COLLABORATORY FOR A REGENERATIVE ECONOMY

Solar Supply Chains:

The Business Case for Effective Management of Environmental and Human Rights Impacts

Clean Production Action

University at Buffalo

CoRE

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Introduction

Renewable energy is essential to solving our climate and pollution crisis. It could decarbonize 90 percent of the power sector in the next 25 years, significantly reducing the emissions responsible for climate change, while simultaneously yielding three times as many jobs as the fossil fuel sector.[1]

Domestic solar deployment in the U.S. is expected to nearly quadruple over the next decade.[2] Globally, solar is set to contribute more than 40% of new power generation capacity through 2030,[3] and the global solar market is projected to be worth $436.36 billion by 2032, up from $253.69 billion in 2023.[4] Factors driving the expansion include skyrocketing demand for clean electricity across the private and public sector, expanding regulatory incentives, and falling costs.

1 United Nations Climate Action website. "Renewable energy – powering a safer future." Accessed 6/2/24 at https://www.un.org/en/climatechange/raising-ambition/renewable-energy; Guterrers, A., United Nations Secretary General. "24 September 2021 UN Headquarters Opening remarks to High-level Dialogue on Energy." Accessed 6/2/24 at https://www.un.org/sg/en/content/sg/speeches/2021-09-24/opening-remarks-high-level-dialogue-energy

2 https://www.seia.org/research-resources/solar-market-insight-report-2023-year-review

3 https://www.iea.org/news/the-energy-world-is-set-to-change-significantly-by-2030-based-on-today-s-policy-settings-alone

4 https://www.fortunebusinessinsights.com/industry-reports/solar-power-market-100764

Yet this growth comes with attendant risks. As the market continues to ramp up, it would be a mistake to neglect them. For instance:

Import restrictions from human rights abuses in critical minerals mining and sourcing of solar components:

Opaque supply chains create a risk that solar components are being produced under exploitative and abusive conditions, which can expose companies to litigation, operational disruption, reputational damage, and regulatory lockout from key markets—as seen in the forceful trade restrictions instituted by the U.S. following revelations that solar materials exported from the Xinjiang region of China were the product of forced labor and were being rerouted through other countries to avoid suspicion.

Reputational risks from using toxic chemicals in solar supply chains:

Solar developers that continue to rely upon toxic chemicals such as lead to construct solar panels may likewise run up against legal, regulatory, and reputational obstacles as countries impose restrictions on the use and disposal of these chemicals to protect workers and consumers from materials that are hazardous to their health—and as temporary exemptions expire for solar panels from disposal regulations such as the EU's Restriction on Hazardous Substances Initiative (RoHS), enacted to incentivize solar production.

Competitive disadvantage for not meeting procurement standards set in ecolabels, including EPEAT:

In the U.S., the Federal Acquisition Regulation (FAR) requires that 95% of all electronic product acquisitions be EPEAT-registered products.[5] Qualifying equipment for the label includes a range of electronics, as well as photovoltaic modules and inverters. Although more than 3,480[6] electronic products are registered with EPEAT, in 2024 only two solar companies, First Solar[7] and Hanwha Qcells,[8] have certified their products to the EPEAT registry—and have therefore benefited from being a first mover to EPEAT registration and disclosure.[9]

Solar companies that proactively implement robust risk management policies, including by tracing the materials they source to their points of origin, identifying and mitigating adverse human rights and environmental impacts, and disclosing their efforts in these areas, will ensure the resiliency and competitiveness of their businesses. Solar companies that fail to adequately address these risks will lose their competitive edge by missing out on financial incentives like the tax credits created by the U.S. Inflation Reduction Act (IRA), or losing access entirely to more heavily regulated markets, like the EU.

5 https://www.epa.gov/greenerproducts/electronic-product-environmental-assessment-tool-epeat

6 https://www.wifcon.com/discussion/index.php?/blogs/entry/5202-the-electronic-product-environmental-assessment-tool-epeat-lauds-nitaac-for-the-third-year-in-a-row/

7 https://epeat.net/product-details/245713cf9d5d4725ae2db312f541a4a5?backUrl=%252Fpvmi-search-result%252Fpage-1%252Fsize-25

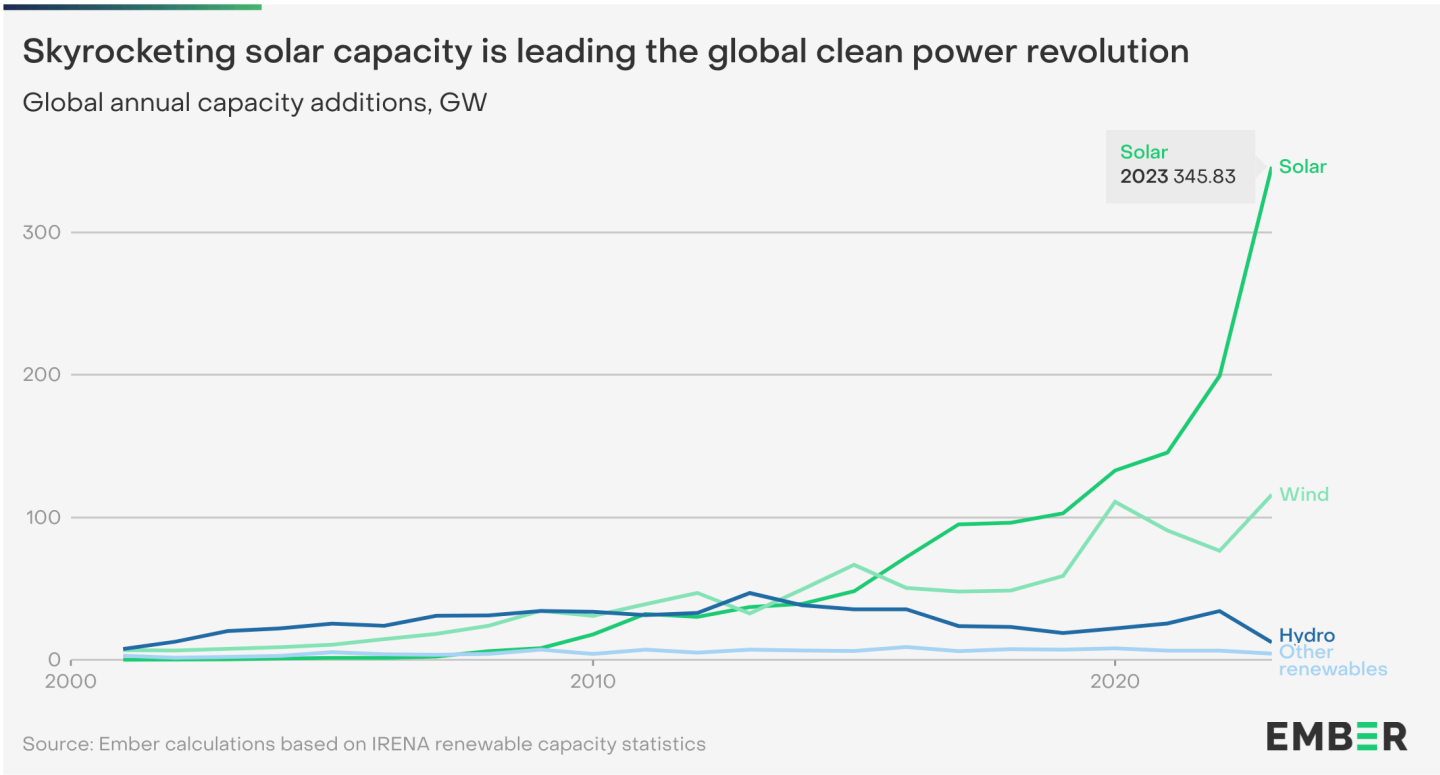
8 https://www.reuters.com/sustainability/first-solar-qcells-panels-score-green-label-preferred-by-us-government-2024-06-04/

