worth approximately $US 52 billion.

Ostensibly, the context for this rare success in an otherwise dysfunctional legislative environment was the COVID pandemic. In addition to the widespread human suffering involved, for business leaders it seemed as if the very foundations of modern trade were at risk. The extent of America's dependence on a supply chain concentrated in the Asia-Pacific became widely evident. Stories of chip supplies stranded in shut-down factories and gridlocked international ports became part of the lobbying toolkit for Pat Gelsinger, CEO of semiconductor manufacturer Intel Corporation, whose comments at a meeting of Washington DC economists shed light on the amount of hubris involved in leading a multinational silicon vendor. Gelsinger leveraged the COVID crisis to win internal support for a major shift in the company's operating model as well as a new line of government subsidies from external stakeholders. Speeches intended to win favor for the CHIPS Act made liberal use of iconic national symbols, such as the beloved Ford F-150 pickup truck, which had apparently stalled production indefinitely because of a missing rear-view mirror sensor (Gelsinger 2021).

Publicity events Intel choreographed to build momentum for the CHIPS Act's generous tax subsidies and co-funding for domestic manufacturing initiatives included a new 1000-acre semiconductor facility announced for Licking County, Ohio. Company executives renamed the Buckeye State the "Silicon Heartland" at a press

conference featuring many elected federal, state and local officials. Intel's statement of intent in Ohio appeared set to extend an already considerable US manufacturing presence in Oregon, Arizona and New Mexico, an arc of blue-collar and bunny-suit opportunity stretching from the Pacific Northwest to the desert sunbelt.

Anticipating the CHIPS Act's passing, Taiwan Semiconductor Manufacturing Company (TSMC) also released plans for a new facility alongside its existing Phoenix operation. Intel and TSMC control a large share of the world's semiconductor supply, with South Korea's Samsung Electronics making up much of the remainder. The COVID pandemic brought home the realization that America's chip prowess had fallen behind foreign nations whose security was tied to geopolitical rivals. The CHIPS Act supported a different approach to high tech manufacturing: a combination of "re-shoring" and "friend-shoring" to ally countries. In this way, political rhetoric drumming up support for domestic chips obscured the amount of interdependence between the US, Southeast-Asian and East-Asian nations which had been a strategy of global companies like Intel for many decades (Yeung 2022).

In the rush to promote the benefits of expanded market competition for silicon, both for consumers and potential employees, the ecological impacts arising from previous periods of hardware manufacturing have been a negligible consideration. This is despite residents in earlier production locations still experiencing ongoing effects of contamination and pollution (Meehan and Turner 2021, Grossman 2006). As Silicon Valley established its name as the foundation for high tech industries, an alliance of nonprofits, scholars and activists revealed the severe cumulative damage caused by chemical exposure and unchecked hazardous waste in many facilities. The air and land surrounding these plants remain polluted today, with clean up actions required by law. Indeed, during the course of writing this essay, regulators granted Intel an air quality permit even though the company underreported its carbon dioxide emissions by 38% in 2022. A contract employee also sued Intel for alleged chemical exposure during the most recent factory build in Oregon (Rogoway 2024a, b).

Chris Miller's Chip War is emblematic of the trend to foreground geopolitical rivalry between manufacturing dynasties while downplaying ecological considerations. Its lengthy treatment of the industry's key protagonists avoids mention of the more toxic aspects of the business, or the unstable climate affecting many of the regions critical to the supply chain today and in future. The design and manufacturing of semiconductors is portrayed as a battle of patriarchs, with the US and China pursuing supremacy in artificial intelligence applications as a new kind of arms race. Readers are left to conclude that expansive chip manufacturing is not only inevitable but the only means to ensure national security, whatever the cost. The fact that two major conflicts commenced amid the backdrop of the CHIPS Act and AI frenzy, in Ukraine and Palestine, reveals that any narrative about the kind of military technology required by modern warfare is selective at best.

Chemicals, metals and sand are the resource foundations of the chip industry, as well as a staggering amount of water. Sand is refined and crystallized as silicon prior to being cast, bound and printed on wafers in the fabrication process. Later, these wafers are sliced and packaged for sale to customers, whether car companies like Ford, computer manufacturers that build laptops, or "cloud" companies that generate, analyze and store our digital data. Transporting wafers to assembly and test sites prior to distribution is a major source of carbon emissions, as are fabs themselves. Water is critical to computer chip production from start to finish: it douses the mines that supply precious metals to produce computer components, it cleans chemical compounds that hold elemental hardware parts together, and it

powers the electrical grid for cloud companies whose data centers rely on renewable energy to cool server racks.

