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# "It's kind of just another factory:" A political ecology of solar panel manufacturing in Perrysburg, Ohio

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## Abstract

Political ecology has been slow to examine solar panel factories, even though manufacturing lower-carbon technologies sits at the crossroads of climate change mitigation and global markets. Influenced by environmental and energy justice, this article takes a political ecology approach to explore First Solar's manufacturing facilities in Perrysburg, Ohio. Employing participant observation, document analysis, semi-structured and informal interviewing, and focus groups, this article investigates solar panel production's local impact. Besides offering a background to First Solar's industrial development, this article has revealed the general community outlook, labor issues and negative impacts related to First Solar factory expansions. This entailed a largely indifferent, 'passively positive' and uninformed public. Solar panel manufacturing sat alongside automobile manufacturing, numerous corporate retail distribution hubs and, to many residents, was "just another factory." This, however, did not take away from people's appreciation of employment and investment in the community.

***Keywords:*** Solar energy, political ecology, decarbonization, solar photovoltaics, renewable energy, industrial strategy, manufacturing

## Résumé

L'écologie politique a été lente à examiner l'industrie de fabrication des panneaux solaires, malgré le fait que la production de technologies à faible teneur en carbone se situe à l'intersection de l'atténuation du changement climatique et des marchés mondiaux. Influencé par les approches de justice environnementale et énergétique, cet article adopte une perspective d'écologie politique pour analyser l'usine de fabrication de First Solar à Perrysburg, dans l'Ohio. Grâce à des méthodes telles que l'observation participante, l'analyse documentaire, les entretiens semi-structurés et informels, et les groupes de discussion, l'impact local de la production de panneaux solaires est étudié. Outre la mise en contexte du développement industriel de First Solar, l'étude révèle les perceptions générales de la communauté, les problèmes de main-d'œuvre et les impacts négatifs associés à l'expansion de l'usine. La communauté était largement indifférente, « passivement positive » et mal informée. La fabrication de panneaux solaires était perçue comme faisant partie du paysage industriel local, partageant l'espace avec l'industrie automobile et les centres de distribution de détail, et était considérée par de nombreux habitants comme « une usine comme les autres ». Cependant, cette perception n'a pas diminué la reconnaissance des avantages économiques que l'usine apporte en termes d'emploi et d'investissement communautaire.

**Mots clés:** énergie solaire, écologie politique, décarbonisation, énergie solaire photovoltaïque, énergies renouvelables, stratégie industrielle, la fabrication

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## Resumen

La ecología política ha tardado en examinar la industria de fabricación de paneles solares, a pesar de que la producción de tecnologías de bajas emisiones de carbono se sitúa en la intersección entre la mitigación del cambio climático y los mercados globales. Influenciado por los enfoques de justicia ambiental y energética, este artículo adopta una perspectiva de ecología política para analizar las instalaciones de fabricación de *First Solar* en Perrysburg, Ohio. A través de métodos como la observación participante, el análisis documental, entrevistas semiestructuradas e informales, y grupos de discusión, se investiga el impacto local de la producción de paneles solares. Además de contextualizar el desarrollo industrial de *First Solar*, el estudio revela percepciones comunitarias generales, problemas laborales e impactos negativos asociados con la expansión de la fábrica. La comunidad se mostró mayormente indiferente, con una actitud "pasivamente positiva" y desinformada. La fabricación de paneles solares fue percibida como parte del paisaje industrial local, compartiendo espacio con la industria automotriz y centros de distribución minorista, siendo considerada por muchos residentes simplemente como "una fábrica más". Sin embargo, esta percepción no disminuyó el reconocimiento de los beneficios económicos que la planta aporta en términos de empleo e inversión comunitaria.

***Palabras clave***: Energía solar, ecología política, descarbonización, energía solar fotovoltaica, energías renovables, estrategia industrial, fabricación

## 1. Introduction

The 'triple planetary crisis'—climate change, biodiversity loss and pollution—remains a worsening issue (UNEP, 2024). Lower-carbon technologies, with an emphasis on solar energy generation, are frequently positioned as a solution to this planetary crisis. *The Economist*'s (2024) recent special issue, titled "Dawn of the Solar Age," celebrates the technological and economic success of solar panels. "To call solar power's rise exponential is not hyperbole, but a statement of fact. Installed solar capacity doubles roughly every three years, and so grows ten-fold each decade," the editorial introduction explains (p. 11). "Buying and installing solar panels is currently the largest single category of investment in electricity generation," exclaims the issues' Research Essay (The Economist, 2024, p. 45). This enthusiasm, however, deserves critical consideration given that materials and industrial technologies are symbiotic, mutually reinforcing and retain socioecological costs.

Grounded in political ecology research design and conceptual approach, this article explores solar panel manufacturing at one of the largest sites in the United States in northwest Ohio. Located on the outskirts of Toledo, the First Solar factory complex, and neighboring subcontractors, are scattered across Perrysburg (Figure 1), Wood County and the wider region across the Michigan and Indiana border. This research emerges within a larger project investigating solar panel lifecycles (e.g. mining, operation & decommissioning), which, in this case, applies a political ecology and energy justice approach to understanding solar panel manufacturing.

Political ecology, as it intersects with environmental and energy justice (Menton *et al*., 2020; Sovacool, 2021), offers the leading studies exploring the complicated entanglements and under-acknowledged concerns related to lower-carbon infrastructures: hydrological (Finley-Brook & Thomas, 2010; Atkins & Hope, 2021; Post, 2023; Käkönen & Nygren, 2023), wind (Zografos & Martínez-Alier, 2009; Avila, 2018; Franquesa, 2018; Dunlap, 2019a; Siamanta, 2021; Ulloa, 2023), and solar energy extraction (Mulvaney, 2019; Siamanta, 2017; Stock, 2022, 2023; Hu, 2023; Dunlap *et al*., 2024a). In this tradition, we ask: *What are the realities, concerns and issues surrounding US solar panel manufacturing?* Based on fieldwork conducted between March and May, 2024, the article presents insights based on participant observation, semi-structured interviews, informal interviews, focus groups and secondary research material (e.g. academic articles, promotional material, newspaper articles). This includes tours of the original research and development (R&D) wing of First Solar and conducting observations of the area via airplane to gain another vantage point on the regional manufacturing complex and deployment of solar panels in the area.

While political ecology and environmental justice studies excel in examining the conflicts and contestations related to lower-carbon infrastructures (Menton *et al*., 2020; Temper *et al*., 2020; Sovacool, 2021), which includes advocating for (decolonial) 'degrowth' policies aimed at reducing material and energy use (Paulson, 2017; Nirmal & Rocheleau, 2019; Dunlap & Laratte, 2022). Political ecology, as Barca and Bridge (2015), Huber (2017) and J. P. Newell and colleagues (2017) remind us, have overlooked the normalized

functions of factories and industrial plants compared to environmental conflict research (see also Müller, 2004; Broto, 2013). Since the 'political' in political ecology is "largely defined by conflicts and struggles," explains Matthew Huber (2017, p. 156), the 'political' immersed within factories—with their various labor conditions, forms of discrimination, ecological and economic issues—have implicitly been 'washed' away by a lack of conflict, normative acceptance and, together, hegemony. "By making visible the hidden ecological entanglements of industrial ecologies," Huber (2017, p. 156) continues, "the goal is not to follow what is already politicized but to politicize the hidden ecologies of industrial manufacturing situated in between extraction and final consumption." While more recent works in political ecology have explored factories and power plants (Pickren, 2019; Jackson, 2020; Nolan *et al*., 2020), this article contributes to expanding the political ecology of industrial production by examining photovoltaic (PV) solar panel manufacturing.

The combination of global climate change mitigation policy, company efforts at decarbonization and investments into lower-carbon infrastructures makes solar manufacturing an important site of research and reflection. The article proceeds by briefly discussing the research design employed, a mixed-methods approach consisting of expert interviews, community interviews, focus groups and document analysis. The following section provides a background on First Solar, and solar panel manufacturing within the United States. This is followed by discussing the literature on the political ecology of manufacturing and lower-carbon infrastructures, specifically around ideas of environmental and energy justice, which precedes the main research findings organized by emergent themes. This leads to a conclusion reflecting on the findings alongside highlighting structural political and economic issues, but also discussing the recommendations from research participants and general observations.


Figure 1: Toledo and Perrysburg in relation to Ohio. Source: Mr. Matté via Wikimedia Commons

## 2. Research design

The project employed participant observation, organized three focus groups and conducted semi-structured and informal interviews. Interviews and correspondence with research participants were largely collected between March and May, 2024, collecting 28 semi-structured interviews with 31 different research respondents (R). Additionally, we also draw on an interview from a previous site in California, related to interviews on solar energy facilities. Semi-structured interviews employed a "snowball," first by drawing on our research network

previous to living in Perrysburg and, then, by organizing focus groups in the public libraries. This combined with talking to local businesses and public institutions. This included frequenting local establishments and finding contacts, but also going door-to-door to speak to people about "what they think about solar panel manufacturing" or "solar panel factories in the area." Following general questions, our concerns were rooted in environmental and energy justice concerns and would focus on the public participation, information sharing, and levels of community input into the development of "solar panel factories." The research questions also asked about any oppositional dynamics, if they existed, as well the "positive" and "negative" aspects of solar panel manufacturing on people, but also the wider environment.

This door-to-door interviewing resulted in semi-structured recorded interviews or informal interviews depending on the level of consent, comfort and interest by research participants. With the exception of interviewing First Solar's public relations representative online, all interviews were with people in the wider Toledo, Ohio, area. The door-to-door and proactive 'snow ball' approach resulted 31 research respondents (R), which entailed 16 men, and 15 women. The semi-structured interviews can be categorized generally as two types of residents. First, in the general area (7)[2] or, secondly, located near or next to First Solar's R&D factory expansion (18). The remainder of people interviewed were ex-employees (3) and civil servants (1). Despite repeated attempts, civil servants in Perrysburg and Wood County townships made themselves unavailable for interviews, meanwhile police and emergency response personnel were interviewed informally.

In addition to conducting the research interviews, we organized three public focus groups (FG) to solicit input from general members of the public. Advertised by posters, fliers and Facebook in the areas, the focus groups occurred in April-May 2024 at Perrysburg (2 respondents), Maumee (2 respondents) and Rossford (5 respondents) public libraries. Our focus group question guide mimicked that of the interview guide. Participant observation and interviews were complemented with secondary research—books, articles, newspapers, blogs, public relations material, state and federal documents. Information was triangulated by drawing on secondary research material, verifying statements with intermediaries and follow-up interviews with various actors. Even if open conflicts remain non-existent, we lean towards preserving research participant confidentiality by changing names or using vague descriptions within the article.

Contrary to Heard (2014) taking issue with Mulvaney (2014a), we found gaining access to First Solar was difficult, and it was by chance and at the 'good will' of a department director within the company that a tour was organized in their original R&D facility.[3] This difficulty of access led us to organize a small Cessna flight to observe First Solar facilities, and related manufacturing factories (e.g. NSG Glass) and general solar panel deployment and use in the area. Aerial observation allowed us to gain a different vantage point to observe the factory size and layout; infrastructural connections (e.g. rail, pipelines, powerlines); and the quantity (or nonexistence) of solar panels on First Solar buildings, neighboring factories and the houses in the Toledo area. A First Solar representative[4] expressed concern over researching First Solar and not Chinese solar companies, concerned that this research will not reveal the claims of "industry best practice" by comparison with Chinese solar companies. The choice to research First Solar relates to institutional positionality (being located in the USA); grant funding criteria; and the desire to advance energy justice within the borders of the US. While we recognize that solar panel manufacturing stretches beyond a single company, let alone this industrial sector, and is deeply intertwined with global political economy, this, we contend, should not serve to justify, ignore or underestimate environmental and energy injustices in the US.

## 3. Political ecology and the factories

*The Economist* (2024) special issue mentioned above reviews the technological, extractive and financial success of solar panels. The modernist facts presented in *The Economist* combines with academic enthusiasm for "sustainable energy," "energy transition" and "solidaric solarities" to mitigate anthropogenic climate change (Knuth, *et al*., 2022; Sareen, 2020; Sareen *et al*., 2023). This enthusiasm for lower-carbon infrastructures even

[2] Many of these residents had friends or family members who were or are working at First Solar.

