



*Quantifying the Economic
Contribution of Key Industries
which use PFAS as Vital Inputs*

A Report Prepared for the
Sustainable PFAS Action Network

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Quantifying the Economic Contribution of Key Industries which use PFAS as Vital Inputs

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Executive Summary

PFAS (Per- and Polyfluoroalkyl Substances) are chemicals which have been used in a wide variety of health, safety, and consumer applications for decades. Their unique properties help provide water, oil, and stain repellency; chemical and temperature resistance; friction reduction; and other useful characteristics. They comprise many different chemistries and forms. Importantly, however, the stability of PFAS compounds also causes concerns about their impact on the environment and human health. While these sustainability issues are important, it is also essential to understand how PFAS are currently used throughout the economy.

The purpose of this study is to quantify the economic contributions of key industries which utilize PFAS as vital inputs, whether as an important part of a final product itself or as an essential part of its production process. For this reason, the economic impacts of PFAS are considered broadly and no distinctions are made among the various substances falling within the broadest definitions of PFAS. While PFAS are used in a diverse set of industries throughout the economy, this study is limited to the following segments where PFAS are known to be important:

- Aerospace manufacturing (NAICS 336411, 336414, 336415)
- Automotive manufacturing (NAICS 336111, 336112, 336120)
- Battery manufacturing (NAICS 335911, 335912)
- Medicine and Pharmaceutical manufacturing (NAICS 325411, 325412)
- Refrigeration and Air Conditioning manufacturing (share of NAICS 333415)
- Semiconductors manufacturing (NAICS 334413)

The industries listed above help support economic activity in addition to what is reported in official statistics. Indeed, they operate in a dynamic network of industries that buy from and sell to each other. These chains of effects mean the focus industries support jobs and contribute to gross domestic product (GDP) via other industries in the U.S. economy. Such effects are known as indirect and induced impacts. To measure the economic impacts of industries which use PFAS as vital inputs, we use input-output (IO) analysis and IMPLAN, a widely used economic modeling system.

The table below provides a summary of the overall total (direct + indirect + induced) contribution of the industries described in this analysis in 2021. In total, the analyzed PFAS-related industries help contribute nearly 6.2 million jobs, approximately \$560 billion in labor income, and more than \$1 trillion towards U.S. domestic GDP.

Table ES-1. Contribution Summary, Analyzed PFAS Industries
Units: Thousand Jobs and Billion \$

PFAS-Related Industry	Employment (1,000 Persons)	Labor Income (Billion \$)	GDP (Billion \$)
Aerospace Manufacturing	1,127.3	107.7	191.0
Automotive Manufacturing	2,421.2	192.5	358.7
Battery Manufacturing	117.3	10.0	15.3
Medicine and Pharmaceutical Manufacturing	1,262.1	124.0	303.9
Refrigeration and AC Manufacturing	283.0	22.0	39.6
Semiconductor Manufacturing	985.5	101.5	173.1
Total	6,196.4	557.7	1,081.5

Source: Inforum, IMPLAN

1. Introduction

PFAS (Per- and Polyfluoroalkyl Substances) are chemicals which have been used in a wide variety of health, safety, and consumer applications for decades. PFAS constitute a very broad group of substances, including polymers, liquids, and gases with vastly different chemistries. Their unique properties help provide water, oil, and stain repellency; chemical and temperature resistance; friction reduction; and other useful traits.

Given their desirable characteristics, PFAS have become integral parts of many industries. In some, they may constitute a significant portion of the final product, contributing directly to its utility. In other applications, PFAS may be used in one or more steps during production but remain only as small residuals in a final product. At the time of this writing, PFAS are often considered essential to a given production process or product. Importantly, however, the stability of some types of PFAS compounds has raised concerns regarding their health and environmental impacts. While important, any PFAS policy discussion benefits from understanding these sustainability issues as well as recognizing how PFAS are used throughout the economy.

