Toxic Chemical Exposure Policy for Semiconductor Manufacturing:

Protecting CHIPS Workers and Fence-Line Communities

Report Prepared By:
Katherine Cohn | *June 2024*

Acknowledgments

Thank you to all of the individuals who generously gave their time to share their expertise and experiences (in alphabetical order): Anonymous (former federal employee close to the development of the CHIPS Act), Charlotte Brody (Blue Green Alliance), Thomas Fox (Center for Environmental Health), Amanda Hawes (Co-Founder of Santa Clara Center for Occupational Health, Project on Health and Safety in Electronics and the Electronics Committee on Safety and Health), Philip Martin (Environmental Defense Fund, TX), Travis Mosier (Center for New American Security), Soji Sajuyigbe (former Research Scientist at Intel), Megan Schwarzman (Berkeley Center for Green Chemistry), Ted Smith (Founder of Silicon Valley Toxics Coalition and co-founder of International Campaign for Responsible Technology), Mary Swanson (Clean Electronics Production Network), David Sonnenfeld (SUNY College of Environmental Science and Forestry), Samantha Wilkinson (former Deputy Director of Texas House Democratic Caucus) and David Wooley (Goldman School of Public Policy Center for Environmental Public Policy).

Thank you to Zane Farr, Etana Jacobi, and Nell Geiser (Communication Workers of America), and Anibel Ferus-Comelo (UC Berkeley Labor Center) for collaborating on this project and providing guidance. Thank you also to Martha Cohn for her incredible accessibility support. Finally, special thanks to Hector Cardenas in his role as capstone advisor for his thoughtful suggestions and input throughout this project.

Executive Summary

A. Introduction

The semiconductor industry has captured the attention of the nation and our Congress. With the computer chip shortage instigating crushing supply chain delays and job losses, and national security concerns around China's advanced chip production, Congress was poised to create the CHIPS Act. However, the industry entails a cost absent from the language of the CHIPS Act: health risks for workers and communities near manufacturing facilities.

Past practices and prioritizing production speed and innovation over worker safety have resulted in documented cases of worker exposure to hazardous chemicals and associated health problems. Non-disclosure agreements and a lack of transparency about chemical use has further obstructed efforts to understand the full picture. Exposure concerns include but are not limited to **physiochemical hazards** such as explosivity; **human toxicity** such as carcinogenicity, endocrine disruption, reproductive and developmental hazards, and neurotoxicity; **ecology toxicity** such as bioaccumulation or aquatic toxicity; **and other workplace hazards** such as radiation. These hazards are serious and threaten people's lives and environmental safety.

This report, commissioned by the Communication Workers of America (CWA) and CHIPS Communities United (CCU), serves as a comprehensive needs assessment, acting as a bridge between historical data and current research findings. By meticulously reassessing past information and incorporating the latest insights, we aim to provide an updated and comprehensive overview of the known health risks posed by potential toxic exposure within semiconductor manufacturing. Our focus is twofold:

- **Synthesizing Existing Knowledge:**
  This report will consolidate available information about the health risks associated with chemical exposures in semiconductor production.

- **Identifying Knowledge Gaps:**
  We will meticulously identify areas where critical information remains elusive, highlighting crucial questions that require further investigation.

By illuminating both what we know and what we still need to learn, this report empowers CWA and CCU to develop well-researched and targeted advocacy strategies.

B. Methodology

This report employs a mixed-methods approach, combining quantitative and qualitative data analysis, to investigate the potential health risks associated with semiconductor manufacturing.

Beyond identifying knowledge gaps, this report includes a best practices assessment guide for identifying safe chemicals with which to replace hazardous ones. This guide provides recommended instructions for CWA and CCU to conduct a survey with a group of experts on best methods for assessing chemical replacements, with the goal of arriving at qualified consensus. Consensus on such an issue will provide meaningful support for advocacy efforts working to prioritize chemical substitution in public policy rather than worker protection or the replacement of human workers with automation.

This study could not directly assess potential risks to workers and communities. Instead, the report relied on existing data sources:

1. **Community Health Needs Assessments:**
   Public health data from counties with major semiconductor facilities was reviewed to gain insights into potential health concerns in these communities.

2. **Literature Review:**
   A comprehensive review of existing research was conducted, focusing on:

   - Scientific studies on health risks associated with specific chemicals used in semiconductor manufacturing processes.
   - Epidemiological and occupational health studies investigating potential links between semiconductor worker exposure and various health outcomes.
   - Public health articles on the ethics, history and case studies of public health policies regulating toxic substances and exposure.

- Academic articles on methodologies for risk assessments, chemical substitution assessments, DELPHI panels, the ethical collection of community health data and the history of United States toxic exposure limit standards.
- Technical publications on the processes of semiconductor manufacturing and use of chemicals at each stage.
- News and journal articles on obstacles to state and federal regulation and enforcement of toxic exposure protections and interagency collaboration.
- Government reports and industry publications on environmental releases, current regulations governing the semiconductor industry, existing guides on protecting from toxic exposure and cleanup of hazardous materials, workforce studies and on the CHIPS Act.
- Archival documents on the activities of past activist groups such as Silicon Valley Toxics Coalition (SVTC) and the Santa Clara Center for Occupational Safety and Health (SCCOSH), including public information campaigns, community health surveys and classes, policy advocacy efforts, primary and secondary sources of evidence of human and environmental exposure to toxins from the semiconductor facilities, and more.

3. **National Workplace Illness and Injury Data:**
   Data from the Bureau of Labor Statistics (BLS) was used to compare illness rates in semiconductor manufacturing to other industries. This analysis revealed a higher proportion of illnesses among semiconductor workers compared to workers in similar sectors.

4. **National Population Data:**
   Data from the U.S. Census Bureau's American Community Survey (ACS) was used to identify the demographic breakdown of semiconductor manufacturing workers. Unfortunately, the data is limited. It only addresses electronic component manufacturing, and does not offer demographic breakdown within specific occupations or states.

5. **Ethical Considerations**

   a. **Data Availability:**
      Incomplete or inaccessible data sets from some government agencies and companies posed a challenge and also raised alarms as to why data is inaccessible or absent. This signals the urgent need for improved transparency and data collection practices.

   b. **National Population Data:**
      The report acknowledges the importance of collecting health equity data directly from workers and communities. However, such data collection was beyond the scope of this study. The collection of this data is recommended as a high priority next step in future research, and resources for planning and implementing the collection are provided in Section V and Appendix G.

C. Findings

The health risks associated with semiconductor manufacturing stem from exposure to a wide range of hazardous chemicals used throughout the complex fabrication process. Exposure to a vast array of hazardous chemicals during various stages of the fabrication raises concerns about both acute and chronic health effects. The report explores the current understanding of these risks, limitations in measuring their impact, and the need for new policies to protect workers and communities. The report's investigation is structured as follows:

- Following the introduction in **Section I,**
- **Section II** reviews the political events that led to the crafting of the CHIPS Act, its lack of reference to potential toxic exposure risks to workers or environment, the importance of the National Institute for Science and Technology's draft Programmatic Environmental Assessment and its shortcomings.
- **Section III** provides an overview of the steps inherent to fabricating a chip, and the chemical hazards present at each stage.
- **Section IV** lays out what we currently know about the risk of exposure to workers and fence-line communities, what we don't know and why we don't know more.
- **Section V** provides a detailed analysis of why toxic exposure standards today are insufficient, what agencies are involved, what regulations currently exist and contemporary gaps in policies around toxic exposure.
- **Section VI** discusses the debate around the best public policy for toxic exposure, and provides a recommendation for how to conduct a survey with experts to help find consensus on the best method for picking safe chemicals with which to replace hazardous ones in the industry.

- **Section VII** presents a summary of the current unmet needs revealed through the investigation, and a list of policy considerations for CWA and CCU as they prepare their advocacy efforts.
- The Conclusion in **section VIII** includes a summary of this report's limitations, and recommendations for future research.

Throughout this report's inquiry, a number of key findings surfaced:

- **Data Landscape Obstruction and a Lack of Transparency Threaten Lives**
  This isn't a passive issue; it's a direct consequence of obstruction by the industry, particularly under the guise of trade secrets. This lack of transparency threatens the lives and well-being of workers by hindering our ability to identify and mitigate potential health hazards.

- **A Broken Regulatory System Leaves Workers Vulnerable**
  The sheer number of standards and the involvement of a plethora of federal and state agencies with conflicting interpretations create a convoluted and ineffective system. California's case study offers one example of the problems plaguing the current regulatory system. While the state has implemented stricter standards than federal regulations, understaffing and ineffective management impede enforcement efforts, leaving workers vulnerable.

- **A Legacy of Political Maneuvering: Standards Failing to Protect People**
  The historical development of these regulations reveals a disturbing truth: Political considerations often trump worker safety. This has resulted in a muddled system of standards and policies that fail to adequately protect workers and communities. The accidental collusion between agencies and the lack of leadership from Congress have created a situation where loopholes and outdated standards leave the safety of the people falling through the cracks.

- **Under-equipped Agencies and Inadequate Protections**
  Federal agencies like the EPA are ill-equipped to handle the task of monitoring and assessing chemical toxicity. This has led to situations where chemicals are deemed safe based on inadequate assessments, further jeopardizing worker health. OSHA's existing exposure limits are outdated and inadequate, failing to reflect current health risks. The lack of enforceable limits further weakens worker protections. OSHA's own website acknowledges this, stating that many of their limits are insufficient for ensuring worker safety.

- **Conflicts of Interest and Outdated Practices**
  The standard-setting process itself is riddled with issues. The lack of transparency and the presence of industry representatives on committees create conflicts of interest, threatening to prioritize industry interests over worker safety and thereby destroy the integrity, not to mention the effectiveness, of standards.

- **Environmental Concerns with the CHIPS Act**
  Several classes of chemicals used in semiconductor manufacturing pose significant risks to the environment as well. The potential bypassing of NEPA environmental assessments for CHIPS Act-funded facilities raises serious concerns. Prioritizing speed over environmental safety could have lasting negative consequences for communities surrounding these facilities.

- **Urgent Need for Congressional Action and a Systemic Overhaul**
  The findings presented in this section paint a stark picture of a system failing to protect workers and communities. Congressional support is crucial to reforming OSHA regulations and establishing enforceable exposure limits based on current health science. Furthermore, a complete overhaul of the standard-setting process is necessary to eliminate conflicts of interest and ensure transparency. The lack of leadership and the dysfunctional procedures within federal agencies require immediate attention. Only through comprehensive reform and a commitment to worker and community health can we create a safer and more sustainable future for the semiconductor industry.

Following is a more detailed review of the findings as they arose throughout sections of the report.

1. **CHIPS Act**
   As addressed in Section II, The CHIPS Act aims to incentivize domestic semiconductor production in the United States. While this initiative is crucial for national security and economic competitiveness, without improved regulations, the growth of the industry also increases the risk of worker and community exposure to hazardous chemicals. Here's a breakdown of potential concerns based on findings:

   a. **Increased Production, Increased Exposure:**
      As production ramps up, the number of workers potentially exposed to hazardous chemicals will likely rise. This necessitates stricter regulations and enforcement mechanisms to ensure worker safety.

   b. **Focus on Speed over Safety:**
      In the rush to meet production goals, prioritizing speed over safety procedures could lead to increased health risks for workers. Precautions that may take more time to implement long-term are necessary.

   c. **Geographic Considerations:**
      The CHIPS Act may incentivize production in states with less stringent environmental regulations. This could exacerbate health risks for communities residing near new facilities. Uniform national regulations for worker safety and environmental protection are crucial.

   d. **Worker Safety:**
      Regulations should mandate clear worker training, safety protocols, personal protective equipment (PPE) requirements and comprehensive health monitoring programs for semiconductor workers.

   e. **Environmental Protection:**
      National regulations should address air and water pollution concerns associated with semiconductor manufacturing facilities. These regulations should set clear standards for emissions and require facilities to implement best practices for waste management.

   f. **Strong NIST PEA:**
      Ensuring a strong NIST Programmatic Environmental Assessment (PEA) for the CHIPS Act is critical. A robust PEA can establish a framework for data collection and risk assessment that would otherwise be difficult due to trade secret restrictions. This information is essential to put precautions into effect that federal agencies may otherwise not be in a position to implement quickly, such as:

      - **Mandating** companies to track and report chemical use and emissions.
      - **Developing** exposure limits and safety protocols specific to the semiconductor industry.

2. **Known Risks and Measuring Risk**
   Research has documented a range of health risks associated with exposure to chemicals used in various stages of semiconductor manufacturing, as discussed in Section III. These potential risks can be categorized into several areas, impacting different bodily systems and presenting both acute and chronic health effects.

   Measuring these risks presents several challenges, as discussed in Section IV:

   a. **Secrecy in Settlements:**
      Many lawsuits related to toxic exposure are settled with non-disclosure agreements. This prevents valuable data on worker health outcomes from being shared publicly, hindering our understanding of the risks.

   b. **Focus on Past Hazards:**
      Much of the existing research on health risks is from studies conducted decades ago. While the findings in these studies are no less powerful today than they were when first published, they may not reflect all of the chemicals and processes used in today's semiconductor manufacturing.

   c. **Lack of Transparency by Companies:**
      Companies might not be fully aware of the health risks associated with every chemical they use in their production processes, or they may be intentionally obfuscating. Limited transparency makes it difficult to assess and manage these risks effectively.

Beyond worker health, semiconductor manufacturing facilities pose potential health risks to surrounding communities. These risks emanate from potential air and water pollution:

a. **Air Emissions:**
Chemicals used in the manufacturing process can be volatile and may be released into the air during various stages. Inadequate air pollution control systems can expose nearby communities to these hazardous chemicals. Residents may experience respiratory problems and other health issues.

b. **Water Discharges:**
Semiconductor manufacturing uses large quantities of water, which becomes contaminated with hazardous chemicals during cleaning and etching processes. Improper treatment and disposal of this wastewater can pollute local water sources, posing potential health risks for communities relying on this water.

The environmental risks are discussed further in Section II in the analysis of the NIST draft PEA.

It's important to note that the severity of health risks depends on several factors, including the specific chemicals involved, the level and duration of exposure, individual susceptibility and the use of proper PPE. The breakdown of these hazards is discussed more in Section VI, when detailing what factors should be prioritized in assessing the safety of a chemical. These health risks highlight the importance of implementing stricter regulations, improving worker training, and conducting ongoing research to better understand and mitigate these potential harms.

3. **Current Toxic Exposure Laws**
The current landscape of exposure laws for hazardous chemicals used in semiconductor manufacturing, discussed in Section V, is spread across federal and state regulations, and varies significantly across different states. In addition to geographic complications, the report highlights significant shortcomings in laws and procedures that create challenges in protecting workers and communities from potential health risks.

Key Findings on Current Laws and Procedures

a. **Standards:**
There are a variety of exposure limits for hazardous chemicals, including:

- **OSHA Permissible Exposure Limits (PELs):** These are the federally enforceable limits set by the Occupational Safety and Health Administration (OSHA), and they are out of date.
- **ACGIH Threshold Limit Values (TLVs):** These are recommendations from the American Conference of Governmental Industrial Hygienists (ACGIH), which are often stricter than OSHA standards. They are updated frequently and recognized worldwide. However, they are based on a tenuous history of industry-involved standard-setting and not enforceable (except by contract).
- **NIOSH Recommended Exposure Limits (RELs):** These are recommendations from the National Institute for Occupational Safety and Health (NIOSH), a research institute with no enforcement power. They are health-based, easier to update than PELs and less frequently updated than TLVs.

b. **Inadequate OSHA PELs:**
A key concern is that OSHA's PELs are outdated and not based on the latest scientific evidence. OSHA itself acknowledges on their website that many PELs are not adequate to protect worker health.

c. **The Race to the Bottom:**
Inconsistencies in exposure laws can create a "race to the bottom" scenario for worker protections. Companies, particularly those operating in multiple states, may be incentivized to locate facilities in states with less stringent regulations to avoid the costs associated with stricter safety protocols. This ultimately weakens worker protections across the board.

d. **Limited Transparency:**
The report emphasizes the difficulty of accessing data on chemical use and production processes within semiconductor companies, as well as inconsistent monitoring. Trade secret protections can hinder efforts to assess potential risks and develop effective regulations.

e. **Lack of Exposure Monitoring Data:**
Lack of regulations mandating the collection of comprehensive data on worker exposure to chemicals over time hinders identification of potential health risks and effective interventions.

f. **Lack of Adequate Data on Risk:**
The industry must collect and report data on chemical use, potential health risks and environmental releases, which is critical to performing effective risk assessments. Currently available data may be insufficient to fully assess these risks.

Based on these findings, the report calls for a significant shift in the policy landscape surrounding toxic exposure in the semiconductor industry. Here are some key areas for reform:

- **Shifting the Burden of Proof:**
The biggest reform that could change the course of federally protecting people from toxic exposure would be to place the burden on industry to prove chemicals are safe, rather than keep the burden on the government to prove chemicals are hazardous. While this may not be politically feasible in the current environment, it would make a significant difference.

- **Strengthening OSHA PELs with a Robust PEA:**
OSHA needs to update its PELs to reflect current scientific understanding of health risks associated with chemical exposure. The NIST Programmatic Environmental Assessment (PEA) for the CHIPS Act could serve as a crucial tool in this process. A robust PEA draft, informed by scientific data and industry expertise, can establish a framework for more effective national exposure limits for all applicants to CHIPS Act funding.

- **Enforceable National Standards:**
Establishing uniform, enforceable national exposure limits based on the most protective limits currently available, such as ACGIH TLVs, would ensure consistent worker protections across the country. Ideally, these standards would be informed by the findings of the PEA and address the limitations of current OSHA PELs.

- **Empowering Communities:**
Develop regulations that prioritize community involvement in data collection and decision-making processes concerning potential environmental risks.

- **Transparency and Source Control:**
Implement stricter regulations requiring companies to disclose information on chemical use and emissions. This transparency is crucial for risk assessment and developing effective source control measures to minimize potential exposures.

- **Increased Funding for Enforcement:**
Allocate sufficient resources to ensure effective enforcement of regulations by agencies like OSHA and state-level environmental protection agencies.

- **Prioritize Data Collection in Regulations:**
Regulations must require industry to monitor and report on chemical use, potential health risks and environmental releases. This data informs the development of targeted policies for improved health protection; without it toxic exposure laws are weak and inadequate.

The report also conducts a case study of two states, California and Texas, to examine the regulatory framework affecting protection from toxic exposure in each location.

Key Findings on State Case Studies

California's Division of Occupational Safety and Health (Cal/OSHA) is known for its stringent regulations and proactive enforcement. The state has adopted stricter PELs for many chemicals used in semiconductor manufacturing compared to federal guidelines.

California presents a complex picture when it comes to worker safety and environmental regulations in the

semiconductor industry.

a. **Strict State EPA Standards:**
The California Environmental Protection Agency (CalEPA) enforces stricter environmental regulations than the federal EPA. These stricter standards offer some level of protection for communities surrounding semiconductor facilities.

b. **Semiconductor-Specific Regulations:**
California has established additional regulations specific to the semiconductor industry, potentially providing more comprehensive safeguards for workers and the environment.

c. **OSHA Enforcement Challenges:**
However, California also faces difficulties with OSHA enforcement. The report highlights staffing shortages within Cal/OSHA, the state's branch of OSHA. This weakens enforcement capabilities and may leave workers vulnerable despite stricter regulations on paper.

The State of Texas primarily relies on the Texas Commission on Environmental Quality (TCEQ) for regulations concerning toxic exposure limits on chemicals used in the semiconductor industry. The commission is historically "industry friendly" and known for challenging "almost every major action the EPA has taken to reduce air pollution."[1] The key strategic takeaways about the state are:

a. **Regulations Designed to Attract Industry:**
Texas regulations are designed to foster a business-friendly environment, which generally means one where costs are low for industry. These policies include tax incentives, lack of income tax and right-to-work laws.

b. **Potential for Advocacy and Initiative:**
Despite the state's reputation, there is still room to advocate for environmental and health initiatives. Former government employees highlight the possibility of motivating state officials and agencies like the TCEQ to act on such initiatives if they are framed as industry-friendly. Creative strategies are key, such as positioning zero-emissions initiatives as benefiting industries through initiatives like electric vehicle infrastructure, and can be effective in garnering support for regulatory action.

The current state of exposure laws creates an uneven landscape for worker health protection. Advocating for and implementing nationally standardized regulations with consistent enforcement is crucial to ensure that all workers in the semiconductor industry, regardless of location, are afforded the same level of health protection.

4. **Driving New Public Policy**
This report delves into the debate around how to craft public health policy specific to toxic exposure. As seen in the NIOSH Hierarchy of Controls triangle in Section VI, the most robust policy is one that eliminates all risk of exposure. The second most robust is one that focuses on substituting harmful chemicals with safe ones. In the absence of transforming the framework of current public policy and shifting the burden of proof onto industry, this report focuses on finding the best method for substituting chemicals. A guide is included in Section VI for conducting a DELPHI Panel, using a survey in **Appendix I,** to find consensus on best practices.

1. High Plains Public Radio. "Texas Has Sued the Obama Administration 40 Times: A Look at the Lawsuits." HPPR, May 30, 2016, www.hppr.org/hppr-government-politics/2016-05-30/texas-has-sued-the-obama-administration-40-times-a-look-at-the-lawsuits. Accessed June 12, 2024. Smith, Ted; Sonnenfeld, David A. and David Naguib Pellow (ed). Challenging the Chip: Labor Rights and Environmental Justice in the Global Electronics Industry. Temple University Press, Philadelphia, USA (2006): 1-12.

D. Policy Considerations

This report highlights data gaps critical for building a campaign for stricter regulations on toxic exposure in semiconductor manufacturing. A more extensive list of policy considerations, medium and long term, can be found in Section VII, but here are some of the highlights directed for government:

- **Shift the Burden of Proof**

  Advocate for shifting the burden of proof from the government to industry in assessing chemical hazards.

- **Prioritize Elimination of Risk**

  Encourage and incentivize the use of safe chemical alternatives:
  to currently employed hazardous chemicals in semiconductor manufacturing processes.

  Promote the development and implementation:
  of cleaner production technologies that eliminate the use of hazardous chemicals altogether.

- **Enhance Transparency and Accountability**

  Strengthen existing right-to-know laws:
  to ensure workers have access to comprehensive information on the chemicals they are exposed to during the course of their work.

  Re-evaluate trade secret protections:
  to ensure they do not impede efforts to collect data on chemical use and potential health risks in the semiconductor industry. A balance needs to be struck between protecting legitimate trade secrets and safeguarding worker health.

- **Update Exposure Limits and Standard Setting**

  Garner Congressional support to:
  - Reform OSHA regulations and establish uniform, enforceable national exposure limits based on the most protective limits currently available and on current health science.
  - Overhaul standard-setting process to eliminate conflicts of interest, ensure transparency and mandate presence of qualified medical professionals in the process.
  - Restructure strong leadership over toxic exposure regulation and enforcement.

- **Update Chemical Assessment Protocol**

  - **Garner Congressional support:**
    to conduct a comprehensive evaluation of EPA procedures for chemical assessments and oversee an overhaul of procedures with the goal of creating a process the EPA can implement to successfully assess all pending chemicals.

  - **Allocate funding and additional resources:**
    to the EPA to empower them to successfully assess all chemicals and enforce toxic exposure policy.

- **Strengthen Worker Protections**

  - **Allocate sufficient resources to agencies:**
  like OSHA and state-level environmental protection agencies to ensure effective enforcement of existing worker safety and environmental regulations.

  - **Strengthen federal EPA enforcement:**
  particularly in states like Texas, to ensure local implementation of federal regulations.

- **Improve Data Collection**

    - **Programs:**
      Implement mandatory health monitoring programs for semiconductor workers.

    - **Database:**
      Establish a federal public health/occupational health database of electronics workers.

    - **Reports:**
      Require CHNA reports to include information on occupational and environmental hazards specific to industries, or establish new reports through local public health departments specific to the semiconductor industry.

    - **Funding:**
      Allocate funding to develop improved methods for assessing worker exposure to hazardous chemicals in semiconductor manufacturing facilities, for comprehensive studies of health risks faced by workers in the semiconductor industry, and for interagency collaboration on data collection and joint analysis.

By implementing these policy considerations, lawmakers and regulatory agencies can create a more robust framework for protecting worker health and the environment in the semiconductor industry. This framework should prioritize source control, transparency, strong worker protections and ongoing research efforts.

E. Report Limitations and Future Research Agenda

The findings presented in this report highlight the limitations of current data on health risks associated with semiconductor manufacturing. While existing research provides some insight, this report emphasizes the critical data gaps and limitations that hinder a comprehensive understanding of toxic exposure risks in semiconductor manufacturing.

- **Limitations to the Report**

    - **Incomplete Government Data:**
      Government databases on worker injuries and illnesses, environmental releases, and health outcomes may be incomplete or lack the necessary detail to effectively assess health risks in the semiconductor industry.

    - **Limited Industry Transparency:**
      The semiconductor industry may not be fully transparent about the specific chemicals used in their processes or the potential health risks associated with these chemicals. This lack of transparency makes it difficult to track exposures and monitor health outcomes.

    - **Scope:**
      The ideal source of health data for this report would have been from surveys collected directly from workers and communities. However, to ethically collect such data would have required more time and resources than the scope of this report allowed. In addition, while using data on environmental releases around semiconductor manufacturing facilities is critical in reviewing evidence of pollution and community exposure to toxins through water or air, due to time restraints, the scope of the report was narrowed to focus on occupational health data analysis.

- **Future Research Agenda**

  The report's conclusion emphasizes the need for further research to definitively assess health risks associated with semiconductor manufacturing. Here are key research initiatives recommended in the report:

    - **Academic Research Topics:**
      E-waste, hazardous storage and cleanup policy recommendations; comprehensive review of past policy proposals in California for occupational health databases for electronics workers to create updated proposals for today; comprehensive review of state-specific toxic exposure regulations to develop a comprehensive list of all state and federal regulations nationwide; brainstorm avenues for achieving zero exposure in the workplace and communities without government regulation.

- **Medical Studies and Biomonitoring Programs:**
  Academic institutions, especially medical institutions with departments for occupational health or chemistry departments with a focus in green chemistry, should conduct medical and scientific studies to examine the current status of toxic exposure in the industry and the country. This includes:
  - Conducting long-term cohort studies of workers in the semiconductor industry. These studies would track worker health outcomes over time, allowing for the identification of potential health effects associated with long-term exposure to hazardous chemicals.
  - Utilizing biomonitoring techniques to directly measure the levels of hazardous chemicals present in workers' bodies. Biomonitoring can provide a more accurate assessment of exposure levels compared to relying solely on self-reported data from workers.

- **Community Health Assessments Specific to the Industry:**
  The report highlights the importance of conducting health studies with residents living in close proximity to semiconductor facilities. These studies, conducted in collaboration with residents and community organizations, would examine potential health impacts from environmental exposures associated with these facilities, comparing health outcomes to control groups residing further away.

- **Environmental Data Collection and Analysis:**
  The use of environmental data is recommended as a high-priority next step in future research. This might include organizing new data collection initiatives, and collaborating with local, state and federal agencies to gain access to existing data collection programs that are not publicly accessible.

- **Standardized Data Collection:**
  Develop standardized data collection protocols for government agencies and the semiconductor industry. This would ensure consistency and facilitate data sharing for improved analysis of health risks.

- **Transparency and Public Access:**
  Advocate for increased transparency from the semiconductor industry regarding chemical use, potential health risks and environmental releases. Publicly available data empowers researchers and communities to conduct independent investigations and hold companies accountable for their operations.

F. Conclusion

This report serves as a springboard for CWA and CCU to ensure a future where worker safety and a healthy environment for all are ensured by the government and semiconductor industry. By highlighting the critical data gaps in our understanding of health risks associated with toxic exposure from the industry, this report encourages the following internal policy considerations as well:

- **Improve Data Collection:**
  Conduct campaigns to collect health equity data from workers and communities, following the ethical principles laid out in **Appendix G.** Research past proposals in California for occupational health databases and state-specific toxic exposure regulations.

- **Build Consensus:**
  Organize surveys with experts to develop consensus on preferred methods for substituting chemicals in the industry, best practices for environmental protections and consensus on applying the precautionary principle to toxic exposure policy.

- **Advocate for Best Practices:**
  Advocate for modernized practices and enforceable best practices in factories.

- **Partner with Researchers:**
  Collaborate with public health experts to conduct comprehensive health studies that definitively link potential exposures to health outcomes.

- **Push for Transparency:**
  Advocate for mandatory reporting of chemicals used in semiconductor manufacturing, fostering a culture of openness and accountability.

By addressing these knowledge gaps and demanding transparency, CWA and CCU can ensure that the future of the semiconductor industry prioritizes not just technological advancement, but also the health and safety of workers and the communities they serve.

Table of Contents

Table of Contents

I. Introduction

A. 50 Years of Toxic Exposure Without Effective Accountability

Semiconductor manufacturing is a field bursting with potential hazards to the health of workers and nearby communities, especially those most vulnerable such as immigrants, women, minorities and families in low-income brackets.[2] Also known as computer chip manufacturing, with the factories referred to as "fabs," the production of electronic and computer components contaminates air, land and water around the globe.[3] However, there is a sweeping lack of public, government and even industry awareness around toxic exposure risks in the industry.[4]

To be clear, major companies in the industry have known about the toxic risks in the manufacturing process for decades. For example, in 2018, Samsung issued an apology to workers at their semiconductor factories who developed cancer working at their factories,"[5] We have failed to properly manage health risks at our semiconductor and LCD factories." The apology comes after 10 years of legal battles, 320 cancer diagnoses and 117 deaths.[6]

The general lack of awareness by the public and governments stems from lack of transparency during past proceedings related to toxic exposure. According to court records compiled by Bloomberg Businessweek, over 66 separate civil actions against American chip- making companies nationwide have been filed since 1997, including cancer and birth defect cases, but none have gone to trial and nearly all have been settled under secret terms. [7] Scientists point to the secrecy of these settlements as a primary reason that the risks of chipmaking have been largely unnoticed: No academic papers were published, and the details remain hidden. [8]

Just recently in June 2024, a great stride was taken toward public awareness when the congenital diseases diagnosed in the children of three female workers from Samsung Electronics' chip plant in South Korea were recognized as "work-related accidents" by the Korea Workers' Compensation and Welfare Service under the Ministry of Employment and Labor. [9] Although the problem existed for decades, this marks the first time such congenital diseases were publicly and officially recognized as results of toxic exposure from semiconductor manufacturing.

While there is a history of companies knowingly exposing workers to dangerous hazards, it is possible that companies in the industry may be unaware of the risks to which they are subjecting their employees. Long-time industry leader South Korean company SK Hynix hired a team of university scientists in 2015 to evaluate the toxic risks in two of its plants. [10] The ensuing report showed that of the 430 chemicals used, over 130 of them were considered dangerous enough to employee health that employees should receive special health checks. [11] This may have been new information for SK Hynix, suggesting a treacherous lack of knowledge for the years prior to the study. However, even with this shocking new information revealed, only some of the report's findings were made public:

> *For each of the 157 distinctive chemical ingredients scientists identified in the study commissioned by SK Hynix, there were more than two chemicals—a total of 363—that weren't disclosed because of "trade secret" designations, according to researchers. Even the chip plants' own health and safety managers have no idea what's in many of the mixes, especially in the photoresists.* [12]

The risk to people's lives that results from this continuing lack of transparency and dangerous levels of ignorance to exposure threats only increases as the Biden administration's CHIPS initiative seeks to incentivize U.S.investment in domestic semiconductor production, but does not implement policies that will provide clear protections specific to the industry. [13]

---

2. Smith, Ted; Sonnenfeld, David A. and David Naguib Pellow (ed). Challenging the Chip: Labor Rights and Environmental Justice in the Global Electronics Industry. Temple University Press, Philadelphia, USA (2006): 1-12.
3. Ibid.
4. Cam, Simpson. 2017. "American Chipmakers Had a Toxic Problem. Then They Outsourced It." www.bloomberg.com. June 15, 2017. https://www.bloomberg.com/news/features/2017-06-15/american-chipmakers-had-a-toxic-problem-so-they-outsourced-it.
5. "Samsung Electronics Apologises over Factory Worker Cancer Cases." www.aljazeera.com, Nov. 23, 2018, www.aljazeera.com/economy/2018/11/23/samsung-electronics-apologises-over-factory-worker-cancer-cases.
6. Ibid.
7. Cam, Simpson. 2017. "American Chipmakers Had a Toxic Problem. Then They Outsourced It." www.bloomberg.com. June 15, 2017.
8. Ibid.
9. "Three Semiconductor Factory Workers Recognized as Having Suffered Fetal Industrial Accident for 1st Time." World.kbs.co.kr, world.kbs.co.kr/service/news_view.htm?lang=e&Seq_Code=184405. Accessed 8 June 8, 2024.
10. Cam, Simpson. 2017. "American Chipmakers Had a Toxic Problem. Then They Outsourced It." www.bloomberg.com. June 15, 2017. https://www.bloomberg.com/news/features/2017-06-15/american-chipmakers-had-a-toxic-problem-so-they-outsourced-it.
11. Ibid.
12. Ibid.
13. U.S. Department of Commerce. "A Strategy for the CHIPS for America Fund." National Institute for Standards and Technology (NIST): 6 September 6, 2022. https://www.nist.gov/chips/implementation-strategy

As is evidenced by the decades of lawsuits previously mentioned, the passage of the CHIPS Act is not the first time that the potential hazards of computer chip fabrication have become a public concern, and we can learn from past events. When fabs replaced the orchards in Silicon Valley in the 1970s, the companies were celebrated as "the industry without pollution, with workers in 'clean rooms' and factories without smokestacks [...], the 'clean industry.'" [14] However, although workers wore hazardous materials suits and worked in "clean rooms," these protections were misleading:

> *The primary goal [of the clean room] was to protect the product against any particle contamination, from dust to dandruff, by using equipment made expressly for this purpose. The workers themselves were largely an afterthought, breathing recirculated air that, unbeknownst to them, was laced with chemicals.*[15]

With no regulations or procedures in place at the time to protect from this new field of toxic exposure risk, worker safety advocates began organizing research and advocacy efforts. As a result, there is a wealth of research, policy reports and innovative policy reform dating from the 1970s-2000s to inform our concerns today.

What's more, major policy changes occurred during that period including the nation's first right-to-know policies and hazardous materials model ordinances.[16] Silicon Valley soon earned the status of having the largest number of superfund sites in one concentrated location in the country. [17] The industry as a whole made public statements declaring companies would phase out the use of hazardous chemicals.[18] IBM went so far as to pledge "to rid its global chip production of them by 1995."[19] However, as companies began moving semiconductor production off American soil in the 2000s, the hazards were merely moved overseas. Now, as we prepare for the hazards to return to the United States, we face a dire lack of data. Without transparency, the data is locked away and the real risks to human health cannot be responsibly shared.

The focus of this report is to take stock of what information we do have and identify what we don't. It examines contemporary evidence and develops a **needs assessment** for the industry at present. What are the hazards, and what information must be released for crucial analysis? What policy changes must be made to make necessary data available for public knowledge and consumption? What information do advocates lack that keeps them from understanding the present-day risk that communities and workers face, and the regulations or changes necessary to resolve them?

We face a dire lack of data. Without transparency, the data is locked away and the real risks to human health cannot be responsibly shared.

B. Current Study

This report was commissioned by Communication Workers of America (CWA), a union representsing workers in sectors from communications to technology manufacturing in collaboration with CHIPS Communities United (CCU) Coalition, a coalition comprising labor, environmental, social justice, civil rights and community organizations nationwide. CCU focuses on the responsible implementation of the CHIPS Act and ensuring the benefits of semiconductor manufacturing expansion reach all.

In response to the CHIPS Act, CWA and CCU aim to submit recommendations to federal and state government agencies on best practices for protecting workers and communities from the industry's toxic hazards of the industry. This report seeks to prepare CWA and CCU to answer the overall research question: *What can OSHA and other governmental regulatory agencies do better to reduce semiconductor manufacturing risks to workers and public health and safety?*

This report serves as a comprehensive needs assessment, acting as a bridge between historical data and current research findings. By meticulously reassessing past information and incorporating the latest insights, it aims to provide an updated and comprehensive overview of the known health risks posed by potential toxic exposure within semiconductor manufacturing.

14. Smith, Ted; Sonnenfeld, David A. and David Naguib Pellow (ed). Challenging the Chip: Labor Rights and Environmental Justice in the Global Electronics Industry. Temple University Press, Philadelphia, USA (2006): 1-12.
15. Morris, J. (2015) "The impenetrable world of Mark Flores," Center for Public Integrity, July 1
16. Smith, Ted; Sonnenfeld, David A. and David Naguib Pellow (ed). Challenging the Chip: Labor Rights and Environmental Justice in the Global Electronics Industry. Temple University Press, Philadelphia, USA (2006): 113.
17. Schlosberg, T. (2019) "Silicon Valley Is One of the Most Polluted Places in the Country," Microchip manufacturers contaminated the groundwater in the 1980s. Almost 40 years later, the cleanup still isn't complete," The Atlantic Magazine, September 22.
18. Cam, Simpson. 2017. "American Chipmakers Had a Toxic Problem. Then They Outsourced It." www.bloomberg.com. June 15, 2017. https://www.bloomberg.com/news/features/2017-06-15/american-chipmakers-had-a-toxic-problem-so-they-outsourced-it.
19. Ibid.

The focus is twofold:

Synthesizing Existing Knowledge:
This report will consolidate available information about the health risks associated with chemical exposures in semiconductor production, what regulations exist and what is the state of enforcement.
Identifying Knowledge Gaps:
We will meticulously identify areas where critical information remains elusive, highlighting crucial questions that require further investigation.

By illuminating both *what we know* and *what we still need to learn,* this report will empower CWA and CCU to develop well-researched and targeted advocacy strategies.

This report uses a mixed-methods approach which means it combines quantitative and qualitative data analysis. For a complete methodology, see **Appendix A.** Beyond identifying knowledge gaps, this report includes a best practices assessment guide for identifying safe chemicals with which to replace hazardous ones. The guide provides recommended instructions for CWA and CCU to conduct a survey with a group of experts on best methods for assessing chemical replacements, with the goal of arriving at qualified consensus. Consensus on such an issue will provide meaningful support for advocacy efforts working to prioritize chemical substitution in public policy rather than worker protection (PPE) or the replacement of human workers with automation.

The scope of the report dictated the following:

Geographic Locations

- The report was unable to analyze the state regulations of all 50 states, so two were chosen for comparative case studies: Texas and California. They were chosen for their significant amount of semiconductor manufacturing and dramatically different regulations.
- The report also chose two states in which to conduct case studies of Community Health Needs Assessments (CHNAs), to assess what relevant data CHNAs can provide for assessing risks to community members. The two states– New York and Texas– were chosen for comparably sized semiconductor manufacturing facilities: Global Foundries (in Malta, NY, Saratoga County) and Samsung (in Taylor, TX, Williamson County). There was no comparable manufacturing facility in California, so California was omitted from these case studies.

Data

- The author of this report consulted the existing literature, conducted quantitative data analysis, and conducted informational interviews to center the voices of those who have been entrenched in advocacy efforts since the first round of activism, and those who have joined the cause along the way.
- The report could only analyze existing health data. While the hope was to center the voices of those who are most affected by the toxic exposure laws such as workers and community members, such organizing was not ethically possible in the short time allotted for this research. Instead, such outreach is recommended in the Section VIII, and guidelines for ethical health equity collection are provided in **Appendix G.** Health equity data collection that centers people who are most affected by the policies will both empower the communities facing the greatest harm and provide critical data that is currently lacking.
- The report focused on worker and community health data available through the U.S. Census Bureau, Department of Labor and CHNAs. It is noted that the use of environmental data to further reveal potential toxic exposure in the community is preferred, however it was not within the scope of the report and is instead referenced in further research.

C. Structure of This Report

The report is organized into eight sections:

Section I
Intoduction to the report.

Section II
Reviews the political events that led to the crafting of the CHIPS Act, its lack of reference to potential toxic exposure risks to workers or environment, the importance of the National Institute for Science and Technology's draft Programmatic Environmental Assessment and its shortcomings.

Section III
Provides an overview of the steps inherent to fabricating a chip, and the chemical hazards present at each stage.

Section IV
Lays out what we currently know about the risk of exposure to workers and fence-line communities, what we don't know and why we don't know more.

Section V
Provides a detailed analysis of why toxic exposure standards today are insufficient, what agencies are involved, what regulations currently exist and contemporary gaps in policies around toxic exposure.

Section VI
Discusses the debate around the best public policy for toxic exposure, and provides a recommendation for how to conduct a survey with experts to help find consensus on the best method for picking safe chemicals with which to replace hazardous ones in the industry.

Section VII
Presents a summary of the current unmet needs revealed through the investigation, and a list of policy considerations for CWA and CCU as they prepare their advocacy efforts.

Section VIII
Conclusion: includes a summary of this report's limitations, and recommendations for future research.

II. Why This Matters More Than Ever: CHIPS Act 2022

The concern over toxic exposure from semiconductor manufacturing in the United States has gained renewed urgency as a result of the Creating Helpful Incentives to Produce Semiconductors (CHIPS) Act. In short, the CHIPS Act was inspired by pressing geopolitical, defense-related and supply chain issues. While these problems rightfully catalyzed movement in Congress, they did not result in any improvements in working conditions or environmental safeguards in the industry. Fortunately, the National Environmental Policy Act (NEPA) is a procedural statute that "requires Federal agencies to assess the environmental effects of proposed major Federal actions." [20] Therefore, even though the lead-up to the CHIPS Act did not center environmental and worker safety, the environmental assessment does.

The National Institute of Science and Technology's (NIST) draft of a programmatic environmental assessment (PEA) was created (2023) to meet NEPA regulations. Several organizations that responded to the draft–including the Center for Public Environmental Oversight, CHIPS Communities United (CCU) and the International Campaign for Responsible Technology (ICRT)–celebrate its objective of identifying potential environmental consequences resulting from modernizing or expanding semiconductor manufacturing facilities. All respondents agree that it is not only a positive act for facilities to modernize–because this offers the opportunity to update processes that more effectively protect from exposure–but it is also extremely important that NEPA environmental assessments be performed prior to any actions taken. Yet, industry would ideally prefer the assessment requirement be waived or significantly streamlined. While civil organizations appreciate the environmental assessment requirements and the existence of the PEA, they also identify several ways the assessment falls short in addressing all the needs associated with potential toxic exposure from the industry.

When considering the big picture of what federal agencies can do to better protect the public from potential toxic exposure from fabs, one key answer is ensuring the PEA sets up proper protections from the start. This section reviews the lead up to the act, the contents of the PEA and the primary critiques of the PEA.

A. The CHIPS Act: Not Focused on Worker and Community Safety

For insight into the political background of the CHIPS Act, an informational interview was conducted with a former federal employee close to the development of the CHIPS Act who prefers to remain anonymous in this report. The employee explained that the early notions of the CHIPS Act began as a working group during the Obama Administration. [21] The Presidential Council of Advisors for Science and Technology (PCAST) organized a semiconductor working group that worked tirelessly over several months to produce a report (2017) on the challenges faced by the semiconductor manufacturing industry in the United States and what solutions exist to maintain U.S. leadership in the sector. [22]

The anonymous employee reports that the Trump Administration demonstrated continued interest in the topic, and a second PCAST working group was organized under the Biden Administration to produce a report (2022) on revitalizing the U.S. semiconductor industry. [23] Following these reports, the CHIPS Act was ultimately a Department of Commerce-led initiative with strong support from the State Department and the Defense Department. [24] The act authorizes funding to each of the three departments with the goal of advancing the country's competitiveness in the industry and, by default, national security interests by building out domestic manufacturing of semiconductors. [25]

In addition to the PCAST working groups, the employee recalls the real catalyst for the Act was when, during the Biden Administration, the Taiwan Semiconductor Manufacturing Company (TSMC) demonstrated interest in investing in a facility in Arizona. [26] One of the most important players in the industry, TSMC makes 90 percent of the world's most advanced computer chips. [27] As the employee recalls, TSMC was accustomed to working in Taiwan where the government provides seed money to support new projects. [28]

20. Council on Environmental Quality, Executive Office of the President. "NEPA | National Environmental Policy Act." ceq.doe.gov, Department of Energy, Office of Environment, Health, Safety and Security, 2023, https://ceq.doe.gov/#:~:text=Congress%20enacted%20the%20National%20Environmental.
21. Anonymous. "Informational Interview with Anonymous." Unpublished Interview, 13 Mar. 2024.
22. Holdren, John P., and Eric S. Lander. Report to the President: Ensuring Long Term U.S. Leadership in Semiconductors. Executive Office of the President, President's Council of Advisors on Science and Technology, Jan. 2017, https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_ensuring_long-term_us_leadership_in_semiconductors.pdf.
23. President's Council of Advisors on Science and Technology. Report to the President: Revitalizing the U.S. Semiconductor Ecosystem. Executive Office of the President, President's Council of Advisors on Science and Technology, Sept. 2022, www.whitehouse.gov/wp-content/uploads/2022/09/PCAST_Semiconductors-Report_Sep2022.pdf.
24. Anonymous. "Informational Interview with Anonymous." Unpublished Interview, 13 Mar. 2024.
25. Senate Committee on Commerce, Science and Transportation . "The CHIPS Act of 2022 Section-by-Section Summary," July 29, 2022. https://www.bennet.senate.gov/public/_cache/files/4/0/40919cb4-ff63-4434-8ae2-897a4a026b30/7BCDD84F555A6B85BEC800514F1D3AFD.chips-and-science-act-of-2022-section-by-section.pdf.
26. Anonymous. "Informational Interview with Anonymous." Unpublished Interview, 13 Mar. 2024.
27. Nicholas, Kristof. "Opinion | Visiting the Most Important Company in the World." The New York Times, 25 Jan. 2024, www.nytimes.com/2024/01/24/opinion/tsmc-taiwan-china.html.
28. Anonymous. "Informational Interview with Anonymous." Unpublished Interview, 13 Mar. 2024.

TSMC expressed concern that it was more expensive to work in the United States, and would need incentives to open facilities there.[29] The United States government could not offer $3 billion to TSMC, but the circumstances proved an opportunity to create a program that would provide a level playing field for all allies and partners in domestic companies to apply for incentives to build or expand.[30]

At this point, the United States lacked the domestic capacity to produce advanced computer chips at volume. While the country was a major player in the manufacturing sector in the 1990s, producing 37% of the world's chips, in 2022 the country only produced 12% of chips, and none of the most advanced chips.[31] In contrast, China has leveraged between $150 and $200 billion of state funding over the past few decades to increase its semiconductor capacity and global competitiveness out of concern for its reliance on foreign chip imports as an economic and national security imperative. By 2018, China accounted for half of global construction spending on semiconductor manufacturing facilities.[32] The decreasing capacity of the United States to produce both quality and quantity of semiconductors became a major concern for Congress, especially when compared to China's abilities. TSMC's interest in building facilities in the United States incorporated the potential for major progress in the United States toward improved chip production.

The comparative manufacturing competency of both countries came into the spotlight when the global semiconductor supply chain shortage arose in the beginning of the COVID pandemic.[33] The lack of a microcontroller chip, which cost around $3, resulted in the loss of approximately $200 billion for the global auto industry in 2021.[34] The subsequent crippling of industries reliant on computer chips drove public attention to the critical role semiconductors play in the global manufacturing supply chain, and how incapacitated the United States was in producing its own.[35]

With this increased awareness also came increased anxiety over job losses related to the chips shortage. GM and Ford announced plans to shut down production lines temporarily in April 2021, and reports surfaced of more shutdowns expected to continue, holding down employment in the sector.[36] In motor vehicle manufacturing alone, 27,000 jobs were lost from March to April 2021. When comparing spring 2020 to spring 2021, the number of seasonally adjusted employees in the sector dropped by over 100,000.[37] These numbers had the full attention of Congress, and this concern for jobs was also one of the only ways that the needs of workers were included in discussions related to the CHIPS Act. Congress worked with the Department of Commerce, the State Department and the Department of Defense to pass the CHIPS Act. As the anonymous employee describes, industry also had a huge role in crafting it.[38]

The chronic shortage of skilled labor specific to the industry also featured in the CHIPS Act's drafting. The 2022 PCAST report put special emphasis on the lack of graduates from U.S. universities, colleges and trade schools trained in the high level engineering and technician skills necessary for the semiconductor industry.[39] The employee notes that there have been a proliferation of workforce reports specific to the semiconductor industry during and since the passage of the CHIPS Act.

In short, the history of the CHIPS Act focused on industry, commerce and national defense concerns. Workers' needs featured in the act primarily through potential job loss from chip shortages and the chronic undersupply of skilled labor specific to the industry. Worker and environmental safety were not part of the conversation.

... the CHIPS Act focused on industry, commerce and national defense concerns ... Worker and environmental safety were not part of the conversation.