[3] We remain grateful for this director's efforts and can only hope the research presentation and findings will not disappoint.

[4] R31, 05-09-2024.

extends to juxtaposing it to 'fossil capital' (Malm, 2015) and viewing "renewable energy" as the next 'stage' within industrial development (Huber, 2022). [5] Lower-carbon infrastructures are frequently positioned as a 'planetary hope' and solution to the 'triple planetary crisis' mentioned above.

This enthusiasm, moreover, manifests in Green New Deal (GND) polices designed to advance the rapid expansion of lower-carbon technologies (e.g. wind, solar, hydrological, biomass, hydrogen); the rolling out of digitalization and 'smart' technologies across countries; energy grid reinforcement; the spread of high-voltage powerlines (HVPLs) across continents; and electrifying the transportation sector with electric vehicles (EVs), bikes and scooters (see Dunlap & Laratte, 2022; Andreucci *et al*., 2023; Tunn *et al*., 2024). These infrastructures and objects have and, to a degree, continue to be uncritically embraced by researchers in energy studies as the two overlap with geography and political ecology.[6] While GNDs and related policy pathways invite useful reforms to agriculture, they wrongly juxtapose hydrocarbon and lower-carbon industries against each other (McCarthy, 2015; Dunlap, 2019a, 2021; Lennon, 2021; Dunlap & Laratte, 2022; Vela-Almeida *et al*., 2023; Andreucci *et al*., 2023; Hanaček *et al*., 2024; Deberdt & Le Billion, 2024; Fressoz, 2024). The fossil fuel versus renewable energy dichotomy aside (Dunlap, 2021, 2018; Lennon, 2021; Fressoz, 2024), political ecology is revealing a plethora of concerns with lower-carbon energy extraction technologies, solar extraction among them.

On closer inspection, the socioecological impacts of solar energy development are more extensive than the average person may normally imagine, particularly when recognizing "the entanglement and symbiotic expansion of all energies:" especially wood, coal, oil and nuclear (Dunlap, 2018, 2021; Lennon, 2021; Fressoz, 2024, p. 9). Solar extraction can perpetuate unequal harms and benefits within communities (Temper *et al*., 2020; Siamanta, 2021; Avila *et al*., 2022; Stock, 2021; Stock *et al*., 2024), which also includes financial speculation (Siamanta, 2017; McCarthy & Thatcher, 2019; Knuth *et al*., 2022), 'grabbing' large amounts of land (Rignall, 2016; Siamanta, 2017; Mulvaney, 2017; Batel & Devine-Wright, 2017; Mulvaney, 2017; Dunlap, 2019; Stock & Birkenholtz, 2019; Allan *et al*., 2022), causing significant ecological damage (Mulvaney, 2019; Stock *et al*., 2023; Tornel, 2023; Dunlap *et al*., 2024a) and disproportionate impacts amongst farmers and Indigenous groups (Dunlap & Jakobsen, 2020; Stock, 2021, 2022). Astrid Ulloa (2023, p. 4), moreover, shows how wind energy public relations material facilitates an "aesthetics of dispossession," which encourages "the making of landscapes to fit specific visions of the future based on 'green spectacle'." Political ecology research, overall, remains essential to foregrounding future socioecological challenges associated with solar energy development.

This extends, often masked by the "renewable energy/fossil fuel" dichotomy (Dunlap, 2021, 2018; Lennon, 2021), to issues of mining, waste disposal and manufacturing (Sovacool *et al*., 2020; Dunlap, 2021, 2023; Stock & Ptak, 2024; Sovacool & Stock, 2024). This extends to 'secondary' infrastructures, such as high voltage power lines (HVPL) (Batel & Devin-Wright, 2017; Neukirch, 2020; Dunlap & Laratte, 2022) and transformer infrastructures (Dunlap, 2020b). The process of acquiring copper for panels (Dunlap, 2019b, 2023), steels for solar panel frames (Normann, 2022; Leeuw & Vogl, 2024), sand to produce glass panels (Lamb & Fung, 2022; Stock & Ptak, 2024), minerals for new battery storage technologies (Archer & Calvão, 2024) and other material and energy intensive components necessary for solar panels (Svobodova *et al*., 2022; Mulvaney, 2024). Even Sareen, along with Stock, are now acknowledging the harms, or 'injustices,' taking place within the mining, manufacturing, operation and decommissioning phases (Stock & Sareen, 2024). Overall, there is, thinking of Huber (2017), a glaring lack of research into solar panel production.

Even with increasing interest in "political-industrial ecology" (J.P. Newell *et al*., 2017), there remains an enormous research gap in supply-webs of "green industrialization" in general and solar panel manufacturing in particular (Brock *et al*., 2021). The rapid production and proliferation of, and profiteering from solar panels, not to forget their positioning as a climate change mitigation and decarbonization technology, makes research

[5] See criticism, and rejection, of Malm, Mitchell and others historical works that deploy defunct energy dichotomies in Jean-Baptiste Fressoz (2024).

[6] This is concerning, as one European Commission representative (with agreement from a national ministry representative), recently acknowledges, referring to the so-called green energy transition, "We know it is not going to work, but we can't admit it," then referring to market interests and a lack of a viable alternative to present to the public.

into 'green' industrialization, 'lower-carbon' or, at the least, the *non-hydrocarbon centric industry* a timely and urgent research focus (see Fressoz, 2024). In this sense, Dustin Mulvaney's (2014a, 2019) work is invaluable, performing a multi-sited ethnography in "[o]ver a dozen PV manufacturing facilities" in Germany, Japan and the US. This included extensive interviews with multiple actors within and outside solar panel factories and, thus, revealing the challenges of doing research on solar panel factories—"PV manufacturing facilities contain highly guarded trade secrets," such as CadTel formulas[7]—along with the socioecological hazards associated with the industry. These secerts are often guarded by (manipulative) limitations of Life-Cycle Assessments (LCAs) and, at the same time, stressing the importance of solar energy development (Mulvaney, 2014a, p. 180; Fressoz, 2024). This research generated a haphazard debate with First Solar (Heard, 2014a), where Mulvaney (2014b) added clarification and defended his critical concerns. While differing in scale, scope and approach, our research builds on Mulvaney's (2014, 2019) work and provides specific insights into the realities and concerns surrounding solar panel manufacturing inside and outside the factory.

Another significant work on solar panel factories was published by Andrea Brock and colleagues (2021, p. 1757) who uncovered "the increasingly invisible and dispersed impacts of green industrialization." Brock and colleagues (2021, p. 1757) explore the aftermath of the German solar industry when it "collapsed due to global competitive pressures" in the Bitterfeld region, Germany. Similar to research participants in Perrysburg area who relate to First Solar's manufacturing complex as "just another factory"[8] or "just another business,"[9] Brock and colleagues (2021, p. 1758) remind us that "solar energy becomes just another global commodity, just another node in a network of global factories and logistic networks contributing to… waste steams, global recycling networks, and systems of resource recovery." While First Solar (2023a) positions themselves as having the "best practices" in matters of social and environmental governance, Brock and colleagues (2021, p. 1172) demonstrate "that 'green' industrial development is by no means automatically social and just—or sustainable." The German solar industrial collapse, however, they recognize played into Chinese solar panel manufacturers who "are now refusing to provide any information about their manufacturing practices at all" (Brock *et al*., 2021, p. 1173). Considering the competition between First Solar and Chinese solar panel manufacturers, this might be the stakes facing First Solar and solar panel manufacturing standards.

Finally, Sovacool and Stock (2024, p. 2) recognize "an unfortunate lacuna in the literature that critically examines national solar transition studies from a justice and equity perspective at each node of the solar PV value chain." While their study explores injustice and equity issues in mining, manufacturing, construction, operation and decommissioning for solar panels in India, Sovacool and Stock (2024) demonstrate the challenges and limitations of supply-chain research, encouraging greater investigation of each node of the symbiotic and mutually reinforcing sectors of solar panel production. "There were significant limitations in our team's ability to collect data at this [manufacturing] node of the solar value chain," (2024, 4), which was related to "issues of privacy and security." The work of Mulvaney (2014a, 2014b, 2019, 2024), Brock and colleagues (2021) and Sovacool and Stock (2024) remain essential in developing a political ecology of solar manufacturing, to which the remainder of this article contributes.

## 4. Background: Welcome to the 'Glass City,' Toledo, Ohio, and its surroundings

The 1973 'Oil Crisis' renewed interest in solar, wind and other lower-carbon infrastructures. "Energy transition," as a term, has emerged to replace notions of oil and 'energy crisis' (Bonneuil & Fressoz, 2016), which triggered public investment into developing lower-carbon infrastructures across the world (García & Wiegink, 2024; Riquito, 2023; Fressoz, 2024). First Solar (FS, 2023a) is a company that emerged from this investment, continuing into the present, but it is the only US top-ten global solar company. Its origins were the inventor Harold McMaster's Glasstech, Inc, which began in a former ketchup factory in east Toledo that, according to First Solar documentarian Jeffery L. Rodengen (2018, p. 28), "would ultimately produce the

[7] Cadmium telluride photovoltaics use cadmium telluride in thin semiconductor layers to absorb and convert sunlight into electricity. Cadmium is a toxic heavy metal held in the layers, and tellurium is a scarce mineral. Polysilicon panels are the other major type of solar panel.

[8] R08, April 25, 2024.

[9] R11,April 25, 2024.

strongest and clearest glass in the world." Toledo, Ohio, is known as "The Glass City" for producing the majority of the glass used in the United States. By Rodengen's (2018, p. 28) estimates, "Glasstech's furnaces manufactured about 80% of the auto glass and half of all the architectural glass in the world, revolutionizing the industry." Alongside federal government spending in the late 1970s and early 1980s, McMaster, an avid inventor and entrepreneur, set his sights on getting into the solar industry and formed Glasstech Solar in 1984 and, shortly after, Solar Cells Incorporated to sell photovoltaic (PV) systems (Rodengen, 2018). Like much of the solar industry, then as now, Glasstech began with selling amorphous silicon semiconductors. This, however, would quickly change.

While working on amorphous silicon PV panels, there were intense debates within Solar Cells concerning the development of silicone-based panels or cadmium telluride (CadTel) panels (Rodengen, 2018). Spurred by concerns related to market competitiveness and solar energy absorption efficiency, in 1991, the debates finally gave way in favor of CadTel with a US$2 million Solar Cells trial project (Rodengen, 2018). CadTel PV is now celebrated as "a uniquely American solar technology, first developed in R&D labs in Ohio and California," explains the First Solar *Sustainability Report* (2023b, p. 14). "CadTel PV technology demonstrated a number of qualities," explains the report, "including a lower manufacturing cost profile, superior scalability and a higher theoretical efficiency limit" (FS, 2023b, p. 14).

CadTel solar panel development was innovative, not only in terms of the size, quality and quantity of solar panels, but in the ability to manufacture and mass-produce them economically and in line with the market (with or without government subsidies). By 1994, Solar Cells was a highly ranked industry competitor, which would only advance with new efficiency rates, cutting manufacturing times, "patient shareholders" and "patient capital" (Rodengen, 2018, p. 77). Through True North Partners, LLC, John Walton, a son of Wal-Marts' Sam Walton, became an investor in 1999, which resulted in buying a 50% share in Solar Cells for $45 million and quickly afterwards in 2000 the company was renamed First Solar. First Solar was born, with large-scale investment and the upscaling of manufacturing operations that would expand internationally.

Despite initial expansion and production challenges, it was Germany's Renewable Energy Sources Act that guaranteed a fixed payment per kilowatt-hour and "feed-in-tariff" system they proved essential for developing an international solar market (Rodengen, 2018, p. 69). The opening of an international market with Germany and, later, silicon shortages (impacting competing solar technologies) allowed the expansion and profitable success of First Solar. In May 2008, First Solar achieved record share prices of US$317, and company profits reached US$104.3 million in the first quarter, up from an earlier US$30 million (Rodengen, 2018). Also that year, First Solar broke the $1 per watt price barrier for solar modules, which, at the time, was a record-breaking achievement.

This record success, however, rebalanced with solar panel oversupply later that year, according to Carol Campbell, former executive vice president of human resources at First Solar:

> When the Chinese entered the polysilicon [market in] full force, they got the cost down because polysilicon was expensive, and then they were able to manufacture their modules at a better efficiency at the same or a lower price, and, of course, they were losing money, but they didn't care (in Rodengen, 2018, p. 103).