9 https://investor.firstsolar.com/news/news-details/2024/First-Solar-becomes-the-Solar-Industrys-First-EPEAT-Climate-Champion-Setting-Global-Standard-for-Ultra-Low-Carbon-Solar/default.aspx

Investors have a crucial role to play in this evolving ecosystem, by:

- Helping companies appreciate the risks irresponsible business practices pose to their viability.
- Recommending companies adopt EPEAT standards and engage with other tools and practices that will allow them to grow sustainably and minimize their human and environmental impacts.
- Encouraging companies to establish themselves as leaders in this space.
- Developing effective engagement strategies to ensure their message is heard.
- Joining Investors for Sustainable Solar, a collaboration coordinated by the Investor Environmental Health Network (IEHN), advancing responsible sourcing and operations for safer chemical use and respect for human rights.

Ultimately, solar companies—and the solar industry as a whole—will not thrive if they remain reliant upon human and environmental exploitation and the accompanying costs, risks, and liabilities.



(Source: https://ember-climate.org/insights/in-brief/2023s-record-solar-surge-explained-in-six-charts/)

Human Rights Abuses in Critical Minerals Mining and Sourcing of Solar Components

Reaching the global climate goal of net-zero greenhouse gas emissions by 2050 will require a six-fold increase in production of critical minerals by 2040 from current levels.[10]

Yet evidence continues to emerge that the scale of human rights abuses connected to mining of critical energy transition minerals is significant.[11] For instance, a May 2024 Business & Human Rights Resource Centre Report documented 400 allegations of human rights abuses—including unpaid labor, exploitative hiring, child labor and discrimination—in just 16 countries in Eastern Europe and Central Asia connected with critical minerals mining over the past five years.[12] Of particular concern is the extraction and processing of "critical minerals," which are defined as essential components of key energy transition technologies (including solar panels)[13] and include copper, lithium, nickel, cobalt, and rare earth elements.

Business Risk

10 https://insideclimatenews.org/news/06052024/eastern-europe-central-asia-critical-mineral-mining-rights-abuse/
https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/executive-summary

11 https://www.weforum.org/agenda/2024/01/energy-transition-critical-minerals-technology/
https://insideclimatenews.org/news/07062023/mining-clean-energy-human-rights/

12 https://insideclimatenews.org/news/06052024/eastern-europe-central-asia-critical-mineral-mining-rights-abuse/
https://www.business-humanrights.org/en/from-us/briefings/fuelling-injustice-transition-mineral-impacts-in-eastern-europe-central-asia/
https://www.greenbiz.com/article/renewables-are-exacerbating-modern-slavery-how-businesses-can-act

13 https://www.iea.org/topics/critical-minerals
https://www.energy.gov/cmm/what-are-critical-materials-and-critical-minerals

Human rights abuses committed during the extraction of critical minerals and the production of solar components can disrupt supply chains and pose material risks to solar companies.

- In Serbia, widespread public protests regarding the environmental impacts of a planned lithium mine led to the mine's license being revoked and the project shut down.[14]
- In the Democratic Republic of the Congo (DRC), the extraction of copper and cobalt has been linked to corruption, environmental destruction, and child labor.[15]

These abuses have been the subject of litigation against companies that source from there.[16]

Efforts are ongoing to eliminate human rights abuses from critical mineral supply chains.

For instance:

- Section 307 of the Tariff Act of 1930 (19 U.S.C. §1307), enforced by U.S. Customs and Border Protection (CBP), prohibits the importation of any goods made or mined using forced labor, including child labor. The U.S. Department of Homeland Security also recently created the interagency Forced Labor Enforcement Task Force.[17]
- The Biden Administration has taken actions including forming the Energy Resource Governance Initiative (ERGI),[18] and directing governmental agencies to review human-rights and forced-labor risks in supply chains.[19]
- The Biden Administration has also responded to evidence of abuses in specific markets. For instance, citing an investigation[20] that exposed the highly toxic mining of rare earth minerals and links to militias in Myanmar, the US government released guidance[21] warning of specific risks of doing business in Myanmar (including a section dedicated to rare earth elements).
- In Europe, the EU Critical Raw Materials Act provides for greater oversight of human rights abuses in supply chains and is intended to prevent goods produced using forced labor and other abuses from entering the EU.[22]

14 https://www.reuters.com/markets/commodities/serbia-wants-talks-with-rio-tinto-over-jadar-lithium-project-2024-01-17/

15 https://www.theguardian.com/global-development/2019/dec/16/apple-and-google-named-in-us-lawsuit-over-congolese-child-cobalt-mining-deaths
https://www.amnesty.org/en/latest/news/2023/09/drc-cobalt-and-copper-mining-for-batteries-leading-to-human-rights-abuses/
https://www.ihrb.org/focus-areas/commodities/global-demand-for-copper-and-human-rights-challenges

16 https://www.theguardian.com/global-development/2019/dec/16/apple-and-google-named-in-us-lawsuit-over-congolese-child-cobalt-mining-deaths

17 https://www.dhs.gov/forced-labor-enforcement-task-force

18 https://ergi.tools/

19 https://insideclimatenews.org/news/07062023/mining-clean-energy-human-rights/

20 https://www.globalwitness.org/en/campaigns/natural-resource-governance/myanmars-poisoned-mountains/

21 https://ustr.gov/about-us/policy-offices/press-office/press-releases/2024/january/supplemental-burma-business-advisory

22 https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1661

Other legislation in the US and the EU, discussed later, are likely to increasingly eliminate minerals mined using forced labor or connected to other abuses, making it essential for companies to conduct meaningful and transparent supply chain mapping and monitoring.

Despite efforts in the United States to onshore renewable energy supply chains, the solar sector and other renewable industries remain heavily reliant upon production abroad,[23] including in regions linked to slave labor, other widespread human rights abuses, and environmental destruction. A 2023 analysis by human rights group Walk Free estimated that G20 countries are importing $14.8 billion in solar panels that may have been made with forced labor,[24] making solar panels the fourth highest value of all at-risk products.

China's use of forced labor to produce key solar components represents a tangible supply chain risk for U.S.-based companies, given that China dominates the market in upstream solar components such as ingots, wafers, and cells,[25] manufactures 80% of the world's solar modules,[26] and produces and exports the majority of the world's polysilicon, a key ingredient in upstream solar products.

