

Sustainable, renewable growth: forces of production, the Triple Helix, and environmental justice

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ABSTRACT: This essay examines the structural and institutional contradictions underlying contemporary technological transitions, energy policies, and the political economy of innovation. Drawing on the foundational divergence between Karl Marx's emphasis on the material forces of production and Max Weber's institutional analysis, the paper examines the global dynamics of the green transition—specifically the persistent extractivism in the Global South, the ecological costs of photovoltaic and semiconductor supply chains, and the geopolitical entanglements of state-sponsored energy strategies. Reflecting on the theoretical origins of the Entrepreneurial University and the Triple Helix model of university-industry-government relations, this paper links historical studies of academic commercialization with grassroots public sociology and environmental justice activism in Silicon Valley. Furthermore, the discussion contrasts Soviet-era conceptualizations of the Scientific-Technological Revolution (STR) with contemporary algorithmic governance, arguing that artificial intelligence increasingly functions as an ideological apparatus for elite political control. Ultimately, the essay advocates for horizontal, multi-intuitional arrangements over rigid vertical state hierarchies to advance democratic oversight and genuine socio-ecological transformation.

KEYWORDS: Triple Helix | forces of production | green transition | entrepreneurial university | environmental justice | public sociology | scientific-technological revolution | Silicon Valley

1. INTRODUCTION¹

A central sociology puzzle regarding contemporary epochal shifts concerns the mechanisms through which large-scale societal transformation occurs (Etzkowitz, 1978). In framing this problem, it is instructive to return to the classical debate between Max Weber and Karl Marx. While Weberian analysis prioritizes institutional bureaucratization, rationalization, and legitimization structures (Weber, 1905/1930, 1922/1978), the fundamental driver of structural historical rupture, as Marx postulated, resides at the level of the forces of production rather than merely the existing relations of production (Marx, 1859/1904). Relations of production, when left unexamined, tend to reproduce the prevailing mode of capitalist accumulation un-

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der different institutional guises.

This theoretical tension is particularly visible across contemporary initiatives surrounding the global green transition. Consider, for example, the political economy of lithium extraction in South America. While regional initiatives—such as Bolivia’s efforts to establish a sovereign, state-controlled lithium value chain—initially promised structural autonomy, global market imperatives and shifting regulatory climates in neighboring Argentina and Brazil have systematically undermined these ambitions (Riofrancos, 2020; Svampa, 2019). Transnational capital continually plays developing nations against one another, foreclosing autonomous industrial paths unless regional actors establish coordinated, collective bargaining strategies.

A parallel contradiction characterizes Brazilian energy policy (Etzkowitz, 1995). Brazil has maintained a prominent international profile regarding bioethanol development; however, ethanol accounts for only a modest fraction—approximately ten percent—of actual automotive fuel consumption. The economic pillar sustaining Brazil’s federal social programs remains *Petróleo Brasileiro S.A. (Petrobras)*, the state-controlled hydrocarbon enterprise. The imperative to generate state revenues for redistributive social policies binds progressive administrations to the continued exploitation of fossil fuels. Consequently, surface-level modifications in fuel blending serve as a decorative facade rather than a fundamental shift in the mode of energy production.

2. MATERIAL CONTRADICTIONS IN THE GLOBAL PHOTOVOLTAIC AND ELECTRONICS REGIMES

A genuine ecological transition requires a transformation of the underlying mode of production, moving decisively away from carbon-intensive, toxic inorganic material substrates toward fully regenerative alternatives (Fig. 1). The prevailing global infrastructure for renewable technology remains deeply compromised by material contradictions.

