U.S. Chamber of Commerce

Impacts of the PFAS Restriction on Trade Between the U.S. and the European Union

Evaluation of PFAS applications across U.S. industries

September 2023

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Executive Summary

The U.S. Chamber of Commerce ("USCC") engaged third party experts in economic and environmental modeling to estimate the potential economic, fiscal, and environmental impacts of a ban on traded goods containing perfluorinated and polyfluorinated alkyl substances ("PFAS") between the U.S. and the European Union ("EU"). PFAS are a large and diverse group of manmade chemicals found in many industrial, commercial, and consumer goods and are considered economically and practically critical for many sectors across the U.S. economy including the manufacturing sector, national security, and public safety.

These experts helped identify the economic sectors most exposed to a potential EU ban on the import and export of goods containing PFAS ("the PFAS Restriction") proposed by the European Chemicals Agency's ("ECHA") Registration, Evaluation, Authorization, and Restriction of Chemicals ("REACH") program.[1] Many sectors rely on PFAS due to the chemistries' unique properties, such as durability and heat, water, and oil resistance. Many products critical to modern society —including aircraft, automobiles, semiconductors, and medical equipment — cannot be produced without these chemistries as there are no feasible or economic PFAS replacements. The PFAS Restriction, therefore, would have significant negative impacts on the operations, business models, and supply chain dynamics in those sectors and others.

This report, using economic, environmental, and international trade data from 2022 as a reference year, evaluates the immediate economic impacts to the U.S. and near-term environmental consequences of potential EU regulation enforcing the PFAS Restriction. The economic assessment evaluates the immediate impacts on the U.S. economy, prior to any substitution of U.S. trading partners for goods currently traded with the EU. In comparison, the environmental assessment evaluates the near-term global emissions impact, which may occur after an eventual substitution of U.S. trading partners. Lastly, this report concludes with case study examples of PFAS applications across a sampling of six U.S. industry sectors that would be significantly impacted by the PFAS Restriction.

Our analysis relied on the USA. Trade Online's 2022 data for trade between the U.S. and the EU to determine the scope of the economic and fiscal impacts. This data is hosted by the U.S. Census Bureau and is categorized by economic sector. We defined a comprehensive list of economic sectors that are critically reliant on PFAS for the products they manufacture. The total value of U.S. trade with the EU for each identified sector was adjusted based on the proportion of goods produced in each sector which would be subject to the proposed PFAS Restriction, or the value "at-risk" within each sector.

Table 1 summarizes the total economic and fiscal impacts of goods exported from the U.S. to the EU that contain PFAS in 2022 and are at-risk. This activity supported 502,000 jobs domestically in 2022, $168 billion in sales output, $81 billion in U.S. gross domestic product ("GDP"), and $46 billion in labor

[1] ECHA defines PFAS as "any substance that contains at least one fully fluorinated methyl (CF3-) or methylene (-CF2-) carbon atom (without any H/Cl/Br/I attached to it)."
https://echa.europa.eu/nl/registry-of-restriction-intentions/-/dislist/details/0b0236e18663449b#:~:text=Per%2D%20and%20polyfluoroalkyl%20substances%20(PFASs,%2FI%20attached%20to%20it).

income. Additionally, the activity generated $12 billion in federal tax revenues and $7 billion in state and local tax revenues.

Table 1 – Total economic and fiscal impacts of goods exported from the U.S. to the European Union that contain PFAS in 2022

Metric	Total Impacts	Unit
Employment	502,000	Jobs (units)
Output	$168	2022 USD (billions)
GDP	$81	2022 USD (billions)
Labor Income	$46	2022 USD (billions)
Federal Tax Revenues	$12	2022 USD (billions)
State and Local Tax Revenues	$7	2022 USD (billions)

The U.S. and EU have the largest bilateral trade and investment relationship. The value of U.S. exports to the EU was $329 billion in 2022, while imports from the EU totaled $553 billion. The sector with the highest value of exports was oil and gas extraction, valued at $68 billion, followed by pharmaceuticals and medicines, valued at $29 billion. The sectors with the highest value of imports were pharmaceuticals and medicines, valued at $111 billion, and motor vehicles, valued at $37 billion. The pharmaceutical and automobile sectors, among others, rely heavily on PFAS applications in their respective manufacturing processes and value chains.

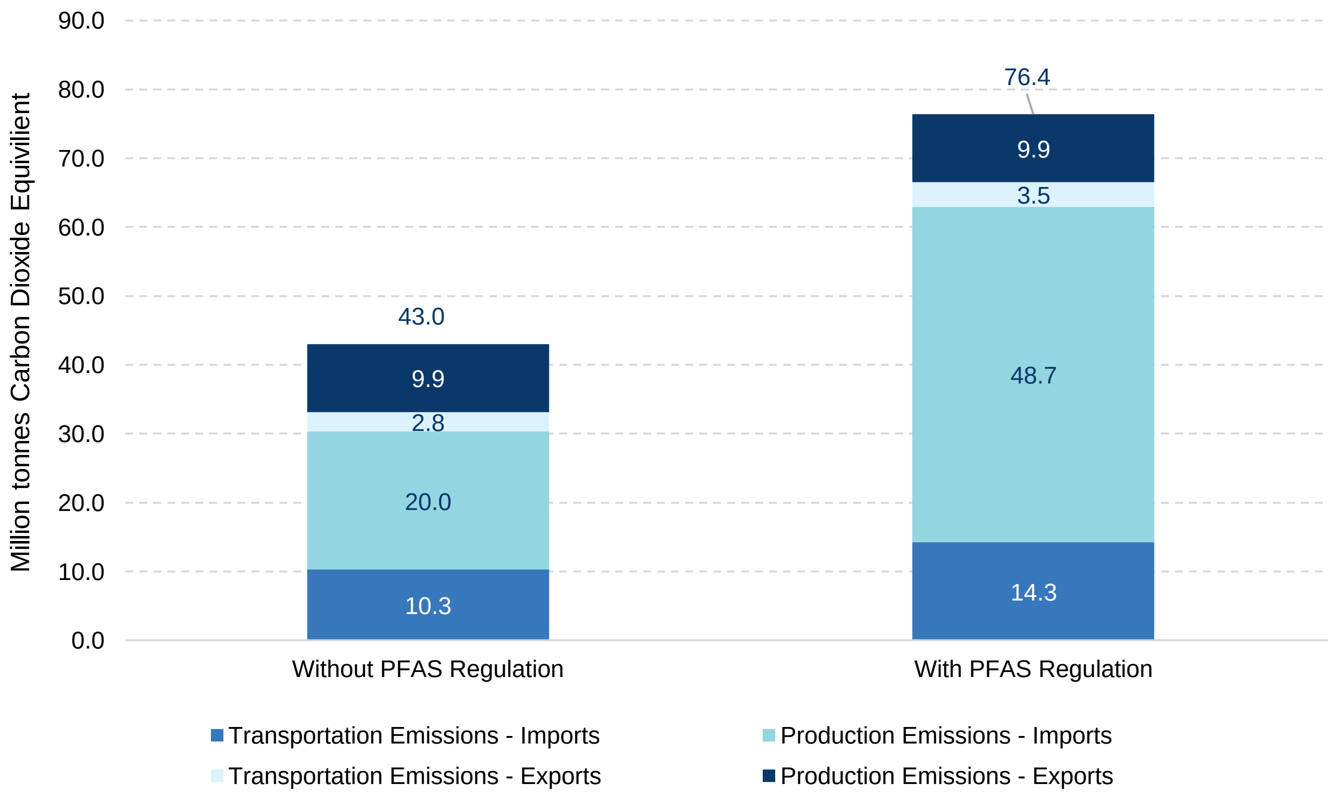
The proposed ECHA PFAS Restriction would significantly disrupt global trade and likely result in the need for the U.S. to seek alternative trading partners. In comparison to other significant U.S. trading partners, the EU is a relatively low emitter of greenhouse gas emissions (“GHGs”) in terms of emission intensity of goods produced. The average emission intensity of goods produced by the U.S.'s top 15 non-EU trading partners is more than double that of the EU. Additionally, the shipping distance between the U.S. and the EU is less than the shipping distance between the U.S. and most other trading partners that could feasibly provide alternative sources of potentially lost imports from the EU. The short-term substitution of trading partners would therefore result in greater shipping distances and increased transportation emissions.

In a scenario where the U.S. replaces trade with the EU with alternative trading partners, the production emissions associated with U.S. imports would increase from 20.0 to 48.7 million tonnes of carbon dioxide equivalent (“CO_2e”), or by 144%. Additionally, the emissions associated with the transportation of U.S. imports would increase from 10.3 to 14.3 million tonnes of carbon dioxide equivalent, or by

38%. In total, the emissions increase from the lost imported goods from the EU would rise by 108%. Under the assumption that the U.S. can substitute trading partners for 100% of U.S. exports exposed to the PFAS Restriction, the production emissions associated with U.S. manufacturing of exported goods would remain unchanged. However, the emissions associated with the transportation of exported goods to alternative trading partners would result in an estimated increase in global emissions from 2.8 to 3.5 million tonnes of CO_2e or 25%.

In total, the estimated combined emissions associated with U.S. import and export activity within sectors that would be impacted by the proposed PFAS Restriction are estimated to nearly double, from 43.0 million to 76.4 million tonnes of carbon dioxide equivalent. ES 1 summarizes the emissions from these activities.

ES 1 – Global emissions impacts of the proposed PFAS Restriction, 2022



Introduction and Context

PFAS substances are a group of manmade chemistries used in industrial and consumer products across many sectors of the economy, including those critical to national security and public safety. PFAS chemistries are highly resistant to heat, oil, and water, making them extremely durable and functional across many applications. PFAS substances are critical in many industries, including transportation (e.g.,automobile, aerospace, rail), military and defense, chemical production, semiconductor, electronics, and protective gear manufacturing. There are currently no feasible substitutes for PFAS in these applications, as well as many others, resulting in an economic dependence on these chemistries across the supply chain.

Fluoropolymers, which contain PFAS, are a specialty plastic and ideal for and often irreplaceable in certain manufacturing applications due to their non-stick properties, chemical resistance, high resistance to heat and friction, low electrical conductivity, and water-repellent characteristics. In 2022, the global market value of fluoropolymers totaled $8 billion.[2] The vast majority of fluoropolymers meet the internationally recognized criteria for being considered polymers of low concern ("PLC"), a characterization that is reserved for compounds which are expected to have immaterial environmental and human health impacts.[3] While some research has suggested that certain types of PFAS could pose environmental and health risks, the U.S. Centers for Disease Controls and Prevention ("CDC") has acknowledged that more research is necessary to determine the comprehensive effects of PFAS exposure.[4]

A ban on goods containing PFAS between the U.S. and EU could impede the implementation of the bipartisan CHIPS and Science Act, which is intended to bolster domestic semiconductor manufacturing, design, and research.[5]

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[2] https://www.futuremarketinsights.com/reports/fluoropolymers-market#:~:text=The%20fluoropolymer%20market%20is%20estimated,6%25%20during%20the%20forecast%20period.

[3] https://urldefense.com/v3/__https://doi.org/10.1002/ieam.4035__;!!NdqAjiViAO0!MZjWm9RnUBPvfB4fAZe4JtW0JD4IQj4bRRF0fd5ie_R4A6GG6nvirSA-kGMd_9GocLwnieU0Fidd9JdB9udAmwFBnaJjwQ$, https://urldefense.com/v3/__https://doi.org/10.1002/ieam.4646__;!!NdqAjiViAO0!MZjWm9RnUBPvfB4fAZe4JtW0JD4IQj4bRRF0fd5ie_R4A6GG6nvirSA-kGMd_9GocLwnieU0Fidd9JdB9udAmwG1xUWyDg$

[4] https://www.cdc.gov/biomonitoring/PFAS_FactSheet.html

[5] https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/09/fact-sheet-chips-and-science-act-will-lower-costs-create-jobs-strengthen-supply-chains-and-counter-china/

PFAS are used in the production of a variety of consumer, commercial, and industrial products, which support crucial sectors of the economy, such as:

- Many pharmaceutical drugs may contain PFAS, including fluoxetine, which is a primary component of Prozac, and sitagliptin, which is used to treat diabetes. Prozac is widely used as a pharmaceutical treatment for depression, with approximately 23 million prescriptions for the drug being filled annually in the United States.[6,7]
- Many medical devices use PFAS due to its anti-adhesive properties. Applications include catheters, wound treatment products, surgical meshes, and much more. Metered- dose inhalers are a particular device that relies on PFAS in its propellant and coating to function properly.[8]
- In aircrafts, PFAS are a critical component of hydraulic systems, which are used for cargo doors, landing gear, brakes, and more. It is estimated that developing a substitute for PFAS used in aviation could take more than 5 years.[9]
- PFAS are used in many areas of the aerospace and defense industry, including propellant systems, surface coatings, turbine-engines, and more. Alternatives to PFAS in this industry will not be available in a short time frame due to the need for regulatory approval for safety purposes.[10]
- PFAS are a critical component of the semiconductor industry, specifically, in the manufacturing of microchips. Currently, there are no viable replacements for this application on the market. [11]
- PFAS are commonly applied to water-resistant textiles used for both consumer and technical purposes, found in 72% of textiles labelled water- or stain-resistant. Substitutes for PFAS components are not feasibly available for most technical textiles, a component of many cars and medical supplies, including those with applications within critical areas such as the national security and public safety.[12]
- Among types of protective gear, such as firefighting or military uniforms, PFAS are a necessary component. Currently, PFAS are the only option for manufacturing firefighter gear that is approved by the National Fire Protection Association.[13]
- Fluorinated gasses are a type of PFAS which are used as refrigerants in indoor and vehicular air conditioning systems, as well as space heating and heat pumps. They are used as a replacement for ozone-depleting substances and more emissions-intensive alternatives, contributing to the transition to low global warming potential gases which can avoid up to 0.5 degrees Celsius in future warming.

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[6] https://www.efpia.eu/media/1oeldyty/efpia-ahe-pfas_position_june-2023-final.pdf
[7] https://clincalc.com/DrugStats/Drugs/Fluoxetine
[8] https://www.americanchemistry.com/chemistry-in-america/chemistries/fluorotechnology-per-and-polyfluoroalkyl-substances-pfas/pfas-critical-to-21st-century-healthcare
[9] https://echa.europa.eu/documents/10162/57812f19-8c98-ee67-b70f-6e8a51fe77e5
[10] Ibid.
[11] Ibid.
[12] https://toxicfreefuture.org/research/pfas-in-stain-water-resistant-products-study/
[13] https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1971

Potential trade restrictions on PFAS-containing products between the U.S. and EU pose significant societal, economic, and environmental risks. The U.S. and EU are major trading partners, with the U.S. exporting $329 billion and importing $553 billion worth of goods from the EU in 2022. The EU is the second-largest trading partner for the U.S. regarding imports and exports, after China and Canada, respectively. In 2022, the U.S. was the most significant export trading partner of the EU. Figure 1 displays the total trade volume and the highest traded sectors between the U.S. and the EU in 2022.

Figure 1 - Top sectors traded between the U.S. and the EU in 2022

This report evaluates the economic and environmental impacts of the proposed PFAS Restriction between the U.S. and EU in 2022. It includes an economic analysis of goods exported from the U.S. to the EU containing PFAS, environmental consequences of prohibiting U.S. imports from the EU, and critical examples of PFAS applications. The analysis will include the 50 U.S. states plus the District of Columbia ("DC").

Methodology and Approach

This section documents the overall methodology and approach used to determine the economic contribution good containing PFAS on U.S. trade with the EU. It includes an overview of input-output ("IO") models, the data used in the analysis, and the steps taken to determine the results.

Data Gathering

The Chamber's experts conducted detailed research regarding the use of PFAS across different economic sectors. The following sources provided the primary information regarding PFAS applications across various products and sectors.

- USA Trade Online ("USTO")[14]
  - USTO is a database maintained by the U.S. Census Bureau, which houses data on U.S. international trade by economic sector, state, and foreign trading partner.
  - For example, USTO provides the value of exports from the pharmaceutical industry from the U.S. nationally to France for 2022.
  - This study sourced all trade related data from USTO.
- World Bank[15]
  - The World Bank is an international development organization that works to stimulate developing nations' economies through loan initiatives and improve living standards worldwide. The World Bank collects and stores various types of economic data.
  - This study relied on 2022 GDP data by country from the World Bank for the U.S.'s top trading partners.
- Environmental Protection Agency ("EPA")[16]
  - The EPA is the federal agency in the U.S. in charge of environmental and health protection regulations. The EPA houses emission factors used to calculate total emissions for various industries, applications, and goods.
  - This study relied on the emission factors for air and shipping vessels to calculate the transportation-related emissions associated with U.S. imports.
- European Chemicals Agency ("ECHA")[17]
  - ECHA is a European Union agency implementing legislation regarding Europe's chemical industry.
  - The ECHA published a "Proposal for the Restriction of PFASs,"[18] which describes the use of PFASs, the current availability of substitutes, and the impact of a total ban on each sector.

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[14] https://usatrade.census.gov/
[15] https://data.worldbank.org/indicator/NY.GDP.MKTP.CD
[16] https://www.epa.gov/
[17] https://echa.europa.eu/
[18] https://echa.europa.eu/documents/10162/57812f19-8c98-ee67-b70f-6e8a51fe77e5

This information is primarily gathered through accredited stakeholder organizations, independent research studies, and market reports from other government agencies.

  - Research regarding many critical use PFAS applications and replacement feasibility was sourced from ECHA.

- Climate Watch
  - Climate Watch is an online platform that provides open climate data, visualizations, and resources. The platform aims to increase transparency and accountability in combating climate change.
  - This study used Climate Watch to access emissions data by country for the U.S.'s top trading partners.

Along with these sources, the Chamber's experts relied on various other reports, research studies, and industry reviews to define the sectors and percentage of at-risk trade impacted by the proposed PFAS Restriction.

Input-Output Modeling

In the 1950s and 1960s, economists developed the first "input-output" or "IO" models of national economies, though the concept itself dates to the late Eighteenth Century without mathematic rigor. IO models represent an economy as a table accounting for all economic transactions between buyers (e.g., consumers) and sellers (e.g., stores).

These transactions can take many forms. The three main categories include:

- *Households/Businesses* – Households sell their labor to earn wages and salaries. Businesses receive household income in the form of consumer expenditures.
- *Private Sector/Public Sector* – Private households and businesses pay the public sector through taxes. The public sector then expends revenues through public expenditures, like building a road or bridge, or through transfer payments back to households.
- *Businesses/Businesses* – Businesses transact between one another throughout the industrial supply chain. For instance, a rubber manufacturer sells materials to a tire manufacturer. The tire manufacturer then creates a tire and sells it to an automobile manufacturer. The multiple steps and linkages in the supply chain are through these transactions.

The IO methodology won one of its main progenitors, Wassily Leontief, the Nobel Prize in 1973.[19] IO models have become a standard tool for analyzing the impacts of public policy, investments, for the understanding of industrial supply chains, and the impact of new technologies.