Many of these components, including around 40% of the world's polysilicon, are produced in the Xinjiang region of China,[27] home to the Uyghur population. Uyghurs in China have been subjected to oppressive policing and surveillance,[28] forced sterilizations,[29] and imprisonment in "re-education" camps[30] by the Chinese government, as well as forced labor in the production of solar components.[31]

Rank	Product	Total import value (in billions $US)
1	Electronics	243.6
2	Garments	147.9
3	Palm oil	19.7
4	**Solar panels**	**14.8**
5	Textiles	12.7
6	Timber	7.4
7	Fish	6.3
8	Gold	5.2
9	Cattle	4.4
10	Sugarcane	2.5

Sources: https://www.greenbiz.com/article/renewables-are-exacerbating-modern-slavery-how-businesses-can-act
https://cdn.walkfree.org/content/uploads/2023/05/17114737/Global-Slavery-Index-2023.pdf

23 https://www.americanprogress.org/press/release-critical-minerals-and-clean-energy-how-to-protect-communities-and-safeguard-human-rights/

24 https://www.greenbiz.com/article/renewables-are-exacerbating-modern-slavery-how-businesses-can-act
https://cdn.walkfree.org/content/uploads/2023/05/17114737/Global-Slavery-Index-2023.pdf

25 https://www.commonfund.org/cf-private-equity/inflation-reduction-act-catalyst-for-u.s.-domestic-solar-manufacturing

26 https://www.iea.org/reports/world-energy-outlook-2023

27 https://www.iea.org/reports/solar-pv-global-supply-chains/executive-summary

28 https://xjdp.aspi.org.au/explainers/how-mass-surveillance-works-in-xinjiang/

29 https://www.justsecurity.org/71615/chinas-forced-sterilization-of-uyghur-women-violates-clear-international-law/

30 https://www.cfr.org/backgrounder/china-xinjiang-uyghurs-muslims-repression-genocide-human-rights

31 https://www.dol.gov/sites/dolgov/files/ILAB/images/storyboards/solar/Solar.pdf
https://www.csis.org/analysis/dark-spot-solar-energy-industry-forced-labor-xinjiang
https://thechinaproject.com/2023/09/14/the-worlds-solar-panel-industry-is-still-powered-by-uyghur-forced-labor/

Investigations conducted by the U.S. Department of Labor and the Department of Homeland Security have led to the imposition of a range of restrictions against the import of goods produced in Xinjiang[32]:

- In June 2021, the U.S. Department of Labor added polysilicon from Xinjiang to its annually updated List of Goods Produced by Child Labor or Forced Labor.[33]
- The CBP—acting pursuant to its authority under Section 307 of the Tariff Act—issued a Withhold Release Order (WRO)[34] against Hoshine Silicon Industry Co. Ltd, instructing U.S. port officers to detain shipments of silica-based products made by the company and its subsidiaries.
- The U.S. Congress passed the Uyghur Forced Labor Prevention Act (UFLPA, which presumptively prohibits all products originating in Xinjiang, or produced by companies that participate in certain suspect Chinese government programs, unless an importer can prove that an entity's goods are not produced using forced labor.[35]

China continues to dominate the solar market, and solar components made with slave labor continue to flow out of Xinjiang. Companies should implement robust, transparent, and well-documented tracking protocols and disclosures to ensure and prove the components they use have not been produced using forced labor or in regions where these abuses are rampant.

The Need for Supply Chain Traceability

This need is underscored by the danger here of "supply chain washing," i.e. attempts by suppliers to avoid the UFLPA and other trade restrictions by routing materials and products tainted by forced labor through intermediary countries.[36] Robust tracing protocols (including artificial intelligence, digital tags, and molecular signatures for minerals) can help companies avoid the kind of supply-chain-wide disasters that have befallen the industry before, including a 2022 incident in which Chinese solar manufacturers dodged tariffs by sending polysilicon wafers and other materials[37] to be assembled into solar cells and modules in Cambodia, Malaysia,

32 https://www.greenbiz.com/article/renewables-are-exacerbating-modern-slavery-how-businesses-can-act
https://www.hrw.org/news/2021/11/24/mass-surveillance-fuels-oppression-uyghurs-and-palestinians
https://www.nottingham.ac.uk/news/solar-the-energy-of-freedom-or-a-driver-of-modern-slavery
https://www.dol.gov/sites/dolgov/files/ILAB/images/storyboards/solar/Solar.pdf
https://www.business-humanrights.org/en/latest-news/usa-senate-passes-bill-to-ban-xinjiang-imports-unless-products-proven-not-made-with-forced-labour/
https://www.nytimes.com/2023/08/01/business/economy/solar-xinjiang-china-report.html
https://www.csis.org/analysis/dark-spot-solar-energy-industry-forced-labor-xinjiang

33 https://www.dol.gov/sites/dolgov/files/ILAB/child_labor_reports/tda2021/2022-TVPRA-List-of-Goods-v3.pdf

34 https://www.cbp.gov/newsroom/national-media-release/department-homeland-security-issues-withhold-release-order-silica

35 https://www.cbp.gov/trade/forced-labor/UFLPA
https://www.fticonsulting.com/insights/articles/us-solar-supply-chain-legislation-complex-road-ahead

36 https://www.interos.ai/mapping-the-solar-panel-supply-chain-is-key-to-avoiding-forced-labor-risks/

37 https://www.canarymedia.com/articles/solar/will-the-biden-administration-let-one-company-kill-us-solar
https://www.morganlewis.com/blogs/powerandpipes/2023/02/how-responsible-labor-and-trade-issues-affect-the-solar-energy-industry

Thailand and Vietnam, sending "shockwaves"[38] across the solar industry.

Effective supply chain tracing capabilities will also soon be essential to avoid lockout from major markets, particularly the EU, and to remain resilient and competitive in the U.S.:

- In April 2024, European Parliament approved the final text of the Corporate Sustainability Due Diligence Directive (CSDDD), which requires large companies to actively monitor and address human rights and environmental risks throughout their supply chains.
- In August 2022, the U.S. Inflation Reduction Act (IRA) was enacted, including the Manufacturing Production Tax Credit (45X MPTC).[39] For products manufactured in US factories to qualify for the credit, developers must analyze the origin of all parts and materials used to make them.[40]

Staying ahead of these regulations will require companies to have a comprehensive and documented grasp of their supply chains from top to bottom. Companies and investors need to be able to identify and mitigate human rights abuses connected to their businesses and suppliers.

- Irresponsible and exploitative business practices can disrupt supply chains by prompting workers and affected communities to mobilize against projects through community opposition and litigation[41]
- New legislation such as the EU's CSDDD will oblige companies to show they have conducted meaningful human rights and environmental due diligence throughout their supply chains in order to access European markets
- In the U.S., the failure to adopt effective tracing mechanisms will lead to the loss of financial incentives, such as those enacted by the IRA
- Evidence that forced labor is practiced in a certain area can lead to supply routes being effectively shut down, as with the passage of the Uyghur Forced Labor Prevention Act (UFLPA).