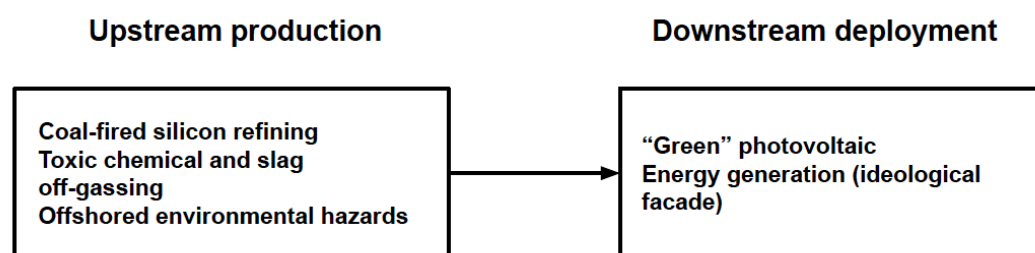


Fig. 1. Upstream production and downstream deployment

The dominant global supply chain for solar photovoltaics (Etzkowitz, 1984), centered heavily in China, remains structurally dependent on coal-fired industrial refining and environmentally damaging chemical processing (Ball et al., 2017). Silicon refinement is an inherently polluting, energy-dense enterprise. Therefore, the assertion that the deployment of conventional silicon photovoltaics constitutes a clean, carbon-neutral solution overlooks the dirty upstream material reality of its manufacture.

This dynamic mirrors the historical trajectory of the semiconductor industry in Silicon Valley. During the late twentieth century, local civic and regulatory resistance to groundwater contamination and chemical pollution forced silicon fabrication facilities to relocate from Northern California to East Asia (Pellow & Park, 2002). Yet, the physical hazards were merely relocated rather than resolved: effluent dumping and toxic discharge continue along Pacific production peripheries. The global electronics and solar energy sectors thus remain tethered to fundamentally unsustainable material inputs.

Attempts to institutionalize sustainable manufacturing through public research funding have faced significant political vulnerabilities. In the United States, initiatives under the National Science Foundation (NSF) to pioneer non-toxic, next-generation semiconductor materials have repeatedly stalled due to ideological turnover across successive presidential administrations. Subsequent attempts to anchor collaborative bilateral ventures with Brazilian science and technology agencies (such as FINEP) further demonstrated that geopolitical dependencies—historical alignments shifting from Great Britain to the United States, and increasingly toward China—render sustained green technology initiatives precarious in the absence of indigenous, institutionalized support mechanisms.

3. THE GENESIS OF THE TRIPLE HELIX AND THE ENTREPRENEURIAL UNIVERSITY

The conceptual formulation of the Triple Helix model—delineating the non-linear, horizontal interactions among university, industry, and government (Etzkowitz & Leydesdorff, 1995, 2000) the national organization of the system of innovation has historically been important in determining competition. Reorganizations across industrial sectors and nation states, however, are induced by new technologies (biotechnology, ICT—emerged directly from empirical observations of technological crises and academic transformations. During the mid-1970s energy crisis, fieldwork conducted at an early photovoltaic startup in California revealed a fundamental shift in academic scientific norms:

When interviewing corporate research physicists, they explicitly stated: “We do not publish for papers; we patent for property.”

Academic scientists from prominent research universities who consulted for these emerging enterprises operated as institutional founders and venture catalysts. This empirical reality necessitated a re-conceptualization of academic labor, leading to the formulation of the concepts of entrepreneurial scientists and the entrepreneurial university as decisive catalysts in the evolution of the forces of production (Etzkowitz, 1983, 2008).

This line of inquiry built upon early critiques of technological determinism and radical proposals for social restructuring. Long before contemporary discourses around social enterprise and academic impact gained institutional currency, earlier sociological paradigms advocated for direct academic involvement in community-level social interventions, establishing community-based daycare enterprises and local development infrastructures (Etzkowitz & Schafflander, 1968).

In contrast to traditional vertical models, where the state hierarchically commands both high-

er education and enterprise, the Triple Helix framework emphasizes the university as a generative, equal peer. In knowledge-based societies, universities serve as primary incubators not only of novel technical artifacts, but of novel organizational relationships and regional innovation ecosystems.

4. PUBLIC SOCIOLOGY, CORPORATE IMPUNITY, AND THE SILICON VALLEY REALITY

The intersection of institutional power, urban development, and corporate disregard for environmental integrity necessitates a renewed commitment to public and activist sociology (Burawoy, 2005). Empirical sociological methods, when integrated into community struggles, provide rigorous tools for civic resistance.