The purpose of this study is to quantify the economic contributions of several key industries which utilize PFAS as vital inputs. It is not a complete list; nor does it attempt to measure the specific economic contribution of PFAS to a given product or process. Instead, it measures the full contribution of the selected PFAS-reliant industries. Although specific PFAS may be of greater or lesser concern, no distinctions are made in considering their roles in the economy, and all substances in the broadest definitions of PFAS are considered.

The study assesses the economic contributions of the following segments:

- Aerospace manufacturing (NAICS 336411, 336414, 336415)
- Automotive manufacturing (NAICS 336111, 336112, 336120)
- Battery manufacturing (NAICS 335911, 335912)
- Medicine and Pharmaceutical manufacturing (NAICS 325411, 325412)
- Refrigeration and Air Conditioning manufacturing (share of NAICS 333415)
- Semiconductors manufacturing (NAICS 334413)

The industries listed above help support economic activity in addition to what is reported in official statistics. Indeed, they operate in a dynamic network of industries that buy from and sell to each other. These chains of effects mean the focus industries support jobs and contribute to gross domestic product (GDP) via other industries in the U.S. economy. Such effects are known as indirect and induced impacts.

Section 2 describes the methodology used to estimate economic impacts as well as key terms to be aware of. Section 3 provides quantitative results showing how industries which use PFAS as vital inputs make economic contributions to the domestic economy. Finally, Section 4 summarizes findings.

2. Methodology and Key Terms

The calculated economic impacts presented in this study make use of input-output (IO) tools, also known as interindustry analysis. Inforum, an economic research organization, has been building economic models and employing IO techniques for over 50 years¹. Inforum researchers explore economic phenomena in a nonpartisan fashion, according to generally accepted economic theory and econometric methods, regardless of the implications for public policy or private strategy. It is known for its proficiency with industry-level data, input-output techniques, global data sets, and modeling software.

To measure the economic impacts of industries which use PFAS as vital inputs, we use IO analysis and IMPLAN², a widely used economic modeling system. These tools can be used to estimate chains of effects that occur through the interrelationships between businesses, government, and households. This analysis uses the 2021 IMPLAN database and model. All economic impacts are presented as inflation-adjusted 2021 dollars (2021\$). All results are for the calendar year 2021.

This section describes the concepts being measured and the methodology employed to estimate the impacts.

Three types of economic impacts are derived in this study:

1. **Direct Impacts** - Activity generated within the focus industry. In this case, manufacturing of aerospace equipment; automobiles; batteries; medicine and pharmaceuticals; refrigeration and air conditioning equipment; and semiconductors serve as direct impacts.
2. **Indirect Impacts** - Activity generated in other industries due to purchases (materials, energy, and services) by the focus industry through the supply chain. For example, an automobile manufacturing firm might purchase tires, steel, and electrical components to produce their final product.
3. **Induced Impacts** - Activity generated by purchases of households from income earned from direct and indirect production.

Using IMPLAN, we estimate the direct, indirect, and induced impacts on:

1. **Employment** - Persons employed by an industry. Employment³ figures use Bureau of Economic Analysis' (BEA) and Bureau of Labor Statistics' (BLS) full-time/part-time annual average for a given industry. The data covers both wage and salary employees and those who are self-employed.

¹ More information about Inforum can be found at: www.inforumecon.com

² More information about IMPLAN is available at: <https://blog.implan.com/what-is-implan>

³ Additional details about employment in the IMPLAN system is available at: <https://support.implan.com/hc/en-us/articles/115009510967-Employment-Data-Details>

2. **Labor Income** - Labor income⁴, a component of value added, is the sum of salary/wages and supplements. Supplements may take the form of employer contributions for employee pensions and insurance funds (such as health insurance) and employer contributions for government social insurance (social security). This concept also includes proprietor income.
3. **GDP** – GDP is the value of goods and services produced by an industry or region. It is equivalent to value added and represents the enhancement an industry provides (ex: assembly) to a product/service before offering it to the end consumer. Furthermore, it is the difference between the total revenue of an industry and the cost of intermediate inputs. Components of value added include employee labor compensation, taxes on production and imports, and gross operating surplus (including profits).