38 A determination of this kind of duty circumvention typically leads to the immediate imposition of tariffs on imports from the offending countries. Given the U.S. solar industry's reliance upon these imports, however, the Biden Administration imposed a two year moratorium on new tariffs to allow U.S. solar companies to find alternative supply routes. The moratorium expired in June 2024, around the same time that the Biden Administration imposed major new tariffs on Chinese imports of solar cells and other renewable technologies. Limiting foreign solar imports through tariffs can be beneficial as the solar sector works to build out domestic supply chains. However, suddenly shutting down critical supply routes would have forced solar companies into a last-minute scramble for substitute materials in a market that is not yet able to meet demand.
https://spectrumnews1.com/oh/columbus/news/2024/06/10/solar-manufacturing-import-asia
https://www.whitehouse.gov/briefing-room/statements-releases/2024/05/14/fact-sheet-president-biden-takes-action-to-protect-american-workers-and-businesses-from-chinas-unfair-trade-practices/

39 https://www.energy.gov/eere/solar/federal-tax-credits-solar-manufacturers

40 https://www.projectfinance.law/publications/2023/may/domestic-content-bonus-credit/
https://www.energy.gov/eere/solar/federal-tax-credits-solar-manufacturer

41 https://ccsi.columbia.edu/sites/default/files/content/pics/publications/Business-Guide-Respecting-Community-Rights-Wind-Solar-Project-Deployment.pdf

Toxic Chemicals in Solar Supply Chains

The environmental and health impacts of unrestricted toxic chemical production have become increasingly well-understood, leading to the proliferation of hazard-based regulations for chemicals of concern.

Across all industrial sectors, companies that fail to proactively advance safer chemical management will face material risks, including increased regulatory oversight, greater penalties, and larger cleanup costs. Where regulatory oversight remains lacking, community opposition to projects involving the use of potentially harmful chemicals may disrupt operations and could lead to litigation.

Decades of largely unregulated use of chemicals in products has created a crisis of chemical pollution on par with climate change and biodiversity loss.[42] Toxic products[43] present risks to the workers who produce them and the consumers who use them, as chemicals leach into water and air during production and product disposal. The financial impacts associated with chemical exposures worldwide likely exceed $11 trillion, or 10% of global gross domestic product (GDP).[44]

Business Risk

42 https://www.cleanproduction.org/resources/entry/iehn-blog-april-20-2023
https://pubs.acs.org/doi/full/10.1021/acs.est.1c04158
https://chemicalfootprint.org/resources/entry/6th-cfp-report

43 https://ehjournal.biomedcentral.com/articles/10.1186/s12940-017-0340-3

44 Grandjean, P., Bellanger, M. "Calculation of the disease burden associated with environmental chemical exposures: application of toxicological information in health economic estimation." Environmental Health 16, 123 (2017). Accessed 6/2/24 at https://ehjournal.biomedcentral.com/articles/10.1186/s12940-017-0340-3

Enhanced understanding of the risks of using and disposing of harmful chemicals has led to increased public and regulatory scrutiny of companies. They are under pressure to disclose the extent of their use and reliance upon toxic chemicals, mitigate impacts on workers, consumers, and the environment, and substitute safer alternatives for toxic substances. For instance:

- 39 U.S. States have adopted some 350 policies to protect people from a wide range of toxic chemicals as of May 2024[45]; among these are environmental justice laws intended to reduce the disparity of exposure to toxic chemicals.
- The U.S. Environmental Protection Agency (EPA)[46] has finalized a series of rules[47] intended to reduce exposure to Per- and Polyfluoroalkyl Substances (PFAS), including a rule requiring companies to disclose all PFAS as well as their uses and levels in any products the companies have manufactured or imported since 2011.
- The EU's Chemical Strategy for Sustainability,[48] part of the European Green New Deal, sets forth an action plan including an increase from around 2,000 restricted chemicals to nearly 7,000,[49] a plan to entirely phase out PFAS,[50] and heightened disclosure requirements on chemical hazards across the value chain.

Like all industries, the solar sector is exposed to the risks of continuing to use toxic chemicals in a tightening regulatory environment.

45 https://www.saferstates.org/bill-tracker/?toxic_chemicals=All

46 https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/tsca-section-8a7-reporting-and-recordkeeping

47 https://www.epa.gov/pfas/key-epa-actions-address-pfas

48 https://echa.europa.eu/hot-topics/chemicals-strategy-for-sustainability
https://environment.ec.europa.eu/strategy/chemicals-strategy_en

49 https://eeb.org/the-great-detox-largest-ever-ban-of-toxic-chemicals-announced-by-eu/

50 https://static1.squarespace.com/static/633b3dd6649ed62926ed7271/t/647f598d5078a921e5283313/1686067597527/V1+SustainableChemistryInvestmentCase.pdf

As the new rules are rolled out, companies that fail to proactively map and disclose their chemical usage, and to invest in the use of safer materials, will be at a competitive disadvantage.

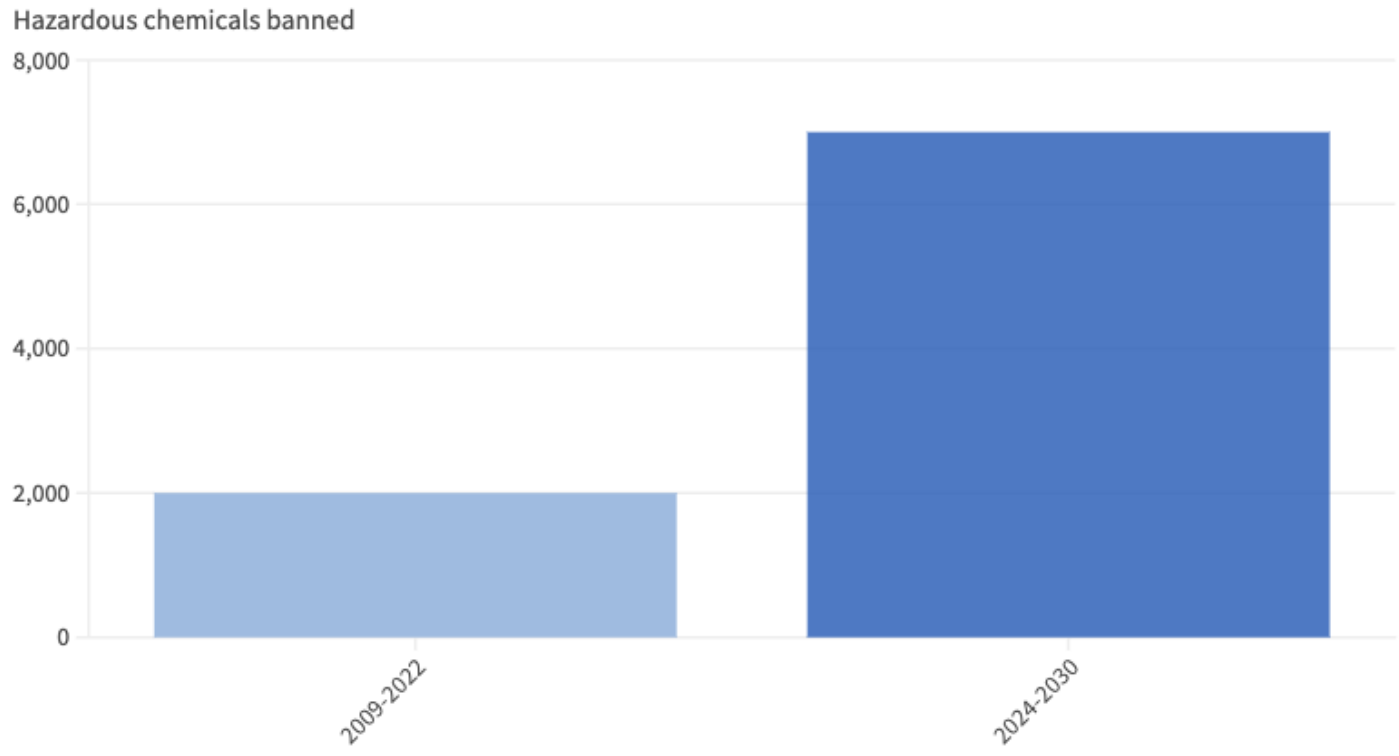
Most solar panels are crystalline-silicon photovoltaic cells, containing a crystal silicon structure. Other types of solar panels under development or entering the market include:

- **Perovskite solar cells**, most of which require numerous chemicals, such as lead and solvents to manufacture.
- **Cadmium-telluride (CdTe)** thin solar technology from some solar companies, including First Solar; lead and cadmium can lead to adverse health impacts.