4.1. INTERGENERATIONAL COHABITATION AND INSTITUTIONAL DISPLACEMENT

When Stanford University acquired the Oak Creek residential complex in Palo Alto with the intention of displacing long-term senior residents to prioritize university affiliates, sociological methodology provided a direct mechanism for collective mobilization. Drawing upon the classic focused interview protocols developed by Robert K. Merton (Merton et al., 1956; Merton & Kendall, 1946), we organized structured focus groups composed of undergraduate students, postdoctoral researchers, senior citizens, corporate employees, and municipal representatives.

Testimonies from residents—including former students of pioneering sociologist Mirra Komarovsky—underscored the crucial cognitive and social value of intergenerational cohabitation. By mobilizing empirical sociological data and sustained civic petitioning, the resident community successfully negotiated binding concessions with university administration, thereby preserving vital multi-generational urban spaces against institutional displacement.

4.2. CORPORATE POLLUTION, MUNICIPAL COMPLICITY, AND ENVIRONMENTAL LITIGATION

Civic engagement within local government structures further reveals the pervasive lack of transparency shielding advanced technology firms. A notable case occurred in the Stanford Research Park, where Tesla's corporate headquarters discharged an estimated 950 gallons of hazardous sodium hydroxide directly into Matadero Creek (Fig. 2). Municipal oversight entities and local environmental protection departments initially concealed the incident, dismissing public concern regarding visible toxic runoff.

In response, grassroots organizing through civic groups such as Neighbors for Environmental and Social Justice initiated substantial legal action against corporate officers and the municipal apparatus. This litigation exposed the systematic tactics utilized by high-technology conglomerates to evade legal accountability, ranging from corporate shell structures to obfuscated physical addresses designed to thwart process servers. Far from being neutral drivers of progress, concentrated high-technology corporations frequently operate with near-total disregard for local ecological systems.

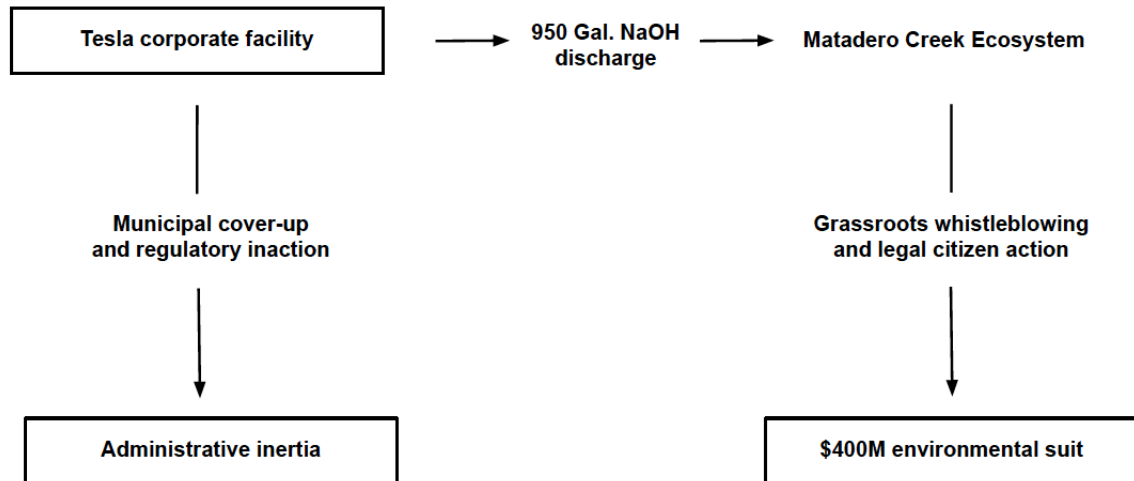


Fig. 2. The Stanford Research Park case

Within this broader socio-technical landscape, modern hype surrounding artificial intelligence functions primarily as an ideological apparatus. Generative AI and automated decision architectures serve to legitimize the hyper-concentration of economic capital and political leverage within a narrow Silicon Valley managerial elite, obfuscating underlying labor displacement and resource extraction.