Historically, activists, journalists and scholars informed local communities of high tech's environmental risks, particularly in the use and disposal of hazardous substances (Wilmsen 2003). A substantial literature on electronics' toxic and human harms accompanied the first wave of organized labor activism in Silicon Valley in the 1970s and 80s, when longitudinal studies finally proved the effects of exposure to certain glycol ethers, trichloroethylene (TCE), trichloroethane (TCA), perflouroalkyl sulfonates (PFAS), and other risky substances (Maxwell and Miller 2012, Kneese 2023). This period delivered substantial regulatory achievements via the Environmental Protection Agency such as the Toxics Release Inventory and the Superfund site registry (Grossman 2006). Activist groups such as the Silicon Valley Toxics Coalition and the Santa Clara Center for Occupational Health and Safety tracked the effects of hardware assembly jobs on workers at home, then followed the movement of operations to new locations, whether across the border to Mexico or the developing industry in Southeast Asia (Smith, Sonnenfeld and Pellow 2006). These projects were vital acts of knowledge transfer when workers were bereft of contemporary digital communication tools, and workplace safety standards for handling and disposing chemicals had yet to be defined and enforced (cf Qiu 2016; Chan, Selden and Ngai 2020).

This advocacy heritage is being rediscovered as a point of contrast to the CHIPS Act's relentlessly positive depiction of work in the semiconductor sector. Chips Communities United is a nonprofit alliance comprising unions, environmental groups and some of the original activists from the first wave of Silicon Valley organizing. Members are sharing resources in order to scrutinize government and industry claims, particularly when it comes to understanding the quantity and quality of jobs resulting from CHIPS Act funding. Meanwhile, scholars are drawing on open-source intelligence techniques to procure relevant data sets that link the long term plans of key silicon providers to climate and resource risk. Josh Lepawsky's (2024) account of the extreme water scarcity projected for existing and future semiconductor production sites is an example of how applied research methods can chasten the optimism of market forecasts and effusive business journalism.

China, Malaysia and Vietnam are some of the key destinations that US companies sent manufacturing tasks "offshore" in recent decades. High tech employment was framed as a more reliable form of income for farming families dependent on the vicissitudes of small-scale agriculture. This rationale repeats a pattern from the early days of Silicon Valley, where fruit orchards once stood as the region's economic backbone. The erasure of farming and other land-based economies in service of advanced manufacturing has happened within living memory in the US as elsewhere. A Vice President I worked with at Intel once told me he went to school with the Jones brothers—whose father's name appears on one of several buildings ("Jones Farm," "Hawthorn Farm," and "Ronler Acres") signaling the agricultural roots of Intel's sprawling Hillsboro, Oregon campus.

Climate and community activists have successfully defeated new data center facilities planned for construction in parts of rural Europe. In the US, local governments have secured additional community benefits in exchange for large corporations' presence (e.g. Facebook's facility in Prineville, Oregon, see Burrell 2020). When it comes to chip processing, however, the record of community involvement is mixed. The appropriation of farmland by wealthy multinationals is enabled by sweetheart deals with local governments. A focus on short term profit reflects a broader amnesia about the lingering effects of soil and water contamination and vapor emissions from a variety of poorly classified and regulated chemicals. The impacts of

property seizures go beyond individual landowners' fortunes and capacity in that they are generally irreversible. The enclosure of an ever-larger land mass for manufacturing and its downstream activities limits the viability of diverse bioregions beyond the immediate perimeter of production.

To date, when environmental concerns are mentioned in relation to the CHIPS Act, they are typically couched as a barrier to making faster progress on factory builds, and the plethora of jobs that were promised in the high stakes lobbying phase. A Bloomberg feature (Hawkins 2023) illustrates how hard-won environmental regulations are too easily pitted against the need for national security, equating artificial intelligence—and hence chip production—with military protection. The public is doubly ostracized from this level of debate: the proprietary nature of business competitiveness justifies a level of secrecy and discretion that matches the military applications of high-tech products. Americans are asked to trust the government and industry to work in their best interests. The frenetic pace and sublime aura attending new applications of computing technologies make it challenging to link the growth of chip manufacturing with the dwindling supply of rare earth minerals, or the quality of land subject to corporate control. The seductive allure of AI is that the technology itself will hold the key to solving any remaining environmental harms that come to light in addition to the vast energy consumption requirements already understood (Nafus 2023).