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[19] https://www.nobelprize.org/prizes/economic-sciences/1973/press-release/

IMPLAN Model Overview

IMPLAN is a leading provider of commercial IO models with its namesake "IMPLAN model." IMPLAN is an IO model of regional and national economies, such as the economy of the U.S., Canada, European nations, and other developed economies globally.[20]

Key Outputs

The economic and fiscal impacts of PFAS related exports are estimated for 2022 for U.S. exports to the EU. IMPLAN produces six main metrics, which are defined as the following:

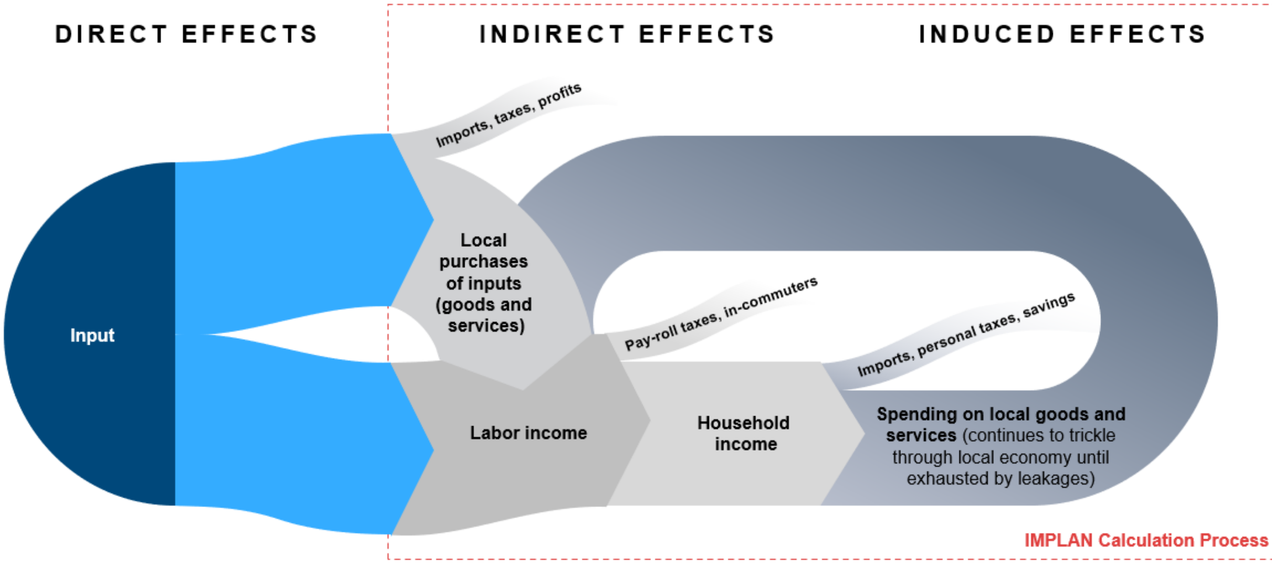
1. *Employment* – the number of jobs supported.
2. *Output* – the revenues of businesses associated with PFAS production or use.
3. *GDP* – the sum of all income related to production.
4. *Labor Income* – the household income supported by PFAS production or use.
5. *Federal Tax Revenues* – incremental tax revenues for the federal government because of higher levels of economic activity, such as higher income tax payments.
6. *State and Local Tax Revenues* –incremental tax revenues for state and local governments because of higher levels of economic activity, such as higher property tax payments.

Direct, Indirect, and Induced Impacts

IMPLAN illustrates how a direct change in employment or expenditures, the "direct" impact, will then influence the rest of the economy. IMPLAN describes these "ancillary" or "ripple" effects through its "indirect" and "induced" multiplier effects as shown in Figure 2:

[20] https://support.implan.com/hc/en-us/articles/12150245873435-2015-International-Product-Release-Notes

Figure 2 – IMPLAN flowchart



The types of IMPLAN effects are defined as the following:

- *Direct Effect* – The direct effect is the direct employment or output associated with PFAS production or use. Examples might include semiconductor manufacturers or automobile assembly line workers.
- *Indirect Effect* – The indirect effect is the impact on the regional or national supply chain. For instance, equipment and material inputs might be used in another sector after first being produced by an initial sector from the raw materials produced by the agriculture or resource sectors. Other sectors, such as utilities or the many professional services and business services needed to operate an enterprise, can also have indirect impacts.
- *Induced Effect* – The induced effect is the consumer expenditures supported by the wages paid to the employees of the direct and indirect economic sectors.
- *Total Effect* – The total effect is the sum of the direct, indirect, and induced impacts.

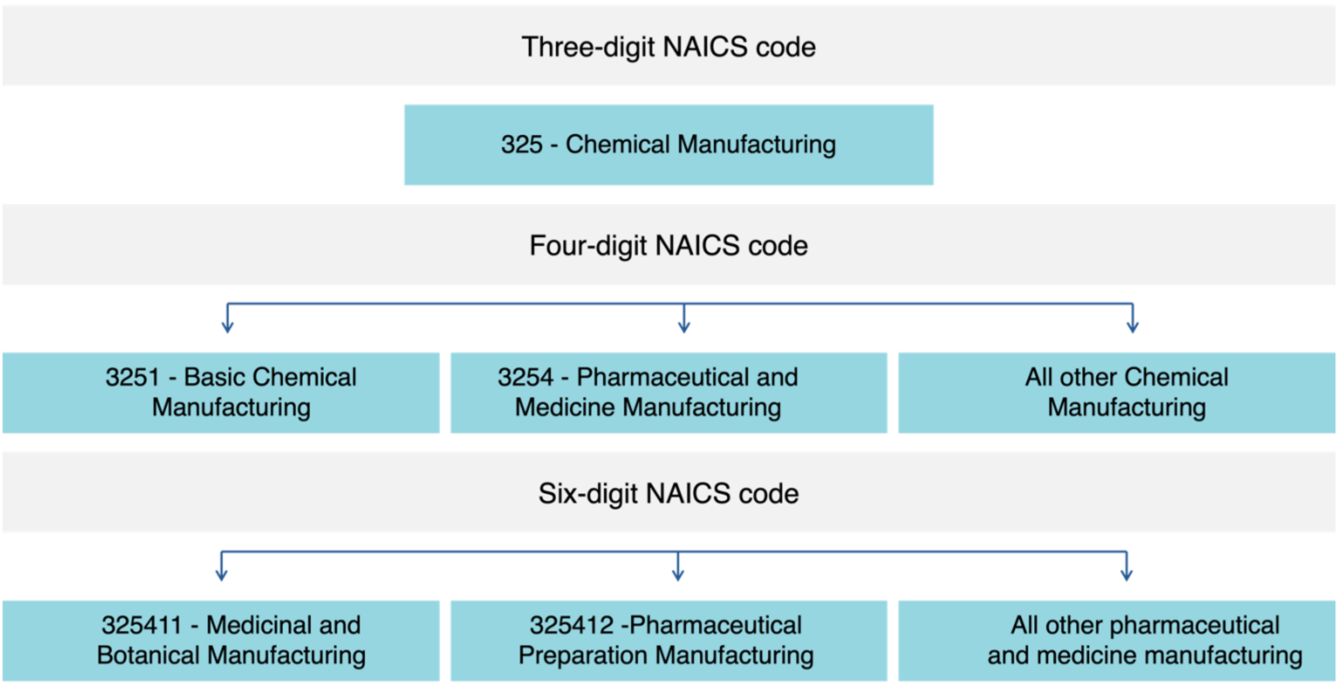
Analyzing USA Trade Online Data

The Chamber's experts used trade data from USTO to analyze the economic and fiscal effects of exporting goods containing PFAS from the U.S. to the EU in 2022. USTO stores data by North American Industry Classification System ("NAICS") code.[21] NAICS is the standard classification system for U.S. businesses and has varying granularity levels depending on the number of digits. NAICS codes define businesses by their broader economic sector. The codes are defined as up to six digits, with each digit representing an additional level of detail. For categorization and reporting purposes, federal economic data is often reported at the four-digit NAICS code level.

[21] https://www.census.gov/naics/

For example, manufacturing businesses are defined by NAICS codes that start with 31, 32, or 33. Chemical Manufacturing has a subsector code of 325, and all industries under chemical manufacturing, including Pharmaceutical and Medicine Manufacturing with a code of 3254, start with 325. The specific sector is defined by an extra two digits at the end. This example hierarchy is visualized in Figure 3.

Figure 3 – Example of NAICS code hierarchy



The trade data exported from the USTO database is categorized by a four-digit NAICS code, which does not provide the highest level of detail categorization, as seen in Figure 3. IMPLAN published a bridge from the IMPLAN sectors to the six-digit NAICS code, which was adapted to create a comprehensive bridge between the four-digit NAICS code and the 546 IMPLAN.[22] This bridge allowed the at-risk trade to be defined according to the IMPLAN sectors.

In many cases, multiple NAICS codes map to a single IMPLAN sector. The USTO data includes 112 four-digit NAICS codes, while the U.S. IMPLAN model contains 546 sectors. To adjust for this overlap, The Chamber's experts relied on NAICS code company counts at the four-digit to calculate weighted averages of NAICS codes by IMPLAN sector. This process allows the results to be defined by IMPLAN sectors while still being comprehensive of NAICS code data.

Developing Modeling Inputs

The Chamber's team conducted detailed research to determine the total value of at-risk trade between the U.S and the EU due to the PFAS Restriction. This process involved identifying primary PFAS-containing products in each sector, estimating the proportion of U.S. export value associated with them,

[22] https://support.implan.com/hc/en-us/articles/10473981710619-546-Industries-Conversions-Bridges-Construction-2021-Data

and assessing the feasibility of replacing these products with alternatives that do not intentionally add PFAS.

Each sector affected by the proposed PFAS Restriction was assigned a percentage of trade at-risk based on the above research. Sectors entirely reliant on PFAS and lacking feasible alternatives are assigned a 100% risk, meaning all trade would be impacted. For example, evidence suggests no feasible alternatives for PFAS use in the semiconductor industry exist. It is expected that no substitutes for these applications would be widely deployed and adopted for the next 15 years.[23] As a result, all trade involving semiconductors is banned due to a 100% risk assessment of the sector.

For sectors with more complex PFAS reliance or where adequate data was not available to define the sector's percentage of trade at-risk, the Chamber's experts referred to IMPLAN's bridge to six-digit NAICS codes. This bridge contains the relevant NAICS descriptions mapped to each IMPLAN sector. The Chamber's experts identified all applicable PFAS reliant products under each IMPLAN ID to estimate the percentage at-risk for these sectors.

For example, PFAS are commonly used in water-resistant or waterproof garments within the textile industry. A 2022 study found 72% of products labeled as "stain- or water-resistant" contained PFAS. Using this information, all products in the NAICS-IMPLAN bridge that manufacture stain or water-resistant products were assigned a 72% risk assessment due to the PFAS Restriction.[24]

For each sector, the proportion of trade value within each sector that would be exposed to the PFAS Restriction was estimated by the Chamber's team based on publicly available data, market research, and industry feedback. Where data was unavailable, all products were evenly weighted in their parent IMPLAN sector. For example, if an IMPLAN sector were associated with 10 NAICS descriptions, each description would be assigned a 10% weight. If three of these descriptions were defined to be entirely reliant on PFAS, two descriptions were 50% reliant, and the remaining five were not reliant on PFAS, then the total sector impact would be 40%.[25] This process was repeated for each of the at-risk sectors. The final sector and percentages at-risk were applied to total U.S. exports to the EU to develop value inputs for the IMPLAN model.

This process resulted in the identification of 59 potentially impacted IMPLAN sectors, representing a total export value of $76 billion. The identified sectors included in this analysis are not comprehensive of all PFAS applications found in traded goods between the U.S. and the EU. However, they highlight the societal reliance and omnipresence of these chemicals across the economy, representing over 20% of total U.S. export value in 2022. The individual sectors were categorized into 12 parent sectors, summarized in Table 2 below.

[23] https://www.semi.org/en/blogs/semi-news/fluorinated-chemicals-are-essential-to-semiconductor-manufacturing-and-innovation
[24] https://toxicfreefuture.org/research/pfas-in-stain-water-resistant-products-study/
[25] (10%*100%*3) + (10%*50%*2) + (10%*0%*5) = 40%

Table 2 – Value of economic sectors exposed to the proposed PFAS Restriction, 2022 (USD millions)

Sector	Total export value	At-risk export value
Chemicals	$15,701	$473
Plastics	$7,608	$2,853
Industrial gasses	$4,347	$269
Consumer products	$3,758	$1,113
Aircraft	$24,817	$24,817
Automobiles	$12,148	$12,070
Semiconductors	$8,402	$8,402
Medical	$30,979	$10,205
Electronics	$7,991	$7,460
Defense	$4,289	$4,289
Machinery	$4,985	$3,798
Textiles	$5,794	$383

Defining environmental impacts

Under the PFAS Restriction between the U.S. and the EU, the U.S. would need to find substitute trading partners for the at-risk imports and exports. This would result in changes in global greenhouse gas ("GHG") emissions related to two primary sources. First, production-related impacts for goods imported into the U.S. would change due to varying emission intensities by country. Second, transportation-related emissions of imports and exports would be impacted due to different shipping distances between the U.S. and alternative trading partners. The Chamber's experts' analysis relies on the assumptions summarized below in Table 3.

Table 3 - Emissions impact assumptions

Category	Assumption
Trade assumptions	All trading alternatives are defined under a static model of the economy, which does not consider dynamic responses to market activity in the short term.
	There are no supply constraints in trading with different countries. All goods the U.S. previously imported from the E.U will be replaceable in the same quantity, cost, and time frame from other countries.
	There are no price impacts of trading with different countries. All goods the U.S. previously imported from the EU will be replaceable at the same price from other countries.
	In the short term, the U.S. does not increase domestic production to offset the goods previously imported from the EU.
	There are no offsetting effects between goods exported/imported from the EU.
Production-related assumptions	Each country has an average production-related emission factor.[26]
	The conversion from GDP to economic output was calculated for each country using an average conversion factor of 175%.[27]
Transportation-related assumptions	Each country has a single port of origin for all traded goods with the U.S.
	Either shipping by ship or air transportation is used for all shipments.
	Intercountry travel to shipping ports is not accounted for and is assumed to be immaterial.
	Shipping into the U.S.is equally allocated between the east and west coat.

To quantify the production related emissions of the $132 billion of imports at-risk, The Chamber's experts derived average emission factors by output and country for the EU and the 15 non-EU import trading partners representing the highest trade value with the U.S.. Economic output data is not publicly available for many international countries, so country specific GDP was used to estimate country specific economic output. All GDP data for 2022 was sourced from the World Bank and total emissions by country were sourced from Climate Watch.[28]

[26] Each country's average production-related emission factor is applied to each sector as a simplifying assumption
[27] The ratio between economic output and GDP in the U.S, sourced from IMPLAN 2022 Study Area Data Statistics
[28] https://www.climatewatchdata.org/ghg-emissions?calculation=PER_GDP&end_year=2020&source=Climate%20Watch&start_year=1990

The Chamber's experts then applied the value of imports at-risk by the average emission factor for the EU to calculate total production-related emissions under the business-as-usual scenario.

Using USTO import data by country and NAICS code, weighted average emission factors were then developed and applied against the total value of imports at-risk by NAICS code to calculate the associated emissions.

To calculate transportation-related emissions of the imported goods at-risk of the PFAS Restriction, the Chamber's experts first estimated the total weight and value of the goods under two scenarios: business-as-usual where all trade is between the U.S. and the EU, and under an updated scenario where the U.S. trades the at-risk goods with its top 15 non-EU trading partners.

The Chamber's experts analyzed the total value and weight of goods traded between the EU and top 15 non-EU partners using USTO data. Weighted averages of dollars per kilogram were calculated by NAICS code and country. The total weight of goods imported by NAICS code was then determined for each scenario. The direct mileage was also calculated for the Port of Los Angeles and the Port of New York and New Jersey from the EU and the top 15 non-EU trading partners.[29]

The team calculated the total weight of trade by air or ship. Weighted averages were calculated by country, NAICS code, and transportation method for 2022 under both scenarios using USTO trade data.

The total tonnes and mileage for each scenario were used to calculate the total ton-miles. EPA emission factors were then applied to this data for vessel and air transportation to calculate the associated transportation-related emissions.

[29] https://www.porttechnology.org/news/the-top-5-ports-in-the-united-states/

Main Findings

Economic Impact Results in the United States

This section describes the potential economic and fiscal impacts at-risk of the PFAS Restriction between the U.S. and the EU on the 50 states and DC in 2022.

Output and GDP

In total, the economic activity at-risk of a PFAS Restriction would total $168 billion of economic output in the U.S. economy as shown in Figure 4 below. Direct, indirect, and induced output impacts would amount to $59 billion, $61 billion, and $49 billion, respectively.

Additionally, the total U.S. GDP impacts at-risk equals $81 billion, shown in Figure 4 below. Direct, indirect, and induced GDP impacts would amount to $24 billion, $29 billion, and $28 billion, respectively.

Figure 4 – Output and GDP impacts

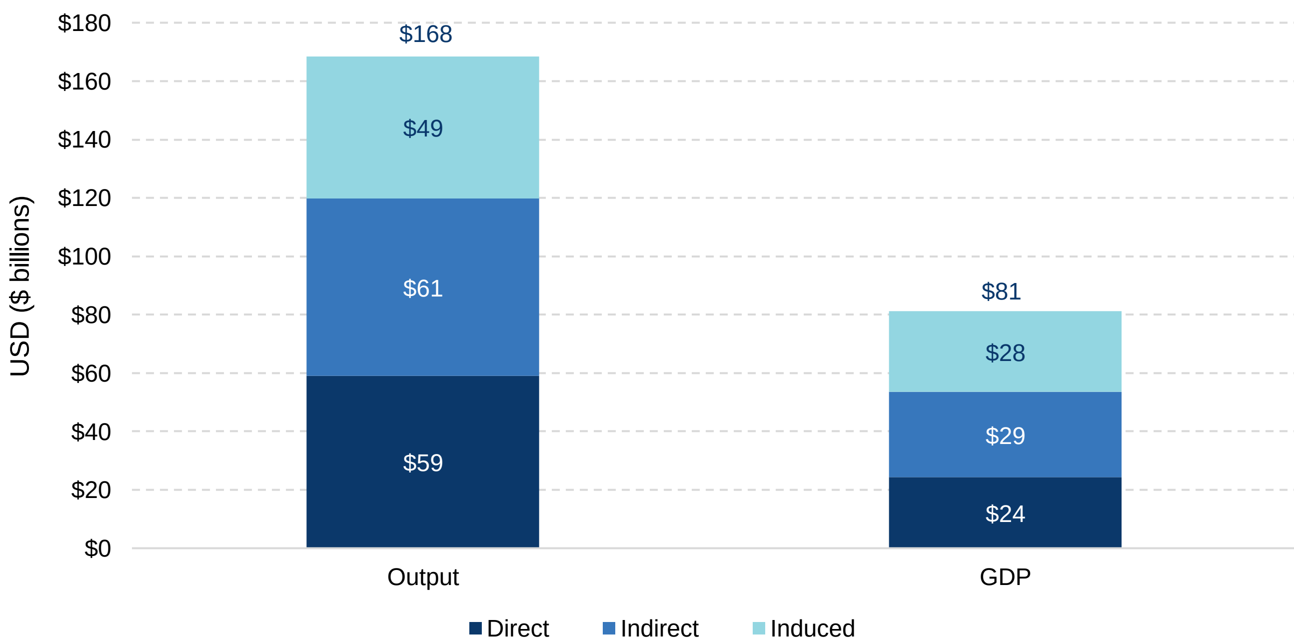
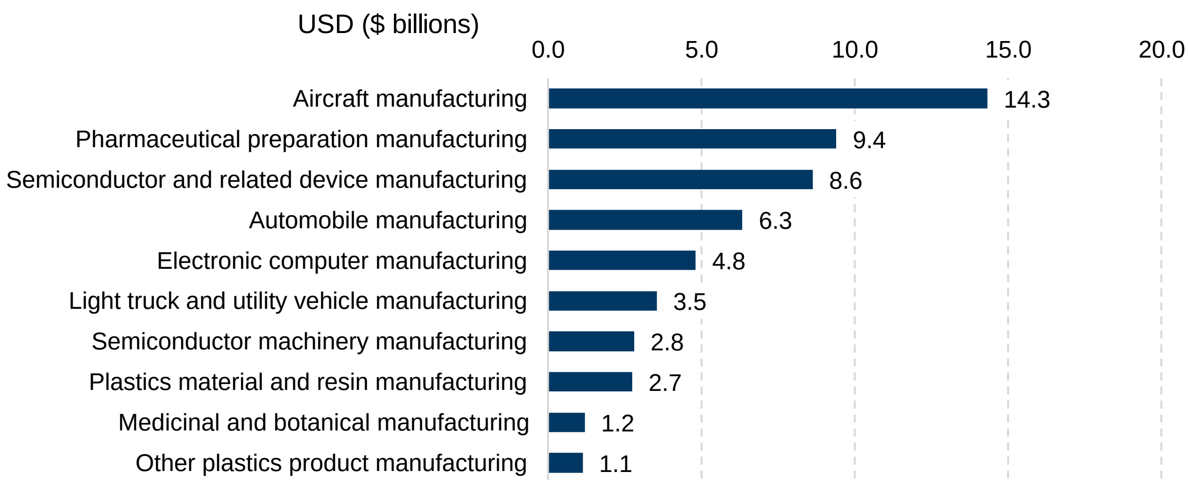