IO analysis is performed using tables that show the interrelationships between industries. Looking down the column of a table, we see all the inputs of other industries used to produce that industry's product. Looking across the row of a table, we see the industries and final uses that the industry sells to. These tables are used to calculate the indirect impacts of a given industry's production.

A *multiplier* can be viewed as the ratio of an impact or contribution over the original stimulus. For example, the employment multiplier would show the ratio of additional indirect and induced employment generated, divided by the employment of the focus industry.



⁴ Labor income definition in the IMPLAN system: <https://implanhelp.zendesk.com/hc/en-us/articles/115009499307-Proprietor-income>

3. Economic Contribution of PFAS-Related Industries

Each subsection below details the economic contribution of key industries which use PFAS as vital inputs. They describe both the direct impact commonly reported in government statistics as well as the indirect and induced impacts estimated using IO analysis.

3.1 Aerospace Manufacturing

PFAS are used in military and civilian aerospace applications to bolster the performance of metal plating, sealants, coatings, and fire suppression. Additionally, they are used in aircraft wiring, electronic, and hydraulic systems. This report defines aerospace manufacturing to include the following:

- Aircraft manufacturing (NAICS 336411)
- Guided missile and space vehicle manufacturing (NAICS 336414)
- Propulsion units and parts for space vehicles and guided missiles manufacturing (NAICS 336415)

The aerospace manufacturing industry directly employs more than 280 thousand people who receive roughly \$42 billion in labor income. On average these workers earn just shy of \$150,000 in labor income; this is double the U.S. economy's average labor income (\$73,100). The industry directly contributes \$79.5 billion to domestic GDP. These numbers can be seen on the first row of Table 1.

This direct activity described above generates indirect activity within the economy. These upstream suppliers, who provide inputs for manufacturers, employ an additional 328 thousand people and generate over \$52 billion in indirect GDP impacts. Finally, a portion of the labor income earned by aerospace manufacturing workers and their supply chains is spent on goods and services.

This activity, seen in the third row of Table 1, supports another half million jobs, almost \$34 billion in labor income, and \$59.4 billion in GDP. In total, aerospace manufacturing and related activity helps contribute more than 1.1 million jobs and \$191 billion towards GDP.

In total, aerospace manufacturing activity helps contribute over 1.1 million jobs and \$191 billion towards GDP.

One aerospace manufacturing job supports 3 other jobs elsewhere in the economy.

The data shown in Table 1 reveals that one aerospace manufacturing job helps support three other jobs in the economy⁵. Additionally, one dollar of the industry's GDP generates \$1.40 of GDP elsewhere in the economy⁶.

⁵ Employment multiplier = (Indirect + Induced Employment) / Direct Employment = (328.3 + 517.2) / 281.7 = 3.0

⁶ GDP multiplier = (Indirect + Induced GDP) / Direct GDP = (52.1 + 59.4) / 79.5 = 1.40

Table 1. Economic Contribution Summary - Aerospace Manufacturing
Units: Thousand Jobs and Billion \$

	Employment (1,000 Persons)	Labor Income (Billion \$)	GDP (Billion \$)
Direct	281.7	41.8	79.5
Indirect	328.3	32.2	52.1
Induced	517.2	33.7	59.4
Total	1,127.3	107.7	191.0

Source: Inforum, IMPLAN

Figure 1. Economic Contribution Summary – Aerospace Manufacturing
Units: Thousand Jobs and Billion \$