A truck driver transporting solar panels from the Port of Los Angeles to Arizona solar projects in the southwest US remembers: "there were shit tons" of Chinese polysilicon panels and that they are "heavy."[10] China's lower-cost polysilicon panels are still in the market today. US President Joe Biden, betraying forty-years of "free market" and "Washington Consensus" policies (Klein, 2006; Springer *et al.*, 2016), " decided to raise the tariff rates it applies to solar cells imported from China to between 25% and 50%" (Bellini, 2024). This global manufacturing competition allows First Solar to juxtapose Chinese polysilicon panels with their own CadTel PV panels.

[10] Interview (from another set) 1.28, Blythe, California, 29-11-2023.

Without explicit reference to the mining companies involved, First Solar (2023b, p. 14) explains that their "semiconductor material is sourced from byproducts of the zinc and copper industries, providing a sustainable use for materials that would otherwise be disposed of." Cadmium is a byproduct of zinc mining, while tellurium is a (scarce) byproduct of copper mining. Rio Tinto began producing the latter at its Kennecott division in Utah in 2022 and has been selling to First Solar (Dunlap *et al*. forthcoming; Rhys, 2023a). Whether in interviews or reports,[11] First Solar positions their CadTel as responsible manufacturing, versus Chinese polysilicon energy intensive and irresponsible manufacturing:

> First Solar has a global set of specifications for the materials used in our products which results in a tightly controlled supply chain, superior traceability and quality products. We also own and operate the facilities which manufacture our modules turning a sheet of glass into a completed module all under one roof. In contrast, many traditional tier one crystalline silicon PV manufacturers have multiple products, processes and bill of materials with a sprawling supply chain, which includes multiple process steps (polysilicon/ingots/wafers/cells/modules) often across multiple continents, resulting in increased risks relating to variability, quality, reliability and traceability. (FS, 2023b, p. 40)

CadTel PV, First Solar (2023b, p. 14) explains, is advantageous to other (silicon based) panels because they offer "[h]igher lifetime energy yield;" "[s]upply chain and energy security advantages;" and maintain a "[s]uperior environmental profile." This entails, according to the First Solar's (FS, 2023b, p. 14) *Sustainability Report,* a 4% increase in panel lifespan in all climates; a vertically integrated manufacturing process that breaks dependency on Chinese materials; and higher-quality labor standards. The company has the "lowest carbon and water footprint, fastest energy payback time" and, as mentioned, the panels are "designed for high-value recycling and closed loop semiconductor recovery." The new Series 7 CadTel PV modules, First Solar (2023, p. 4, 12-13) explains, have "as much as 16% recycled content" and 90% recycling recovery rates (FS, 2023b, p. 4, 12-13). Manufacturing responsibility is further established through corporate responsibility. First Solar (2023, p. 15) reminds readers that "all PV technologies are not created equal," stressing that they manufacture "PV modules with the lowest environmental footprint in the industry" and continue to be committed "to reducing our operational impact." Complying with Environmental, Social, Governance (ESG) standards, First Solar joined the Responsible Business Alliance (RBA) in 2021, applying Validated Audit Processing (VAP). First Solar (2023b) has received the highest rankings from "third-party" auditors with one exception in their Malaysian factory (Reuters, 2023), where they self-reported forced and captive labor conditions.

As of December 31, 2023, explains First Solar (FS, 2023a), "we had approximately 6,700 associates (our term for full and part-time employees), the majority of which work in the United States, Malaysia, Vietnam, and India." Expanding its operations globally, First Solar recently inaugurated 3.3 GW Manufacturing Facility in India (FS, 2024b), two R&D facilities in Perrysburg totaling approximately 1.3 million square feet (120,774 $m^2$, Roger, 2022; see Figures 2 & 3) and has acquired a distribution center in Wood County in Ohio (Ojea, 2024). There are also new factory expansions in Alabama and Louisiana (FS, 2023a). Receiving billions of dollars under the Obama administration, First Solar executives and lobbyists met repeatedly with the Biden administration in between 2022-2023, extending to a working relationship with John Podesta, the Senior Advisor to Biden's Clean Energy Innovation and Implementation and chair of the National Climate Task Force (PBS, 2024). They benefited from US President Biden's Inflation Reduction Act (IRA). First Solar, according to the Public Broadcasting Service (PBS, 2024), has emerged as "perhaps the biggest beneficiary from the US$1 trillion in environmental spending" and has witnessed a doubling of their stock prices.

[11] First Solar Tour & R31, May 9, 2024.

Figure 2: First Solar assembly, recycling and R&D expansions in Perrysburg, Ohio, 2024.
Source: Authors

First Solar currently specializes in the design, manufacturing and marketing of utility-scale photovoltaic solar modules. The recent net sales of PV panels are distributed geographically as follows: the United States (96%), France (2.1%), Japan (0.2%), and other (1.7%) (MS, 2024). The annual manufacturing capacity, according to First Solar (2023b, p. 11), "has grown from 15 megawatts (MW) in 2002 to 9.8 gigawatts (GW) as of December 31, 2022." The company, with the support of the IRA, has committed to over US$2.8 billion in capital investment and 7.9 GW of additional manufacturing capacity in the US (FS, 2023a, p. 11).

First Solar (US:FSLR), according to Financial Intelligence (FinTel, 2024), has 1,477 institutional owners and shareholders registered with the Securities Exchange Commission (SEC). This includes the Vanguard Group Inc. (11.3%), BlackRock Inc. (11.8%),[12] State Street Corp (4.5%), Fidelity Management & Research Co. LLC (3.69%), Wellington Management Co. LLP (2.91%), Capital Research & Management Co. (2.75%), BNP Paribas Asset Management Europe SAS (2.61%), Geode Capital Management LLC (2.34%), Jane Street Group, Llc (0.29%) and Farhad "Fred" Ebrahimi owns 5.1% alongside the remaining company shareholders (FinTel, 2024; MS, 2024). "We ended 2023," explains The Annual Report (FS, 2023a, p. 3), "with a gross cash balance of US$2.1 billion, compared to US$2.6 billion at the end of the prior year." This profit decline, the Report (FS, 2023a, p. 3) continues, was "offset by capital expenditures related to manufacturing capacity expansions in Alabama, Ohio, Louisiana, and India." Solar panel manufacturing is positioned as environmental and climate action, establishing First Solar as the leading US solar panel manufacturer and an essential national asset in matters of 'green' industrial development and international competition.

[12] BlackRock Advisors LLC (USA;7.190%) & BlackRock Life Ltd. (UK; 3.854%).

## 5. A political ecology of First Solar in Perrysburg

An established industry in the area since 1984, First Solar remains firmly embedded in the Toledo region and neighboring counties. Five years ago, NSG Glass, in partnership with First Solar, built a factory (fifteen-minutes away by car) in Lucky, Ohio, dedicated to producing the glass sheets for CadTel panels (Rhys, 2023b; see Figure 6 below). Likewise, approximately a 35 minute drive away just over the Michigan state line, First Solar sources its "ultra-low iron silica sand" used to produce glass (Rhys, 2023b). Steel is sourced from companies in Delta and Cleveland, Ohio (Rhys, 2023c), while copper and tellurium comes, as noted above, from the BP Kennecott mine in Utah through M5Plus specialties metal vendor (Dunlap *et al*., forthcoming; Rhys, 2023a). This speaks to First Solar's "vertically integrated supply chain" and recent US efforts started by ex- and current US President Trump, and continuing under Biden, to "onshore" mining and industry to the US. While this will allow First Solar to remain a profitable business, and provide employment, we demonstrate our major findings by discussing:

(1) The general community outlook;
(2) internal company dynamics;
(3) solar factory expansions; and
(4) general critical concerns.

These categories emerged from the field research and illustrate the different geographical experiences of the research participants.

*Community reflections on solar panel manufacturing*

Residents of the Toledo area, situated in the US 'rustbelt,' are familiar with factories. Research participants, especially away from the recent R&D factory expansion (see Figures 2 & 4), were generally positive about First Solar. The majority of people were what we would describe as "passively positive," which was followed by people not expressing an opinion (e.g. indifferent) or being "actively positive" about solar manufacturing and/or First Solar. A common response to questioning was: "I have never met anybody that works at First Solar that has said anything bad about it," explains a retail clerk.[13] Other people frequently mention friends who work there. "I actually got a friend that is a maintenance man out there," explains "Jim," "He said he likes it."[14] Overall, people saw First Solar as a positive force for the community, bringing jobs, economic development and advancing a more environmentally friendly source of energy production. "It brings good paying jobs; it is more green energy, which we need, and it is a net good for the area," explained a veteran mailman. "I don't know all their environmental impacts that their manufacturing practices have, but as far as I'm aware, it's a net good to the area."[15] A civil servant exclaimed "They're great corporate citizens, and we love having them in our community."[16]Outside the areas of factory expansion, First Solar was viewed as a largely positive force.

While residents frequently recognized jobs and economic development captured in the region, inequality was also a recurring theme. The greatest beneficiaries were understood as the company, government, "community" and workers. Community, here, is used to indicate people who live in the Toledo area and, in some instances, the suburbs surrounding Perrysburg and Toledo (see Figure 1). Residents acknowledged employment and local benefits, but laughed cynically how it was the company and government who are the greatest beneficiaries. "CEOs" benefit the most, Jim contended, continuing that "hopefully, you know, if they [First Solar] bring it [solar panels] out to the public, people can purchase from them [directly] or something at

[13] R01, April 18, 2024.
[14] R09, April 25, 2024.
[15] R07, April 25, 2024.
[16] R15, April 29, 2024.

a reduced price."[17] Living next to the new factory expansion, Jim indicates a desire to have cheaper electricity and solar panels, which has not been realized. Residents also believe the government benefits the most from solar panel factories because of "taxes," another resident contents: "there'll be an abatement to give them."[18] People who want solar panels were also understood to be among the largest beneficiaries of First Solar's operations. Thinking of an earlier time at First Solar, an ex-employee thought the greatest beneficiaries are "people overseas," referencing a time when First Solar was big in international markets (Rodengen, 2018). Overall, residents distant from the new expansion saw a general benefit from solar manufacturing, but recognized what we would describe as a "solar-trickledown effect" (Dunlap *et al*. 2024b). This effect, or solar 'Reaganomics,' indicates an uneven concentration of wealth and benefits between the production workers, the middle-upper management at First Solar and the politicians receiving taxes and/or, in the mind of residents, receiving real or imagined 'kick-backs' from the company.

There were numerous other concerns. Central was the "reshoring" of industry, government subsidies and competition with China. Grateful for First Solar, and with some friends in the industry, a local business owner "Scarecrow" explains:

> Literally, we have manufacturing here, we should be stoked [slang for happy] that we even have the opportunity because, as NAFTA [The North American Free Trade Agreement] proved, everything else [industry] can get shipped over quickly and then never come back. You're going to get passed up, you know, like even with [Chinese] televisions. It's funny because what's happening with EVs [electric vehicles] right now is that all these Asian manufacturers are building them. We made all these concessions to our lazy ass American counterparts [companies] who are like, we're not building stuff in [North] America. We're going to build it in Mexico because it's way cheaper there; and it is, but it hurt the wider public.[19]

Scarecrow acknowledged the negative domestic impacts on employment in the wider US Midwest and Toledo, emphasizing the importance of US industry, but also how US corporations are dangerously opportunistic, and China is taking advantage of this.

This concern with Chinese industry resurfaces, except this time in relation to the Inflation Reduction Act (IRA). An ex-long term First Solar employee, "Barry," acknowledged how "Hanwha Qcells, out of Korea, has a huge [panel] finishing facility in Georgia" and "since this Inflation Reduction Act came out, they went and produced an Ingot and Wafer manufacturing [site] on the front of the plant." Competing foreign companies utilizing free trade policies are now moving into the US to benefit from the IRA and, it appears, are attempting to build a "vertically integrated" solar panel manufacturing system akin to what First Solar champions. Korean and Chinese companies "were just like, wait a minute, we need this tax credit," explains Barry, describing their strategy to "get the raw material, let's make the ingots, compress the wafers, cut everything in the US" and, so now, "there are more production jobs, construction jobs." The issue they contend, "is where do all the raw material come from? It's still China." This concern of extraction and government subsidies coincides with issues of solar panel efficiency.