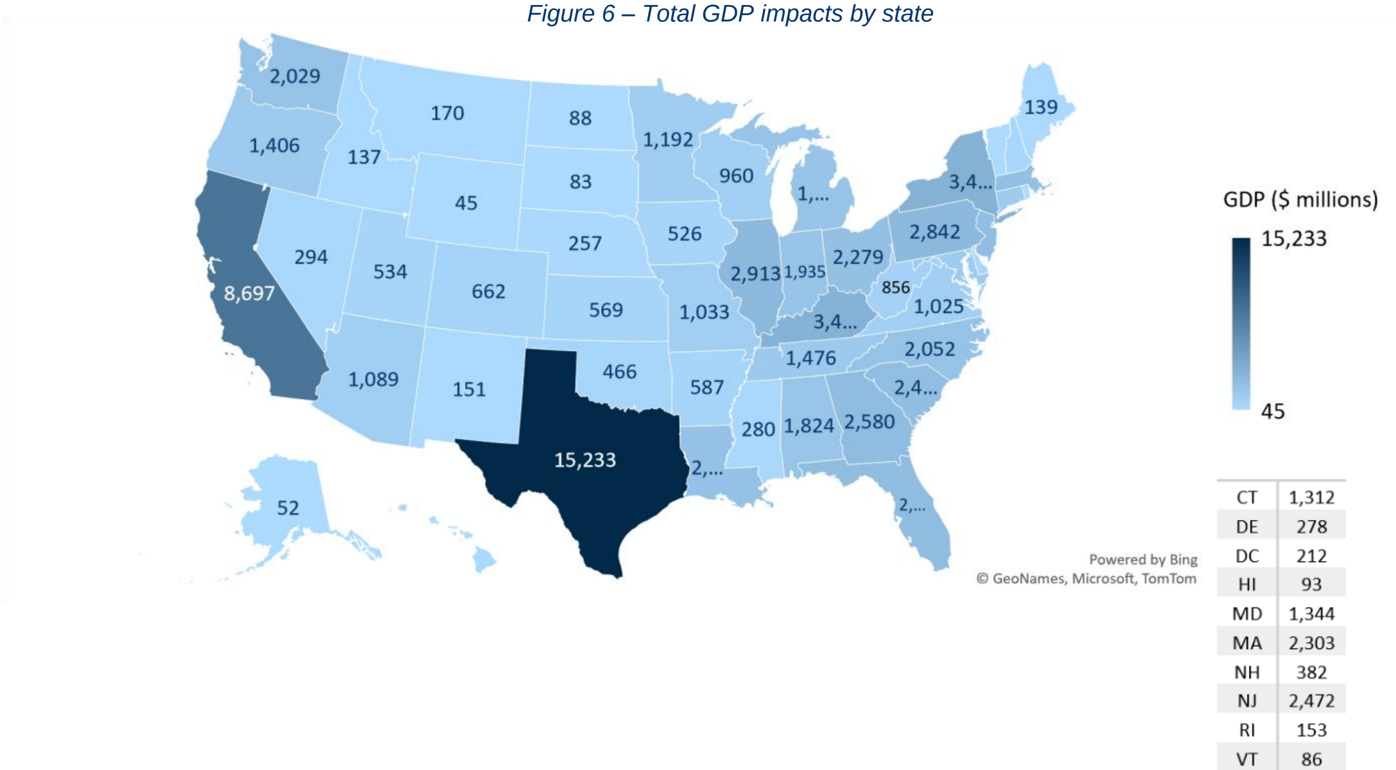
Figure 5 below summarizes the sectors most impacted by the PFAS Restriction in terms of economic output. These sector impacts are compared to employment impacts below in Figure 8.

Figure 5 – Top 10 most impacted sectors by output



Total GDP impacts are distributed across all states plus DC, as summarized inFigure 6. The states with the highest impacts are Texas and California, followed by, New York, Kentucky, and Illinois. GDP is generally proportional to economic output, so states with larger economies have larger impacts, on average.

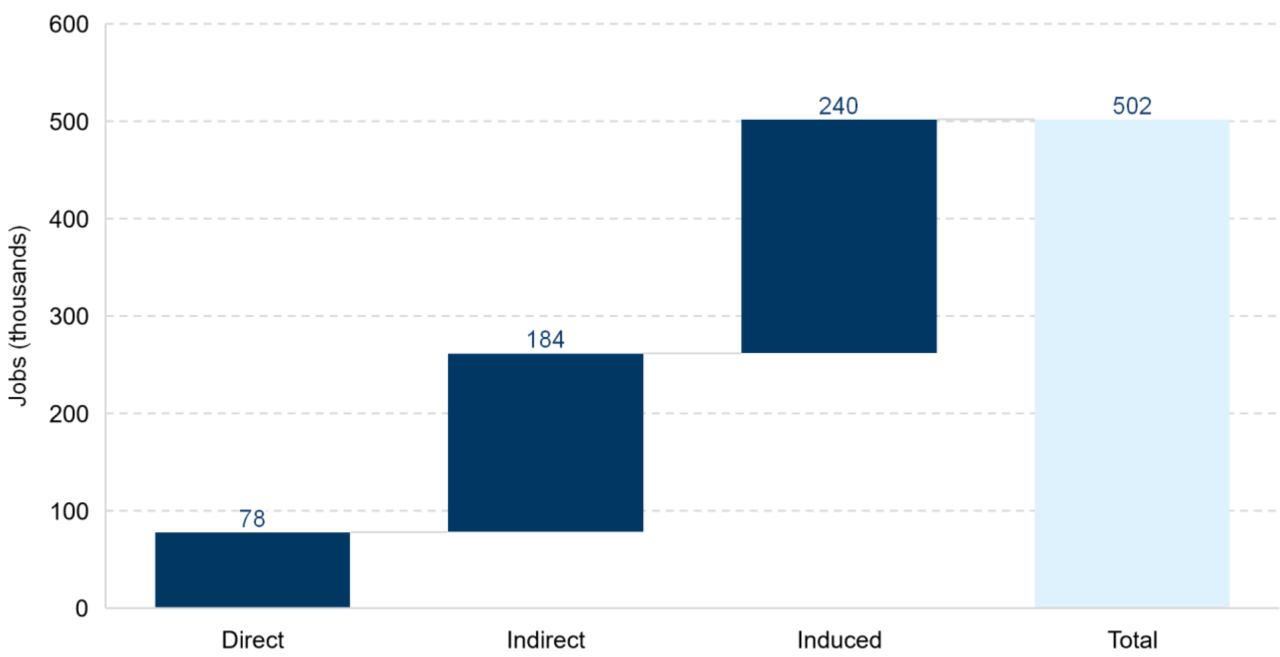
Figure 6 – Total GDP impacts by state



Employment

The PFAS Restriction would impact over 502,000 U.S.jobs as shown in Figure 7 below. Direct, indirect, and induced employment impacts would amount to 78,000, 184,000, and 240,000, respectively.

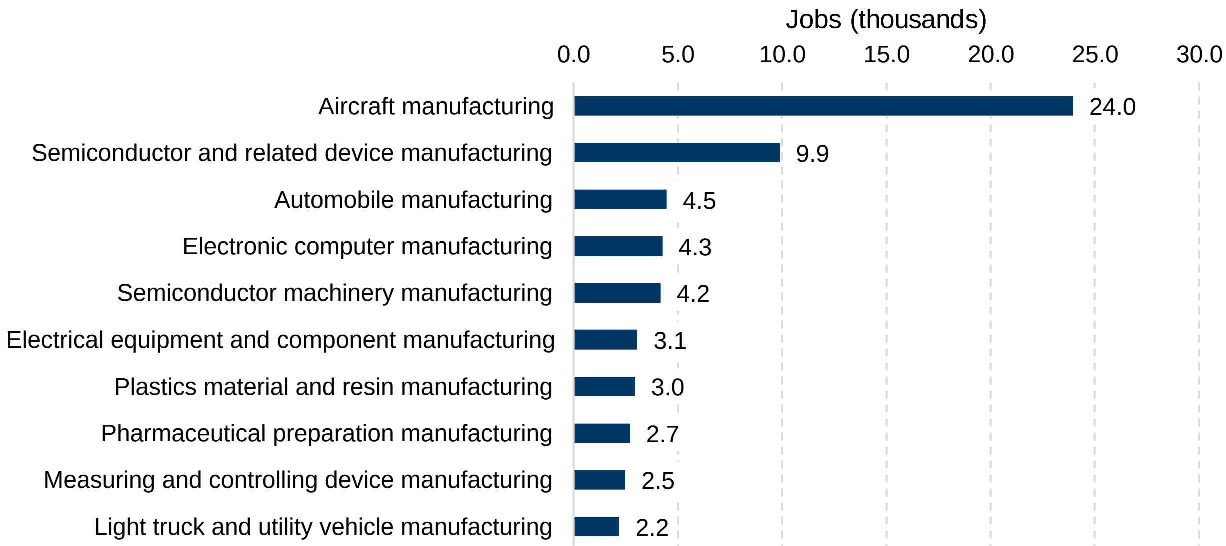
Figure 7 – Employment impacts



The sectors most impacted by the PFAS Restriction in terms of employment, as shown in Figure 8, are similar to those outlined in Figure 5 above, which summarizes the sectors most affected by PFAS in terms of output. These results show that job and output impacts generally follow the same trends. However, different sectors have varying levels of labor productivity in terms of output, resulting in a difference in the rankings of sectors between the two figures.

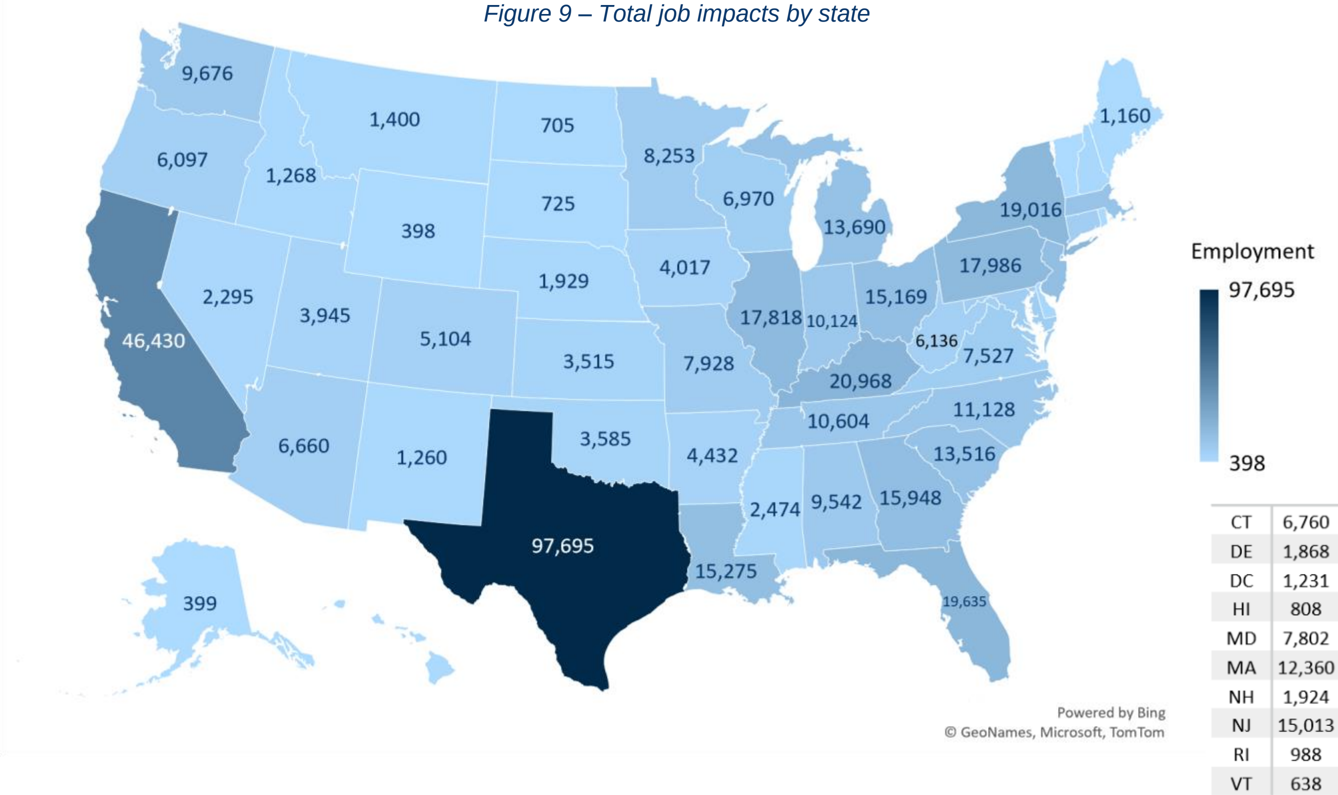
Both figures show that the aircraft industry dominates the sectors most impacted in terms of output and jobs. These impacts are resulting from the full dependence of PFAS in the aviation industry, where the PFAS Restriction would result in a full trade ban of U.S. aviation products to the EU. Semiconductor, automotive, and electronics manufacturing are the following most impacted sectors.

Figure 8 – Top 10 most impacted sectors by jobs



The distribution of the total job impacts would reach all 50 states plus D.C., as summarized in Figure 9. These impacts are generally proportional to the GDP state-level impacts in Figure 6where Texas and California have the highest impacts at-risk of the PFAS Restriction.

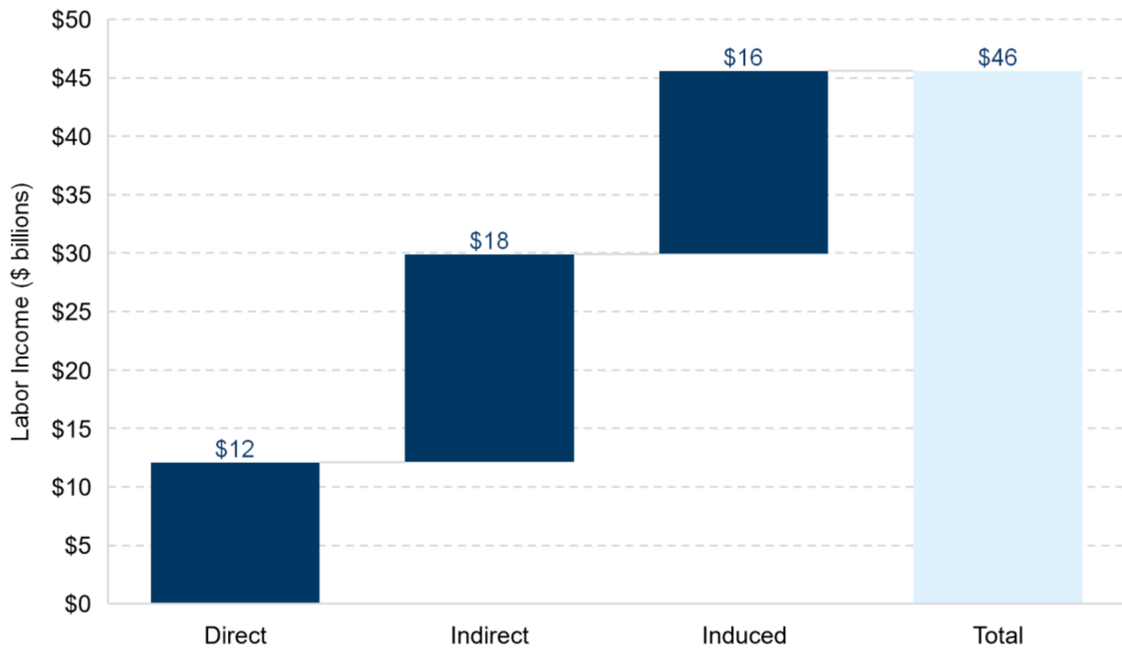
Figure 9 – Total job impacts by state



Labor Income

As shown in Figure 10 below, total labor income at-risk equals $46 billion for U.S. workers. Direct, indirect, and induced impacts would amount to $12 billion, $18 billion, and $16 billion, respectively.

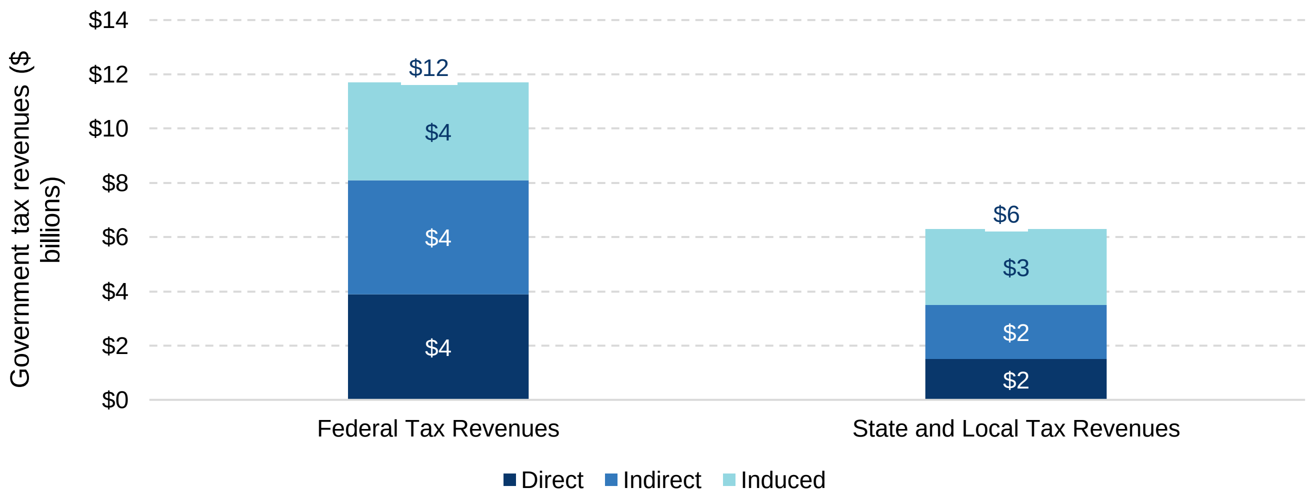
Figure 10 – Labor income impacts



Government Revenues

The total federal tax revenues and state and local tax revenues at-risk equal $12 billion and $7 billion, respectively, as shown in Figure 11. The impacts of direct, indirect, and induced effects are roughly equal for federal tax revenues, with each portion amounting to $4 billion. For state tax revenues, direct and indirect impacts are $2 billion and induced impacts are $3 billion.

Figure 11 – Government tax revenues



Summary Impacts

Table 4 summarizes the at-risk activity to the U.S. under the PFAS Restriction on U.S. exports to the EU in 2022.

Table 4 - 2022 economic and fiscal impacts of the PFAS Restriction on exports from the U.S. to the EU, 2022

Metric	Unit	Direct	Indirect	Induced	Total
Employment	Jobs (Thousands)	78	184	240	502
Output	2022 $ billions	$59	$61	$49	$168
GDP	2022 $ billions	$24	$29	$28	$81
Labor Income	2022 $ billions	$12	$18	$16	$46
Federal Tax Revenues	2022 $ billions	$4	$4	$4	$12
State and Local Tax Revenues	2022 $ billions	$2	$2	$3	$7

Environmental Impacts of the PFAS Restriction

This section describes the unintended greenhouse gas impacts of a ban on traded goods containing PFAS between the U.S. from European Union. The analysis will focus on the emissions from production and transportation of traded goods between the U.S. and the EU under the PFAS Restriction. In 2022, U.S. imports from the EU were valued at $533 billion and exports to the EU were valued at $329 billion. Based on current research, the import and export value at-risk of the PFAS Restriction totals $132 billion and $76 billion, respectively. In this case, the U.S. would need to find alternative trading partners to trade with to offset these lost goods.