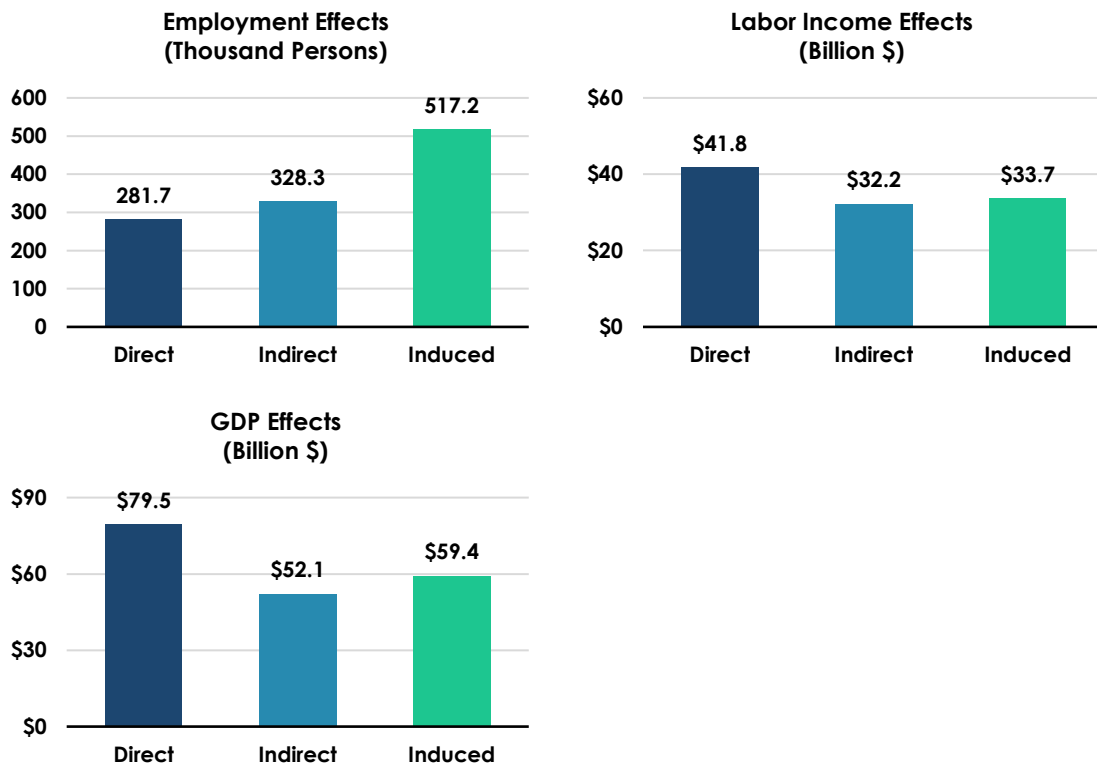


Table 2 highlights the fact that, in many ways, aerospace manufacturing has a long, sector-specific supply-chain; the two largest affected upstream suppliers are 'Aircraft engine and engine parts manufacturing' (\$10.5 billion) and 'Other aircraft parts and auxiliary equipment manufacturing' (\$6.3 billion). These two sectors alone account for nearly one-third of total indirect GDP impacts. Other important industries to aerospace manufacturing include the production of semiconductors (\$3.2 billion) and management (\$3.0 billion).

Table 2. Indirect GDP, Aerospace Manufacturing – Top 10 Industries
Units: Billion \$

Industry	Indirect GDP (Billion \$)
Aircraft engine and engine parts manufacturing	10.5
Other aircraft parts and auxiliary equipment manufacturing	6.3
Semiconductor and related device manufacturing	3.2
Management of companies and enterprises	3.0
Wholesale - Machinery, equipment, and supplies	2.3
Wholesale - Household appliances and electrical and electronic goods	1.9
Custom computer programming services	1.3
Employment services	1.3
Wholesale - Other durable goods merchant wholesalers	1.0
Computer systems design services	0.7
All Other Industries	20.6
Total Indirect GDP	52.1

Source: Inforum, IMPLAN



3.2 Automotive Manufacturing

Automotive firms utilize PFAS compounds in a variety of ways, including fluids, seals, and tubing in engines, sensors for Advanced Driver Assistance Systems (ADAS), and electric insulators for electronics and cabling. This report defines automotive manufacturing to include:

- Automobile manufacturing (NAICS 336111)
- Light truck and utility vehicle manufacturing (NAICS 336112)
- Heavy duty truck manufacturing (NAICS 336120)

The automotive manufacturing industry directly employs more than a quarter million people who earn \$26.5 billion in labor income. On average these workers earn over \$105,000 in labor income; this is roughly 44% greater than the U.S. economy's average labor income (\$73,100). The industry contributes \$81.6 billion to domestic GDP. These numbers can be seen on the first row of Table 3.