In matters of solar efficiency, companies are competing amongst themselves and, common to Green New Deal and IRA rhetoric, people are juxtaposing solar with the hydrocarbon industry. "First Solar was the first company to go below a dollar for a watt," Barry reminds us:

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[17] R09, April 25, 2024.
[18] R17, April 30, 2024.
[19] R11, April, 25, 2024.

> And now it's like $0.23 a watt because they were just forced by China, because they were completely supported [by the Chinese government] and they didn't care if they made money. It's just like what the people want, like 40GW of solar panels a year, you know, and First Solar went from 30GW to 20GW now. And they didn't give any market share at first. It was only 5% of the global market.[20]

Barry provides greater context to the new solar cell tariffs, seeing the IRA and other actions being taken by the US government as eroding, if not betraying, its 'free market' policies to protect US industry. This competition, at least how it is presented publicly, enters another scale. "I'm not an expert by any means, but it sounds like it's not quite as efficient as it should be, as it needs to be ready to replace fossil fuels," explains ex-First Solar employee:

> The first time solar was profitable is because of government subsidies. Yup. So, I'm not really stoked on that. Personally. I'm not a big government person. Yeah. I really think businesses should, you know, stand or fail on their own merits.[21]

Ignoring the government subsidies (past and present) that were given to the hydrocarbon industries (Fressoz, 2024), this intersection between market competition, government subsidies and ecological damage arising from "green industry" remained a sustained concern through select interviews, which are revisited below.

There were numerous residents who firmly had "no opinion." A common response when asked, "what do you think about solar panel manufacturing," people would reply: "I don't have anything against it"[22] or "I think they're [solar panel manufacturing is] probably fine. Yeah. But I don't. I don't know too much about them."[23] Another resident neighboring a new factory expansion explained: "Well, it really doesn't bother me one way or the other. I spent 43 years working in a machine shop."[24] One young participant in the Rossford focus group (FG) even stated, "solar manufacturing, what's that, making stuff in outer space?" There was a serious lack of public knowledge and interest in solar panel manufacturing.

Some people new to the area within a year or two, even working real estate next to the new factories, did not even know about the factory—" I didn't know they were over there actually," explains a young woman.[25] Another woman when asked about the environmental impacts says: "My mind's not with it; I don't know what to say."[26] One Maumee resident in a focus group complained: "As I said, they are off the radar. I can't tell you anything about First Solar's impact as they have a low profile." The resident continued by comparing them to a local quarry that has an open day, but considering First Solar's available documents online it appears—as many mentioned—few have any knowledge about First Solar's operations and they wanted more information.

The largest region-wide issue that surfaced was a lack of information and participation in the community. Whether with general or more specific information, First Solar, according to residents, could definitely improve on their local public relations to inform the public about their operations and job opportunities. This extended to sharing information and creating participation outlets for the arrival of the new factories. "So, what are you [First Solar] doing? What are the opportunities available, you know? That would help, I think, everybody [in the area]," exclaimed a resident and ex-member of the Airforce in FG 1. This was a particularly glaring issue where there had been factory expansion, discussed below, but there is also a flipside to this: people's active disinterest in solar panel manufacturing. While the person in FG 1 was a rather attentive member of the Perrysburg community, a handful of other people were actively not interested in solar panels or local

[20] R28, May 2, 2024.
[21] R10, April 25, 2024.
[22] R03, April 25, 2024.
[23] R12, April 26, 2024.
[24] R23, April 30, 2024.
[25] R06, April 25, 2024.
[26] R02. April 25, 2024.

manufacturing affairs. "I'm not interested in any of that [information]," explains a female resident.[27] Besides a general positive understanding related to employment and the potential of producing a product less destructive than fossil fuels, people were rather unaware, disinterested and, overall, related to First Solar as "just a business there as far as we're concerned."[28] The appeal of First Solar, a local agent in a neighboring estate summarizes: is "basically financial for people and obviously the county and state and whatever, but—yeah—other than that, it's kind of just another factory."[29]

*Company dynamics and the factory floor*

First Solar is among the IRA (Inflation Reduction Act) beneficiaries, which was designed, as Joe Biden said (PBS, 2024), to "save the world" from climate change and, at the same time, is a large-scale (digitalized) industrial manufacturing operation. This tension plays out, we are told, within First Solar as well. "There's the group that think they're the elite and they're changing the world, and are just a bunch of snobs," explains Barry, "[m]ost of them are based in Tempe or Houston and not really in Perrysburg." Barry continues "is all the R&D and manufacturing and then, the clan that is in Perrysburg, they don't care about changing the world. They want a job that's not in automotive" and "all the engineers are conservative." The 'Perrysburg clan' are "all hunters," "farmers" or, at the least, are related to this background. Then there are "everyone else that there [that] are on visa and visas from China or India."[30] The Perrysburg group are presented as more conservative, grounded and largely unamused by robust claims of "saving the world."

This, however, does not question the dedication and commitment to the company or to solar technology. The Toledo region is not only the 'Glass City,' but it emerges as a logistics hub and working at First Solar is frequently juxtaposed to working in auto manufacturing or Amazon warehouses. "[T]here are good paying engineering jobs over there [at First Solar] and it's not automotive," Barry explains.

> Automotive can just be cutthroat, right, because there is so much pressure to get stuff out and meet milestones. There is pressure there [at First Solar] too, but it's not like automotive. And a lot of engineers and people who work at First Solar came from automotive or something like applied materials or Intel.[31]

Recounting their friend's experience at First Solar, "She says it's really nice," remembers 'Gary,' "she can work all the hours she wants, nice people and you know, I guess it's nothing like the Amazon plant." Providing more detail to this comparison, 'Brian' worked the production line at First Solar for over two years, over 3 years ago. Talking with Brian, he remembers his 12-hour night shifts that started at 6pm/18h in the evening and ended at 6am in the morning.

> B: Everybody would get as much sleep as we could, yeah, so back up and do the same thing, but, like, it was two days on, two days off, three on three off…. I liked it for a minute, but after, like, you do that for a minute [over two years], and you don't see the sunshine that often, yeah, it's not good for your mind.
>
> AD: You're just working in a f%&king box, like, you're in a factory, you know, are there lots of windows?
>
> B: Yeah, kind of, well, not in the factory floor area, but, yeah, the break room is real nice. It had a gym, you know. *But you couldn't leave the [First Solar] campus, you know*? But we

[27] R17, April 30, 2024. Also interviews 12, 14, 15 & 16.
[28] R12, April 26, 2024.
[29] R08, April 25, 2024.
[30] R28, May 2, 2024.
[31] R28, May 2, 2024

> had it really nice. The lunch setup, you know, a lot of the time there would be somebody cooking actual, like, hot food for us and shit. In that aspect, they [First Solar] tried to make you comfortable while you're there. Like, that was cool, because, I work at Amazon now, or I used to work in the fulfillment center, but now I do delivery driving for like, the campus at Amazon and, dude, there is no comfort, like, this fucking stupid plastic tables, plastic ass-chairs, no couches nowhere. Like, you're there also for 12 hours. Like, no comfort man. (emphasis added)

The Amazon distribution center was notoriously uncomfortable. While talking with a Policewoman, explaining the dynamic between the police and First Solar, she admits: "Amazon is the biggest drain, we are dealing with more emergency responses," noting the bleak environment within the warehouse, long working hours that would lead people to freak out and fight each other. "Police go for industrial accidents and are escorted in by security [at First Solar], the officer explains, but "Amazon is a way more common occurrence."[32] First Solar, while still a factory, notably provided better working conditions for its workers in comparison to Amazon.

When visiting First Solar, we observed it looked a lot more like a "hospital" than a common conception of a 1970s "factory." While our visit was limited, from what we witnessed it was a mix between a hospital style environment, offices and numerous rooms with enormous assemblages of complex highly-digitalized and automated systems (and we were not allowed to take photos). Another retired auto manufacturer had a similar observation:

> I've been in their [First Solar] buildings and it looks like you're walking into a hospital. The floors are clean, the walls are clean. There is no asbestos hanging from the ceiling that you used to get…. it's the difference between walking into a backyard or a back road garage and walking into a hospital.[33]

The people to machine ratio was by far disproportionally—especially in terms of space—in favor of machines. This cleanliness was, among other reasons, to identify black cadmium residue. "Cadmium powder is black, but all the floors at First Solar are very light gray, you know, safety things so you can see spills and everything," explains Barry. Workers were tested for cadmium until the last couple years because it became pointless. Recounting the reason why, Barry says: "They stopped it because the only people that were popping up for cadmium were smokers. Because there is more cadmium poison in cigarettes than what's happening at First Solar."[34] By all accounts, First Solar was said to take safety seriously as one could. "Honestly, for the most part, I can't talk that much shit outside of like the actual conditions in the building, in the area where I worked," says an ex-water reclamation monitor, "Alex," "It seems like the disposal is handled above board, you know? And like, believe me, if it wasn't, I'd be the first to say it."[35]

The biggest issues emerging from interviews were the shift hours; hiring and firing practices; pay rates; contention between engineers and production line workers and employing migrant labor. As Brian explained: "But you couldn't leave the [First Solar] campus." First Solar was strict and if someone left the campus during work hours, even to get their medicine they forgot during lunch, that worker would get terminated from employment—"They fired me because I went home at lunch to go get my Adderall," says an ex-First Solar employee.[36] Brian, who recounts:

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[32] FN, April 24, 2024, Perrysburg Township parking lot.
[33] R23, April 30, 2024.
[34] May 2, 2024.
[35] R10, April 25, 2024.
[36] R10, April 25, 2024.

> …it was cool the majority of the time that I worked there, but like, this new general manager came in, and she was a b#&ch. She was trying to fire everybody. Why? I don't know, dude, but she fired like 50 people in the first month of her working there, and she couldn't wait to fire me. When I first met her, dude, like I could tell she just wanted to fire me for no reason. And the day that she did, she smiled about it. I showed up two minutes late. *I clocked in two minutes late*, and I didn't have any more time, you know, like points or whatever.

First Solar had a notoriously high employee turn-around on the factory floor (e.g. quality control, packing, shipping, water management, etc.), nobody who Brian worked with at First Solar still works there, for example. Some speculated their termination was related to negotiating a US$4 higher wage, while "you can see the layoffs. 2012. 2016. 2020. Right on four years," which, people relate to economic cycles and events (e.g. overproduction, lawsuits, CoVID19).

The high employee turnaround (in production), relates to wages. General wages in production and monitoring, depending on how you got the job (e.g. through an employment agency/program), were between US$17-21. "Yeah, they're not really providing a living wage," says the ex-water monitor, Alex. "Yeah. I mean, the wage goes up, but you're watching the cost of everything go up around you." With reference to assembly line workers getting paid US$17 an hour, the ex-employee comments: "In the economy right now you pretty much should just go flip burgers."[37] While infrequent, power outages also gave extra breaks. But people were forced to supplement their wages, often through illicit activities (e.g. drug dealing). Overall, Alex says, "it would help if they would pay people what they are worth too." This combines with repeated complaints about the shift hours. "First Solar," according to a community college employee, whose job was to help "companies to train their workforce," commented that First Solar was "pretty generous about sending their employees to school and upgrading the workforce," but "[t]hey run different shifts, though. The shifts are kind of funny." The shifts, to them, made doing part-time work and schooling difficult, as well as prevented the development of apprenticeship programs.

This dynamic on the assembly line floor, was very different in upper management. First Solar are "bringing production jobs. I don't think they're good paying jobs," explains "Jared," which he juxtaposed with management jobs. "[T]he production jobs and people are making 19 bucks an hour and, you know, they will hire you in a minute for production. But management jobs, that is the big money jobs" and these are far more inaccessible, according to Jared. A veteran with an extensive background in auto manufacturing, Jared obtained an MBA in finance, numerous certifications, and became proactive at RE+—the "Largest Clean Energy Event in North America"—alongside other efforts. But First Solar refused to hire him. Unsure whether it was his age, Jared recounts that he had written to "the head of H.R.[human resources] there [at First Solar] and they don't reply. They don't get back to me" and "every time I apply," he recounts HR telling him: "although you have an impressive resumé, we decided to go with someone else." Repeated efforts over the years left Jared perplexed. "But, you know, like I said," Jared continues, "who's getting these jobs? Are you familiar with an H-1b visa where they bring these people in?" Because of their experience delivering coffee at First Solar and seeing a lot of foreigners from India, Taiwan and elsewhere, it left a feeling that First Solar is giving the "big money jobs" to foreigners. "And it's like, you know, I don't get it, why don't they hire people from this community [for management jobs]?"