29. Anonymous. "Informational Interview with Anonymous." Unpublished Interview, 13 Mar. 2024.
30. Ibid.
31. Commerce Secretary Gina Raimondo has noted that the U.S. lacks the advanced chip manufacturing capacity. Sourced from Center for a New American Society Travis Mosier's presentation at CITRIS and the Banatao Institute: https://www.youtube.com/watch?v=VEv3QGE7CyQ&t=1154s
32. Center for a New American Society Travis Mosier's presentation at CITRIS and the Banatao Institute: https://www.youtube.com/watch?v=VEv3QGE7CyQ&t=1154s
33. Sweney, Mark. 2021. "Global Shortage in Computer Chips 'Reaches Crisis Point.'" The Guardian. March 21, 2021. https://www.theguardian.com/business/2021/mar/21/global-shortage-in-computer-chips-reaches-crisis-point.
34. Center for a New American Society Travis Mosier's presentation at CITRIS and the Banatao Institute: https://www.youtube.com/watch?v=VEv3QGE7CyQ&t=1154s
35. Shead, Sam. 2021. "The Global Chip Shortage Is Starting to Have Major Real-World Consequences." CNBC. May 7, 2021. https://www.cnbc.com/2021/05/07/chip-shortage-is-starting-to-have-major-real-world-consequences.html.
36. Rittenberg, Jason. "Semiconductor Shortages Dragged down April Employment, Other Takeaways from a Dive into the Jobs Data." State Science and Technology Institute (SSTI), May 20, 2021, ssti.org/blog/semiconductor-shortages-dragged-down-april-employment-other-takeaways-dive-jobs-data. Accessed 10 June 2024.
37. Ibid.
38. Anonymous. "Informational Interview with Anonymous." Unpublished Interview, 13 Mar. 2024.
39. President's Council of Advisors on Science and Technology. Report to the President: Revitalizing the U.S. Semiconductor Ecosystem. Executive Office of the President, President's Council of Advisors on Science and Technology, Sept. 2022, www.whitehouse.gov/wp-content/uploads/2022/09/PCAST_Semiconductors-Report_Sep2022.pdf.

B. The NIST PEA: Aims to Prioritize Safety

There is a National Environmental Policy Act (NEPA) requirement that if a project is going to receive significant federal funding, a NEPA review must be conducted first. After the CHIPS Act was passed, the Department of Commerce's National Institute of Standards and Technology (NIST) drafted a programmatic environmental assessment (PEA) (2023). The PEA is crucial because it brings serious concerns of potential toxic exposure back into focus for both the CHIPS Office and industry applicants.

A PEA report details the different types of environmental consequences that may occur as a result of a proposed action. In this case, the proposed action is when a semiconductor manufacturing facility proposes modernization or internal expansion and requests funding from the CHIPS Act for this change. It requires informing the public.[40] As such, NIST's draft PEA (2023) was distributed to the public for comments and feedback within 30 days of publication.

The draft PEA identifies nine potential environmental consequences that could result from proposed actions:

1. Climate Change and Climate Resilience
2. Air Quality
3. Water Quality
4. Human Health and Safety
5. Hazardous and Toxic Materials
6. Hazardous Waste and Solid Waste Management
7. Utilities
8. Environmental Justice
9. Socioeconomics

Without the NEPA environmental assessment requirement, CHIPS-funded facilities would likely* bypass studies or activities to ensure environmental safety *for the sake of speed and progress in the industry.

Each of these topics is essential to ensuring the safety and security of people impacted by these manufacturing facilities. In addition, the draft PEA provides an overview of how semiconductors are manufactured, a helpful table with every type of semiconductor manufacturing equipment used at each stage of the production process, and the general industry trends today for pollution control and conservation of water and energy. It also pays careful attention to hazards such as PFAS (per- and polyfluoroalkyl substances), which were not regulated in past decades.

The PEA's most important quality is its role in mandating that the well-being of humans and nature be a goal of all CHIPS activities. Without the NEPA environmental assessment requirement, CHIPS-funded facilities would likely bypass studies or activities to ensure environmental safety for the sake of speed and progress in the industry. As the anonymous employee describes, if drafters of the act could have exempted CHIPS Act applicants and award recipients from having to meet the NEPA requirements, they would have.

> *There have been a couple of attempts at [exempting CHIPS Act applicants and award recipients from NEPA requirements] subsequent to the funding of the CHIPS Act, most recently by Senator Mark Kelly of Arizona (co-sponsor of the act). [...] [Kelly] could not get that through, so now the administration has encouraged NIST to look at ways to streamline and simplify the deeper process since [applicants and awards recipients] still have to do it. I think they're still going to try to get something through but it's going to be too late.*
>
> *The reason why [the administration] is trying to make [the environmental assessment requirements] as easy as possible is because the NEPA review can be very onerous, very expensive and time-consuming. When we were first talking about NEPA [...] there was concern about the order of magnitude: It took up to 18 months, sometimes even two years to do a full proper NEPA review. At the speed of business, especially fabs, to wait for two years to get your permits, and get your funding... it's just not going to work [...] People who are applying for funding are hoping that the federal government, at some point, can figure out a fix to make it faster, more streamlined.*[41]

The PEA is a necessary evaluation crucial to the protection of the public from toxic exposure by the industry. However, it also unfortunately contains areas of weakness and underrepresents the potential consequences of certain industry hazards.

40. Council on Environmental Quality, Executive Office of the President. "NEPA | National Environmental Policy Act." Http://ceq.doe.gov, Department of Energy, Office of Environment, Health, Safety and Security, 2023, ceq.doe.gov/#:~:text=Congress%20enacted%20the%20National%20Environmental.
41. Anonymous. "Informational Interview with Anonymous." Unpublished Interview, 13 Mar. 2024.

C. The NIST PEA: What Is Missing

The author of this report has reviewed the PEA as have several organizations that provided public comments in response, including CHIPS Communities United (CCU), the International Campaign for Responsible Technology (ICRT) and the Center for Public Environmental Oversight (CPEO). Subsections A and B above provided the political context of the CHIPS Act and the NIST PEA, and their relationship to protecting workers and communities from toxic exposure by fabs. Here, in section C, we discuss the key findings of what gaps remain in the PEA.

Ultimately, these findings should be a principal focus of advocacy because a rigorous PEA cements regulations and protections that can help overcome existing failures in federal policies and regulations, which will be discussed in Section IV.

Overall, the main concerns that CCU and ICRT have with the draft PEA are outlined directly from their responses as follows: [42]

1. Use fairer and more robust standards for use and disposal of toxic substances.
    a. Standards written by the semiconductor industry fail to advance the public good.
    b. OSHA standards are inadequate.
    c. What should CPO do to provide a better set of standards?
    d. Clean Electronics Production Network (CEPM) is another source of standards and practices.
    e. Best Management Practices (BMPs) should be mandated, not just recommended.
2. CPO should improve transparency and accountability among CHIPS Incentive Grant recipients.
    a. Monitor exposures and releases.
    b. Adopt Best Available Technology (BAT) approach.
    c. Make monitoring regular and public.
    d. Make due diligence process public.
    e. Educate affected communities about permitting, permit modification and results of monitoring.
    f. Ensure public access to information about hazardous substances.
    g. Hold companies accountable for failure to comply.
3. Elevate standards for environmental outcomes.
4. Improve standards around PFAS.
    a. Adopt EPA's proposed rule on corrective action.
    b. Reduce risk of PFAS in wastewater through pre-treatment at point-of-use.
    c. Require monitoring of pre-treatment systems.
    d. Monitor total organic fluorine.
5. Address historic contamination.
6. Improve disposal of hazardous waste.
7. Ensure workers are safe from workplace hazards.
8. Encourage processes to reduce greenhouse gas emissions (GHGs).
9. Advance environmental justice.
10. Advance high-road job creation.
    a. Create jobs for underserved workers.
    b. Track manufacturing jobs.
    c. Track operations and maintenance (O&M) jobs.
    d. Track construction jobs.
    e. Track training, demographics and employment benefits.

The responses provide great detail into the reasoning and background behind the recommendations. Given that the CCU and ICRT responses are not currently available for public review, I have included copies of the 2 responses in **Appendix B.**

In addition to the recommendations listed above, the CPEO expressed the following concerns and made these additional recommendations: [43]

42. See Appendix B.
43. "Comments on Draft Programmatic Environmental Assessment." cpeo.org, Center for Public Environmental Oversight, Pacific Studies Center, 9 Feb. 9, 2024: p. 6, www.cpeo.org/pubs/CPEODPEAcomments.pdf.

1. Government definitions of best practices should be independent of industry, specifically of SEMI standards. As CPEO points out,

> *It is a best practice in environmental, health, and safety regulation that a regulated entity not write the regulations to which they are subject [...] SEMI's guidelines were not developed with input from other, relevant stakeholders. In fact, they are only available to non-SEMI members for hundreds of dollars each [...] [In excerpts from SEMI Standards, such as 12.2 SEMI Safety Guidelines for Tool Design, the term "OEL" is used when defining exposure limits.] It appears that the OEL's mentioned in this text refer to Permissible Exposure Limits set by the U.S. Occupation Health and Safety Administration. In general, those Limits are outdated and unprotective. Even 1% of existing OELs is unprotective. Furthermore, we are not aware of any OELs for PFAS.* [44]

2. Do not qualify the rate of injuries and illnesses across the sector as "low and falling rate," which is a misrepresentation. Illnesses and conditions associated with substances used in manufacturing do not manifest for many years, sometimes decades.
3. Reorient the focus of the evaluation to preventing exposures rather than reducing exposures.
4. Make the CHIPS Program Office Environmental Questionnaire available to the public, as well as applicant responses.
5. Produce a database of semiconductor environmental compliance to allow full transparency of all efforts by industry to comply, and of all violations or incidents, if the database does not already exist. The CHIPS Office needs access to information recommended for this database to independently discover environmental violations or incidents when considering grant applications and monitoring progress. This, and the previous recommendation, serve CCU and ICRT's goal of making the due diligence process public.
6. Use the thresholds in California's Accidental Release Prevention Program rather than the EPA's threshold quantities for Risk Management Programs (RMPs). The EPA's RMP threshold quantities are not sufficiently protective. This supports CCU and ICRT's goal of using fairer and more robust standards for use and disposal of toxic substances.
7. Provide examples of how the CHIPS Office should monitor and ensure that facilities modernize tools and change processes to minimize direct emissions from fab processes. This is an added recommendation on top of CCU and ICRT's point to elevate standards for environmental outcomes.

Finally, the author of this report offers a few additional comments:

1. **In support of CPEO's goal "Do not qualify the rate of injuries and illnesses across the sector as 'low and falling rate,' which is a misrepresentation."** When discussing industry injury and illness rates (found in section 3.7.1.3, or page 44), qualifying this rate as "low and falling" also fails to acknowledge that a decline in injury and illness rates is likely due to a decline in overall manufacturing in the United States:

> *The decline in injury and illness rates over the last 30 to 40 years is likely the result of a combination of increased regulation and regulatory scrutiny, public activism and lawsuits, development of stricter industry standards, and advances in semiconductor manufacturing technology, equipment safety features, and automation.* [45]

2. **In support of CCU and ICRT's point "Standards written by the semiconductor industry fail to advance the public good," and CPEO's goal "Government definitions of best practices should be independent of industry, specifically of SEMI standards."** Government agencies and the PEA should depend purely on SEMI standards for defining best management practices. One of the requirements the report asserts is that facilities seeking CHIPS funding must commit to appropriate best management practices within the industry to reduce environmental effects from the project. Out of the 11 best management practices listed in the draft PEA's Appendix A,[46] nine are SEMI standards. SEMI is a global trade association that writes and publishes industry-approved international standards and guidelines, and requires a standard be purchased to read the publication. For a stakeholder to review the best practice laid out by NIST, they would have to pay $1,620 to acquire the standards, and no accommodations have been made for members of the public or advocacy organizations to access the standards without paying this price. The purpose of the NEPA environmental assessment is to protect communities from the outlined risks, not to promote SEMI. Therefore,

44. "Comments on Draft Programmatic Environmental Assessment." cpeo.org, Center for Public Environmental Oversight, Pacific Studies Center, 9 Feb. 9, 2024: p. 6, www.cpeo.org/pubs/CPEODPEAcomments.pdf.: pp 3-4.
45. Department of Commerce National Institute of Standards and Technology CHIPS Program Office. "Programmatic Environmental Assessment for Modernization and Internal Expansion of Existing Semiconductor Fabrication Facilities under
46. To be clear, this does not refer to Appendix A of this report.

with the inaccessibility of the standards criteria, NIST is not staying true to the purpose of a NEPA assessment. NIST should instead provide best management standards independent of SEMI standards, and they should be open to periodic assessment and revision by non-industry experts.

3. **Estimates of negative environmental consequences should include pre-existing negative consequences of existing facilities or processes.** The draft PEA is structured so that environmental consequences are determined depending on whether the current policy ("No Action") or the new policy being proposed ("Proposed Action") occurs. No Action means facilities are not expanded or modernized, but they may still be utilized in their current condition. The Proposed Action consists of the modernization plan of semiconductor manufacturing facilities included in the report.

   When the draft PEA estimates the environmental consequences of No Action, it is assessing whether a change in environmental hazards results from doing nothing. Similarly, when it estimates consequences of Proposed Actions, it is assessing whether a change in environmental hazards results from the Proposed Actions. So, if environmental hazards already exist as a result of current facilities or manufacturing processes, then the PEA estimates no negative environmental consequences no matter whether No Action or Proposed Actions are implemented. In other words, no new negative consequences would occur from No Action or Proposed Action.

   However, the potential hazards of existing or new manufacturing processes that the PEA lists are concerning and should not be dismissed just because they pre-exist the application. The PEA is meant to be used for assessing standards for health and environmental safety. Its evaluation needs to be re-framed so environmental consequences factor in pre-existing environmental hazards of facilities and processes.

4. **In support of CCU and ICRT's goal "Best Management Practices (BMPs) should be mandated, not just recommended."** In section "Hazardous and Toxic Material Use in Semiconductor Fabrication" (section 3.8.1.2, page 53), the PEA believes that an increase in production will lead to

   > *negligible to minor [effects] due to active monitoring of hazardous substances of concern, reduction or substitution with less hazardous materials, and use of engineering controls such as automated chemical delivery systems.* [47]

   The PEA's determination assumes all of these actions will take place at every facility, but these actions are hypothetical and not guaranteed. The PEA should instead require that all of these actions take place, especially when they impact the assessment of potential negative consequences.

47. Department of Commerce National Institute of Standards and Technology CHIPS Program Office. "Programmatic Environmental Assessment for Modernization and Internal Expansion of Existing Semiconductor Fabrication Facilities under the CHIPS Incentives Program." December 2023: p 33. https://www.nist.gov/system/files/documents/2023/12/26/CHIPS%20Modernization%20Draft%20PEA.pdf.

III. The Known Use and Hazards of Chemicals in Semiconductor Manufacturing

When considering the risks of exposure and methods for safeguarding from the risks, it is important to understand how semiconductors are made and how chemicals feature in their production. This section provides a clear look at the steps required to produce a semiconductor and the potential chemical hazards each step of the way. However, it must be emphasized that the majority of the resources used for this summary date back to the 1980s-2000s. Some recent publications, including the Department of Commerce's National Institute for Standards and Technology's Programmatic Environmental Assessment for the CHIPS Act, have informed this section. But the majority are several decades old. Dates of publications are included intermittently in the text to help emphasize this point, and the text is also heavily cited with footnotes.

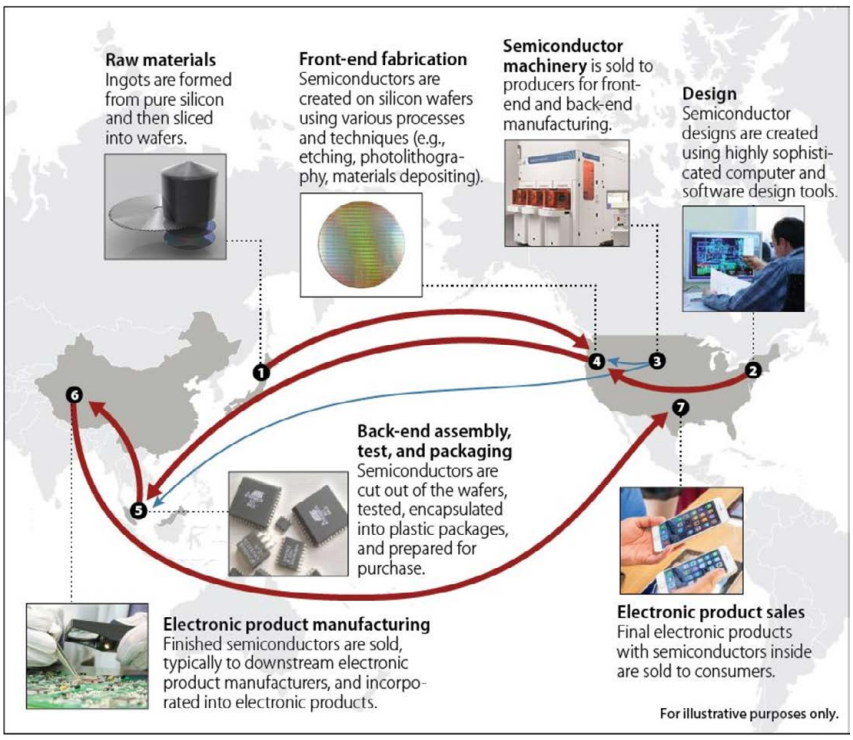
Steps to Create a Semiconductor

A semiconductor is fabricated as an integrated circuit (IC) chip, then encapsulated, assembled on a board and finally put into a final product, whether a computer, smartphone or other device. [48]

In very broad terms, the three main steps to create a semiconductor are:

1. Silicon crystal growth (using epitaxy, which is the process of growing thin films of crystal and is the only affordable method of high-quality crystal growth for many semiconductor materials.) "The goal of the epitaxial process is to deposit a layer with well-controlled structure, composition, and concentration of active impurities, or dopants, to obtain semiconductor materials suitable for device applications." [49] Grown crystals are sawed from an "ingot"–a salami-shaped bar of silicon–and cut into thin slices called wafers. The wafers are cut, smoothed, polished and cleaned to complete their fabrication.
2. Semiconductor circuit fabrication begins on the silicon wafer. A photochemical process called patterning creates complex circuits on thousands of tiny squares, or "chips" on the wafers. Steps include oxidation, diffusion, chemical vapor deposition, ion implantation, passivization and metallization. Wafers are "split into individual chips, bonded to wire leads, and encapsulated in ceramic, metal, or plastic." [50] At this point, they can be attached to a printed circuit board. The board or "laminate" must be produced, and then a printed circuit pattern is created, so that semiconductors and other electronic components (resistors, capacitors and semiconductors) are put into holes on the board.
3. From there, the boards go into finished products.

Here is a slightly more detailed diagram (2023) of the semiconductor ecosystem which gives further context to the semiconductor fabrication process. [51] This chart was taken from the SVTC archives, therefore it is important to note that, as semiconductor fabrication methods have changed due to advances in technology (and will continue to do so), so, too, have the processes on this chart.



48. "Unmasking the Hazards: A Workers Guide to Job Hazards in the Electronics Industry." Santa Clara Center for Occupational Health and Safety, 1981.
49. "Epitaxial Growth of III-V Semiconductor," ScienceDirect, https://www.sciencedirect.com/topics/materials-science/epitaxial-growth-of-iii-v-semiconductor#:~:text=The%20goal%20of%20the%20epitaxial,several%20common%20and%20basic%20considerations.
50. "Unmasking the Hazards: A Workers Guide to Job Hazards in the Electronics Industry." Santa Clara Center for Occupational Health and Safety, 1981.
51. Hein, L., Whittaker, M., and Fong, A. "Chemicals Used in the Electronics Industry." Patty's Industrial Hygiene and Toxicology, 2023. https://www.researchgate.net/publication/365174648

Common Chemicals Used and Their Hazards

A few classes of different chemicals are used at multiple stages of semiconductor manufacturing, [52] and each class carries with it a series of risks to workers and the environment (1981). These classes include:

Solvents

used to clean, strip and degrease electronics. They are a common workplace hazard and cause headaches, drowsiness and dizziness, and over time can lead to long-term nervous system and organ damage as well as cause cancer and present reproductive hazards. Inhalation and skin contact are the main ways workers are exposed to solvents. Gloves, PPE and ventilation are all important protections though some solvents can penetrate gloves. Some solvents react with other chemicals and have other unexpected effects, so risk mitigation should be context-specific for particular chemicals. [53]

Acids and Bases

used in electroplating, etching, crystal polishing, fluxes and metal pickling (a form of cleaning). They can be breathed in or create skin burns when accidental splashes happen. Acids and bases are dangerous, and some acids create toxic gases or fire risk as a byproduct when exposed to air or water. For example, hydrofluoric acid, when in contact with potassium cyanide, gives off cyanide gas. [54]

Metals

used in electronics for processes such as "etching, electroplating, metallization, soldering, bonding, sealing, crystallization, deposition, and for coating various electrical and electronics parts (such as cathodes and electrodes)." [55] Workers can breathe in metal dusts and fumes (both of which can irritate lungs) or come in skin contact by touching metals. Fume particles are smaller than metal dust particles, so they can cause more lung damage than metal dusts. Soldering is extensive in electronics and involves the metal lead, which is known to be neurotoxic, bad for reproductive health and harmful to developing fetuses. Employees working with metals need to know which forms they will be using. [56]

Gases

used in doping and crystal growing can also be products of decomposition. Some gases, such as helium, have few hazards other than they are dangerous to breathe in high amounts; others are extremely dangerous, causing lung irritation and other health problems such as cancer. Gases can also be highly flammable. Crystal growing and doping gases should ideally be contained in machines running these processes, but leaks can occur and must be checked for continually. Most hazardous gases are used in doping and deposition processes, and to a lesser extent, in the etching processes. [57]

Other Hazardous Substances

include asbestos and fiberglass. Asbestos is a known carcinogen, and fiberglass is also suspected of causing cancer. They are found in fillers in epoxy resins and other plastics, in wire coatings, as reinforcements in printed circuit boards and as electrical insulation. Other hazards are plastics and resins, which include known carcinogens and can be flammable. [58]

52. "Unmasking the Hazards: A Workers Guide to Job Hazards in the Electronics Industry." Santa Clara Center for Occupational Health and Safety, 1981.
53. Ibid.
54. Ibid.
55. Ibid.
56. Ibid.
57. Bozzini, Chris, and Harriman, Elizabeth. "Hazardous Materials in the Semiconductor Industry." Tufts University, April 24, 1991.
58. Ibid.

Radiation

includes ionizing forms from x-rays, radioisotopes and nuclear sources found in various chemicals such as Krypton 85, used especially in military orders. They are pumped into sealed packages to test for leaks that can cause an IC to fail. X-rays are also used to quality control circuit boards and for lithography, experimentally. Other types of radiation that might be used are microwave and laser radiation. [59]

PFAS "Forever Chemicals"

Per- and polyfluoroalkyl substances (PFAS) are also known as "forever chemicals" because they can persist in the body for a long time, cause a variety of effects on multiple organ systems and can have neurodevelopmental effects on developing fetuses. [60] "PFAS can be present in the chemicals directly used to manufacture semiconductor and related devices such as in photoresist liquids, etch chamber gases, as well as the containers that hold them," writes SEMI. [61] Even as the semiconductor industry claims they are decreasing the use of PFAS, alternatives such as "perfluorobutane sulfonamide derivatives are emerging as a new trend in fluorosurfactants used in the semiconductor industry." [62] While "shorter fluorosurfactants may be less prone to accumulating in mammals, there is still some concern that they may be harmful to both humans and the environment," though research is still being conducted into these alternatives to see if they are workable alternatives to "forever chemicals." [63]

Chemical Hazards at Each Step of Production

While breaking down the hazards of chemical groupings is helpful when trying to understand the big picture of hazards, it is also crucial to understand which chemicals are used at different steps of the production process.

The first step of production involves silicon and purification processes, which can involve cleaning and purification agents, while the semiconductor fabrication step can involve many chemicals, including acids for etching processes or doping steps, which include a variety of performance-enhancing chemicals for the semiconductor. The last step, incorporating metallization, involves metals added to the chip to better integrate it into electronic products, and can involve epoxies or resins to mount the semiconductor.

Step One: Silicone Purification and Manipulation

Semiconductors are made of raw materials including silicon of high purity and quality, as well as other substances such as germanium (Ge), gallium arsenide (GaAs) and gallium phosphide (GaP). [64] Silicon undergoes chemical treatment in order to become as pure as possible. [65] After it's purified, it is melted at a high temperature and other chemicals and substances may be added to give the chip high-performing properties. "Through the process of heat and added chemicals such as trichlorosilane, boron, chlorides, and phosphine, pure silicon is derived and ready to be manufactured into the silicon crystal."[66]

Hazards in this stage relate to chemicals added to the silicon ingot – at a very high temperature, as the melting point of silicon is over 2,500 degrees F. Therefore, gases are the biggest source of toxicity in this step. Phosphine, a doping agent used in fabrication of silicon wafers, occurs naturally when phosphoric acid is heated. Phosphine can create explosive and fire hazards by way of a spontaneous chemical reaction. Germanium, which is added to enhance doping, can be very toxic when alloyed with arsenic, part of another compound added in this process, gallium arsenide (GaAs). [67] Manufacturers are now transitioning to single-wafer processes, where only one wafer is processed at a time as opposed to batch processing where multiple are processed simultaneously. Single-wafer processes offer higher quality deposition and etch processes, but require more water, which will be a significant issue, especially in places with drier climates, such as Texas, California and Arizona (2023). [68]

59. Bozzini, Chris, and Harriman, Elizabeth. "Hazardous Materials in the Semiconductor Industry." Tufts University, April 24, 1991.
60. Adelman, Marguerite. "The True Cost of PFAS and Global Foundries Government Grants and Contracts," Military Poisons Newsletter, April 7, 2024.
61. "PFAS Explainer," SEMI, https://www.semi.org/en/ehs_PFAS/PFAS_in_Semiconductor_Mfg#:~:text=It%20is%20important%20to%20understand,the%20containers%20that%20hold%20them..
62. Chen, et al. "Emerging Perfluorobutane Sulfonamido Derivatives as a New Trend of Surfactants Used in the Semiconductor Industry." Environ. Sci. Technol. 2024, 58, 1648−1658.
63. U.S. EPA,OW. 2016. "PFOA, PFOS and Other PFASs | US EPA." US EPA. March 30, 2016. https://www.epa.gov/pfas.
64. Bozzini, Chris, and Harriman, Elizabeth. "Hazardous Materials in the Semiconductor Industry." Tufts University, April 24, 1991.
65. LaDou, Joseph, and Rahm, Timothy. "The International Electronics Industry." Silicon Valley Toxics Coalition, 1998.
66. Dyal, D. "Semiconductor Manufacturing." 1997. https://www.laits.utexas.edu/~anorman/long.extra/Projects.F97/DAVID/paper.html#:~:text=Through%20the%20process%20of%20heat,in%20to%20the%20silicon%20crystal.
67. Talbot, Cynthia E and PHASE Staff. "Toxic Substances Commonly Found in Electronics: A Guide for Health Professionals." Santa Clara Center for Occupational Safety and Health.
68. Programmatic Environmental Assessment for Modernization and Internal Expansion of Existing Semiconductor Fabrication Facilities Under the CHIPS Incentives Program." U.S. Department of Commerce. December 2023; memsstar. "Single Wafer vs Batch Wafer Processing." Memsstar, 21 Feb. 2018, memsstar.com/single-wafer-vs-batch-wafer-processing/.

Step Two: Chip Fabrication

In this step, "circuits are etched onto silicon or germanium wafers in sequential photolithography stages, comprising etching, thin film (T/F) production, including chemical vapor deposition (CVD) and physical vapor deposition (PVD); diffusion, including doping steps such as implanting and furnace heating (oxidation, annealing); and chemical mechanical polishing and cleaning." [69] Solvents are a concerning source of toxicity in the etching step, particularly because many chemical additions or subtractions to the wafer might occur. [70]

Circuit fabrication requires many steps such as photolithography, etching/stripping, doping, deposition of steps and metallization. [71] Photolithography transfers circuit patterns on the photomasks to the substrate surface. This can involve coating the substrate, normally covered by silicon dioxide, with a light-sensitive substance called photoresist. UV light, and less often, electron beams or x-rays, may be the light enabling photoresist's activity. There are positive and negative photoresists, which either are strengthened or weakened in the presence of light. Some photoresists, such as xylene, are not only toxic but also cause reproductive effects (1998). [72]

Additional materials can be added to or removed from the silicon wafer via plasma processes, which occur at high heat, creating fumes. Chemical vapor deposition is one way materials are deposited on a substrate using plasma. [73] Compounds might also be removed or cleaned using plasma. These processes can happen at high temperatures, with a variety of chemicals. Lastly, metallization involves adding metal so the wafer can connect electronically in a circuit. [74] Common ways to add metal to a wafer include filament evaporation, electron-beam evaporation, flash evaporation, induction evaporation and sputtering. [75] Metal fumes and dust alike are a challenge from a health perspective for the metallization process.

In sum, many of the methods involved in circuit fabrication require water and energy while generating pollution and posing chemical exposure risks to individual workers (2023).

The processes and chemicals involved in these stages introduce a number of hazards and risks for individual workers as well as the environment and surrounding communities. For example, lithography and etching steps involve PFAS or "forever chemicals." As the U.S. Department of Commerce notes (2023), "Currently, per- and polyfluoroalkyl substances (PFAS) are used in lithography and etching. PFAS compounds are resistant to hydrolytic, photolytic, and oxidative reactions which limits wastewater treatment technologies to high temperature processes (high cost) or adsorption onto a media."[76]

Deposition and dry etching are two other fabrication methods, and they use high global warming potential (GWP), fluorinated greenhouse gases (GHGs)/(F-GHGs) including perfluorochemicals (PFCs), hydrofluorocarbons (HFCs) and nitrous oxide (N2O). [77] Emissions can be reduced through "process optimization, alternative chemistries, and/or abatement." [78]

In sum, many of the methods involved in circuit fabrication require water and energy while generating pollution and posing chemical exposure risks to individual workers (2023). [79]

69. Hein, L., Whittaker, M., and Fong, A. "Chemicals Used in the Electronics Industry." Patty's Industrial Hygiene and Toxicology, 2023. https://www.researchgate.net/publication/365174648
70. Bozzini, Chris, and Harriman, Elizabeth. "Hazardous Materials in the Semiconductor Industry." Tufts University, April 24, 1991.
71. Ibid.
72. LaDou, Joseph, and Rahm, Timothy. "The International Electronics Industry." Silicon Valley Toxics Coalition, 1998.
73. Ibid.
74. Ibid.
75. Ibid.
76. "Programmatic Environmental Assessment for Modernization and Internal Expansion of Existing Semiconductor Fabrication Facilities Under the CHIPS Incentives Program." U.S. Department of Commerce. December 2023.
77. Ibid.
78. Ibid.
79. Ibid.

Step Three: Semiconductor Chip Packaging and Circuit Board Fabrication / Assembly

In printed circuit board (PCB) assembly, "Multiple electronic components are incorporated onto a PCB, followed by cleaning, fluxing, soldering, trimming, and testing." The assembled PCB is combined with other components and materials to produce the end electronic product. [80]

Encapsulation refers to the placing of a silicon wafer in an integrated circuit. This can involve epoxy resins, which include known carcinogens. Solder and fluxes are also part of these processes, and solder is typically 40% lead (although this report's sources for this process may be out of date.)". [81] Flux, on the other hand, has ethanol, propanol or isopropanol as the major ingredient. The risks here are both to the individual workers as well as environmental risks of waste to air, water and the overall environment for local communities (2023). [82]

Conclusion

To protect workers and communities from potential hazards, we need to know:

- All of the *current* processes that fabs use to produce chips and printed circuit boards.
- What hazards occur at each phase of production in these updated processes.
- What metals are used throughout the current manufacturing of chips and boards.
- The toxic details of every chemical used at each stage.
- The contemporary work process for technicians (tasks, exposure potential) to better understand hazards facing technicians today.

80. Hein, L., Whittaker, M., and Fong, A. "Chemicals Used in the Electronics Industry." Patty's Industrial Hygiene and Toxicology, 2023. https://www.researchgate.net/publication/365174648
81. LaDou, Joseph, and Rahm, Timothy. "The International Electronics Industry." Silicon Valley Toxics Coalition, 1998.
82. "Programmatic Environmental Assessment for Modernization and Internal Expansion of Existing Semiconductor Fabrication Facilities Under the CHIPS Incentives Program." U.S. Department of Commerce. December 2023.

IV. Health Risks to Workers and Communities: What We Know and What We *Don't Know*

With clarity on the known hazards of chemicals used in semiconductor manufacturing, and the existing albeit tenuous protections currently in place for workers, the fundamental question we must all ask is: What risk do workers and communities currently face?

The answer is, unfortunately, not simple. First of all, there is not enough data available to this team to undertake any traditional risk assessment. More generally, without unfettered access to industry information on comprehensive chemicals and processes, including details about chemicals considered trade secrets, a complete risk analysis is an impossibility. Most importantly, the lack of current regulations around monitoring and systematic data collection by industry for public use results in a treacherous lack of transparency and lack of data. The lack of transparency, especially under the protection of trade secrets, threatens lives.

A. Risk Assessments

i. Methods for Calculating Risk, and Why We Can't Use Most of Them

To calculate the risk workers and fence-line communities face from potential toxic exposure by fabs, two assessments must be conducted: a **workplace risk assessment** and a **pollution risk assessment.**

The most common techniques for conducting a risk assessment include: [83]

- actuarial techniques (which rely on historical data to determine the probability of an event)
- engineering-based techniques (which use a theoretical model to estimate the failure rate of each component in a system to develop the overall risk of an event)
- qualitative techniques (where all risk factors associated with a project are listed, each category is assigned a relative score, scores are totaled for each alternative and used to determine whether risk reduction justifies higher costs)

In all cases, the goal is to identify potential liabilities based on current processes or products used at factories. Once liabilities have been identified, alternatives can be reviewed to assess potential changes to processes or products to reduce future liabilities. Liabilities might include penalties, fines, personal injuries or illnesses, property damage or natural resource damage. Liabilities, in other words, are another way of saying costs that the client hiring the assessment (most often, the company) must face.

This report is concerned with the risk to workers or people living in fence-line communities, and by "risk" we are referring to the risk to human health, the risk of harm. However, in the above risk assessments, the "risk" is the risk of added costs, the risk that a product cannot be made because it is too expensive to produce.

As a result, a risk assessment is similar to a cost-benefit analysis. This means final recommendations are made based on which path forward will result in the lowest cost to the company. In the case of decisions that affect human or environmental health, this can include putting a price on a human life or on the safety of parts of the environment. For example, is it more costly to update a process so there are no risks of exposure, or is it more costly to pay for the cost of a human's loss of life or deteriorating health? Do we use hospital costs to represent the cost of human health? If there are no legal requirements to pay for medical bills, then is the cost of human health relevant in the cost analysis?

A skilled policy analyst will emphasize that costs should not be the final arbiter of a policy decision, especially when part of the equation is "putting specific quantified values on things that are not normally quantified" [84] and the same goes for risk assessments. However, there is no predicting how these assessments will be used. Therefore, this report recommends caution when taking risk assessments at face value, and encourages consumers to carefully review what is quantified and how, and whether the quantifying choices made reflect the consumer's ethical values.

Aside from the theoretical debate around risk assessments, all of the above mentioned techniques were not feasible in this study because they require intimate involvement with the company(ies) producing the semiconductors. The techniques either require knowledge of past events of unintended exposure by the company, the failure rate of each component in the production system or the risk factors of each component in the production process, including the risk of using trade secret chemicals. This team did not have the relationships necessary to conduct such assessments.

83. Badgett, Lona, et al. Analysis of Pollution Prevention and Waste Minimization Opportunities Using Total Cost Assessment: A Case Study in the Electronics Industry. Pacific Northwest Pollution Prevention Research Center, July 1996.
84. Kelman, Steven. "Cost-Benefit Analysis: An Ethical Critique." American Enterprise Institute - AEI, Feb. 7, 1981, www.aei.org/articles/cost-benefit-analysis-an-ethical-critique/.

ii. Lack of Transparency from Industry

Even when teams have the participation of companies, there is no guarantee companies will disclose all necessary information, either because they don't have the complete picture or because there are concerns around trade secrets. For example, in 2018, Sunju Kim et al conducted a study entitled "Chemical use in the semiconductor manufacturing industry" wherein they attempted to identify chemical hazards in semiconductor manufacturing. They were given access to the chemical information database of a company "with a large market share of the worldwide semiconductor industry." [85] However, the authors found that a large proportion of the products contained trade secret ingredients:

> *[...] more than 150 pure chemical substances were used in about 430 chemical products in a semiconductor company; about 40% of these chemical products contained trade secret ingredients. In photolithography, one of the most widely used processes in semiconductor manufacturing, nearly all products (about 98%) contained trade secret ingredients, with an average number of approximately two per product [...] Therefore, it was difficult to determine the exact characteristics of the products using the SDSs [Safety Data Sheets] of products provided by the chemicals manufacturer [...] Trade secrets are necessary for companies but difficult in terms of work environment management because we do not know the harmfulness of the substance without knowing the ingredient.* [86]

When the authors attempted to extrapolate information with the data provided, they ran into further obstacles:

> *In the company investigated here, there was no DB or management system that could be consulted to determine how many chemical products were used in each process, and in what amounts [...] It was difficult to classify chemical products by process because the Safety, Health, and Environment (SHE) team in the company had no DB available that we could consult.* [87]

The obstacles in this study demonstrate the difficulty in assessing the risk to workers even with company cooperation. Without regulations that guide companies on data collection for risk assessments, the process is remarkably difficult.

Trade secrets are necessary for companies but difficult in terms of work environment management because we do not know the harmfulness of the substance without knowing the ingredient.

iii. Need for Better Regulations around Data Collection and Monitoring

Not only is it difficult for advocacy and research organizations, it's also challenging for federal agencies to collect the necessary data for risk assessments. In "The Unsteady State of Inertia of Chemical Regulation Under the U.S. Toxic Substances Control Act" (2017), Sheldon Krimsy describes the obstacles the EPA itself encounters:

> *The law requires the EPA to have 10 ongoing risk evaluations in the first 180 days and 20 within 3.5 years. Let us assume it will have to undertake risk evaluations for 10% of the existing [unstudied] chemicals—that's 8,500 in groups of 20 to be completed every 3.5 years. That would take about 1,500 years to complete. That is not a very encouraging outcome and mirrors the glacial pace of evaluating endocrine-disrupting chemicals. With a priority list of 500 chemicals a year and a 3-year completion time, the task could be completed in 50 years.* [88]

This estimate is written with the assumption that industry is not intentionally obfuscating the process. However, procedure estimates must also take into account past events where industry has hidden the potential toxicity of unregulated substances. One example of such obfuscation lies in the myriad of lawsuits against the American multinational chemical company DuPont. While DuPont still refuses to accept responsibility, the lawsuits have made clear through evidence and proceedings that the company had knowledge of PFOA's toxicity and presence in the environment in violation of the Toxic Substances Control Act.[89]

85. Kim, Sunju, Chungsik Yoon, Seunghon Ham, Jihoon Park, Ohun Kwon, Donguk Park, Sangjun Choi, Seungwon Kim, Kwonchul Ha, and Won Kim. 2018. "Chemical Use in the Semiconductor Manufacturing Industry." International Journal of Occupational and Environmental Health 24 (3-4): 109–18. https://doi.org/10.1080/10773525.2018.1519957.
86. Ibid.
87. Ibid.
88. Krimsky, Sheldon. "The Unsteady State and Inertia of Chemical Regulation under the US Toxic Substances Control Act." Edited by Linda S. Birnbaum. PLOS Biology 15, no. 12 (December 18, 2017): e2002404. https://doi.org/10.1371/journal.pbio.2002404.
89. Rich, Nathaniel. "The Lawyer Who Became DuPont's Worst Nightmare." The New York Times, Jan. 6, 2016, www.nytimes.com/2016/01/10/magazine/the-lawyer-who-became-duponts-worst-nightmare.html.

What's more, companies seeking to avoid liability have a variety of methods for doing so. A recent court decision on DuPont lawsuits in North Carolina acknowledged that offshoot and associated companies will be held liable along with the original incriminated company. As North Carolina Attorney General Josh Stein summarized in a public statement (2024),

> *Companies cannot engage in corporate shell games to avoid liability for the messes they make [...] I'm pleased that this ruling provides that Chemours, DuPont, and its related companies cannot avoid responsibility by engaging in corporate restructuring schemes. Our fight for clean drinking water continues.* [90]

When industry obfuscation is included in the estimates, it is easy to imagine the EPA will never complete studies of the remaining unstudied chemicals.

However, as Krimsky emphasizes, the process of protecting the public from toxic exposure would be dramatically different if toxic exposure laws reversed the burden of proof and made industry responsible for proving safety rather than government responsible for proving toxicity. As Krimsy suggests,

> *If we operated under the assumption that a substance is unsafe until proven otherwise, the onus would be reversed: the manufacturers would have to spend decades in research to remove all uncertainty and demonstrate that a chemical was unimpeachably safe—a true precautionary approach. Society would not be spending a millennium playing catchup with the unknown risks from having adopted an approach that favors commerce over health.* [91]

Such a change in policy would require monumental action, including an act of Congress. In lead up to advocacy efforts for change of that scale, qualitative data in the form of personal accounts is often the most important data to collect, especially for advocacy groups representing the needs of people most affected.

The process of protecting the public from toxic exposure would be dramatically different if toxic exposure laws reversed the burden of proof.

B. What We Know about Worker and Community Health

Ethical Collection of Health Data

As mentioned in Section I, this report strongly recommends using health data collected in and with the community. However, such organizing was not possible in the short time allotted for this research. Instead, future research should prioritize the collection of health data with workers and community members. It is critical that this is done in a way that empowers the community members. **Appendix G** presents a summary of ethical principles for collecting, analyzing and using health data. The main takeaway is that it is critical that the affected people/communities be involved in decisions and processes of collecting and using the data.

When SVTC and SCCOSH were organizing in Silicon Valley in the 1970s and 1980s, they conducted countless programs to bring workers and community members together, share experiences, document experiences, learn about hazards and more. Folders in the San Jose State University Archives share the organizations' archived surveys, workbooks and worksheets, and organizing notes, including records from individual workshops designed for women workers from specific national origins. Facilitators fluent in the native languages and translators were placed in the programs, and the events were designed to include opportunities to share through culturally specific artistic means, including dance, song or other media. There are dozens of handwritten surveys with resoundingly positive comments about the events.

Clearly, there are resources available to help design nuanced events for different audiences and groups of people. More importantly, in Texas and California, there are already highly organized and productive community-driven nonprofits dedicated to environmental and racial justice with track records of fighting toxic exposure. For example, in Texas there are groups including T.E.J.A.S. (Texas Environmental Justice Advocacy Services) in Houston, PODER (People Organized in Defense of Earth and Her Resources) in Austin, Southwest Workers Union Centro Por La Justicia in San Antonio, and several other environmental justice organizations and branches of national groups like Greenpeace, the National Audubon Society and the Sierra Club. In

90. Ahmed, Nazneen. "Court Grants Significant Win in Attorney General Stein's PFAS Case against Chemours and DuPont." NCDOJ, Feb. 8, 2024, ncdoj.gov/court-grants-significant-win-in-attorney-general-steins-pfas-case-against-chemours-and-dupont/#:~:text=Attorney%20General%20Stein%20sued%20DuPont.
91. Ibid.

California, not only are the retired founders of SCCOSH and SVTC still active, there are member organizations of the California Environmental Justice Alliance (CEJA) that span the entire state and the Center for Environmental Health (CEH), to name a few.

The data used to gain insight into the health hazards the workers and communities face was gleaned from existing data through the Bureau of Labor Statistics (BLS), American Community Survey (ACS) data and Community Health Needs Assessments (CHNAs) in counties that house major semiconductor manufacturing facilities.

BLS Data: National Statistics

One method for evaluating the current health hazards of semiconductor manufacturing is to review the data that BLS collects on workplace injuries and illnesses.

In the following Tables 1 and 2, the methods of Dr. Joseph LaDou are modified for contemporary BLS data to present the proportion of workers with reported illnesses in an industry category compared to the total number of workers with reported illnesses and injuries. As noted in Table 1, workers in Semiconductor and Related Devices manufacturing experience a much higher proportion of illnesses than workers in Electronic Components and Accessories. In fact, semiconductor workers experience nearly double the proportion of illnesses than workers in all manufacturing industries.

Table 1
National Statistics on Reported Occupational Injuries and Illnesses, 1997-2001.

	All Manufacturing Industries	Electronic Components and Accessories *(SIC Code 367)*	Semiconductor and Related Devices *(SIC Code 3674)*
1997			
Proportion of Illnesses out of Total Injuryand Illness Cases	13.5%	17.5%	27.4%
Total Injury Cases	1,662,100	26,400	6,100
Total Illness Cases	259,300	5,600	2,300
1998			
Proportion of Illnesses out of Total Injuryand Illness Cases	12.9%	16.9%	22.9%
Total Injury Cases	1,598,500	25,100	6,400
Total Illness Cases	236,400	5,100	1,900
1999			
Proportion of Illnesses out of Total Injuryand Illness Cases	13.1%	18.8%	30.5%
Total Injury Cases	1,483,100	21,600	4,100
Total Illness Cases	223,000	5,000	1,800
2000			
Proportion of Illnesses out of Total Injuryand Illness Cases	12.7%	16.5%	22.1%
Total Injury Cases	1,441,700	21,800	5,300
Total Illness Cases	209,700	4,300	1,500
2001			
Proportion of Illnesses out of Total Injuryand Illness Cases	13.0%	17.5%	28.6%
Total Injury Cases	1,209,700	19,300	4,500
Total Illness Cases	181,200	4,100	1,800

The proportion of illnesses out of total injury/illness cases is calculated by dividing "total of injury cases" by "total cases of injuries and illnesses."

Source: Bureau of Labor Statistics, Historical Data for Occupational Injuries and Illnesses by Industry, https://www.bls.gov/iif/nonfatal-injuries-and-illnesses-tables/soii-summary-historical.htm, Years 1997-2001.

In Table 2, similar trends are witnessed again 20 years later. It is heartening to notice that across the board in 2018, all industries appear to have reduced the proportion of illnesses workers experience, however, semiconductor workers are experiencing nearly three times the proportion of illnesses than workers in all other manufacturing industries. By 2019, semiconductor manufacturing workers are experiencing nearly four times the proportion of illnesses when compared to all manufacturing workers. Once COVID arrives in 2020, the data is more difficult to judge given the overall prevalence of illness across the world.

Table 2
National Statistics on Reported Occupational Injuries and Illnesses, 2018-2022.

	All Manufacturing Industries *(NAICS Code 31-33)*	**Electronic Components and Accessories** *(NAICS Code 3344)*	**Semiconductor and Related Devices** *(NAICS Code 334413)*
2018			
Proportion of Illnesses out of Total Injuryand Illness Cases	8.1%	7.5%	23.5%
Total Injury Cases	395,300	3,700	1,300
Total Illness Cases	35,000	300	400
2019			
Proportion of Illnesses out of Total Injuryand Illness Cases	7.8%	11.9%	31.3%
Total Injury Cases	388,400	3,700	1,100
Total Illness Cases	33,000	500	500
2020			
Proportion of Illnesses out of Total Injuryand Illness Cases	16.3%	24.3%	38.5%
Total Injury Cases	312,400	2,800	800
Total Illness Cases	60,900	900	500
2021			
Proportion of Illnesses out of Total Injuryand Illness Cases	13.1%	22.7%	42.9%
Total Injury Cases	334,500	3,400	800
Total Illness Cases	50,600	1,000	600
2022			
Proportion of Illnesses out of Total Injuryand Illness Cases	12.3%	26.5%	42.9%
Total Injury Cases	347,800	3,600	1,200
Total Illness Cases	49,000	1,300	900

The proportion of injuries out of total injury/illness cases is calculated by dividing "total of injury cases" by "total cases of injuries and illnesses."

Source: Bureau of Labor Statistics, Historical Data for Occupational Injuries and Illnesses by Industry, https://www.bls.gov/iif/nonfatal-injuries-and-illnesses-tables/soii-summary-historical.htm, Years 1997-2001.

While these numbers show consistently higher levels of illness proportionally for semiconductor manufacturing workers than other manufacturing workers, the question remains whether these numbers are enough to indicate toxic exposure illnesses.

Table 3 compares the proportion of illnesses to the proportion of injuries across industries between 2018-2022, and there is an inverse relationship between the proportion of illness and proportion of injury. The higher the proportion of injuries, the lower the proportion of illnesses. However, that doesn't necessarily cancel out the importance of semiconductor manufacturing having more illnesses than any other industry. The question should rather be why there are more illnesses.

Table 3
National Statistics on Reported Occupational Injuries and Illnesses, 2018-2022.

	All Manufacturing Industries *(NAICS Code 31-33)*	**Electronic Components and Accessories** *(NAICS Code 3344)*	**Semiconductor and Related Devices** *(NAICS Code 334413)*
2018			
Proportion of Illnesses out of Total Injury and Illness Cases	8.1%	7.5%	23.5%
Proportion of Injuries out of Total Injury and Illness Cases	91.9%	92.5%	76.5%
2019			
Proportion of Illnesses out of Total Injury and Illness Cases	7.8%	11.9%	31.3%
Proportion of Injuries out of Total Injury and Illness Cases	92.2%	88.1%	68.8%
2020			
Proportion of Illnesses out of Total Injury and Illness Cases	16.3%	24.3%	38.5%
Proportion of Injuries out of Total Injury and Illness Cases	83.7%	75.7%	61.5%
2021			
Proportion of Illnesses out of Total Injury and Illness Cases	13.1%	22.7%	42.9%
Proportion of Injuries out of Total Injury and Illness Cases	86.9%	77.3%	57.1%
2022			
Proportion of Illnesses out of Total Injury and Illness Cases	12.3%	26.5%	42.9%
Proportion of Injuries out of Total Injury and Illness Cases	87.7%	73.5%	57.1%

The proportion of illnesses out of total injury and illness cases is calculated by dividing "total of illness cases" by "total cases of injuries and illnesses."
The proportion of injuries out of total injury/illness cases is calculated by dividing "total of injury cases" by "total cases of injuries and illnesses."