Although substitutes for traded goods may be available worldwide, switching trading partners can pose environmental risks. Compared to other trading partners of the United States, the European Union is a relatively low emitting country in terms of GHG emissions. Table 5 summarizes the average production-related emissions intensity by country for the EU and U.S.'s top 15 non-EU import trading partners (the "alternative trading partners"). These intensities are measured in tonnes of carbon dioxide equivalent ("tCO_2e") per million dollars of economic output.[30]

For example, for each $1 million of economic output produced by the EU, 102 tonnes of CO_2e are emitted. Of the regions in Table 5, Indonesia has the highest emissions intensity. For every million dollars the U.S. imports from Indonesia instead of the EU, the emissions generated are over 500% higher.

Table 5 – 2020 Production Emissions Intensity by Country[31]

Country	Emissions intensity (tCO_2e/ million $ output)	Percentage Difference From EU
European Union	102	--
Switzerland	30	-71%
United Kingdom	77	-25%
Singapore	79	-22%
Japan	144	41%
Taiwan	125	23%
Korea, South	211	107%
Canada	196	92%
Mexico	247	142%
China	392	285%
Thailand	522	413%
Brazil	438	331%
Malaysia	518	409%
India	536	426%
Vietnam	642	531%
Indonesia	641	530%

[30] Output is equivalent to sales revenue.
[31] https://www.climatewatchdata.org/ghg-emissions

The largest sector of imports from the EU to the U.S. in 2022 was Pharmaceuticals & Medicines, valued at $111 billion.[32] Finished vehicles followed at $37 billion, shown in in Table 6. The trade in Pharmaceuticals & Medicines between the U.S. and EU is significant. In this sector, the U.S. imports more from the EU than from the top 15 non-EU trading partners combined.

Table 6 - Top 10 U.S. imports from the EU by NAICS code, 2022

NAICS Code	Sector	U.S. Total Import Value from the EU ($ Billions 2022)	U.S. At-Risk Import Value from the EU ($ Billions 2022)
3254	Pharmaceuticals & Medicines	$110.6	$41.5
3361	Finished Vehicles	$37.2	$37.2
3251	Basic Chemicals	$23.3	$1.2
3339	Other General Purpose Machinery	$21.1	$21.1
3364	Aerospace Products & Parts	$19.5	$19.5
3345	Navigational/measuring/medical /control Instrument	$18.1	$9.5
3391	Medical Equipment & Supplies	$16.0	$1.7
3363	Motor Vehicle Parts	$14.9	$14.9
3241	Petroleum & Coal Products	$14.5	$0.7
3331	Ag & Construction & Machinery	$13.6	$0.0

[32] https://usatrade.census.gov/

The U.S. exported $329 million to the EU in 2022.[33] The largest sector of exports was Oil & Gas, valued at $68.7 billion. Pharmaceuticals & Medicines followed at $40.1 billion, as shown in Table 7.

Table 7 - Top 10 U.S. exports to the EU by NAICS code, 2022

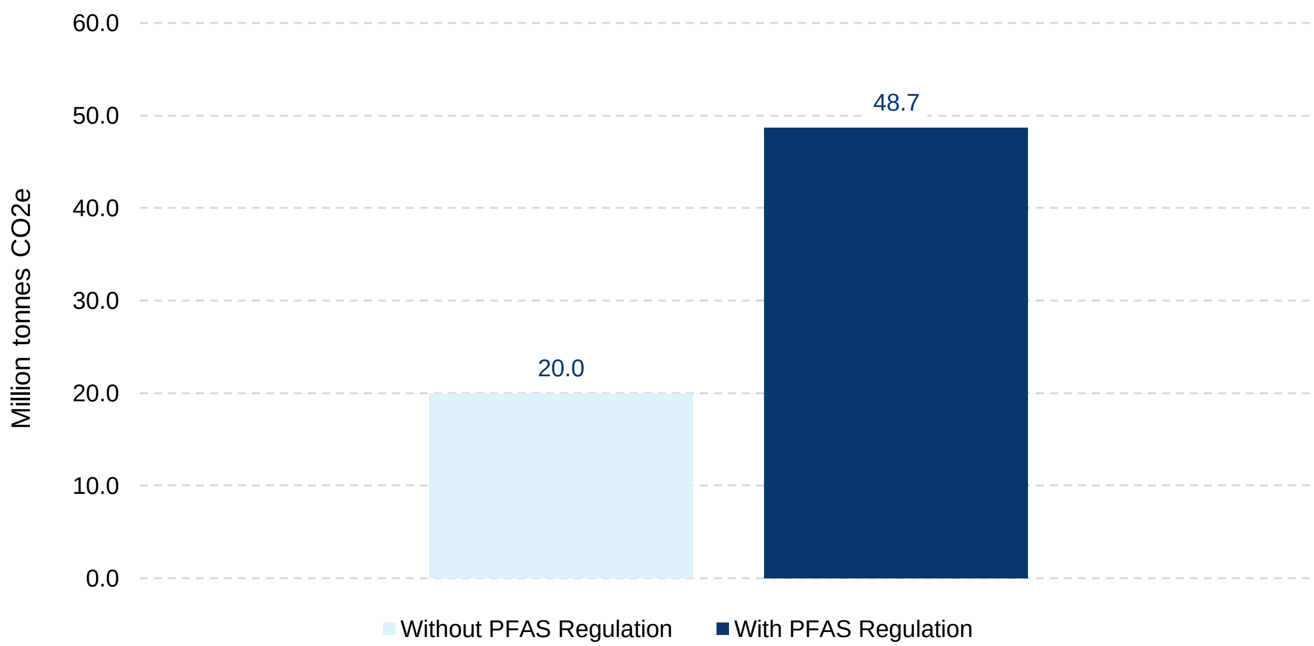
NAICS Code	Sector	U.S. Total Export Value from the EU ($ Billions 2022)	U.S. At-Risk Export Value from the EU ($ Billions 2022)
2111	Oil & Gas	$68.7	$0.0
3254	Pharmaceuticals & Medicines	$40.1	$15
3364	Aerospace Products & Parts	$29.0	$29.0
3251	Basic Chemicals	$17.2	$0.9
3345	Navigational/measuring/medical/ control Instrument	$14.2	$7.4
3391	Medical Equipment & Supplies	$13.8	$1.4
3361	Motor Vehicles	$10.2	$10.2
9900	Other Special Classification Provisions	$10.1	$0.0
3344	Semiconductors & Other Electronic Components	$8.3	$7.6
3252	Resin/synthetic Rubber	$7.8	$2.9

[33] Ibid.

Production-related emissions impacts

The Chamber's experts estimated the value of U.S. imports from the EU of products containing PFAS would equal $132 billion. In a scenario where the U.S. replaces lost imports with its top 15 non-EU trading partners, the production of these imports would generate 48.7 million tonnes of CO_2e emissions, as shown in Figure 12. If these imports were sourced from the EU, the emissions generated from producing goods would only be 20.0 million tonnes of CO2e. In this case, the PFAS Restriction would increase production-related emissions by 144% and emit an additional 28.7 million tonnes of CO_2e.

Figure 12 - Production-related emissions from at-risk U.S. imports from the EU, 2022

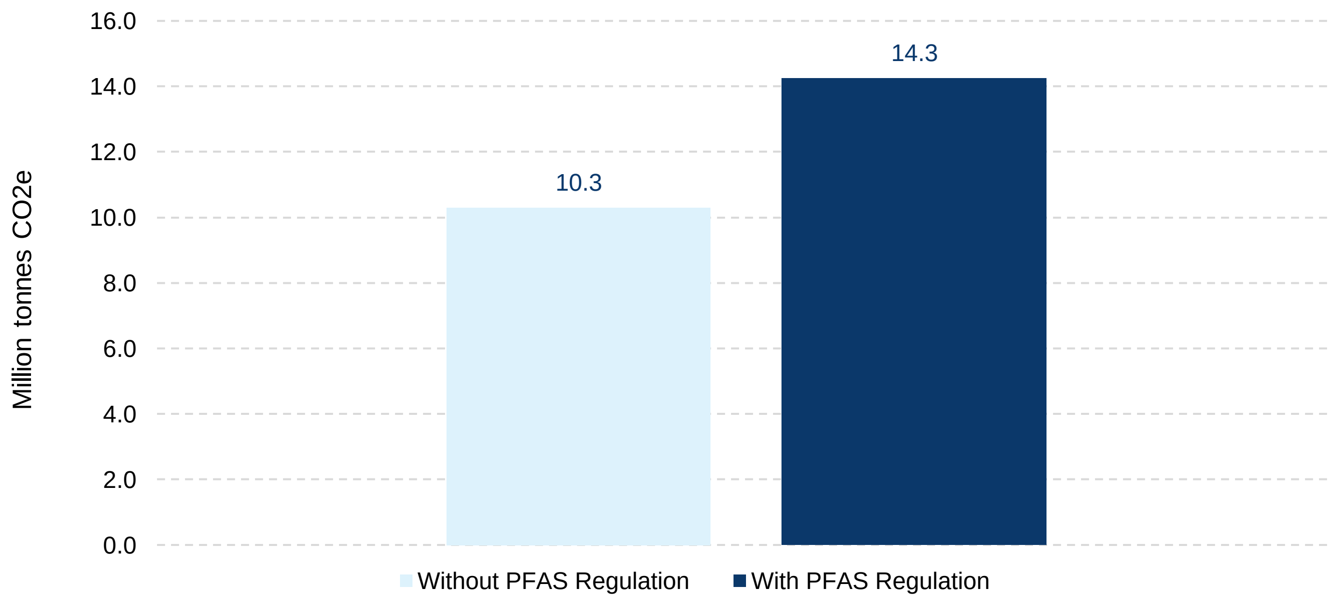


An estimated export value of $76 billion is at-risk of the PFAS Restriction. Assuming the U.S. can source non-EU trading partners to purchase these goods without significant disruption, the production-related emissions remain unchanged, as the same goods are being produced by the U.S. and sold to a different trading partner. These emissions would total 9.9 million tonnes of CO_2e in 2022.

Transportation-related emissions impacts

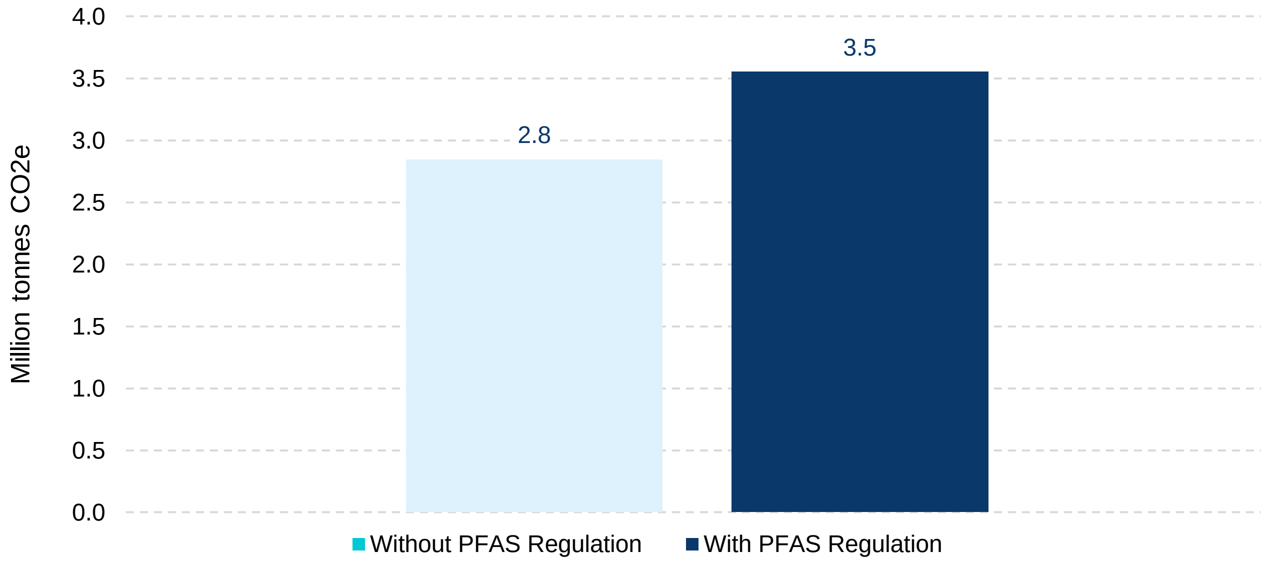
Figure 13 shows the transportation-related emissions of at-risk imports. If the U.S. imported these goods from the EU, the transportation of these goods would emit 10.3 million tonnes of CO_2e. Under the PFAS Restriction, the transportation-related emissions would produce 14.3 tonnes of CO_2e, a 38% increase.

Figure 13 - Transportation-related emissions from at-risk U.S. imports from the EU, 2022



In terms of the $76 billion of exports at-risk, without the PFAS Restriction, the transportation-related emissions of these goods would total 2.8 million tonnes of CO_2e. With the PFAS Restriction, transportation would emit 3.5 tonnes of CO_2e, a 25% increase, as summarized in Figure 14. The increase in emissions due to PFAS-Restriction has a lesser impact on exports than imports because Canada and Mexico are two of the primary export trading partners of the U.S., and as such, fewer goods are transported over long distances compared to imports.

Figure 14 - Transportation-related emissions from at-risk U.S. exports to the EU, 2022



Industry Case Studies

Overview

This section describes the potential societal and environmental consequences of a ban on trade containing PFAS between the U.S. and the EU ("PFAS Restriction"). Given the high volume of trade between these countries and the wide range of goods that contain PFAS with critical uses for national security, public safety, and everyday applications, there are significant risks that span many economic sectors.

The case studies, listed below, highlight applications of PFAS within industries across a selected list of U.S. economic sectors that were identified as some of the most likely to be impacted by the potential PFAS Restriction.[34]

- Healthcare
- Aviation, Aerospace, and Defense
- Semiconductors and Electronics
- Protective Gear and Water-Resistant Textiles
- Fluorinated Gases
- Automotive Transportation

The economic risk to U.S. industries was assessed by first calculating the value of goods traded between the U.S. to the EU in each selected sector using USTO data. The Chamber's experts then identified the major products within each sector that contain PFAS and were most likely to be banned from trade under the potential PFAS Restriction and estimated the proportion of U.S. export value within each sector associated with products containing PFAS. Lastly, the experts evaluated the practicality of replacing PFAS containing components with components that do not intentionally add PFAS within each sector's manufacturing process to identify and exclude products that could be produced without PFAS at reasonable costs and with comparable quality.

Table 8 summarizes the estimated value of trade at-risk of the PFAS Restriction between the U.S. and the EU for the six highlighted sectors. These sectors do not reflect the total value of trade at-risk, but they represent 84% of the total trade at-risk. The sector with the largest estimated trade value at-risk is the Aviation, Aerospace, and Defense sector, with potential trade losses in excess of $48 billion.

[34] The selected sectors do not represent an exhaustive list of all sectors impacted by a potential PFAS Restriction.

Table 8 - Value of trade at-risk of the PFAS Restriction between the U.S. and the EU in 2022 by sector, (USD billions)

PFAS Application	Value of Imports At-Risk	Value of Exports At-Risk	Total Trade Value At-Risk
Healthcare	$38.1	$5.7	$43.8
Aviation, Aerospace, and Defense	$19.4	$28.8	$48.2
Semiconductors and Electronics	$13.4	$15.5	$28.9
Protective Gear and Water-Resistant Textiles	$0.6	$0.4	$1.0
Fluorinated Gases	$0.6	$0.3	$0.9
Automotive Transportation	$42.5	$11.9	$54.4

Environmental risk was evaluated by first estimating the total production-related emissions associated with the manufacture of the identified goods under a "business-as-usual" scenario using CO_2e emission factors.[35] The same set of calculations were then applied under an alternative scenario in which the U.S. must offset the impacted trade activity with the EU with alternative trading partners for both imports and exports. In each of the following case studies, the Chamber's experts assume that impacted U.S. imports within each sector are offset with increased imports from the non-EU country that accounted for the highest sector import value to the U.S. in 2022, while U.S. exports are similarly offset based on the non-EU country with the highest sector export value from the U.S.[36] It is further assumed that production and estimated emissions decreases in the EU are replaced by production and estimated emission increases from the alternative trading partners. Production-related emissions associated with the manufacture of U.S. goods for export is assumed to remain unchanged.

Next, the impact to transportation-related emissions was assessed by estimating the change in total emissions associated with the U.S. offsetting impacted EU trade with alternative trading partners. The Chamber's experts used USTO data to calculate the average cost per kilogram of goods traded in each sector. Total transportation mileage was then calculated between the U.S., the EU, and each alternative trading partner and the total ton-miles of goods in each sector were calculated.[37] The Chamber's experts applied CO_2e per ton-mile emission factors sourced from the EPA to estimate

[35] Emission factors were calculating through an analysis of Climate Watch and World Bank data performed by the Chamber's experts.
[36] The assumption in each case study that U.S. sector imports from the EU are offset "one-to-one" with sector imports from a single alternative trading partner differs from the methodology used to assess the impacts across the entire U.S. economy, which considered the full basket of goods at-risk and assumed a pro rata allocation of offsetting imports across U.S. trading partners.
[37] It is assumed that all goods are shipped via sea vessel, and shipments are equally distributed between the east and west coast of the U.S.

transportation emissions associated with trade activity under the business-as-usual and alternative trading partner scenarios.

Table 9 below summarizes the estimated change in emissions, including both production and transportation impacts, resulting from a ban on products containing PFAS between the U.S. and the EU.

Table 9 – 2022 estimated emission impacts of the PFAS Restriction, (thousand tonnes of carbon dioxide equivalent)

PFAS Application	Net Change in Emissions from U.S. Exports	Net Change in Emissions from U.S. Imports	Net Change in Total Emissions All U.S. Trade
Healthcare	58	(2,472)	(2,414)
Aviation, Aerospace, and Defense	(322)	1,713	1,391
Semiconductors and Electronics	(611)	1,781	1,170
Protective Gear and Water-Resistant Textiles	(5)	38	34
Fluorinated Gases	(23)	211	188
Automotive Transportation	(133)	5,858	5,725

Healthcare

Sector Overview

The healthcare sector includes a wide range of industries and products, many of which use PFAS in the manufacturing process. The use of PFAS chemistries in production is particularly significant in the pharmaceutical and medical equipment manufacturing subsectors. Products manufactured in these two subsectors accounted for approximately 9% of all U.S. exports to the EU in 2022.

The medical equipment sector covers various devices and tools frequently used in healthcare procedures and treatments. This equipment plays a role in diagnosis, treatment, and patient care, which contributes to advancements in medical practices. The medical equipment sector employed more than 333,000 people across the U.S. in 2022.[38] The medical equipment sector's impact extends beyond national borders, demonstrated by the value of over $11 billion in total U.S. medical equipment exports to the EU in 2022.

The pharmaceutical manufacturing sector is vital to the U.S. healthcare industry, producing crucial medications that support public health. The 2022 pharmaceutical manufacturing sector supported nearly 332,000 jobs in the U.S. and exports to the EU were valued at $29 billion.[39] The reliance of domestic and international economies on this sector underscores the need for careful consideration of the replacement materials associated with PFAS.