The deployment of these substances poses potential for worker exposure to toxic chemicals in the supply chain, chemical releases from installed solar arrays,[51] and leaching into the water supply during end-of-life management and disposal of solar panels.

300% increase in chemicals targeted for restrictions

Based on proposed regulations from the Chemical Strategy for Sustainability, part of the European Union's Green Deal



Sources: European Environmental Bureau https://eeb.org/the-great-detox-largest-ever-ban-of-toxic-chemicals-annouced-by-eu/

51 SEC Solar Letter (11 June 2021)

Hazardous Chemicals Used in Silicon Solar Panels[52]

CHEMICAL	DOT HAZARDOUS CLASSIFICATION	CRITICAL EFFECTS
Aluminum	Not classified as hazardous	Respiratory and neurological effects
Ammonia	Toxic gas	Irritation and burns to skin and eyes with possible eye damage; nose, throat, and lung irritation; coughing, shortness of breath, pulmonary edema; possible asthma-like allergy that can lead to lung damage
Ammonium flouride	Poisonous material	Irritation, burns, cough, wheezing, nausea, vomiting, loss of appetite, nosebleeds; fluorosis; high exposure can cause stomach pains, weakness, convulsions, collapse, death
Argon gas	Non-flammable gas	Irritation and burns to skin and eyes; headache, rapid breathing, dizziness, confusion, tremors, lightheaded, loss of coordination and judgment; nausea, vomiting, unconsciousness, coma, death
Arsine	Toxic gas	Inhalation can be fatal
Boron bromide	Corrosive chemical	Irritation, burns, cough, shortness of breath, pulmonary edema, bronchitis; may affect the nervous system

52 https://www.solarindustrymag.com/online/issues/SI1309/FEAT_05_Hazardous_Materials_Used_In_Silicon_PV_Cell_Production_A_Primer.html
https://www.ecfr.gov/current/title-49/subtitle-B/chapter-I/subchapter-C/part-172/subpart-B/section-172.101
https://web.doh.state.nj.us/rtkhsfs/factsheets.aspx?lan=english&alph=A&carcinogen=False&new=False
https://handbook.cganet.com/monographs/Diborane
https://www.atsdr.cdc.gov/pfas/health-effects/index.html
https://www.epa.gov/system/files/documents/2024-04/pre-publication_final-rule-cercla-pfoa-pfos-haz-sub.pdf

Boron trichloride	Corrosive chemical	Irritation, burns, cough, shortness of breath, pulmonary edema, bronchitis; may cause kidney and/or liver damage; high exposure can cause seizures, convulsions, depression, coma, death
Copper catalyst	Environmentally hazardous material	Irritation and burns to skin and eyes with possible eye damage; nose and throat, irritation; can cause a sore and/or hole in the septum; nausea, vomiting, diarrhea, abdominal pain, headache; metal fume fever; skin allergy; may cause kidney and/or liver damage
Diborane	Gas poisonous by inhalation	Irritation and burns to skin and eyes; nose and throat irritation; nausea, vomiting, tremor, confusion; lung irritation, pulmonary edema; may cause kidney, liver, and/or nervous system damage
Ethyl acetate	Flammable liquid	Irritation to the skin, eyes, nose, and throat; dizziness, lightheadedness, passing out; drying and cracking of the skin; liver and/or kidney damage
Hydogen peroxide	Oxidizer	Mutagen; Irritation and burns to skin and eyes with possible eye damage; nose and throat irritation; headache, dizziness, nausea, vomiting; lung irritation, pulmonary edema
Hydrochloric acid	Corrosive substance	Can cause severe skin burns and eye damage
Hydrogen	Extremely flammable gas	Suffocation with symptoms of headache, dizziness, weakness, loss of coordination and judgment, loss of consciousness, death

Hydrogen flouride	Acute toxicity	Highly toxic; can cause severe skin burns and eye damage
Isopropyl alcohol	Flammable liquid	Irritant to eyes and respiratory tract
Lead	Toxic substance	Neurotoxin, harmful to nervous system
Nitric acid	Oxidizing substance	Can cause severe skin burns and eye damage
Nitrogen	Non-flammable gas	Dizzy, lightheaded, loss of consciousness, death
Oxygen	Non-flammable gas	Reproductive damage; mutations; nausea dizziness, muscle twitching, vision loss, convulsions, loss of consciousness; lung irritation, coughing, shortness of breath, pulmonary edema
Per- and polyfluoroalkyl substances (PFAS)	Perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS), including their salts and structural isomers, are classified as “hazardous substances”	Increases in cholesterol levels (PFOA, PFOS, PFNA, PFDA); lower antibody response to some vaccines (PFOA, PFOS, PFHxS, PFDA); changes in liver enzymes (PFOA, PFOS, PFHxS); pregnancy-induced hypertension and preeclampsia (PFOA, PFOS); small decreases in birth weight (PFOA, PFOS); Kidney and testicular cancer (PFOA)
Phosphine	Toxic gas	Inhalation can be fatal
Phosphorous	Flammable and reactive	Irritation and burns to skin and eyes with possible eye damage; lung irritation, coughing, shortness of breath, pulmonary edema; may cause kidney and/or liver damage

Phosphorous oxychloride	Corrosive chemical; Poison inhalation hazard	Irritation and burns to skin and eyes with possible eye damage; nausea, vomiting, headache, dizziness, loss of appetite, lung irritation, coughing, shortness of breath, pulmonary edema; may cause kidney damage
Phosphorous trichloride	Corrosive chemical	Danger to eyes, lungs, and skin; may cause kidney and/or liver damage
Potassium hydroxide	Corrosive chemical	Danger to eyes, lungs, and skin
Silane gas	Extremely flammable gas	Explosive; potential danger to workers and communities
Silicon tetrachloride	Corrosive substance	Causes skin burns; respiratory, skin, and eye irritant
Silver	Not classified as hazardous	General irritant and allergen
Sodium hydroxide	Corrosive substance	Danger to eyes, lungs, and skin
Stannic chloride (Stannic chloride hydrated)	Corrosive chemical	Irritation and burns to skin and eyes with possible eye damage; nose and throat irritation, coughing, wheezing
Sulfur hexafluoride	Non-flammable gas	Potential greenhouse gas; respiratory hazard
Sulfuric acid	Corrosive substance	Can cause severe skin burns and eye damage
Tin	Corrosive chemical; Poison inhalation hazard	Irritation and burns to skin and eyes with possible eye damage; nausea, vomiting, diarrhea, abdominal pain, headache, fatigue, tremors; lung irritation, coughing, shortness of breath, pulmonary edema stannosis; may cause liver and/or kidney damage; may cause damage to the nervous system

Increased Regulations for Disposal

Solar panels have a life span of around 20 to 30 years,[53] and as the solar market continues to grow, so will the volume of end-of-life panels. In recognition of this mounting concern, regulators are instituting stronger regulations.