Source: Bureau of Labor Statistics, Historical Data for Occupational Injuries and Illnesses by Industry, https://www.bls.gov/iif/nonfatal-injuries-and-illnesses-tables/soii-summary-historical.htm, Years 1997-2001.

Unfortunately, the data does not have the same categorical breakdowns that existed in the 2000s. For example, in 2003 when LaDou was constructing these occupational health analyses, BLS data had subcategories that identified whether illnesses were a result of exposures to caustic, noxious or allergenic substances. That breakdown is no longer possible.

There are also more general limitations to the data available through BLS. For example, while demographic breakdowns are available, they cannot be cross-referenced. Either the demographics are broken down for all workers in all industries, or injuries and illnesses are available for individual industries, but the demographic breakdown of illnesses or injuries cannot be identified.

It is also important to note that semiconductor manufacturing today is not what it was in 1997-2003. In 1997, there were 658,000 people employed in semiconductor manufacturing. By 2003, it had already dropped to 451,000.[92] In 2020, there were 277,000 employed in semiconductor manufacturing, and the landscape of manufacturing in the United States had dramatically changed to include far more research, development and design.

Ultimately, the takeaway from the tables above is to emphasize the importance of collecting occupational health data, particularly more detailed data that can offer heightened insight into illnesses and injuries that may result from toxic exposure, and to follow the trends as the industry ramps up and more workers and communities are put in the position of potential exposure.

92. U.S. Bureau of Labor Statistics. 2015. "Injuries, Illnesses, and Fatalities." Bls.gov. September 2015. https://www.bls.gov/iif/.

ACS Data: National Demographic Statistics

American Community Survey (ACS) data is one source for collecting demographic information. As has been noted by labor academics in the industry, the global labor market in the production side of electronics manufacturing has often employed more women than men, and has attracted workers from across national borders. As labor academic Anibel Ferus-Comelo noted about international labor trends between 1985-2000 (2006), "immigrant workers in electronics production tend to be women, and there is a growing trend toward the 'feminization of migration' [...]" [93] When examining ACS data, on first glance it seems trends are not parallel in present electronic manufacturing in the United States. However, ultimately it's unclear.

ACS data indicates that national semiconductor manufacturing trends show that the majority of workers in 2022 were non-Hispanic white (53.2%) and native born (67.4%). [94] Women are underrepresented (47.3%), and the vast majority of women working in the electronic component and product manufacturing industry (70.5%) did not have children under 18 living with them. [95]

A closer look at these statistics, however, reveals that they only represent electronic component and product manufacturing; they do not zoom in on the specifics of semiconductor manufacturing. Moreover, the statistics represent all occupations in the industry, including engineers, managers, software developers and sales representatives in addition to production jobs such as assemblers, fabricators, "other production workers," etc. Without a demographic breakdown of the specific occupations, it's unclear how women and minorities are represented in the areas of the industry with more risk of toxic exposure.

Health Equity Data: Texas vs. New York

When attempting to identify the health status of community members living near semiconductor manufacturing facilities, the ideal scenario is to use health data collected from and with community members. Another option is to refer to Community Health Needs Assessments (CHNAs), reports nonprofit hospitals are federally required to produce every three years.

To gain a sense of what data might be available through CHNAs, this report conducted case studies of two key counties where large semiconductor manufacturing facilities exist. The first, Williamson County, Texas, contains the city of Taylor, where Samsung facilities are located and expected to hire 2,000 employees by the end of 2024. [96] The second, Saratoga County, New York, contains the city of Malta, where GlobalFoundries facilities are located with an estimated 3,000 employees. [97] These two locations were chosen based on the comparable size of the facilities and ensuing impact on the locale.

Following is a summary of the findings of these case studies.

Comparing Geographies

One key difference between the two is Williamson County, Texas, also contains several other fabs. In addition to the planned Samsung facility in Taylor, Williamson County also contains parts of Austin, where there are six other semiconductor manufacturing factories: Intel/Tower, Samsung, AMD, Applied Materials, Infineon Technologies and NXP. The county also includes Georgetown (where Schunk Xycarb is located), and Roundrock (where Littlefuse is located). [98] Therefore, while the Samsung facility has not yet been built in Taylor proper, the county's community health data still reflects the impact that the existence of fabs can have on people living in the area.

In contrast, Saratoga County, New York, does not contain other fabs besides GlobalFoundries. The county abuts Albany and Rensselaer Counties, both of which contain semiconductor companies, but none of the facilities are involved in manufacturing. However, GlobalFoundries already exists and is operational. Health data should also reflect the impact a local manufacturing facility can have on people living in the area. Therefore, the locations are not perfectly comparable, but they are a close match.

93. Ferus-Comelo, Anibel. "Double Jeopardy: Gender and Migration in Electronics Manufacturing." article sourced from: Smith, Ted; Sonnenfeld, David A. and David Naguib Pellow (ed). Challenging the Chip: Labor Rights and Environmental Justice in the Global Electronics Industry. Temple University Press, Philadelphia, USA (2006): 44.
94. Laughlin, Lynda, and Anthony Martinez. "Powering the Economy One Chip at a Time: Electronics Industry Facing an Aging Workforce." Census.gov, Sept. 29, 2023, www.census.gov/library/stories/2023/09/one-chip-at-a-time.html#:~:text=The%20ACS%20categorizes%20semiconductor%20workers. Accessed June 11, 2024.
95. Ibid.
96. "Taylor." Samsung Semiconductor USA, semiconductor.samsung.com/us/sas/company/taylor/.
97. McGill, Eric. "Global Foundries Moves Corporate Headquarters to Its Most Advanced Semiconductor Manufacturing Facility in New York." Global Foundries, April, 26, 2021, gf.com/gf-press-release/globalfoundries-moves-corporate-headquarters-its-most-advanced-semiconductor/#:~:text=GF%20employs%20more%20than%2015%2C000. Accessed June 11, 2024.
98. Sonnenfeld, David. "Informational Interview with David Sonnenfeld." Unpublished Interview, June 6, 2024.

Health and Economic Indicators

CHNAs provide data on a county level, and in the case of both Williamson County and Saratoga County CHNAs, there was no special attention given to potential environmental hazards from local semiconductor manufacturing industries.

The reports offer a demographic breakdown of counties and highlight potential changes in the population that might have implications on public health. This includes projected changes in the overall population age or size. The CHNAs also offer a demographic breakdown by self-identified race and ethnicity, and income bracket.

Both Williamson County and Saratoga County demographics are comparable to national demographic percentages for electronic components and manufacturers. In Williamson, rates of white- and Asian-identifying persons are higher. In both counties, rates of Hispanic-identifying persons are lower. In Saratoga County, Black/African American-identifying persons make up the third-largest racial group, which is relatively higher than national statistics for electronic components and manufacturers.[99] It can be useful to identify whether community demographics mirror worker demographics in the facilities to assess how demographics are distributed in each area, how racial equity factors in hiring practices and how these might impact public health. However, as noted previously, ACS data on worker demographics is very limited so an adequate comparison is not presently possible.

Otherwise, in order to assess the health equity of a community and the resulting precarity of the community if it were to face added exposure to hazards, it is important to study the health and economic indicators present in a community.

Both areas also have increased female breast cancer and lung cancer rates ... Given the generally positive health outcomes across the board in these two counties, this outlying statistic raises questions for further research.

Findings

Both Williamson and Saratoga County are economically affluent areas with around half the rate of poverty seen nationwide. In addition, both areas have low rates of medically uninsured residents and low rates of unemployment. This indicates that the counties should be relatively well equipped to handle an environmental contaminant if introduced to the area.

However, both areas also have pockets of low-income community members who have not benefited from local economic growth and who struggle to meet basic needs that make up essential social determinants of health. Vulnerable populations would likely be deeply impacted by an environmental contamination event such as toxic exposure. These populations include primarily low-income households and racial minorities currently experiencing health disparities.

Both areas also have increased female breast cancer and lung cancer rates, with increased rates of prostate and all other cancer types in Williamson County alone (where there is a higher concentration of fabs throughout the county). Given the generally positive health outcomes across the board in these two counties, this outlying statistic raises questions for further research.

Conclusion and Further Research

There are many obstacles to performing risk assessments for workers and communities affected by chip manufacturing, including lack of data about the risks workers and communities currently face, limited or no disclosure from companies, federal agencies that are already overwhelmed and the significant need for more robust data collection. Unfortunately, for the most part, CHNAs are not an ideal source of data for these studies. While they can offer surprising discoveries that warrant more investigation for industry-specific risk assessments, such as the prevalence of cancer in fab communities despite otherwise positive health outcomes in the area, CHNAs are not enough.

There is likely existing data, at least in certain geographic locations, that can be combined with workplace individual health data to make data analysis more robust and provide multiple points of reference for assessing community health and potential exposure to contaminants from local facilities.

99. "Comprehensive Community Needs Assessment: Saratoga County 2022," 14.

David Sonnenfeld, Emeritus Professor of Sociology and Environmental Policy at SUNY College of Environmental Science and Forestry, gives examples of data sources from a recent student's masters thesis: [100]

- New York State Department of Environmental Conservation is gathering water quality data from across the state including from groundwater sampling and landfill sites.
- New York State Department of Health has, in cooperation with the State Department of Environmental Conservation, been sampling private wells (drinking water sources), and collecting blood samples in de-identified ways to analyze population exposure to PFAS, PFOA, and other contaminants.

In New York, therefore, there are multiple data points and layers, from a geographic perspective, being gathered by multiple state agencies and overlaid for meaningful research on environmental exposure.

However, as Sonnenfeld also notes, the challenge is accessing, utilizing and working with the data to compare individual, workplace and community level exposures and impacts. [101]

Where there are illnesses, such as cancers, blood samples may already be being taken. In New York, data collection and analysis are being done in a cautious way where there's significant reluctance to share working findings with the general public out of fears of litigation, causing panic and other concerns for public well-being.

This report, therefore, recommends further research into state-level data being collected on environmental exposures and encourages a collaborative effort with civil society organizations to identify methods of monitoring and data analysis that can offer consistent, long-term insight into environmental exposure of toxins by local facilities to the community.

100. Sonnenfeld, David. "Informational Interview with David Sonnenfeld." Unpublished Interview, June 6, 2024.
101. Martin, Philip. "Informational Interview with Philip Martin." Unpublished Interview, March 18, 18 Mar. 2024.

V. Current Toxic Exposure Laws in The United States and the Gaps in Those Productions

Toxic exposure laws in the United States are not easy to understand. Their administration is scattered across federal, state and regional agencies, and there are both regulations and agency processes that disagree on exposure levels. In order to develop a working understanding of what laws protect workers and communities, and how to navigate them, we must consider two key questions:

1. **How have toxic exposure limits been set up until today?**
2. **How do the regulatory agencies that administer toxic exposure laws work?**

Federal Exposure Limits and Agencies

The complicated nature of current exposure limits and varying regulations can be better understood by looking at the history leading up to them. Please find an infographic in **Appendix C** that presents the entire timeline of the many agencies that have contributed to the laws over the past century. The following section breaks down federal standards across agencies and eras in order to identify the key obstacles that stand in the way of effective toxic exposure laws and government protection of health and safety.

Food and Drug Administration

Burden of Proof.
The early history of toxic exposure laws underlines the fundamental debate at the root of these laws: Who should be responsible for proving danger or safety?

The first food and drug legislation passed in 1906 to prohibit interstate commerce on misbranded and adulterated foods, drugs and drinks.[102] It was assumed that, with accurate labeling, the general public could be trusted to avoid products with dangerous ingredients like arsenic. However, as advances in synthetic organic chemistry accelerated during the 20th century, and new untested compounds were introduced into commerce, dangers to public health rose exponentially and the public could no longer be expected to know the dangers of every product. [103]

As chemicals proliferated, the government was considered responsible for proving that a product was unsafe if it was going to take action in the name of public health. However, when the 1937 Elixir Sulfanilamide tragedy occurred and 107 people died from a poisonous ingredient in the drug, the event prompted Congress to pass the Federal Food Drug and Cosmetic Act (1938) that reversed the burden of proof and required instead that the drug manufacturers give scientific evidence that new products could be safely used before placing them on the market. [104]

Outside of drug manufacturers, however, the burden of proof has remained on the government. As chemical production has grown exponentially over the decades, keeping the burden of proof on government is an unmanageable framework and has led to a failing system of regulations, implementation and enforcement. As we will see in the following discussion of OSHA and the EPA, the best solution to resolving these failures is to reverse the direction of burden of proof and require companies to demonstrate chemicals are safe beyond a doubt, not require government to prove whether each chemical is dangerous or not.

The American Conference for Governmental Industrial Hygienists (ACGIH)

Ineffective Standards.
The first debates around standardized exposure limits reveal the nexus of agendas at play: political, technical and economic.

World War II catalyzed the commercial production of industrial chemicals put to use in agriculture, manufacturing, mining, construction and consumer products. [105] At the same time, the first organization to begin conceptually brainstorming what we now consider exposure limits was formed: the American Conference for Governmental

102. Krimsky, Sheldon. "The Unsteady State and Inertia of Chemical Regulation Under the US Toxic Substances Control Act." PLOS Biology, Challenges in Environmental Health: Closing the Gap between Evidence and Regulations Collection. 18 December 18, 2017.
103. Ibid.
104. Ibid.
105. Ibid.

Industrial Hygienists (ACGIH).[106] In 1946 they released their first list of "maximum allowable concentrations" (aka MACs) encompassing 144 substances.[107] No definition was given for MACs, not whether they related to environmental or human exposure, what the timeframe was for exposure or anything. Ultimately, ACGIH had no intention of these MACs becoming standards for toxic exposure.[108] By 1948, ACGIH stopped using the term MAC and started using the term "Threshold Limit Values" (aka TLVs), however, they weren't given a formal definition until 1953: "maximum average concentrations of contaminants to which workers may be exposed for an 8-hour working day, day after day, without injury to health."[109]

This vacillating around terms and definitions emphasizes the newness of the process. The limits were being invented live, and there was much debate about whether the processes used to define the limits were, in fact, appropriate. When the MACs were issued, ACGIH refused to define them, let alone refer to them as measurements of chemical exposure considered safe.

Technical Concern: Unqualified Experts.
The technical concern over lack of physician involvement in setting health-related standards was legitimate and pointed to unqualified experts defining early limits.

ACGIH was concerned about ascribing definitive value to their numbers out of fear of standardizing exposure levels when "people vary greatly in their response to drugs and toxic substances," and the added fear that standards would place an impossible burden on manufacturers.[110] In addition, there was debate over whether industrial hygienists were qualified to determine exposure limits without the review of a physician, of which there were none on the ACGIH committee. So, instead, ACGIH issued MACs with the caveat that "the table is not to be construed as recommended safe concentrations [...] The material is presented without comment."[111]

Starting in 1970, the TLV committee began allowing "consultants" from Dow, Dupont and Bayer to submit corporate communication to them. By 1986, unpublished corporate communications had become an important resource when the committee decided whether to support TLVs.

Political Concern: Procedural Efficiency vs. Local Accuracy.
Standard setters were pressured to develop a national standard reflecting the goal to streamline procedures.

In 1946, when ACGIH was issuing uncommented numbers, most state governments, cities and counties each had their own industrial health units. Each agency evaluated MAC values for different chemicals used in their districts, and rarely did the agencies agree. For example, depending on the location of the workplace, MAC values for n-butanol ranged across agencies from 25 to 300 ppm in air, a vast degree of difference.[112] The lack of consensus across agencies was a problem government officials wanted to resolve.

When ACGIH finally committed to a definition of TLVs in 1953, it was also accepting the responsibility of navigating the difficult technical, political and economic problems it previously sought to avoid, and that government agencies were eager to discard. ACGIH TLVs were, as a result, eagerly accepted as a standard across the board by government agencies, and local industrial health units were quickly disbanded. However, the ACGIH committee setting TLVs consisted only of four to eight members until 1962, while industry was rapidly commercializing new chemicals every year.

Economic Concern: Overburdening Industry vs. Conflict of Interest.
Standard setters were influenced by industry demands; out of a desire to avoid hindering the economy, industry became involved in standard-setting, leading to a conflict of interest and compromised standards.

Starting in 1970, the TLV committee began allowing "consultants" from Dow, Dupont and Bayer to submit corporate communication to them. By 1986, unpublished corporate communications had become an important resource when the committee decided whether to support TLVs. Ultimately, 104 substances out of less than 600 listed in the Documentation of Threshold Limits were accepted on the basis of recommendations made by chemical company consultants.

106. "ACGIH - Association Advancing Occupational and Environmental Health." www.acgih.org.
107. Ziem, Grace E. and Barry I. Castelman. "Threshold Limit Values: Historical Perspectives and Current Practice." Journal of Occupational Medicine, Vol. 31, No. 11 (November 1989), pp. 910-918.
108. Ziem, Grace E. and Barry I. Castelman. "Threshold Limit Values: Historical Perspectives and Current Practice." Journal of Occupational Medicine, Vol. 31, No. 11 (November 1989), pp. 910-918.
109. Ibid.
110. Ibid.
111. Ibid.
112. Ibid.

Lack of Transparency.
In addition to industry presence being a conflct of interest, it also brought with it a lack of transparency which obstructed public awareness of the process or threat of harm due to a biased process.

Meanwhile, the committee maintained strict secrecy in its operations and would not allow interested scientists to attend its meetings as observers. By 1989, practically nothing had been disclosed to the public about the role assigned to committee members who had part-time consulting relationships with chemical producers. As of 1989, ACGIH had never required members of the TLV committee who performed corporate consulting to either disclose those business connections or excuse themselves from the development of TLVs on chemicals of importance to their clients.

Occupational Safety and Health Administration (OSHA)

Outdated and inadequate exposure limits.
In terms of the effects of TLVs on federal enforcement agencies, most of OSHA's permissible exposure limits (PELs) were issued shortly after the Occupational Safety and Health (OSH) Act was passed in 1970, and have not been updated since that time. [113] Section 6(a) of the OSH Act granted the Agency the authority to adopt existing federal standards or national consensus standards as enforceable OSHA standards. The majority of the standards were adopted from TLVs at the time. However, there is insufficient data on long-term effects for at least 90% of the TLVs adopted by OSHA in 1986. As the most explicit example of this problem, OSHA itself explicitly recognizes that many of its permissible exposure limits are "outdated and inadequate for ensuring protection of worker health" on its website. [114]

Enforcement failures.
OSHA's Hazard Communication standard (1910.1200 Appendix D) requires that safety data sheets list not only the relevant OSHA PEL but also the ACGIH TLV and any other exposure limit used or recommended by the chemical manufacturer, importer or employer preparing the safety data sheet. However, the problem with this approach is that, while OSHA is providing examples of better exposure limits, they are only able to enforce their own PELs. So, if a complaint is made to OSHA about hazards in the workplace, OSHA will measure the toxic levels based on their PELs, despite the fact that they explicitly recognize that their PELs are insufficient.

Call for Congress to intervene.
In a call with OSHA Directorate of Standards and Guidance Andrew Levinson on March 21, 2024, he stated that:

> *We [here at OSHA] are a very under-resourced agency. It has a broad mission with not a lot of people or money to do it. We have been focusing our resources, at least in the standard and guidance side, on some regulatory activities around emergency response, infection disease, workplace heat and workplace violence. I think one of the other challenges from our side is that the agency has said pretty consistently over the last 10-12 years, certainly since the Obama Administration, that our rulemaking process does not work for chemicals. We have tried to talk about the challenges of dealing with PELs and going through full-blown rulemaking on every individual chemical with staff and the resources that we have are just simply not feasible. [...] This has fallen on deaf ears because what we would need is literally an act of Congress in order to update our regulations or allow us some special thing like we had at the very beginning of the OSH Act where we could just by fat adopt updated panels. We can't do that now.*
> *[...]*
> *There are so many chemicals that are used, there are a number in the semiconductor industry that are not really used in other places. And the chemistry in the semiconductor industry changes so rapidly, and the rulemaking process for us takes so long because of what our law requires us to go through, that we can't really keep up with the chemicals that are being used in the semiconductor industry. And that's why we've concluded we need a more broad approach or some new authorization from Congress to give us a special power for a limited amount of time to update chemicals.*
> *[...]*
> *[Currently,] we have switched internal work and this is not really external facing, but we've tried to switch toward thinking about frameworks for chemical management. That's the sort of thing that we think we might be able to [provide] guidance on and maybe eventually, if we develop a system that is robust enough, perhaps rulemaking down the road.* [115]

113. OSHA. n.d. "Permissible Exposure Limits - Annotated Tables | Occupational Safety and Health Administration." Www.osha.gov. https://www.osha.gov/annotated-pels.
114. Ibid.
115. Zoom Call with OSHA staff and CHIPS Communities for America representatives on 21 March 21, 2024 at 6 a.m. PST.

U.S. Environmental Protection Agency (EPA)

Inadequate assessments of chemical toxicity.
As OSHA has been failing to update, let alone enforce, its existing PELs, the EPA has suffered similar setbacks. After the Toxic Substances Control Act (TSCA) was passed in 1976, the EPA compiled an inventory of 62,000 industrial chemicals then in use (which had purportedly been reviewed by the TLV Committee). Those chemicals were essentially grandfathered into commercial use and assumed to be safe unless the EPA could show otherwise. The process for performing such an assessment, however, was complicated and extremely time-consuming. Under TSCA, chemical manufacturers had to notify the EPA by submitting a premanufacture notice (PMN) before marketing a new chemical. The PMN did not require that a company produce a minimum amount of health and safety data, and there were no penalties for lack of data from the manufacturer. After receiving a PMN, the EPA had 90 days to determine whether the new chemical was unsafe or allow its use. In 2003 the EPA found that 85% of the PMNs lacked data on health effects.

Failures of original TSCA implementation.
The authority provided under the original TSCA did not provide EPA adequate control and led to inadequate monitoring and lack of authority to collect necessary data to assess new chemicals for toxicity. Industry resistance to TSCA implementation and enforcement also slowed EPA progress.

Added to the deficiency of data, the EPA's resources did not come close to meeting its statutory responsibilities. The Government Accountability Office (GAO) reported in 2013 that the EPA had used its authority under TSCA to limit or ban only five existing chemicals since 1976. In 2010 the Office of Inspector General (OIG) found that between 1996 and 2008, the EPA received approximately 1,500 PMNs annually, and less than 10% on average were subjected to regulatory actions. Because TSCA gave the EPA little authority to require toxicological information from manufacturers of new and old chemicals, the agency could not fulfill even a priority-setting program based on a complete review of existing chemicals. The government's finite resources to investigate chemicals and enforce its decisions were also stretched by industry lawsuits that challenged regulatory decisions with major economic impacts, thus restricting the EPA to regulate no more than two or three chemicals per year.

This has fallen on deaf ears because what we would need is literally an act of Congress in order to update our regulations or allow us some special thing like we had at the very beginning of the OSH Act where we could just by fiat adopt updated panels. We can't do that now.

Revised TSCA (2016) improved EPA's authority but still was not enough.
In 2016, 40 years after TSCA was passed, it was revised by the Frank R. Lautenberg Chemical Safety for the 21st Century Act (Lautenberg Act), which gave the EPA somewhat greater authority to require chemical companies to provide the agency with chemical toxicity and exposure data to enable hazard evaluations. When passing the Lautenberg Act, Congress mandated that the EPA review every new chemical or significant new use of an existing chemical to determine whether it presented an unreasonable risk, and gave the EPA authority to apply PMN requirements to existing chemicals if there was a reasonable potential for exposure. However, despite the EPA's new authority, the mandate to make headway in assessing tens of thousands of chemicals then in use was nearly impossible.

Lengthy process for assessing chemicals remains unchanged and still hinders EPA's progress toward adequate toxic determinations and ensuing regulation.
Fulfilling the mandate could take many years as the EPA would have to contract out or require companies to develop new tests to meet its risk assessment data needs. Without that basic information, the EPA could not begin to prioritize which of the tens of thousands of chemicals already in commerce should be assessed for relative risks. The ultimate effectiveness of the Lautenberg Act in reviewing the chemicals in current use depends on the number of high-priority versus low-priority chemicals on the Act's inventory of more than 85,000 chemicals that can be evaluated over a reasonable time period. The law required the EPA to have 10 ongoing risk evaluations in the first 180 days after passage and 20 within 3.5 years. Assuming it will have to undertake risk evaluations for 10% of the existing chemicals, or 8,500, in groups of 20 to be completed every 3.5 years, that would take about 1,500 years to complete. With a priority list of 500 chemicals a year and a 3-year completion time, that task could be completed in 50 years.

Key Findings

As it stands today, the federal agencies with enforcement power over exposure limits, OSHA and the EPA, are both struggling or altogether failing to keep up with the demand for chemical assessments, exposure limits and enforcement of said limits. These agencies are ill-equipped, under-staffed and facing procedures that are impossible to achieve in an adequate timeline.

In the absence of a framework overhaul, a list of factors that have limited a comprehensive and rational approach to chemical safety include:

- Burden of proof is on government to prove the dangerous quality of chemicals, but this should be shifted to industry to prove safety of chemicals.
- Federal agencies have limited authority to require health and safety data, Congress must empower them to require the collection and monitoring of a more expanded scope.
- Federal agencies are underfunded and understaffed compared to what is needed to analyze large amounts of data for thousands of chemicals in a timely manner. If we are to keep the burden of proof on government, Congress must strengthen OSHA and EPA significantly to grant them the capacity for such expansive work.
- Lack of leadership to embolden federal agencies. Not only do the agencies need the support of the executive branch and Congress to change their procedures and strengthen their capacities, but currently there is no leader uniting the joint effort across agencies to tackle toxic hazards.
- Procedural complexity for implementing the law. For further information on procedures and regulations of today's toxic exposure laws, see **Appendix D** which contains a full list of every regulation found in a scan of the U.S. Code of Regulations that pertain to potential toxic exposure by semiconductor manufacturing facilities.
- Inconclusiveness of data or failure of replication in testing outcomes resulting in regulatory stalemates.
- Delays arising from corporate legal challenges that frequently follow new chemical safety rules. If the burden of proof is to remain on government, the authority of agencies and enforcement abilities must be strengthened.

Current Federal Regulations

While there are a plethora of obstacles standing in the way of effective regulations by OSHA and EPA, there is also some hope.

MOU

OSHA and EPA have a Memorandum of Understanding (MOU)[116] that requires them to develop a system to track and manage referrals of potential violations, allegations of violations, and situations that require inspection, evaluation or follow-up. The two agencies also coordinate the development of regulations concerning occupational exposure to new chemicals and exchange information and reports on enforcement matters.

Delegation

In addition to federal enforcement of laws including the Clean Water Act and the Clean Air Act, the agencies may delegate enforcement to state agencies. State agencies may enforce these laws under the following conditions: (1) the state must have the ability to take on the responsibility of managing these laws, such as issuing permits and conducting inspections and (2) the state must have laws that impose penalties on violators through an agency or its court system. Whether delegation is effective is questionable and will be discussed further in the case studies.[117]

Monitoring State Matters

In addition, the EPA can become involved in the most egregious cases, leading to much higher fines and penalties. Examples of penalties assessed for 2023 can be found in the EPA's Enforcement and Compliance Annual Results Report: [118]

- 1791 civil settlements were concluded;
- 199 criminal cases were opened; and
- Over $1 billion was assessed in cleanup and recovery costs.

While this is laudable, the question remains whether it is enough. Given that the EPA struggles to adequately assess the toxicity of chemicals each year, the amount of resources available to properly monitor state or federal matters is suspect.

116. Occupational HealthHealthy and Safety Administration. "Memorandum of Understanding between the U.S. Department of Labor Occupational Safety and Health Administration and the U.S. Environmental Protection Agency Office of Enforcement." Osha.gov, 23 Nov. 1990, www.osha.gov/laws-regs/mou/1990-11-23#:~:text=This%20MOU%20establishes%20a%20process. Accessed 11 June 11, 2024.
117. The Conversation. "Fines for breaking US pollution laws can vary widely among states – that may violate the Constitution". March 15, 2023. https://theconversation.com/fines-for-breaking-us-pollution-laws-can-vary-widely-among-states-that-may-violate-the-constitution-201457
118. EPA Enforcement and Compliance Annual Report Annual Results Fiscal Year 2023. Dec. 18, 2023. https://www.epa.gov/enforcement/enforcement-and-compliance-annual-results-fiscal-year-2023.

Department of Justice Office of Environmental Justice

The Department of Justice (DOJ) created an Office of Environmental Justice (OEJ) [119] in 2022. The OEJ, under the auspices of the Environment and Natural Resources Division (EPA), is mandated to use all resources of the DOJ in pursuit of environmental justice. Similar to the OSHA and EPA MOU discussed earlier, the OEJ is expected to use "all the legal authorities available" [120] and "coordinate with [our] federal partners...to advance environmental justice." [121]

A primary target of the OEJ is to identify areas within the country which have been "historically underserved, overburdened and marginalized." [122] Environmental violations pose dangers to these often impoverished areas where civil rights may be violated when hazardous toxic substances are released.

The Comprehensive Environmental Justice Enforcement Strategy authorizes a partnership with agencies like the EPA and the Department of Housing and Urban Development (HUD) to strengthen its enforcement efforts. [123]

Additional agency collaborations

In addition to the partnership with the DOJ, a number of other agencies and departments collaborate with the EPA to bolster its investigation and enforcement efforts. Some of these include:

- The Agency for Toxic Substances and Disease Registry (ATSDR) [124] is an agency of the Department of Health and Human Services and is the principal public health agency dealing with hazardous waste issues and human health. It was created as part of the Superfund Law in 1980, which was passed to determine and regulate toxic waste violations. While it does not have any enforcement authority, it can make recommendations about dangerous activities of a plant or business to the EPA.
- The Environment and Natural Resources Division (ENRD) [125] is part of the OEJ and is responsible for suing those who violate environmental laws. It may also defend the U.S. government when it is involved in environmental litigation.
- The Centers for Disease Control and Prevention (CDC) uses data compiled from organizations like the ATSDR, including like the National Toxic Substance Incident Program, to help its medical professionals gain better understanding of the causes of incidents and injuries due to exposure to toxic substances. This data can inform plan prevention efforts as well as emergency plans for toxic exposure incidents.

While there is still evidence of egregious failure by both the EPA and OSHA to properly assess chemical toxicity and enforce toxic exposure monitoring and protections, there is hope in the collaborative task forces and interagency collaborations that work is being done to try and improve agency abilities, and create a safe environment and safe working conditions for those in jeopardy of toxic exposure incidents.

State Exposure Limits and Agencies

In addition to the problems on the federal regulatory level, several state regulatory frameworks further complicate standards and policies meant to protect people. Texas agencies choose to interpret federal laws as unconstitutional and refuse to implement them, resulting in the state government suing federal agencies and further weakening them. Meanwhile, California agencies implement federal regulations and even set stronger standards than federal ones. However, California state agencies are struggling to follow through on implementation and enforcement due to understaffing and failing management and leadership.

Texas

The laws in Texas relating to semiconductor manufacturing are mainly state laws that reinforce federal regulations. For a full list of state regulations that relate to semiconductor manufacturing, see **Appendix E.** However, with a heavy pro-industry stance, Texas has challenged the implementation of the laws in court and the state has sued the national EPA, arguing that the limits are too stringent.

119. U.S. Department of Health and Human Services, The Office of Environmental Justice. Accessed June 12, 2024. https://www.hhs.gov/ash/oej/index.html.
120. Justice Department Releases First-Ever Comprehensive Environmental Justice Enforcement Strategy Report, Oct. 13, 2023. https://www.justice.gov/opa/pr/justice-department-releases-first-ever-comprehensive-environmental-justice-enforcement.
121. Ibid.
122. Ibid.
123. Comprehensive Environmental Justice Enforcement Strategy. May 5, 2022. https://www.justice.gov/d9/2023-10/02._asg_strategy_memorandum.pdf.
124. Agency for Toxic Substances and Disease Registry. Accessed June 12, 2024. https://www.atsdr.cdc.gov/index.html.
125. Environment and Natural Resources Division. Accessed June 12, 2024. https://www.justice.gov/enrd.

Federal enforcement of federal laws
In Texas, semiconductor manufacturers must abide by federal laws including the Clean Air Act (CAA) [126] and Clean Water Act (CWA)[127]. Under both the CWA and CAA, states must develop state implementation plans or SIPs outlining how they will achieve the established national standards. The federal Environmental Protection Agency (EPA) has primary enforcement responsibility for both acts. In addition, Texas is one of many states that does not have a state OSHA. The state's OSHA regulations are therefore entirely under federal jurisdiction and rely on federal OSHA for enforcement.

State Agencies: Texas Commission on Environmental Quality (TCEQ)
The TCEQ is tasked with implementing the CAA and CWA. It sets specific permitting and emissions standards for semiconductor manufacturers. TCEQ establishes guidelines for e-waste processors and recyclers as well; these guidelines ensure environmentally sound practices during e-waste handling, minimizing risks to public health and the environment.

TCEQ has a long history of being pro-industry and lax in environmental regulation. It is run by three, full-time commissioners appointed by the governor who provide agency direction and policy, retain ultimate say in enforcement affairs and make final determinations on contested permits. TCEQ sued the Obama administration 40 times between 2008 and 2016 in attempts to challenge the former President's climate change proposal due to the many environmental safeguards they opposed. [128]

TCEQ ... weakened exposure guidelines and allowed a 40 percent increase in exposure levels of the highly toxic benzene... the EPA had imposed heavy restrictions on industrial use of benzene as far back as 1989 because it was found to cause leukemia in adults

Primary examples of a TCEQ policy accomplishment includes:

> TCEQ celebrated the passage of the "Texas Risk Reduction Program," which allowed a sweeping overhaul of the state's air pollution standards in the mid-2000s. The program *weakened* exposure guidelines, allowed a 40 percent increase in exposure levels of the highly toxic benzene, and further softened regulations for two-thirds of its 45 other restricted chemicals. Meanwhile, the EPA had imposed heavy restrictions on industrial use of benzene as far back as 1989 because it was found to cause leukemia in adults.[129]
>
> The new regulations and revised rules were published in the "Texas Register" (32 Tex Reg 5296) in the August 24, 2007 issue.
>
> House Bill 3354, 80th Legislature, Regular Session of 2007, allowed the proposed rulemaking to be incorporated into an agency rule, becoming effective on September 1, 2007.

A former scientist with the National Institute of Environmental Health, Ron Meinick, evaluated and analyzed the TCEQ's pro-industry decreasing exposure guidelines and its new regulation of butadiene, an overused industrial chemical that has the same derivative of benzene. Both are carcinogens. He found the TCEQ regulations are 340 times less protective than California's regulations and 60 times less protective than the EPA's requirements. [130]

State agencies: agencies that supplement occupational safety and health
In addition to federal OSHA oversight, several other state and local agencies also carry some responsibility for occupational health regulations, as is common in many states.

- Texas Department of State Health Services (DSHS): The DSHS Occupational Safety and Health Surveillance Program conducts activities to track occupational injuries and illnesses that affect Texans and recommends intervention strategies. However, little is known about the health-related risk behaviors, chronic conditions and health-related quality of life among the working population in Texas. The hope is more will be known as, starting in 2018, the Texas Behavioral Risk Factor Surveillance System (BRFSS) survey added questions on industry and occupation.
- The Texas Hazard Communication Act (THCA): Chapter 502 of the Texas Health and Safety Code requires

126. "Overview of the Clean Air Act." Environmental Protection Agency. https://www.epa.gov/clean-air-act-overview.
127. "Summary of the Clean Water Act." Environmental Protection Agency. https://www.epa.gov/laws-regulations/summary-clean-water-act
128. High Plains Public Radio. "Texas Has Sued the Obama Administration 40 Times: A Look at the Lawsuits." HPPR,May 30, 2016, www.hppr.org/hppr-government-politics/2016-05-30/texas-has-sued-the-obama-administration-40-times-a-look-at-the-lawsuits. Accessed June 12, 2024.
129. (1989, Sept. 1. "US Adopts Limits on use of Benzene, The New York Times, Sec. A, Pg 1).
130. (2014, Adams and Song, Dec. 18, The Center for Public Integrity, Environment).

public employers to provide employees with specific information on the hazards of chemicals to which employees may be exposed in the workplace.

State agencies: agencies that administer hazardous materials management
These policies are similarly broken up between multiple agencies and regulations:

- TCEQ: implements federal hazardous waste regulations in Texas, including specific requirements for storing, labeling and transporting hazardous materials used in semiconductor production.
- Resource Conservation and Recovery Act (RCRA): This federal law governs the generation, storage, transportation and disposal of hazardous waste.
- Department of Transportation (DOT): has regulations for the safe transportation of hazardous materials. These regulations include specific protocols for responding to transportation accidents involving hazardous materials spills.
- State and Local Fire Marshals: The state and most Texas localities adopt the International Fire Code (IFC) with amendments for their area. The IFC includes a chapter dedicated to hazardous materials (Chapter 50), which applies to semiconductor manufacture due to the chemicals used. This chapter outlines fire safety protocols for storage, handling and use of hazardous materials.

Political analysis of state regulations
It is important to note a few key points about Texas regulations to protect workers and communities from toxic exposure by fabs:

- The state is known to attract semiconductor manufacturing because of its ample available land and its "industry-friendly" policies, which generally implies policies that save corporations money. This includes sales tax incentives, lack of income tax and right-to-work laws. Examples of companies that have been attracted to the state include Tesla and Samsung, the latter of which moved to the Austin area and is spending $17 billion to build a fabrication plant.
- Although the state is famous for prioritizing "industry-friendly" policy, former government employees have emphasized that it is possible to motivate the TCEQ and state officials to act on environmental initiatives, as well as health and safety initiatives, if ways can be found to frame the initiatives as industry-friendly.[131] For example, zero emissions initiatives have met with little resistance when purchasing electric vehicles for public transportation or investing in the electric vehicle infrastructure, which is argued to benefit industry.[132] Therefore, a key strategy for advocacy is to think creatively about what makes a policy industry friendly.

California

Federal enforcement of federal laws
Federal regulations apply to all states and, while California agencies implement federal regulations just as Texas does, individual states may also have their own policies, which the state of California has. The majority of regulations and policies in California are therefore housed under the state.

State regulations stricter than federal regulations
The California Code of Regulations has laws to not only enforce federal regulations but any additional state laws for worker or environmental protections. In addition to stricter regulation across the board for occupational health and environmental safety, discussed below, there is much more regulation specifically around semiconductor manufacturing. For a detailed list of all the regulations in California which relate specifically to semiconductor manufacturing, see **Appendix F.**

State agencies: California OSHA
California's division of Occupational Safety and Health (Cal/OSHA), for example, has the most extensive list of Permissible Exposure Limits of all the states that have OSHA-approved state plans.[133]

State agencies: California EPA
Similarly, California's EPA has some of the strictest environmental regulations, a reality which NPR reported can cause a ripple effect across other states known as the "California Effect."[134]

131. Martin, Philip. "Informational Interview with Philip Martin." Unpublished Interview, March 18, 2024.
132. Ibid.
133. OSHA. 2022. "Chemical Hazards and Toxic Substances - Overview | Occupational Safety and Health Administration." Www.osha.gov. 2022. https://www.osha.gov/chemical-hazards.
134. Woods, Darian, and Adrian Ma. 2022. "The Impact of California's Environmental Regulations Ripples across the U.S." NPR.org, September 9, 2022. https://www.npr.org/2022/09/09/1121952184/the-impact-of-californias-environmental-regulations-ripples-across-the-u-s.

These stricter regulations include: general toxic exposure laws and occupational health and safety laws in electronics manufacturing; regulations around air and water pollution; regulations around storage of hazardous chemicals in liquid, gas and solid form; regulations around recycling of e-waste; regulations around responding to emergency toxic exposure and regulations around cleaning of hazardous waste.

State agencies: The Bay Area Air Quality Management District

The Bay Area Air Quality Management District or BAAQMD enforces a semiconductor-specific rule: Regulation 8, organic compounds, rule 30, semiconductor wafer fabrication operations. This Semiconductor Rule targets semiconductor wafer-fabrication facilities to limit VOC (volatile organic compounds) emissions and improve air quality, especially ozone levels. It mandates specific requirements for handling and storing solvents used in fabrication, such as keeping tanks covered, labeling them, proper storage, disposal of waste solvents, operating sealed solvent vapor stations and promptly repairing solvent leaks or faulty equipment.

History of stricter regulations in California: SVTC and SCCOSH

It is not surprising that California has stricter regulations than most related to semiconductor manufacturing. Silicon Valley, located near San Francisco, is one of the main, if not the main, originators of activism around toxic exposure in the industry. When worker-safety advocates in the Bay Area first discovered the potential dangers in the industry in the 1970s and 1980s, they formed groups including the Santa Clara Center for Occupational Safety and Health (SCCOSH, founded in 1978), and the Silicon Valley Toxics Coalition (SVTC, founded in 1982), both of which paved the way in organizing to protect against the hazards borne by this industry.

They advocated for "community right-to-know," policies that "provide more information to workers and residents about potential toxic chemical exposures." [135] The nation's first community right-to-know laws were passed throughout localities in Silicon Valley. Following local changes, SVTC went on to organize with other groups and form the Campaign for Responsible Technology (CRT) which, together, succeeded in urging the U.S. Congress to "pass the right-to-know provisions of the Superfund amendments that created the Toxics Release Inventory (TRI)."[136]

These groups were also seminal in the passage of first local and then the national Hazardous Materials Model Ordinances "which required secondary containment and strict monitoring for underground storage tanks," and Toxic Gas Model Ordinances. [137]

Nationally, on a federal level but specific to Silicon Valley, SVTC's activism ultimately prompted the Environmental Protection Agency to step in and investigate the hazards in the region, at which point they identified 29 "Superfund" sites in Silicon Valley, the largest concentration of these sites in the country. [138]

This means people who sustain serious injuries but don't die will never receive the benefit of an investigation into possible criminal negligence on behalf of the employer.

State Agencies: Enforcement Failures

However, while California may have more focused regulations, the question remains: Does it have the capacity to implement and enforce them? In February 2024, a "Sacramento Bee" investigation found that Cal-OSHA is not only suffering a severe staffing shortage, but that the shortage is causing harm to both state employees and California front-line workers.[139] Among the "Bee"'s findings, alarming statistics were revealed including:

- The overall vacancy rate at Cal-OSHA is 34%.
- Federal OSHA's 2022 annual evaluation of Cal-OSHA noted, among other issues caused by staffing, that "Cal/OSHA cannot conduct planned inspections of high hazard employers at the national average rate."
- Federal OSHA also noted that only 18.5% of Cal-OSHA inspections are "programmed," which means preventative, compared to the national average of 40%. In other words, only one in five inspections by Cal-OSHA could catch violations before an accident occurs.

135. Smith, Ted; Sonnenfeld, David A. and David Naguib Pellow (ed). Challenging the Chip: Labor Rights and Environmental Justice in the Global Electronics Industry. Temple University Press, Philadelphia, USA (2006): 113.
136. Ibid.
137. Ibid.
138. Schlosberg, T. (2019) "Silicon Valley Is One of the Most Polluted Places in the Country," Microchip manufacturers contaminated the groundwater in the 1980s. Almost 40 years later, the cleanup still isn't complete," The Atlantic Magazine, September 22.
139. Miller, Maya. (2024) "Putting Workers at Risk – CalOSHA's Shrinking Staffs Make Employees Less Safe." The Sacramento Bee: February 25, 2024. Access via Newsbank May 5, 2024.

- The Cal-OSHA Bureau of Investigations (BOI), which is legally obligated to investigate every fatality for possible criminal negligence, has operated with at least 50% vacancy rate for each of the last six years. Currently, the BOI has only two investigators for the entire state – a 67% vacancy rate.
- Due to the lack of staff, the BOI is unable to look at cases that aren't fatalities. This means people who sustain serious injuries but don't die will never receive the benefit of an investigation into possible criminal negligence on behalf of the employer.

Political analysis of Cal-OSHA monitoring and enforcement failures

According to current and former Cal-OSHA employees interviewed by The Sacramento Bee, the following changes could help dramatically improve Cal-OSHA's quality of performance:

- Fill vacant positions:
  - Fill vacant leadership positions.
  - Fill vacant positions in the Department of Industrial Relations' (DIR) human resources team, the team responsible for hiring personnel for Cal-OSHA.
  - Double down on recruitment efforts to fill vacancies throughout Cal-OSHA.
- Motivate leaders to tackle existing problems, including a failing workplace culture that causes low employee morale, a problem which has plagued the agency for decades.
- Review and amend the existing, highly stringent and overly bureaucratic hiring process in order to make the jobs easier to access and more competitive compared to jobs in the private sector.
  - Improve the hiring timeline.
  - Improve the salary range.
  - Improve recruitment programs to make jobs at Cal-OSHA more accessible.
- Receive stalwart support from the Governor: "Newsom could return Cal-OSHA to its once-premier status as a national leader in worker health and safety, if only he put Cal-OSHA's leadership and staffing issues near the top of his priority list." [140]

140. Miller, Maya. (2024) "Putting Workers at Risk – CalOSHA's Shrinking Staffs Make Employees Less Safe." The Sacramento Bee: February 25, 2024. Access via Newsbank May 5, 2024.

VI. Choosing a Toxic Exposure Policy Despite So Many Unknowns

A. Controlling Exposures to Hazards

Despite unknowns regarding potential risks of semiconductor manufacturing, we do know that it is vital to protect workers and communities from exposures to hazards in the workplace and in the community. So, how do we do this?

In the absence of complete information, scholarship on decision-making in the setting of scientific uncertainty is based on the precautionary principle. Still evolving as a concept, the precautionary principle simplified is an approach that posits an action should not occur if it will cause harm. As the International Institute for Sustainable Development points out,

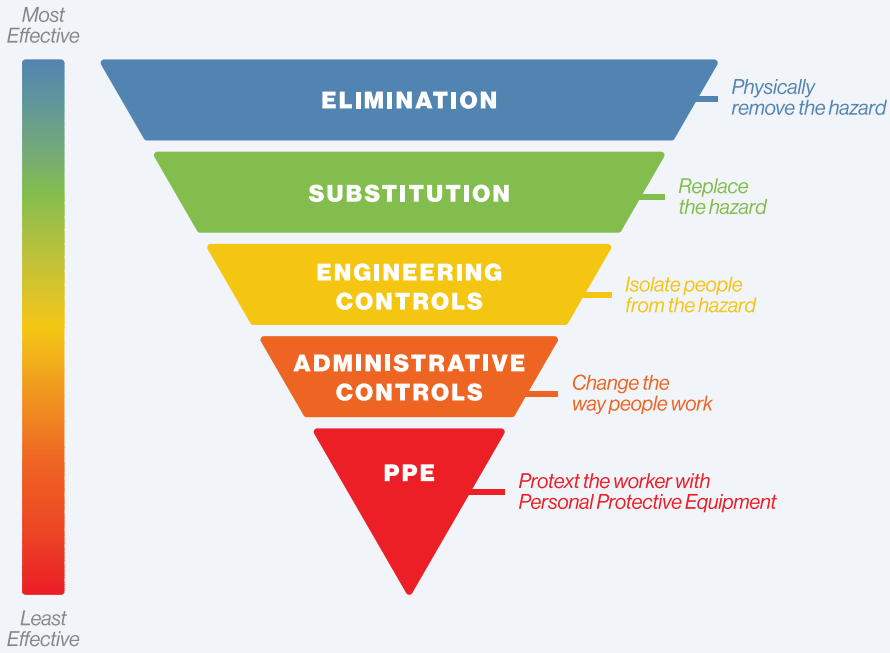
> *One of the most controversial elements of the principle is the shift of the burden of proof. Traditionally, the person claiming an activity could cause harm should produce proof to back up that claim. The precautionary principle reverses the burden of proof—the individual or entity proposing the activity must prove the activity is not harmful.* [141]

There is significant debate over how to operationalize the precautionary principle: Does this mean halting the use of all chemicals that cannot be proven harmless? Or does it mean immediately implementing an aggressive substitution policy that identifies safer chemicals that can replace hazardous chemicals in their current technical tasks?

The National Institute for Occupational Safety and Health (NIOSH) has developed a concept called the "hierarchy of controls" which is a way of determining which actions will best control exposures

It is primarily meant for protecting workers in the workplace, but the concepts are in essence a descending hierarchy of policies for applying the precautionary principle. The hierarchy features five levels of actions to reduce or remove hazards. The order of action is organized by most effective to least effective:

1. **Elimination**
2. **Substitution**
3. **Engineering controls**
4. **Administrative controls**
5. **Personal protective equipment (PPE)**



When elimination is not an option, the next best option is substitution. While there are many chemicals in use with unknown toxic levels, the method of substitution involves assessing what chemicals are safe and urging the use of safe chemicals in all steps of the production process. Ultimately, the goal of a substitution approach would be to achieve zero exposure through substitution.

Substituting hazardous chemicals with safe chemicals is a widely supported choice with multiple nonprofits, government agencies and private sector programs around the world promoting the process. However, if hazardous chemical replacement is the goal, then what is the best method for achieving this?

141. Pinto-Bazurco, Jose Felix. 2020. "The Precautionary Principle." International Institute for Sustainable Development. October 23, 2020. https://www.iisd.org/articles/deep-dive/precautionary-principle.

B. Prioritizing a Method for Substituting Hazardous Chemicals

It is critical that any method for substituting hazardous chemicals includes a careful evaluation of the substitutes, otherwise "regrettable substitutions" can result.[142] In the absence of an effective method of review, a chemical might be chosen to replace a hazardous one only to discover later that the replacement chemical is also hazardous. For example, in the 1990s, known carcinogen solvents such as trichloroethylene and methylene chloride were replaced with 1-bromopropane. However, only a few months later, case studies began reporting severe neurotoxicity in workers exposed to 1-bromopropane.[143] This report provides a method for performing a best practice review, so that CCU or CWA can work with a panel of experts to examine which methods for substituting hazardous chemicals are the most effective for the purposes of protecting toxic chemical exposure from semiconductor manufacturing facilities.