Jared's concerns are not entirely unfounded, even if different management and section directors are from the region. "It's cheaper skilled labor," Barry says without hesitation, "I mean, there are PhDs coming out of Cincinnati and, if they're Chinese or Indian, you don't have to pay the U.S. wage," it's possible to "pay them a step below [the normal wage] there or do whatever the visa allows. This relates to a recurring complaint that, in so many words, "some or all of the leadership are foreigners." While this is an exaggerated statement, it remains a recurring concern inside and outside First Solar. This has created interesting—and new dynamics. Caste systems create internal workplace struggles. Barry watched as "someone who was from a lower social status in India becomes a manager and gets insubordination from their subordinate who is from a higher level

[37] R10, April 2024.

of society in India." Social hierarchies unfamiliar to people in the Midwest USA provide new workplace experiences. "I see it. We all saw it on Indian and Indian employees," explains Barry, "[b]ut someone had to point it out. And then you're like: 'Ohhh, I get it.'" This employment of migrant labor, which some claim is to push down wages, creates concerns and challenges for locals eager to gain employment at First Solar beyond the assembly line. There is a struggle for highly lucrative positions, which are fewer in number in the corporate pyramid.

Figure 3: The white rooftop buildings are First Solar's R&D facility expansion. The other buildings are automobile manufacturing, distribution, offices and other First Solar facilities towards the top-left of the photograph. Source: Authors

*Solar factory expansions*

The greatest concern and hostility towards First Solar were in the areas neighboring the new building expansion. Indifference and passive positivity was still present, but the impact from the building expansion was felt by residents to various degrees. The largest concern, mentioned nearly by everyone in the area was the new traffic light on the main road installed for the new facilities that residents would sit at "for like five minutes" without any traffic.[38] Aside from the light, this estate agent, rightly confirms: "I think most of the complaints you'll get is with having to deal with that construction process." [39] This was certainly the case, which ranged from the facility construction creating noise, negative visual impacts, to vibrating houses and wildlife disruption.

The proximity of houses to the plant corresponded with factory construction complaints (see Figures 4, 5 & 6). That said, indifference and 'positively passive' exceptions still existed, shown by oppositional residents: "It's the new people…. and its newer homes and they have only been here for about only a year."[40] This was correct: people who were less upset had only lived there for, give or take, a year and in newer RV home constructions. The factories created change, the most pronounced were visual impacts because "there are a lot

[38] R08, April 25, 2024.
[39] R08, April 25, 2024.
[40] R20, April 30, 2024.

of damn buildings"[41] and its "a building that takes a country mile."[42] As the estate agent said, "it's just another factory," which even passively positive residents felt was "kind of eye-sore."[43] Another resident explains: "We had a nice view out here at one time, but now we're looking at a factory."[44] An ex-employee exclaimed: "But I mean, the buildings are ugly as shit."[45] While I do not think many people would disagree with this sentiment, it enraged some residents, and a mother explains: "but come on, I f#%king live here. I don't want to live between all these buildings."[46]

Figure 4: R&D Facility under construction seen from the vantage point of the Friendly Village Estate, 2024. Source: Authors

Noise and house vibration were strongly felt by residents in the two Friendly Village hamlets closest to the new First Solar R&D facility (Figures 4 & 5). "The noise, that's about it,"[47] residents would say, or "I don't like there is noise sometimes."[48] A resident who works nightshifts in a nearby distribution factory was annoyed by the helicopter working on the roofs: "I think they have a helicopter going around frequently, and it's kind of annoying. But yeah, I'm a very light sleeper."[49] Another woman complains about the reversing indicator noise from machinery, saying: "And I have a real keen sense of hearing, so, I mean, I could hear the workers talking, you know. And it just kept getting closer, closer and closer."[50] This even resulted in houses vibrating for some

[41] R09, April 25, 2024.
[42] R29, May 2, 2024.
[43] R18, April 30, 2024.
[44] R25, April 30, 2024.
[45] R10, April 25, 2024.
[46] R21, April 30, 2024.
[47] R18, April 30, 2024.
[48] R17, April 30, 2024.
[49] R24, April 30, 2024.
[50] R29, May 2, 2024.

residents. Referring to a Facebook group filled with complaints, the estate agent confirms: "But it was rattling houses."[51] Another woman explains: "We kind of moved out here just for the peace and quiet, farmland and other stuff and it's just loud and obnoxious."[52] Their mother followed up: "I would come outside; I could enjoy having a cup of coffee. I could hear the birds chirping away and stuff like that, and there was no noise and that [tranquility] is gone now."[53]

Figure 5: R&D Facility under construction seen from another vantage point in the Friendly Village Estate, 2024. Source: authors

The impact on wildlife emerged as another concern for residents. Since the construction of the factories, a junior estate agent observes: "Geese are just coming over here now. Okay. So, like there are pools, they go in the pond, they're pooping everywhere."[54] While we imagine geese would seek out ponds generally, this created other animal displacements. The has been a loss of hawks, cows, deer and other wildlife and, a mother claims: "Other than that, the only animals that we see any more and stuff like the possums. The raccoons." The new facility, the mother continues, pushed "[a]ll the animals this way towards the community. Yeah. And now we're dealing with the possums and the raccoons and all the shit that was living over there. And it's bullshit." There has been an increase in possums and raccoons coming into the area, resulting in conflicts with the neighbors. Her daughter's boyfriend, for example, was fighting a group of them the night before. The boyfriend eventually comes out of the house and explains: "And all of a sudden, they showed up the last few years. And now I have raccoons," they continue:

[51] R08, April 25, 2024.
[52] R20, April 30, 2024.
[53] R21, April 30, 2024.
[54] R06, April 25, 2024.

> I'm fighting possums living under my house and tearing up my plumbing, skirting my insulation and getting into the underbelly of the house. I got to worry about all that shit. Why am I setting down humane fucking traps for wild animals—I shouldn't have to do that. I mean, he went out to my shed the other day and I had to fight a f#%cking possum from getting into the house.[55]

This issue was ongoing and frequent, and confirmed by estate agents. "Oh, and now with the number of buildings that have gone up, the skunks had to find another area."[56] And another resident rhetorically asks: "What happened to all that wildlife that was living where they built the factories? Yeah, they ended up in my yard, okay, which is, you know, fine, but I don't have enough space [for them]."[57] Questioning whether it was like this before, the family replied: "It started when they started building all over here and, then, it just got even worse after that."[58]

There are other issues deserving consideration: a loss of pollinators, and health issues. "And we're not getting pollinators and we're getting the grubs and shit that f#%cking just tear up your lawn," explains the boyfriend who does landscaping in the neighborhood. The family explains that all the animals that were over there now "come over here and ate our stuff and now we're left with destroyed lawns, literally." The animals eating pollinating flowers and insects, they claim has resulted in a loss of bees and the destruction of lawns, the mother explains: "Displacing the animals, the pollinators in these things [animals] like this and now is making a rise in different kind of decomposers."[59] According to them the factory construction completely disrupted the local ecology, which manifests with a loss of bees, wildlife invasion and challenging lawn maintenance. The political ecology of solar panel factory development reveals unexpected relational concerns and harms of this nature.

Select residents were also convinced that the factory construction negatively impacted their health. "[M]any people started having breathing issues all of a sudden," explains the mother. "And ask them when it f#%king started; because it started in 2019. I started having asthma attacks so bad that I went into a seizure. I never had it before."[60] The mother explained how she got histoplasmosis, which, according to the Cleveland Clinic (CC, 2024), is a fungal infection "found in soil where there's bird or bat poop" and "commonly found in the Midwestern U.S., Africa, and South and Central America." "In 2019, I went from being physically able to unload trucks," explains the mother, "to not barely being able to walk from my car to my house." They had breathing issues, a heart attack and stroke—"My breathing, my oxygen level was at 70%. Now it's at 100%." When we asked what their doctors said, they replied:

> **Mother:** They don't know what caused it. They found it; it was there all of a sudden, and now I have to live with it. It's always going to be there, and now every six months I have lung scans done. My lymph nodes are inflamed and they don't know how that happened. All this digging [constructing the First Solar facilities], protection of f#%king air. I'm curious how many other people got it.
>
> **Daughter:** Yeah, actually there was one summer, while they were doing construction, there was just nothing but dust and debris and shit like that f#%king rolling through here.
>
> **AD:** But did they didn't have trucks with water sprinklers and dust control measures? You didn't see any of that?
>
> **M:** Nope. All I know is we would have periods of time where we had to take the kids inside the house because the dust was so thick.
>
> **D:** Yeah, it was bad.

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[55] R22, April 30, 2024.
[56] R23, April 30, 2024.
[57] R29, May, 2, 2024.
[58] R22, April 30, 2024.
[59] R21, April 30, 2024.
[60] R21 April 30, 2024.

The daughter, likewise, already had some health issues that she was born with, "but it hasn't gotten any easier either with the environment going to shit." While these concerns are difficult to verify, it does alert us to the political ecology of factory construction in rural areas. And, as the mother acknowledges, "I wouldn't just pin it on solar plants. It would have happened if it would have been any factory."

Finally, all of these concerns relate to participatory justice issues concerning information availability, local decision making and project inclusion. Little-to-no one in these neighborhoods was aware of any information or planning meetings related to the R&D facility expansion and, when people were aware of it, as the estate agent recalls: "[i]t happened really fast. Like the land deal went through, the farmer sold the land, and then you saw the trucks moving off the dirt and putting everything where it needed to be [for the factory]. So it all happened really, really fast."[61] When asking residents if there was any information or opportunity to participate in the plans for factory construction, common responses were: "No, I knew nothing about it,"[62] "none that I can recall"[63] or "No, I hadn't heard anything."[64] This bothered residents sympathetic to solar panel manufacturing in general, and First Solar in particular. One resident, speaking on behalf of a small group of people active in "the trustee meetings" in their neighborhood, remain dissatisfied with the process and, overall, felt betrayed by the process and was completely disturbed by the factory construction. "I'm a country girl; I'm not an industrial girl," explains 'Carolyn', "I've bought this piece of property in '87 to be in the country, not to be around factories." For some periods of time, Carloyn said, "I would sit and cry every day" at the disappointment. "I'm not proud to be an American—let's put it that way. And as you see by my flag [on my lawn], I'm red, white and blue, through and through." Following up, and asking her what it means to lose pride in being [North] American, Carloyn clarified: "We have no rights. They [authorities] never listen to us, they don't care. This [is what] talks [gesturing money with her fingers]. Yeah, money talks, words don't. People caring about other people doesn't exist anymore." While Carolyn was extremely dissatisfied, the issue of information sharing and public participation was a reoccurring issue with residents around the new R&D facilities.

*Concerns over pollution, corruption, and exclusion*

While the factory expansion generated negative experiences with land-use change, health concerns and feelings of loss, there were numerous other issues that emerged. These ranged from unsubstantiated claims of pollution events; conjecture regarding township corruption; RV real estate agents being surprised First Solar never reached out to collaborate with them; and people acknowledging solar manufacturing does not benefit them in any way. This notion of solar manufacturing, or First Solar, not benefiting local residents combines with rising electricity prices that have affected Ohio: despite living next to a solar factory and the fact that there is not much solar in the Toledo region (see Figures 1 & 7). First Solar only does utility-scale solar installations in fields, deserts and so-called 'vacant lands' (Stock, 2022). First Solar does not do rooftop solar or any other type of building installations. This has generated a criticism, and surprise, not only in terms of community development, but at a corporate level for failing to diversify their product into other areas (e.g. building integrated solar PV),. The overall viability of solar development was also questioned.