PFAS Applications

The pharmaceutical manufacturing sector uses PFAS in many capacities, such as manufacturing and development, refrigeration, filters, and packaging. In packaging, fluoropolymers protect pharmaceuticals from humidity and moisture, which can extend the shelf life of many medicines.[40]

PFAS are a valuable component in the medical equipment field due to their durable and nonreactive nature. This sector utilizes PFAS in life-saving devices such as catheters, stents, surgical meshes, implantable medical devices, and metered-dose inhalers ("MDIs"). PFAS are also used in medical textiles, such as gowns and other personal protective gear, for their ability to repel bacteria and disease.[41]

In MDIs, for example, PFAS are used in the propellant which distributes the active ingredients, and the non-stick coating, which resists corrosive environments and allows for accurate dosage. Patients with asthma and chronic obstructive pulmonary disease can use inhalers in their daily treatment since they deliver medicine directly to the lungs. The EPA estimated that 75% of all inhaler sales were MDIs, amounting to over $55 million U.S. sales in 2020.[42]

Polytetrafluoroethylene ("PTFE"), also known as Teflon, is a type of PFAS that has proved beneficial in various medical equipment applications. PTFE is a biocompatible material, meaning it can be inserted

[38] Occupational Employment and Wage Statistics, May 2022. NAICS 339100. https://www.bls.gov/oes/current/naics4_339100.htm
[39] Occupational Employment and Wage Statistics, May 2022. NAICS 325400. https://www.bls.gov/oes/current/naics3_325000.htm
[40] https://www.americanchemistry.com/chemistry-in-america/chemistries/fluorotechnology-per-and-polyfluoroalkyl-substances-pfas/pfas-integral-to-life-saving-drugs
[41] https://www.americanchemistry.com/chemistry-in-america/chemistries/fluorotechnology-per-and-polyfluoroalkyl-substances-pfas/pfas-critical-to-21st-century-healthcare
[42] https://www.epa.gov/sites/default/files/2021-03/documents/epa-hq-oar-2021-0044-0002_attachment_1-mdis.pdf

into living tissue with limited risk of introducing toxins or creating an immune response, reducing potential complications.[43] PTFE is highly versatile with unique properties such as anti-corrosion, heat and friction resistance, hydrophobicity, and can be non-stick. In the medical field, medical grade coatings made of PTFE, and other types of PFAS, are used in various surgical instruments and implantable medical devices.[44]

> *"Material properties like biocompatibility, heat resistance, low friction, chemical inertness of fluoropolymers like PTFE, PFA, FEP and PVDF are unique. Alternative materials available for this type of applications do not cover the whole range of properties."[45]*
> ***– ECHA***

In additional to medical equipment manufacturing, PFAS is also used as an active pharmaceutical ingredient ("API") in many common medicines used to treat illnesses such as diabetes, high cholesterol, depression, and more. Of the top-sold 200 small molecule drugs in 2018, 25 contained PFAS.[46] For example, fluoxetine, the API in Prozac (a popular antidepressant), contains PFAS. [47] Other examples include sitagliptin, which is used to control blood sugar levels for patients with diabetes, and teriflunomide, which is used to help treat multipole sclerosis.[48]

As of 2020, fluoxetine was the 25th most prescribed drug on the U.S. market with an estimated 23 million prescriptions filled annually. Along with treating depression, fluoxetine can be used to treat patients with obsessive-compulsive disorder, bulimia nervosa, and panic disorder. [49]

PFAS Replacements

Research suggests the substitution potential for propellants that do not intentionally add PFAS in MDIs is high, however such substitutes would still be banned under the proposed PFAS Restriction which includes F-gases. Furthermore, the coatings of the canisters must contain PFAS to function properly.[50] If the inhaler is not non-stick, medicine may adhere to the walls, affecting the dosage administered. Thus, it is currently not feasible to produce an MDI completely free of PFAS. Although some patients have the option of switching from MDIs to a dry powder inhaler for certain medications, which tend not to include PFAS, those individuals with severe lung disease and young children can struggle to use inhalers without a propellant.

[43] https://www.merriam-webster.com/dictionary/biocompatibility#:~:text=%3A%20the%20condition%20of%20being%20compatible,biocompatible
[44] https://www.sciencedirect.com/science/article/abs/pii/S2468519420301725
[45] https://echa.europa.eu/documents/10162/57812f19-8c98-ee67-b70f-6e8a51fe77e5
[46] https://www.efpia.eu/media/636866/pfas-position-_-efpia-and-animalhealtheurope-january-2022.pdf
[47] Ibid.
[48] https://www.mayoclinic.org/drugs./sitagliptin./drg-20069730?p=1#:~:text=Sitagliptin%20helps%20to%20control%20blood,dependent%20or%20type%201%20diabetes, https://www.mayoclinic.org/drugs-supplements/teriflunomide-oral-route/side-effects/drg-20075757?p=1#:~:text=Teriflunomide%20is%20used%20to%20treat,and%20active%20secondary%20progressive%20disease.
[49] https://clincalc.com/DrugStats/Drugs/Fluoxetine
[50] https://echa.europa.eu/documents/10162/57812f19-8c98-ee67-b70f-6e8a51fe77e5

Alternatives for medical textiles that do not intentionally add PFAS, such as gowns, are available, but regulatory approval is required before widespread implementation.[51] In implantable medical devices, there are no feasible alternatives for PFAS in their current applications which could be deployed and approved within the next 5-10 years.[52]

Although there may be substitutes for specific drug purposes, PFAS cannot be replaced in pharmaceutical products in which it is used in an API, such as fluoxetine. Should feasible replacements be identified, regulatory requirements necessary to receive approval for such alternatives would likely result in significant time delays prior to implementation.

"Even if PFAS APIs such as Fluoxetine or Sitagliptin coexist with nonfluorinated drugs in the same therapeutic class, it is incorrect to assume that these APIs are interchangeable…. Limiting the options in a therapeutic class because some have fluorinated groups would have a profound impact on the ability to treat patients with the most safe and efficacious medicine."

– European Federation of Pharmaceutical Industries and Associations[53]

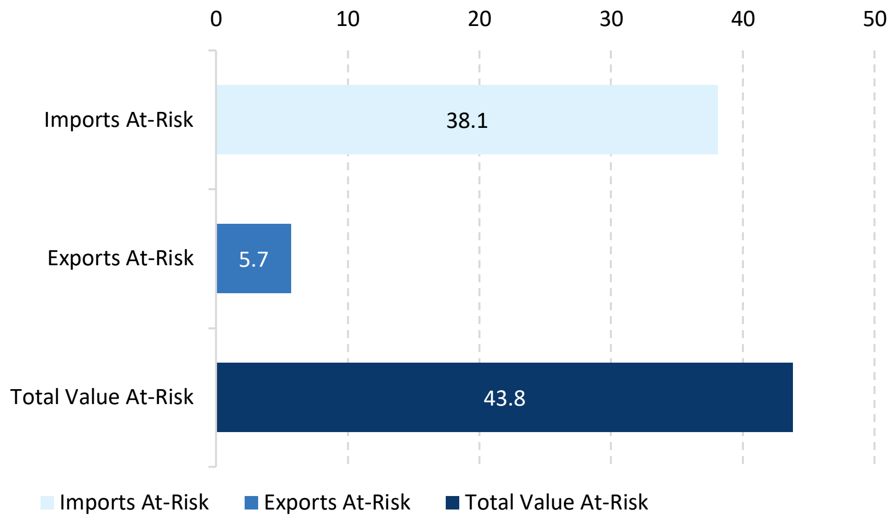
Pharmaceutical packaging which contains PFAS is not expected to be replaced within the next 5 years.[54] Since these products are in direct contact with the relevant pharmaceuticals, replacements would also need to be approved by regulatory bodies, which is also expected to take at least five years.[55]

Economic and Environmental Impacts of Regulation

PFAS are frequently utilized in medical equipment due to their durability, non-reactive nature, and biocompatibility, particularly in surgical instruments and implantable devices. As a result of the nature of PFAS application in medical equipment and pharmaceuticals, all products that contain PFAS are at-risk of a ban on imports of goods containing PFAS into the European Union. The potential ban would disrupt global supply chains and ultimately limit consumer access to certain medicines.[56] The Chamber's experts estimate approximately $37.3 billion in pharmaceutical and $885.9 million in medical equipment would be at-risk due to a ban on imported goods to the U.S. from EU that contain PFAS. An additional $10.2 billion in pharmaceuticals and $802 million of U.S. exports to the EU would be at-risk due to the PFAS Restriction, as summarized in Figure 15.

[51] https://echa.europa.eu/documents/10162/57812f19-8c98-ee67-b70f-6e8a51fe77e5
[52] Ibid.
[53] https://www.efpia.eu/media/1oeldyty/efpia-ahe-pfas_position_june-2023-final.pdf
[54] Ibid.
[55] Ibid.
[56] https://www.euractiv.com/section/health-consumers/news/pharma-industry-proposed-forever-chemicals-ban-would-stifle-innovation-access-to-drugs/

Figure 15 - Value of healthcare manufacturing trade at-risk of the PFAS Restriction, 2022 (USD billions)



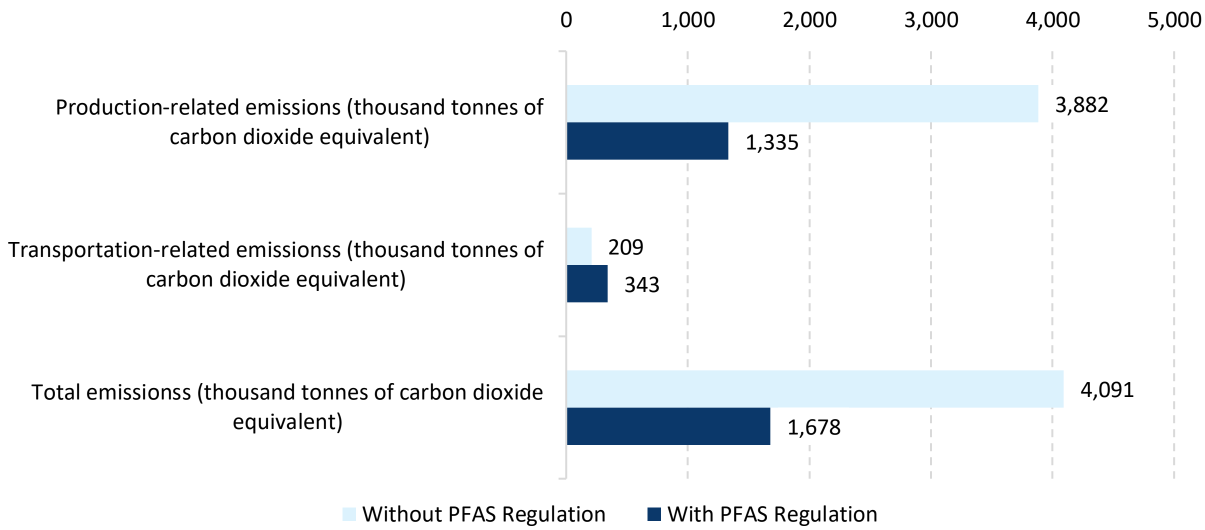
In a scenario in which PFAS Restrictions are put into effect, the U.S. could find alternative trading partners to offset the lost imports of pharmaceuticals and medical equipment from the EU. Switzerland is the largest non-EU trading partner to the U.S. in terms of imports for pharmaceuticals, and Mexico is the largest trading partner in terms of imports for medical equipment. If the U.S. were to offset imports of pharmaceuticals and medical equipment from the EU with imports from Switzerland and Mexico on a one-to-one basis based on 2022 data, the estimated annual emissions associated with the production of products would fall from 3,882 thousand tonnes to 1,335 thousand tonnes of CO_2e, a 66% decrease. Switzerland has the lowest average production-related emission factor of the non-EU trading partners, making the substitution of EU to Swiss pharmaceutical productions decrease total emissions. The annual emissions associated with the transportation of these products to the U.S. would increase from 161 to 236 thousand tonnes of CO_2e, or by 47%.

In a scenario in which PFAS Restrictions are put into effect, the U.S. would also need to find alternative trading partners to offset the lost exports of pharmaceuticals and medical equipment from the U.S. to the EU.

Canada is the largest non-EU trading partner to the U.S. in terms of exports for medical equipment, and China is the largest non-EU trading partner to the U.S. in terms of exports for pharmaceuticals. If the U.S. were to offset exports of pharmaceuticals and medical equipment from the EU with exports to Canada and China, respectively, on a one-to-one basis based on 2022 data, the estimated annual emissions associated with the transportation of these products from the U.S. would increase from 49 to 107 thousand tonnes of CO_2e, or by 117%.

Figure 16 summarizes the total change in pharmaceutical and medical equipment manufacturing emissions due to the PFAS Restriction between the U.S. and EU for both imports and exports combined. Production related emissions would fall from 3,882 to 1,335 thousand tonnes of CO_2e, and transportation related emissions would increase from 209 to 343 thousand tonnes of CO_2e. Total emissions would fall from 4,091 to 1,678 thousand tonnes of CO_2e or by 59%.

Figure 16 - Annual emissions impacts of substituting U.S. trade of pharmaceuticals and medical equipment with the EU, 2022



Aviation, Aerospace, and Defense

Sector Overview

The U.S. is the global leader in the manufacture and development of aircrafts.[57] In 2022, the U.S. employed over 510,400 workers. 2022 exports to the EU were valued at $24.8 billion in finished aircrafts, aircraft engines, and other aircraft parts and components to the EU.[58]

There are an estimated 16.4 million flights handled yearly in the U.S. by the Federal Aviation Administration. This includes passenger flights, which transport almost 3 million passengers daily, as well as cargo flights accounting for the transport of over 44.5 billion pounds of freight each year. [59]

The U.S. Aerospace and Defense industry supported 2.1 million jobs in 2022 and exports to the EU were valued at $4.3 billion.[60] These exports include aerospace vehicles and their replaceable parts along with defense products such as military aviation, ground defense applications, space systems, missiles, and similar products. The aerospace industry has been expanding in recent years with the rise of new commercial services and markets, such as Unmanned Aerial Vehicles ("UAVs"), such as drones, and the space tourism market, which are expected to reach $91.3 and $13.2 billion in value by 2033, respectively.[61,62]

PFAS Applications

PFAS compounds are vital to the aircraft manufacturing industry and have applications in many stages of the production of aircrafts. A primary application of PFAS in this sector is the use of fluoropolymers in the manufacture of hydraulic systems, which work by using a small amount of water to create high pressures. Hydraulic systems play a role in the operation of multiple aircraft components including cargo doors, landing gear, and wheel brakes. PFAS are used as additives in hydraulic fluids to alter the electrical potential of the metal, protecting it from corrosion.

Along with hydraulic systems, PFAS and fluoropolymers can also be found in the operation of military aircraft and space vehicles. This includes aircraft components, such as turbine-engines, propellant systems, satellite instrumentation, general surface coating, and many more parts of common aerospace products due to its ability to operate at a wide temperature range and its resistance to corrosion.[63]

PFAS and fluoropolymers are also heavily used to manufacture mechanical components of wiring. This includes tubing, piping, cables, and insulators.[64] This wiring is especially used in military aircrafts, attributable to the chemicals exhibiting extreme temperature support, outstanding insultation, and being lightweight. [65]

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[57] https://www.statista.com/statistics/263290/aerospace-industry-revenue-breakdown/
[58] https://www.ibisworld.com/industry-statistics/employment/aircraft-engine-parts-manufacturing-united-states/
[59] https://www.faa.gov/air_traffic/by_the_numbers
[60] https://www.aia-aerospace.org/industry-impact/
[61] https://www.futuremarketinsights.com/reports/space-tourism-market#:~:text=Space%20Tourism%20Market%20Outlook%20(2023,US%24%2013%2C239.5%20million%20in%202033.
[62] https://www.digitaljournal.com/pr/news/xherald/autonomous-drone-market-is-expected-to-progress-at-a-cagr-of-19-3-by-2033
[63] https://osf.io/km9j5/download
[64] https://pfas-1.itrcweb.org/2-5-pfas-uses/
[65] https://www.gao.gov/assets/gao-23-105982.pdf

"Fluorotechnology enables high- and low-temperature, chemical-resistant tubes, hoses and fluid seals; high- and low- temperature brake and hydraulic fluids used in aircraft control systems and brakes; and ultrahigh frequency wire and cable insulation necessary for navigation, fly-by-wire control and aircraft communications."[66]

– American Chemistry Council

In addition to these properties, the aerospace and defense sector utilizes PFAS in numerous application areas for their characteristics of being anti-corrosive, lubricative, permeable, insulative, and a host of others. This enables the PFAS applications to increase lifecycle, reliability, controllability, and safety of aircrafts in various environments.[67]

PFAS Replacements

There are no feasible alternatives for PFAS for most of its applications in the aerospace and defense industry, which requires durable insulation, high-temperature permeability, and clear displays.[68] Should feasible replacements be developed, there would be a lag in application due to lengthy approval processes by regulators. This is due to the restricted licensing procedures, lengthy production timelines, and multifaceted international supply chains.[69]

"No acceptable non-PFAS alternatives have been approved for use [in the] aerospace industry, where PFASs are used for example for anti-erosion/anti-corrosion purposes in hydraulic systems, including landing gear."[70]

– ECHA

Currently, there are no practical alternatives to PFAS in hydraulic systems, and previous research estimates it will take many years before a safe, reliable substitute is developed.[71] According to the Aerospace and Defense Industries Association of Europe, the safety and efficacy of aircraft production and operations is the primary issue when evaluating the effectiveness of chemical replacements by the standards of the Registration, Evaluation, Authorization and Restriction of Chemicals ("REACH") regulation.[72]

There is currently limited evidence of suitable replacements for wiring and cables in aircraft and aerospace products.[73] The only considerable competitor for wire insulation is polyetheretherketone, which a high-performing thermoplastics that is extremely expensive.[74] This is due to the limited

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66 https://www.americanchemistry.com/chemistry-in-america/chemistries/fluorotechnology-per-and-polyfluoroalkyl-substances-pfas/pfas-critical-to-america-s-air-travel

67 https://www.oecd.org/chemicalsafety/portal-perfluorinated-chemicals/webinars/2%20Kai%20Schubert%20-%20Major%20Uses_2.pdf

68 https://echa.europa.eu/documents/10162/57812f19-8c98-ee67-b70f-6e8a51fe77e5

69 Ibid.

70 https://echa.europa.eu/documents/10162/57812f19-8c98-ee67-b70f-6e8a51fe77e5

71 Ibid.

72 https://echa.europa.eu/documents/10162/13637/aviation_industry_and_reach_en.pdf/0a5ed713-a1b7-49a3-84c8-a90363ae649d

73 Ibid.

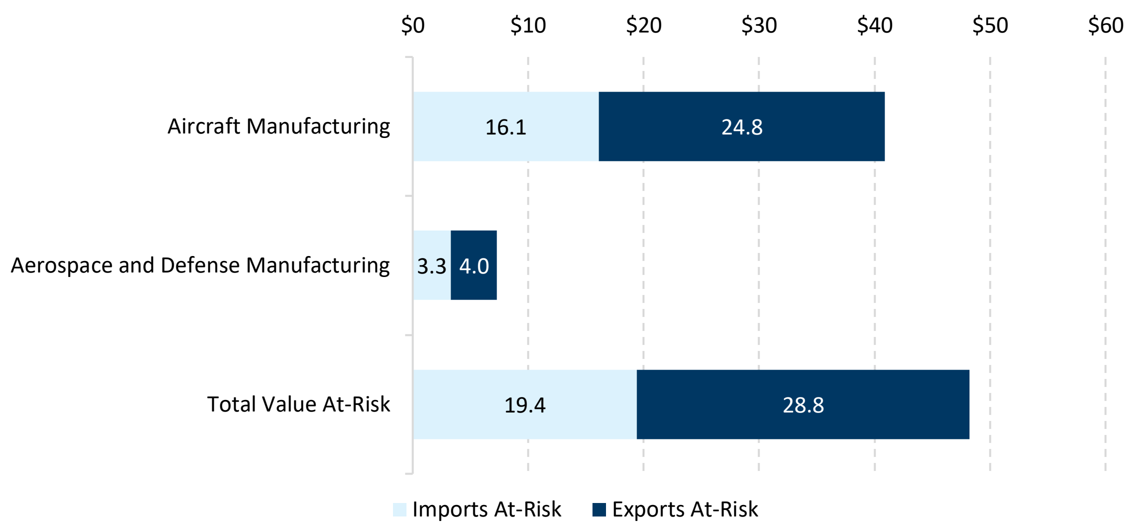
74 https://echa.europa.eu/documents/10162/57812f19-8c98-ee67-b70f-6e8a51fe77e5

availability of materials that have reliable properties to withstand extreme heat and to operate effectively in diverse environmental conditions.[75]

Economic and Environmental Impact of Regulation

PFAS compounds are commonly used in aircraft production for their exceptional temperature support, insulation, and lightweight properties in wiring, hydraulic systems, and insulation. Due to the aviation industry's strong dependence on PFAS to create reasonably priced, reliable aircrafts, all of the industry's trade is at-risk of a ban on imports of goods containing PFAS into the European Union, which could impact over $19.4 billion in imports from the EU to the U.S., and $28.8 billion in U.S. exports to the EU, as summarized in Figure 17.