C. Designing a Best Practice Review

There is currently no publication that provides a best practice analysis of current methods for substituting chemicals specific to semiconductor manufacturing. However, the comprehensive literature review of methods produced by researchers Molly M. Jacobs et al in 2015 remains the best resource for comparing methods for substituting chemicals to date. Organizing a DELPHI Panel of experts to develop a scoring, or weighting, method for ranking the core hazard and exposure measures addressed in Jacobs et al's literature review is the ideal method for CCU or CWA to identify a preferred method for substitution.

Defining Key Criteria

As can be seen in **Appendix H,** Jacobs et al's literature review provided comprehensive examinations of the methods that each framework used to evaluate whether one chemical is a safe and effective alternative to replace an existing chemical of concern. The authors broke the methods down into six core components for evaluation: hazard assessment, exposure characterization, life-cycle impacts, technical feasibility evaluation, economic feasibility assessment and decision making. Within each component, multiple endpoints were identified as key elements of the process, and the authors created an all-inclusive spreadsheet for each component to visualize which framework features what endpoint in each component. These spreadsheets have been reproduced in **Appendix H.** These comparative tables are what make a subsequent best practice review manageable.

A best practice review typically involves defining key criteria for success and developing a scoring mechanism to highlight which practice will likely achieve the highest marker of success. In this case, Jacobs et al have already presented an excellent set of criteria. The question is, which endpoints in each criterion are more important than others?

For example, "hazard assessment" is made up of four categories: physicochemical, human toxicity, ecological toxicity and other workplace hazards. Within those categories, there are a total of 32 individual endpoints including flammability (in physicochemical), reproductive toxins (in human toxicity), aquatic toxicity (in ecological toxicity) and ergonomics (in other workplace hazards). Human toxicity also includes endpoints such as carcinogenicity, endocrine-disrupting toxins, developmental toxins, etc. So, if a framework addresses 31 of all 32 endpoints, but the missing endpoint is reproductive toxins, should that framework be considered more desirable than a framework that addresses fewer endpoints but does include reproductive toxins?

According to Amanda Hawes of Safe Jobs, Healthy Families, the neurodevelopmental aspects of toxic chemicals have been known for quite some time but are rarely codified into legislation.[144] Even when a limit has been established, whether TLV or PEL or REL, it can be difficult to gauge reproductive harm and risk of neurodevelopmental detriments. As a result, families of workers have experienced "clusters" of neurodevelopmental delay stemming from childrens' mothers' time at their semiconductor manufacturing jobs.[145] Hawes tells of a case in Mexico when a special education teacher traced students' developmental deficits back to maternal glycol ether exposure from mothers working at the same factory. In another study sponsored by UC Davis, industry leader IBM opted out, claiming that their work conditions were safe for pregnant employees.[146] Therefore, studies of reproductive harm, while existing, face barriers on the level of industry, as well as a poor

142. OSHA (U.S. Occupational Health and Safety Administration) "Why Transition to Safer Chemicals?" 2015 Available: https://www.osha.gov/dsg/safer_chemicals/why_transition.html [accessed May 4, 2024].
143. Ichihara G, Kitoh J, Li W, Ding X, Ichihara S, Takeuchi Y. "Neurotoxicity of 1-bromopropane: Evidence from Animal Experiments and Human Studies." J Adv Res. 2012; 3:91-98; CDC (Centers for Disease Control and Prevention) Neurologic Illness Associated with Occupational Exposure to the Solvent 1-Bromopropane – New Jersey and Pennsylvania (2007-2008)." MMWR Morb Mortal Wkly Rep. 2008; 57:1300-1302.
144. Hawes, A. "Comments to UN Special Rapporteur on Toxics and Human Rights. Response to Call for Input on Gender and Toxics." March 28, 2024.
145. Ibid.
146. Ibid.

recognition of downstream impacts for people who may become pregnant during or after working at a semiconductor manufacturing plant.

Hawes further writes that specific aspects of semiconductor manufacturing can pose differential reproductive harm:

> *Based on a questionnaire survey of female workers and spouses of male workers in semiconductor industry, Pastides et al. reported that working in diffusion and photolithography process was associated with higher risk for SAB, while through a community survey Lipscomb et al. observed that women with a solvent exposure history in electronics production during the first trimester of pregnancy were more likely to experience SAB than controls* [147]

Can a framework for evaluating alternative chemicals for substitution be recommended if reproductive toxins are not included in the hazard assessment? Considering the literature, this report would suggest the answer is a resounding no. More importantly, current limits are so vague and the data so scarce and challenged by industry using any available means that the truth is evasive. Therefore, not only should reproductive toxins be required as part of an alternative chemical assessment, but the resources used to evaluate reproductive toxins should also be carefully vetted and critically reviewed for adequate information.

Scoring and Weighting: Using "Gate Factors"

It is therefore recommended that each core component's endpoints be reviewed with a panel of experts to identify which endpoints should be "gate factors." [148] In other words, which endpoints are key criteria that must exist for the framework to be recommended? In the example of hazard assessment, this report would recommend reproductive toxins be set as a gate factor. **Appendix I** contains a template survey to assist in reviewing all of the endpoints with the panel of experts.

Once all the endpoints have been reviewed, then they can be scored. Each non-gate factor endpoint is either given a score of "0" if it is not addressed or "1" if it is, and then they are all added together. The gate factors are then also assigned a score of "0" if the endpoint is not addressed or "1" if it is, and then multiplied by the sum of the rest of the endpoints. If any of the gate factors are not addressed, the entire score for the hazard assessment therefore results in zero.

To give an example, according to Jacobs et al's table on hazard assessments (see **Appendix H, Table 1**), the U.S. EPA CSTA publication and the U.S. EPA SNAP Program would each be scored as follows:

U.S. EPA CSTA:

1 * (1 + 1 + 1 + 1 + 1 + 0 + 0 + 1 + 1 + 1 + 0 + 1 + 0 + 0 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0) **= 16**

U.S. EPA SNAP:

0 * (0 + 0 + 1 + 0 + 0 + 1 + 1 + 0 + 0 + 0 + 0 + 1 + 0 + 0 + 1 + 1 + 0 + 1 + 0 + 1 + 1 + 1 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0) **= 0**

It is therefore recommended that each core component's endpoints be reviewed with a panel of experts to identify which endpoints should be "gate factors."

While the U.S. EPA SNAP program addresses 10 endpoints in its framework, the entire hazard assessment scores as zero because it does not include reproductive toxins.

One concern that has been raised about using gate factors is the finality of the process. What if a method was ideal in most ways but had two glaring problems that would, in this case, be considered gate factors that would dismiss the method entirely? Instead of dismissing the method, the committee of experts could recommend different approaches for the key problem areas, thereby amending the method to an ideal form. That is also an option. In that case, the committee of experts should still identify the key criteria that would otherwise be gate factors to flag problems in methods for amendment.

147. Hawes, A. "Comments to UN Special Rapporteur on Toxics and Human Rights. Response to Call for Input on Gender and Toxics." March 28, 2024.
148. This term has been adopted from programming language. A "gate factor" is used in circuit design. If a condition (or "factor") is present, the gate allows the circuit to continue in a certain direction. If the condition is not present, gate stops the circuit. In the context of weighting and scoring a hazard assessment, the idea would be that if one of the endpoints is deemed a "gate factor," then its presence is required for the entire hazard assessment to be considered effective.

Panel of Experts

This best practice review would use a method called the "DELPHI" method, which is a systematic process of seeking consensus on a topic using the collective opinion of panel members. [149]

There are four key steps to a DELPHI method:

1. A group of experts, or "panelists," is questioned about the topic of interest through a survey;
2. The process is anonymous to avoid the bandwagon effect (social pressure to conform to a dominant view);
3. The process is iterative and includes several rounds of inquiry; the rounds can vary in format from surveys to one-on-one interviews or other setups;
4. Each subsequent round is informed by a summary of the group response of the previous round. [150]

DELPHI methods are most useful when evidence is limited, conflicting, ethically controversial or logistically difficult to collect. [151] Therefore, when designing a best practice review for the first time of how to assess "safe" chemicals for the substitution of hazardous chemicals, a DELPHI method is recommended.

It is important to develop a rigorous protocol in advance of initiating the process, including carefully selecting panelists, designing and testing a survey prior to implementation, and discussing with your team how many rounds of inquiry would be ideal for the topic at hand. In this case, and if resources such as time and payment for participation are not an issue, this report recommends a minimum of three rounds:

- The first collects initial responses;
- The second collects reasoned responses upon hearing initial feedback;
- The third collects the greatest amount of compromise panelists might be able to offer given further feedback.

Ideally, the team conducting the survey should reflect on the process after each round and confirm how many rounds still feel appropriate given the responses from the panelists and existing resources.

DELPHI methods are most useful when evidence is limited, conflicting, ethically controversial or logistically difficult to collect.

The panel of experts should include:

- At least one physician who specializes in occupational health
- At least one green chemist
- At least one industrial hygienist who specializes in semiconductor manufacturing chemicals
- At least one expert in environmental hazard management (for example: air/water/ground pollution and cleaning of hazardous waste in environmental setting, chemical storage)
- At least one advocate from CHIPS Communities United
- At least one or two advocates on behalf of workers in communities affected

In particular, this report would recommend inviting, at the minimum:

- Amanda Hawes (Advocate)
- Bob Harrison (Physician)
- Darius Sivin (Industrial Hygienist)
- Thomas McKeag (Chemist, Berkeley Center for Green Chemistry), or a chemist recommended by him
- Lenny Siegel (Expert in Environmental Hazard Management), or an expert recommended by him
- Meg Schwarzman (MD, MPH, also associated with Berkeley Center for Green Chemistry)
- A member of PODER, TEJAS or other related organizations in other target locations who can propose a member for participation.

While any chosen method for substituting chemicals will still ultimately encounter obstacles– such as a lack of sufficient toxicology reports to properly assess the hazardous characteristics and exposure risks of many chemicals– identifying a preferred method will nevertheless help CHIPS Communities United set priorities in their advocacy efforts with the government.

149. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8299905/
150. Jünger, Saskia; Payne, Sheila A.; Brine, Jenny; Radbruch, Lukas; and Sarah G Brearley. "Guidance on Conducting and Reporting Delphi Studies (CREDES) in palliative care: Recommendations based on a methodological systematic review." Palliative Medicine, Vol 31:8 (2017): 684-706.
151. Ibid.

VII. Policy Considerations

Current Unmet Needs

This report has provided a comprehensive review of current information to inform policy decisions about toxic exposure to chemicals used by the semiconductor manufacturing industry. It has also outlined information gaps. Here is a summary of the current unmet needs:

Improved Data Collection

- To protect workers and communities from potential hazards, we need to know:
  - All of the current processes that fabs use to produce chips and printed circuit boards.
  - What hazards occur at each phase of production in these updated processes.
  - What metals are used throughout the current manufacturing of chips and boards.
  - The toxic details of every chemical used at each stage.
  - Better disclosure of chemical injury data in the publicly available OSHA Inspection establishment search.
- It is impossible to conduct a complete risk analysis of workplace hazards, let alone risks of pollution, without unfettered access to industry information on all chemicals and processes, including trade secrets.
- Even when research has company support, often companies lack the databases to properly provide information necessary for risk assessments. Without regulations that govern or standardize data collection procedures that can accommodate risk assessments, the current process is overwhelming.
- Data on health indicators is not always done ethically, see **Appendix G** for ethical principles for collecting, analyzing and using health data.
- The CCU does not currently have any campaigns underway to work with communities with high amounts of semiconductor manufacturing to collect health equity data.
- The Bureau of Labor Statistics provides limited data; improved data collection would include demographic breakdowns of illnesses or injuries specific to individual industries. They also do not currently collect much detail regarding "exposure to harmful substances or environments". If they were to do so, it would offer heightened insight into illnesses and injuries that may result from toxic exposure, and allow us to follow trends as the industry ramps up following the CHIPS Act.
- Community Health Needs Assessment (CHNA) reports rarely provide much information about occupational health indicators. Even CHNAs in counties where multiple semiconductor manufacturing facilities are located do not mention potential environmental or occupational exposures that might be of particular concern in their counties. Ensuing data about heightened cancer levels therefore go unstudied in relation to the potential hazards in the communities.

Gaps in Current Regulations

- The burden of proof is currently on the government to demonstrate if a chemical is hazardous, rather than on the industry to demonstrate that a chemical is safe.
- OSHA PELs are outdated, and OSHA is incapable of updating its PELs, let alone conducting the review process necessary to define new ones.
- Despite the benefits of the 2016 Lautenberg Act, the EPA does not have the staff or funding necessary to meet the mandate that the EPA review every new chemical, or significant new use of an existing chemical, to determine whether it presents an unreasonable risk.
- ACGIH does not require members of the TLV committee who perform corporate consulting to either disclose those business connections or excuse themselves from the development of TLVs on chemicals of importance to their clients.
- Texas regulations are illegally implementing exposure limits above those of the EPA.

Lack of Enforcement of Existing Exposure Laws

- While OSHA can enforce its PELs, it is counterproductive to do so given that even OSHA explicitly recognizes that their PELs are outdated and inefficient.
- Similarly, while the EPA has the capacity to enforce its New Chemical Exposure Limits (NCELs), it is severely behind in producing updated NCELs, and it is understaffed to properly enforce NCELs.
- Texas agencies are unmotivated to enforce many exposure regulations, unless they are considered industry-friendly.
- California's OSHA is severely understaffed, riddled with workplace culture failures and does not receive enough support from the Governor to remedy these critical issues.
- There is a trend to look to other methods of "managing chemicals" such as identifying substitution methods, because the current methods of creating exposure limits and enforcing them are not bureaucratically feasible.

Designing Policy with Significant Unknowns

- Given the fact that there is such a glaring lack of data available to clearly understand the risks that workers and communities currently face, government agencies and advocacy groups are confronted with how to design policy in the face of significant unknowns.
- While the precautionary principle is the driving philosophy in the scientific community and many governmental agencies, there is still much debate around the ideal way to implement the precautionary principle in designing regulation. From preliminary informational calls with different members of the CCU, it appears that not even everyone within the group agrees on how to best implement the precautionary principle into practice.

The original goal of the CWA and CCU in commissioning this report was to receive concrete policy recommendations to deliver to government agencies. However, it became clear that there were too many unknowns to adequately evaluate policy recommendations against alternatives. Without the data, it is impossible to measure which recommendations would more effectively decrease the risk of toxic exposure to workers and community members. Therefore, this report instead tallies the unmet needs and offers a list of policy considerations.

Policy considerations are differentiated from recommendations because they have not been measured quantitatively for their potential impact on solving the problem. They are instead ideas, raised in the literature or in qualitative interviews, that are proposed as possible ways to resolve current unmet needs. For these considerations to become proper recommendations, further data must be collected to allow a comprehensive analysis of the potential impact of each recommendation.

The policy considerations are broken down into medium-term and long-term. Medium-term are considerations that, with further analysis, will likely be relevant for formulating recommendations in the next year. Long-term considerations will likely be relevant after additional study in two to three years, or more. In addition, there are two types of policy considerations offered: those to be provided to government agencies, and those to be discussed internally with CWA and CCU members for their own organizing efforts.

Medium-Term Policy Considerations

For Government Agencies

- **Improved Data Collection**
  - Establish a federal public health/occupational health database of electronics workers. This would ideally be housed under BLS, but another agency like HHS could also administer it.
  - Implement mandatory health monitoring programs for semiconductor workers.
  - Require CHNA reports to include information on occupational and environmental hazards specific to industries, or establish new reports through local public health departments specific to the semiconductor industry.
  - Allocate funding to develop improved methods for assessing worker exposure to hazardous chemicals in semiconductor manufacturing facilities, for comprehensive studies of health risks faced by workers in the semiconductor industry, and for interagency collaboration on data collection and joint analysis.
- **Toxic Exposure Policy**
  - Push for Congressional approval to switch the burden of proof from the government to industry when it comes to the assessment of chemical hazards. Rather than have the burden be on government to prove that a chemical is hazardous, move the burden to industry to prove that a chemical is safe before it can be introduced into commercial circulation.
  - ACGIH must require TLV committee members to disclose conflicts of interest, and to excuse themselves from the development of TLVs on chemicals of importance to their clients.
  - Allocate sufficient resources to agencies like OSHA and state-level environmental protection agencies to ensure effective enforcement of existing worker safety and environmental regulations.
  - Allocate funding and additional resources to the EPA to empower them to successfully assess all chemicals and enforce toxic exposure policy .
  - Encourage and incentivize the use of safe chemical alternatives to currently employed hazardous chemicals in semiconductor manufacturing processes.
  - Promote the development and implementation of cleaner production technologies that eliminate the use of hazardous chemicals altogether.

- **Enforcement Policy**
  - Governor Newsom, or the Governor of California at the time, must prioritize remedying the critical issues reported in Cal-OSHA.
  - Strengthen federal EPA enforcement, particularly in states like Texas, to ensure local implementation of federal regulations.
- **Best Practice**
  - Require that, if SEMI Standards are to be used as government-issued best practice standards, then the relevant standards should be made freely available to the public. In addition, it should be required that the standards are reviewed by a committee of non-industry experts in occupational medicine, and the standards must be made available to periodic assessment and revision by non-industry experts.

For CWA/CCU

- **Improved Data Collection**
  - Following the ethical principles for collecting health equity data laid out in Appendix G, organize a campaign to collect data from workers and communities in high-risk locales. SCCOSH and SVTC have boxes of examples of workshops, teach-ins, surveys and other methods used in the 1980s that will help.
  - Perform further research on past proposals already designed for occupational health databases for electronics workers. This includes a California HHS initiative that Dr. Joseph LaDou supported in 1997 that would run a cohort of electronics workers through the California Disease Registries and the birth defects registry that Ted Smith notes was proposed in 1997 by California HHS, with the support of the EPA, only to be shot down by industry resistance in 1998. [152]
- **Toxic Exposure Policy**
  - Advocate for shifting the burden of proof from the government to industry in assessing chemical hazards.
  - Organize academic classes, such as Anibel Ferus-Comelo's undergraduate class "Work, Justice and the Labor Movement," to research state-specific toxic exposure regulations. The ultimate goal should be to develop a comprehensive list of all state and federal regulations nationwide.
- **Enforcement Policy**
  - Organize academic classes or professional workshops and panels to brainstorm avenues for achieving zero exposure in the workplace and communities alongside government regulation. One example is the work of organizations like CEPN that focus on collaborating with industry to implement the substitution of hazardous chemicals with safe ones.
- **Designing Policy with Significant Unknowns**
  - Organize across the coalition to develop an agreed-upon approach to the precautionary principle
- **Best Practice**
  - Per activist Lenny Siegel:

> *Best management practices should be considered important for the coalition. NIST's PEA for CHIPS sees best practice as an opportunity to modernize practices. As a coalition, identifying best practices that we want to advocate will enable us to push for CHIPS offices to modernize practices in a way we approve, and hold their feet to the fire to enforce/require these practices in factories regardless of local regulations.*[153]

  - In line with Siegel's assertion, it would be ideal to not only organize a DELPHI Panel to rank a preferred method on substituting chemicals, but also to review the SEMI Best Practice publications put forward by NIST's PEA and confirm these best practice are in line with CCU's goals for environmental protections.

152. The proposal was to utilize California health registries as a way of studying the rates at which disease occurs among electronics workers and their families. The project would have developed a record-keeping system for the semiconductor industry to monitor and identify the incidence of cancer and birth defects among its workers. Access to employee records was vital to the project, but by 1998, the industry had publicly refused to participate. Tim Mohin, an Intel spokesperson, told the press in a widely reported statement, "To participate in a project like this would be like giving discovery to plaintiffs. I might as well take a gun and shoot myself." https://ehp.niehs.nih.gov/doi/pdf/10.1289/ehp.99107a452 Both HHS initiatives are also documented in the SVTC archives at SJSU.
153. Summary of Lenny Siegel's comments, approved April 23, 2024.

Long-Term Policy Considersations

For Government Agencies

- **Improved Data Collection**
  - Implement new federal regulation that requires firms to collect data that will reduce the burden of federal and NGO programs conducting risk assessments.
- **Toxic Exposure Policy**
  - TSCA
    - » Improve transparency.
    - » Revise chemicals in TSCA to ALL have toxicological information.
  - EPA
    - » Garner Congressional support to conduct a comprehensive evaluation of EPA procedures for chemical assessments and oversee an overhaul of procedures with the goal of creating a process the EPA can implement to successfully assess all pending chemicals.
  - OSHA
    - » Garner Congressional support to:
      - Reform OSHA regulations and establish uniform, enforceable national exposure limits based on the most protective limits currently available and on current health science.
      - Overhaul standard-setting process to eliminate conflicts of interest, ensure transparency and mandate presence of qualified medical professionals in the process.
      - Restructure strong leadership over toxic exposure regulation and enforcement.
  - Exposure Limits
    - » Streamline exposure limits: EPA and OSHA should have the same limits.
    - » Implement a program or special task force focused on interagency cooperation to set future limits together, or restructure agency authority so only one agency controls all limits occupational and environmental.
    - » Exposure limits must include reproductive harm.
    - » Medical professionals must be a part of setting toxic exposure standards.

- **Transparency and Accountability**
  - Strengthen existing right-to-know laws to ensure workers have access to comprehensive information on the chemicals they are exposed to during the course of their work.
  - Re-evaluate trade secret protections to ensure they do not impede efforts to collect data on chemical use and potential health risks in the semiconductor industry. A balance needs to be struck between protecting legitimate trade secrets and safeguarding worker health.

- **Enforcement Policy**
  - EPA must enforce its regulations in Texas and end the illegal state regulations that set higher exposure limits than the EPA.

For CWA/CCU

- **Transparency and Accountability**
  - Advocate for mandatory reporting of chemicals used in semiconductor manufacturing, fostering a culture of openness and accountability.
- **Improved Data Collection**
  - Build academic support to develop medical and scientific studies to examine the current status of toxic exposure in the industry, and the country.
  - Collaborate with public health experts (academic and not) to conduct comprehensive health studies that definitively link potential exposures to health outcomes.
- **Best Practices**
  - Advocate for modernized practices and enforceable best practices in factories.

VIII. Conclusion

This study was limited mainly by the lack of time to build relationships with community-based organizations and industry that would have allowed for potential collaboration on collecting health equity data and performing occupational and environmental risk assessments. While this report makes clear the remaining lack of data available to produce rigorous policy recommendations, these are not treated as study limitations as much as key gaps addressed by the needs assessment.

Avenues for Future Research:

Academic Research Topics:

E-waste, hazardous storage and cleanup policy recommendations; comprehensive review of past policy proposals in California for occupational health databases for electronics workers to create updated proposals for today; comprehensive review of state-specific toxic exposure regulations to develop a comprehensive list of all state and federal regulations nationwide; brainstorm avenues for achieving zero exposure in the workplace and communities without government regulation.

Medical Studies and Biomonitoring Programs:

Academic institutions, especially medical institutions with departments for occupational health or chemistry departments with a focus in green chemistry, should conduct medical and scientific studies to examine the current status of toxic exposure in the industry and the country.

This includes:

- Conducting long-term cohort studies of workers in the semiconductor industry. These studies would track worker health outcomes over time, allowing for the identification of potential health effects associated with long-term exposure to hazardous chemicals.
- Utilizing biomonitoring techniques to directly measure the levels of hazardous chemicals present in workers' bodies. Biomonitoring can provide a more accurate assessment of exposure levels compared to relying solely on self-reported data from workers.

Community Health Assessments Specific to the Industry:

The report highlights the importance of conducting health studies with residents living in close proximity to semiconductor facilities. These studies, conducted in collaboration with residents and community organizations, would examine potential health impacts from environmental exposures associated with these facilities, comparing health outcomes to control groups residing further away. The data collected might also include details about occupational experiences. With greater knowledge on the current work process for workers, a better understanding of exposure potential and the hazards facing technicians and other workers today can be achieved. Following the ethical principles for collecting health equity data, laid out in Appendix G, this report strongly recommends that a campaign be organized to collect data from workers and communities in high-risk locales.

Environmental Data Collection and Analysis:

The use of environmental data is recommended as a high-priority next step in future research. This might include organizing new data collection initiatives, and collaborating with local, state and federal agencies to gain access to existing data collection programs that are not publicly accessible.

Standardized Data Collection:

Develop standardized data collection protocols for government agencies and the semiconductor industry. This would ensure consistency and facilitate data sharing for improved analysis of health risks.

Transparency and Public Access:

Advocate for increased transparency from the semiconductor industry regarding chemical use, potential health risks and environmental releases. Publicly available data empowers researchers and communities to conduct independent investigations and hold companies accountable for their operations.

Bibliography

1. Brody, Julia Green, Rachel Morello-Frosch, Ami Zota, Phil Brown, Carla Pérez, and Ruthann A. Rudel. "Linking Exposure Assessment Science With Policy Objectives for Environmental Justice and Breast Cancer Advocacy: The Northern California Household Exposure Study." American Journal of Public Health 99, no. S3 (November 2009): S600–609. https://doi.org/10.2105/AJPH.2008.149088.
2. Byster, Leslie A., and Ted Smith. "From Grassroots to Global: The Silicon Valley Toxics Coalition's Milestones in Building a Movement for Corporate Accountability and Sustainability in the High-Tech Industry." In Challenging the Chip: Labor Rights and Environmental Justice in the Global Electronics Industry, 111–19. Temple University Press, 2008. https://doi.org/10.2307/j.ctt14bs81m.
3. California Department of Toxic Substances Control. "Toxic Release Inventory (TRI) Facilities," January 14, 2020. https://gis.data.ca.gov/datasets/DTSC::toxic-release-inventory-tri-facilities/about.
4. California Environmental Reporting System (CERS). "Hazardous Materials And Wastes Inventory Matrix Report - 10633816," November 3, 2016.
5. "CHIPS Implementation Strategies." NIST, March 26, 2023. https://www.nist.gov/chips/chips-implementation-strategies.
6. Chen, Yi-Ju, Ren-De Wang, Yu-Lin Shih, Hsiao-Yi Chin, and Angela Yu-Chen Lin. "Emerging Perfluorobutane Sulfonamido Derivatives as a New Trend of Surfactants Used in the Semiconductor Industry." Environmental Science & Technology 58, no. 3 (January 23, 2024): 1648–58. https://doi.org/10.1021/acs.est.3c04435.
7. Choudhury, Harlal, Jim Cogliano, Richard Hertzberg, Debdas Mukerjee, Glenn Rice, Linda Teuschler, Elizabeth Doyle, Yintak Woo, and Rita Schoeny. "Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures." Risk Assessment Forum U.S. Environmental Protection Agency, August 2000. https://ordspub.epa.gov/ords/eims/eimscomm.getfile?p_download_id=4486.
8. Communications Workers of America (CWA). "CWA Occupational Safety and Health Fact Sheet Vinyl Chloride and the Workplace." n.d. https://cwa-union.org/sites/default/files/osh-fact-sheet-11-vinyl_chloride_and_the_workplace.pdf.
9. Cone, James E., Gordon R. Reeve, and Philip J. Landrigan. "Clinical and Epidemiological Studies." In Toxic Substances and Human Risk: Principles of Data Interpretation, edited by Robert G. Tardiff and Joseph V. Rodricks, 95–120. Life Science Monographs. New York, NY: Springer US, 1987. https://doi.org/10.1007/978-1-4684-5290-7_6.
10. County Health Rankings & Roadmaps. "2023 County Health Rankings National Findings Report: Cultivating Civic Infrastructure and Participation for Healthier Communities," March 2023. https://www.countyhealthrankings.org/findings-and-insights/2023-county-health-rankings-national-findings-report.
11. County Health Rankings & Roadmaps. "Explore Health Topics | County Health Rankings & Roadmaps." Accessed March 18, 2024. https://www.countyhealthrankings.org/what-impacts-health/county-health-rankings-model.
12. Dalkey, Norman, and Olaf Helmer. "An Experimental Application of the Delphi Method to the Use of Experts." In Management Science, 9:458–67. INFORMS, 1963. https://www.jstor.org/stable/2627117.
13. Department of Commerce National Institute of Standards and Technology CHIPS Program Office. "Programmatic Environmental Assessment for Modernization and Internal Expansion of Existing Semiconductor Fabrication Facilities under the CHIPS Incentives Program." December 2023. https://www.nist.gov/system/files/documents/2023/12/26/CHIPS%20Modernization%20Draft%20PEA.pdf.
14. Department of Commerce National Institute of Standards and Technology CHIPS Program Office. "Vision for Success: Commercial Fabrication Facilities." February 13, 2023. https://www.nist.gov/system/files/documents/2023/02/28/Vision_for_Success-Commercial_Fabrication_Facilities.pdf.
15. EnDyna and Tellevate, LLC. "Spill Prevention, Control and Countermeasure Plan." National Institutes of Health Bethesda Campus, September 13, 2017. https://nems.nih.gov/Documents/NIH%20Bethesda%20SPCC%20Final_13%20Sept_2017_with%20signature%20pages_508.pdf.
16. EPA Office of Research and Development. "Closed Waste Sites as Community Assets: A Guide for Municipalities, Landfill Owners, and Regulators," November 2014. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100LHOS.PDF?Dockey=P100LHOS.PDF.
17. EPA Science Advisory Board. "Reducing Risk: Setting Priorities and Strategies for Environmental Protection," September 1990.
18. Enhesa. "Chemical Assess Factsheet." n.d. https://enhesa-cdn-prod.s3.amazonaws.com/uploads/2024/04/Enhesa-SCH-Chemical-Assess-Fact-sheet.pdf.
19. Global Framework on Chemicals. "For a Planet Free of Harm from Chemicals and Waste," March 13, 2024. https://www.chemicalsframework.org/sites/default/files/documents/The%20Global%20Framework%20on%20Chemicals%20ENG_28022024.pdf.
20. Grima, Simon, Murat Kizilkaya, Ramona Rupeika-Apoga, Inna Romānova, Rebecca Dalli Gonzi, and Mihajlo Jakovljevic. "A Country Pandemic Risk Exposure Measurement Model." Risk Management and Healthcare Policy13 (October 9, 2020): 2067–77. https://doi.org/10.2147/RMHP.S270553.
21. Gul, Muhammet, and M. Fatih Ak. "A Comparative Outline for Quantifying Risk Ratings in Occupational Health and Safety Risk Assessment." Journal of Cleaner Production 196 (September 2018): 653–64. https://doi.org/10.1016/j.jclepro.2018.06.106.
22. Gul, Muhammet, Busra Guven, and Ali Fuat Guneri. "A New Fine-Kinney-Based Risk Assessment Framework Using FAHP-

FVIKOR Incorporation." Journal of Loss Prevention in the Process Industries 53 (May 2018): 3–16. https://doi.org/10.1016/j.jlp.2017.08.014.
23. Gunderson, Morley, and Douglas Hyatt. "Workplace Risks and Wages: Canadian Evidence from Alternative Models." The Canadian Journal of Economics / Revue Canadienne d'Economique 34, no. 2 (2001): 377–95. http://www.jstor.org/stable/3131859.
24. Harrison, Kathryn, and George Hoberg. "Cancer Risk Assessment: Concepts and Controversies." In Risk, Science, and Politics: Regulating Toxic Substances in Canada and the United States, 16–31. McGill-Queen's University Press, 1994. https://doi.org/10.2307/j.ctt7zpgh.
25. Harrison, Kathryn and Hoberg, George. "Policy Making amid Scientific Uncertainty" In Risk, Science, and Politics: Regulating Toxic Substances in Canada and the United States, 1-15. McGill-Queen's University Press, 1994. https://doi.org/10.1515/9780773565050-003.
26. Hazard Evaluation System and Information Service (HESIS) and Labor Occupational Health Program (LOHP), University of California, Berkeley. "Understanding Toxic Substances: An Introduction to Chemical Hazards in the Workplace." State of California Department of Public Health Department of Industrial Relations, 1986. https://www.cdph.ca.gov/Programs/CCDPHP/DEODC/OHB/HESIS/CDPH%20Document%20Library/introtoxsubstances.pdf.
27. International Labour Office. National System for Recording and Notification of Occupational Diseases: Practical Guide. Geneva: ILO, 2013.
28. Işık, Işıl Nurdan, and Emine Atasoylu. "Occupational Safety and Health in North Cyprus: Evaluation of Risk Assessment." Safety Science 94 (April 2017): 17–25. https://doi.org/10.1016/j.ssci.2016.12.020.
29. Jacobs, Molly M., Timothy F. Malloy, Joel A. Tickner, and Sally Edwards. "Alternatives Assessment Frameworks: Research Needs for the Informed Substitution of Hazardous Chemicals." Environmental Health Perspectives 124, no. 3 (March 2016): 265–80. https://doi.org/10.1289/ehp.1409581.
30. Jünger, Saskia, Sheila A Payne, Jenny Brine, Lukas Radbruch, and Sarah G Brearley. "Guidance on Conducting and REporting DElphi Studies (CREDES) in Palliative Care: Recommendations Based on a Methodological Systematic Review." Palliative Medicine 31, no. 8 (September 2017): 684–706. https://doi.org/10.1177/0269216317690685.
31. Johnston, Jill, and Lara Cushing. "Chemical Exposures, Health and Environmental Justice in Communities Living on the Fenceline of Industry." Current Environmental Health Reports 7, no. 1 (March 2020): 48–57. https://doi.org/10.1007/s40572-020-00263-8.
32. Karasan, Ali, Esra Ilbahar, Selcuk Cebi, and Cengiz Kahraman. "A New Risk Assessment Approach: Safety and Critical Effect Analysis (SCEA) and Its Extension with Pythagorean Fuzzy Sets." Safety Science 108 (October 2018): 173–87. https://doi.org/10.1016/j.ssci.2018.04.031.
33. Kokangül, Ali, Ulviye Polat, and Cansu Dağsuyu. "A New Approximation for Risk Assessment Using the AHP and Fine Kinney Methodologies." Safety Science 91 (January 2017): 24–32. https://doi.org/10.1016/j.ssci.2016.07.015.
34. Krimsky, Sheldon. "The Unsteady State and Inertia of Chemical Regulation under the US Toxic Substances Control Act." Edited by Linda S. Birnbaum. PLOS Biology 15, no. 12 (December 18, 2017): e2002404. https://doi.org/10.1371/journal.pbio.2002404.
35. LaDou, Joseph. "Health Issues in the Global Semiconductor Industry." Annals of the Academy of Medicine, Singapore,23, no. 5 (September 1994): 765–69. Box 32, Folder 19.
36. Mahmoudi, Shahram, Fakhradin Ghasemi, Iraj Mohammadfam, and Esmaeil Soleimani. "Framework for Continuous Assessment and Improvement of Occupational Health and Safety Issues in Construction Companies." Safety and Health at Work 5, no. 3 (September 2014): 125–30. https://doi.org/10.1016/j.shaw.2014.05.005.
37. National Equity Atlas. "Life Expectancy | National Equity Atlas." Accessed March 18, 2024. https://nationalequityatlas.org/indicators/Life_expectancy.
38. National Skills Coalition and BlueGreen Alliance. "Executive Summary of PERI Report: Employment Impacts of New U.S. Clean Energy, Manufacturing, and Infrastructure Laws." September 18, 2023. https://nationalskillscoalition.org/wp-content/uploads/2023/09/0923-Executive-Summary-PERI-Report.pdf.
39. Opportunity Index. "What Is the Opportunity Index?" Accessed March 18, 2024. https://opportunityindex.org/about/.
40. Pinto-Bazurco, Jose F. "The Precautionary Principle." International Institute for Sustainable Development, October 23, 2020. https://www.iisd.org/articles/deep-dive/precautionary-principle.
41. PolicyLink and The USC Program for Environmental and Regional Equity (PERE). "Advancing Health Equity and Inclusive Growth in Fresno County." April 2017. https://nationalequityatlas.org/sites/default/files/FresnoProfile_final.pdf.
42. "Reassessing Chemical Control Policies." In Chemicals without Harm: Policies for a Sustainable World, 37–57. The MIT Press, 2015. https://doi.org/10.7551/mitpress/8079.003.0005.
43. Ross, Ángel. "Powering Health Equity Action with Online Data Tools: 10 Design Principles." PolicyLink and Ecotrust, September 2017. https://ecotrust.org/wp-content/uploads/10-Design-Principles-For-Online-Data-Tools.pdf.
44. Rural Health Information Hub. "Using Community Health Assessment to Determine Needs - RHIhub Community Paramedicine Toolkit." Accessed March 18, 2024. https://www.ruralhealthinfo.org/toolkits/community-paramedicine/4/community-health-assessment.
45. Santa Clara Center for Occupational Safety and Health. "Vinyl Chloride SCCOSH Fact Sheet." n.d.
46. Schwarzman, Megan R., and Heather L. Buckley. "Not Just an Academic Exercise: Systems Thinking Applied to Designing Safer Alternatives." Journal of Chemical Education 96, no. 12 (December 10, 2019): 2984–92. https://doi.org/10.1021/acs.

jchemed.9b00345.
47. Semiconductor Industry Association (SIA). "Chipping Away: Assessing and Addressing the Labor Market Gap Facing the U.S. Semiconductor Industry." July 20, 2023. https://www.semiconductors.org/wp-content/uploads/2023/07/SIA_July2023_ChippingAway_website.pdf.
48. Semiconductor Industry Association (SIA). "Chipping In: The Positive Impact of the Semiconductor Industry on the American Workforce and How Federal Industry Incentives Will Increase Domestic Jobs." May 19, 2021. https://www.semiconductors.org/wp-content/uploads/2021/05/SIA-Impact_May2021-FINAL-May-19-2021_2.pdf.
49. Senate Committee on Commerce, Science and Transportation . "The CHIPS Act of 2022 Section-by-Section Summary," July 29, 2022. https://www.bennet.senate.gov/public/_cache/files/4/0/40919cb4-ff63-4434-8ae2-897a4a026b30/7BCDD84F555A6B85BEC800514F1D3AFD.chips-and-science-act-of-2022-section-by-section.pdf.
50. Sivin, Darius D. "Occupational Exposure Limits: How the Sausage Was Made." PowerPoint Slides, January 8, 2024.
51. State of California Department of Industrial Relations and Division of Occupational Safety and Health. "The Cal/OSHA Hazard Communication Regulation — a Guide for Employers That Use Hazardous Chemicals," June 2023. https://www.dir.ca.gov/dosh/dosh_publications/hazcom.pdf.
52. Stefanović, Violeta, Snežana Urošević, Ivana Mladenović-Ranisavljević, and Petar Stojilković. "Multi-Criteria Ranking of Workplaces from the Aspect of Risk Assessment in the Production Processes in Which Women Are Employed." Safety Science 116 (July 2019): 116–26. https://doi.org/10.1016/j.ssci.2019.03.006.
53. Sutter, Karen M., John F. Sargent, and Manpreet Singh. "Semiconductors and the CHIPS Act: The Global Context." Congressional Research Service (CRS), September 28, 2023. https://crsreports.congress.gov/product/pdf/R/R47558.
54. Thadani, Akhil, and Gregory C. Allen. "Mapping the Semiconductor Supply Chain: The Critical Role of the Indo-Pacific Region." The Center for Strategic and International Studies (CSIS), May 30, 2023. https://www.csis.org/analysis/mapping-semiconductor-supply-chain-critical-role-indo-pacific-region.
55. Thompson, Ben. "Using a Community Health Needs Assessment to Prove the Value of MIH." EMS1, October 4, 2018. https://www.ems1.com/ems/articles/how-to-prove-the-value-of-community-paramedicine-DO47fYUShl5XrdqJ/.
56. United States Environmental Protection Agency. "Use Multiple Data Sources for Safer Emergency Response," June 1999. https://www.epa.gov/sites/default/files/2013-11/documents/respnd1.pdf.
57. U.S. Bureau of Labor Statistics. "TABLE 1. Incidence Rates(1) of Nonfatal Occupational Injuries and Illnesses by Industry and Case Types, 2022," 2022. https://www.bls.gov/web/osh/table-1-industry-rates-national.htm.
58. U.S. Congress. House. House Appropriations Committee. LEGISLATIVE BRANCH APPROPRIATIONS BILL, 2022 (to accompany H.R. 4346). 117th Cong., 1st sess., 2022. H. Rep. 117–80. https://www.congress.gov/117/crpt/hrpt80/CRPT-117hrpt80.pdf.
59. Whittaker, Margaret H., Arthur Fong, and Lauren Heine. "Chemicals Used in the Electronics Industry." In Patty's Toxicology, edited by Eula Bingham, Barbara Cohrssen, and Charles H. Powell, 1st ed., 1–50. Wiley, 2023. https://doi.org/10.1002/0471125474.tox170.
60. Wicks-Lim, Jeannette, and Robert Pollin. "Labor Supply, Labor Demand, and Potential Labor Shortages Through New U.S. Clean Energy, Manufacturing, and Infrastructure Laws." Political Economy Research Institute (PERI), February 2024. https://peri.umass.edu/images/publication/PERI_BGA_Labor_2_28_24.pdf.
61. Ziem, Grace E., and Barry I. Castleman. "Threshold Limit Values: Historical Perspectives and Current Practice." Journal of Occupational Medicine 31, no. 11 (1989): 910–18. https://www.jstor.org/stable/45014113.

References from Silicon Valley Toxics Coalition Archives at San Jose State University Archives

1. Adams, Gary. "Adams G. Letter to Louis V. Gerstner." IBM Corporation, March 2, 1997. Box 32, Folder 19. San José State University Archives.
2. Adams, Gary. "Adams G. Letter to Stan R. Ciraulo." IBM Corporation, September 29, 1996. Box 32, Folder 19. San José State University Archives.
3. Allentown Morning Call. "Study Prompts Transfer of Pregnant Chip Workers." January 15, 1987. Box 32, Folder 18. San José State University Archives.
4. "A PWWER Fact Sheet: Right to OSHA Inspections." Santa Clara Center for Occupational Safety & Health, n.d. Box 32. San José State University Archives.
5. Badgett, Lona, Beth Hawke, and Karen Humphrey. "Analysis of Pollution Prevention and Waste Minimization Opportunities Using Total Cost Assessment: A Case Study in the Electronics Industry." Pacific Northwest Pollution Prevention Center, September 1995. Box 32, Folder 16. San José State University Archives.
6. Belliveau, Michael. "Belliveau M. To IGC Members: The CAL/OSHA Director's List of Hazardous Substances for Inclusion in the Hazardous Materials Permit Ordinance." Silicon Valley Toxics Coalition, February 2, 1983. Box 8, Folder 8. San José State University Archives.
7. Boice, John D., Donald E. Marano, Heather M. Munro, Bandana K. Chadda, Lisa B. Signorello, Robert E. Tarone, William J. Blot, and Joseph K. McLaughlin. "Cancer Mortality Among US Workers Employed in Semiconductor Wafer Fabrication." Journal of Occupational and Environmental Medicine 52, no. 11 (November 2010): 1082–97. Box 33, Folder 1. San José State University Archives.

8. Bulkeley, William M. “IBM Settles Workers’ Cancer Claims.” The Wall Street Journal, June 24, 2004. Box 33, Folder 2. San José State University Archives.
9. Burggraaf, Pieter. “Coping with the High Cost of Wafer Fabs.” Semiconductor International, March 1995, 45–49. Box 32, Folder 19. San José State University Archives.
10. Butterfield, Bruce. “Group Hit Chip Industries Policies.” The Boston Globe, January 16, 1987. Box 32, Folder 18. San José State University Archives.
11. California Department of Health Services. “Fact Sheet #2: North First Street Plume, San Jose Site,” August 1989. Box 30, Folder 7. San José State University Archives.
12. California Environmental Protection Agency Department of Toxic Substances Control. “Fact Sheet No. 6: Varian Associates, Inc.,” February 1996. Box 30, Folder 7. San José State University Archives.
13. California Environmental Protection Agency Department of Toxic Substances Control. “Pure Etch Facility Operations Suspended DTSC Takes Steps to Revoke Permit,” April 1997. Box 30, Folder 7. San José State University Archives.
14. California Water Quality Control Board San Francisco Bay Region. “Community Relations Plan for Superfund Sites in the City of Mountain View,” February 1989. Box 30, Folder 7. San José State University Archives.
15. California Water Quality Control Board San Francisco Bay Region. “Community Relations Plan for Superfund Sites in the City of San Jose,” October 1989. Box 30, Folder 7. San José State University Archives.
16. Chapman, Gary, and Joel Yudken. “Summary of The 21st Century Project: Setting a New Course for Science and Technology Policy.” Computer Professionals for Social Responsibility, July 1993. Box 32, Folder 19. San José State University Archives.
17. City of Sunnyvale and Santa Clara Valley Water District. “Management of Investigation and Cleanup at Superfund Sites in Sunnyvale California,” n.d. Box 32, Folder 19. San José State University Archives.
18. Clevenger, Mark, and Stephen Jones. “Top 25 Semiconductor Companies.” San Jose Business Journal, January 1987. Box 32, Folder 18. San José State University Archives.
19. Cohen, Richard. “Digital Equipment Corporation Study of Wafer Fabrication Employees.” Signetics Corporation, November 7, 1986. Box 34, Folder 10. San José State University Archives.
20. Council of the City of San Jose. “Ordinance No. 23450: Ordinance of the City of San Jose Amending Title 17 of the San Jose Municipal Code by Adding a New Chapter 17.78 Regulating Facilities Where Materials Which Are or Which May Become Toxic Gases Are Found and Amending Chapter 17.68 of Title 17 of the San Jose Municipal Code to Make Corresponding Technical Changes in the Hazardous Materials Storage Ordinance,” April 20, 1990. Box 30, Folder 7. San José State University Archives.
21. County of Santa Clara . “Procurement Policy Relating to Chlorofluorocarbons and Other Ozone Depleting Substances,” April 3, 1990. Box 30, Folder 7. San José State University Archives.
22. Court Paper State of California. “Declaration of George V. Alexeeff, PH.D., In Response to Preliminary Injunction.” January 22, 1987. Box 33, Folder 18. San José State University Archives.
23. Coyle, Patricia, and Catherine Sonquist Forest. “Workplace Chemical Hazards to Reproductive Health: A Resource for Worker Health and Safety Training and Patient Education.” Hazard Evaluation System and Information Service Occupational Health Branch, May 1990. Box 4, Folder 18. San José State University Archives.
24. “CRT Toxic Timeline on Glycol Ethers, Excerpts on the History of Health Studies That Lead up to the IBM and SIA Studies, and Chemical Use and Occupational Health in the Semiconductor Industry,” n.d. Box 32, Folder 19. San José State University Archives.
25. Donohue, James F. “The Microprocessor’s First Two Decades: The Way It Was.” EDN Microprocessor Issue, October 27, 1988. Box 32, Folder 19. San José State University Archives.
26. Environmental Health Coalition. “Action Alert: BHOPAL in San Diego? Community Pressures Phoenix Research to Leave.” Toxinformer, 1988. Box 32, Folder 19. San José State University Archives.
27. Environmental Justice/Environmental Racism. “Principles of Environmental Justice,” April 6, 1996. Box 5, Folder 7. San José State University Archives.
28. EPA. “National Priorities List: Superfund Hazardous Waste Site Listed Under the Comprehensive Environmental Response,” 1986. Box 18, Folder 1. San José State University Archives.
29. “Fact Sheet: Minority Workers and Occupational Illness and Injury,” n.d. Box 4, Folder 19. San José State University Archives.
30. Ferraro, Pat. “Memo to Members of IGC Environmental Safety Committee: January 6th Meeting.” County of Santa Clara, December 21, 1991. Box 30, Folder 7. San José State University Archives.
31. Fowler, Bruce A., Hiroshi Yamauchi, E.A. Conner, and M. Akkerman. “Cancer Risks for Humans from Exposure to the Semiconductor Metals.” Scandinavian Journal of Work 19, no. 1 (1993): 101–3. Box 32, Folder 19. San José State University Archives.
32. Fraust, C.L. “Semiconductor Workers Face Unique Health Risk in Manufacturing Sector.” Occupational Health & Safety, October 1987. Box 32, Folder 18. San José State University Archives.
33. Froines, John R., Harlan Rotblart, Cornelia Dellenbaugh, Jessie Schnell, Mitchell Shandling, and Jacqueline Nowell. “Occupational Exposures in Santa Clara County.” Santa Clara Valley Integrated Environmental Management Project, July 1986. Box 34, Folder 10. San José State University Archives.
34. Harrison, Myron. “Semiconductor Manufacturing Hazards.” Hazardous Materials Toxicology: Clinical Principles of Environmental Health, 1992, 472–504. Box 32, Folder 19. San José State University Archives.