This direct activity helps support upstream suppliers. These firms, who provide inputs for manufacturers, employ over 1.2 million people and generate more than \$171 billion in indirect GDP impacts. Finally, a portion of the labor income earned by automotive manufacturing workers and their supply chains is spent on goods and services. This activity, seen in the third row of Table 3, supports an additional 922,000 jobs, \$60 billion in labor income, and almost \$106 billion in GDP. In total, automotive manufacturing and related activity helps contribute more than 2.4 million jobs and nearly \$359 billion towards GDP.

In total, automotive manufacturing activity helps contribute over 2.4 million jobs and \$359 billion towards GDP.

One dollar of the automotive industry's GDP generates \$3.39 elsewhere in the economy.

Using the data in Table 3, we are able to estimate that one automotive manufacturing job helps support 8.6 other jobs in the economy⁷. Additionally, one dollar of the industry's GDP generates \$3.39 of GDP elsewhere in the economy⁸.

Table 3. Economic Contribution Summary - Automotive Manufacturing
Units: Thousand Jobs and Billion \$

	Employment (1,000 Persons)	Labor Income (Billion \$)	GDP (Billion \$)
Direct	252.0	26.5	81.6
Indirect	1,247.0	106.0	171.4
Induced	922.2	60.0	105.6
Total	2,421.2	192.5	358.7

Source: Inforum, IMPLAN

⁷ Employment multiplier = (Indirect + Induced Employment) / Direct Employment = (1,247.0 + 922.2) / 252.0 = 8.6

⁸ GDP multiplier = (Indirect + Induced GDP) / Direct GDP = (171.4 + 105.6) / 81.6 = 3.39

Figure 2. Economic Contribution Summary – Automotive Manufacturing
Units: Thousand Jobs and Billion \$