Figure 17 - Value of aircraft and aerospace products trade at-risk of the PFAS Restriction, 2022 (USD billions)



In a scenario in which PFAS Restrictions are put into effect, the U.S. could find alternative trading partners to offset the lost imports of aircraft and aerospace products from the EU. In 2022, the U.S. imported the highest value of aircraft and aerospace products from Canada than from any other top 15 non-EU import trading partner. If the U.S. were to offset imports of aircraft and aerospace products from the EU with imports from Canada on a one-to-one basis based on 2022 data, the estimated annual emissions associated with the production of the lost aircraft and aerospace products would increase from 1,895 to 3,646 thousand tonnes of CO_2e, or by 92%. The annual emissions associated with the transportation of these vehicles to the U.S. would decrease from 55 to 17 thousand tonnes of CO_2e, or by 69%.

In a scenario in which PFAS Restrictions are put into effect, the U.S. would also need to find alternative trading partners to offset the lost exports of aircraft and aerospace products from the U.S. to the EU.

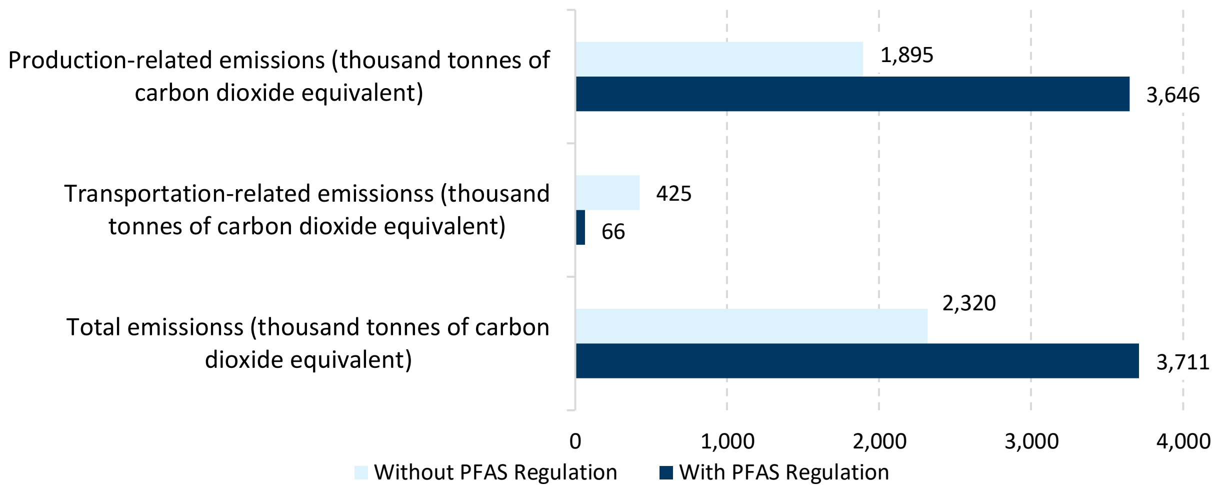
Canada is the largest non-EU trading partner to the U.S. in terms of exports for aircraft and aerospace products. If the U.S. were to offset exports of aircraft and aerospace products from the EU with exports

[75] https://echa.europa.eu/documents/10162/13637/aviation_industry_and_reach_en.pdf/0a5ed713-a1b7-49a3-84c8-a90363ae649d

to Canada on a one-to-one basis based on 2022 data, the estimated annual emissions associated with the transportation of these products from the U.S. would decrease from 307 to 48 thousand tonnes of CO_2e, or by 87%.

Figure 18 summarizes the total change in aircraft and aerospace manufacturing emissions due to the PFAS Restriction between the U.S. and EU for both imports and exports combined. Production related emissions would increase from 1,895 to 3,646 thousand tonnes of CO_2e, and transportation related emissions would decrease from 435 to 66 thousand tonnes of CO2e. Total emissions would increase from 2,320 to 3,711 thousand tonnes of CO_2e or by 60%.

Figure 18 - Annual emissions impacts of substituting U.S. trade of aircraft and aerospace products with the EU, 2022



Semiconductors and Electronics

Sector Overview

PFAS are essential in semiconductor and electronics manufacturing. The value of semiconductor and electronic imports from the EU were valued at $8 billion, and exports were valued at $8.4 billion in 2022.

Semiconductors are pivotal in the U.S. economy, driving technological progress and innovation across many sectors. Semiconductors are used to power electronic devices and support modern communication, computing, and automation. The semiconductor sector employed 345,000 people across the U.S. and exports were valued at approximately $8.4 billion to the EU in 2022.[76] Due to the many uses of PFAS in this sector, all the industry's traded goods are at-risk of a ban on imports of goods containing PFAS into the EU.

PFAS Applications

PFAS are present in chemicals used in multiple stages in the manufacturing process of semiconductors. The substance is a key component in the photolithography process, which involves applying photoresist material to a silicon wafer to create a circuit. Using PFAS in the manufacture of photoresist material increases its resistances to high temperatures and harsh chemicals, enhances its durability, and helps with its adhesion to the silicon wafer.[77]

> *"Moving away from PFAS in photoresist applications, is likely to require a change in the entire photolithographic process. Photoresists are not interchangeable; they ar*e designed to work with a specific photolithography method and are needed for the life of that manufacturing facility which is dedicated to the particular device technology (generation) being manufactured. Qualifying an alternative as a drop-in photoresist replacement part way through the life of a facility would not be possible in many cases and would need assessing for each facility individually."[78]
> **– Semiconductor Industry Association**

The elasticity, chemical inertness, dielectric properties, and moisture resistance of PFAS and their resistance to extreme temperatures, UV light, and corrosion make them ideal for many hardware applications critical to semiconductor manufacturing. These applications include chemical tanks and distribution systems, filters, seals and O-rings for valves, emission abatement units, and process chambers.

PFAS are also present in many commodity electronic components necessary to the operation of semiconductor manufacturing equipment, such as barrier films in lithium batteries, dielectric fluids and films in capacitors, fire retardant, and machining additives in plastics, and high temperature and chemically inert insulation for wiring and cable.

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[76] https://www.semiconductors.org/wp-content/uploads/2023/07/SIA_State-of-Industry-Report_2023_Final_072723.pdf
[77] https://www.allaboutcircuits.com/news/chipmakers-defend-the-place-of-forever-chemicals-as-ban-looms
[78] https://www.semiconductors.org/the-impact-of-a-potential-pfas-restriction-on-the-semicondu

Semiconductor manufacturing equipment relies on PFAS components throughout its long lifespan. Redesigning semiconductor equipment and components to operate from replacement parts that do not contain PFAS is not economically feasible.

Semiconductors are utilized in every sector of the electronics industry including mobile phones, laptops, cars, refrigerators, and much more. Internationally, over one hundred billion semiconductors are used daily[79]. In many electronic devices, a semiconductor chip placed between the conductor and insulator of an electronic device controls the flow of the electric current.

The electronics market, both for new products and resales, relies heavily on PFAS availability as it is considered an essential component in the manufacturing process, which is illustrated by the average usage of 4,400 tonnes of PFAS per year in the EU.[80] These markets have a high dependency on semiconductors, and therefore inherently rely on PFAS. As a result of the possible PFAS Restriction, both markets will experience increased shortages, which would lead to higher prices for resold products that have historically been the economical choice and catalyst in extending the lifecycle of electronics.

PFAS Replacements

Due to the qualities of PFAS necessary for semiconductor manufacturing, the ubiquitous presence of PFAS in electronics, and the need to exhaustively requalify semiconductor production lines when process-critical changes are undertaken, efforts to quickly replace PFAS with materials that are resistant to chemicals and heat will significantly disrupt global supply chains.[81] Semiconductors are complex devices that take around 6 and one-half months to manufacture and test. The process requires an average of 2,000 production steps and involves the use of many intermediate materials. [82] PFAS is a functional material used in various steps of this manufacturing process for the vast majority of semiconductors produced. Research conducted by industry stakeholders, government organizations, and independent scientists has concluded that there are no feasible replacements for PFAS in these applications at this time.[83]

There are currently no feasible replacements for PFAS in the electronics sector nor the subsequent electronics resale market. In cases where there may be replacement options, there is no solid evidence that substitutes have been adequately developed to support the industry or prevent imminent catastrophic shortages due to the pending injunction on PFAS.[84] These societal risks could include potential business closures, high expenditures, and uncertainty associated with research and development needed to identify whether viable non-PFAS alternatives can be used and whether such non-PFAS alternatives are lower risk than existing PFAS use.[85]

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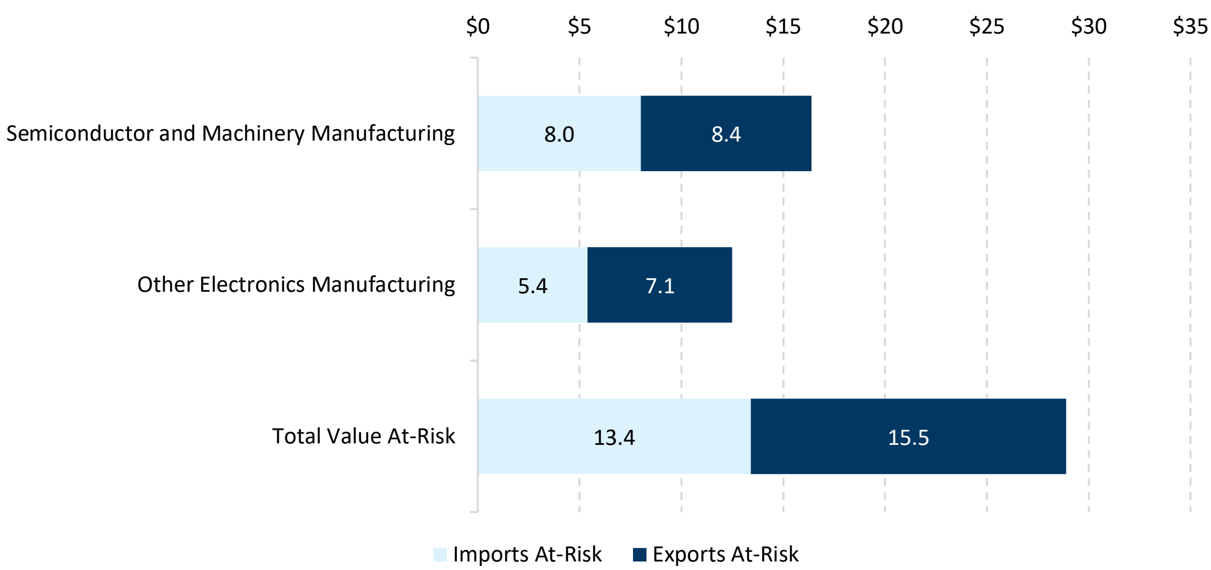
[79] https://irds.ieee.org/topics/semiconductor-materials
[80] https://chemsec.org/app/uploads/2023/04/Check-your-Tech_230420.pdf
[81] https://www.semiconductors.org/wp-content/uploads/2023/04/Impact-of-a-Potential-PFAS-Restriction-on-the-Semiconductor-Sector-04_14_2023.pdf
[82] https://chemsec.org/app/uploads/2023/04/Check-your-Tech_230420.pdf
[83] https://www.spiedigitallibrary.org/journals/journal-of-micro-nanopatterning-materials-and-metrology/volume-21/issue-01/010901/Review-of-essential-use-of-fluorochemicals-in-lithographic-patterning-and/10.1117/1.JMM.21.1.010901.full
[84] https://echa.europa.eu/documents/10162/57812f19-8c98-ee67-b70f-6e8a51fe77e5
[85] ibid.

> *"Research is actively* ongoing into substitutes for PFAS in the semiconductor industry, but to date, no suitable alternatives have been found that successfully replace many of the essential uses of PFAS in the chip manufacturing [processes], equipment, and infrastructure."
> ***– Semiconductor Industry Association***[86]

Economic and Environmental Impacts of a Regulation

PFAS are irreplaceable in semiconductors due to their exceptional temperature resistance, anti-corrosive properties, and moisture resistance. Due to the many uses of PFAS in this sector, all the industry's traded goods are at-risk of a ban on trade containing PFAS between the U.S. and the EU. The value of total imports at-risk were equal to $13.4 billion, and the value of exports at-risk were valued at $15.5 billion in 2022, as summarized in Figure 19.

Figure 19 - Value of semiconductor and electronic products trade at-risk of the PFAS Restriction, 2022 (USD billions)



In a scenario in which PFAS Restrictions are put into effect, the U.S. could find alternative trading partners to offset the lost imports of semiconductor and electronic products from the EU. In 2022, the U.S. imported the highest value of semiconductors from Taiwan and the highest value of computers and other electronics from China than from any other top 15 non-EU import trading partner. If the U.S. were to offset imports of semiconductors and electronics from the EU with imports from Taiwan and China on a one-to-one basis based on 2022 data, the estimated annual emissions associated with the production of the lost semiconductors and electrical components electrical would increase from 1,361 to 3,107 thousand tonnes of CO_2e, or by 128%. The annual emissions associated with the transportation of these semiconductors and electronics to the U.S. would increase by from 126 to 161 thousand tonnes of CO_2e, or by 27%.

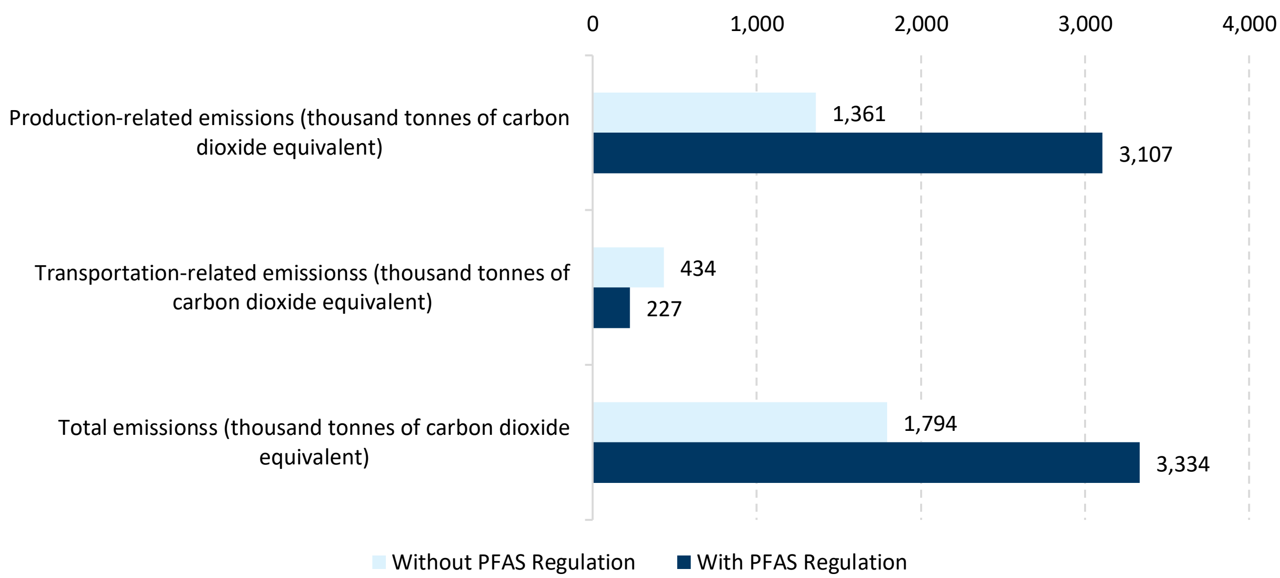
[86] https://www.semiconductors.org/technical-papers-highlight-need-to-maintain-essential-uses-of-pfas-in-semiconductor-industry/

In a scenario in which PFAS Restrictions are put into effect, the U.S. would also need to find alternative trading partners to offset the lost exports of semiconductors and electrical components from the U.S. to the EU.

Mexico is the largest non-EU trading partner to the U.S. in terms of exports for semiconductors and electrical components. If the U.S. were to offset exports of semiconductors and electrical components from the EU with exports to Mexico on a one-to-one basis based on 2022 data, the estimated annual emissions associated with the transportation of these products from the U.S. would decrease from 308 to 66 thousand tonnes of CO_2e, or by 79%.

Figure 20 summarizes the total change in semiconductor and electronics manufacturing emissions due to the PFAS Restriction between the U.S. and EU for both imports and exports combined. Production related emissions would increase from 1,361 to 3,107 thousand tonnes of CO_2e, and transportation related emissions would decrease from 434 to 227 thousand tonnes of CO_2e. Total emissions would increase from 1,794 to 3,334 thousand tonnes of CO_2e or by 86%.

Figure 20 - Annual emissions impacts of substituting U.S. trade of semiconductors and electronics with the EU, 2022



Protective Gear and Water-Resistant Textiles

Sector Overview

A ban on traded goods containing PFAS between the EU and the U.S. would impact water-resistant textiles and protective gear which contain PFAS. These imports from the EU were valued at $613 million, and exports to the EU were valued at $383 million in 2022. The emissions impact of a ban on U.S. imports of these products from the EU would increase by 232% when compared to the business-as-usual scenario.

PFAS is regularly used in textiles to provide water, stain, and heat protection. Water-resistant textiles have become indispensable in a wide array of industries due to the sector's functionality catering to diverse needs in consumer comfort and industrial efficiency. PFAS are a key component in water-resistant textiles used in consumer and professional sectors, ranging from outdoor apparel to medical equipment manufacturing. In protective gear and clothing, such as firefighting turnout gear, PFAS is required to create safe and durable equipment. The market value for waterproof breathable textiles in the U.S. was valued at $414 million in 2022.[87]

PFAS Applications

PFAS provides high quality water resistance, waster proofing, and water repelling properties. U.S. exports were valued at approximately $5 billion in water-resistant textiles and protective gear to the EU in 2022.

For example, an expanded form of the fluoropolymer PTFE (ePTFE) is used to create a waterproof, windproof, durable, and breathable membrane found in a wide variety of GORE-TEX® apparel and footwear. The PFAS material in GORE-TEX ® fabric has nine billion pores per square inch. Each pore is 20,000 times smaller than a water droplet and 700 times bigger than a water vapor molecule, making the material impenetrable by water, but also highly breathable and comfortable. This material produces products including water and wind-proof apparel, outerwear, and jackets, gloves, and footwear for a variety of activities such as skiing, hiking, cycling, and everyday wear.[88]

The textile industry is the largest consumer of fluorotelomers, a major subgroup of PFAS.[89] Fluorotelomers are used as a chemical treatment in textiles, creating a barrier to oil, water, and stains. This sector includes common consumer products, such as rain jackets, ski wear, carpets and rugs, and water-resistant footwear. A recent study testing everyday products detected PFAS in 72% of a sample of 47 textiles labeled water- or stain-resistant. PFAS are also used for professional apparel such as personal protective equipment used to safeguard workers, such as construction workers, chemists, and welders, from harmful environments.