First Solar "would sell more solar panels if they had more people out there installing stuff," exclaims a participant in FG 1, "why wouldn't they want to get with the community? You know, maybe even take like a neighborhood over in the North end [of Toledo], you know, and rehabilitate it or something, you know, make a model, you know—'look what First Solar can do'." People believe installing rooftop solar would sell more panels and, as suggested, could perform meaningful company public relations "in the North end," which is an underserved neighborhood. This, according to the respondent, would demonstrate the practical usefulness and viability of solar panels. Rooftop solar installations can reduce spending on electricity, and many residents next to the factory were surprised few people had solar panels in the area and, most of all, they were hoping since

[61] R08, April 25, 2024.
[62] R09, April 25, 2024.
[63] R12, April 26, 2024.
[64] R23, April 30, 2024.

they lived next to a factory and, in the words of Carolyn, that it "looks like shit," the company would provide free or discounted panels. "I think that they [First Solar] should probably offer a way for local residents to purchase solar panels at a discount to install them on their houses," explains a resident. "That would put in more energy into the system as well and help everybody."[65] Another resident exclaims: "Tax breaks! We made the solar panels here, so why not help us out a little bit, you know?"[66] An ex-employee agrees: "[E]verybody's paying crazy electrical bills out here, all the prices are rising. But why not [support the community with solar panels]? Where are the solar panels? You know?"[67] This concern was widespread among interviewees, and suggests a sentiment that expensive local solar installers take advantage of people. In another research site in California (Dunlap *et al*. 2024b), we have witnessed this and heard about it elsewhere in the United States.

Figure 6: R&D Facility seen from the air, next to Friendly Village I at the bottom and Friendly Village II at the top, 2024. Another new facility similar was placed to the right outside the estate. Source: Authors

Expensive electricity bills, living in a solar manufacturing hub and having few solar panels in the region, raises a number of questions. The First Solar facilities are enormous, but few—if any—have solar panels on them—only in the car parking lot (Figures 2, 3 & 6). "[T]he US, the National Electric Code added in a rapid shutdown requirement," explains a First Solar representative, "It means, you know, the rooftop panels have to have a certain voltage, so utility scale panels aren't suited for that." This means, they continue, First Solar "can use our panels on carports, but not on rooftops, because they need to meet the rapid shutdown requirements. Even with rooftop solar, we wouldn't be able to power all that much of our power needs. We would need a

[65] R27, April 30, 2024.
[66] R09, April 25, 2024.
[67] R14, April 28, 2024.

larger off-site project."[68] Overcoming the regulations would mean energy conversion technologies and new manufacturing equipment to produce different sized solar panels. Lightning also hits the roofs of these First Solar facilities (Pickerel, 2024), which might dissuade covering the enormous roof surface area with solar panels.

Figure 7: Houses outside downtown Perrysburg seen from the air. Source: Authors

Neighboring residents and local contractors were puzzled by First Solar's disinterest in bringing solar power to the Toledo area (see Figure 6). It was recognized that the weather conditions are not optimal for solar, but for them, there was a contradiction with solar manufacturing occurring without directly promoting solar in their own facilities, or where the workforce live. This issue surfaced internally to First Solar, and with an economic consideration as well. "First Solar makes one product, I do not know why they do not get into making more products," explains Barry: "Everybody I know at First Solar, the smart ones, that I'm friends with, everybody is just like: 'I just don't know if we're going down the right path of just building all these plants doing the same thing'." This references the plant expansion and R&D facilities designed in the service of utility-scale solar panels. First Solar, Barry continues, "are getting all this money from the IRA now and I think they should be investing in other [solar] markets instead of just building the panel." Barry points to Dubai and other places developing automotive PV and building integrated photovoltaics (BIPV), the latter employing "semi-transparent PV" on the "facades of [building] high rises" to collect solar energy. While First Solar has a history of solar panel refrigerators (Rodengen, 2018), attentive research respondents found it odd that they are not diversifying their products to rooftop, BIPV or even applying them on automobiles.

[68] R31, May 9, 2024.

The concern was solar panel manufacturing plants and subsidiary industries, like NSG glass, are sustainable. An ex-NSG employee explained:

> So, these factories are producing solar panels, but they're not using them? They're still running on a lot of natural gas for heat requirements in some coal or oil. The glass factory is running on gas, right. Not yet running on solar panels? Of course not. Right. I would assume that you would need an insane amount of glass panels or solar energy just to run a factory like that.

NSG glass is located next to a natural gas power plant (see Figure 8). Heavy industry in the Ohio grid is running on coal, oil, nuclear and natural gas. There are notifications of oil pipelines going into First Solar's new R&D facilities (see Figure 9). "Funny thing about First Solar," Barry admits, "they don't have any arrays on their buildings, or next to any of the facilities they built, and all the power comes from the coal plant." "I mean, I'm a nature person I love and I just like it; we need to preserve it, not destroy it," explains the mother, but "that is pretty much what they're [First Solar] doing: Destroying nature in order to do something to preserve it." She speaks in the context of factory expansion, which is another factor in addition to mining raw materials, smelting, transportation and decommissioning of panels.

Figure 8: NSG Glass (bottom structure) and the Troy Energy Facility (top structure), a 796MW Gas Fuel Oil power plant providing heat and energy to the factory, 2024. Photo: Authors

An ex-First Solar employee, now working in waste management, discusses the issue of mining. "I don't know what the long-term" impact of mining for solar panels is, they explain, but "I don't think anybody can honestly say they do." They continue that people "don't know what the environmental impact of all the extraction is going to be and I know that the [mining] industry doesn't exactly have the best reputation in terms

of their waste byproducts."[69] The material, energy and water intensive reality of lower-carbon infrastructures (Mulvaney, 2019, 2024; Dunlap, 2023; Stock & Ptak, 2024), not to mention their waste streams, are a daunting issue (Sovacool *et al*., 2020; Sovacool & Stock, 2024). This extends to the widespread under-accounting of environmental effects and waste in mining in general (Svobodova *et al*., 2022; Maus & Werner, 2024), but also in the material demand predictions that exclude assessments of secondary infrastructures required for solar panels, such as high-voltage powerlines, energy transformers and battery storage technologies (Neukirch, 2020; Dunlap, 2023; Archer & Calvão, 2024). There is mining necessary for the so-called green digital or 'smart' infrastructures (Bresnihan & Brodie, 2021; Brodie, 2024). This is why, in matters of mining and production, Alex says, "There are no free lunches"—every technology has an extensive socioecological cost.


Figure 9: Crude oil pipeline warning with the First Solar R&D facility behind it. Source: Authors

## 6. Discussion and Conclusion: Towards a more informed political ecology of solar manufacturing

Solar panel manufacturing is located at an important nexus of US global industry and climate change mitigation. Taking a political ecology approach, influenced by environmental and energy justice, this article has explored solar panel manufacturing by First Solar in Perrysburg, Ohio. Employing (short-term) participant observation, document analysis, and semi-structured and informal interviewing, we have sought to explore "the hidden middle ecologies" of solar panel manufacturing, "situated between extraction and final consumption"

[69] R10, April 25, 2024.

(Huber 2017, p. 156). Besides offering a background to First Solar's development, the article has revealed the general community outlook, labor issues and negative impacts related to the expansion of the corporate footprint. The public were found to be largely indifferent to, passively positive or uninformed about the presence of the company, and its work. Solar panel manufacturing sits alongside other regional industries: automobile manufacturing, and numerous corporate retail distribution hubs. To many residents, it was "just another factory." This, however, did not take away from peoples' appreciation of employment and investment in the community coming from First Solar.

While the solar panel factory, or complex, is a research and manufacturing hub, it appeared more like a "hospital" than a traditional factory. Solar panel factories are highly automated, complex, and hold within them numerous industry secrets related to CadTel panels and how they are produced. While ex-workers reported working on the assembly line at First Solar was monotonous, restrictive (e.g. workers cannot leave the complex) and had uncomfortable shifts, it was qualitatively preferable to Amazon and auto manufacturing facilities in the region. First Solar made efforts to create a comfortable workplace environment. This, however, co-existed with worker experiences of low wages, harsh terminations ('firing'), difficulty accessing middle-management jobs, and frustration at the company for hiring foreign skilled workers. Nonetheless, the 'onshoring' of industry to the US, and having solar panel manufacturing in the region was viewed positively by residents.

The area of critical concern, however, related to experiences with the R&D factory expansion, which is converting farmland and lightly forested areas into factories. Residents experienced this as disruptive to all their senses: visually (e.g. ugly warehouse buildings); audibly (noisy construction & helicopters); and physically—inhaling dust, combating displaced animals, shaking ground and buildings, and more. Land-use change for many culminated in a sense of loss (and anger), while others were surprised at the lack of solar panels in the area, considering that the region has become a solar manufacturing hub. This was framed and experienced as the company's disinterest and lack of engagement with the local community. This lack of local solar up-take generated wider accusations that the industry was failing to advance solar installations locally and in their own operations (by placing solar panels alongside or on the roof of their factories). There were wider concerns among some respondents about charting the socioecological costs related to mining, chemical processing and energy use for manufacturing solar panels.

First Solar has commissioned short journalistic exposés into different facets of their supply-chain (see Rhys, 2023a, 2023b, 2023c), which extend to discussing these issues and providing information graphics within their sustainability reports and elsewhere (FS, 2023b). In this effort to be transparent, however, the devil is in the details in terms of what constitutes data, its method of collection, and the models they are using (e.g. bounding, assumptions, etc.) to build their statistics and information graphics (Dunlap, 2023; Archer, 2024; DuPuis & Mulvaney, 2024). When asking company representatives about supply-chain issues, we were constantly referred to their websites and methodological information which—while likely available—was not in any easy and accessible form.[70] Responsible Business Alliance (RBA) and the Validated Audit Process (VAP) were highly referenced on websites and in reports about manufacturing. There is an "Operations Manual" that, in 2021, was 39 pages and, in 2023, is now 151 pages. Despite lengthy documents, whether addressing mining or manufacturing, there is still a great deal unknown about exactly how these processes are certified, made 'platinum' or constructed as 'green' industry; and, most of all, how materials are sourced from 'sustainable' mines. This remains another area deserving sustained engagement from political ecologists, geographers and anthropologists. The overall impression in the industry is that if a mine or factory has solar panels, wind turbines, meets environmental regulations and (murky) private sector certification schemes then this allows it to be considered 'sustainable,' 'green,' and 'decarbonized.'

Our research has limitations. Researching solar, or other lower-carbon manufacturing plants, deserves greater on-site investigation and supply-chain analysis. Political ecology, thinking of Jean-Baptiste Fressoz (2024), still remains influenced by simplistic material dichotomies (e.g. fossil fuels versus renewables) and modeling exercises, that obstruct the identification of the cumulative and multi-scalar harms of (green) capitalism. The paradox of industrial production is that it is not physically or geographically concealed. From

[70] This included reaching out to the First Solar sustainability representative multiple times and writing to sustainability@firstsolar.com.

oil refineries to solar factories all stand guarded in plain sight. But the details of material throughput (e.g. timber, coal, oil, natural gas, nuclear, hydroelectricity), automation layouts (e.g. digital infrastructures), waste flows and industrial functions become hidden in their immediate infrastructure, and industrial dance. Factories are large-scale and physically present Latourian 'Black Boxes' operating in plain sight (Latour, 1999), guarded by fences, security and everyday work routines that leave them unquestioned until disaster strikes and the services stop functioning (Nye, 2010; Winther & Wilhite, 2015). Modernized humanity has become increasingly integrated into highly technical industrial-cybernetic operations, the consequences of which are frequently ignored and reduced to a potential employment opportunity.

Within their immediate circumstances, research participants saw ways to remedy injustice and/or bring solar power development closer to its marketed aspirations in numerous ways. First Solar's inaction to diversify into domestic solar appliances (e.g. rooftop solar) and other innovative integrated building photovoltaics were understood as a failed opportunity for the company, but more so to advance community and public relations to demonstrate a felt, and direct, positive impact of solar development and manufacturing. People wanted First Solar to "sell directly to locals." This, moreover, was felt by residents near the factory seeking free, or discounted, solar panels to compensate for the sustained disruptions and the replacement of fields, trees and animals with 'ugly' buildings. This idea, moreover, extended to a general hope for discounted energy prices, tax breaks for residents and, then predictably, a desire to make solar panels last longer. A handful of people raised the possibility of energy autonomy: individually or in the locality. For others, this extended to limiting foreign companies and workers taking 'green' manufacturing jobs inside the US.