35. Hazard Evaluation System and Information Service, California Occupational Health Program, and California Departments of Health Services and Industrial Relations. "HESIS Hazard Alert: Chromium-6 Causes Lung Cancer," October 1992. Box 33, Folder 14. San José State University Archives.
36. Hazard Evaluation System and Information Service and California Occupational Health Program. "HESIS Fact Sheet: Trichloroethylene (TCE)," November 1997. Box 33, Folder 14. San José State University Archives.
37. Hazard Evaluation System and Information Service and California Occupational Health Program. "HESIS Hazard Alert: Hexavalent Chromium," June 1992. Box 33, Folder 14. San José State University Archives.
38. Hembree, Diana, and Sarah Henry. "Baffling Ills Hit 'Silicon Valley' Work." The Arizona Republic, December 14, 1980. Box 32, Folder 18. San José State University Archives.
39. Herbert, Bob. "Clouds in Silicon Valley." The New York Times, September 8, 2023. Box 33, Folder 2. San José State University Archives.
40. Herbert, Bob. "I.B.M. Families Ask, 'Why?'" The New York Times, September 15, 2003. Box 33, Folder 2. San José State University Archives.
41. Herbert, Bob. "Sick and Suspicious." The New York Times, September 4, 2003. Box 33, Folder 2. San José State University Archives.
42. Hinkelman, T. D. "Possible Health Effects Associated with Occupational Exposure to Cellosolve and Certain Other Glycol Ethers." Semiconductor Industry Association. May 11, 1982. Box 33, Folder 2. San José State University Archives.
43. IBM. "IBM Environmental Policy," September 8, 2009. Box 33, Folder 2. San José State University Archives.
44. Ikeda, Masayuki. "Exposure to Complex Mixtures: Implications for Biological Monitoring." Toxicology Letters 77 (January 13, 1995): 85–91. Box 32, Folder 19. San José State University Archives.
45. "Judge Challenges IBM in Case Filed by Ill Workers." USA Today, September 26, 2003. Box 33, Folder 2. San José State University Archives.
46. LaDou, Joseph. "Occupational Health in the Semiconductor Industry." International Center for Occupational Medicine, March 18, 2004. Box 33, Folder 1. San José State University Archives.
47. LaDou, Joseph. "Semiconductor Industries." Toxicology and Industrial Health 7, no. 5/6 (1991): 59–62. Box 32, Folder 19. San José State University Archives.
48. LaDou, Joseph, and Philip A. Edelman. "Health Issues in the Microelectronics Industry," n.d. Box 32, Folder 18. San José State University Archives.
49. LaDou, Joseph, and Timothy J. Rohm. "Occupational Hazards in the Microelectronics Industry," n.d. Box 32, Folder 19. San José State University Archives.
50. LaDou, Joseph, and Timothy J. Rohm. "The International Electronics Industry." International Journal of Occupational and Environmental Health 4, no. 1 (1998): 1–18. Box 33, Folder 1. San José State University Archives.
51. Lofgren, Zoe. "Lofgren Z. Letter to Ted Smith and Dr. David Walworth." County of Santa Clara Board of Supervisors, April 20, 1987. Box 32, Folder 18. San José State University Archives.
52. Lupi, Carla. "Technical Report: Ethylene Glycol Monoethyl Ether Acetate." Project on Health and Safety in Electronics, January 29, 1981. Box 33, Folder 2. San José State University Archives.
53. Lyons, Julie Sevrens. "IBM Knew of Workers' High Cancer Rate, Lawyers Claim." The Mercury News, September 23, 2003. Box 33, Folder 2. San José State University Archives.
54. National Association of County and City Health Officials . "Community Environmental Health Assessment: Concepts and Issues," May 25, 1995. Box 32, Folder 19. San José State University Archives.
55. Marano, Donald E., John D. Boice, Heather M. Munro, Bandana K. Chadda, Michael E. Williams, Colleen M. McCarthy, Peggy F. Kivel, William J. Blot, and Joseph K. McLaughlin. "Exposure Assessment Among US Workers Employed in Semiconductor Wafer Fabrication." Journal of Occupational and Environmental Medicine 52, no. 11 (November 2010): 1075–81. Box 33, Folder 1. San José State University Archives.
56. McCurdy, Stephen A., Marc B. Schenker, and Donald V. Lassiter. "Occupational Injury and Illness in the Semiconductor Manufacturing Industry." American Journal of Industrial Medicine 15 (1989): 499–510. Box 32, Folder 19. San José State University Archives.
57. McDonald, Tim L., Charles D. Treser, and Jack B. Hatlen. "Development of an Environment Health Addendum to the Assessment Protocol for Excellence in Public Health." Journal of Public Health Policy, 1994, 203–17. Box 32, Folder 19. San José State University Archives.
58. McKay, Kenneth P. "MacKay Response to Fred Miller," June 12, 1987. Box 33, Folder 18. San José State University Archives.
59. National Institute for Occupational Safety and Health. "Hazard Assessment of the Electronic Component Manufacturing Industry." Environmental Chemistry Department Systems and Management Division Research Triangle Institute, February 1985. Box 34, Folder 9. San José State University Archives.
60. Newman, Dave. "Telecommunications Workers Hook Up in Holland ," n.d. Box 32, Folder 18. San José State University Archives.
61. Noble, Chris Bozzini, and Elizabeth Harriman. "Hazardous Materials in the Semiconductor Industry." Tufts University, April 24, 1991. Box 32, Folder 19. San José State University Archives.
62. "Occupational Health and Safety Reporter." The Bureau of National Affairs, Inc., January 14, 1987. Box 32, Folder 18. San José State University Archives.

63. Osby, Robert E. “City of San Jose Memorandum to Environment Committee: Hazardous Materials Program Tri-Annual Report.” City of San Jose, March 11, 1992. Box 30, Folder 7. San José State University Archives.
64. Pacific Northwest Pollution Prevention Center. “Electronics Industry Casebook,” n.d. Box 32, Folder 16. San José State University Archives.
65. Practicon Associates and Microsafe, Inc. “Toxic Gas Model Ordinance,” November 14, 1986. Box 33, Folder 19. San José State University Archives.
66. Project Management Committee (PMC) of the Semiconductor Industry Association (SIA) Worker Health Project. “Request for Proposal for Scoping Study to Determine the Feasibility of a Retrospective Epidemiologic Cohort Mortality Study of Semiconductor Wafer Fabrication Workers,” 2002. Box 33, Folder 1. San José State University Archives.
67. Project on Health and Safety in Electronics. “PHASE Factsheet #1: Trichloroethylene (TCE).” January 1981. Box 33, Folder 14. San José State University Archives.
68. Project on Health and Safety in Electronics. “PHASE Factsheet #2: Reproductive Hazards in the Electronics Industry,” n.d. Box 4, Folder 12. San José State University Archives.
69. Project on Health and Safety in Electronics. “PHASE Factsheet #5: Epoxy Resins Factsheet,” n.d. Box 4, Folder 12. San José State University Archives.
70. Project on Health and Safety in Electronics. “PHASE Factsheet #6 Carcinogens in the Electronics Industry,” n.d. Box 4, Folder 12. San José State University Archives.
71. Project on Health and Safety in Electronics. “PHASE Factsheet #7: Acids and Bases,” n.d. Box 4, Folder 12. San José State University Archives.
72. Project on Health and Safety in Electronics. “PHASE Factsheet #8: Vision in the Electronic Industry,” n.d. Box 4, Folder 12. San José State University Archives.
73. Project on Health and Safety in Electronics. “PHASE Factsheet #9: Solvents in the Electronics Industry,” n.d. Box 4, Folder 12. San José State University Archives.
74. Protecting Workers Who Exercise Rights. “A PWWER Fact Sheet: Your OSHA Rights in a Nutshell.” National COSH Network, n.d. Box 32. San José State University Archives.
75. Reed, Sally. “Reed S. to Santa Clara County Board of Supervisors.” Edited by Sally Logothetti, Jane Decker , and George Newell. County of Santa Clara Office of the County Executive, January 1, 1990. Box 30, Folder 7. San José State University Archives.
76. Robbins, Philip J., Charles R. Butler, and Kathryn R. Mahaffey. “Occupational Injury and Illness in the Semiconductor Industry for 1980-1985.” National Institute for Occupational Safety and and Health, Division of Standards Development Technology Transfer, n.d. Box 32, Folder 18. San José State University Archives.
77. Russell, Joe. “SFGate: Big Blue Settles Lawsuits/Sick Employees Blamed Chemicals.” June 24, 2004. Box 33, Folder 2.
78. San Jose Fire Department Bureau of Fire Prevention. “Chapter 17.68: Hazardous Materials Storage Permit,” January 1992: 3413-3430. Box 30, Folder 7. San José State University Archives.
79. Sanger , David E. “Pregnancy Transfers By AT&T: Miscarriages Feared After Study on Chips.” The New York Times, January 14, 1987. Box 32, Folder 18. San José State University Archives.
80. Santa Clara Center for Occupational Safety and Health. “Asian Workers at Risk,” n.d. Box 4, Folder 12. San José State University Archives.
81. Santa Clara Center for Occupational Safety and Health. “Health and Safety Fact Sheet: The Hazard Communication Standard,” n.d. Box 32. San José State University Archives.
82. SEMATECH. “Proposals for SEMATECH: Promote Environmentally Sustainable Manufacturing in the Semiconductor Industry,” March 24, 1993. Box 32, Folder 19. San José State University Archives.
83. Seta, Joseph A., and David S. Sundin. “Semiconductor Industry--A Hazard Surveillance Perspective.” In Hazard Assessment and Control Technology in Semiconductor Manufacturing, 37–46. Industrial Hygiene Science Series. Lewis Publishers, n.d. Box 32, Folder 18. San José State University Archives.
84. Schenker, Marc B., Stephen A. McCurdy, Lynne Morrin, and Susan Klasing. “Final Report to the Semiconductor Industry Association: A Review of the Semiconductor Industry Occupational Health System.” University of California, Davis School of Medicine Division of Occupational and Environmental Medicine, August 27, 1987. Box 32, Folder 18. San José State University Archives.
85. SCCOSH. “Hazard Communication Standard (HazCom) and Material Safety Data Sheet (MSDS),” August 2003. Box 4, Folder 12. San José State University Archives.
86. SCCOSH. “Pamphlet on Right to Know Law,” n.d. Box 4, Folder 12. San José State University Archives.
87. Silicon Valley Toxics Coalition. “Silicon Valley Toxics Coalition Recommendations to Improve AB 1021,” n.d. Box 30, Folder 7.
88. Silicon Valley Toxics News. “Position Paper on Health and Safety in the Semiconductor Industry.” 1987. Box 32, Folder 18. San José State University Archives.
89. Smith, Ted. “Media Advisory: IBM Health Study Shows 1 in 3 Semiconductor Workers Suffer Miscarriage.” Silicon Valley Toxics Coalition, October 12, 1992. Box 33, Folder 2. San José State University Archives.
90. Smith, Ted. “Community Organizing Strategies for Affecting Local Government Toxics Policy,” 1984. Box 20, Folder 16. San José State University Archives.
91. Smith, Ted. “Smith T. Letter to Senator Bill Lockyer, Senate Rules Committee.” Silicon Valley Toxics Coalition, June 20, 1994.

Box 30, Folder 7. San José State University Archives.
92. State of California Employment Development Department. "Santa Clara County Labor Market for Affirmative Action Programs," March 1986. Box 4, Folder 12. San José State University Archives.
93. Stijkel, Anne, Lucas Reijnders. "Implementation of the Precautionary Principle in Standards for the Workplace." Occupational and Environmental Medicine 52, no. 5 (1995): 304–12. Box 34, Folder 11. San José State University Archives.
94. Superior Court of California County of Santa Clara. "Declaration of Richard Clapp, D. Se. In Support of Plaintiffs' Opposition to IBM's Motion for Summary Judgment," October 26, 2003. Box 33, Folder 2. San José State University Archives.
95. The Boston Herald. "AT&T Makes Call on Production Line." January 14, 1987. Box 32, Folder 18. San José State University Archives.
96. The Evening Gazette, Worcester. "Group Says Reduce Hazards." January 16, 1987. Box 32, Folder 18. San José State University Archives.
97. The Wall Street Journal. "AT&T Is Urging Transfers for Some Pregnant Women." January 14, 1987. Box 32, Folder 18. San José State University Archives.
98. Tomasi, Timothy J. "Tomasi T. Letter to Gary Adams." IBM Corporation, July 31, 1997 Box 32, Folder 19. San José State University Archives.
99. Torres, Art. "Toxic Issues in California's Microelectronics Industry." Senate Committee on Toxics and Public Safety Management, November 30, 1987. Box 32, Folder 18. San José State University Archives.
100. University of Lowell Technology and Work Program. "A New Approach in Technology Development and Workforce Education," n.d. Box 32, Folder 19. San José State University Archives.
101. U.S. Department of Health and Human Services and U.S. Department of Labor. "Occupational Health Guidelines for Copper Dust and Mists," September 1978. Box 33, Folder 14. San José State University Archives.
102. U.S. Department of Health and Human Services and U.S. Department of Labor. "Occupational Health Guidelines for Copper Dusts and Mists," January 6, 1999. Box 32. San José State University Archives.
103. Vasconcellos, John. "Vasconcellos J. to Ted Smith: Hazardous Materials Ordinance Documents." Assembly California Legislature , February 27, 1985. Box 8, Folder 8. San José State University Archives.
104. What Works. "Back to Basics: Soap Replaces CFCs at IBM's San Jose Plant," June 1, 1990. Box 33, Folder 2. San José State University Archives.
105. Yakubek, Paul M. "Rebuttal to Modeling Toxic Gas Releases Using a Simple Screening Model," February 1, 1987. Box 33, Folder 18. San José State University Archives.
106. Yesney, Michelle. "City of San Jose Memorandum to Environment Committee: CFC Ordinance," March 21, 1990. Box 30, Folder 7. San José State University Archives.
107. Yesney, Michelle. "City of San Jose Memorandum to Environment Committee: CFC Reduction Program Phase Two-Blown Foam Products." City of San Jose, October 25, 1990. Box 30, Folder 7. San José State University Archives.
108. Young, Michael S. "Executive Summary: AB 1021-Toxic Gas Management Study." Santa Clara County Fire Chiefs' Association, February 2, 1987. Box 30, Folder 7. San José State University Archives.

Appendix A: Methodology

Literature Review

A literature review was undertaken to establish a foundation for the research moving forward. It sought to clarify what was currently known about the chemical exposure risks that workers and communities of semiconductor manufacturing face in Texas and California. The key questions examined were:

1. **Historical Context and Policy Enactment:**
   a. When were the first toxic exposure policies enacted in the United States. and what was the context surrounding their enactment?
   b. What led to the development of current toxic exposure policies in California, Texas and at the federal level, specifically as they relate to semiconductor manufacturing?
2. **Perspectives on Chemical Exposure Policies:**
   a. Is there literature on chemical exposure and the reduction or elimination of toxic chemicals in semiconductor manufacturing from various perspectives, including community development theory, social and environmental justice, and industry viewpoints?
   b. What are the key differences, if any, in these perspectives?
3. **Measurement of Risks:**
   a. What measurements are currently used to define the state of workplace and environmental risks in semiconductor manufacturing?
   b. Are there preferred measurements used by activists, and if so, what are the reasons for any differences?
4. **Impacts of Policies:**
   a. What are the impacts, if any, of toxic exposure policies in the United States, California and Texas on semiconductor manufacturing workers, communities, and companies?

The review included documents pulled from 13 boxes of material in the San José State University (SJSU) Silicon Valley Toxics Coalition (SVTC) archives, as well as articles, studies and white papers located through search engines, shared by the project team and pulled from Berkeley Library resources. The databases and archives searched in the Berkeley Library include but are not limited to: Proquest Social Sciences, Harvard Library's Think Tank Search, Historical Abstracts, Urban Institute and PolicyLink. Results were screened to determine if articles met the inclusion or exclusion criteria, ending with 61 articles, reports and documents examined from searches and shared materials, and 109 documents reviewed from the SVTC archives.

One noted drawback in the literature review is that, while the SJSU SVTC archive contained substantial information on past advocacy methods for changing policies to protect workers and communities, all of the records are from 1978-2005. They are not ideal as primary evidence or pre-packaged implementation plans because (1) much has changed in the industry since SVTC disbanded, and (2) policymakers will be less likely to engage with policy recommendations founded entirely on outdated information. It is for that reason that the additional 61 articles and studies were sourced, and materials written within the past 10 years (preferably within the past 3 years) were prioritized while older information was used as a secondary support.

Ultimately, the review of sources focused on the following:

- Scientific studies on health risks associated with specific chemicals used in semiconductor manufacturing processes.
- Epidemiological and occupational health studies investigating potential links between semiconductor worker exposure and various health outcomes.
- Public health articles on the ethics, history and case studies of public health policies regulating toxic substances and exposure.
- Academic articles on methodologies for risk assessments, chemical substitution assessments, DELPHI panels, the ethical collection of community health data and the history of U.S. toxic exposure limit standards.
- Technical publications on the processes of semiconductor manufacturing and use of chemicals at each stage.
- News and journal articles on obstacles to state and federal regulation and enforcement of toxic exposure protections and interagency collaboration.
- Government reports and industry publications on environmental releases, current regulations governing the semiconductor industry, existing guides on protecting from toxic exposure and cleanup of hazardous materials, workforce studies and on the CHIPS Act.
- Archival documents on the activities of past activist groups such as Silicon Valley Toxics Coalition (SVTC) and the Santa Clara Center for Occupational Safety and Health (SCCOSH), including public information campaigns, community health surveys and classes, policy advocacy efforts, primary and secondary sources of evidence of human and environmental exposure to toxins from the semiconductor facilities, and more.

Quantitative Data Analysis

To build on the findings from the literature review, quantitative data analysis was conducted to identify demographic and health trends for workers and fence-line community members to semiconductor manufacturing facilities.

For demographic and health trend data for workers, the report relies primarily on data from the Bureau of Labor Statistics (BLS) and the U.S. Census Bureau's American Community Survey.

Worker Health

First, there was an effort to replicate Joseph LaDou's two groundbreaking work-loss tables (see Tables 1 and 2) using current data from the BLS Injuries, Illnesses, and Fatalities (IIF) database.

Table 1
Work-loss Occupational Illnesses as Percentages of All Reported Injuries and Illnesses

	1997	1998	1999	2000	2001
All Manufacturing Industries	6.1	5.9	6.1	6.1	6.3
Electronic Components and Accessories (367)	8.4	7.5	10	8.3	9.5
Semiconductor and Related Devices (3674)	12.3	9.2	14.9	9.9	15.4

Source: Bureau of Labor Statistics, U.S. Department of Labor, 2003. [1]

Table 2
Percentages of Work-loss Injuries and Illnesses Involving Exposures to Caustic, Noxious, or Allergenic Substances

	1997	1998	1999	2000	2001
Manufacturing Industries	2.6	2.5	2.4	2.2	2.4
Electronic Components and Accessories (367)	5.1	7.3	6	7.6	6.2
Semiconductor and Related Devices (3674)	8.4	8.6	9.7	7.7	8.5

Source: Bureau of Labor Statistics, U.S. Department of Labor, 2003 [2]

In attempting to replicate LaDou's tables, however, it became clear that data provided by IIF today is very different from data provided in 2003, when Joseph LaDou created his work-loss tables.

Table 1

For Table 1, the first and most obvious difference that became apparent is that, in 2003, BLS used Standard Industry Classification (SIC) codes to calculate IIF data. Today, IIF uses North American Industry Classification System (NAICS) codes. NAICS codes do not have the same classifications as SIC codes.

For example, while SIC code 367, which LaDou uses, signifies "Publicly Traded Electronic Components and Accessories Companies," NAICS does not have such a category and instead offers the following:

1. "Computer and Electronic Product Manufacturing" (NAICS code 334)
2. "Navigational, Measuring, Electromedical, and Control Instruments Manufacturing" (NAICS code 3345)
3. "Electrical Equipment, Appliance, and Component Manufacturing" (NAICS code 335)
4. "Other Electrical Equipment and Component Manufacturing" (NAICS code 3359)

For the purposes of this report, it was determined that NAICS code 334 seemed closest in nature to SIC code 367, and to the intention of LaDou's table, and therefore NAICS code 334 was used. However, the codes do not represent identical information.

This report therefore estimated a calculation that was similar but not identical to LaDou's: Total Cases of Illnesses with Lost Workday Cases/Total Cases of Injuries and Illnesses.

However, given that contemporary BLS data does not provide numbers of total Cases of Illnesses with Lost Workday Cases, the equation was modified for this report to be: Total Cases of Illnesses/Total Cases of Injuries and Illnesses.

Table 2

When trying to recreate LaDou's table 2, an insurmountable obstacle was encountered. While in 2003 there was a subcategory in IIF data for "Exposure to caustic, noxious, or allergenic substances," today no such category exists. In fatal datasets, only the umbrella category "Exposure to harmful substances or environments" is given, and no further distribution is provided.

In non-fatal datasets, the list of illnesses is:

- Total illness cases
- Skin diseases or disorders cases
- Respiratory conditions cases
- Poisoning cases
- Hearing loss cases
- All other illnesses cases

None of these categories adequately match the former category from 2003. Therefore, it was not possible to recreate LaDou's tables of "Percentages of Work-loss Injuries and Illnesses Involving Exposures to Caustic, Noxious, or Allergenic Substances."

Worker Demographics

The team hoped to find demographic breakdowns of the IIF data; unfortunately, that was not possible. When using BLS data, the team could pull any of the following data, but none of it was cross-referenced:

- Demographic breakdown of workers categorized under Standard Occupation Code (SOC) 51000: "Production Occupations," without cross-referencing of these demographics by industry or by illness/fatality categories.
- Demographic breakdown of IFF data on workers categorized under NAICS code 334413 "Semiconductor and related device manufacturing," without cross-referencing of the demographics of workers in different occupations within the industry.

Further still, the demographic breakdowns available on IFF data were inconsistent. In 2019, there was limited demographic data given for NAICS code 334413 from all ownerships (the sources of the data included public and private sources), however, in 2020, there was demographic data available only from private industry reports, and with far fewer demographic categories.

For breakdown of numbers based on demographic characteristics, data can be mainly divided into two categories: Data prepared before 2020 was based on annual numbers but did not provide very detailed breakdowns of data based on demographic characteristics. After 2020, numbers and rates are presented on a biennial basis but with detailed breakdowns of data based on demographic characteristics of the population. The first biennial dataset was released for years 2021-2022. In addition, data prior to 2021 was only presented for private industry.

Ultimately, a report published by the U.S. Census Bureau using ACS data was used as the primary source for demographic data.[154] However, the data is significantly limited. The data represents "electronic component and product manufacturing" workers, workers identified using census industry codes not NAICS codes. The ACS data does not break down further to semiconductor manufacturing workers specifically, it only represents national statistics, and statistics for the total population of workers in that Census Industry Code, it does not offer demographic breakdowns for individual occupations performed within industry code. Therefore, managers and software developers are grouped with production workers.

The primary difference between Census Industry Codes and NAICS codes is their scope and detail for data analysis. NAICS codes are broader and used internationally (within North America), making them more versatile for cross-country economic analysis. Census Industry Codes, meanwhile, are tailored to specific requirements and nuances of U.S. economic data collection and analysis, and they are less consistent across years. While it would have been preferable to use NAICS data for demographics, we make do with the ACS data.

154. Laughlin, Lynda, and Anthony Martinez. "Powering the Economy One Chip at a Time: Electronics Industry Facing an Aging Workforce." Census.gov, 29 Sept. 29, 2023, www.census.gov/library/stories/2023/09/one-chip-at-a-time.html#:~:text=The%20ACS%20categorizes%20semiconductor%20workers. Accessed 11 June 11, 2024.

Appendix B: Public Responses to the NIST Draft PEA

This appendix presents the public responses to the NIST draft PEA submitted by CHIPS Communities United (CCU) and the International Campaign for Responsible Technology (ICRT) (in that order).

This report also references the public response issued by the Center for Public Environmental Oversight, a project of the Pacific Studies Center, however their report is available to the public through their website,[155] therefore, it is not replicated in this appendix.

February 9, 2024

FR Doc. 2024–02042:
CCU Response to Draft Programmatic Environmental Assessment for Modernization and Internal Expansion of Existing Semiconductor Fabrication Facilities Under the CHIPS Incentives Program

CHIPS Communities United (CCU) is a labor-community coalition collaborating to ensure sustainable, equitable implementation of the CHIPS and Science Act. Our partnership believes that reshoring the semiconductor industry can benefit workers, communities and the environment, but only if local communities and workers have a voice in new and expanding chip fabs. CCU welcomes this extended opportunity to comment on the Draft Programmatic Environmental Assessment (PEA) for Modernization and Internal Expansion of Existing Semiconductor Fabrication Facilities under the CHIPS Incentives Program.

We appreciate the document's comprehensive overview of the semiconductor industry and analysis of the direct, indirect, and cumulative effects of possible CHIPS-supported projects. The document is informative and useful, particularly to people unfamiliar with the environmental impacts of typical semiconductor wafer fabrication facilities (fabs). But given the industry's history of negative impacts on the environment, as well as on worker health and safety, there remains significant room for improvement.

The CHIPS Program Office (CPO), like other federal environmental regulators, has an opportunity to help create and ensure high-road manufacturing and improve the environmental and safety practice of semiconductor producers, both to protect human health and the environment and also to establish a level playing field among manufacturers, so good corporate actors are not put at a competitive disadvantage for doing the right thing. We urge CPO and NIST to use the PEA to encourage the modernization of environmental and safety practices at existing manufacturing facilities and serve as a model for environmental review of the large new factories seeking CHIPS Act funding in other funding rounds.

Recommendations for the Final Programmatic Environmental Assessment

1. **Use fairer and more robust standards for use and disposal of toxic substances.**

   We are concerned by the use of toxic substances in the manufacture of semiconductors and the threat of toxicants to workers and neighbors. This concern is reflected in the PEA's sections 3.5 (Air Quality), 3.6 (Water Quality), 3.7 (Human Health and Safety), 3.8 (Hazardous and Toxic Materials), 3.9 (Hazardous Waste and Solid Waste Management), and in the dozens of chemicals listed in Appendix C-1, which enumerates chemicals commonly used in semiconductor manufacture that are listed in the Toxic Substances Control Act (TSCA) inventory.

   In addition to our substantive concerns about individual toxic substances and exposure levels for workers and community residents (see below), we are also concerned about the process of standard-setting referenced in the PEA, which relies on standards that in some cases are insufficiently protective and in other cases were developed as proprietary standards by the very corporations that the standards are designed to regulate. In this section, we call for the use of more robust, independent standards developed through public processes with the aim of reducing the use and release of toxic substances.

   a. **Standards written by the semiconductor industry fail to advance the public good.**

      The PEA relies heavily on SEMI standards to define Best Management Practices, but these standards are private, proprietary, not established through a multi-stakeholder process, and are not publicly available without charge. Further, it violates basic principles of government regulation to allow a regulated entity to write the regulations that will be applied to it. We urge NIST to use standards created by public agencies through transparent, public processes by accountable actor.

155. "Comments on Draft Programmatic Environmental Assessment." cpeo.org, Center for Public Environmental Oversight, Pacific Studies Center, 9 Feb. 2024, www.cpeo.org/pubs/CPEODPEAcomments.pdf.

b. OSHA standards are inadequate.

We understand that SEMI guidelines often use OSHA standards as a starting place, for example in identifying Permissible Exposure Limits to hazardous substances. But OSHA standards for chemicals were mostly developed in the 1960s and 70s, and have long been acknowledged by OSHA leadership to be out of date and insufficiently protective. To provide one small example, a resolution passed unanimously by the Santa Clara County Board of Education in January 2024 reaffirmed the inadequacy of OSHA standards and the resulting catastrophic health impacts on the workers and community in Silicon Valley, where the semiconductor industry was born. (See https://www.sccoe.org/countyboard/Resolutions/01102024%20RESOLUTION%20Safe%20Jobs%20Healthy%20Families.pdf)

c. What should CPO do to provide a better set of standards?

At a minimum, we urge the CPO to incorporate standards that are more health protective than OSHA standards and are not industry-only standards (such as the SEMI standards) and which can be included in grant award documents as a condition of receiving the grant contracts.

TSCA explicitly requires EPA to protect workers from unreasonable risk from chemical exposures (and prohibits the use of PPE in determining risk). Since TSCA gives the EPA this authority, and since the EPA standards are orders of magnitude more health protective than OSHA standards, we recommend that the CHIPs office require all applicants to meet toxic exposure standards that are health protective in the workplace as well as in the outside environment. This would mean that the companies would be required to adopt the EPA exposure standards in most cases. The Clean Water Act and the Clean Air Act include regulations for many of the same chemicals that are used in semiconductor manufacturing; it makes no sense to regulate these chemicals inside the factory with weaker standards than are applied once the chemicals are discharged from the factory.

Even before TSCA workplace standards are finalized, the CHIPS Office can protect workers from toxic exposures by relying on hazard and risk assessments conducted by EPA under programs such as IRIS, which will likely provide more current assessments of safe exposure levels than OSHA standards. If the EPA IRIS program has developed a hazard value for a chemical before the TSCA program has adopted a risk management rule for that substance, the CHIPS Office should require that workplace exposures not exceed that value. In sum, because EPA standards are often orders of magnitude more health-protective than existing occupational health standards, they will do a better job protecting everyone, including people with pre-existing conditions, elders, children, developing fetuses, and other vulnerable populations. The same rationale applies in the workplace, where workers may be members of vulnerable populations, and is particularly important in electronics and semiconductor fabs where so many hazardous chemicals are present.

Recognizing that the semiconductor industry uses many chemicals–some with government standards and many without–a successful applicant should be required to show how they will meet or exceed the protective safety practices required by EPA standards and values (CAA, CWA, IRIS, etc.) and achieve the same protections even in the absence of such standards.

As a policy matter, in order to carry out the Administration's intent to create a high-road, world class program, the CHIPS office should require adherence to workplace standards that are based on the most recent risk/hazard assessments conducted by EPA. Further, the grant award contracts should require that standards be reviewed every two years to ensure that as new standards and science is developed, the workplace standards are updated.

d. Clean Electronics Production Network (CEPM) is another source of standards and practices.

The Clean Electronics Production Network (CEPN) is a multi-stakeholder initiative with more than twenty member organizations, including electronics companies Intel, Apple, Dell, H-P, and Seagate; the Responsible Business Alliance; environmental NGOs; and labor organizations. We urge the CHIPS Office to adopt these standards, where applicable, to reduce the use of toxic chemicals in semiconductor manufacture.

CEPN has developed several tools that should be included as BMPs in the PEA. They include:

1. The Priority Chemicals list, which identifies hazardous process chemicals to be prioritized for elimination or substitution in electronics manufacturing.
2. Toward Zero Exposure program, which supports brands and suppliers in assessing the use of process

chemicals. It strengthens the culture of worker safety and engagement, reduces worker exposure to identified priority process chemicals, and substitutes safer alternatives in manufacturing processes and the supply chain.
3. The Safer Alternatives program, which assists companies and facilities in the electronics supply chain in finding safer alternatives and helps chemical suppliers certify safe chemical products.
4. The Process Chemicals Data Collection Tool, developed and piloted by CEPN members, a free and publicly available standardized reporting tool that improves the task of collecting and managing process chemicals data.
5. The Joint Chemical Safety Committee Guidance, covering the key elements for developing and operating successful Joint Committees aimed at addressing chemical health and safety concerns in facilities. **A BMP that uses this guide to establish joint health and safety committees in the fabs would be a significant step forward.**

See https://cleanelectronicsproduction.org/tools-resources for further information.

e. Best Management Practices (BMPs) should be mandated, not just recommended.

We recommend that CPO require the use of BMPs for recipients of CHIPS Act funding. In most cases, BMPs would be more protective of workers and community environmental health than the minimum standards set by OSHA or the EPA.

2. CPO should improve transparency and accountability among CHIPS Incentive Grant recipients.

For many years the semiconductor industry has followed the mantra, "what gets measured gets managed". The PEA should articulate clear monitoring and reporting requirements to assure that implementation will meet the stated goals of sustainability. The monitoring data should be publicly available to assure credibility and compliance.

The CPO has both the authority and obligation to ensure that its investments in chip-plant modernization protect human health and the environment. We recommend that all funding agreements contain enforceable, transparent environmental language, including monitoring to confirm compliance.

a. Monitor exposures and releases.

In the absence of robust, consensus, multi-stakeholder standards for most BMPs, it is even more essential to require effective monitoring of exposures and releases, both for occupational exposures and for environmental releases to air and water.

b. Adopt Best Available Technology (BAT) approach.

Monitoring requirements should include adopting a Best Available Technology (BAT) approach to setting the appropriate levels of detection, e.g. parts per billion for most hazardous materials used and parts per trillion for PFAS and nanomaterials.

c. Make monitoring regular and public.

Monitoring should be done on a regular basis and reported to the CHIPs office as public information. We encourage the CHIPs office to establish a publicly accessible website as a portal for companies who receive CHIPS funding to routinely post monitoring results in a template developed by the CPO.

d. Make due diligence process public.

The results of the due diligence exercise (in awarding CHIPS Incentive Grants) should be made public, and the public should have the opportunity to ensure that it is complete.

e. Educate affected communities about permitting, permit modification, and results of monitoring.

As the draft PEA explains, the expansion and operation of semiconductor manufacturing plants are subject to environmental permitting by federal, state, and local agencies. However, neighbors and workers at these plants are generally unfamiliar with these permitting processes. Applicants for CPO funding should be required to create

and update timetables of permit and permit modification applications so those affected by the plants are aware of the applications and have an opportunity to provide comments, as allowed, indeed encouraged, by most environmental statutes. Representatives of affected populations not only have a right to know about the potential environmental consequences of CHIPS Act investments. They often have site-specific knowledge unfamiliar to governments, corporations, and their consultants.

f. Ensure public access to information about hazardous substances.

Historically, industry has often used the claim of confidential business information (CBI) to conceal information about the use and release of hazardous substances. In conducting due diligence and sharing the results with the public, CPO should narrowly define CBI. That is, while specific chemical formulations - the chemical product recipe - may be concealed as CBI, the presence of any individual hazardous substance should be disclosed publicly. The public relies on CPO to push back against claims of business secrets that prevent workers and neighbors from understanding potential threats to their health.

In lieu of, and in addition to, public access to hazardous substances used and released at their workplaces, in their water systems, and in their communities, CPO should regularly share with civil society and impacted communities the degree to which CPO is aware of all substances used and their impacts on public and environmental health, as well as mitigations secured or that should be secured to adequately lessen impacts. Further information on substance replacements negotiated or suggested by CPO would be useful to assist the public in assessing needless harms and opportunities for investments to advance private sector and public sphere benefits.

f. Hold companies accountable for failure to comply.

Funding recipients that fail to comply comprehensively and regularly with monitoring requirements and/or that violate other commitments made to CPO must be held accountable. We recommend CPO institute clawbacks of subsidies and/or other tools to enforce preferred and promised outcomes.

3. Elevate standards for environmental outcomes.

The information applicants are required to submit in their Climate and Environmental Responsibility Plans and the questions asked in the Questionnaire are more limited than the potential harms and benefits described in the PEA. Specifically, there are a number of key omissions: applicants are not required to describe how and whether they plan to reduce the use of PFAS, TSCA regulated substances, and other hazardous chemicals, greenhouse gasses and other air emissions, and solid and hazardous waste. Even in the PEA's appendix on Best Management Practices (Appendix A), there are no recommendations on replacing hazardous chemicals with safer alternatives.

We recommend that the PEA be revised to better capture information on PFAS, TSCA regulated substances, and other hazardous materials. Information collected should include a description of the engineering controls and monitoring methods and plans for reduction or substitution of toxic chemicals with less hazardous materials, waste treatment technology improvements, and how workers will be engaged and educated on how to protect themselves and others from the hazards of PFAS, TSCA substances, and other chemicals of concern.

The PEA (pp. 54-55 – emphasis added) states that semiconductor modernization projects "could allow for enhanced reduction, reuse, and recycling of hazardous or toxic substances as compared to current conditions. These projects **could** result in direct, localized, long-term, and beneficial effects. In addition, process innovation **could** lead to procurement of materials that are safer and more sustainable ..." We agree, but we would go further. We recommend that source reduction and substitution of hazardous materials **should** be considered BMPs and ought to be a criteria for evaluating applications.

4. Improve standards around PFAS

As the draft PEA notes, "semiconductor fabrication facilities use PFAS as an essential material in several steps in the fabrication process." While industry has shown an interest in finding less hazardous substitutes for PFAS in some production steps, significant reduction is years, if not decades away. Because PFAS are persistent, bio-accumulative, and toxic at extremely low concentrations, a significant investment is required to prevent their discharge into the environment. Because most PFAS have not been studied for toxicity, fate, and transport, it is essential to develop ways to regulate, monitor, and publicly report on all of the thousands of compounds – as a class.

a. Adopt EPA's proposed rule on corrective action.

The EPA's proposed rule "Definition of Hazardous Waste Applicable to Corrective Action for Releases from Solid Waste Management Units" is a step in the right direction. EPA explains, "The proposed rule would provide clear regulatory authority to fully implement EPA's statutory authority to require corrective action to address releases not only of substances identified as hazardous waste in the regulations but of any substance that meets the statutory definition of hazardous waste." We urge CPO to adopt this approach.

b. Reduce risk of PFAS in wastewater through pre-treatment at point-of-use.

The draft PEA explains, "Wastewater discharge from semiconductor manufacturing facilities presents the greatest risk for PFAS contamination of the environment." Furthermore, the presence of PFAS in wastewater indicates the possibility that leaks and spills may cause PFAS to enter groundwater, where they are likely to remain and spread. Until regulatory agencies develop standards and other requirements for the capture and possibly the destruction of all PFAS in waste streams, the CPO due diligence process may be our best opportunity to limit the discharge of PFAS. Specifically, producers should be required to pre-treat wastewater– that is, remove for subsequent treatment - all PFAS at the point of use.

c. Require monitoring of pre-treatment systems.

Because some filtration systems in current use do not adequately remove all PFAS from water, facility operators should be required to demonstrate – through monitoring – that their wastewater pre-treatment systems are designed to remove all PFAS. Indeed, they should be designed to remove all hazardous substances. Regular public reporting should be required to confirm compliance.

c. Monitor total organic fluorine.

Note that studies – including some sponsored by the semiconductor industry – show that the concentrations of non-targeted PFAS compounds significantly exceed those of targeted (and better known and better studied) PFAS in industrial waste streams, so **monitoring should measure both targeted compounds and total organic fluorine.**

5. Address historic contamination.

We are pleased that the draft PEA mentions Historic Site Contamination at semiconductor production facilities, but it does not acknowledge its significance. Any facility with a history of subsurface contamination that seeks CHIPS money should provide evidence that remedial actions have been taken that 1) protect public health and the environment and 2) are designed to reach remedial action objectives.

Furthermore, given the absence of comprehensive regulation of PFAS, it is possible that PFAS releases into the subsurface have commingled with legacy contaminants, such as trichloroethylene (TCE). There is evidence that treatment systems for other chemicals do not capture certain PFAS compounds. Monitoring and if necessary, additional treatment, should be required to ensure that groundwater treatment and extraction systems are not spreading PFAS in the environment. The CHIPS Incentives Program is meant to serve as an enduring boost to domestic production of semiconductors with critical economic and national defense applications. Redressing past harms while advancing present-and-future community and worker health must be understood as a key feature if the Incentives Program is to be successful long term.

6. Address historic contamination.

The document should provide more details about the disposal of hazardous wastes. Where will hazardous wastes be disposed? Will they be shipped across state lines? Will wastes be "treated" in environmental justice communities? If incineration is used to destroy wastes, what will be done to prevent the releases of products of incomplete combustion or transformation products? If incineration is used, will there be a waste-to-energy component, how will the energy be used, and how may energy generation lessen cumulative impacts? How will all of these end of life treatments be monitored and reported?

7. Ensure workers are safe from workplace hazards.

Despite the use of industrial robots and particle-free "clean rooms," workers in semiconductor fabrication facilities may be exposed to industrial chemicals. Providing workplaces that are safe for workers must be a top priority of the CPO in administering grant funds. This should be the responsibility of CHIPS Incentive Grant recipients, with monitoring and accountability standards to assure workplace health and safety.

Workers without labor representation (which applies to virtually all workers in the semiconductor industry) often find it difficult to learn about workplace risks, file suggestions, or register complaints. Employers should be required to ensure that employees are properly trained to work in an environment where hazardous substances are used and/or hazardous wastes are generated. They should also be required to develop procedures for employees to raise health and safety concerns without fear of retribution.

Ultimately, however, it must be the responsibility of companies to protect workers, not workers to protect themselves. We encourage CPO to require grantees to adopt and implement the Joint Health and Safety Committee Guidance adopted by the Clean Electronics Production Network. (See Section 1d above.)

8. Encourage processes to reduce greenhouse gas emissions (GHGs).

The draft PEA does a good job of identifying emissions of greenhouse gasses, such as fluorinated gasses, from semiconductor wafer fabrication. It reports, "modernization projects present an opportunity for facilities to modernize their tools and change processes to minimize direct emissions from semiconductor manufacturing processes." But there is nothing in the CPO to ensure that this will happen. We argue that the PEA should require and incentivize applicants to take steps to reduce GHGs.

The following sentence appears to provide both a literal and figurative escape valve: "Even if such improvements are not made, however, the marginal increase in GHG emissions from an individual modernization project would be negligible compared to overall U.S. emissions and emissions from the semiconductor industry sector." Such reasoning should be rejected, for it would excuse most emissions of greenhouse gasses around the globe.

According to a report by Greenpeace East Asia, by 2030, global chip manufacturing will emit more carbon dioxide equivalent than Portugal and consume as much electricity as Australia. (See https://www.greenpeace.org/eastasia/press/7930/semiconductor-industry-electricity-consumption-to-more-than-double-by-2030-study/) Electricity use and costs can diminish the long-term financial health of fabs, in addition to making certain legacy sites less attractive. In addition to lifting up public and environmental benefits, GHGs reduction is a sound metric to better assess the enduring viability of expansions and modernizations, as capital investments in and access to reliable emissions-free renewable electricity will reduce long-term costs and risks.

Furthermore, any equipment installed to capture and store or sequester greenhouse gas emissions should be evaluated for secondary releases.

Finally, it is particularly important that cumulative impacts analyses be used so that the overall burden on communities is accounted for with emissions and co-pollution reductions prioritized in overburdened communities.

9. Advance environmental justice.

Section 3.11 of the PEA focuses on environmental justice implications. Commerce should do its due diligence to ensure that communities and tribes receive the maximum possible flow of investment

benefits, maximum harm reduction, and that, if net benefit calculations are made, harms to environmental justice communities be part of the calculation.

Any adequate environmental justice must consider cumulative impacts. In order to protect communities from environmental injustice, CPO should detail all information related to air and water quality associated with manufacturing, port activities, construction, and ongoing operations and maintenance. It should also include any community consultation related to adverse impacts and methods for continued community engagement around the oversight, monitoring, and structuring of mitigation plans including adaptive management strategies. Pre-construction, construction, and post-construction monitoring should be conducted, especially in areas of known vulnerability such as those adjacent to known sources of contaminants and near environmental justice communities. Commerce should

include any request made by the community that is publicly available, such as, but not limited to, request for Community Benefits Agreements and community governance of projects/facilities.

10. Advance high-road job creation.

Section 3.12 discusses socioeconomic consequences of the proposed actions. We urge CPO to use this piece of the PEA to ensure recipients of CHIPS Act Incentive Grants pursue high-road economic development practices and advance equity.

a. Create jobs for underserved workers.

We recommend affirmative recruitment and training for women, people of color, veterans, citizens returning from incarceration, and other economically disadvantaged workers, including residents of environmental justice communities.

Commerce should include appropriate language access to ensure jobs are accessible to a diverse workforce. Any agreements that project developers have made to increase access, be it to jobs in manufacturing, operations and maintenance, construction, or otherwise, should be detailed through the PEA to increase transparency and the local community's ability to access resources and benefits.

b. Track manufacturing jobs.

Maximizing the creation of manufacturing jobs across a domestic semiconductor supply chain is key for this industry to fulfill its economic benefit potential. We recommend that the Draft PEA and any future PEAs should:

- Specify job categories and job numbers per category resulting from each domestically manufactured component, specifying the minimum hourly wages and benefits to be paid in each category, as well as how these numbers are accounted for in the total number of direct, indirect, and induced jobs, gross state product, and anticipated personal income.
- How benefits are calculated and explain and quantify each item included in benefit calculations.
- Include an assessment of education and certifications necessary to access each job category, the training, minimum and average wages, hours, career advancement, physical demands, and safety information, as well as any commitments the company has made to ensure workers have the free and fair choice to join a union, such as through a union neutrality agreement. This information is essential for the U.S. workforce to have equitable access to employment opportunities.
- Contain information about the manufacture of semiconductor components that did not take place in the U.S., in order to understand the full breadth of employment benefits that could be expected as a domestic supply chain matures.

c. Track operations and maintenance (O&M) jobs.

Similarly, for O&M job impacts, the PEA should specify O&M job categories, job numbers in each category, and how job numbers are accounted for in the total number of direct, indirect, and induced jobs, gross state product, and anticipated personal income. The PEA should also include an assessment of education and certifications necessary to access those jobs, training, average wages, career advancement, hours, physical demands, and safety information, as well as any commitments the company has made to ensure workers have the free and fair choice to join a union, such as through a union neutrality agreement. The PEA assessment should also indicate the number of jobs that, if any, require specialized experience that would prohibit workers in the U.S. from accessing those jobs, and the specific experience and training that is required. Any apprenticeship utilization should also be documented, and the types of apprenticeships to ensure that they are DOL-certified.

d. Track construction jobs.

The PEA should include all relevant construction jobs. Consistent with the previous two categories, Commerce should specify job categories, job numbers in each category, and how job numbers are accounted for in the total number of direct, indirect, and induced jobs, gross state product, and personal income. The PEA and any future PEAs should also include an assessment of education and certifications necessary to access each job category, the training, average wages, hours, career advancement, physical demands, and safety information. If any construction jobs require specialized experience that prohibit workers in the U.S. from accessing these jobs, that

should also be detailed, including the number of jobs, as well as the training and experience required.

e. Track training, demographics, and employment benefits.

Commerce should be sure to include detailed information regarding training, including specific dollar amounts per worker that the companies will invest in training. One of the main mechanisms for building career pathways is through registered apprenticeship, pre-apprenticeship, and other union-affiliated training programs. Pre-apprenticeship programs aim to ensure that workers can qualify for entry into an apprenticeship program and have the skills and support they need to succeed. These programs are generally designed to target certain populations or demographics such as low-income workers, workers

of color, women, and other marginalized communities. Additionally, many unions offer training throughout a member's career to enable them to stay up to date with changes in technology. The most successful pre-apprenticeship programs are those affiliated with registered apprenticeships or other contractually agreed on-the-job training programs. Apprenticeships are registered through a state apprenticeship agency or through the Federal Department of Labor. Registered apprenticeships are paid positions that combine on-the-job training with classroom instruction in a trade. Construction unions operate robust registered apprenticeship programs while industrial unions work with employers on joint labor management training programs that also provide a combination of classroom and on-the job skills training. When these programs are paired with recruitment strategies such as partnering with a community group to provide information about workforce and training opportunities and providing wrap-around services, the benefits can be even greater. Many examples of programs providing such services can be found in the Department of Labor's High Road to the Middle Class map, an evolving resource of training programs.

February 9, 2024

FR Doc. 2024–02042:
ICRT Response to Draft Programmatic Environmental Assessment (PEA) for Modernization and Internal Expansion of Existing Semiconductor Fabrication Facilities Under the CHIPS Incentives Program

International Campaign for Responsible Technology (ICRT) welcomes the opportunity to comment on the Draft PEA . ICRT was formed in 2002 at an international conference attended by 50 organizations from 15 counties who came together to share knowledge, experiences and concerns about the challenges presented by the rapid growth of the global electronics industry. The main focus was on occupational and environmental health - both in the factories as well as in the communities - as well as electronics workers' rights to organize for self-protection. After a 3 day conference, attendees adopted the following mission statement:

> "We are an international solidarity network that promotescorporate and government accountability in the global electronics industry. We are united by our concern for the life-cycle impacts of this industry on health, the environment, and workers 'rights. By sharing resources, we seek to build the capacity of grassroots organizations, local communities, workers and consumers, to achieve social, environmental, and economic justice."

The founding conference was sponsored by Silicon Valley Toxics Coalition and the Santa Clara Center for Occupational Safety and Health, both of which were based in San Jose, CA and which played leading roles in identifying the many hazards associated with the rapid development of the "clean industry" throughout Silicon Valley.

For additional background on this important history, see footnotes 1-15.

We adopt and incorporate by reference the excellent comments from Chips Communities United filed separately on this docket.

We appreciate the Draft PEA's comprehensive overview of the semiconductor industry and analysis of the direct, indirect, and cumulative effects of possible CHIPS-supported projects. The document is informative and useful, particularly to people unfamiliar with the environmental impacts of typical semiconductor wafer fabrication facilities (fabs). But given the industry's history of the many negative impacts on the environment - as outlined above - as well as on worker health and safety, we are filing these comments because we know from first hand experience that there is still significant room for improvement.

We strongly believe that the CHIPS Program Office (CPO has an historic opportunity to use the use its substantial resources to help create and ensure high-road manufacturing and improve the environmental and safety practice of semiconductor producers, both to protect human health and the environment and also to create a level playing field among manufacturers, so good corporate actors are not put at a competitive disadvantage for doing the right thing. We also believe that by encouraging "high-road" standards and practices, that the U.S. can lead the way globally to encourage "harmonization upward" rather than downward.

We urge CPO and NIST to use the PEA to encourage the modernization of environmental and safety practices at existing manufacturing facilities and serve as a model for environmental review of the large new factories seeking CHIPS Act funding in other funding rounds.

Recommendations for the Final Programmatic Environmental Assessment

1. **Use fairer and more robust standards for use and disposal of toxic substances.**

   We are concerned by the use of toxic substances in the manufacture of semiconductors and the threat of toxicants to workers and neighbors. This concern is reflected in the PEA's sections 3.5 (Air Quality), 3.6 (Water Quality), 3.7 (Human Health and Safety), 3.8 (Hazardous and Toxic Materials), 3.9 (Hazardous Waste and Solid Waste Management), and in the dozens of chemicals listed in Appendix C-1, which enumerates chemicals commonly used in semiconductor manufacture that are listed in the Toxic Substances Control Act (TSCA) inventory.