[87] https://www.statista.com/statistics/857055/waterproof-breathable-textiles-us-market-value-forecast/
[88] Ibid.
[89] https://saicmknowledge.org/sites/default/files/publications/5.%20PFAS%20as%20a%20chemical%20class%20in%20textiles.pdf

"[A] type of PFAS technology is being used in medical garments, hospital gowns, drapes and divider curtains to create a barrier that provides life-saving protection against infections and transmission of diseases in hospitals."[90]
– American Chemistry Council

PFAS plays a critical role in protective clothing. PFAS is required for protection against liquid and gaseous chemicals, microorganisms, and for firefighting activities.[91] PFAS is essential in firefighting gear because of its remarkable heat-resistance, where PFAS are used as a coating on the outer layer and inner moisture barrier to repel water and oil and resist heat, which are critical safety features.

"The PFAS-coated outer layer…repels slick liquids such as oils and fuels. The PFAS compounds in the moisture barrier allow moisture vapors to escape while also preventing moisture from collecting on the skin and potentially burning a firefighter who's in an environment where temperatures can soar."[92]
– Bryan Ormond, Assistant Professor of Textile Protection at North Carolina State

In military or police settings, PFAS materials are utilized to enhance the performance of protective gear, such as bulletproof vests, due to its strength and reliability. Certain types of PFAS can further improve the durability and strength of products like bulletproof vests.

"The pressure-induced transition properties of PTFE generate a significantly different response to ballistic impact compared to other elastomeric polymers. The material changes to a solid in approximately 10 nanoseconds, which is more than adequate for beating ballistic impact time frames"[93]
– Naval Research Laboratory

PFAS Replacements

Due to the expensive production of PFAS, the compound tends to be used in textiles that do not have adequate replacement or where a smaller amount of PFAS can be used compared to the nonfluorinated substitute. The European Chemicals Agency believes that PFAS are required for textile applications of protection against liquid and gaseous chemicals, including aerosols, solid particles, and microorganisms, which is important in professional apparel and technical textiles. For example, research suggests that there are no technically feasible substitutes for medical gowns that have the desired properties, such as chemical inertness and biocompatibility.[94]

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[90] https://www.americanchemistry.com/chemistry-in-america/news-trends/blog-post/2020/the-facts-about-pfas-and-covid-19
[91] https://echa.europa.eu/documents/10162/57812f19-8c98-ee67-b70f-6e8a51fe77e5
[92] https://www.wunc.org/health/2023-01-25/firefighters-worry-about-chemicals-in-their-gear-but-alternatives-could-present-problems-too
[93] https://techlinkcenter.org/technologies/polytetrafluoroethylene-material-for-armor-improves-ballistic-impact-resistance/e5119c28-8155-4a7a-94d1-b0dbbea839eb
[94] https://echa.europa.eu/documents/10162/57812f19-8c98-ee67-b70f-6e8a51fe77e5

“Information provided in relation to the technical textile industry (which is dominated by information relating to high performance membranes) suggests a clear tendency towards business closures as reaction to a ban of PFASs with very few or no respondents already using alternatives or being expected to substitute in response to the restriction.”[95]
– ECHA

Alternative water-proofing products may offer water-resistance or water-repelling properties, but independent hazard assessments have not been conducted on all of them.

In firefighting gear, no replacements exist which would pass the National Fire Protection Association standard for turnout gear, making it irreplaceable in this application. The National Fire Protection Association creates codes and standards to protect against dangers due to fire, electrical, and other related hazards. In 2007, the association implemented a requirement for the middle layer in turnout gear to withstand 40 hours of continuous UV light. To pass this test, the turnout gear requires the textiles to contain PFAS and there are currently no alternatives which can meet this requirement.[96]

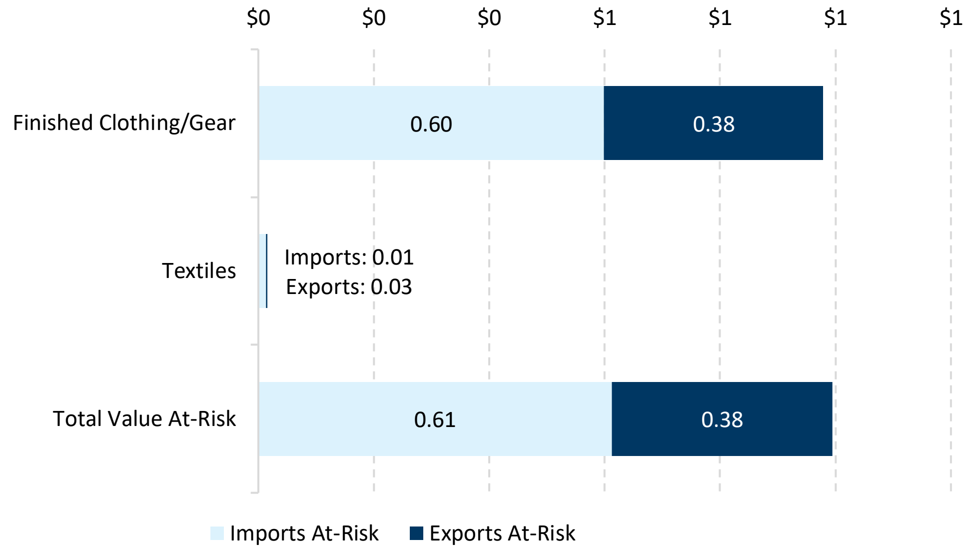
PFAS are a valuable addition to protective gear, such as bulletproof vests. While replacements exist for PFAS in bulletproof vests, it is important to note that once Kevlar, a standard protective material, gets wet, its protective properties are diminished. Therefore, PFAS is a useful supplement in these products to ensure water protection is met.[97]

Economic and Environmental Impacts of a Regulation

The heat-resistant properties of PFAS make it irreplaceable for firefighting gear, while its water resistance makes it a popular choice for consumer textiles. For those sub-industries of textiles with limited availability of substitutes all exports are at-risk of a ban on imports of goods containing PFAS into the European Union. The impacts would be highest for professional apparel and technical textile companies. Due to the full reliance of PFAS in PPE for firefighting and other activities, a ban on imports of goods containing PFAS into the European Union from the U.S. would disrupt a significant portion of the textile industry, including an estimated $613 million in U.S. imports from the EU. The value of at-risk exported goods to the EU from the U.S. in 2022 containing PFAS is valued at $383 million, as summarized in Figure 21.

[95] ibid.
[96] https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1971
[97] https://echa.europa.eu/documents/10162/57812f19-8c98-ee67-b70f-6e8a51fe77e5

Figure 21 - Value of water-resistant textiles and protective gear trade at-risk of the PFAS Restriction, 2022 (USD billions)



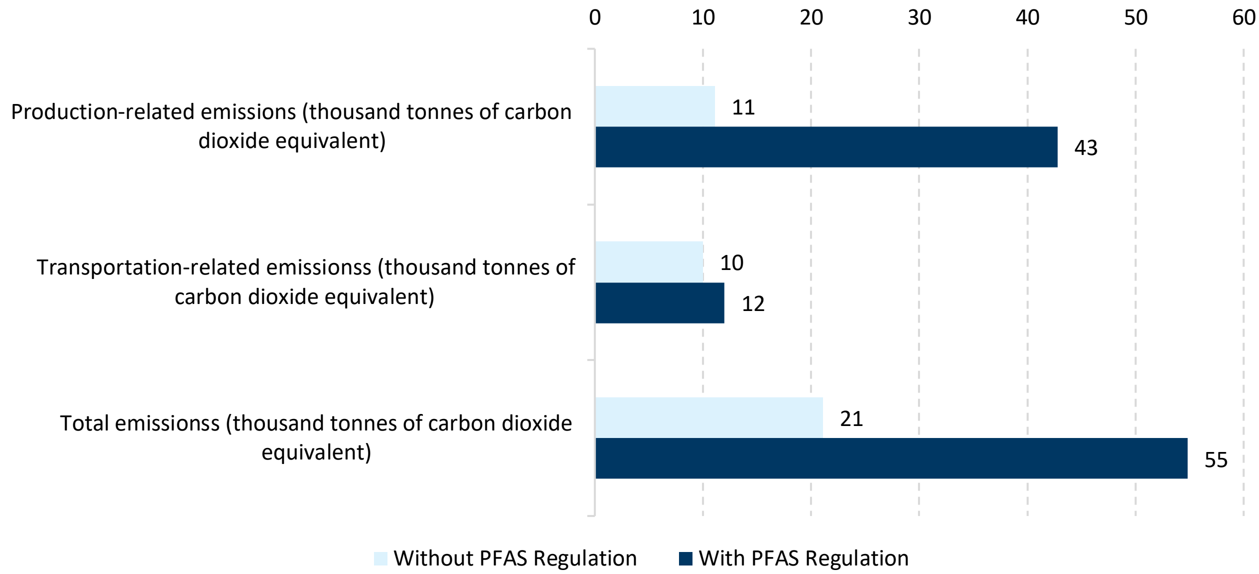
In a scenario in which PFAS Restrictions are put into effect, the U.S. could find alternative trading partners to offset the lost imports of water-resistant textiles and protective gear from the EU. In 2022, the U.S. imported the highest value of textiles from China than from any other top 15 non-EU import trading partner. If the U.S. were to offset imports of water-resistant textiles and protective gear from the EU with imports from China on a one-to-one basis based on 2022 data, the estimated annual emissions associated with the production of the lost water-resistant textiles and protective gear would increase from 11 thousand to 43 thousand tonnes of CO_2e, or a 285% increase. The annual emissions associated with the transportation of these water-resistant textiles and protective gear to the U.S. would increase from 3 thousand to 10 thousand tonnes of CO_2e, or a 232% increase.

In a scenario in which PFAS Restrictions are put into effect, the U.S. would also need to find alternative trading partners to offset the lost exports of water-resistant textiles and protective gear from the U.S. to the EU.

Mexico is the largest non-EU trading partner to the U.S. in terms of exports for water-resistant textiles and protective gear. If the U.S. were to offset exports of water-resistant textiles and protective gear from the EU with exports to Mexico on a one-to-one basis based on 2022 data, the estimated annual emissions associated with the transportation of these products from the U.S. would decrease from 7 to 2 thousand tonnes of CO_2e, or by 71%.

Figure 22 summarizes the total change in water-resistant textiles and protective gear manufacturing emissions due to the PFAS Restriction between the U.S. and EU for both imports and exports combined. Production related emissions would increase from 11 to 43 thousand tonnes of CO_2e, and transportation related emissions would increase from 10 to 12 thousand tonnes of CO_2e. Total emissions would increase from 21 to 55 thousand tonnes of CO_2e or by 162%.

Figure 22 - Annual emissions impacts of substituting U.S. trade of water-resistant textiles and protective gear with the EU, 2022



Fluorinated Gases

Sector Overview

Fluorinated gases ("F-gases") are a type of PFAS which would be at-risk of a trading ban between the U.S. and the EU of goods containing PFAS. This ban would disrupt U.S. imports from the EU valued at $597 million, and $269 million in exports from the U.S. to the EU.

F-gases are emissions primarily caused by industrial activities. F-gases were originally developed to substitute common ozone-depleting substances ("ODS"), such as chlorofluorocarbons and hydrochlorofluorocarbons. In 1987, the Montreal Protocol was established designed to protect the earth's ozone layer by phasing out the use of ODS, leading to the widespread adoption of F-gases as their substitutes. To date, 197 countries have agreed to the protocol, which includes a set of standards and guidelines aimed towards the global reduction of ODS.[98]

In 2022, the U.S. joined the Kigali Amendment, which calls for reducing consumption and producing HFCs, which are a type of F-gas. The Kigali Amendment supplements the original Montreal Protocol, which aims to avoid half a degree Celsius of temperature rise by 2,100 through the phase-down of HFCs.[99] The U.S. is a major global supplier of ammonia, carbon dioxide, and low global warming potential HFCs and HFOs, which are common substitutes for HFCs. Industry estimates predict that the U.S. joining the Kigali Amendment will create 33,000 new U.S. manufacturing jobs over the next 10 years through the increased demand for HFC substitutes.[100] The PFAS Restriction would prevent this important phasedown from continuing.

PFAS Applications

PFAS are commonly used in air conditioning, space heating, heat pumps, and refrigeration systems. A primary application of F-gases is for air-conditioning and heating in indoor buildings, automobiles, and airplanes. F-gases are a primary coolant in the cold chain which maintains the quality and safety of temperature-sensitive products such as food and medicine during storage and transportation. F-gases are used in immersion cooling to remove heat from electrical systems, batteries, motors, and computer servers and data centers. Liquid coolants, often F-gases, are directly deployed in contact with hot systems and then circulated through a heat exchanger to remove the heat. The primary sources of F-gases are summarized below in Figure 23.

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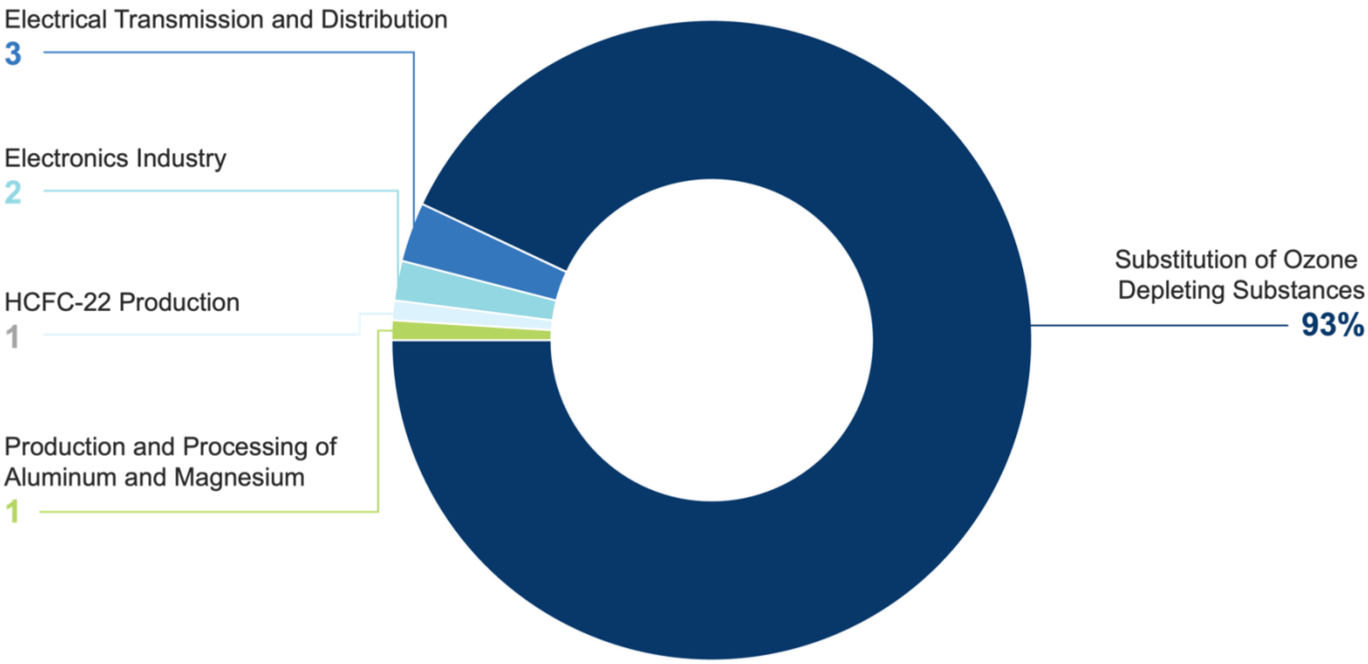
98 https://www.epa.gov/ozone-layer-protection/international-actions-montreal-protocol-substances-deplete-ozone-layer#:~:text=The%20Montreal%20Protocol%20is%20signed,most%20successful%20environmental%20global%20action.

99 https://www.state.gov/key-topics-office-of-environmental-quality-and-transboundary-issues/the-montreal-protocol-on-substances-that-deplete-the-ozone-layer/

100 https://www.state.gov/u-s-ratification-of-the-kigali-amendment/

Figure 23 — U.S. Fluorinated gas emissions by source[101]



PFAS Replacements

The feasibility of replacing these F-gases is very limited due to the alternatives having to exhibit characteristics of low GWP, toxicity, and life cycle cost, while being affordable, safe, and environmentally friendly.[102]

Feasible alternatives to F-gases for indoor cooling exist, especially for small scale use like individual houses. For larger-scale cooling in commercial settings, CO_2 is a commonly used replacement. Two potential alternatives for F-gases in refrigerants are ammonia and carbon dioxide, but they come with potential challenges. Ammonia has toxicity concerns, while CO_2 requires high pressurization for storage and use.[103]

In refrigerated transportation, there are potential alternatives, but these have lower energy efficiency and increased safety concerns compared to traditional F-gas applications. CO_2 can be used at a smaller scale but is less effective for larger-scale refrigeration or long-range transportation.

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[101] The Chamber's expert's analysis of https://www.epa.gov/ghgemissions/overview-greenhouse-gases#f-gases
[102] https://assets.danfoss.com/documents/latest/211728/AD224586434178en-001001.pdf
[103] https://echa.europa.eu/documents/10162/57812f19-8c98-ee67-b70f-6e8a51fe77e5

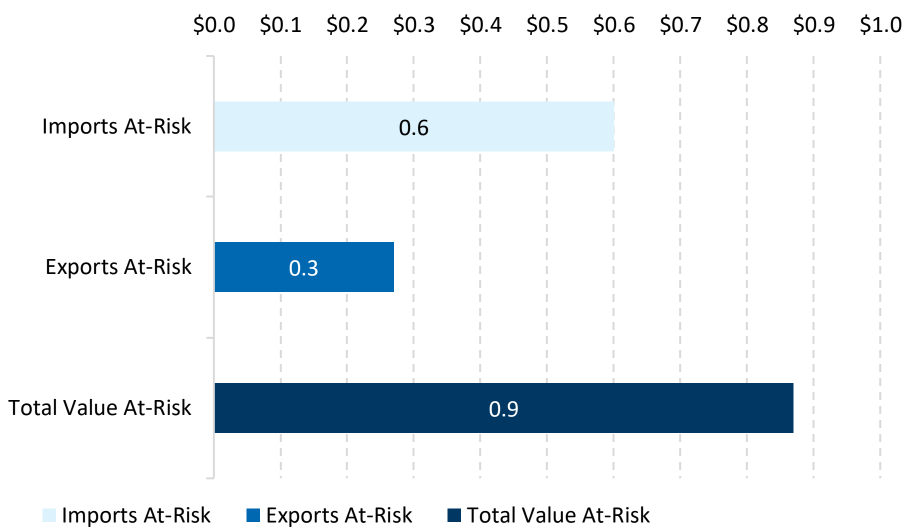
> “There is no non-PFAS alternatives yet available to meet the required performance, energy efficiency and safety. CO2 systems are currently not reliable systems due to restrictions in available space and increase in energy consumption. Therefore, continued need for fluorinated gases is expected in the transport of refrigerated goods over long distances and variable operating conditions between warm and cold climate.”
> **– ECHA**

In immersion cooling, alternatives to F-gas exist and are actively being used.[104] It is important to note, however, F-gases provide excellent heath-resistance and electrical insulation properties in immersion cooling.[105]

Economic and Environmental Impacts of a Regulation

All traded goods of F-gases would be at-risk of a trading ban between the U.S. and the EU of products which contain PFAS. Total U.S. imports from the EU of these goods were valued at $596 million, while total exports from the U.S. to the EU were valued at $269 million, summarized in Figure 24.

Figure 24 - Value of F-gases trade at-risk of the PFAS Restriction, 2022 (USD billions)



In a scenario in which PFAS Restrictions are put into effect, the U.S. could find alternative trading partners to offset the lost imports of F-gases from the EU. In 2022, the U.S. imported the highest value of industrial gases from China than from any other top 15 non-EU import trading partner. If the U.S. were to offset imports of industrial gases, which would encompass F-gases, from the EU with imports from China on a one-to-one basis based on 2022 data, the estimated annual emissions associated with

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[104] Ibid.