Residents imagined noise barriers and dust mitigation measures would be essential if there was any further factory construction or expansion, and they extended concern to greater consideration for nearby residents. Considering the numerous dilapidated or derelict factories in the Toledo area, and the Midwest Rustbelt in general, a handful of residents stressed the importance of not taking over farmland, forest or 'new spaces' but to utilize the existing 'brownfield' sites and abandoned factories. The small group of workers, and people working with the First Solar workforce, believed the labor pattern of a three days in a row shift should be stopped, not only for general health and sanity, but—for one person—to advance First Solar apprenticeship programs that could allow part-time workers who were also in school to advance the pool of automated and skilled labor.

The lack of information for the community related to jobs, new initiatives and education about solar power and manufacturing were also concerns. First Solar is vigilant about press releases on their website and local media outlets picking up First Solar news stories, but this is not translating well on the ground. Public education about solar panels and solar panel manufacturing, along with the availability of more technical supply-chain information, appears increasingly necessary, especially with public funds coming from the IRA. Furthermore, the idea of expanding solar as a public good would involve free solar panels for schools, libraries, orphanages and other public institutions. Considering serious economic competition between the US and China add the need to maintain margins, some of this might sound unreasonable, yet these were the concerns from the communities surrounding First Solar.

While solar power is generating hope, and a great amount of revenue, there are still wider issues to consider related to sourcing materials through mining, production using chemicals, operational impacts and the decommissioning of panels. The profound material entanglements required to build solar panel factories and then to manufacture the panels has a capitalist growth imperative that political ecology has often challenged. The field could attempt to locate positive 'net' benefits of solar extraction zones, but also accurately chart the material, energetic and socio-ecological costs of solar panels, or other so-called "renewable" infrastructures, as they intersect with timber, concrete, steel, hydrocarbon, digital and computational sectors among others. Despite the rapid growth in solar power, until rapacious consumerism and capitalist growth imperatives are challenged, the 'green,' 'sustainable' and 'renewability' claims appear highly questionable and guarded by highly technical data collection and modelling practices. The challenge for political ecology remains to avoid falling prey to simplistic, and inaccurate, energy and material dichotomies and modeling practices like life-cycle assessments (see Dunlap, 2023; DuPuis & Mulvaney, 2024; Fressoz, 2024). Solar panel manufacturing, while it can expand and provide immediate remedies for the communities that it occupies, raised so many wider issues about

industrial development and digital capitalism that are preventing a true socioecological transformation that will begin remediating ecological and climate catastrophes.

## References


Allan, J., Lemaadel, M. & Lakhal, H. (2022). Oppressive energopolitics in Africa's last colony: Energy, subjectivities, and resistance. *Antipode*, 54, 44–63. https://doi.org/10.1111/anti.12765

Andreucci, D., López, G. G., Radhuber, I. M., Conde, M., Voskoboynik, D. M., Farrugia, J. & Zografos, C. (2023). The coloniality of green extractivism: Unearthing decarbonisation by dispossession through the case of nickel. *Political Geography*, 107, 1-10. https://doi.org/10.1016/j.polgeo.2023.102997

Archer, M. (2024) *Unsustainable: Measurement, reporting, and the limits of corporate sustainability*. New York University Press.

Archer, M. & Calvão, F. (2024). Sustaining decarbonisation: Energy storage, green extractivism, and the future of mining. *Antipode*, 1–21. https://doi.org/10.1111/anti.13066

Aronoff, K., Battistoni, A., Cohen, D. A. & Riofrancos, T. (2019). *A planet to win: Why we need a Green New Deal*. Verso Books.

Atkins, E. & Hope, J. (2021). Contemporary political ecologies of hydropower: Insights from Bolivia and Brazil. *Journal of Political Ecology*, 28, 246–265. https://doi.org/10.2458/jpe.2363

Avila, S. (2018). Environmental justice and the expanding geography of wind power conflicts. *Sustainability Science*, 13, 599–616. https://doi.org/10.1007/s11625-018-0547-4

Avila, S., Deniau, Y., Sorman, A. H. & McCarthy, J. (2022). (Counter) mapping renewables: Space, justice, and politics of wind and solar power in Mexico. *Environment and Planning E: Nature and Space*, 5, 1056–1085. https://doi.org/10.1177/25148486211060657

Barca, S. & Bridge, G. (2015). Industrialization and environmental change. In Perrault, T., Bridge, G., McCarthy, J. (Ed.) *The Routledge handbook of political ecology* (pp. 366-377). Routledge.

Batel, S. & Devine-Wright, P. (2017). Energy colonialism and the role of the global in local responses to new energy infrastructures in the UK: A critical and exploratory empirical analysis. *Antipode*, 49, 3–22. https://doi.org/10.1111/anti.12261

Bellini, E. (2024, May 15). *US government doubles tariff rates on PV cell imports from China to 50%*. PV Magazine. https://www.pv-magazine.com/2024/05/15/us-government-doubles-tariff-rates-on-pv-cell-imports-from-china-to-50/

Bonneuil, C., Fressoz, J.-B. (2016). *The shock of the Anthropocene: The earth, history and us*. Verso Books.

Broto, V. C. (2013). Employment, environmental pollution and working class life in Tuzla, Bosnia and Herzegovina. *Journal of Political Ecology*, *20*(1), 1-13. https://doi.org/10.2458/v20i1.21743

Bresnihan, P. & Brodie, P. (2021). New extractive frontiers in Ireland and the moebius strip of wind/data. *Environment and Planning E: Nature and Space*, 4(1), 1645–1664. https://doi.org/10.1177/2514848620970121

Brock, A., Sovacool, B. K. & Hook, A. (2021). Volatile photovoltaics: Green industrialization, sacrifice zones, and the political ecology of solar energy in Germany. *Annals of the American Association of Geographers*, 111(1), 1756–1778. https://doi.org/10.1080/24694452.2020.1856638

CC (2024). Histoplasmosis. Retrieved June 16, 2024, from https://my.clevelandclinic.org/health/diseases/24811-histoplasmosis

de Leeuw, G. & Voglm V. (2024). Scrutinising commodity hype in imaginaries of the Swedish green steel transition. *Environment and Planning E: Nature and Space*, 7(4), 1844–1867. https://doi.org/10.1177/25148486241238398

Deberdt R. & Le Billon, P. (2024). Green Transition's Necropolitics: Inequalities, climate extractivism, and carbon classes. *Antipode*, 56(4), 1264–1288. https://doi.org/10.1111/anti.13032

Dunlap, A. (2018, May 10). End the "green" delusions: Industrial-scale renewable energy is fossil fuel+. Verso Books https://www.versobooks.com/blogs/3797-end-the-green-delusions-industrial-scale-renewable-energy-is-fossil-fuel

Dunlap, A. (2019a). *Renewing destruction: Wind energy development, conflict and resistance in a Latin American contex*t. Rowman & Littlefield.

Dunlap, A. (2020). Bureaucratic land grabbing for infrastructural colonization: Renewable energy, L'Amassada and resistance in southern France. *Human Geography*, 13(2), 109–126. https://doi.org/10.1177/1942778620918041

Dunlap, A. (2021). Does renewable energy exist? Fossil fuel+ technologies and the search for renewable energy. In Batel, S. & Rudolph, D. P. (Eds.) *A critical approach to the social acceptance of renewable energy infrastructures* (pp. 83–102). Palgrave.

Dunlap, A. (2023). The green economy as counterinsurgency, or the ontological foundations for permanent ecological catastrophe. *Environmental Policy and Science*, 139(1), 39–50. https://doi.org/10.1016/j.envsci.2022.10.008

Dunlap, A. & Laratte, L. (2022). European Green Deal necropolitics: Exploring 'green' energy transition, degrowth & infrastructural colonization. *Political Geography*, 97(1), 1–17. https://doi.org/10.1016/j.polgeo.2022.102640

Dunlap A., Novaković B. & Sovacool, B. K. (Forthcoming). Mining as environmentalism: Green/grey extractivism and the production of extractive subjectivities around the Rio Tinto Kennecott Mine, USA. *Globalizations*, 1–25.

Dunlap A., Sovacool B. K. & Novaković, B. (2024a). "A dead sea of solar panels:" Solar enclosure, extractivism and the progressive degradation of the California desert. *Journal of Peasant Studies*, 1–28. https://doi.org/10.1080/03066150.2024.2388051

Dunlap A., Sovacool B. K. & Novaković, B. (2024b). "Our town is dying": Exploring utility-scale and rooftop solar energy injustices in Southeastern California. *Geoforum*, 156(1), 1–15. https://doi.org/10.1016/j.geoforum.2024.104120

DuPuis, E. M. & Mulvaney, D. (2024). Opening the black box: Carbon-footprint calculators, meat consumption, and the "wicked problem" of metric governance. *Sustainability: Science, Practice and Policy*, 20(1), 1–10. https://doi.org/10.1080/15487733.2024.2390232

Finley-Brook, M. & Thomas, C. (2010). Treatment of displaced indigenous populations in two large hydro projects in Panama. *Water Alternatives*, 3(2), 269-290. https://www.water-alternatives.org/index.php/all-abs/93-a3-2-16/file

First Solar (2023a). Annual report. Retrieved March 20 2024, from https://s202.q4cdn.com/499595574/files/doc_financials/2023/ar/first-solar-web-pdf-2023-annual-report.pdf

First Solar (2023b). Sustainability report 2023 Retrieved March 20, 2024, from https://www.firstsolar.com/-/media/First-Solar/Sustainability-Documents/FirstSolar_Sustainability-Report_2023.ashx

First Solar (2023c). Governance: Responsible solar. Retrieved March 20, 2024, from https://www.firstsolar.com/en/Responsible-Solar/Governance

First Solar (2024a). First Solar inaugurates 3.3 GW manufacturing facility in India. Retrieved April 24, 2024, from https://investor.firstsolar.com/news/news-details/2024/First-Solar-Inaugurates-3.3-GW-Manufacturing-Facility-in-India/default.aspx

Franquesa, J. (2018). *Power struggles: Dignity, value, and the renewable energy frontier in Spain*. Indiana University Press.

Fressoz J-B. (2024). *More and more and more: An all-consuming history of energy*. Allen Lane.

García, A.K. & Wiegink, N. (2024). Mining the energy transition: An introduction. *Anthropological Quarterly*, 97(2), 311–327. https://doi.org/10.1353/anq.2024.a929491

Hanacek K, Kröger, M. & Martinez-Alier, J. (2024). Green and climate colonialities: Evidence from Arctic extractivisms. *Journal of Political Ecology*, 31(1), 538–566. https://doi.org/10.2458/jpe.5512

Heard, A. (2014). Response to Mulvaney, 'Are green jobs just jobs? Cadmium narratives in the life cycle of photovoltaics.' *Geoforum*, 56(1), 249–250. http://dx.doi.org/10.1016/j.geoforum.2014.01.014

Hu, Z. (2023). Towards solar extractivism? A political ecology understanding of the solar energy and agriculture boom in rural China. *Energy Research & Social Science*, 98(1), 1–13. https://doi.org/10.1016/j.erss.2023.102988

Huber, M. T. (2022, August 18). Mish-Mash Ecologism. *New Left Review*. Available at: https://newleftreview.org/sidecar/posts/mish-mash-ecologism

Huber, M. T. (2017). Hidden abodes: Industrializing political ecology. *Annals of the American Association of Geographers* 107(1), 151–166. https://doi.org/10.1080/24694452.2016.1219249

Jackson, D. D. (2020). A perfect storm: embodied workers, emplaced corporations, and delayed reflexivity in a Canadian 'Risk Society'. *Journal of Political Ecology*, *27*(1), 150-168. https://doi.org/10.2458/v27i1.23138

Käkönen, M. & Nygren, A. (2023). Resurgent dams: shifting power formations, persistent harms, and obscured responsibilities. *Globalizations*, 20(6), 866–886. https://doi.org/10.1080/14747731.2022.2098668

Klein, N. (2007). *The Shock Doctrine: The rise of disaster capitalism*. Allen Lane.

Knuth, S., Behrsin, I., Levenda, A. & McCarthy, J. (2022). New political ecologies of renewable energy. *Environment and Planning E: Nature and Space*, 5(6), 997–1013. https://doi.org/10.1177/25148486221108164

Lamb, V. & Fung, Z. (2022). Expanding transboundary environmental governance: A mobile political ecology of sand and shifting resource-based livelihoods in Southeast Asia. *Environmental Policy and Governance*, 32(1), 281–291. https://doi.org/10.1002/eet.1972

Lennon, M. (2021). Energy transitions in a time of intersecting precarities: From reductive environmentalism to antiracist praxis. *Energy Research & Social Science*, 73(1), 101930. https://doi.org/10.1016/j.erss.2021.101930

Malm, A. (2016). *Fossil capital: The rise of steam power and the roots of global warming*. Verso Books.