- Under the U.S. Resource Conservation and Recovery Act (RCRA), certain solar panels qualify as hazardous waste and are subject to heightened regulations.[54]
- States including California[55] have already added solar panels to their universal waste management regulations, and more are expected to follow.
- In Europe, solar panels are no longer exempt from the Waste from Electrical and Electronic Equipment (WEEE) Directive,[56] a law that makes companies responsible for the collection, treatment, recycling, and recovery of their products.
- The EU Restriction on Hazardous Substances in Electrical and Electronic Equipment (RoHS) Directive[57] restricts the use of lead, cadmium, and many other hazardous substances in electrical and electronic equipment; while certain photovoltaic products have received exemptions, these may be lifted in the near future.

Companies that institute safe and effective disposal policies will get ahead of these regulations. Investors aware of the evolving regulatory environment can ensure that their companies are well placed to comply with regulatory requirements and the elimination of solar waste exemptions they may have previously relied upon.

53 https://www.epa.gov/hw/end-life-solar-panels-regulations-and-management

54 https://www.epa.gov/hw/end-life-solar-panels-regulations-and-management

55 https://dtsc.ca.gov/photovoltaic-modules-pv-modules-universal-waste-management-regulations/

56 https://environment.ec.europa.eu/topics/waste-and-recycling/waste-electrical-and-electronic-equipment-weee_en

57 https://environment.ec.europa.eu/topics/waste-and-recycling/rohs-directive_en

A failure to be proactive can compound the risk of community opposition and legal liabilities. As an example, when a large solar development project in Virginia (likely to be serviced by First Solar) was opposed by many local stakeholders, the county planning commission recommended that no cadmium-telluride (CdTe) panels be used, and that the installer fund a $36 million bond to cover the cost of cleanup and decommissioning at the end of the solar farm's life. Although these recommendations were ultimately reduced, investors should understand the evolving standards and fierce opposition from local communities.[58]

Safer Solutions are Possible

History is filled with proof that companies can transition away from harmful chemicals with the appropriate incentives, regulations, and processes:

- Despite offering improved performance, leaded gasoline was phased out in the U.S. in 1996 due to health concerns.
- Following pressure from consumers and NGOs, significant limits were placed on how computer chip manufacturers could use trichloroethylene (TCE), a solvent linked to miscarriages, congenital disabilities, and cancer.[59]
- Launched in partnership with Apple, the GreenScreen Certified® for Cleaners & Degreasers in Manufacturing program set a new safety standard for the electronics sector with certified safer solvents.

Companies can adopt multi-faceted and comprehensive approach to chemical management by establishing chemical management policies, reducing their use of chemicals of concern, investing in safer solutions, and committing to enhanced transparency to build trust and stay competitive.[60] Third-party tools are available to aid companies in this journey, such as:

- The Chemical Footprint Project Survey enables companies to assess progress and identify areas of improvement.
- The GreenScreen for Safer Chemicals, a comparative hazard assessment protocol, helps companies replace or reduce exposure to chemicals in their products that have the potential to harm human health.[61]

58 SEC Solar Letter (11 June 2021)

59 Quinn, A. "To 'Win the Future,' the U.S. Needs a Semiconductor Industry That Learns From the Past." Time.com, January 3, 2024. Accessed 6/2/24 at https://time.com/6333723/semiconductor-history-chips-act/

60 https://www.cleanproduction.org/resources/entry/iehn-blog-april-20-2023

61 https://www.pbs.org/newshour/science/pfas-are-everywhere-what-can-we-do-to-change-that

Case Example

PFAS (“Forever Chemicals”)

As public pressure mounts and new rules are introduced, companies will face increased legal exposure from any harm caused by their products and processes. Recent high-profile examples involving PFAS demonstrate how expensive it can be to be reactive instead of proactive in managing avoidable chemical pollution risk.

Per- and polyfluoroalkyl substances (PFAS), known as the “forever chemicals,” have contaminated the entire planet and been found in areas as remote as the Himalayas. Exposure to PFAS is associated with cancer, liver damage, decreased fertility, and increased risk of asthma and thyroid disease,[62] and their overall use continues to increase rapidly.[63]

Manufacturers and downstream users of PFAS are facing significant and growing liabilities due to the chemical’s environmental persistence and toxicity to human health. In June 2023, chemical manufacturer 3M reached a $10 billion settlement with over 300 U.S. public drinking water systems over PFAS contamination levels. In 2023, 3M announced that it would end all PFAS production by year-end 2025, but its delay in addressing harms and adopting safer substitutes for its PFAS product portfolio is likely to continue to cost the company.

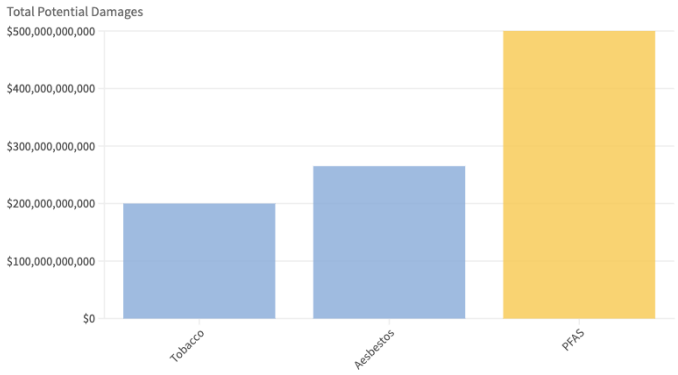
62 https://www.pbs.org/newshour/science/pfas-are-everywhere-what-can-we-do-to-change-that
https://static1.squarespace.com/static/633b3dd6649ed62926ed7271/t/647f598d5078a91e5283313/1686067597527/V1+SustainableChemistryInvestmentCase.pdf
Bonato, M. et al. PFAS Environmental Pollution and Antioxidant Responses: An Overview of the Impact on Human Field. Int
J Environ Res Public Health. 2020. https://doi.org/10.3390%2Fijerph17218020

63 https://www.theguardian.com/lifeandstyle/article/2024/may/25/can-i-eradicate-toxic-forever-chemicals-from-my-home

UBS estimates that the total market capitalization of companies who will be impacted by PFAS regulations is an estimated US $30 trillion. Lawyers predict that lawsuits over forever chemicals such as PFAS "could dwarf asbestos litigation...."[64] Moreover, PFAS comprise an extremely wide and varied class of chemicals, not all of which have yet been subjected to in depth studies and whose effect on human health and the environment is not yet known.

"Prepare for a wave of lawsuits with potentially 'astronomical' costs..."