[105] https://en.capchem.com/product/97/#:~:text=Cooling%20agent%20for%20data%20center,dissipation%20design%20for%20IT%20hardware

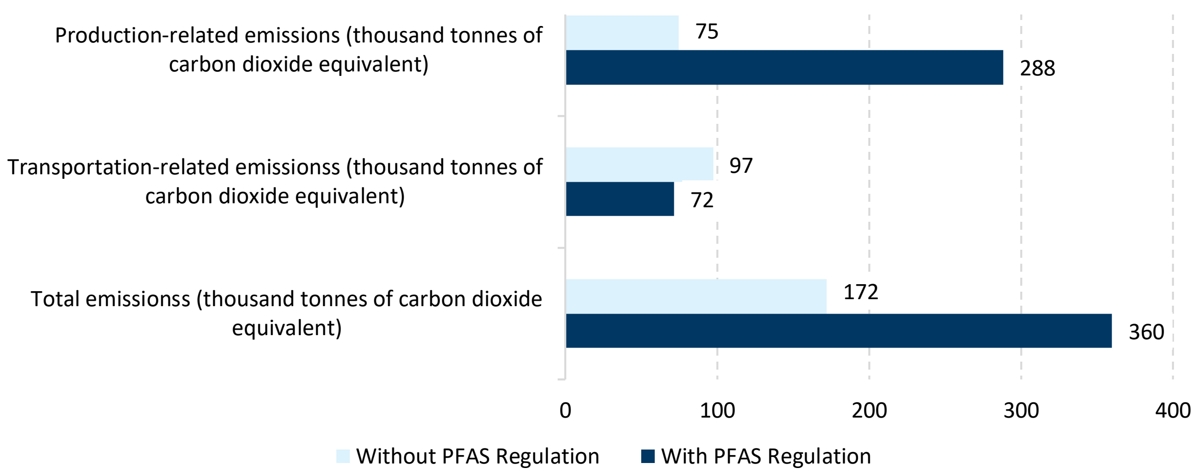
the production of the lost gases would increase from 75 thousand to 288 thousand tonnes of CO_2e. The annual emissions associated with the transportation of F-gases to the U.S. would decrease from 55 thousand to 52 thousand tonnes of CO_2e, or a 5% decrease.

In a scenario in which PFAS Restrictions are put into effect, the U.S. would also need to find alternative trading partners to offset the lost exports of F-gases from the U.S. to the EU.

Mexico is the largest non-EU trading partner to the U.S. in terms of exports for F-gases. If the U.S. were to offset exports of F-gases from the EU with exports to Mexico on a one-to-one basis based on 2022 data, the estimated annual emissions associated with the transportation of these products from the U.S. would decrease from 42 to 19 thousand tonnes of CO_2e, or by 54%.

Figure 25 summarizes the total change in F-gases manufacturing emissions due to the PFAS Restriction between the U.S. and EU for both imports and exports combined. Production related emissions would increase from 75 to 288 thousand tonnes of CO_2e, and transportation related emissions would decrease from 97 to 72 thousand tonnes of CO_2e. Total emissions would increase from 172 to 360 thousand tonnes of CO_2e or by 109%.

Figure 25 - Annual emissions impacts of substituting U.S. trade of F-gases with the EU, 2022



Automotive Transportation

Sector Overview

In 2022, the U.S. automotive manufacturing sector employed nearly 3 million workers and sold over 13.7 billion vehicles globally. [106,107] U.S. exports to the EU include finished passenger cars, light, medium, and heavy-duty trucks, as well as engines, break lines, and other components and parts. Total exports, which include both internal combustion and parts of electric vehicles, were valued at $10.2 billion in finished products and $4.2 billion in components and parts in 2022.

In 2022, the hybrid and electric vehicle manufacturing industry employed over 34,000 workers in the U.S.[108] While no recent research is available to determine the value of U.S. electric vehicle exports to the EU, in 2020 approximately 150,000 electric vehicles were exported by the U.S. to all of Europe.[109]

The adoption of electric vehicles in the U.S. has accelerated rapidly since the mid-2010s. In 2011, only 22,000 electric vehicles were sold, accounting for just 0.2% of total vehicle sales. However, by 2021, electric vehicles made up approximately 2 million or 4.5% of total vehicle sales, as shown in Figure 27. Forecasted growth rates predict strong adoption of electric vehicles globally, with the International Energy Association projecting that 20% of vehicles on the road in 2030 will be electric.[110]

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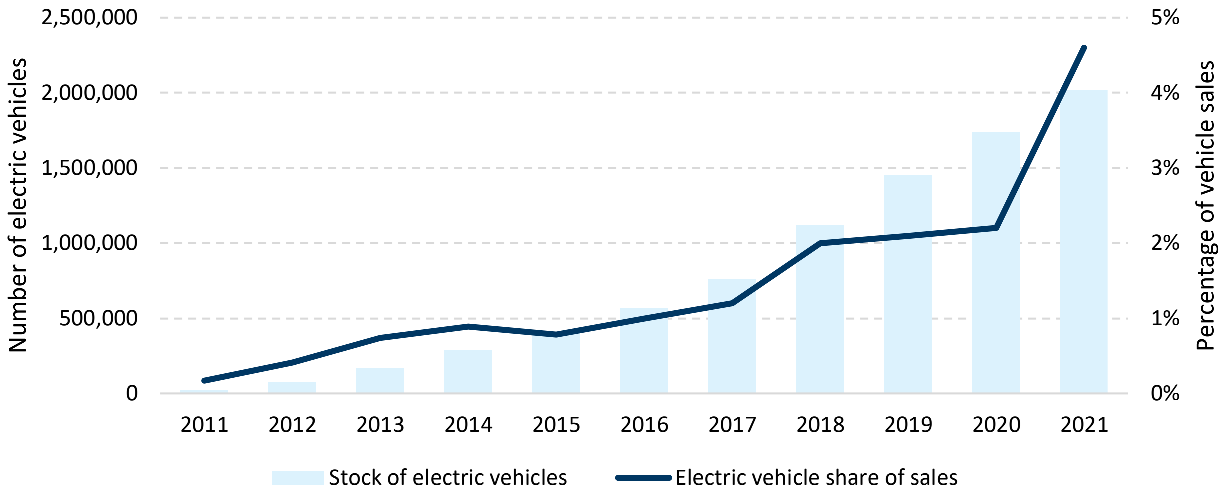
[106] https://www.statista.com/statistics/276474/automotive-industry-employees-in-the-united-states-by-sector/
[107] https://www.nada.org/nada/press-releases/nada-issues-analysis-2022-auto-sales-and-2023-sales-forecast#:~:text=2022%20ended%20with%20new%20light, and%20additional%20supply%20chain%20disruptions.
[108] https://www.ibisworld.com/industry-statistics/employment/hybrid-electric-vehicle-manufacturing-united-states/#:~:text=There%20are%2041%2C841%20people%20employed, the%20US%20as%20of%202023.
[109] https://theicct.org/wp-content/uploads/2022/06/us-can-evs-power-play-unlock-potential-of-auto-trade-with-elec-vehicles-jun22.pdf
[110] https://iea.blob.core.windows.net/assets/dacf14d2-eabc-498ª-8263-9f97fd5dc327/GEVO2023.pdf#page=9

Figure 27 – EV adoption in the U.S.[111]



[111] The Chamber's expert's analysis of https://www.bls.gov/opub/btn/volume-12/charging-into-the-future-the-transition-to-electric-vehicles.htm

PFAS Applications

PFAS are used in various transportation applications such as in mechanical components, electronics, air-conditioning, and electric vehicle batteries. Fluoropolymers are commonly used to manufacture mechanical components and surface treatments that are applied in several stages in the process of manufacturing automobiles.[112] Fluoropolymers are a critical component in the production of automotive lubricants, fuel hoses, seals, lubricants, and gaskets due to their durability and reliability.[113,114] Fluoropolymer's beneficial characteristics include water and oil repellence, resistance to extreme temperatures, and chemical resistance. PFAS are present in the manufacturing and components of all vehicles on the road today. Access to reliable replacement parts for all vehicles, including out-of-production or vintage vehicles, is crucial to ensure comparable quality.

"Typical applications include seals and gaskets in the vicinity of the engine and the transmission, in fuel and coolant systems, and hoses for fuels and coolants. Replacing these materials with inadequate alternatives would reduce vehicle lifetimes, increase the rate of damage, and push up emissions during vehicle operation."[115]

– German Association of the Automotive Industry

Both combustion vehicles and electric vehicles use fluorinated gases in their air-conditioning systems. While potential substitutes exist, they are unproven in terms of being better for the environment. Most cars today use HFC-134a as the coolant, which is a type of F-gas and has a GWP of 1,430.[116] These replaced ozone-depleting CFC-12 coolants in the 1990s which have a GWP of 10,900.[117]

In vehicle electronic systems, semiconductors are essential components in modern vehicles with between 1,000-3,000 in every vehicle on average. [118] They serve as the building blocks of electronic components, enabling safety features such as cruise control, airbag deployment, blind spot, and lane departure warnings. This technology also supports infotainment and navigation systems, adaptive cruise control, and touchscreens.[119] Semiconductors have allowed modern vehicles to switch from manual systems to electronic ones, such as power windows and door locks.[120] Semiconductors are small and lightweight, delivering high value for a low cost in vehicle design.

Electric vehicles rely on PFAS in many of the same capacities as traditional combustion vehicles, but PFAS are also critical components in the production of EV batteries. Most electric vehicles are powered by lithium-ion batteries, which are commonly used in consumer electronics such as laptops, phones, power tools, and more. PFAS are used in lithium-ion batteries as a separator material, which improves the adhesion of the electrode material, limits the risk of short circuits, and enhances the performance

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112 https://www.chemours.com/en/-/media/files/corporate/pfas/fluoropolymers-automotive-fact-sheet.pdf?rev=9de3d4743af441618675ddc90f7f8f8b&hash=F27A561A2EE81D466F5FA5C98AC2C3CA
113 http://www.environmentalrestoration.wiki/images/2/2e/ITRC_PFAS-1.pdf
114 https://norden.diva-portal.org/smash/get/diva2:1295959/FULLTEXT01.pdf
115 https://www.vda.de/dam/jcr:0e95a041-1cc3-432c-b6ac-915788e5ead8/Position_PFAS_2021-09-20_EN.pdf?mode=view
116 https://www.epa.gov/mvac/refrigerant-transition-environmental-impacts
117 Ibid.
118 https://www.forbes.com/sites/willyshih/2022/11/20/why-are-automotive-chips-still-in-short-supply/?sh=72a2d33e782a
119 https://www.automoblog.net/research/news/semiconductor-shortage-explained/
120 https://www.forbes.com/sites/willyshih/2022/11/20/why-are-automotive-chips-still-in-short-supply/?sh=72a2d33e782a

and safety of the battery. Additionally, electric vehicles use fluorinated gases as coolants to maintain battery temperature, especially during charging. If there is no cooling during this process, batteries may be at-risk of overheating.

Overall, the properties of PFAS improve the quality of finished vehicles by decreasing vehicle weight, increasing fuel economy, and overall reliability. They also create more efficient and user-friendly vehicles that are safer, more advanced, and more environmentally friendly than their historic counterparts.[121] Current applications of PFAS in the transportation sector provide durability and extend the useful life of vehicles. Without PFAS, there would be reliability implications resulting in more wear and tear, higher maintenance needs, and an overall increase in vehicle maintenance costs for drivers.

PFAS Replacements

Currently, there are no viable substitutes for PFAS in the automotive manufacturing sector.[122] In mechanical components, PFAS are relied on for their heat, resistance, and corrosion resistant properties. Replacement parts for existing motor vehicles must be identical to existing parts, so even if PFAS free mechanical components were developed in the near-term, it is possible that they could not be utilized as replacement parts for existing vehicles. The use of PFAS free replacement parts in existing vehicles could result in negative consumer impacts including shorter average vehicle life, decreased vehicle performance, and more frequently required maintenance.

Semiconductors are ubiquitous with modern vehicles. For example, the automotive market was severely disrupted due to a semiconductor shortage across global supply chains during and after the COVID-19 pandemic. In 2021, the shortage resulted in the loss of over 7.7 million vehicles and $210 billion in revenue for the industry.[123] The PFAS Restriction could potentially have a similar impact on the industry, as research suggests that semiconductors that do not intentionally add PFAS with comparable performance to current products will likely not be available for at least 15 years.[124]

HFCs are current being phased down as a coolant in vehicle air-conditioning units. Starting with model year 2021 light duty vehicles, HFC-134a is no longer an acceptable coolant due to its high GWP. Replacements for F-gases in vehicle AC units include HFO-1234yf and carbon dioxide.

Currently, there are no practical substitutes for PFAS in the electrical components of lithium-ion batteries, despite active research for alternative options.[125] CO_2 has been evaluated as a substitute for PFAS in this application but has been found inadequate for these purposes in combustion vehicles because it leaks, unlike fluorinated gases. Once a suitable replacement is found, a full industry transition to a different coolant type for electric vehicle temperature maintenance is estimated to take approximately 15 years.[126]

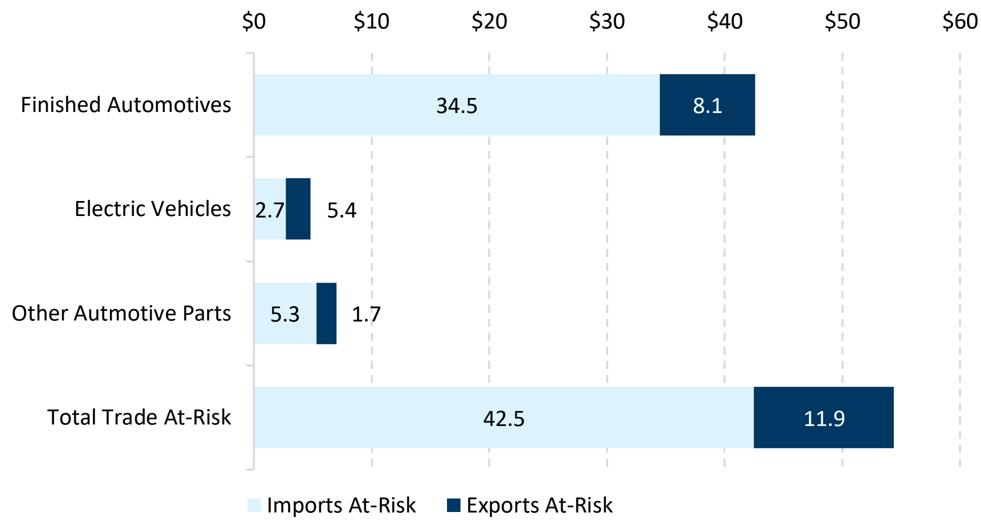
[121] https://www.chemours.com/en/-/media/files/corporate/pfas/fluoropolymers-automotive-fact-sheet.pdf?rev=9de3d4743af441618675ddc90f7f8f8b&hash=F27A561A2EE81D466F5FA5C98AC2C3CA
[122] https://echa.europa.eu/documents/10162/57812f19-8c98-ee67-b70f-6e8a51fe77e5
[123] https://www.reuters.com/business/autos-transportation/automakers-chip-firms-differ-when-semiconductor-shortage-will-abate-2022-02-04/
[124] https://www.semi.org/en/blogs/semi-news/fluorinated-chemicals-are-essential-to-semiconductor-manufacturing-and-innovation
[125] https://echa.europa.eu/documents/10162/57812f19-8c98-ee67-b70f-6e8a51fe77e5
[126] Ibid.

Economic and Environmental Impacts of Regulation

Both fluoropolymers and F-gasses are irreplaceable components in the manufacture of automotives and electric vehicles at present.[127] Due to the widespread use of PFAS in this sector, the entirety of the sector's bilateral trade value would be at-risk of the PFAS Restriction, or approximately $42.5 billion in U.S. imports from the EU and $11.9 billion in U.S. exports to the EU, as summarized in

Figure 27.

Figure 27 - Value of automotive manufacturing trade at-risk of the PFAS Restriction, 2022 (USD billions)



The PFAS Restriction would result in a significant disruption in the electric vehicle market and greatly reduce the pace of EV adoption of globally, resulting in more combustion vehicles remaining on the road in the near term and, potentially, the long term. Research suggests that over the full "cradle-to-grave" life of vehicles, electric vehicles can reduce emissions by 50-70% over their lifetime when compared to standard combustion vehicles, when measured by CO_2e.[128]

In a scenario in which PFAS Restrictions are put into effect, the U.S. could find alternative trading partners to offset the lost imports of automotives from the EU. In 2022, the U.S. imported the highest value of automotives from Mexico than from any other top 15 non-EU import trading partner. If the U.S. were to offset imports of automotives from the EU with imports from Mexico on a one-to-one basis based on 2022 data, the estimated annual emissions associated with the production of the lost automotives would increase from 4,328 thousand to 10,489 thousand tonnes of CO_2e. The annual emissions associated with the transportation of these automotives to the U.S. would decrease 560 thousand to 258 thousand tonnes of CO_2e, or a 54% decrease.

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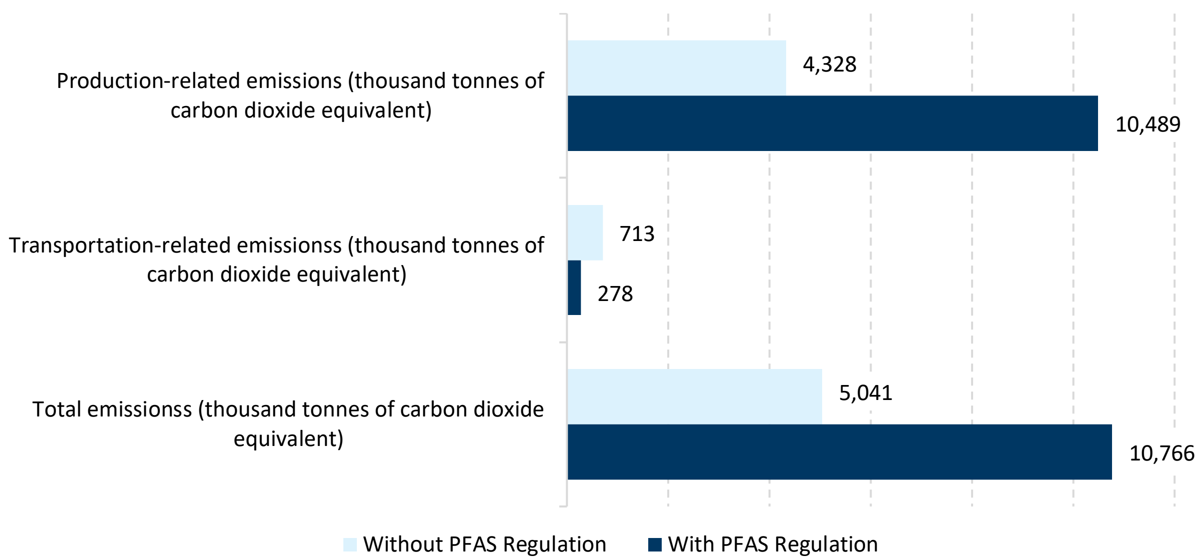
[127] https://www.chemours.com/en/pfas-advocacy/ev-auto

[128] https://www.nytimes.com/2022/10/19/business/electric-vehicles-carbon-footprint-batteries.html#:~:text=%E2%80%9CAll%20studies%20agree%20that%20electric,faster%20you'll%20recoup.%E2%80%9D

Canada is the largest non-EU trading partner to the U.S. in terms of exports automotives. If the U.S. were to offset exports automotives from the EU with exports to Canada on a one-to-one basis based on 2022 data, the estimated annual emissions associated with the transportation of these products from the U.S. would decrease from 153 to 20 thousand tonnes of CO_2e, or by 87%.

Figure 28 summarizes the total change in F-gases manufacturing emissions due to the PFAS Restriction between the U.S. and EU for both imports and exports combined. Production related emissions would increase from 4,328 thousand to 10,489 thousand tonnes of CO_2e, and transportation related emissions would decrease from 713 to 278 thousand tonnes of CO_2e. Total emissions would increase from 5,041 to 10,766 thousand tonnes of CO_2e or by 114%.

Figure 28 - Annual emissions impacts of substituting U.S. trade of automotives with the EU, 2022



U.S. Chamber of Commerce