   In addition to our substantive concerns about individual toxic substances and their exposure levels to workers and community residents (see below), we are also concerned about the process of standard-setting referenced in the PEA, which relies on standards that in some cases are insufficiently protective and in other cases were developed as proprietary standards by the very corporations that the standards are designed to regulate. In this section, we call for the use of more robust, independent standards developed through public processes to reduce the use and release of toxic substances.

2. **Standards written by the semiconductor industry fail to advance the public good.**

The PEA relies heavily on SEMI standards to define Best Management Practices, but these standards are private, proprietary, not established through a multi-stakeholder process, and are not publicly available without charge. Further, it violates basic principles of government regulation to allow a regulated entity to write the regulations that will be applied to it. We urge NIST to use standards created by public agencies through transparent, public processes by accountable actors.

3. Standards written by the semiconductor industry fail to advance the public good.

We understand that SEMI guidelines often use OSHA standards as a starting place, for example in identifying Permissible Exposure Limits to hazardous substances. But OSHA standards for chemicals were mostly developed in the 1960s and 70s, and have long been acknowledged by OSHA leadership to be out of date and insufficiently protective. Dr. Michaels, the former Head of U/. S. OSHA explained:

> "Many of these PELs are dangerously out of date and do not adequately protect workers. Past efforts to update our PELs have largely been unsuccessful. Since 1971, OSHA has successfully established or updated PELs for only about 30 chemicals. We have issued only one new exposure limit since the year 2000. As a result, many workers are currently being exposed to levels of chemicals that are legal, but not safe."

When dealing with an industry that is still governed by Moore's Law, this clearly doesn't work. A resolution passed unanimously by the Santa Clara County Board of Education in January 2024 reaffirmed the inadequacy of OSHA standards and the resulting catastrophic health impacts on the workers and community in Silicon Valley, where the semiconductor industry was born. (See https://www.sccoe.org/countyboard/Resolutions/01102024%20RESOLUTION%20Safe%20Jobs%20Healthy%20Families.pdf)

4. What should CPO do to provide a better set of standards?

At a minimum, we urge the CPO to incorporate standards that are more health protective than OSHA standards and are not industry only standards (such as the SEMI standards) and which can be included in grant award document as a condition of receiving the grant contracts. TSCA explicitly requires EPA to protect workers from unreasonable risk from chemical exposures (and prohibits the use of PPE in determining risk). Since TSCA gives the EPA this authority, and since the EPA standards are orders of magnitude more health protective than OSHA standards, we recommend that the CHIPs office require all applicants to

meet toxic exposure standards that are health protective in the workplace as well as in the outside environment. This would mean that the companies would be required to adopt the EPA exposure standards in most cases. The Clean Water Act and the Clean Air Act include regulations for many of the same chemicals that are used in semiconductor manufacturing - it makes no sense to regulate these chemicals inside the factory with weaker standards than are applied once the the chemicals are discharged from the factory.

Even before TSCA workplace standards are finalized, the CHIPS Office can protect workers from toxic exposures by relying on hazard and risk assessments conducted by EPA under programs such as IRIS, which will likely provide more current assessments of safe exposure levels than OSHA standards. If the EPA IRIS program has developed a hazard value for a chemical before the TSCA program has adopted a risk management rule for that substance, the CHIPS Office should require that workplace exposures not exceed that value. In sum, because EPA standards are often orders of magnitude more health-protective than existing occupational health standards, they will do a better job protecting everyone, including people with pre-existing conditions, elders, children, developing fetuses, and other vulnerable populations. The same rationale applies in the workplace, where workers may be members of vulnerable populations, and is particularly important in electronics and semiconductor fabs where so many hazardous chemicals are present."

Recognizing that the semiconductor industry uses many chemicals - some with government standards and many without - a successful applicant should be required to show how they will meet or exceed the protective safety practices required by EPA standards and values (CAA, CWA, IRIS, etc.) and achieve the same protections even in the absence of such standards.

Additional approaches that could be considered are to adopt the ACGIH TLVs, the EU REACH OELs (see https://echa.europa.eu/oelas), or the NIOSH exposure banding e-tool to meet the recommended OELs for chemicals that don't currently have any exposure limits.
See https://www.cdc.gov/niosh/topics/oeb/default.html. The most significant role that CPO can play in the implementation of safer fabs is to require effective standards with strict public reporting requirements to ensure compliance. See Section 7 below.

As a policy matter, in order to carry out the Administration's intent to create a high-road world class program, the CHIPS office should require adherence to workplace standards that are based on the most recent risk / hazard assessments conducted by EPA. Further, the grant award contracts should require that these standards be reviewed every 2 years to ensure that as new standards and science is developed, the workplace standards are updated.

We also take note of and applaud EPA's proposed ban on all uses of TCE under TSCA because it found that there was no feasible workplace level that would protect against unreasonable risk. This is a good step, one that many in Silicon Valley started advocating for more than 50 years ago, when the Santa Clara Center for Occupational Safety and Health led a campaign to ban TCE (which was widely used in the industry). The campaign was initiated after animal tests in late 1970s showed TCE was carcinogenic. A complaint "hot-line" organized by SCCOSH prompted a study which found that many electronics workers had TCE detected in their breast milk.

5. Clean Electronics Production Network (CEPM) is another source of standards and practices.

Over the past several years, ICRT has worked closely with The Clean Electronics Production Network (CEPN), which is a multi-stakeholder initiative with more than twenty member organizations, including electronics companies such as Intel, Apple, Dell, H-P, and Seagate; the Responsible Business Alliance; environmental; NGOs; and labor organizations.

CEPN's mission states:

> *CEPN members commit to working together in the service of a shared goal of moving toward zero exposure of workers to toxic process chemicals in electronics manufacturing. (emphasis added)*

The goal of "zero exposure" was critical to the formation and success of CEPN since it was widely understood that current OSHA standards were not health protective and that the parties didn't want to get bogged down in endless debates about appropriate standards. They agreed that do adopt the "zero exposure" approach made both policy and practical sense. While the preferred way of achieving "zero exposure" is through substitution to safer chemicals, it is also understood that "zero exposure" can be met through management controls if those controls are adequately and a[appropriately measured, monitored and reported.

We urge the CHIPS Office to adopt several of the the CEPN consensus standards, where applicable, to reduce the use of toxic chemicals in semiconductor manufacture. CEPN has developed several tools that we recommend be included as BMPs in the PEA. They include:

a. Toward Zero Exposure program, which supports brands and suppliers in assessing the use of process chemicals. It strengthens the culture of worker safety and engagement, reducing worker exposure to identified priority process chemicals, and substituting them with safer alternatives within their own manufacturing processes, as well as ultimately reaching deeper into their supply chain.

b. The Priority Chemicals list, which identifies process chemicals to be prioritized for elimination or substitution in electronics manufacturing.

c. The Safer Alternatives program, which assists companies and facilities in the electronics supply chain in finding safer alternatives and helps chemical suppliers certify safe chemical products.

d. The Process Chemicals Data Collection Tool, developed and piloted by CEPN members, a free and publicly available standardized reporting tool that improves the task of collecting and managing process chemicals data.

e. The Joint Chemical Safety Committee Guidance, covering the key elements for developing and operating successful Joint Committees aimed at addressing chemical health and safety concerns in facilities. A BMP that uses this guide to establish joint health and safety committees in the fabs would be a significant step forward.

See https://cleanelectronicsproduction.org/tools-resources for further information.

6. Best Management Practices (BMPs) should be mandated, not just recommended.

We recommend that CPO require the use of BMPs for recipients of CHIPS Act funding. In most cases, BMPs would

be more protective of workers and community environmental health than the minimum standards set by OSHA or the EPA.

7. **CPO should improve transparency and accountability among CHIPS Incentive Grant recipients.**

   For many years the semiconductor industry has followed the mantra, "what gets measured gets managed". The PEA should articulate clear monitoring and reporting requirements to assure that implementation will meet the stated goals of sustainability. The monitoring data should be publicly available to assure credibility and compliance.

   The CPO has both the authority and obligation to ensure that its investments in chip-plant modernization protect human health and the environment. We recommend that all funding agreements should contain enforceable, transparent environmental language, including monitoring to confirm compliance.

8. **Monitor exposures and releases.**

   In the absence of robust consensus multi-stakeholder standards for most BMPs, it is even more essential to require stringent and effective monitoring of exposures and releases, for occupational exposures as well as environmental releases to air and water.

9. **Adopt Best Available Technology (BAT) approach.**

   Monitoring requirements should include adopting a Best Available Technology (BAT) approach to setting the appropriate levels of detection, e.g. parts per billion for most hazardous materials used and parts per trillion for PFAS and nanomaterials.

10. **Make monitoring regular and public.**

    Monitoring should be done on a regular basis and reported to the CHIPs office as public information. We encourage the CHIPs office to establish a publicly accessible website as a portal for the companies who are the recipients of the CHIPS funding to routinely post their regular monitoring results in a template developed by the CPO.

11. **Require medical monitoring/surveillance programs for workers**

    Medical surveillance/ monitoring should be required for all workers who are potentially exposed to hazardous materials or are in close proximity to hazardous materials (such as chemical handlers/technicians).

    These surveillance results should be publicly reported to the CPO without compromising the privacy of the workers. The regular periodic reports should include data on the numbers of workers in each area in the fab who are getting monitoring based on their exposure/proximity, what medical tests are they provided, and all medically significant results that are detected.

    For further information, see the OSHA website - https://www.osha.gov/medical-surveillance

12. **Make due diligence process public.**

    The results of the due diligence exercise (in awarding CHIPS Incentive Grants) should be made public, and the public should have the opportunity to ensure that it is complete.

13. **Educate affected communities about permitting, permit modification, and results of monitoring.**

    As the draft PEA explains, the expansion and operation of semiconductor manufacturing plants are subject to environmental permitting by federal, state, and local agencies. However, neighbors and workers at these plants are generally unfamiliar with these permitting processes. Applicants for CPO funding should be required to create and update timetables of permit and permit modification applications so those affected by the plants are aware of the applications and have an opportunity to provide comments, as allowed, indeed encouraged, by most environmental statutes. Representatives of affected populations not only have a right to know about the potential environmental consequences of CHIPS Act investments. They often have site-specific knowledge unfamiliar to governments, corporations, and their consultants.

14. Ensure public access to information about hazardous substances.

Historically, industry has often used the claim of confidential business information (CBI) to conceal information about the use and release of hazardous substances. In conducting due diligence and sharing the results with the public, CPO should narrowly define CBI. That is, while specific chemical formulations - the chemical product recipe - may be concealed as CBI, the presence of any individual hazardous substance should be disclosed publicly. The public relies on CPO to push back against claims of business secrets that prevent workers and neighbors from understanding potential threats to their health.

In lieu of, and in addition to, public access to hazardous substances used and released at their workplaces, in their water systems, and in their communities, CPO should regularly share with civil society and impacted communities the degree to which CPO is aware of all substances used and their impacts on public and environmental health, as well as mitigations secured or that should be secured to adequately lessen impacts. Further information on substance replacements negotiated or suggested by CPO would be useful to assist the public in assessing needless harms and opportunities for investments to advance private sector and public sphere benefits.

15. Hold companies accountable for failure to comply.

Funding recipients that fail to comply comprehensively and regularly with monitoring requirements and/or that violate other commitments made to CPO must be held accountable. We recommend CPO institute clawbacks of subsidies and/or other tools to enforce preferred and promised outcomes.

16. Improve standards around PFAS

As the draft PEA notes, "Semiconductor fabrication facilities use PFAS as an essential material in several steps in the fabrication process." While industry has shown an interest in finding less hazardous substitutes for PFAS in some production steps, significant reduction is years, if not decades away. Because PFAS are persistent, bio-accumulative, and toxic at extremely low concentrations, a significant investment is required to prevent their discharge into the environment. Because most PFAS have not been studied for toxicity, fate, and transport, it is essential to develop ways to regulate, monitor, and publicly report on all of the thousands of compounds – as a class.

U.S. EPA's proposed rule, "Definition of Hazardous Waste Applicable to Corrective Action for Releases from Solid Waste Management Units," is a step in the right direction. EPA explains, "The proposed rule would provide clear regulatory authority to fully implement EPA's statutory authority to require corrective action to address releases not only of substances identified as hazardous waste in the regulations but of any substance that meets the statutory definition of hazardous waste." We urge CPO to adopt this approach.

a. Reduce risk of PFAS in wastewater through pre-treatment at point-of-use

The draft PEA explains, "Wastewater discharge from semiconductor manufacturing facilities presents the greatest risk for PFAS contamination of the environment." Furthermore, the presence of PFAS in wastewater indicates the possibility that leaks and spills may cause PFAS to enter groundwater, where they are likely to remain and spread. Until regulatory agencies develop standards and other requirements for the capture and possibly the destruction of all PFAS in waste streams, the CPO due diligence process may be our best opportunity to limit the

discharge of PFAS. Specifically, producers should be required to pre-treat wastewater– that is, remove for subsequent treatment - all PFAS at the point of use.

b. Require monitoring of pre-treatment systems.

Because some filtration systems in current use do not adequately remove all PFAS from water, facility operators should be required to demonstrate – through monitoring – that their wastewater pre-treatment systems are designed to remove all PFAS. Indeed, they should be designed to remove all hazardous substances. Regular public reporting should be required to confirm compliance.

c. Monitor total organic fluorine.

Note that studies – including some sponsored by the semiconductor industry – show that the concentrations of non-targeted PFAS compounds significantly exceed those of targeted (and better known and better studied) PFAS in industrial waste streams, so monitoring should measure both targeted compounds and total organic fluorine.

d. Address historic contamination.

We are pleased that the draft PEA mentions Historic Site Contamination at semiconductor production facilities, but it does not acknowledge its significance. Any facility with a history of subsurface contamination that seeks CHIPS money should provide evidence that remedial actions have been taken that 1) protect public health and the environment and 2) are designed to reach remedial action objectives.

Furthermore, given the absence of comprehensive regulation of PFAS, it is possible that PFAS releases into the subsurface have commingled with legacy contaminants, such as trichloroethylene (TCE). There is evidence that treatment systems for other chemicals do not capture certain PFAS compounds.

Monitoring and if necessary, additional treatment, should be required to ensure that groundwater treatment and extraction systems are not spreading PFAS in the environment. The CHIPS Incentives Program is meant to serve as an enduring boost to domestic production of semiconductors with critical economic and national defense applications. Redressing past harms while advancing present-and-future community and worker health must be understood as a key feature if the Incentives Program is to be successful long term.

17. Improve disposal of hazardous waste.

The document should provide more details about the disposal of hazardous wastes. Where will hazardous wastes be disposed? Will they be shipped across state lines? Will wastes be "treated" in environmental justice communities? If incineration is used to destroy wastes, what will be done to prevent the releases of products of incomplete combustion or transformation products? If incineration is used, will there be a waste-to-energy component, how will the energy be used, and how may energy generation lessen cumulative impacts? How will all of these end of life treatments be monitored and reported?

18. Ensure workers are safe from workplace hazards.

Despite the use of industrial robots and particle-free "clean rooms," workers in semiconductor fabrication facilities may be exposed to industrial chemicals. But workers without labor representation (which applies to virtually all workers in the semiconductor industry) often find it difficult to learn about workplace risks, file suggestions, or register complaints. Employers should be required to ensure that employees are properly trained to work in an environment where hazardous substances are used and/or hazardous wastes are generated. They should also be required to develop procedures for employees to raise health and safety concerns without fear of retribution.

Providing workplaces that are safe for workers must be a top priority of the CPO in administering grant funds. This should be the responsibility of CHIPS Incentive Grant recipients, with monitoring and accountability standards to assure workplace health and safety. Educating workers about the chemicals they'll be handling, guaranteeing workers 'right-to- know, and providing opportunities to speak out if conditions are unsafe are critical to that goal, but it must be the responsibility of companies to protect workers, not workers to protect themselves. We encourage CPO to require grantees to adopt and implement the Joint Health and Safety Committee Guidance adopted by the Clean Electronics Production Network. (See Section 4d above.)

19. Encourage processes to reduce greenhouse gas emissions (GHGs).

The draft PEA does a good job of identifying emissions of greenhouse gasses, such as fluorinated gasses, from semiconductor wafer fabrication. It reports, "modernization projects present an opportunity for facilities to modernize their tools and change processes to minimize direct emissions from semiconductor manufacturing processes." But there is nothing in the CPO to ensure that this will happen. We argue that the PEA should require and incentivize applicants to take steps to reduce GHGs.

The following sentence appears to provide both a literal and figurative escape valve: "Even if such improvements are not made, however, the marginal increase in GHG emissions from an individual modernization project would be negligible compared to overall U.S. emissions and emissions from the semiconductor industry sector." Such reasoning should be rejected, for it would excuse most emissions of greenhouse gasses around the globe. According to a report by Greenpeace East Asia, by 2030, global chip manufacturing will emit more carbon dioxide equivalent than Portugal and consume as much electricity as Australia. (See https://www.greenpeace.org/eastasia/press/7930/semiconductor-industry-electricity-consumption-to-more-than-double-by-2030-study/)

Electricity use and costs can diminish the long-term financial health of fabs, in addition to making certain legacy sites

less attractive. In addition to lifting up public and environmental benefits, GHGs reduction is a sound metric to better assess the enduring viability of expansions and modernizations, as capital investments in and access to reliable emissions-free renewable electricity will reduce long-term costs and risks.

Furthermore, any equipment installed to capture and store or sequester greenhouse gas emissions should be evaluated for secondary releases. And it is particularly important that cumulative impacts analyses be used so that the overall burden on communities is accounted for with emissions and co-pollution reductions prioritized in overburdened communities.

20. Advance environmental justice.

Section 3.11 of the PEA focuses on environmental justice implications. Commerce should do its due diligence to ensure that communities and tribes receive the maximum possible flow of investment benefits, maximum harm reduction, and that, if net benefit calculations are made, harms to environmental justice communities be part of the calculation.

Any adequate environmental justice must consider cumulative impacts. In order to protect communities from environmental injustice, CPO should detail all information related to air and water quality associated with manufacturing, port activities, construction, and ongoing operations and maintenance. It should also include any community consultation related to adverse impacts and methods for continued community engagement around the oversight, monitoring, and structuring of mitigation plans including adaptive management strategies. Pre- construction, construction, and post-construction monitoring should be conducted, especially in areas of known vulnerability such as those adjacent to known sources of contaminants and near environmental justice communities. Commerce should include any request made by the community that are publicly available, such as, but not limited to, request for Community Benefits Agreements and community governance of projects/facilities.

Footnotes

1. Hazardous from inception The US electronics industry has dealt with many hazardous chemical-related incidents over the years but is this pattern now emerging in Asia? Chemical Watch, December 2015 by Ted Smith
2. Report of the U.N. Special Rapporteur on the implications for human rights of the environmentally sound management and disposal of hazardous substances and wastes U.N. Human Rights Council, 10–28 September 2018
3. "To 'Win the Future, 'the U.S. Needs a Semiconductor Industry That Learns From the Past", Time Magazine, 1/3/24
4. "The fight to clean up the toxic legacy of semiconductors: President Joe Biden has promised to revitalize American manufacturing. Longtime Silicon Valley residents hope hazardous chemicals won't be coming back with it", The Verge, 12/9/23
5. "The impenetrable world of Mark Flores", Center for Public Integrity, 7/5/15
6. Schenker et al "Association of Spontaneous Abortion and Other Reproductive Effects with Work in the Semiconductor Industry" Amer J of Industrial Medicine 28:639-659 (1995;
7. Hallock et al "Assessment of Task and Peak Exposures to Solvents in the Microelectronics Fabrication Industry, Appl. Occup. Environ Jug 8(110 November 1993;
8. Correa A et al "Ethylene Glycol Ethers and Risks of Spontaneous Abortion and Subfertility: Amer. J of Epidemiology, Vol. 143, NO. 7, 1996;
9. Corn, M et al "Real-Time Measurement of Sub-ppm Concentrations of Airborne Chemicals in Semiconductor Manufacturing" Journal of Exposure Analysis and Environmental Epidemiology, Vol. 3, Supp. 1, 1993
10. http://cen.acs.org/safety/industrial-safety/Former-OSHA-head-David-Michaels/99/i24
11. Savaadra-Ontiveros et al "Contaminacion Industrial Con Solventes Organicos Como Causa de Teratogenesis" Salud Publica de Mexico, Enero-Febrero de 1996, Vol. 38, no. 1;
12. Savaadra-Ontiveros et al "Teratogenic Effect of Ethylene Glycol-Methyl Cellosolve Mixture in Rats. I. Reproductive Damage" Int. J. Morphol,28(4) 1087-1092, 2010;
13. Rodier "Developing Brain as a Target of Toxicity" Environmental Health Perspectives Vol. 103, Supp. 6 (Sept 1995) pp. 73-76;
14. Laslo-Baker et al" Child Neurodevelopmental Outcome and Maternal Occupational Exposure to Solvents" Archives of Pediatric and Environmental Medicine, Vol. 158, no 10, Oct. 2004;
15. Khattak, Sohail MD et al "Pregnancy Following Gestational Exposure to Organic Solvents, a Prospective Controlled Study" JAMA, March 24/31 1999, Vol, 281, No. 12 p. 1106-1109

Appendix C: Timeline of History of U.S. Toxic Exposure Regulations

This appendix presents the timeline of key U.S. toxic exposure regulations and actions taken that affect toxic exposure regulations. As you can see, it includes the following nine different government agencies, institutes, departments and affiliated organizations:

ACGIH:
ACGIH is a 501(c)(3) charitable scientific organization that advances occupational and environmental health. It works closely with government, but is not a federal agency or institute.

NIOSH:
The National Institute for Occupational Safety and Health (NIOSH) is a federal institute. It is part of the Centers for Disease Control and Prevention (CDC), in the Department of Health and Human Services (DHHS).

HHS:
U.S. Department of Health and Human Services.

FDA:
U.S. Food and Drug Administration

CDC:
U.S. Centers for Disease Control and Prevention. CDC is one of the major operating components of HHS.

EPA:
U.S. Environmental Protection Agency

OSHA:
The Occupational Safety and Health Administration is part of the United States Department of Labor.

White House:
This refers to the Executive Branch of the federal government.

SBA:
The U.S. Small Business Administration (SBA) is an independent agency of the federal government.

	ACGIH	NIOSH | HHS FDA | CDC	EPA	OSHA	WHITE HOUSE	SBA
1906		**FDA Established**				
1937	**Elixir Sulfanilamide Tragedy**					
1938		**Federal Food, Drug, and Cosmetic Act** passed in 1938, which shifted the burden of proof for drug safety to manufacturers.				
1941	**Threshold Limit Values for Chemical Substances (TLV-CS) Committee established** at ACGIH, American Conference for Governmental Industrial Hygienists.					
1944	**TLV-CS Committee becomes standing committee.**					
1946	**TLV-CS Committee releases first list of exposure limits** for 144 substances, then referred to as "Maximum Allowable Concentrations" or MAC.	**Centers for Disease Control and Prevention (CDC)** was established.				
1948	Term **"Threshold Limit Values" (TLV) first used** by ACGIH instead of MAC.					
1953	**First time a definition was provided** for "Threshold Limit Values": "maximum average concentrations of contaminants to which workers may be exposed for an 8-hour working day, day after day, without injury to health."					

	ACGIH	NIOSH | HHS FDA | CDC	EPA	OSHA	WHITE HOUSE	SBA
1954	**TLV redefined** as the concentration of a substance that "should cause no significant injury to the health of the large majority of persons" exposed daily. **TLV-CS committee publishes** first edition of Documentation of the Threshold Limit Values.					
1962	**Rachel Carson's "Silent Spring" published, catalyzes the modern environmental movement and interest in regulation of toxic chemicals**					
1964	**A committee of the Industrial Medical Association acknowledges** that unpublished data was in the possession of companies that could contribute to the establishment of "realistic TLVs."					
1968	**Farmington Mine disaster in West Virginia**					
1970	**Explosion at the Chemical Manufacturers Association plant in Sterling, Illinois, highlights the urgent need for stronger federal oversight of workplace safety and health.**					
1970		**National Institute for Occupational Safety and Health (NIOSH)** established.	**Environmental Protection Agency (EPA)** established. **Clean Air Act Amendment** passed, established to reduce and control pollution nationwide.	**Occupational Safety and Health Agency (OSHA)** established. Soon after OSHA is established, it creates Permissible Exposure Limits (PELs). The OSH Act mandates OSHA to set standards to protect workers from hazards in the workplace, including exposure to toxic substances. As part of this mandate, OSHA begins.		

	ACGIH	NIOSH | HHS FDA | CDC	EPA	OSHA	WHITE HOUSE	SBA
1971				**Respiratory Protection Standard** enacted (revised in 1998): requires employers to provide workers with respiratory protection when exposed to hazardous airborne contaminants. It includes requirements for respirator selection, fit testing, training and medical evaluation.		
1972			**Clean Water Act (CWA)** passed. It regulates the discharge of pollutants into water bodies and establishes water quality standards for surface waters.			
1974			**Safe Drinking Water Act** was launched.			
1976			**Toxic Substances Control Act (TSCA)** was enacted. Provides EPA with authority to require reporting, record-keeping and testing requirements, and restrictions relating to chemical substances and/or mixtures. **Resource Conservation and Recovery Act (RCRA) passed:** governs the management and disposal of hazardous waste, including regulations for the treatment, storage and disposal of hazardous waste.		
1978		**National Toxicology Program (NTP)** was established as an interagency program within the Department of Health, Education, and Welfare (now the Department of Health and Human Services).				

	ACGIH	NIOSH | HHS FDA | CDC	EPA	OSHA	WHITE HOUSE	SBA
1980		**Agency for Toxic Substances and Disease Registry (ATSDR)** established as an agency within the Department of Health and Human Services. Mission: to prevent exposure and adverse human health effects associated with exposure to hazardous substances from waste sites, environmental spills and other sources of pollution.	**Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund)** passed, established for the cleanup of hazardous waste sites and the management of hazardous substances released into the environment.			
1981					**Executive Order 12291:** required agencies including, EPA and OSHA, to submit draft regulations to the Office of Information and Regulatory Affairs (OIRA, under the OMB) to determine whether the benefits of the regulation outweighed the costs. Increased bureaucratic requirements for any toxic exposure rules, and increased timelines for such policies.	
1983				**Hazard Communication Standard (HCS)** enacted (revised in 2012): also known as the "Right to Know" standard, requires employers to communicate information about hazardous chemicals in the workplace through labels, safety data sheets (SDS) and employee training programs.		
1986			**Amendment** to the Safe Drinking Water Act passed.			

	ACGIH	NIOSH | HHS FDA | CDC	EPA	OSHA	WHITE HOUSE	SBA
1990				**Hazardous Waste Operations and Emergency Response (HAZWOPER)** Standard enacted: regulates workers' safety and health when engaged in hazardous waste cleanup and emergency response activities. It establishes requirements for training, medical surveillance and the use of protective equipment.		
1991				**Bloodborne Pathogens Standard** enacted to protect workers from occupational exposure to bloodborne pathogens such as HIV, hepatitis B and hepatitis C. It requires employers to implement measures to prevent exposure, including the use of personal protective equipment (PPE) and the establishment of an exposure control plan.		
1993				**Executive Order 12866** gave OIRA the authority to review significant draft rules at both the proposed and final stages by agencies including EPA and OSHA. For economically significant rules, OIRA also reviewed the economic analyses, and was given the ability to clear the rules with or without changes, return the rules to the agencies for reconsideration or encourage the agencies to withdraw them. Added bureaucratic burden on agencies implementing toxic exposure-related policies.		

	ACGIH	NIOSH | HHS FDA | CDC	EPA	OSHA	WHITE HOUSE	SBA
1994		**The Government Accountability Office (GAO) testified** that in 18 years "TSCA has not played a major role in EPA's efforts to protect human health and the environment from the harmful effects of toxic chemicals."				
1996			**EPA first given the authority** to screen certain chemicals for endocrine-disrupting properties and contaminants through amendments to two different acts: the Food Quality Protection Act (FQPA), which amended the Federal Food, Drug, and Cosmetic Act (FFDCA), and the second major amendment to the Safe Drinking Water Act (SDWA) both in 1996. **FQPA requires,** in part, that EPA screen pesticide chemicals for their potential to produce effects similar to those produced by the female hormones (estrogen) in humans and gives EPA the authority to screen certain other chemicals and to include other endocrine effects. **EPA begins** the Endocrine Disruption Screening Program (EDSP). **EPA chartered** a scientific advisory committee - the Endocrine Disruptor Screening and Testing Advisory Committee (EDSTAC) to advise EPA on establishing a program to carry out Congress's directives.			**Congress passes the Small Business Regulatory Enforcement Fairness Act (SBREFA)** which required three federal agencies (OSHA, EPA and the Consumer Financial Protection Bureau aka CFPB) to convene Small Business Advocacy Review panels for every rule the agency is considering implementing that could have a significant economic impact on small businesses. This includes rules about toxic exposure.
1998			**First recommendations** for how EPA should screen chemicals for endocrine disrupting properties and contaminants issued by EDSTAC.	**Respiratory Protection Standard** revision standardized and updated respiratory regulations.		

	ACGIH	NIOSH | HHS FDA | CDC	EPA	OSHA	WHITE HOUSE	SBA
1999 - 2000	**Growing concerns about the health and environmental risks posed by industrial chemicals, particularly endocrine-disrupting compounds**					
2010			**The Office of the Inspector General (OIG) reviewed** the EPA's New Chemical Program and found it "limited by an absence of test data and a reliance on modeling" because EPA doesn't require upfront testing by chemical manufacturers before marketing a new chemical.			
2011					**Executive Order 13563** directed agencies to seek the views of those likely to be affected before issuing a notice of proposed rulemaking and required agencies to quantify anticipated benefits and costs of proposed rulemakings. OIRA received OSHA's proposed silica standard in February and held the proposal until August 2013 before releasing it for notice and comment (even though OIRA is permitted to hold a rule for no more than 90 days.)	
2012				**Hazard Communication Standard (HCS) revision** added major requirements for employers including that they disclose toxic and hazardous substances, provide employees with unrestricted access to Safety Data Sheets, and provide health and safety training for employees.		

	ACGIH	NIOSH | HHS FDA | CDC	EPA	OSHA	WHITE HOUSE	SBA
2016			**Frank R. Lautenberg Chemical Safety for the 21st Century Act** revised the TSCA (40 years after TSCA was enacted), aiming to improve regulatory oversight and enhance protections against hazardous chemicals.			
2017					**Executive Order 13771** directed agencies to eliminate at least two existing regulations for every new regulation; made OIRA the final arbiter of benefits and costs; authorized OIRA to set regulatory cost caps. Further bolsters OIRA operations and adds burdens to agencies implementing toxic exposure policies.	
2021					**Executive Order 13771** revoked, along with several other executive orders, by incoming Administration in 2021. While the orders were revoked, the impact of the orders during the time they were in existence nevertheless impacted toxic exposure policy in the moment.	
2023	**Today, TLV-CS's** Documentation of the Threshold Limit Values is in its 7th edition. The list of TLVs includes over 700 chemicalsubstances and physical agents, and more than 50 Biological Exposure Indices (BEIs®) for selected chemicals. **The Ventilation Manual** is now in its 28th edition. **The ASI Manual** is now in its 9th edition. **New publication in progress** titled Air Sampling Technologies: Principles and Applications will represent the latest air sampling principles and practices.					

Appendix D: Federal Regulations and Enforcement Authorities for Toxic Hazard and Exposure

This appendix presents the results of a scan of the Code of Federal Regulations for regulations pertaining to toxic hazard and exposure.

Title of the Regulation	Significance of the regulation with regard to toxic exposure and/or semiconductor manufacturing, summary of the content and subject of the regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
29 CFR 1910.119, Process Safety Management of Highly Hazardous Chemicals standard	• The PSM standard enforces management systems to identify and address hazards associated with hazardous chemicals used in semiconductor manufacturing, reducing the risk of accidental release and worker exposure. • It requires training for employees on safe work practices, emergency procedures, and the specific hazards of the chemicals they handle. • The standard mandates the creation of process safety information (PSI) detailing the chemicals used, their hazards, and the engineering controls in place to prevent accidents.	Occupational Safety and Health Administration (OSHA)	Failure to comply with 29 CFR 1910.119 may result in penalties such as fines, citations, and possible legal actions enforced by OSHA
	Website for Reference: https://www.ecfr.gov/current/title-29/subtitle-B/chapter-XVII/part-1910/subpart-H/section-1910.119		
29 CFR 1910.1450, Occupational Exposure to Hazardous Chemicals in Laboratories	• This OSHA regulation applies specifically to lab settings in semiconductor manufacturing, ensuring proper handling of hazardous chemicals to minimize worker exposure. • It requires adherence to exposure limits and monitoring for certain chemicals to identify and address potential hazards. • The regulation necessitates a Chemical Hygiene Plan (CHP) outlining procedures, personal protective equipment, and work practices to safeguard employees from chemical hazards.	Occupational Safety and Health Administration (OSHA)	Yes, similar to other OSHA regulations, failure to comply with 29 CFR 1910.1450 may result in penalties, including fines, citations, and possible legal actions. OSHA has the authority to enforce compliance, conduct inspections, and impose penalties on employers who do not adhere to the requirements outlined in the regulation. Penalties may vary depending on the severity of the violation, the employer's history of violations, and other factors, but they can be significant and serve as a deterrent to non-compliance.
	Website for Reference: https://www.ecfr.gov/current/title-29/subtitle-B/chapter-XVII/part-1910/subpart-Z/section-1910.1450		
29 CFR 1910.1200 Hazard Communication Standard (HCS)	• The Hazard Communication Standard (HCS) educates semiconductor workers about hazardous chemicals they encounter, including their physical and health risks. • It requires employers to maintain Safety Data Sheets (SDS) detailing properties, hazards, safe handling, and first aid measures for each chemical. • The HCS mandates proper labeling of containers with pictograms, signal words, and hazard statements for clear communication of risks.	Occupational Safety and Health Administration (OSHA)	Yes, failure to comply with the 29 CFR 1910.1200 Hazard Communication Standard (HCS) can result in penalties imposed by the Occupational Safety and Health Administration (OSHA). Penalties for non-compliance may include citations, fines, and possible legal actions. OSHA has the authority to conduct inspections, issue citations, and impose penalties on employers who do not adhere to the requirements of the HCS. The severity of penalties can vary depending on factors such as the nature of the violation, the employer's history of violations, and the potential harm to employees. Therefore, it is essential for employers to ensure compliance with the HCS to avoid penalties and protect the safety and health of their workers
	Website for Reference: https://www.ecfr.gov/current/title-29/subtitle-B/chapter-XVII/part-1910/subpart-Z/section-1910.1200		
29 CFR Part 1910.132 Personal Protective Equipment (PPE) Standard:	• Requires employers to assess hazards like chemicals, dust, or electrical dangers in the semiconductor workplace. • Based on these hazards, the standard mandates providing appropriate PPE like gloves, safety glasses, respirators, or cleanroom suits. • Employers must train workers on proper use, limitations, and care of the designated PPE for maximum protection.	Occupational Safety and Health Administration (OSHA)	Yes, failure to comply with the 29 CFR Part 1910.132 Personal Protective Equipment (PPE) Standard can result in penalties such as citations, fines, and potential legal actions enforced by the Occupational Safety and Health Administration (OSHA).
	Website for Reference: https://www.ecfr.gov/current/title-29/subtitle-B/chapter-XVII/part-1910/subpart-I/section-1910.132		
29 CFR 1910.1026 Chromium (VI)	• Safe Exposure Limit: Sets a maximum safe level for airborne chromium (VI) that workers can be exposed to in an 8-hour workday. • Mandatory PPE: Requires employers to provide appropriate gear like gloves, safety glasses, or clothing for skin and eye protection when chromium (VI) contact is possible. • PPE Care: Employers must ensure PPE is cleaned, maintained, and replaced to stay effective. Removing chromium (VI) contamination by methods that spread it (blowing/shaking) is prohibited.	Occupational Safety and Health Administration (OSHA)	Yes, failure to comply with 29 CFR 1910.1026, which regulates occupational exposure to hexavalent chromium (Cr(VI)), can lead to penalties including citations, fines, and potential legal actions enforced by the Occupational Safety and Health Administration (OSHA).
	Website for Reference: https://www.ecfr.gov/current/title-29/subtitle-B/chapter-XVII/part-1910/subpart-Z/section-1910.1026		
29 CFR 1910.147 Control of Hazardous Energy (lockout/tagout)	• Reduced Accident Risk: Prevents injuries from electrical shock, mechanical hazards, or stored energy release during maintenance by requiring lockout/tagout procedures. • Systematic Approach: Enforces documented procedures using energy isolating devices (locks & tags) to de-energize equipment and prevent accidental startup. • Worker Training: Mandates training for all relevant workers on the proper application and use of lockout/tagout procedures for safe maintenance.	Occupational Safety and Health Administration (OSHA)	Yes, failure to comply with 29 CFR 1910.147, which pertains to the Control of Hazardous Energy (Lockout/Tagout) standard, can result in penalties including citations, fines, and potential legal actions enforced by the Occupational Safety and Health Administration (OSHA).
	Website for Reference: https://www.ecfr.gov/current/title-29/subtitle-B/chapter-XVII/part-1910/subpart-J/section-1910.147		

Title of the Regulation	Significance of the regulation with regard to toxic exposure and/or semiconductor manufacturing, summary of the content and subject of the regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
29 CFR 1910.1000 OSHA Standards for Occupational Exposure to Airborne Contaminants	• Sets Permissible Exposure Limits (PELs) for airborne contaminants, defining safe exposure levels for workers. • Requires employers to monitor workplace air to ensure contaminant levels stay below PELs and identify areas needing improvement. • Emphasizes engineering controls (ventilation) to minimize exposure, and mandates respiratory protection when controls are insufficient.	Occupational Safety and Health Administration (OSHA)	Failure to comply with 29 CFR 1910.1000, which establishes permissible exposure limits for hazardous chemicals in the workplace, may result in penalties such as citations, fines, and potential legal actions enforced by OSHA.
	Website for Reference: https://www.ecfr.gov/current/title-29/subtitle-B/chapter-XVII/part-1910/subpart-Z/section-1910.1450		
Clean Air Act, CCA	• This federal law establishes the overall framework for regulating air emissions from various sources. It sets national air quality standards. CAA sets broad air quality goals, and the EPA creates detailed regulations for industries like semiconductor manufacturing. • The CAA requires use of air pollution control devices (scrubbers, filters) and sets emission limits. These limits include national outdoor air standards (NAAQS) and specific limits for pollutants from semiconductor manufacturing processes. • Facilities must obtain permits outlining emission limitations, required control technologies, and monitoring/reporting to operate legally under the CAA.	Environmental Protection Agency (EPA)	Failure to comply with the Clean Air Act can result in penalties imposed by the EPA or, in some cases, by state environmental agencies that enforce federally approved air quality programs. Penalties for non-compliance may include fines, citations, enforcement actions, and legal proceedings.
	Website for Reference: https://www.epa.gov/laws-regulations/summary-clean-air-act		
40 CFR Part 60 NSPS (New Source Performance Standards)	• Focus on New Sources: Regulates new or modified equipment, potentially reducing exposure risks for workers by setting stricter controls on future emission sources. • Limits on HAPs: Sets emission standards for hazardous air pollutants (HAPs) relevant to semiconductor manufacturing, like benzene or arsenic, to minimize overall HAP emissions and potential exposure. • Engineering Control Promotion: Emphasizes implementing engineering controls like ventilation or enclosed equipment to minimize pollutant emissions at the source, indirectly safeguarding workers from toxic exposure.	Environmental Protection Agency (EPA)	Failure to comply with the requirements outlined in 40 CFR Part 60 can result in penalties enforced by the EPA. These penalties may include citations, fines, and potential legal actions. The severity of penalties can vary depending on factors such as the nature and extent of the violation, the potential harm to the environment or public health, and the history of compliance of the violator.
	Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-60		
40 CFR Part 63 Subpart BBBBB	• Applies to area source semiconductor facilities (not major sources) like terminals, pumping stations, and plants. • Targets and aims to reduce air emissions of various hazardous air pollutants (HAPs) from these facilities. • Requires implementing management practices like leak detection/repair, operating procedures, and record-keeping to achieve emission control.	Environmental Protection Agency (EPA)	Yes, failure to comply with 40 CFR Part 63 Subpart BBBBB can result in penalties including citations, fines, and potential legal actions enforced by the Environmental Protection Agency (EPA). This subpart specifically pertains to National Emission Standards for Hazardous Air Pollutants (NESHAP) for Semiconductor Manufacturing.
	Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-60		
40 CFR Part 131 Water Quality Standards	• Sets Framework for Discharge Permits: 40 CFR Part 131 establishes water quality standards that influence the permits issued to semiconductor facilities for wastewater discharge. • Impacts Wastewater Treatment: Permit limitations based on these standards often necessitate wastewater treatment at semiconductor plants to remove pollutants before discharge and meet water quality requirements. • Protects Water Quality: By treating wastewater, semiconductor facilities can comply with discharge permits and help minimize potential pollution of waterways as mandated by water quality standards.	Environmental Protection Agency (EPA)	Failure to comply with the requirements outlined in 40 CFR Part 131 can result in penalties enforced by the EPA. Penalties for non-compliance may include citations, fines, and potential legal actions. The severity of penalties can vary depending on factors such as the nature of the violation, the extent of non-compliance, and the potential impact on public health and the environment.
	Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-60		
40 CFR Part 130 Water Quality Planning and Management	• Focus on Priority Pollutants: Water quality planning helps identify pollutants of concern in waterways, which might be relevant to discharges from semiconductor plants. • Informs Permitting: The planning process can inform permit limitations for these pollutants in a facility's wastewater discharge, potentially leading to stricter controls. • Public Input on Regulations: Public participation in water quality planning can influence regulations or industry practices to minimize environmental impact from semiconductor manufacturing.	Environmental Protection Agency (EPA)	Failure to comply with the requirements outlined in 40 CFR Part 130 can result in penalties enforced by the EPA. Penalties for non-compliance may include citations, fines, and potential legal actions. The severity of penalties can vary depending on factors such as the nature of the violation, the extent of non-compliance, and the potential impact on water quality and public health.
	Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-D/part-130		

Title of the Regulation	Significance of the regulation with regard to toxic exposure and/or semiconductor manufacturing, summary of the content and subject of the regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
40 CFR Part 401 General Policies and Procedures	• NPDES Permitting Foundation: 40 CFR Part 401 outlines procedures for NPDES permits, which semiconductor plants require to discharge wastewater into waterways or sewer systems. • Permit Application Details: The regulation defines the information facilities must submit in their permit applications, including details about their operations and wastewater characteristics. • Water Quality Standards Considered: Part 401 ensures NPDES permits consider water quality standards, indirectly influencing limitations on pollutants allowed in a facility's wastewater discharge.	Environmental Protection Agency (EPA)	Failure to comply with the requirements outlined in 40 CFR Part 401 can result in penalties enforced by the EPA. These penalties may include citations, fines, and potential legal actions. The severity of penalties can vary depending on factors such as the nature of the violation, the extent of non-compliance, and the potential impact on water quality and public health.
			Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-N/part-401
40 CFR Part 280	• Semiconductor manufacturing often involves the use of hazardous chemicals stored in underground storage tanks (USTs). • Compliance with 40 CFR Part 280 is crucial for semiconductor manufacturers to prevent leaks, spills, and potential contamination of soil and groundwater. • Failure to adhere to these regulations can lead to penalties, fines, and legal actions enforced by the EPA or state regulatory agencies, emphasizing the importance of strict adherence to UST regulations in semiconductor manufacturing.	Environmental Protection Agency (EPA)	Yes, failure to comply with the regulations outlined in 40 CFR Part 280 can result in penalties enforced by regulatory agencies such as the Environmental Protection Agency (EPA) or state environmental agencies. Penalties for non-compliance may include citations, fines, corrective actions, and potential legal actions. The severity of penalties can vary depending on factors such as the nature of the violation, the extent of non-compliance, and the potential harm to human health and the environment.
			Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-I/part-280
40 CFR Part 63 NESHAP (National Emission Standards for Hazardous Air Pollutants)	• Targets HAP Reduction: NESHAP directly regulates hazardous air pollutants (HAPs) used in semiconductor manufacturing to minimize worker exposure to these toxic substances. • Comprehensive Approach: It covers various emission sources within the facility (process vents, storage tanks, leaks) for a more complete HAP reduction strategy. • Specific Control Measures: NESHAP outlines specific requirements like operating procedures, work practices (PPE use), and monitoring to ensure effective control of HAP emissions and worker protection.	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 40 CFR Part 63 can result in penalties enforced by the EPA. Penalties for non-compliance may include citations, fines, and potential legal actions. The EPA has the authority to conduct inspections, issue notices of violation, and impose penalties on facilities that fail to adhere to the requirements of the NESHAP standards.
			Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-63
Resource Conservation and Recovery Act (RCRA)	• Classifies Hazardous Waste: RCRA helps identify hazardous waste in semiconductor manufacturing by establishing criteria for waste classification. Some chemicals used in this industry may fall under these criteria. • Regulates Storage and Tracking: RCRA focuses on safe storage and tracking of hazardous waste. This translates to specific requirements for semiconductor facilities, including proper identification, safe storage with secondary containment, and a manifesting system for transporting the waste. • Focus on Hazardous Waste: RCRA primarily addresses hazardous waste management, so not all e-waste from semiconductor manufacturing will be subject to these regulations.	Environmental Protection Agency (EPA)	Failure to comply with RCRA regulations can result in penalties enforced by the EPA. Penalties may include citations, fines, corrective actions, and potential legal actions. The severity of penalties can vary depending on factors such as the nature of the violation, the extent of non-compliance, and the potential impact on public health and the environment.
			Website for Reference: https://www.epa.gov/rcra
The Electronic Waste Disposal Act (EWDA) (NOT RELEASED YET)	• Potential Federal Standards: The Electronic Waste Disposal Act (EWDA), if enacted, could establish minimum federal standards for e-waste collection, recycling, and disposal in the US, potentially streamlining compliance for semiconductor manufacturers. • Focus on Sustainable Recycling: The EWDA emphasizes environmentally sound recycling practices, which could encourage better technology for recovering valuable materials from complex e-waste generated by semiconductor manufacturing. • Manufacturer Responsibility System: The EWDA might introduce a system where manufacturers share the responsibility for e-waste management, potentially incentivizing them to design recyclable products and support recycling infrastructure.	NTD	NTD

Title of the Regulation	Significance of the regulation with regard to toxic exposure and/or semiconductor manufacturing, summary of the content and subject of the regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
40 CFR Part 68 Chemical Accident Prevention Provisions	• Applies to Facilities with Hazards: 40 CFR Part 68 applies to semiconductor plants that handle hazardous chemicals above specific amounts, commonly used for etching, cleaning or deposition. • Risk Management Program (RMP): Facilities must create and implement an RMP to identify potential hazards, assess release consequences, and implement prevention measures. • Prevention and Emergency Response: The RMP requires measures like engineering controls, safe handling procedures, and emergency response plans to minimize accidental releases and their impact.	Environmental Protection Agency (EPA)	If regulations under 40 CFR Part 372 are not met, there can be several potential consequences or punishments, including: Fines or penalties: Non-compliance may result in fines or penalties imposed by the EPA. Legal action: The EPA has the authority to take legal action against companies that fail to comply with TRI reporting requirements. Enforcement actions: The EPA may undertake enforcement actions such as issuing compliance orders or pursuing civil or criminal enforcement actions against non-compliant entities. Public disclosure: Failure to comply with TRI reporting requirements may lead to negative publicity and reputational damage for the company, as non-compliance information is publicly available. Corrective measures: The EPA may require companies to take corrective measures to address violations and come into compliance with TRI reporting regulations.
	Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-68		
40 CFR Part 372 Toxic Chemical Releaser reporting	• Requires semiconductor manufacturers to report toxic chemical releases and waste management activities to the EPA. • The reporting is mandatory and aims to inform the public about potentially harmful chemical releases, encourage pollution prevention measures, and track trends in chemical emissions. • By annually reporting emissions of listed toxic chemicals above specified thresholds, semiconductor manufacturers contribute to safeguarding human health and the environment while promoting transparency and accountability.	Environmental Protection Agency (EPA)	Failure to comply with 40 CFR Part 372 may result in fines, legal action, and enforcement measures by the Environmental Protection Agency, aimed at ensuring adherence to toxic chemical release reporting requirements and safeguarding public health and the environment.
	Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-68		
40 CFR Part 264 Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	• 40 CFR Part 264 establishes standards for owners and operators of hazardous waste treatment, storage, and disposal facilities, ensuring safe handling and management of hazardous waste. • Semiconductor manufacturing involves the use of various hazardous chemicals, generating waste that must be managed according to these regulations to prevent environmental contamination. • Compliance with 40 CFR Part 264 is essential for semiconductor manufacturers to responsibly handle and dispose of hazardous waste, mitigating environmental risks and ensuring regulatory adherence.	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 40 CFR Part 264 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.
	Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-I/part-264		
Specialized definitions	40 CFR 469.12 -- Specialized definitions.	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in EPA regulations can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.
	Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-N/part-469/subpart-A/section-469.12		
NSPS (New source performance standards)	40 CFR 469.17 -- New source performance standards (NSPS).	Environmental Protection Agency (EPA)	Here are some of the penalties for 40 CFR 469.17: Violating a compliance order: $117,468 per day Failing to take corrective action: $70,752 per day General RCRA violations: $87,855 per day Record keeping violations: Up to $1,544 per day, up to $15,445 Knowing falsification of records: Up to $15,445 if the action misrepresents a fact that constitutes a violation other than a reporting or recordkeeping violation
	Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-N/part-469/subpart-A/section-469.17		