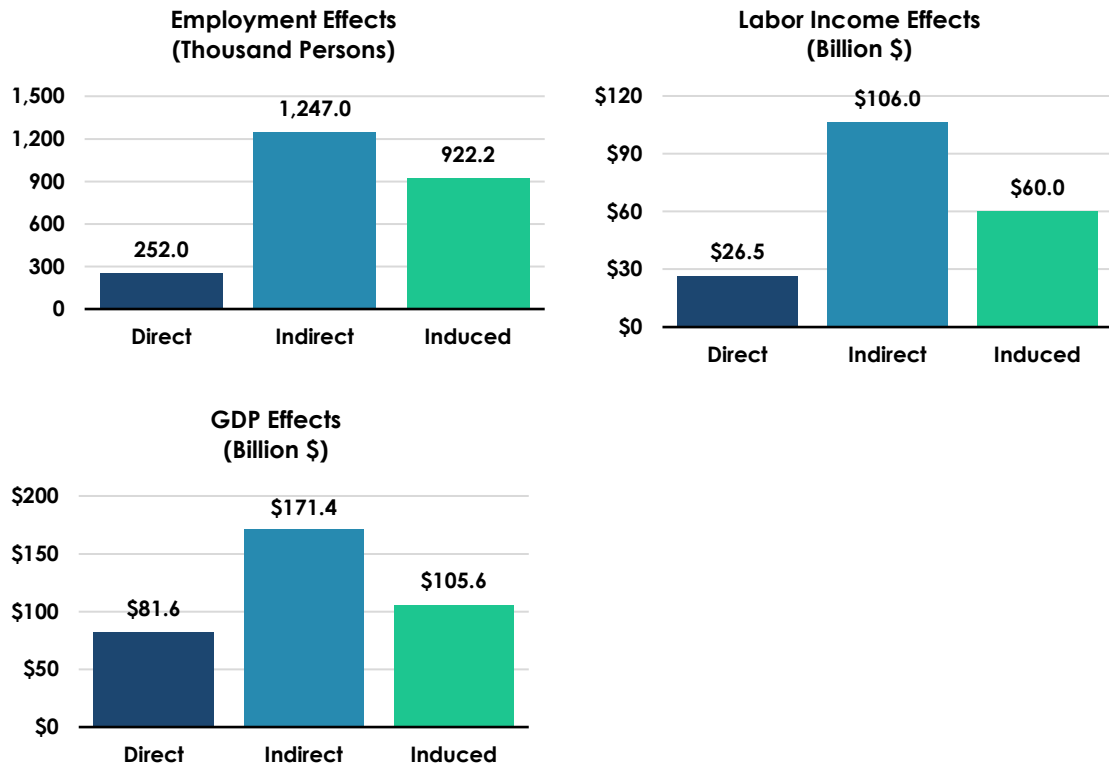


Table 4 lists indirect GDP impacts by detailed industries which help automotive manufacturers meet demand. Three of the top four industries are wholesalers, including 'Motor vehicle and motor vehicle parts and supplies' (\$16.9 billion), 'Machinery, equipment, and supplies' (\$7.8 billion), and 'Other durable goods merchant wholesalers' (\$6.9 billion). Other key upstream suppliers include 'Management of companies and enterprises' (\$8.3 billion) and a variety of manufactured goods specific to motor vehicle production.

Table 4. Indirect GDP, Automotive Manufacturing – Top 10 Industries
Units: Billion \$

Industry	Indirect GDP (Billion \$)
Wholesale - Motor vehicle and motor vehicle parts and supplies	16.9
Management of companies and enterprises	8.3
Wholesale - Machinery, equipment, and supplies	7.8
Wholesale - Other durable goods merchant wholesalers	6.9
Motor vehicle metal stamping	5.3
Motor vehicle seating and interior trim manufacturing	5.1
Motor vehicle transmission and power train parts manufacturing	5.1
Truck transportation	3.9
Semiconductor and related device manufacturing	3.8
Other motor vehicle parts manufacturing	3.6
All Other Industries	104.8
Total Indirect GDP	171.4

Source: Inforum, IMPLAN

3.3 Battery Manufacturing

PFAS compounds are used by manufacturers to produce a wide array of battery types due to their chemical, temperature, and oxidation resistance. The uses of batteries include a growing number of green energy applications, including solar energy storage and electric vehicle propulsion. For the purposes of this analysis, battery manufacturing is defined to include NAICS 335911 and 335912.

The battery manufacturing industry directly employs over 43 thousand people who earn \$4.6 billion in labor income. On average these workers earn almost \$107,000 in labor income; this is nearly 46% greater than the U.S. economy's average labor income (\$73,100). The industry directly contributes \$6.1 billion to domestic GDP. Direct contributions can be seen on the first row of Table 5.

Battery manufacturers generate indirect activity via upstream suppliers, who provide inputs for manufacturers. These firms employ an additional 26.2 thousand people and generate \$3.7 billion in indirect GDP impacts. Finally, a portion of the labor income earned by battery manufacturing workers and their supply chains is spent on goods and services. This activity, seen in the third row of Table 5, supports another 47.8 thousand jobs, \$3.1 billion in labor income, and \$5.5 billion in GDP. In total, battery manufacturers and related activity helps contribute over 117 thousand jobs and more than \$15 billion towards GDP.

In total, battery manufacturing activity helps contribute 117 thousand jobs and \$15 billion towards GDP.

One dollar of battery manufacturing GDP helps generate \$1.51 elsewhere in the economy.