As time moves on in Arizona and Ohio, the rhetoric is fading on the fortunes to come as construction costs and the availability of workers slow the pace of progress. Intel has revised estimates of its Ohio factory completion date to 2027 (McDonnell 2024), while TSMC is importing Taiwanese workers more willing and trained to meet the company's performance expectations. Land clearing in Arizona's already parched desert landscape continues even while city leaders admit that residential water use is unsustainable (Flavelle and Healy 2023). Until now, tech companies have fortified ancient city aquifers to prove their benefit to the community. When supplies are exhausted, however, water is imported across state borders and through tribal nations whose claims to land and water sovereignty are caught in decades-long arbitration (Smith, Olalde and Farooq 2023). By the time these nations have their claims settled, it may be too late to offset the industrial contamination and biodiversity loss that has already transpired.

Transferring ecological stewardship from community-based stakeholders to large corporate multinationals is a substantial social and political accomplishment of the past two decades. It has happened alongside the evolution of environmental governance as a professional skill set and industry-developed standards mediating the harmful outputs of high-tech products. Sustainable silicon manufacturing, an extension of so-called "green chemistry" (Grossman 2006), is part of an elite discourse of self-imposed, malleable targets, designed to meet abstract goals that contribute to non-binding international agreements. In this world of green business accounting, there is little incentive to reduce material and ecological dependencies, or mention their vulnerability (Archer 2024; Gregg and Strengers 2024).

The analogy to God in Gelsinger's quip about fab locations suits this evolving context for corporate responsibility. It reflects an industrialist worldview that nature's resources are controllable (McLaughlin). As a born-again Christian, religious zeal inflects Gelsinger's tenure as Intel CEO. Both internally and externally, his return to run the company after a prominent early departure is portrayed as a "second coming." Gelsinger's peculiar sense of duty to supply the world's chips encapsulates the will to dominate nature embedded in Western Christian traditions. In a recent podcast episode, Paris Climate Agreement negotiator Christiana Figueres (2024) quoted from to the Book of Genesis to explain this lineage and

anthropocentrism's deep roots. For Christians, The Bible is the ultimate source that bestows Man the responsibility to hold "dominion… over every living thing that moveth upon the earth." But even if the many nations affected by the chip industry shared this belief in Man's responsibilities – or the American habit of confusing commercial and religious calling – citizens, consumers and workers alike have little recourse to express "where we want" the fabs, if we want them at all.

The patriotism fueling government incentives for US manufacturing derives from a longer tradition of frontier behavior evident in the gold digging and produce racketeering that predate San Jose's transformation to Silicon Valley (Pellow and Park 2002, Harris 2023). As the post-pandemic chip shortage collides with AI hype, high-performance computing is being touted as common-sense business practice, even while access to the technology and its production facilities is limited to a handful of industry players. Once established, chip plants rely on an on-demand, increasingly automated workforce to build products for a rapidly deskilling user base. This scenario brings little benefit to the majority of workers, let alone other species left behind by high-tech's digital divide.

A more balanced assessment of high tech's green credentials would do well to keep the early foundations for the industry, and its related activism, in mind. A revitalized ecological ethic to suit the AI goldrush should insist that chip manufacturers not only prove their environmental responsibility to host communities, but offer evidence that their subsidized, for-profit applications serve the true national interests of a livable environment. As the effects of climate change compound, national defense must include safeguarding biodiversity and safe water supply for the future. In practice, this also means a commitment to regenerating ecosystems harmed by previous generations of industrial activity.

Whether or not there is any substance to the media fascination with a "chip war," it is unhelpful to inflame geopolitical tensions in regions critical to the chip industry's past and present. Supporting the chip industry's ongoing ingenuity and success should not require fearmongering patriotism as justification. Recalling the broad range of participants involved in previous moments of high-tech expansion, a more useful approach can be found in the archives of the Vietnam era, when Bay Area activists demanded a "Peace Dividend" for government investment in advanced military applications for technology. Well in to the 1980s, the Mid-Peninsula Conversion Project in Santa Clara County proposed "reorienting electronics production toward nonmilitary purposes" given that taxpayer dollars had subsidized the industry's growth years (Pellow and Park 2002, Harris 2023). Decades later, we are still waiting for this payout. Nonetheless, these alternative visions of environmental justice offer solace and instruction in the present context of paranoid hardware acceleration. They provide imaginative openings and fruitful directions for those of us who remain unconvinced that the threat of AI is as real as the existing zealotry of an untrammeled, extractive, patriarchal economy.

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