Maus, V., Werner, T. T. (2024). Impacts for half of the world's mining areas are undocumented. *Nature* 625, 26–29. https://doi.org/10.1038/d41586-023-04090-3

McCarthy, J. (2015). A socioecological fix to capitalist crisis and climate change? The possibilities and limits of renewable energy. *Environment and Planning A*, 47(12), 2485–2502. https://doi.org/10.1177/0308518X15602491

McCarthy, J. & Thatcher, J. (2019). Visualizing new political ecologies: A critical data studies analysis of the World Bank's renewable energy resource mapping initiative. *Geoforum*, 102(1), 242–254. https://doi.org/10.1016/j.erss.2021.101930

Menton, M., Larrea, C., Latorre, S., Martinez-Alier, J., Peck, M., Temper, L. & Walter, M. (2020). Environmental justice and the SDGs: from synergies to gaps and contradictions. *Sustainability Science*, 15, 1621–1636. https://doi.org/10.1007/s11625-020-00789-8

MS (2024, November 11). First Solar, Inc. Retrieved November 11, 2024, from https://www.marketscreener.com/quote/stock/FIRST-SOLAR-INC-37008/company/

Müller, B. (2004). Images of nature as designs for Czech post-socialist society. *Journal of Political Ecology*, *11*(1), 31-42. https://doi.org/10.2458/v11i1.21657

Mulvaney, D. (2014a). Are green jobs just jobs? Cadmium narratives in the life cycle of photovoltaics. *Geoforum*, 54, 178–186. https://doi.org/10.1016/j.geoforum.2014.01.014

Mulvaney, D. (2014b). Response to Dr. Alex Heard's comments. *Geoforum*, 56, 251–253. https://doi.org/10.1016/j.geoforum.2014.08.002

Mulvaney, D. (2017). Chapter 11: Geographies of solar power. In Clavert, K. & Solomon, B. (Eds.) *Handbook on the geographies of energy* (pp. 148-162). Edward Elgar.

Mulvaney, D. (2019). *Solar Power: Innovation, sustainability, and environmental justice*. University of California Press.

Mulvaney D. (2024). Embodied energy injustice and the political ecology of solar power. *Energy Research & Social Science*, 115, 1–9. https://doi.org/10.1016/j.erss.2024.103607

Nader, L. (1972). *Up the anthropologist: Perspectives gained from studying up*. US Department of Health.

Neukirch, M. (2020). Grinding the grid: Contextualizing protest networks against energy transmission projects in Southern Germany. *Energy Research & Social Science*, 69, 101585. https://doi.org/10.1016/j.erss.2020.101585

Newell, J. P., Cousins, J. J. & Baka, J. (2017). Political-industrial ecology: An introduction. *Geoforum*, 85, 318–322. https://doi.org/10.1016/j.geoforum.2016.11.011

Nirmal, P. & Rocheleau, D. E. (2019). Decolonizing degrowth in the post-development convergence: Questions, experiences, and proposals from two Indigenous territories. *Environment and Planning E: Nature and Space*, 2, 465–492. https://doi.org/10.1177/2514848618819478

Nolan, C., Goodman, M. & Menga, F. (2020). In the shadows of power: The infrastructural violence of thermal power generation in Ghana's coastal commodity frontier. *Journal of Political Ecology*, *27*(1), 775-794. https://doi.org/10.2458/v27i1.23571

Normann, S. (2022). "Time is our worst enemy:" Lived experiences and intercultural relations in the making of green aluminum. *Journal of Social Issues*, 78, 163–182. https://doi.org/10.1111/josi.12472

O'Connor, J. (1998). *Natural causes: Essays in ecological Marxism*. Guilford Press.

Ojea, S. (2024, January 19). *First Solar buys Peloton's Ohio-based manufacturing facility*. Wall Street Journal https://www.wsj.com/articles/first-solar-buys-pelotons-ohio-based-manufacturing-facility-58659a7b

Paulson, S. (2017). Degrowth: Culture, power and change. *Journal of Political Ecology*, 24, 425–448. https://doi.org/10.2458/v24i1.20882

PBS (2024, June 26). *Biden's Inflation Reduction Act aimed to boost renewable energy. Subsidies could help one company reap billions*. PBS https://www.pbs.org/newshour/nation/bidens-inflation-reduction-act-aimed-to-boost-renewable-energy-subsidies-could-help-one-company-reap-billions

Pickren, G. (2019). The frontiers of North America's fossil fuel boom: BP, Tar Sands, and the re-industrialization of the Calumet Region. *Journal of Political Ecology*, *26*(1), 38-56. https://doi.org/10.2458/v26i1.23106

Pickerel, K. (2024, May 6). *Recent fires may impact production output for two leading solar panel manufacturers*. Solar Power World. https://www.solarpowerworldonline.com/2024/05/recent-fires-may-impact-production-output-for-two-leading-solar-panel-manufacturers/

Reuters (2023, August 15). *First Solar audit reveals forced labor at Malaysia factory*. Reuters https://www.reuters.com/business/energy/first-solar-says-audit-found-unethical-labor-practices-malaysia-factory-2023-08-15/

Rhys, D. (2023a). Critical Materials: Tellurium. Available at: https://www.americassolarworkers.com/critical-materials

Rhys, D. (2023b). Glass Manufacturing: Raw materials to finished goods, available at: https://www.americassolarworkers.com/glass

Rhys, D. (2023c). American Steel: Locally sourced. Available at: https://www.americassolarworkers.com/steel

Rignall, K. E. (2016). Solar power, state power, and the politics of energy transition in pre-Saharan Morocco. *Environment and Planning A*, 48, 540–557. https://doi.org/10.1177/0308518X15619176

Riquito, M. (2023). Beyond the master narrative of 'green' modernity: A critical reading of the energy transition. *Relações Internacionais*, 80, 23–34. https://doi.org/10.23906/ri2023.sia03

Rodengen, J. L. (2018). *Solar flair: The history of First Solar*. Write Stuff Enterprises.

Rogers, D. (2022, October 27). *First Solar announces $270M research, development facility in Perrysburg*. Sentinel Tribune https://www.sent-trib.com/2022/10/27/first-solar-announces-270m-research-development-facility-in-perrysburg/

Sareen, S. (2020). *Enabling sustainable energy transitions: Practices of legitimation and accountable governance*. Palgrave.

Siamanta, Z. C. (2017). Building a green economy of low carbon: the Greek post-crisis experience of photovoltaics and financial' green grabbing'. *Journal of Political Ecology*, 24, 258–276. https://doi.org/10.2458/v24i1.20806

Siamanta, Z. C. (2021). Conceptualizing alternatives to contemporary renewable energy development: Community Renewable Energy Ecologies (CREE). *Journal of Political Ecology*, 28, 258–276. https://doi.org/10.2458/jpe.2297

Sovacool, B. K. (2021). Who are the victims of low-carbon transitions? Towards a political ecology of climate change mitigation. *Energy Research & Social Science*, 73, 1–16. https://doi.org/10.1016/j.erss.2021.101916

Sovacool, B. K., Hook, A., Martiskainen, M., Brock, A. & Turnheim, B. (2020a). The decarbonisation divide: Contextualizing landscapes of low-carbon exploitation and toxicity in Africa. *Global Environmental Change*, 60, 102028. https://doi.org/10.1016/j.gloenvcha.2019.102028

Sovacool, B. K., Martiskainen, M., Hook, A. & Baker, L. (2020b). Beyond cost and carbon: The multidimensional co-benefits of low carbon transitions in Europe. *Ecological Economics*, 169, 1-15. https://doi.org/10.1016/j.ecolecon.2019.106529

Sovacool B. K. & Stock, R. (2024). "We struggle to survive": Exploring the whole systems energy injustices of solar photovoltaics in India. *The Electricity Journal*, 37(1), 1–12. https://doi.org/10.1016/j.tej.2024.107426

Springer, S., Birch, K., & MacLeavy, J. (Eds.) (2016). *Handbook of neoliberalism*. Routledge.

Stock, R. (2021). Illuminant intersections: Injustice and inequality through electricity and water infrastructures at the Gujarat Solar Park in India. *Energy Research & Social Science*, 82, 102309. https://doi.org/10.1016/j.erss.2021.102309

Stock, R. & Birkenholtz, T. (2019). The sun and the scythe: Energy dispossessions and the agrarian question of labor in solar parks. *The Journal of Peasant Studies, 48(5),* 984–1007. https://doi.org/10.1080/03066150.2019.1683002

Stock, R., Nyantakyi-Frimpong, H., Antwi-Agyei, P. & Yeleliere, E. (2023). Volta photovoltaics: Ruptures in resource access as gendered injustices for solar energy in Ghana. *Energy Research & Social Science*, 103, 103222. https://doi.org/10.1016/j.erss.2023.103222

Stock, R. & Ptak, T. (2024). Miner threat: Premature death to prefigurative politics for unearthing solar-grade silica. *Human Geography*, 1–14. https://doi.org/10.1177/19427786241258717

Stock, R. & Sovacool, B. K. (2024). Blinded by sunspots: Revealing the multidimensional and intersectional inequities of solar energy in India. *Global Environmental Change*, 84, 102796. https://doi.org/10.1016/j.gloenvcha.2023.102796

Stock, R, & Sareen, S. (2024). Solar aporias: On precarity and praxis in interdisciplinary research on solar energy. *Energy Research & Social Science*, 116, 103661. https://doi.org/10.1016/j.erss.2024.103661

Svobodova, K., Owen, J.R., Kemp, D., Moudrý, V., Lèbre, É., Stringer, M. & Sovacool, B. K. (2022). Decarbonization, population disruption and resource inventories in the global energy transition. *Nature Communications*, 13, 1–16. https://doi.org/doi.org/10.1038/s41467-022-35391-2

The Economist (2024). *Dawn of the Solar Age*. Profile Books.

Torres Contreras, G. A. (2023). Who owns the land owns the wind? Land and citizenship in the Isthmus of Tehuantepec, Mexico. *Journal of Agrarian Change*, 23(2), 365–384. https://doi.org/10.1111/joac.12527

Tornel, C. (2023). Energy justice in the context of green extractivism: Perpetuating ontological and epistemological violence in the Yucatan Peninsula. *Journal of Political Ecology*, 30, 846–873. https://doi.org/10.2458/jpe.5485

Tunn, J., Kalt, T., Müller, F., Simon, J., Hennig, J., Ituen, I., & Glatzer, N. (2024). Green hydrogen transitions deepen socioecological risks and extractivist patterns: Evidence from 28 prospective exporting countries in the Global South. *Energy Research & Social Science*, *117*, 103731. https://doi.org/10.1016/j.erss.2024.103731

Ulloa, A. (2023). Aesthetics of green dispossession: From coal to wind extraction in La Guajira, Colombia. *Journal of Political Ecology*, 30, 743–764. https://doi.org/10.2458/jpe.5475

UNEP (2024). *Global Resources Outlook 2024*. *United Nations Environmental Programme*, available at: https://www.unep.org/resources/Global-Resource-Outlook-2024?__cf_chl_tk=.uhO9B3W9bBdS3IxJhl6dBdwNXXVYcdEEb4W_QvfLKs-1710883838-0.0.1.1-1557

Vela-Almeida, D., Kolinjivadi, V., Ferrando, T., Roy, B., Herrera, H., Gonçalves, M. V. & Van Hecken, G. (2023). The "Greening" of Empire: The European Green Deal as the EU first agenda. *Political Geography*, 105, 1-9. https://doi.org/10.1016/j.polgeo.2023.102925

Winther, T., Wilhite, H. (2015). Tentacles of modernity: why electricity needs anthropology. *Cultural Anthropology*, 30, 569–577. https://doi.org/10.14506/ca30.4.05

Zografos, C. & Martínez-Alier, J. (2009). The politics of landscape value: A case study of wind farm conflict in rural Catalonia. *Environment and Planning: A*, 41, 1726–1744. https://doi.org/10.1068/a41208