Using the data shown in Table 5, we are able to estimate economic multipliers attributable to battery manufacturing. One battery manufacturing job helps support 1.7 other jobs in the economy⁹. Additionally, one dollar of the industry's GDP generates \$1.51 of GDP elsewhere in the economy¹⁰.

Table 5. Economic Contribution Summary – Battery Manufacturing
Units: Thousand Jobs and Billion \$

	Employment (1,000 Persons)	Labor Income (Billion \$)	GDP (Billion \$)
Direct	43.3	4.6	6.1
Indirect	26.2	2.2	3.7
Induced	47.8	3.1	5.5
Total	117.3	10.0	15.3

Source: Inforum, IMPLAN

⁹ Employment multiplier = (Indirect + Induced Employment) / Direct Employment = (26.2 + 47.8) / 43.3 = 1.7

¹⁰ GDP multiplier = (Indirect + Induced GDP) / Direct GDP = (3.7 + 5.5) / 6.1 = 1.51

Figure 3. Economic Contribution Summary – Battery Manufacturing
Units: Thousand Jobs and Billion \$

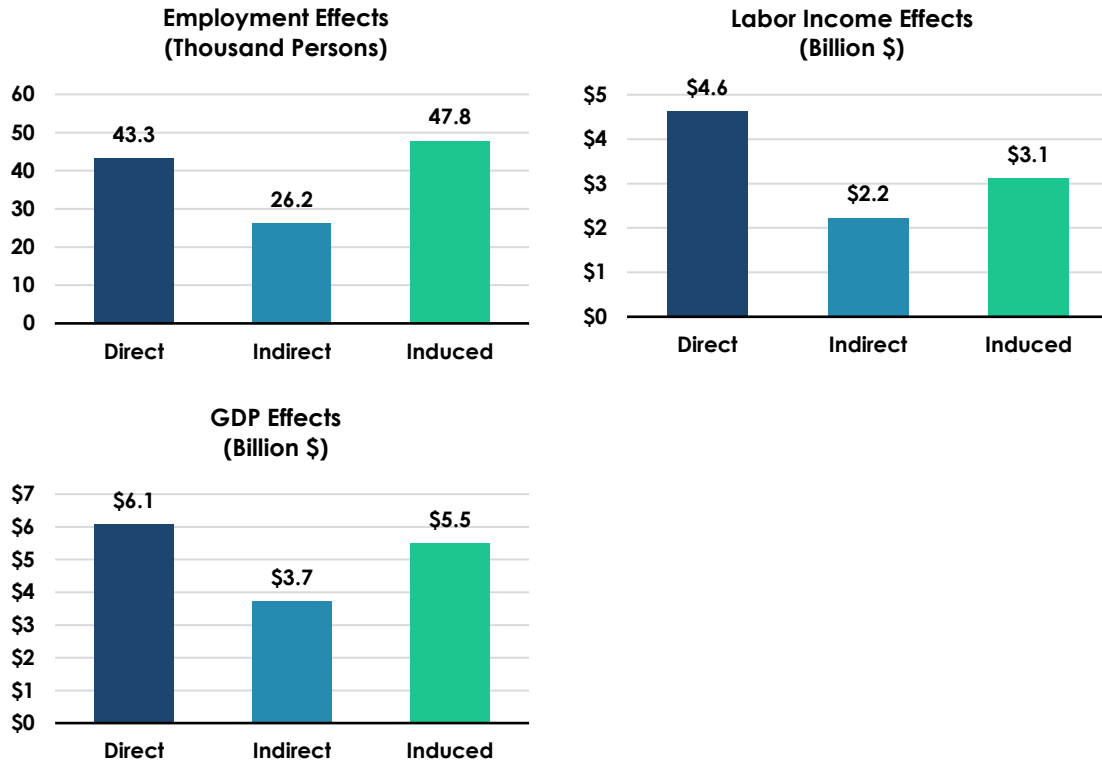


Table 6 displays the indirect GDP impacts associated with battery manufacturing. These upstream industries help firms by supplying needed materials and services. The largest industry listed is 'Wholesale – Other durable goods merchant wholesalers'; these firms are responsible for selling capital goods which battery manufacturers use to produce their merchandise. 'Management of companies and enterprises' (\$0.2 billion) oversee the organization and provide strategic planning. Other top industries include 'Truck transportation' (\$0.1 billion) and 'Electric power transmission and distribution' (\$0.1 billion).