5. THE SCIENTIFIC-TECHNOLOGICAL REVOLUTION AND GEOPOLITICAL REALIGNMENTS

To contextualize the trajectory of modern socio-technical regimes, contemporary scholarship must revisit analytical frameworks developed during the late Cold War. While Western sociology celebrated Daniel Bell's thesis of the post-industrial service economy (Bell, 1976), Central and Eastern European scholars developed the paradigm of the Scientific-Technological Revolution (STR) (Richta, 1969/2018).

The STR framework correctly posited that scientific research was becoming an immediate, direct force of production, necessitating an integrated institutional nexus between research academies, specialized polytechnics, and industrial manufacturing plants. Following the dissolution of the Soviet bloc, the abandonment of STR theory left many post-socialist science policy establishments devoid of a macro-sociological framework, reducing science policy discourse to a disjointed accounting of research expenditures.

During collaborative projects in the 1990s and 2000s with Russian academic centers—particularly institutions in Tomsk with historical roots in Soviet aerospace and satellite infrastructure—the Triple Helix model was actively adopted to facilitate the conversion of military-technological assets toward civilian innovation ecosystems. However, the subsequent re-militarization of state governance systematically terminated these civilianization programs. Academic leaders who sought to preserve open, university-centered research ecosystems were displaced to peripheral administrative posts, and computational competencies were redirect-

ed back into the military-industrial apparatus—an institutional pivot that directly foreshadowed subsequent geopolitical aggression.

This historical trajectory illuminates a profound paradox within the United States. While American ideological orthodoxies celebrate free-market venture dynamics, Silicon Valley itself has always functioned as a deeply subsidized Triple Helix construct, relying extensively on federal defense procurement, state-funded basic research, and top-tier university research infrastructure (Block & Keller, 2016). The persistent refusal of American political culture to explicitly acknowledge the state's foundational role prevents the establishment of transparent, democratic oversight of technological development.

6. CONCLUSION: THE IMPERATIVE OF HORIZONTAL GOVERNANCE

A comprehensive sociological appraisal of contemporary technology policy requires moving beyond conventional, vertical state-to-enterprise command structures (Fig. 3). When technological governance is organized purely vertically, scientific production is invariably subjugated either to authoritarian state interests or to unchecked corporate consolidation.

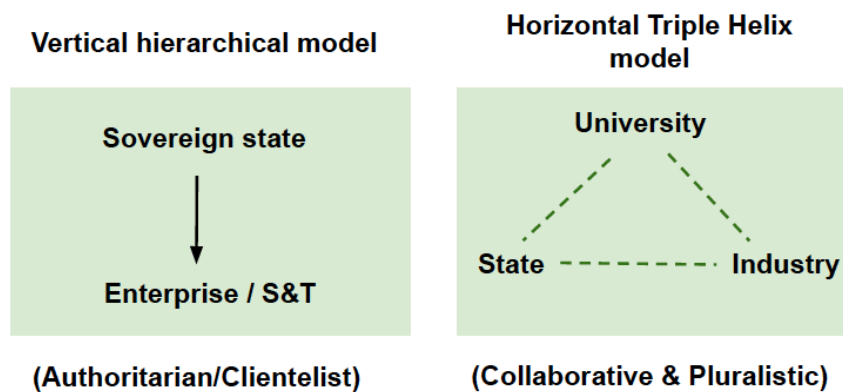


Fig. 3. Vertical versus horizontal model

As demonstrated by democratic near-crises across both North and South America, the defense of democratic institutions relies upon diversified, resilient, and autonomous centers of institutional power. Genuine socio-technical transformation—whether in the realization of non-polluting photovoltaic technologies, the regulation of generative algorithmic systems, or the defense of local ecological and community habitats—demands robust horizontal relationships across universities, civil society, industry, and the public sector. Only through such pluralistic, collaborative governance can the forces of production be directed toward equitable, ecologically sustainable, and democratic ends.

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