"...the coming litigation could 'dwarf anything related to asbestos'"



Sources: https://time.com/6292482/legal-liability-pfas-chemicals-lawsuit/, https://www.nber.org/digest/jul04/asbestos-and-future-mass-litigation, https://www.nytimes.com/2024/05/28/climate/pfas-forever-chemicals-industry-lawsuits.html

PFAS in the Solar Industry

Solar and other clean energy companies are susceptible to these risks.[65] The class of PFAS chemicals most relevant to the industry are fluoropolymers, which are sometimes used in solar panel coatings, wind turbines, lithium-ion batteries, and other clean energy technologies.[66] While some newer solar panels are increasingly being made with safer substitutes to PFAS, the practice is not yet uniform.

- Over the past year, the EPA has rolled out an array of new rules to strengthen governmental oversight of the use and disposal of PFAS and expand reporting requirements. These include the rule[67] referenced previously, which will require companies to disclose the full extent of PFAS substances used in their products dating back to 2011; rules adding certain PFAS to the Toxics Release Inventory (TRI)[68] and designating other PFAS as hazardous substances[69]; and many others.[70]
- According to Safer States,[71] 28 U.S. states have adopted 142 policies intended to protect people from PFAS, while a total of 297 policies have been introduced in 34 states. These include laws recently passed in Maine[72] and Minnesota[73] outlawing the production and

64 https://www.nytimes.com/2024/05/28/climate/pfas-forever-chemicals-industry-lawsuits.html

65 https://graham.umich.edu/media/pubs/Facts-about-solar-panels--PFAS-contamination-47485.pdf
https://www.ourherald.com/articles/vermonts-soaring-solar-spree-is-trickier-than-you-think/

66 https://www.crowell.com/a/web/5DJWjYcyJvSsRqddEQQc2M/clean-energy-cos-must-pay-heed-to-pfas-crackdown.pdf

67 https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/tsca-section-8a7-reporting-and-recordkeeping

68 https://www.epa.gov/toxics-release-inventory-tri-program/addition-certain-pfas-tri-national-defense-authorization-act

69 https://www.saferstates.org/bill-tracker/?toxic_chemicals=All

70 https://www.epa.gov/pfas/key-epa-actions-address-pfas

71 https://www.saferstates.org/priorities/pfas/

72 https://www.maine.gov/dep/spills/topics/pfas/PFAS-products/

73 https://www.pca.state.mn.us/get-engaged/pfas-in-products

use of all PFAS substances with only narrow and temporary exemptions.[74]

PFAS regulations are blanketing the market, and companies that continue to use PFAS will inevitably run into regulatory restrictions. It is essential for companies to get ahead of these regulations now by understanding and documenting the role PFAS play in their products and manufacturing processes and exploring all options for replacing PFAS with safer substitutes.

Increasingly, PFAS-free alternatives are viable renewable energy technologies. Companies are at risk if they rely upon product exemptions, even where the use is "currently unavoidable." At the rate at which technology and the regulatory environment is evolving, proactively transitioning towards safer substitutes may ultimately be a more cost-effective risk management strategy than using an exemption that may expire on an unpredictable timeline. Regulatory exemptions will also not protect solar companies from potential personal injury or environmental litigation. Investors can track company efforts in this area to ensure that they are taking these necessary steps.

Are PFAS Essential in Clean Energy Technologies?

Ariana Spentzos, PhD; Lydia Jahl, PhD; Arlene Blum, PhD. Green Science Policy Institute

Lithium-Ion Batteries

Uses

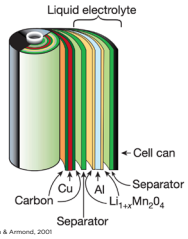


Image courtesy of Tarascon & Armond, 2001

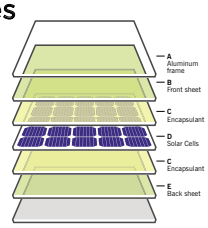
- Cathode binder typically PVDF or PVDF copolymers (PVDF-HFP, PVDF TrFE); can contain PTFE; some separators are PVDF[1]
- Electrolyte salts & additives are often PFAS, e.g. Li-triflate, LiTFSI and LiBETI; additive F-EPE[2]
- Valves, gaskets, and separators commonly FKM, PTFE, or FEP[2]

Alternatives

- Multiple binder-free options
- Commercially available drop-in electrode replacements with high energy density based on nanocarbon mesh with polymeric additives
- Some liquid electrolytes are PFAS-free
- Hydrocarbon-based gasket materials commonly used

Solar Panels

Uses



PFAS may be found in[3]:

A)Aluminum frame: FEVE or fluoropolymers
B) Front sheet: ETFE, ECTFE, FEP
C) Encapsulant: PVDF, ETFE
E) Back sheet: PVF, PVDF, ECTFE, ZEFFLE, a polymer of TFE, HFP, and VDF

Alternatives

- Fully PFAS-free commercially available PV modules contain backsheets made with UV-resistant polypropylene
- Front sheets also made of polypropylene with mechanical stability from backplate
- Ethylene octene copolymer based encapsulant with lower degradation risk[4]

Ion Exchange Membranes

Uses

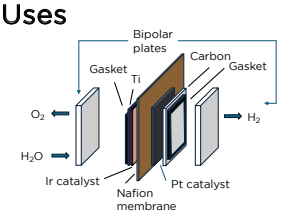


Image adapted from Rivera et al., 2018

- Nafion®, Aquivion® and similar perfluorosulfonic acids (PFSAs) used in hydrogen systems as membranes, ionomer (active catalyst binder)[5]
- Gas diffusion layers often use PTFE as a binder & hydrophobic agent[6]
- Gaskets fluoroelastomers (Viton)
- PTFE used in diaphragms & valves[6]

Alternatives

- Commercially available non-PFSA membrane materials with higher chemical and thermal stability include fully polyphenylene sulfonic acids
  - Inherently stable to oxidation
  - Long lifetime
  - Reinforcement material replacement for ePTFE includes electrospun PBI-type materials[6]

Refrigerant Gases

Uses

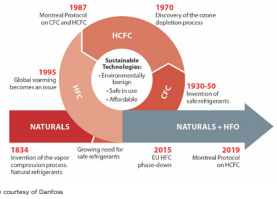


Image courtesy of Danfoss

- Many HFOs found to degrade into TFA (trifluoroacetic acid)[7] or into high GWP chemicals[8] TFA levels in the environment have increased recently and it is widely detected in people and the environment[9]
- F-gases responsible for over 60% of annual PFAS emissions[10]

Alternatives

- Natural refrigerants (CO_2, ammonia, hydrocarbons)
  - CO_2 already in use for supermarket refrigeration[11]
  - Propane and CO_2 used in EU heat pumps
  - Beginning to see propane used for vehicle heating and cooling in EU[12]
  - Wide adoption in transport and cold warehouse refrigeration[11]

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1. Rensmo, A. et al. Environ. Sci. Processes Impacts, 2023
2. ZVEI, Factsheet PFAS in Batteries, 2023
3. Green Science Policy Institute, PFAS in Building Materials
4. Sabic, Plastindia 2023
5. ChemSec, PFAS Alternatives Webinar, 2023
6. Hydrogen Europe Position Paper on PFAS, 2023
7. Joudan, S. Environ. Sci.: Processes Impacts, 2021
8. Salierno, G. ChemSusChem , 2024
9. Salamova and coworkers, Environ. Sci. Tech., 2023
10. ChemSec, 2024
11. ASHRAE Position Document on Natural Refrigerants, 2009
12. Hydrocarbons21, ATMO Europe: Rheinmetall Develops R290 E-Compressor and Heat Pump Module for Electric Vehicles, 2023

Policy Implications

- PFAS-free alternatives exist across all sectors
- False choice between climate goals and PFAS phaseout
- Lifecycle impacts must be considered
- Time unlimited exemptions not needed
- Funding needed to support broader implementation and scale up

74 https://www.maine.gov/dep/spills/topics/pfas/PFAS-products/cuu.html
https://www.pca.state.mn.us/get-engaged/pfas-in-products-currently-unavoidable-use

Business Opportunity

Federal Purchasing Power for Responsible Solar (EPEAT)

Companies that move early to manage these risks and vulnerabilities will secure first mover advantages in a tightening regulatory and legal environment. They will also be able to take advantage of growing opportunities for companies that produce environmentally sustainable products, including energy.