Title of the Regulation	Significance of the regulation with regard to toxic exposure and/or semiconductor manufacturing, summary of the content and subject of the regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
Effluent limitations representing the degree of effluent reduction attainable by the application of the best available technology (BAT) economically achievable	40 CFR 469.15 -- Effluent limitations representing the degree of effluent reduction attainable by the application of the best available technology achievable (BAT)	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 40 CFR 469.15 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.
	Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-N/part-469/subpart-A/section-469.15		
Effluent limitations representing the degree of effluent reduction attainable by the application of the best available technology (BAT) economically achievable	40 CFR 469.14	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 40 CFR 469.14 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.
	Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-N/part-469/subpart-A/section-469.14		
Pretreatment standards for existing sources (PSES)	40 CFR 469.16 -- Pretreatment standards for existing sources (PSES)	Environmental Protection Agency (EPA)	Employers, insurance carriers, or self-insured employers who fail to submit a required report or make a false statement in a report may face a civil penalty of up to $10,000 for each failure.
	Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-N/part-469/subpart-A/section-469.16		
Pretreatment standards for existing sources (PSES)	40 CFR 469.18 -- Pretreatment standards for existing sources (PSNS).	Environmental Protection Agency (EPA)	EPA has the following civil monetary penalties for violations of 40 CFR 469.18: Violating a compliance order: $117,468 per day Failing to take corrective action in the required time: $70,752 per day General violations of RCRA requirements: $87,855 per day
	Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-N/part-469/subpart-A/section-469.18		
Monitoring	40 CFR 469.13 -- Monitoring. Provides option in lieu of monitoring for TTO; direct dischargers may certify as a "comment" on the Discharge Monitoring Report required by s122.44(i), vertifying that no dumping of concentrated toxic organics into wastewaters has occurred since the last discharge monitoring report, and that the facility is implementing its submitted solvent management plan; Provides option in lieu of monitoring for TTO, industrial users of POTWs may certify as a "comment" to peridodic reports required by s403.12(e), vertifying that no dumping of concentrated toxic organics into wastewaters has occurred since the last discharge monitoring report, and that the facility is implementing its submitted solvent management plan.	Environmental Protection Agency (EPA)	The Criminal Provisions of the Toxic Substances Control Act (TSCA) under 40 CFR 469.13 states that the penalty for violations is up to $50,000 per day and/or one year in prison.
	Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-N/part-469/subpart-A/section-469.13		
Semiconductor manufacturing	15 CFR 231.116 -- Semiconductor manufacturing. This section defines the different stages of semiconductor manufacturing which include: wafer production; semiconductor fabrication; and semiconductor packaging.	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 15 CFR 231.116 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.
	Website for Reference: https://www.ecfr.gov/current/title-15/subtitle-B/chapter-II/subchapter-C/part-231/subpart-A/section-231.116		

Title of the Regulation	Significance of the regulation with regard to toxic exposure and/or semiconductor manufacturing, summary of the content and subject of the regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
Semiconductors critical to national security	15 CFR 231.118 -- Semiconductors critical to national security. Semiconductors critical to national security include the list in this regulation and any other semiconductors that the Secretary, in consultation with the Secretary of Defense and the Director of National Intelligence, determines is critical to national security and issues a public notice of that determination. This regulation's importance has become more prevalent since the CHIPS act became law in 2022.	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 15 CFR 231.118 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.
	Website for Reference: https://www.ecfr.gov/current/title-15/subtitle-B/chapter-II/subchapter-C/part-231/subpart-A/section-231.118		
Semiconductor manufacturing capacity	15 CFR 231.117 -- Semiconductor manufacturing capacity. This section sets the capacity and standards for measurement for different facilities for semiconductor manufacturing: a wafer production facility is measured in wafers per year. -a semiconductor fabrication facility is measured in wafer starts per year. a semiconductor fabrication facility for wafers designed for wafer-to-wafer bonding structure is measured in stacked wafers per year. a packaging facility is measured in packages per year.	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 15 CFR 231.117 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.
	Website for Reference: https://www.ecfr.gov/current/title-15/subtitle-B/chapter-II/subchapter-C/part-231/subpart-A/section-231.117		
What definitions apply to this subpart?	40 CFR 63.7195 -- What definitions apply to this subpart? Terms used in this subpart are defined in the Clean Air Act, in §§ 63.2 and 63.981, the General Provisions of this part (40 CFR part 63, subpart A), and in this section as follows, including "semiconductor manufacturing" and "semiconductor manufacturing process unit". See also 40 CFR 469.12 for "specialized definitions".	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 40 CFR 63.7195 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.
	Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-63/subpart-BBBBB/subject-group-ECFRb95e69e02a132f8/section-63.7195		
What parts of my facility does this subpart cover?	40 CFR 63.7182 -- What parts of my facility does this subpart cover? An affected source subject to this subpart is the collection of all semiconductor manufacturing process units used to manufacture p-type and n-type semiconductors and active solid-state devices from a wafer substrate, including research and development activities integrated into a semiconductor manufacturing process unit. This subpart applies to each new, reconstructed, or existing affected source that you own or operate that manufactures semiconductors.	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 40 CFR 63.7182 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.
	Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-63/subpart-BBBBB/subject-group-ECFRd0076e083d9c9f9/section-63.7182		
Applicability	40 CFR 469.10 -- Applicability. The provisions of this subpart are applicable to discharges resulting from all process operations associated with the manufacture of semiconductors, except sputtering, vapor deposition, and electroplating.	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 40 CFR 469.10 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.
	Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-63/subpart-BBBBB/subject-group-ECFRd0076e083d9c9f9/section-63.7182		

Title of the Regulation	Significance of the regulation with regard to toxic exposure and/or semiconductor manufacturing, summary of the content and subject of the regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
What is the purpose of this subpart?	40 CFR 63.7180 -- What is the purpose of this subpart? This subpart establishes national emission standards for hazardous air pollutants (NESHAP) for semiconductor manufacturing facilities. This subpart also establishes requirements to demonstrate initial and continuous compliance with the emission standards.	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 40 CFR 63.7180 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.
Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-63/subpart-BBBBB/subject-group-ECFRd0076e083d9c9f9/section-63.7180			
Data reporting requirements	40 CFR 98.96 -- Data reporting requirements This section addresses greenhouse gas reporting requirements including (in addition to the information required by § 98.3(c)): (a) Annual manufacturing capacity of each fab at your facility used to determine the annual manufacturing capacity of your facility in Equation I–5 of this subpart. (b) For facilities that manufacture semiconductors, the diameter of wafers manufactured at each fab at your facility (mm). (c) Annual emissions, on a fab basis as described in paragraph (c)(1) through (5) of this section.	Environmental Protection Agency (EPA)	40 CFR Part 98 of the eCFR states that there are significant penalties for submitting false or incomplete statements and information, including the possibility of imprisonment or fines
Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-98/subpart-I/section-98.96			
Effluent limitations (BCT)	40 CFR 469.19 -- Effluent limitations representing the degree of effluent reduction attainable by the application of the best conventional pollution control technology (BCT) Except as provided in 40 CFR 125.30 through 125.32, any existing point source subject to this subpart must achieve the following effluent limitations representing the degree of effluent reduction attainable by the application of the best conventional pollution control technology (BCT):	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 40 CFR 469.19 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.
Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-N/part-469/subpart-A/section-469.19			
Pretreatment standards for existing sources (PBES)	49 CFR 469.16 -- Pretreatment standards for existing sources (PBES) Except as provided in 40 CFR 403.7 and 403.13, any existing source subject to this subpart which introduces pollutants into a publicly owned treatment works must comply with 40 CFR part 403 and achieve the following pretreatment standards for existing sources (PSES):	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 40 CFR 469.16 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.
Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-N/part-469/subpart-A/section-469.16			
Pretreatment standards for new sources (PSNS)	40 CFR 469.18 -- Pretreatment standards for new sources (PSNS) Except as provided in 40 CFR 403.7, any new source subject to this subpart which introduces pollutants into a publicly owned treatment works must comply with 40 CFR part 403 and achieve the following pretreatment standards for new sources (PSNS):	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 40 CFR 469.18 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.
Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-N/part-469/subpart-A/section-469.18			
Reporting threshold	40 CFR 98.91 -- Reporting threshold (a) You must report greenouse gas reporting (GHG) emissions under this subpart if electronics manufacturing production processes, as defined in § 98.90, are performed at your facility and your facility meets the requirements of either § 98.2(a)(1) or (a)(2).	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 40 CFR 98.91 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.
Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-98/subpart-I/section-98.91			

Title of the Regulation	Significance of the regulation with regard to toxic exposure and/or semiconductor manufacturing, summary of the content and subject of the regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
What are my monitoring installation, operation, and maintenance requirements?	40 CFR 63.7188 -- What are my monitoring installation, operation, and maintenance requirements? If you comply with the emission limitations of § 63.7184 by venting the emissions of your semiconductor process vent through a closed vent system to a control device, you must comply with the requirements of paragraphs (a) and (b) of this section. (a) You must meet the applicable general monitoring, installation, operation, and maintenance requirements specified in § 63.996. (b) You must meet the monitoring, installation, operation, and maintenance requirements specified for closed vent systems and applicable control devices in §§ 63.983 through 63.995. If you used the design evaluation procedure in § 63.7187(i) to demonstrate compliance, you must use the information from the design evaluation to establish the operating parameter level for monitoring of the control device.	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 40 CFR 63.7188 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.

Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-63/subpart-BBBBB/subject-group-ECFR4357f48f4594fdd/section-63.7188

What emission limitations, operating limits, and work practice standards must I meet?	40 CFR 63.7184 -- What emission limitations, operating limits, and work practice standards must I meet? New, reconstructed, or existing affected source, as defined in § 63.7182(b), must comply with all applicable emission limitations in this section on and after the compliance dates specified in § 63.7183. You must meet the notification requirements in § 63.7189 and in subpart A of this part. You must submit some of the notifications (e.g., Initial Notification) before the date you are required to comply with the emission limitations in this subpart.	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 40 CFR 63.7184 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.

Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-63/subpart-BBBBB/subject-group-ECFR2b7f3cfa57caf8e/section-63.7184

By what date...?	40 CFR 63.7186 -- By what date must I conduct performance tests or other initial compliance demonstrations? For each process vent or storage tank vent emission limitation in § 63.7184 for which initial compliance is demonstrated by meeting a percent by weight HAP emissions reduction, or a HAP concentration limitation, you must conduct performance tests or an initial compliance demonstration within 180 days after the compliance date that is specified for your source in § 63.7183 and according to the provisions in § 63.7(a)(2).	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 40 CFR 63.7186 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.

Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-63/subpart-BBBBB/subject-group-ECFR4357f48f4594fdd/section-63.7186

In what form and how long must records be kept?	40 CFR 63.7192 -- In what form and how long must records be kept? Records must be readily available for expeditious review, and must be kept for 5 years, at least 2 of those years onsite after the recorded occurence.	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 40 CFR 63.7192 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.

Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-63/subpart-BBBBB/subject-group-ECFRe979c9013112dbc/section-63.7192

What records must I keep?	40 CFR 63.7191 -- What records must I keep? (1) all documentation supporting any Notification of Compliance Status and periodic report of compliance that you submitted, according to the requirements in § 63.10(b)(2)(xiv). (2) The records related to startup, shutdown, and malfunctions. (3) Records of performance tests and performance evaluations.	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 40 CFR 63.7191 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.

Website for Reference: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-63/subpart-BBBBB/subject-group-ECFRe979c9013112dbc/section-63.7191

Title of the Regulation	Significance of the regulation with regard to toxic exposure and/or semiconductor manufacturing, summary of the content and subject of the regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
What are my monitoring installation, operation, and maintenance requirements?	40 CFR 63.7188 -- What are my monitoring installation, operation, and maintenance requirements? If you comply with the emission limitations of § 63.7184 by venting the emissions of your semiconductor process vent through a closed vent system to a control device, you must comply with the requirements of paragraphs (a) and (b) of this section. (a) You must meet the applicable general monitoring, installation, operation, and maintenance requirements specified in § 63.996. (b) You must meet the monitoring, installation, operation, and maintenance requirements specified for closed vent systems and applicable control devices in §§ 63.983 through 63.995. If you used the design evaluation procedure in § 63.7187(i) to demonstrate compliance, you must use the information from the design evaluation to establish the operating parameter level for monitoring of the control device.	Environmental Protection Agency (EPA)	Failure to comply with the regulations outlined in 40 CFR 63.7188 can result in various penalties and enforcement actions. These may include fines, legal actions, enforcement orders, or other punitive measures imposed by the EPA. The severity of the punishment depends on the nature and extent of the violation, with the goal of ensuring compliance with hazardous waste management standards and protecting human health and the environment.

Examples of Chemical-Specific Regulations

40 CFR 721.10584	Cyclopentene, 1,3,3,4,4,5,5-heptafluoro-...
40 CFR 721.10433	Cyclopentene, 1,2,3,3,4,4,5,5-octafluoro-...
40 CFR 63.99	Delegated Federal authorities
40 CFR 721.11601	Sulfonium, trisaryl-, 7, 7-dialkyl-2-heteropolycyclic-1-alkanesulfonate (1:1) (generic)...
40 CFR 721.11707	Sulfonium, triphenyl-, heterocyclic compound-carboxylate (1:1) (generic)...
40 CFR 721.11710	Heteropolycyclic, trihaloalkyl carbomonocycle-, hydroxy carbomonocyclic salt (generic)...
40 CFR 721.11711	Sulfonium, tricarbocyclic-, 2-heteroatom-substituted-4-(alkyl)carbomonocyclic carboxylate (1:1) (generic)
40 CFR 721.11709	Sulfonium, triphenyl-, polyfluoro-polyhydrospiro[9H-carbopolycyclic-9,2′-[4,7]methano[1,3] benzodioxole]-5′-alkenesulfonic acid (1:1) (generic)
40 CFR 721.11708	Sulfonium, carbocyclic-, salt with 1-(alkyl) 2-[4-[polyhydro-2-carbomonocyclic-5-(polyfluoro-2-sulfoalkyl)-4,7-methano-1,3-benzodioxol-2-yl]carbomonocyclic oxy]acetate (1:1) (generic) ...
40 CFR 721.11533	Substituted triarysulfonium, substituted carbopolycyclic carboxylate (generic)
40 CFR 721.11521	Sulfonium, triphenyl-, salt with disubstituted-heterocyclic compound (1:1) (generic)
	See more sulfonium...
40 CFR 721.11528	Heterotrisubstituted-bile acid, 1-(difluorosulfomethyl)- 2,2,2-trifluoroethyl ester, ion(1-), (5)-, triphenylsulfonium (1:1) (generic)
40 CFR 721.11515	Thiophenium, 1-(2,7-disubstituted-1-naphthalenyl)tetrahydro-, salt with polyfluoro-N-polyfluoroalkylsulfonyl-1-alkanesulfonamide (1:1) (generic)
40 CFR 721.11540	Triarylsulfonium, alkylestersulfonate (generic)
40 CFR 721.11520	Substituted triphenysulfonium, inner salt (generic)
40 CFR 721.11529	Aromatic sulfonium, tricyclo fluoroalkyl sulfonic acid salt (generic)
40 CFR 721.11525	Dibenzothiophenium, aryl substituted trifluoro-hydroxy- (triheterosubstitutedalkyl)alkanoate (1:1) (generic)
40 CFR 721.11530	Substituted, (alkylaromaticdiaromatic salt, with trihalo-[(trihaloalkyl)substituted]substituted alkaneamide (generic)
40 CFR 721.11539	Heteropolycycle, aromatic-, salt with dihalo-substituted alkyl carbopolycycle carboxylate (1:1) (generic)
40 CFR 721.11514	Organic sulfonate compound (generic)
40 CFR 721.11652	Substituted -2H-thiopyrylium, salt with heterosubstituted-alkyl tricycloalkane-carboxylate (1:1) (generic)
40 CFR 721.11655	Phenoxanthiiinium, 10-phenyl, 5-alkyl-2-alkyl-4-(2,4,6-substituted tri-carbomonocycle, hetero-acid) benzenesulfonate (1:1) (generic)
40 CFR 721.11647	Sulfonium, triphenyl-, 1,2-substituted-alkyltricycloalkyl-1-carboxylate (1:1) (generic).
40 CFR 721.11657	Substituted, triaryl-, tricycloalkane alkyl disubstituted (generic) (P-20-162).
40 CFR 721.11648	substituted-beta-alanine, heterosubstituted-alkyl ester, ion(1-), triphenyl sulfonium (1:1) (generic)
40 CFR 721.11645	Carbomonocyclic sulfonium, salt with trihalo-sulfoalkyl hydroxycarbopolycyclic carboxylate (generic)
40 CFR 721.10536	Long-chain perfluoroalkyl, carboxylate chemical substances
40 CFR 1910.1018	Inorganic arsenic
40 CFR 721.9582	Certain perfluoroalkyl sulfonates

Appendix E: Texas Regulations and Enforcement Authorities for Toxic Hazard and Exposure

This appendix presents the results of a scan of the Texas Administrative Code for regulations pertaining to toxic hazard and exposure.

Classification	Title of the Regulation	Significance of regulation to semiconductor manufacturers	Summary of this regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
Hazard Communication, Texas **Hazard Communication Act (THCA)**	Title 25, TAC, Chapter 295, Subchapter A	• This section requires employers in various industries, including semiconductor manufacturing, to have a hazard communication program. This program ensures employees are informed about hazardous substances they might encounter, including: ◦ Identifying and assessing the hazards of chemicals ◦ Providing labels and safety data sheets (SDS) ◦ Training employees on safe handling procedures	Establishment of the jurisdiction of the Texas Department of State Health Services (DSHS) over occupational health and environmental control matters. Chapter 502 of the Texas Health and Safety Code, requires public employers to provide employees with specific information on the hazards of chemicals to which employees may be exposed in the workplace.	Texas Department of State Health Services Division for Regulatory Services Enforcement Unit (DSHS)	Doesn't mention any specific punishment. However, failure to comply can lead to enforcement actions such as citations or fines to employer.
Environmental Quality: General Air Quality Rules	Title 30, TAC, Chapter 101.10, Subchapter A	• In Texas, the registration of emissions from facilities is handled by the Texas Commission on Environmental Quality (TCEQ). TCEQ utilizes two primary registration programs for air emissions in Texas: 1. Emission Inventory (EI) Program: This mandatory program requires most facilities with the potential to emit air contaminants to register and report their emissions annually. • The EI program helps TCEQ track air quality trends and identify facilities with significant emissions. 2. Texas Pollutant Discharge Elimination System (TPDES): This program focuses on facilities that discharge pollutants into water bodies. While not strictly for air emissions, some industrial facilities may need to register under both TPDES and the EI program if their processes involve air and water discharges. • The Hazardous Air Pollutants (HAPs) list is found in §112(b) of the Federal Clean Air Act and revisions to this list are found in 40 CFR Part 63, Subpart C.	Facilities that meet certain criteria for potential air emissions or water discharges are required to register under the respective TCEQ program. The Hazardous Air Pollutants (HAPs) list is found in §112(b) of the Federal Clean Air Act and revisions to this list are found in 40 CFR Part 63, Subpart C.	Texas Commission on Enviromental Quality (TCEQ)	Failing to register can also lead to enforcement actions from TCEQ. This could involve orders to cease operations until you come into compliance. Not registering can also make it difficult to obtain other air quality permits you may need in the future.
Texas Clean Air Act (TCAA) **Air Quality and Emission Limitations (CAA § 101-131; USC § 7401-7431)**	Title 30, Part 1 Chapter 113	• The TAC sets emissions standards and requirements for various air pollutants, such as volatile organic compounds (VOCs), nitrogen oxides (NOx), sulfur dioxide (SO2), and particulate matter (PM). Semiconductor manufacturing facilities may emit these pollutants during wafer fabrication, chemical vapor deposition, and other manufacturing processes. Compliance with these emissions standards is essential for semiconductor manufacturers to ensure they meet regulatory requirements.	Aims to reduce and control air pollution in Texas. Sets health-based air quality standards for various pollutants.	The Environmental Protection Agency (EPA) and the Texas Commission on Enviromental Quality (TCEQ) enforces the CAA	Texas Clean Air Act (CAA) itself doesn't specify exact fines for violations. Instead, it establishes maximum penalty amounts, and the actual fines are determined on a case-by-case basis depending on the severity of the violation and the violator's history.

Classification	Title of the Regulation	Significance of regulation to semiconductor manufacturers	Summary of this regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
Texas Pollutant Discharge Elimination System (TPDES)	Title 30, TAC Part 1, Subchapter A	• The wastewater from semiconductor manufacturing can contain a range of contaminants, due to the hazardous nature of these contaminants, semiconductor manufacturers cannot discharge untreated wastewaterManufacturers that discharge wastewater need a TPDES permit. • Permit types and requirements vary depending on the industry, size of the facility, and the nature of the wastewater discharge. These permits streamline the permitting process but still require compliance with specific pollution control measures: Allowable discharge limits for specific contaminants based on federal and state regulations. • Monitoring and reporting requirements to ensure the manufacturer is meeting the permitted discharge limits. • Specific treatment technologies or practices required to achieve compliance.	The Texas Pollutant Discharge Elimination System (TPDES) is a program implemented by the Texas Commission on Environmental Quality (TCEQ) to regulate the discharge of pollutants into waters of the state. It operates under the authority of the federal Clean Water Act (CWA) and the Texas Water Code.	Texas Commission for Enviromental Quality (TCEQ) Water Quality Division	If they discover a violation through inspections, self-reporting by the manufacturer or public complaints, they can take various enforcement actions: A formal written notice outlining the violation and requiring corrective actions within a specific timeframe. A more serious enforcement tool that may mandate specific actions, impose fines, or even restrict operations until compliance is achieved. The TCEQ can assess civil penalties for violations, with fines ranging from thousands to hundreds of thousands of dollars depending on the severity and duration of the non-compliance. In some cases, the TCEQ or the Environmental Protection Agency (EPA) may pursue legal action against a semiconductor manufacturer for egregious violations. This could involve lawsuits seeking injunctions to halt polluting activities or even criminal charges against responsible individuals within the company.
Underground Injection Control (UIC) Program	Title 30, TAC, Part 1 Chapter 319	• This regulates the injection of hazardous substances, including chemicals used in semiconductor manufacturing processes, underground to protect groundwater quality and prevent contamination.	Texas implements the UIC program under the authority of the Safe Drinking Water Act and the Texas Water Code. The program regulates the subsurface disposal of fluids, including wastewater, brine, and industrial fluids, into underground injection wells to protect underground sources of drinking water and prevent contamination.	The Texas Commission on Environmental Quality (TCEQ) is responsible for administering the UIC program in Texas. The TCEQ issues permits for injection wells, establishes technical requirements for well construction and operation, conducts inspections and monitoring to ensure compliance, and takes enforcement actions against violations.	Failure to comply could result in fines, penalties, legal action and potential shutdowns for non-compliance.
Storage and Handling of Liquefied Petroleum Gases	Title 30, TAC, Part 1 Chapter 285	• Regulates the storage and handling of hazardous chemicals, including those used in semiconductor manufacturing processes.	Regulates the storage and handling of hazardous chemicals, including those used in semiconductor manufacturing processes.	Texas Department of Licensing and Regulation (TDLR)	Fines, penalties, and potential shutdowns for non-compliance.
The Texas Surface Water Quality Standards	Title 30, Part 1, Chapter 307, (Subchapter A)	• The foundation for water pollution control. • Sets national water quality standards. • This regulation outlines waste discharge requirements for industrial facilities, including semiconductor manufacturing plants, regarding permits for discharging industrial wastewater into surface waters or municipal sewer systems. • Compliance with these regulations is crucial for semiconductor manufacturers to ensure that their wastewater discharges meet water quality standards, with permits specifying allowable limits for pollutants like heavy metals, toxic chemicals, and acids/bases to prevent pollution of surface waters.	Requires permits for facilities that discharge pollutants into navigable waters (rivers, lakes, streams) through the National Pollutant Discharge Elimination System (NPDES).	The Texas Commission on Environmental Quality (TCEQ) is responsible for enforcing Water Quality Standards as an arm of the Federal Government in Texas.	The EPA or TCEQ (Texas Commission on Environmental Quality) will issue a formal written notice outlining the specific violations and requiring corrective actions within a set timeframe. If violations persist, the agency may issue a more serious order mandating specific actions, imposing fines, or even restricting operations until compliance is achieved. The EPA or TCEQ can assess significant civil penalties for violations. These fines can range from thousands to hundreds of thousands of dollars depending on the severity, duration, and history of non-compliance.

Classification	Title of the Regulation	Significance of regulation to semiconductor manufacturers	Summary of this regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
Storage of Hazardous Materials	Title 30, TAC Chapter 338	• Most Texas localities adopt the International Fire Code (IFC) with amendments for their area. The IFC includes a chapter dedicated to hazardous materials (Chapter 50), which applies to semiconductor manufacture due to the chemicals used. • This chapter outlines fire safety protocols for storage, handling, and use of hazardous materials. • Local amendments might include additional fire safety requirements specific to semiconductor facilities.	This chapter covers general requirements for hazardous materials, including: • Classification of hazardous materials • Storage requirements (quantity limitations, separation from other materials, etc.) • Fire protection systems (sprinklers, fire alarms, etc.) • Spill control and containment procedures • Ventilation requirements • Training for employees on handling hazardous materials safely	International Code Council (IFC Publisher), Texas Commission on Environmental Quality (TCEQ)	In extreme cases, the fire department may restrict a facility's operation or even order a complete shutdown until all fire code violations are addressed and the facility is deemed safe.
Hazardous Waste Determination	Title 30, TAC, Part 1, Chapter 335 Subchapter R	• This regulation provides disposal of industrial waste and hazardous waste. Generators of hazardous waste are responsible for ensuring it's cleaned in a way that minimizes risks and complies with these regulations. • This title incorporates the provisions of the RCRA which establishes a framework for hazardous waste management, including cleaning procedure.s RCRA Regulations for Semiconductor Manufacturers include • RCRA classifies these wastes based on their specific characteristics.	This chapter of the TAC addresses regulations related to the management, storage, treatment, and disposal of industrial solid waste and hazardous waste. Manufacturers must determine if their waste falls under RCRA's definition of hazardous waste. They can use EPA guidelines or consult with hazardous waste experts for proper classification. Resource Conservation and Recovery Act (RCRA). Title 40 of the Code of Federal Regulations (CFR), Part 239	The Environmental Protection Agency (EPA) implements RCRA and provides guidance on hazardous waste cleaning practices. Their guidance documents outline best practices for cleaning different types of hazardous waste containers and equipment.	Notices of Violation (NOVs): The EPA will issue a formal written notice outlining the specific violations identified during an inspection. This serves as a warning and requires corrective actions within a set timeframe to come into compliance. Administrative Orders: If violations persist, the EPA may issue a more serious order mandating specific actions: • Stopping certain activities until compliance is achieved. • Implementing corrective measures to address violations (e.g., proper waste management practices, upgraded storage facilities). • Conducting additional training for personnel on RCRA regulations. • Fines: The EPA can assess civil penalties for RCRA violations. These fines can vary significantly depending on the severity, duration, and history of non-compliance. Potential fines can range from: ◦ Hundreds of dollars for minor labeling or packaging issues. ◦ Tens of thousands of dollars for serious violations like offering hazardous materials for transport without proper documentation or training.
Spill Prevention and Control	Title 30, TAC, Part 1, Chapter 327	• EPA's emergency response program responds to oil spills, chemical, biological, radiological, and nuclear incidents and large-scale national emergencies, including homeland security incidents. EPA provides support when requested or when state and local first responder capabilities have been exceeded.	National Response System (NRS): The NRS is a coordinated national program for responding to oil spills and releases of hazardous substances. It involves federal, state and local agencies working together to ensure a swift and effective response.	The Texas Commission on Environmental Quality (TCEQ)	Fines, penalties and potential shutdowns for non-compliance. Furthermore, the state can issue fines for violators to reimburse costs of treating and cleaning up of such spillage.
USDOT Hazardous Materials Regulations (HMR)	Title 30, TAC, Chapter 335 Subchapter R	• The Department of Transportation (DOT) has regulations for the safe transportation of hazardous materials. These regulations include specific protocols for responding to transportation accidents involving hazardous materials spills.	PHMSA is responsible for regulating and ensuring the safe and secure movement of hazardous materials to industry and consumers by all modes of transportation, including pipelines. PHMSA rules and notices are linked to the Code of Federal Regulations Title 49, Subtitle B Chapter I Subchapter C Part 172.	U.S. Department of Transportation Through the State of Texas	Inspections: USDOT inspectors can conduct roadside inspections or facility audits to verify compliance with HMR. Violations identified during inspections will result in enforcement actions. Citations and Fines: The severity of the violation will determine the type of citation issued and the associated fine. Fines can range from: • Hundreds of dollars for minor labeling or packaging issues. • Tens of thousands of dollars for serious violations like offering hazardous materials for transport without proper documentation or training. Orders: USDOT may issue orders restricting or suspending a company's or individual's ability to transport hazardous materials until they come into compliance.

Classification	Title of the Regulation	Significance of regulation to semiconductor manufacturers	Summary of this regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
Federal Operating Permits Program	Title 30, TAC Part 1, Chapter 122	• Permitting Requirements: The FOPP requires certain industrial facilities, including semiconductor manufacturing plants, to obtain federal operating permits. These permits consolidate all applicable air quality regulations and emission limits into a single, comprehensive document. Semiconductor manufacturers must comply with the permitting requirements outlined in Chapter 122 to operate legally and ensure environmental compliance. • Emission Monitoring and Reporting: Federal operating permits issued under Chapter 122 typically include provisions for monitoring emissions from semiconductor manufacturing processes. Semiconductor manufacturers are required to monitor their air emissions, report data to regulatory authorities, and demonstrate compliance with emission limits and regulatory requirements. This helps track pollutant releases, assess air quality impacts, and ensure transparency in environmental performance. • Compliance Assurance: The FOPP serves as a tool for regulatory agencies, such as the Texas Commission on Environmental Quality (TCEQ), to enforce compliance with air quality regulations among semiconductor manufacturers. By requiring permits and establishing clear compliance obligations, Chapter 122 helps ensure that semiconductor facilities operate in accordance with environmental laws, protect air quality, and minimize their environmental impact. • Streamlined Regulatory Oversight: The FOPP streamlines regulatory oversight by consolidating air quality requirements into a single permit document. Semiconductor manufacturers benefit from a clear understanding of their compliance obligations, reduced administrative burden associated with multiple permits, and improved efficiency in regulatory interactions. This facilitates smoother permitting processes, enhances regulatory certainty, and supports sustainable business practices in the semiconductor industry.	Governs the issuance of federal operating permits for facilities, including semiconductor manufacturing plants, that emit air pollutants.	The Texas Commission on Environmental Quality (TCEQ]	Fines, penalties and potential shutdowns for non-compliance.
Texas Risk Reduction Program	Title 30, Part 1 Chapter 350	• The Texas Risk Reduction Program establishes a regulatory framework for managing environmental risks associated with their operations. Semiconductor manufacturing involves the use of hazardous chemicals and generates potentially harmful waste. Compliance with the TRRP ensures that companies can operate responsibly while minimizing environmental impacts and protecting public health.	The Texas Risk Reduction Program establishes a framework for addressing environmental contamination incidents. The program emphasizes balancing human health and environmental protection with the economic well-being of the state's residents.	This program is regulated by the TCEQ	TCEQ has the authority to impose significant fines depending on the nature and severity of the violation. These fines can range from administrative penalties of up to $25,000 per day to civil penalties as high as $25,000 per day, depending on the specific violation. In some cases, penalties can be even steeper, with additional economic benefit penalties based on the gains from non-compliance.

Appendix F: California Regulations and Enforcement Authorities for Toxic Hazard and Exposure

This appendix presents the results of a scan of the California Code of Regulations for regulations pertaining to toxic hazard and exposure.

Classification	Title of the Regulation	Significance of the regulation with regard to toxic exposure and/or semiconductor manufacturing, summary of the content and subject of the regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
Section A: General Toxic Exposure and Occupational Health and Safety Laws	8 CCR § 5189 Process Safety Management of Acutely Hazardous Materials	• Although not directly aimed at semiconductor manufacturing, these regulations apply due to hazardous materials presence. • The section mandates requirements for hazard assessment, operating procedures, training, and emergency response planning. • Compliance with these regulations is vital for semiconductor manufacturers to ensure safe handling and minimize risks to workers and the community.	California Division of Occupational Safety and Health (Cal/OSHA)	Doesn't mention any specific punishment. However, failure to comply can lead to enforcement actions such as citations or fines to employer.
	Website for Reference: https://govt.westlaw.com/calregs/Document/I47843A215A0F11EC8227000D3A7C4BC3?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default)			
	8 CCR § 5191 Occupational Exposure to Hazardous Chemicals in Laboratories	• Although not directly aimed at semiconductor manufacturing, these regulations apply due to hazardous materials presence. • The regulations outline requirements for hazard communication, employee training, exposure monitoring, medical surveillance, and control measures implementation. • Compliance with these regulations is vital for semiconductor manufacturers to safeguard the health and safety of laboratory workers and employees handling chemicals within their facilities.	California Division of Occupational Safety and Health (Cal/OSHA)	Doesn't mention any specific punishment. However, failure to comply can lead to enforcement actions such as citations or fines to employer.
	Website for Reference: https://govt.westlaw.com/calregs/Document/I48FD1E835A0F11EC8227000D3A7C4BC3?viewType=FullText&listSource=Search&originationContext=Search+Result&transitionType=SearchItem&contextData=(sc.Search)&navigationPath=Search%2fv1%2fresults%2fnavigation%2fi0ad62d2e0000018e24bc69717a7391ed%3fppcid%3d4e886e525c4c4df299e6c64aa7b86de4%26Nav%3dREGULATION_PUBLICVIEW%26fragmentIdentifier%3dI48FD1E835A0F11EC8227000D3A7C4BC3%26startIndex%3d1%26transitionType%3dSearchItem%26contextData%3d%2528sc.Default%2529%26originationContext%3dSearch%2520Result&list=REGULATION_PUBLICVIEW&rank=2&t_T2=5191&t_S1=CA+ADC+s			

	8 CCR § 5194 Hazard Communication	• This section requires employers in various industries, including semiconductor manufacturing, to have a hazard communication program. This program ensures employees are informed about hazardous substances they might encounter, including:
		  • Identifying and assessing the hazards of chemicals
		  • Providing labels and safety data sheets (SDS)
		  • Training employees on safe handling procedures
			California Division of Occupational Safety and Health (Cal/OSHA)	Doesn't mention any specific punishment. However, failure to comply can lead to enforcement actions such as citations or fines to employer.

	Website for Reference: https://govt.westlaw.com/calregs/Document/I4B8F3B125A0F11EC8227000D3A7C4BC3?viewType=FullText&listSource=Search&originationContext=Search+Result&transitionType=SearchItem&contextData=(sc.Search)&navigationPath=Search%2fv1%2fresults%2fnavigation%2fi0ad7140a0000018e21f06e4d3cda436c%3fppcid%3d01550b2bfc8d4271ae5926c80725dde2%26Nav%3dREGULATION_PUBLICVIEW%26fragmentIdentifier%3dI4B8F3B125A0F11EC8227000D3A7C4BC3%26startIndex%3d1%26transitionType%3dSearchItem%26contextData%3d%2528sc.Default%2529%26originationContext%3dSearch%2520Result&list=REGULATION_PUBLICVIEW&rank=2&t_T2=5194&t_S1=CA+ADC+s			
	8 CCR § 5155 Airborne Contaminants	• Cal/OSHA enforces federal Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs) and may have additional state specific PELs for certain chemicals, defining maximum airborne concentrations permissible for employee exposure. • Semiconductor facilities must determine relevant PELs for chemicals used in their processes by consulting Cal/OSHA resources or industrial hygienists.	California Division of Occupational Safety and Health (Cal/OSHA)	Yes, Failing to comply with 8 CCR § 5155 could result in penalties for employers besides the potential for worker health issues.
	Website for Reference: https://govt.westlaw.com/calregs/Document/I45CB66935A0F11EC8227000D3A7C4BC3?viewType=FullText&listSource=Search&originationContext=Search+Result&transitionType=SearchItem&contextData=(sc.Search)&navigationPath=Search%2fv1%2fresults%2fnavigation%2fi0ad62d2e0000018e225be8a17a72e602%3fppcid%3dec07d13bf9784bce8ef6fc11b7b90c13%26Nav%3dREGULATION_PUBLICVIEW%26fragmentIdentifier%3dI45CB66935A0F11EC8227000D3A7C4BC3%26startIndex%3d1%26transitionType%3dSearchItem%26contextData%3d%2528sc.Default%2529%26originationContext%3dSearch%2520Result&list=REGULATION_PUBLICVIEW&rank=2&t_T2=5155&t_S1=CA+ADC+s			
	8 CCR § 5214 Inorganic Arsenic	• This regulation controls employee exposure to inorganic arsenic, applicable to semiconductor manufacturing processes involving this substance. • Exemptions might exist for semiconductor applications where arsenic is encapsulated, while transportation regulations for inorganic arsenic could be overseen by the California Highway Patrol, with the regulation aiming to ensure workplace safety while accommodating specific exemptions for semiconductor manufacturing.	California Division of Occupational Safety and Health (Cal/OSHA)	Yes, Though not explicitly mention, however search shows that DOL has filed penalities for non compliance.
	Website for Reference: https://govt.westlaw.com/calregs/Document/I59F5C1135A0F11EC8227000D3A7C4BC3?viewType=FullText&listSource=Search&originationContext=Search+Result&transitionType=SearchItem&contextData=(sc.Search)&navigationPath=Search%2fv1%2fresults%2fnavigation%2fi0ad7140b0000018e21f9665a5f8defb7%3fppcid%3dcd86b026ece744dfa6f7d719b1d8df67%26Nav%3dREGULATION_PUBLICVIEW%26fragmentIdentifier%3dI59F5C1135A0F11EC8227000D3A7C4BC3%26startIndex%3d1%26transitionType%3dSearchItem%26contextData%3d%2528sc.Default%2529%26originationContext%3dSearch%2520Result&list=REGULATION_PUBLICVIEW&rank=1&t_querytext=semiconductor			

Classification	Title of the Regulation	Significance of the regulation with regard to toxic exposure and/or semiconductor manufacturing, summary of the content and subject of the regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
Section A: General Toxic Exposure and Occupational Health and Safety Laws	17 CCR § 38005 Occupational Lead Poisoning Fee: Applicable Industries	• This regulation mandates an Occupational Lead Poisoning Fee applicable to industries, including semiconductors, where lead exposure risk exists. • Semiconductor manufacturers must comply with this regulation and pay the fee if their operations involve lead processes posing a risk of occupational lead exposure, with the fee supporting programs aimed at preventing and addressing lead poisoning in the workplace.	California Department of Industrial Relations (DIR) and California Division of Occupational Safety and Health (Cal/OSHA)	Yes, Section 105190 of the California Health and Safety Code mandates employers with ten or more employees in such industries to pay the fee. Non-payment consequences: Failure to pay the fee could result in: • Late penalties and interest: The California Department of Public Health (CDPH) might impose late fees and interest charges on unpaid balances. • Referral to Franchise Tax Board (FTB): CDPH could refer delinquent accounts to the FTB for collection efforts. The FTB has broader enforcement powers, which could include: • Withholding tax refunds • Issuing liens on property.
	Website for Reference: https://govt.westlaw.com/calregs/Document/ICA98FD435A2011EC8227000D3A7C4BC3?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default)			
Section B: Air Pollution	17CCR § 93100 to 93115 Airborne Toxic Control Measures (ATCMs)	• This regulation focuses on regulating emissions from semiconductor manufacturing operations, with a notable regulation being the Semiconductor Manufacturing ATCM. • The ATCM sets emission limits and control requirements for volatile organic compounds (VOCs) and hazardous air pollutants (HAPs), crucial for semiconductor manufacturers to minimize environmental impact and comply with air quality standards enforced by the California Air Resources Board (CARB).	California Air Resources Board (CARB)	The penalties for non-compliance with California's Airborne Toxic Control Measures (ATCMs) typically involve financial repercussions enforced by local air districts. However, there's no single penalty structure that applies across all ATCMs (17 CCR § 93100 to 93115). Here's a breakdown of what to expect: • Varied Penalties by Air District: Each local air district in California has the authority to establish its own enforcement procedures and penalty schemes for ATCM violations. This means the specific fines or penalties can differ depending on your location. • Potential Penalties: Generally, penalties for ATCM violations can range from: • Warning letters: For minor infractions, a district might issue a warning letter outlining the violation and requesting corrective actions. • Citations and fines: For more serious violations, the district can issue citations with fines. The amount of the fine can vary depending on the severity of the violation, history of non-compliance, and other factors. • Orders to comply: The district might issue a formal order requiring the facility to take specific actions to achieve compliance. • Referral to CARB: In cases of repeated or egregious violations, the air district might refer the case to the California Air Resources Board (CARB) for further enforcement actions.
	Website for Reference: https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=IF01F77105A2011EC8227000D3A7C4BC3&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default)			
	17 CCR § 95320 to § 95326 Regulations to Achieve Greenhouse Gas Emission Reductions	• This regulation aims to decrease fluorinated gas emissions from the semiconductor industry, aligning with the California Global Warming Solutions Act of 2006. • It applies to owners or operators of semiconductor operations utilizing fluorinated gases or heat transfer fluids, encompassing various processes such as diodes, transistors, solar cells, and light-emitting devices.	California Air Resources Board (CARB)	While the specific penalties aren't detailed within 17 CCR § 95320 to § 95326, non-compliance for the semiconductor industry likely results in financial penalties enforced by the California Air Resources Board (CARB).
	Website for Reference: https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I06FF2D905A2111EC8227000D3A7C4BC3&transitionType=Default&contextData=%28sc.Default%29#I070177835A2111EC8227000D3A7C4BC3Default%29#I070177835A2111EC8227000D3A7C4BC3			

Classification	Title of the Regulation	Significance of the regulation with regard to toxic exposure and/or semiconductor manufacturing, summary of the content and subject of the regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
Section B: Air Pollution	17 CCR § 93400 to 93410 Article 1, General Requirements for Criteria and Toxics Reporting	• This regulation enforces reporting requirements for criteria air pollutants and toxic air contaminants. • While not semiconductor-specific, these regulations apply due to potential emissions from semiconductor manufacturing processes, ensuring regulatory oversight of air quality, and mitigating associated health and environmental risks through compliance.	California Air Resources Board (CARB)	While 17 CCR § 93400 to 93410, Article 1, General Requirements for Criteria and Toxics Reporting, focuses on establishing reporting requirements, it doesn't explicitly mention penalties for non-compliance. However, there can still be consequences for not meeting these reporting obligations. Here's a possible scenario: Enforcement by Air Districts: Local air districts in California are responsible for enforcing air quality regulations. They might take action if a facility fails to submit required reports under these criteria and toxics reporting regulations. Potential Actions: These actions could include: Notices of Violation: The air district might issue a Notice of Violation (NOV) outlining the reporting deficiency and requesting corrective action. Fines: Depending on the severity and duration of non-compliance, the district could impose fines. Finding Specific Penalties: Unfortunately, due to the decentralized enforcement structure, there's no single penalty structure across all California air districts.
	Website for Reference: https://govt.westlaw.com/calregs/Document/IF9DFF4A35A2011EC8227000D3A7C4BC3?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default)			
	Regulation 8 organic compounds rule 30, semiconductor wafer fabrication operations	• This Semiconductor Rule, enforced by BAAQMD, targets semiconductor wafer fabrication facilities to limit VOC emissions and improve air quality, especially ozone levels. • It mandates specific requirements for handling and storing solvents used in fabrication, such as keeping tanks covered, labeling them, proper storage, and disposal of waste solvents, operating sealed solvent vapor stations, and promptly repairing solvent leaks or faulty equipment.	Bay Area Air Quality Management District (BAAQMD)	Penalties for non-compliance with Regulation 8, Rule 30, targeting semiconductor wafer fabrication operations, typically include fines, compliance orders, and permit revocation or suspension. Legal action and injunctions may also be pursued, leading to mandates for compliance, additional penalties, or cessation of operations. Facilities should prioritize adherence to emission standards and regulatory requirements to avoid penalties and contribute to environmental protection efforts.
	Website for Reference: https://www.baaqmd.gov/~/media/dotgov/files/rules/reg-8-rule-30-semiconductor-wafer-fabrication-operations/documents/rg0830.pdf?rev=6399035c055b4951b147495054fb5057&sc_lang=en			
Section C: Water Pollution	23 CCR California Code of Regulations Title 23, Division 3 Chapter 16, Underground Storage Tank Regulations	• This regulation outlines waste discharge requirements for industrial facilities, including semiconductor manufacturing plants, regarding permits for discharging industrial wastewater into surface waters or municipal sewer systems. • Compliance with these regulations is crucial for semiconductor manufacturers to ensure that their wastewater discharges meet water quality standards, with permits specifying allowable limits for pollutants like heavy metals, toxic chemicals, and acids/bases to prevent pollution of surface waters.	State Water Resources Control Board (SWRCB)	Penalties for non-compliance with California Code of Regulations (CCR), Title 23, Division 3, Chapter 16, Underground Storage Tank Regulations, may include fines, enforcement actions, and corrective measures. Specific penalties can vary depending on the severity of the violation, the duration of non-compliance, and any prior violations. Enforcement agencies may also require corrective actions to address violations and prevent future non-compliance. Additionally, facilities found to be in violation may face permit suspension or revocation, legal action, or injunctions to ensure compliance with underground storage tank regulations.
	Website for Reference: https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=ICAC98F605B6E11EC9451000D3A7C4BC3&transitionType=Default&contextData=%28sc.Default%29			

Classification	Title of the Regulation	Significance of the regulation with regard to toxic exposure and/or semiconductor manufacturing, summary of the content and subject of the regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
Section C: Water Pollution	23 CCR § 3900 to 3991, Water Quality Control Plans, Policies, and Guidelines	• The regulation incorporates hazardous waste control laws, regulations, and guidelines into the California Code of Regulations, making them readily accessible and enforceable. • It ensures that regulations pertaining to hazardous waste management are effectively integrated into the state's regulatory framework for enforcement.	Regional Water Quality Control Boards (RWQCBs)	No specific information on the penalties for non-compliance with 23 CCR § 3900 to 3991. However, the California Water Code (CWC) outlines general penalties for water quality violations. Here's a summary: Civil liability: Up to $10,000 per day for violations California Water Code Section 13350: https://codes.findlaw.com/ca/water-code/wat-sect-13350 Administrative civil liabilities: Up to $25,000 per day for violations California Water Code Section 13350(b): https://codes.findlaw.com/ca/water-code/wat-sect-13350 Criminal penalties: Up to $25,000 per day of violation, imprisonment for up to one year, or both California Water Code Section 13387: https://codes.findlaw.com/ca/water-code/wat-sect-13387/
	Website for Reference: https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=ID6000B285B6E11EC9451000D3A7C4BC3&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default)			
Section D: Chemical Storage	24 CCR, Part 9, Chapter 27 Semiconductor Fabrication Facilities	• This chapter of the California Fire Code addresses fire safety in semiconductor facilities while acknowledging the presence of hazardous materials such as flammable liquids, gases, and toxic substances commonly used in fabrication processes. • Although its primary focus is fire safety and property protection, it indirectly addresses toxic chemical exposure by requiring measures to control hazards, likely involving ventilation systems, storage procedures, and potential use of Personal Protective Equipment (PPE).	California Building Standards Commission	Does not mention explicitly. While there aren't defined penalties within the regulation, failing to comply with safety standards can lead to consequences such as: Stop Work Orders: If inspectors discover safety violations during inspections, they may issue a stop work order prohibiting further construction or operation until the violations are addressed. Permit Revocation: In cases of serious or repeated violations, the local agency could revoke the facility's building permit, essentially halting operations. Fines: Depending on the local jurisdiction and the severity of the violation, fines might be imposed.
	Website for Reference: https://codes.iccsafe.org/content/IFC2018/chapter-27-semiconductor-fabrication-facilities			
Section E: E-Waste Recycling	14CCR, Division 7, Chapter 8.2 Sections 18660-18669, Electronic Waste Recovery and Recycling	• This regulation pertains to the Electronic Waste Recycling Act (EWRA), specifically regarding semiconductor manufacturing and the management of electronic waste (e-waste). • Semiconductor manufacturers must comply with requirements for the proper management, recycling, and reporting of e-waste generated during manufacturing processes, contributing to environmental sustainability efforts in California and meeting their obligations under the EWRA.	California Department of Resources Recycling and Recovery (CalRecycle)	While 14 CCR, Division 7, Chapter 8.2 Sections 18660-18669, Electronic Waste Recovery and Recycling doesn't explicitly outline penalties within the regulation itself, failing to comply can lead to serious repercussions. Here's a breakdown of the potential consequences: Administrative Civil Penalties: The California Department of Resource Recycling (CalRecycle) can impose administrative civil penalties for violations. These penalties can be substantial, reaching thousands of dollars per day for ongoing violations. Enforcement Actions: CalRecycle can take various enforcement actions depending on the severity of the non-compliance. This could include: Informal Actions: Warnings or notices of violation requiring corrective actions. Formal Orders: Issuing a formal order mandating specific actions to achieve compliance. License Revocation or Denial: In extreme cases, CalRecycle can revoke or deny a recycler's license to operate in California. Criminal Charges: In cases of intentional dumping or hazardous waste violations, criminal charges might be pursued.
	Website for Reference: https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=IAA4F5CE05B4D11EC976B000D3A7C4BC3&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default)			