Investors can leverage the benefits of the growing purchasing power for responsible renewables including solar. Specifically, investors should be aware of the opportunities available to solar companies that produce environmentally sustainable electronic products in accordance with the Electronic Product Environmental Assessment Tool (EPEAT®).[75] EPEAT was developed initially by the EPA and is managed by the Global Electronics Council (GEC). It is an ecolabel used internationally by institutional purchasers, as well as in the public and private sectors, that identifies eligible products as environmentally sustainable according to an extensive and evolving set of criteria.[76]

75 https://www.epeat.net/about-epeat

76 https://www.epa.gov/greenerproducts/electronic-product-environmental-assessment-tool-epeat

In the U.S., the Federal Acquisition Regulation (FAR) requires that 95% of all electronic product acquisitions be EPEAT-registered products.[77]

Qualifying equipment for the label includes a range of electronics, as well as photovoltaic modules and inverters. EPEAT is the only electronics ecolabel recognized by the US EPA for use by federal government agency purchasers of photovoltaics modules and inverters.[78] Although more than 3,480[79] electronic products are registered with EPEAT, in 2024 only two solar companies, First Solar[80] and Hanwha Qcells,[81] have certified their products to the EPEAT registry—and have therefore benefited from being a first mover to EPEAT registration and disclosure.[82]

The federal government is the largest energy consumer in the United States, and therefore well placed to increase solar energy demand through procurement.

In addition to the government, many purchasing entities require or prefer the presence of the EPEAT eco-label, making demand significantly higher for products that contain such a label.

77 https://www.epa.gov/greenerproducts/electronic-product-environmental-assessment-tool-epeat

78 https://www.epa.gov/greenerproducts/recommendations-specifications-standards-and-ecolabels-federal-purchasing

79 https://www.wifcon.com/discussion/index.php?/blogs/entry/5202-the-electronic-product-environmental-assessment-tool-epeat-lauds-nitaac-for-the-third-year-in-a-row/

80 https://epeat.net/product-details/245713cf9d5d4725ae2db312f541a4a5?backUrl=%252Fpvmi-search-result%252Fpage-1%252Fsize-25

81 https://www.reuters.com/sustainability/first-solar-qcells-panels-score-green-label-preferred-by-us-government-2024-06-04/

82 https://investor.firstsolar.com/news/news-details/2024/First-Solar-becomes-the-Solar-Industrys-First-EPEAT-Climate-Champion-Setting-Global-Standard-for-Ultra-Low-Carbon-Solar/default.aspx

Conclusion

Evidence continues to emerge regarding three critical risks in the solar industry:

- Human rights abuses connected to the extraction and production of key energy transition minerals and solar components
- Public and worker health impacts of PFAS and other harmful chemicals used to manufacture solar panels
- Financial liability, potentially in the billions of dollars, for companies that use these chemicals

In response, lawmakers, civil society, and the public are intensifying the pressure on companies to address and internalize the human and environmental impacts of their operations through chemical footprinting, EPEAT certification, safer chemical alternatives, and other solutions.

Addressing these emerging risks will help sector companies ensure their long-term viability and resiliency, while those that fail to do so may face legal, regulatory, and reputational repercussions.

It is essential that investors understand the vulnerabilities in the solar supply chain and the range of available solutions in order to take full advantage of the myriad opportunities presented by the booming solar industry.

ADDENDUM 1:
Legislation & Regulation Addressing Supply Chain Abuses

United States

- Section 307 of the Tariff Act of 1930 prohibits the importation of any goods made or mined using forced labor, including child labor.
- The Uyghur Forced Labor Prevention Act (UFLPA) presumptively prohibits all products originating in Xinjiang, or produced by companies that participate in certain suspect Chinese government programs unless an importer can prove via clear and convincing evidence that an entity's goods are not produced using forced labor.
- The U.S. Inflation Reduction Act (IRA) includes incentives for the domestic production of renewable energy technologies, including the Manufacturing Production Tax Credit (45X MPTC), which requires qualifying developers to analyze the origin of all parts and materials used to make them.

Europe

- The EU Critical Raw Materials Act expands countries' supply chain monitoring capabilities to prevent goods produced using forced labor and other abuses from entering the EU.
- The Corporate Sustainability Due Diligence Directive (CSDDD) requires large companies to actively monitor, document, disclose and address human rights and environmental risks throughout their supply chains.

ADDENDUM 2:
Legislation & Regulations Addressing Toxic Chemicals

United States

Federal

- The U.S. Environmental Protection Agency (EPA) has finalized rules intended to reduce exposure to PFAS, including by requiring companies to disclose all PFAS in products manufactured or imported since 2011.
- Under the U.S. Resource Conservation and Recovery Act (RCRA) certain solar panels qualify as hazardous waste and are subject to heightened regulations to ensure their safe disposal.
- For the subset of solar panels that qualify as hazardous waste under the RCRA, the EPA is engaged in rulemaking to add solar panels to the universal waste management regulations.

State

- States including California have added solar panels to their universal waste management regulations, and more are expected to follow.
- 39 U.S. states have adopted some 350 policies to protect people from toxic chemicals, including environmental justice laws intended to reduce the disparity of exposure to toxic chemicals.
- 28 U.S. states have adopted 142 policies intended to protect people from PFAS, including laws recently passed in Maine and Minnesota outlawing the production and use of all PFAS substances unless the use of PFAS is "currently unavoidable."

Europe

- The Chemical Strategy for Sustainability sets forth an action plan to ban the most harmful chemicals in consumer products unless their use is “essential” by restricting thousands of chemicals, phasing out PFAS, and requiring disclosure of chemical hazards across the value chain.
- The Waste from Electrical and Electronic Equipment (WEEE) Directive has a takeback policy for electronic and electrical products—including solar panels—making companies responsible for the collection, treatment, recycling, and recovery of their products
- The Restriction on Hazardous Substances in Electrical and Electronic Equipment (RoHS) Directive restricts the use of certain hazardous substances, including lead and cadmium, in electrical and electronic equipment. The current exemption for solar panels is likely to expire in the future.

COLLABORATORY FOR A REGENERATIVE ECONOMY

Let's make a difference, together

For more information about managing environmental and human rights impacts in solar supply chains:

CoRE:
CoREBuffalo.org

Investors for Sustainable Solar:
iehn.org/our-work/investors-for-sustainable-solar