Classification	Title of the Regulation	Significance of the regulation with regard to toxic exposure and/or semiconductor manufacturing, summary of the content and subject of the regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
Section F: Emergency Toxic Exposure	19 CCR Section 4.5, §2735 to §2785 ,California Accidental Release Prevention (CalARP) Program Detailed Analysis	• The act aligns with the California Emergency Services Act (ESA), establishing protocols for emergency response to hazards, including incidents involving hazardous materials. • It grants authority to the Governor's Office of Emergency Services (OES) to coordinate response efforts among various agencies, while CalARP mandates facilities handling hazardous materials to report accidental releases above a specified threshold to aid emergency responders in protecting public health and the environment.	California Governor's Office of Emergency Services	Doesn't mention any specific punishment. However, failure to comply can lead to enforcement actions such as citations or fines to employer.
	Website for Reference: https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I2980FB845BE511EC98C8000D3A7C4BC3&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default)			
Section G: Cleaning of Hazardous Waste	22 CCR § 66264 Standards for Owners and Operators of Hazardous Waste Transfer, Treatment, Storage, and Disposal Facilities	• This regulation establishes standards for handling, storing, treating, and disposing of hazardous wastes produced in semiconductor manufacturing. • They aim to minimize risks to workers, communities, and the environment by ensuring proper management of hazardous wastes, including safe storage practices such as container requirements, labeling, and segregation of incompatible wastes.	Department of Toxic Substances Control (DTSC)	22 CCR § 66264, Standards for Owners and Operators of Hazardous Waste Transfer, Treatment, Storage, and Disposal Facilities, doesn't explicitly outline specific penalties within the regulation itself. However, there can be significant consequences for non-compliance enforced by the California Department of Toxic Substances Control (DTSC). Here's a breakdown of what might happen: Enforcement by DTSC: DTSC is responsible for enforcing these hazardous waste management standards. They conduct inspections to ensure facilities comply with the regulations. Potential Penalties: In case of violations, DTSC can take a range of enforcement actions, including: Notices of Violation (NOVs): These outline the violations and require corrective actions within a specific timeframe. Administrative Civil Penalties: DTSC can impose fines for non-compliance. The amount depends on the severity, extent, and history of the violation. Corrective Action Orders: DTSC may issue an order mandating specific actions to achieve compliance. This could involve repairs, process changes, or additional training for personnel. Permit Suspension or Revocation: In serious or repeated violation cases, DTSC could suspend or revoke the facility's permit to operate. This would essentially shut down the facility's hazardous waste management operations. Criminal Charges: For egregious violations or incidents causing harm to people or the environment, criminal charges might be filed.
	Website for Reference: https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I878D43205B6111EC9451000D3A7C4BC3&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default)			

Classification	Title of the Regulation	Significance of the regulation with regard to toxic exposure and/or semiconductor manufacturing, summary of the content and subject of the regulation	Who enforces the regulation	Does this regulation include any punishment for failure to comply?
Section G: Cleaning of Hazardous Waste	27 CCR, Title 27, Environmental Protection–Division 2, Solid Waste	• This regulation addresses solid waste management, including hazardous waste, universal waste, and used oil management. • Semiconductor manufacturing facilities must comply with Chapter 14 for hazardous waste management, Chapter 15 for universal waste management (e.g., batteries, electronic devices), and Chapter 16 for used oil management, ensuring proper handling, treatment, and disposal of materials to adhere to environmental protection regulations and maintain regulatory compliance.	California Department of Resources Recycling and Recovery (CalRecycle)	27 CCR, Title 27, Environmental Protection–Division 2, Solid Waste, is a comprehensive set of regulations governing the treatment, storage, processing, and disposal of solid waste in California. While the specific penalties for non-compliance might not be explicitly mentioned within each section of Title 27, there are generally established enforcement procedures. Here's a breakdown of how enforcement works for 27 CCR: Enforcement by CalRecycle: The California Department of Resources Recycling and Recovery (CalRecycle) is the primary agency responsible for enforcing Title 27 regulations. Varied Enforcement Actions: CalRecycle can take a range of actions depending on the severity and nature of the violation. These could include: Informal Actions: Issuing warnings or notices of violation requiring corrective actions. Administrative Civil Penalties: CalRecycle can impose fines for non-compliance. The amount of the fine depends on factors like the severity, duration, and history of the violation. Stop Work Orders: In cases where continued operation could pose a threat to public health or the environment, CalRecycle may halt operations at a solid waste facility. Permit Revocation or Denial: For serious or repeated violations, CalRecycle can revoke or deny a facility's permit to operate.
	Website for Reference: https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=IABB2C340512211EC828B000D3A7C4BC3&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default)			

Appendix G: Ethical Principles for Collecting, Analyzing and Using Health Data

Ethical principles for collecting, analyzing and using health data, as summarized from an article written by Ángel Ross for Policy Link and Ecotrust in 2017.[156]

1. **Put communities in the driver's seat of data collection, analysis and display, with the goal of self-determination**
   a. Partner with local organizations to hold community engagement sessions before building out the data collection plan to ensure that community members inform the goals of the project and research questions that lead to the selection of data and indicators.
      i. If building a national tool, consider forming a community advisory committee of local advocates across regions to inform the process.
      ii. Identify the population(s) of interest and community-based organizations to partner with early in the process.
      iii. Identify core community-based partners who comprise or represent the impacted communities and bring in a broad coalition of other partners to advise.
   b. Flatten the unequal power dynamics that exist in multisector collaborative processes by ensuring that community partners' voices and participation are comparably weighted to other partners and by informing powerful interests like funders about the importance of community input and remaining accountable to community visions and goals.
   c. Go into communities to share major findings throughout the development of the tool, test for their relevance within the community and adjust as necessary.
   d. After launching the data collection plan, hold free or affordable trainings in accessible locations for community members on how to use the data collection process and ensuing data for change.
2. **Keep equity a priority throughout the process.**
   a. Beware of mission creep as the project develops and additional partners weigh in. Do not lose sight of the purpose of data collection: to serve the people bearing the brunt of injustice.
   b. Exclude important data that might be interesting but not relevant to furthering the stated equity goals.
   c. If data that can advance the equity outcome does not exist, use the lack of data as a point of advocacy.
      i. Provide a list of policies that have been proven to address or ameliorate each indicator.
      ii. Provide the contact information of local, state or federal elected officials who influence the recommended policies.
      iii. Connect users to advocacy or membership-based organizations who work on issues related to the data.
      iv. Because action often happens locally, both national and local tools should address how the data is relevant in a local setting.
3. **Disaggregate data.**
   a. Disaggregate all data by race/ethnicity and allow users, where possible, to disaggregate below the major race/ethnic categories.
   b. Include data on American Indian and Alaska Native people to the extent possible and encourage advocacy when data is not reported.
   c. Include as many social dimensions of difference as possible for users to examine the data, including, but not limited to, gender, nativity, country of origin, language proficiency, ancestry, income and sexual orientation.
   d. To underscore why place matters, include maps, when possible, that show which neighborhoods or areas are most impacted by a given indicator.
   e. Be intentional about the names of categories and vet language and displays with community members to ensure fidelity with how people self-identify.
   f. Advocate for more disaggregated data in public institutions, as advocates within the Asian or Pacific Islander community successfully did for state health and education data in California (AB 1726).
4. **Move beyond maps and numbers.**
   a. Supplement maps and charts with explanatory narratives and community member perspectives.
   b. Include indicators and displays based on qualitative data and community knowledge.
5. **Emphasize assets and opportunities, not just inequities.**
   a. Identify community assets and resources to highlight in addition to indicators of inequity.
   b. Avoid publishing identifiable data.
   c. Anticipate how others might misuse or misrepresent data.
   d. Allow community members to share their stories and experiences of their community.
6. **Make data analysis clear.**
   a. Supplement maps and charts with explanatory narrative.
   b. Use clear and concise language and infographics that are accessible to young people and those with a range of educational and cultural backgrounds.
   c. Offer the tool in languages other than English.
   d. Be sure that color-coded maps and charts are distinguishable to all users, including those with colorblindness.
   e. Anticipate user workflows (i.e., how people use data) and design tools/visualizations/reports accordingly. The likelihood of use increases if the data analysis does not have a huge learning curve.

156. Ross, Ángel. "Powering Health Equity Action with Online Data Tools: 10 Design Principles." National Equity Atlas, PolicyLink and ecotrust, Sept. 2017, nationalequityatlas.org/sites/default/files/10-Design-Principles-For-Online-Data-Tools.pdf.

7. **Contribute to data democracy.**
    a. Allow users to download underlying datasets.
    b. Provide a detailed methodology.
    c. Prepare community members to use data collected and/or analyzed in their own advocacy and research.
8. **Honor indigenous data sovereignty.**
    a. When reporting data on or about American Indian or Alaska Native peoples, at a minimum, consult with the respective and/or local tribal leaders on the analysis and interpretation of the data.
    b. Advocate for meaningful partnership, not just consultation, between federal, state, and local agencies and American Indian tribes.

Appendix H: Evaluating Methods for Substituting Chemicals of Concern with Alternatives

The following tables are reproductions of the tables in Jacobs et al's "Alternatives Assessment Frameworks: Research Needs for the Informed Substitution of Hazardous Chemicals."

When scoring, the filled boxes will be replaced with "1"s, and the blank boxes will count as "0"s. Columns that include quantitative data would be scored on a case by case basis.

Source: Jacobs, Molly M., et al. "Alternatives Assessment Frameworks: Research Needs for the Informed Substitution of Hazardous Chemicals." Environmental Health Perspectives, vol. 124, no. 3, Mar. 2016, pp. 265–280, https://doi.org/10.1289/ehp.1409581.

Table 1
Hazar Assessment End Points
(most frequently addressed, not comprehensive)

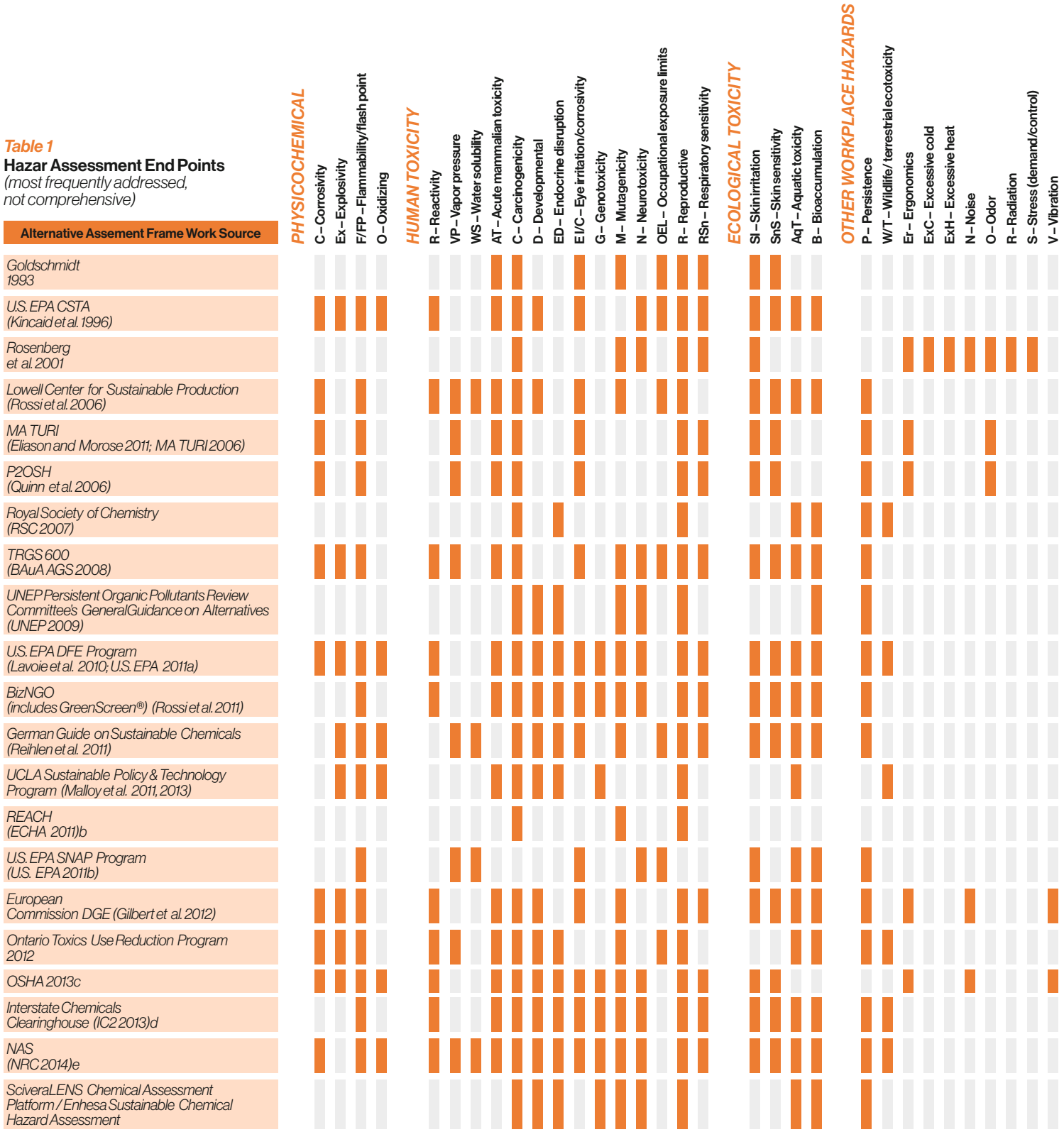


Table 2

Technical Feasibility Assessment Characteristics

(most frequently addressed, not comprehensive)

Alternative Assement Frame Work Source	TECHNICAL FEASABILITY	AS – Authoritative source	CR – Consumer	F – Feasibility	FR – Functional requirements	MR – Maintenance requirement	P/Q – Performance/quality includes measures such as reliability, longevity, durability)	ECOLOGICAL TOXICITY	Reg – Conformity with regulations / requirements	SC – Supply chain availability	W–Worker perception/acceptance
Goldschmidt 1993					■						
U.S. EPA CSTA (Kincaid et al. 1996)			■		■		■		■		
Rosenberg et al. 2001					■	■			■		■
Lowell Center for Sustainable Production (Rossi et al. 2006)					■		■			■	
MA TURI (Eliason and Morose 2011; MA TURI 2006)					■		■		■		
P2OSH (Quinn et al. 2006)				■	■		■				■
Royal Society of Chemistry (RSC 2007)					■		■				
TRGS 600 (BAuA AGS 2008)			■	■	■		■		■	■	
UNEP Persistent Organic Pollutants Review Committee's GeneralGuidance on Alternatives (UNEP 2009)					■	■					
U.S. EPA DFE Program (Lavoie et al. 2010; U.S. EPA 2011a)											
BizNGO (includes GreenScreen®) (Rossi et al. 2011)					■		■				
German Guide on Sustainable Chemicals (Reihlen et al. 2011)					■		■				
UCLA Sustainable Policy & Technology Program (Malloy et al. 2011, 2013)			■	■	■		■				
REACH (ECHA 2011)b					■	■	■				
U.S. EPA SNAP Program (U.S. EPA 2011b)			■	■	■		■		■		
European Commission DGE (Gilbert et al. 2012)				■	■						
Ontario Toxics Use Reduction Program 2012			■	■	■		■		■	■	■
OSHA 2013c			■	■	■	■	■		■		
Interstate Chemicals Clearinghouse (IC2 2013)d			■		■	■	■		■		
NAS (NRC 2014)e		■	■	■	■	■	■			■	
SciveraLENS Chemical Assessment Platform / Enhesa Sustainable Chemical Hazard Assessment					■		■				

Table 3

Economic Assessment Attributes

(most frequently addressed, not comprehensive)

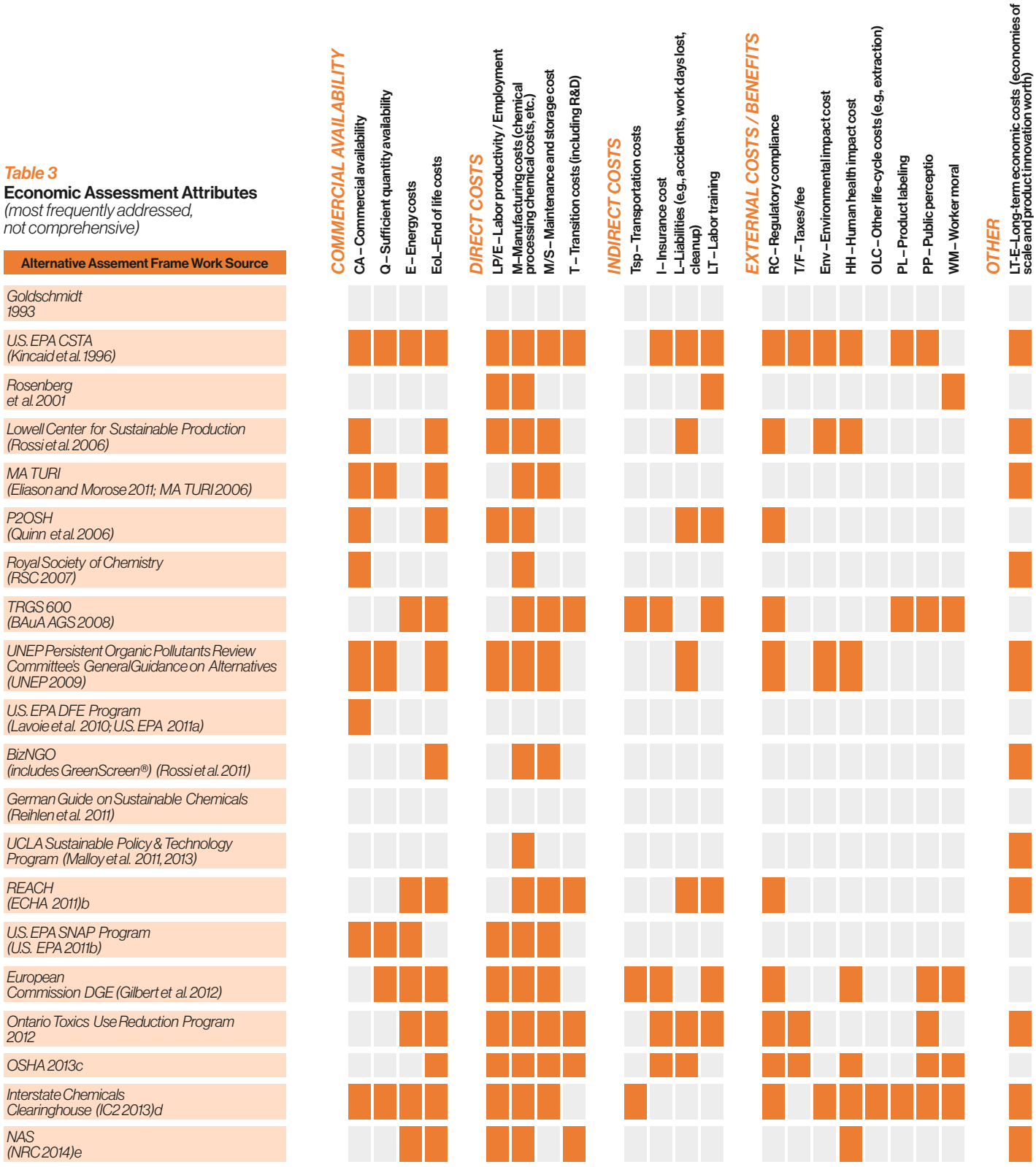


Table 4

Purpose of Exposure Characterization

Alternative Assement Frame Work Source	Exposure addressed?	Discreteprocess element?	Risk characterization	Other (as described)
Goldschmidt 1993	■		■	*Simply states, "assess the risk of being exposed."*
U.S. EPA CSTA (Kincaid et al. 1996)	■	■	■	
Rosenberg et al. 2001				
Lowell Center for Sustainable Production (Rossi et al. 2006)				*Inherent exposure properties and routes of exposure that substantively increase exposure levels are identifed and integrated into the hazard assessment (human and ecological toxicity).*
MA TURI (Eliason and Morose 2011; MA TURI 2006)	■			*Physicochemical properties are considered for worker exposure potential. Considered when identifying priority uses to include in the alternatives assessment and for comparing alternatives.*
P2OSH (Quinn et al. 2006)	■			*Worker use conditions are characterized to identify exposure potential.*
Royal Society of Chemistry (RSC 2007)	■	■	■	
TRGS 600 (BAuA AGS 2008)	■		■	
UNEP Persistent Organic Pollutants Review Committee's GeneralGuidance on Alternatives (UNEP 2009)	■	■	■	
U.S. EPA DFE Program (Lavoie et al. 2010; U.S. EPA 2011a)	■			*Considered when applying life-cycle thinking to target exposure pathways of priority concern.*
BizNGO (includes GreenScreen®) (Rossi et al. 2011)	■		■	*Use of risk assessment suggested only when alternatives differ from current practice. Addressed during the last step of the alternatives assessment process under Step 6, "Apply Lifecycle Thinking."*
German Guide on Sustainable Chemicals (Reihlen et al. 2011)	■			*Physicochemical properties considered for worker exposure potential. Releases/long-range transport considered regarding mobility and environmental exposure potential.*
UCLA Sustainable Policy & Technology Program (Malloy et al. 2011, 2013)	■			*Characterized as part of subcriteria/end point within the hazard assessment (human health and environment). Considered the nature of exposure in comparison of alternatives, yet not for the explicit purpose of risk calculations.*
REACH (ECHA 2011)b	■	■	■	
U.S. EPA SNAP Program (U.S. EPA 2011b)	■			*Characterized exposure potential using physicochemical properties, use characteristics, emissions information and industrial hygiene information, yet not for the purpose of estimating risk.*
European Commission DGE (Gilbert et al. 2012)	■	■	■	
Ontario Toxics Use Reduction Program 2012	■			*Considered primarily in the assessment of physicochemical properties and during the life-cycle assessment process.*
OSHA 2013c	■			*Worker use conditions are characterized to identify exposure potential. Characterized as part of subcriteria/end point within the hazard assessment.*
Interstate Chemicals Clearinghouse (IC2 2013)d	■	■	■	*Exposure considered when examining potential trade-offs with the identifed alternatives. In addition to risk assessment, several other options are offered that address exposure potential without estimating risk, such as physicochemical properties, use characteristics, emissions, and industrial hygiene information.*
NAS (NRC 2014)e	■	■		*Included "intrinsic exposure" to determine whether exposure to the chemical of concern and alternatives are a) substantially equivalent; b) increased; or c) inherently (lower) preferable. More rigorous exposure assessment is suggested where increased exposure is indicated*

Table 5

Exposure Characterization Attributes

(most frequently addressed, not comprehensive)

Table 6

Addressing Chemical Life-Cycle Impacts

Alternative Assement Frame Work Source	Life-cycle impacts addressed?	Addressed as a discrete process element?	Life-cycle thinking	Life-cycle assessment	Other (as described)
Goldschmidt 1993					
U.S. EPA CSTA (Kincaid et al. 1996)	■		■		
Rosenberg et al. 2001	■		■		
Lowell Center for Sustainable Production (Rossi et al. 2006)	■		■		
MA TURI (Eliason and Morose 2011; MA TURI 2006)	■		■		
P2OSH (Quinn et al. 2006)					
Royal Society of Chemistry (RSC 2007)	■				
TRGS 600 (BAuA AGS 2008)	■	■			*References the use of "tried and tested expert method" for social, environmental, and economic end points.*
UNEP Persistent Organic Pollutants Review Committee's GeneralGuidance on Alternatives (UNEP 2009)	■		■		
U.S. EPA DFE Program (Lavoie et al. 2010; U.S. EPA 2011a)	■		■		
BizNGO (includes GreenScreen®) (Rossi et al. 2011)	■	■	■	■	
German Guide on Sustainable Chemicals (Reihlen et al. 2011)	■	■	■		
UCLA Sustainable Policy & Technology Program (Malloy et al. 2011, 2013)	■				*Addresses 14 end points associated with life-cycle impacts.*
REACH (ECHA 2011)b	■				*References LCA for comparative evaluation of "far-reaching impacts," yet states that LCA methods are not designed for the selection of lower-risk alternatives to hazardous chemicals associated with specific uses. Only alternative method offered is the Column Model.*
U.S. EPA SNAP Program (U.S. EPA 2011b)	■				*Addresses environmental releases and exposure at specific life-cycle stages: manufacture, use, and disposal. Also interested in specific regulatory/programmatic end points, including ozone depletion and greenhouse gas emissions*
European Commission DGE (Gilbert et al. 2012)	■		■		
Ontario Toxics Use Reduction Program 2012	■			■	
OSHA 2013c	■		■		
Interstate Chemicals Clearinghouse (IC2 2013)d	■	■	■	■	
NAS (NRC 2014)e	■	■	■	■	

Table 7
Decision Analysis

Alternative Assement Frame Work Source	DECISION FUNCTION				DECISION APPROACH				DECISION TOOLS / RULES								WEIGHTING
	C - Comparative	SR - Selection Ranking	N - None		Sq - Sequential	Si - Simultaneous	Mix - Mixed selection (for screening)		Mnu - Menu (type noted)	NA / NS	NarA - Narrative alone	S - Structural	A - Analytical	NA / NS	Addressed		Method
Goldschmidt 1993		■								NS			NS		NS		
U.S. EPA CSTA (Kincaid et al. 1996)		■					Sim N/S				■				NS		
Rosenberg et al. 2001			■							NA			NA		NA		
Lowell Center for Sustainable Production (Rossi et al. 2006)		■								NS	■				Implicit		
MA TURI (Eliason and Morose 2011; MA TURI 2006)	■				■						■				NS		
P2OSH (Quinn et al. 2006)		■					Sq N/S						NS		Implicit		
Royal Society of Chemistry (RSC 2007)		■				■					■				Explicit / Qual		Elicited
TRGS 600 (BAuA AGS 2008)		■				■					■				Explicit / Qual		
UNEP Persistent Organic Pollutants Review Committee's GeneralGuidance on Alternatives (UNEP 2009)		■								NS				NS	NS		
U.S. EPA DFE Program (Lavoie et al. 2010; U.S. EPA 2011a)	■									NA				NA	NS		
BizNGO (includes GreenScreen®) (Rossi et al. 2011)		■					Sq N/S					■			Implicit		
German Guide on Sustainable Chemicals (Reihlen et al. 2011)	■	■								NA				NA	NA		
UCLA Sustainable Policy & Technology Program (Malloy et al. 2011, 2013)		■							■				■		Explicit / Quant		Elicited
REACH (ECHA 2011)b		■					Sq Si				■				Explicit / Quant		
U.S. EPA SNAP Program (U.S. EPA 2011b)		■				■					■				NS		
European Commission DGE (Gilbert et al. 2012)		■					Sq Si				■		■		Implicit		
Ontario Toxics Use Reduction Program 2012		■					Sq Si				■		■		Explicit / Quant		Elicited
OSHA 2013c		■								NS				NS	NS		
Interstate Chemicals Clearinghouse (IC2 2013)d		■							■			■	■		Explicit / Qual & Quant		Default / Calculated / Elicited
NAS (NRC 2014)e		■				■						■	■		Explicit / Qual & Quant		

Appendix I: Survey of Questions for DELPHI Panel on Substituting Chemicals of Concern with Alternatives

There is currently no publication that provides a best practice analysis of current methods for substituting chemicals specific to semiconductor manufacturing. However, the comprehensive literature review of methods produced by researchers Molly M. Jacobs et al in their 2015 publication "Alternatives Assessment Frameworks: Research Needs for the Informed Substitution of Hazardous Chemicals" remains the best resource for comparing methods for substituting chemicals to date.

In their publication, Jacobs et al shares search results of more than 200 publications from 1990-2014, and using key criteria that deem most important for effective substitution assessments, the authors narrow their study down to only 20 frameworks. Jacobs and her colleagues then perform a rigorous breakdown of the various frameworks to compare the similarities and differences between them. In so doing, they identified six components they found core to all of the frameworks: hazard assessment, exposure characterization, life-cycle impacts, technical feasibility evaluation, economic feasibility assessment and decision making. Within each component, multiple endpoints were identified as key elements of the process, and the authors created an all-inclusive spreadsheet for each component to visualize which framework features what endpoint in each component.

This survey takes as its starting point the tables presented by Jacobs et al, which can be found reproduced in **Appendix H**.

The purpose of this survey is to provide a list of questions for review with a panel of experts. The goal of reviewing the questions is to seek consensus among experts on what scoring and weighting measures to apply when judging the frameworks addressed by Jacobs et al. The larger purpose of this exercise is to identify the best framework overall for evaluating whether an alternative chemical should be used as a substitute for a chemical of concern, **specifically with regard to chemicals used in semiconductor manufacturing.**

There are 8 sections in this survey. The entire survey should take approximately 50 minutes to complete. Each section varies in content, and may take anywhere from 4-9 minutes to complete.

We thank you for your involvement in this highly important review. Your feedback is invaluable to the process.

1. Hazard Assessment Endpoints

Table 1 features all of the endpoints that different frameworks use to evaluate a chemicals' hazardous nature. They are organized into four general categories: physicochemical, human toxicity, ecological toxicity and other workplace hazards. Within these categories, the researchers include 32 individual endpoints such as flammability (in physicochemical), reproductive toxins (in human toxicity), aquatic toxicity (in ecological toxicity) and ergonomics (in other workplace hazards). Please review each category and their respective endpoints, and answer the following questions:

- Are any of the following categories unimportant when considering the hazards of chemicals in semiconductor manufacturing? Please check any that are unimportant.
    - ☐ Physicochemical
    - ☐ Human Toxicity
    - ☐ Ecological Toxicity
    - ☐ Other Workplace Hazards

    - Of the categories you consider important, if any, do you consider all of them equally important? Please check one.
        - ☐ Physicochemical
        - ☐ Human Toxicity
        - ☐ Ecological Toxicity
        - ☐ Other Workplace Hazards

        - If you selected "No", please rank them in order of importance, where 1 is highest priority (write "N/A" for a category that is unimportant):
            - _____ Physicochemical
            - _____ Human Toxicity
            - _____ Ecological Toxicity
            - _____ Other Workplace Hazards

- Are there any endpoints that must be present in a hazard assessment if the hazard assessment is to be considered effective? If so, please check any that are critical:
    - ☐ Corrosivity
    - ☐ Explosivity
    - ☐ Flammability/Flash Point
    - ☐ Oxidizing
    - ☐ Reactivity
    - ☐ Vapor Pressure
    - ☐ Water Solubility
    - ☐ Acute Mammalian Toxicity
    - ☐ Carcinogenicity
    - ☐ Developmental
    - ☐ Endocrine Disruption
    - ☐ Eye Irritation/Corrosivity
    - ☐ Genotoxicity
    - ☐ Mutagenicity
    - ☐ Neurotoxicity
    - ☐ Occupational Exposure Limits
    - ☐ Reproductive
    - ☐ Respiratory Sensitivity
    - ☐ Skin Irritation
    - ☐ Skin Sensitivity
    - ☐ Aquatic Toxicity
    - ☐ Bioaccumulation
    - ☐ Persistence
    - ☐ Wildlife/Terrestrial Ecotoxicity
    - ☐ Ergonomics
    - ☐ Excessive Cold
    - ☐ Excessive Heat
    - ☐ Noise
    - ☐ Odor
    - ☐ Radiation
    - ☐ Stress (Demand/Control)
    - ☐ Vibration

    - If there is more than one **endpoint** that must be present, are all of these critical endpoints equally important? Please check one:
        - ☐ Yes
        - ☐ No

        - If you selected "No", please list them in order of importance.

    - If there are endpoints that could be omitted, please list them:

    - If there are any **endpoints** or **categories** that you believe should be included that have not been, please list and describe them in 6 sentences or less.

2. Technical Feasibility Assessment Characteristics

Table 2 features all of the endpoints that different frameworks use to evaluate the technical feasibility of replacing a chemical of concern with the alternative chemical in question. This endpoints of this component are broken down into two categories: (1) legal, labor and/or supply chain feasibility and (2) technical feasibility. The second category includes endpoints such as whether the chemical comes from an authoritative source, whether it meets consumer requirements, and the functional use of a chemical and its performance with regard to specific tasks.

To provide a bit more insight into the concept of a chemical's functional use: if a safe chemical is not able to serve the practical purpose that the hazardous chemical is, then it is unlikely that the substitution will be adopted. For example, if the purpose of using a chemical of concern is to provide flame retardancy in a foam product, the replacement chemical must achieve the same purpose to the same level of performance as the chemical of concern.

There are 9 total endpoints considered in this component of assessment. Please review the two categories and their respective endpoints, and then answer the following questions:

- Are either of the **categories** unimportant when considering the technical feasibility of substituting one chemical with another in semiconductor manufacturing? Please check any that are unimportant.
  - ☐ Technical Feasibility
  - ☐ Legal / Labor / Supply Chain Feasibility

  - Of the categories you consider important, if more than one, do you consider all of them equally important? Please check one.
    - ☐ Yes
    - ☐ No

    - If you both categories are important, but not of equal importance, which is more important? Please check one.
      - ☐ Technical Feasibility
      - ☐ Legal / Labor / Supply Chain Feasibility

  - Are there any **endpoints** that must be present when evaluating the technical feasibility of substituting one chemical with another in semiconductor manufacturing? If so, please check any that are critical:
    - ☐ Authoritative Source
    - ☐ Consumer Requirements
    - ☐ Feasibility
    - ☐ Functional Requirements
    - ☐ Maintenance Requirements
    - ☐ Performance / Quality (includes measures such as reliability, longevity, durability)
    - ☐ Conformity with Regulations / Requirements
    - ☐ Supply Chain Availability
    - ☐ Worker Perception / Acceptance

  - If there is more than one **endpoint** that must be present, are all of these critical endpoints equally important? Please check one
    - ☐ Yes
    - ☐ No

    - If you selected “No”, please list them in order of importance.

- If there are endpoints that could be omitted, please list them:

- If there are any **endpoints** or **categories** that you believe should be included that have not been, please list and describe them in 6 sentences or less.

3. Economic Assessment Attributes

Table 3 features all of the endpoints that different frameworks use to evaluate the economic feasibility of replacing a chemical of concern with the alternative chemical in question. This table not only includes whether a framework merely mentions the value of an economic assessment, but also lists specific costs and measures specified by various frameworks for evaluating economic feasibility.

There are ultimately 21 costs and measures (aka endpoints) broken into five categories: commercial availability, direct costs, indirect costs, external costs/benefits, and other.

Please review the categories and their respective endpoints, and then answer the following questions:

- Are any of the categories unimportant when considering the economic feasibility of replacing a chemical of concern with an alternative chemical in question, specific to chemicals in semiconductor manufacturing? Please check any that are unimportant.
  - ☐ Commercial Availability
  - ☐ Direct Costs
  - ☐ Indirect Costs
  - ☐ External Costs / Benefits
  - ☐ Other

  - Of the categories you consider important, if more than one, do you consider all of them equally important? Please check one.
    - ☐ Yes
    - ☐ No

    - If you selected "No", please rank them in order of importance, where 1 is highest priority (write "N/A" for a category that is unimportant):
      - _____ Commercial Availability
      - _____ Direct Goods
      - _____ Indirect Goods
      - _____ External Costs / Benefits
      - _____ Other

  - Are there any **endpoints** that must be present when evaluating the technical feasibility of substituting one chemical with another in semiconductor manufacturing? If so, please check any that are critical:
    - ☐ Commercial Availability
    - ☐ Sufficient Quantity Availability
    - ☐ Energy Costs
    - ☐ End of Life Costs
    - ☐ Labor Productivity / Employment
    - ☐ Manufacturing Costs (Chemical Costs / Equipment Costs / Additional Processing Chemical Costs, etc)
    - ☐ Maintenance and Storage Costs
    - ☐ Transition Costs
    - ☐ Transportation Costs
    - ☐ Insurance Costs
    - ☐ Liabilities (e.g., Accidents, Work Days Lost, Cleanup)
    - ☐ Labor Training
    - ☐ Regulatory Compliance
    - ☐ Taxes / Fees
    - ☐ Environmental Impact Costs
    - ☐ Human Health Impact Costs
    - ☐ Other Life-Cycle Costs (e.g., Extraction)
    - ☐ Product Labeling
    - ☐ Public Perception
    - ☐ Worker Morale

- If there is more than one **endpoint** that must be present, are all of these critical endpoints equally important? Please check one
  - ☐ Yes
  - ☐ No

    - If you selected "No", please list them in order of importance.

- If there are endpoints that could be omitted, please list them:

- If there are any **endpoints** or **categories** that you believe should be included that have not been, please list and describe them in 6 sentences or less.

4. Purpose of Exposure Characterization

Table 4 features big picture endpoints that Jacobs et al developed to categorize frameworks based on what they consider the role of performing an exposure assessment. Some consider exposure a discrete process component– one critical step to take in assessing an alternative chemical–whereas others do not consider exposure assessment as a unique step but instead a component of other steps such as hazard assessment or in final decision making. Four endpoints are identified for reviewing the different purposes frameworks cite: simply whether a publication addresses exposure at all, whether it considers exposure assessment a discrete process element, whether it is treated mainly as a risk assessment or whether it is assessed beyond the concept of risk.

These endpoints are a bit more theoretical and ultimately push us to articulate the importance of characterizing the elements of potential exposures workers and/or community may have to a chemical. Please consider the four endpoints, and also spend a moment reflecting on the purpose you believe an exposure evaluation serves in the larger concept of substituting hazardous chemicals with alternative ones. Then, please answer the following questions:

1. What purpose do you believe an exposure evaluation serves when assessing whether an alternative chemical should be approved as a safe substitute for a chemical of concern? Please answer in 6 sentences or less.

2. Do you feel that any of the **categories** or **endpoints** provided by Jacobs et al, including any of the answers entered into the "Other" field, match what you believe is the purpose of performing an exposure evaluation? Please select one.
    - ☐ Yes
    - ☐ No

    - If you selected "yes," which one(s)? Please check all that apply.
        - ☐ Exposure Addressed?
        - ☐ Discrete Process Element?
        - ☐ Risk Characterization
        - ☐ Other (as Described)

        - If you selected more than one, are any more relevant than others? Please check one.
            - ☐ Yes
            - ☐ No

    - If you selected "No" for question 2, please provide the title and description of an endpoint that would best meet your definition, in 6 sentences or less.

5. Exposure Characterization Attributes

Table 5 features all of the endpoints that different frameworks use to measure potential exposure of the chemical to workers and/or communities. While hazard assessment considers the inherent hazards of a chemical, exposure characterization considers the exposure potential of the chemical of concern and alternative chemicals.

Some of the frameworks that Jacobs et al review use indirect measures such as volume in commerce or dispersive potential, while others use actual exposure models or data. The endpoints identified for methods measuring exposure refer to frameworks that use actual exposure models or data. The endpoints are organized into four general categories: physicochemical properties, use characteristics, emissions and fate, and industrial hygiene measures. In total, there are 20 endpoints identified across the four categories. Please review each category and their respective endpoints, and answer the following questions:

- Are any of the **categories** unimportant when considering the potential exposure of chemicals in semiconductor manufacturing? Please check all that are unimportant
    - ☐ Physicochemical Properties
    - ☐ Use Characteristics
    - ☐ Emissions and Environmental Fate
    - ☐ Industrial Hygiene Measures

    - Of the categories you consider important, if more than one, do you consider all of them equally important? Please check one.
        - ☐ Yes
        - ☐ No

        - If you selected "No", please rank them in order of importance, where 1 is highest priority (write "N/A" for a category that is unimportant):
            - _____ Physicochemical
            - _____ Use Characteristics
            - _____ Emissions and Fate
            - _____ Industrial Hygiene Measures

    - Are there any **endpoints** that must be present when evaluating potential exposure of a chemical if the evaluation is to be considered effective? If so, please check all critical endpoints.
        - ☐ Binding Strength / Migration Potential
        - ☐ Density / Specific Gravity
        - ☐ Disassociation Constant
        - ☐ Dust-Generating Solids / Aerosols
        - ☐ Melting Point
        - ☐ Molecule / Particle Size
        - ☐ Molecular weight
        - ☐ pH
        - ☐ Physical State (at Room Temperature)
        - ☐ Solubility
        - ☐ Vapor Pressure / Boiling Point
        - ☐ Amount Consumer Use
        - ☐ Amount Manufacturer Use
        - ☐ Extent Dispersive Use
        - ☐ Processing / Handling Characteristics
        - ☐ Bio Monitoring / Environmental Monitoring
        - ☐ Emissions
        - ☐ Persistent, Bio Accumulative, Toxic
        - ☐ Industrial Hygiene Controls
        - ☐ Occupational Monitoring

- If there is more than one **endpoint** that must be present, are all of these critical endpoints equally important? Please check one
  - ☐ Yes
  - ☐ No

    - If you selected "No", please list them in order of importance.

- If there are endpoints that could be omitted, please list them:

- If there are any **endpoints** or **categories** that you believe should be included that have not been, please list and describe them in 6 sentences or less.

6. Addressing Chemical Life-Cycle Impacts

Table 6 features big picture endpoints that Jacobs et al developed to categorize frameworks based on the key questions each one uses to assess how sustainable a product is. In this case, the "product" refers to both the chemical of concern, and the alternative chemical being considered for substitution.

A Life Cycle Assessment (sometimes called "LCA") is an analysis of the environmental impact of a product over the course of the entire life cycle of a product. An LCA "models the environmental implications of the many interacting systems that make up industrial production. When accurately performed, it can provide valuable data that decision-makers can use in support of sustainability initiatives. [158]

Jacobs et al note that some frameworks don't include explicit LCA models but instead address sustainability with "life-cycle thinking" which, as the authors describe, is "less analytical and generally less resource-intensive than LCA. Life-cycle thinking identifies significant impacts at different life-cycle stages but does not typically include quantitative assessment." [159]

The literature review identifies 5 endpoints broken into 3 categories: whether life-cycle impacts are addressed at all, whether they are addressed as a discrete process element and general methods (in which they break down whether the framework uses LCA, life-cycle thinking or "other"). Please review each category and their respective endpoints, and answer the following questions:

- Are any of the **categories** unimportant when considering the sustainability of chemicals in semiconductor manufacturing? Please check all that are unimportant
  - ☐ Life-Cycle Impacts Addressed
  - ☐ Life-Cycle Addressed as a Discreet Process Element
  - ☐ General Methods

  - Of the categories you consider important, if more than one, do you consider all of them equally important? Please check one.
    - ☐ Yes
    - ☐ No

    - If you selected "No", please rank them in order of importance, where 1 is highest priority (write "N/A" for a category that is unimportant):
      - _____ Life-Cycle Addressed
      - _____ Life-Cycle as a Discreet Process Element
      - _____ General Methods

  - Do you believe that either life-cycle thinking or life-cycle assessment is a better approach? Please check one.
    - ☐ Yes
    - ☐ No

    - If you selected "Yes", which one do you believe is better? Please check one
      - ☐ Life-Cycle Thinking
      - ☐ Life-Cycle Assessment

    - If you selected "No", do you believe both methods are useful or that neither is useful? Please check one.
      - ☐ Both are useful
      - ☐ Neither is useful

  - Is there a better method for evaluating the sustainability of a product that has not been listed? Please check one.
    - ☐ Yes
    - ☐ No

    - If you selected "Yes", please provide the name of the method and describe its qualities. Please answer in 6 sentences or less.

157. RIT. "What Is Life Cycle Assessment (LCA)? | Golisano Institute for Sustainability | RIT." www.rit.edu, 2 July 2020, www.rit.edu/sustainabilityinstitute/blog/what-life-cycle-assessment-lca.
158. Jacobs, Molly M., Timothy F. Malloy, Joel A. Tickner, and Sally Edwards. "Alternatives Assessment Frameworks: Research Needs for the Informed Substitution of Hazardous Chemicals." Environmental Health Perspectives 124, no. 3 (March 2016): 265–80. https://doi.org/10.1289/ehp.1409581.

7. Decision Analysis

Table 7 features big picture endpoints that Jacobs et al developed to categorize frameworks based on the sequence each one uses to make a decision about whether a chemical should indeed be used as a safer substitute. Jacobs et al identify four different categories of decision making: the decision function, the decision approach, decision tools or methods, and the weighting of decision criteria.

The decision function refers to the role that the alternatives assessment plays in the ultimate evaluation of alternatives. For some frameworks, the end goal is to provide a comparative list of trade-offs but do not offer a definitive ranking system or recommendation for selecting an alternative chemical to replace the hazardous one. Other frameworks offer more conclusive suggestions, while still others offer no discussion at all.

The decision approach touches on the order in which a decision is made. Some frameworks prescribe a specific order. This means that each step has a criteria that must be approved before moving to the next step otherwise the chemical is automatically rejected. Other frameworks consider everything simultaneously, allowing positive results to offset negative ones. There are also mixed frameworks that perform a mixture of the two.

This best practice review will itself be used to develop a decision approach. Depending on your answers, this review will ultimately recommend whether to use a sequential, simultaneous or mixed-methods approach.

Decision tools or methods are formal and informal aids that contribute to the decision and can be divided into three categories: narrative, structured and analytical. Narrative methods generally refer to using qualitative data, such as expert interviews, to inform a decision. Structured and analytical methods are different ways of supplementing narrative approaches, in one case structuring the narrative for a guided summary for the decision maker, and in the other offering mathematically based decision making systems such as multicriteria decision analysis (MCDA) to help guide the decision maker.

Once everyone in this panel has answered the questions in this survey, the person or people conducting this survey will report back the findings using a narrative, structured or analytical approach, or possibly a combination.

Weighting of decision criteria refers to different methods that might be used to prioritize elements of the analysis over others. This can include implicit weighting methods through sequential decision making, and explicit weight methods such as using quantitative weights when statistically analyzing the results.

Some of the questions in this survey will help guide whether it seems best to use implicit or explicit weighting methods when judging certain components, categories or endpoints.

Ultimately, there are 14 endpoints broken into four categories in decision making: decision function, decision approach, decision tools/rules, weighting. Please review each category and their respective endpoints, and answer the following questions:

- Are any of the **categories** unimportant when choosing a framework for evaluating whether a chemical can safely replace a hazardous one, specifically in semiconductor manufacturing? Please check all that are unimportant.
    - ☐ Decision Function
    - ☐ Decision Approach
    - ☐ Decision Tools / Rules
    - ☐ Weighting

    - Of the **categories** you consider important, if any, do you consider all of them equally important? Please check one.
        - ☐ Yes
        - ☐ No

        - If you selected "No", please rank them in order of importance, where 1 is highest priority (write "N/A" for a category that is unimportant):
            - _____ Decision Function
            - _____ Decision Approach
            - _____ Decision Tools or Methods
            - _____ Weighting or Decision Criteria

- Are there any **endpoints** that must be present when evaluating potential exposure of a chemical if the evaluation is to be considered effective? If so, please check all critical endpoints.

  Decision Function
  - ☐ Comparative
  - ☐ Selection/Ranking
  - ☐ None

  Decision Approach
  - ☐ Sequential
  - ☐ Simultaneous
  - ☐ Mixed (For screening--selection, type noted)
  - ☐ Menu (Where options are provided without expressing preference)
  - ☐ NA/NS (NA, not applicable because framework did not include a decision-making function; NS, nonspecified, meaning the framework did not discuss this dimension)

  Decision Tools / Rules
  - ☐ Narrative Alone
  - ☐ Structural
  - ☐ Analytical
  - ☐ NA/NS

  Weighting
  - ☐ Addressed
  - ☐ Method

- If there is more than one **endpoint** that must be present, are all of these critical endpoints equally important? Please check one
  - ☐ Yes
  - ☐ No

    - If you selected "No", please list them in order of importance.

- If there are endpoints that could be omitted, please list them:

- If there are any **endpoints** or **categories** that you believe should be included that have not been, please list and describe them in 6 sentences or less.

8. Overall Framework

Now that we have carefully reviewed the individual criteria laid out by Jacobs et al, please answer the following questions:

- Do you believe any of the core components are unimportant when choosing a framework for evaluating whether a chemical can safely replace a hazardous one, specifically in semiconductor manufacturing? Please check all that are unimportant.
    - ☐ Hazard Assessment Endpoints
    - ☐ Technical Feasibility Assessment Characteristics
    - ☐ Economic Assessment Attributes
    - ☐ Purpose of Exposure Characterization
    - ☐ Exposure Characterization Attributes
    - ☐ Addressing Chemical Life-Cycle Impacts
    - ☐ Decision Analysis

    - Of the components you consider important, if any, do you consider all of them equally important? Please check one.
        - ☐ Yes
        - ☐ No

        - If you selected "No", please rank them in order of importance, where 1 is highest priority (write "N/A" for a category that is unimportant):
            - _____ Hazard Assessment Endpoints
            - _____ Technical Feasibility Assessment Characteristics
            - _____ Economic Assessment Attributes
            - _____ Purpose of Exposure Characterization
            - _____ Exposure Characterization Attributes
            - _____ Addressing Chemical Life-Cycle Impacts
            - _____ Decision Analysis

- Out of all the components, are there any that must be present when choosing a framework for evaluating whether a chemical can safely replace a hazardous one, specifically in semiconductor manufacturing? If so, please list them:

    - Of the components you consider important, if any, do you consider all of them equally important? Please check one.
        - ☐ Yes
        - ☐ No

        - If you selected "No", please list them in order of importance:

- Are there any components that you believe should be included that have not been? If so, please provide a list of additional components and describe each, in 6 sentences or less.

- Do you have any additional thoughts you wish to share?