Table 6. Indirect GDP, Battery Manufacturing – Top 10 Industries
Units: Billion \$

Industry	Indirect GDP (Billion \$)
Wholesale - Other durable goods merchant wholesalers	0.5
Management of companies and enterprises	0.2
Truck transportation	0.1
Electric power transmission and distribution	0.1
Iron and steel mills and ferroalloy manufacturing	0.1
Other real estate	0.1
Wholesale - Machinery, equipment, and supplies	0.1
Monetary authorities and depository credit intermediation	0.1
Employment services	0.1
Semiconductor and related device manufacturing	0.1
All Other Industries	2.3
Total Indirect GDP	3.7

Source: Inforum, IMPLAN

3.4 Medicine and Pharmaceutical Manufacturing

The medicine and pharmaceutical manufacturing industries uses PFAS in production facilities to maintain cleanliness and prevent contamination. Additionally, hundreds of active ingredients in medicines including cardiovascular health products, antidepressants, and COVID-19 treatments are themselves classified as PFAS. For the purposes of this analysis, medicine and pharmaceutical manufacturing is defined to cover NAICS 325411 and 325412.

The medicine and pharmaceutical manufacturing industries directly employ nearly 224 thousand people who receive \$42.1 billion in labor income. On average these workers earn just over \$188,000 in labor income; this is more than 2.5 times greater than the U.S. economy's average (\$73,100). The industry directly contributes over \$162 billion to domestic GDP. These numbers can be seen on the first row of Table 7.

Medicine and pharmaceutical manufacturers make purchases of materials and services from upstream suppliers. These firms employ an additional 446.1 thousand people and generate over \$74.4 billion in indirect GDP impacts. A share of the labor income earned directly and indirectly is subsequently spent on a wide variety of goods and services. This activity, seen in the third row of Table 7, supports another

In total, activity related to medicine and pharmaceutical manufacturing helps contribute more than 1.2 million jobs and nearly \$304 billion towards GDP.

592.4 thousand jobs, \$38.4 billion in labor income, and \$67.3 billion in GDP. In total, medicine and pharmaceutical manufacturing and related activity helps contribute more than 1.2 million jobs and nearly \$304 billion towards GDP.

One medicine and pharmaceutical manufacturing job supports 4.6 jobs elsewhere in the economy.

The data shown in Table 7 allows us to estimate economic multipliers attributable to the medicine and pharmaceutical manufacturing industries. One job in these industries helps support 4.6 other jobs in the economy¹¹. Additionally, one dollar of the industry's GDP generates \$0.87 of GDP elsewhere in the economy¹².

Table 7. Economic Contribution Summary - Medicine and Pharmaceutical Manufacturing
Units: Thousand Jobs and Billion \$

	Employment (1,000 Persons)	Labor Income (Billion \$)	GDP (Billion \$)
Direct	223.6	42.1	162.2
Indirect	446.1	43.5	74.4
Induced	592.4	38.4	67.3
Total	1,262.1	124.0	303.9

Source: Inforum, IMPLAN

¹¹ Employment multiplier = (Indirect + Induced Employment) / Direct Employment = (446.1 + 592.4) / 223.6 = 4.6

¹² GDP multiplier = (Indirect + Induced GDP) / Direct GDP = (74.4 + 67.3) / 162.2 = 0.87

Figure 4. Economic Contribution Summary – Medicine and Pharmaceutical Manufacturing
Units: Thousand Jobs and Billion \$

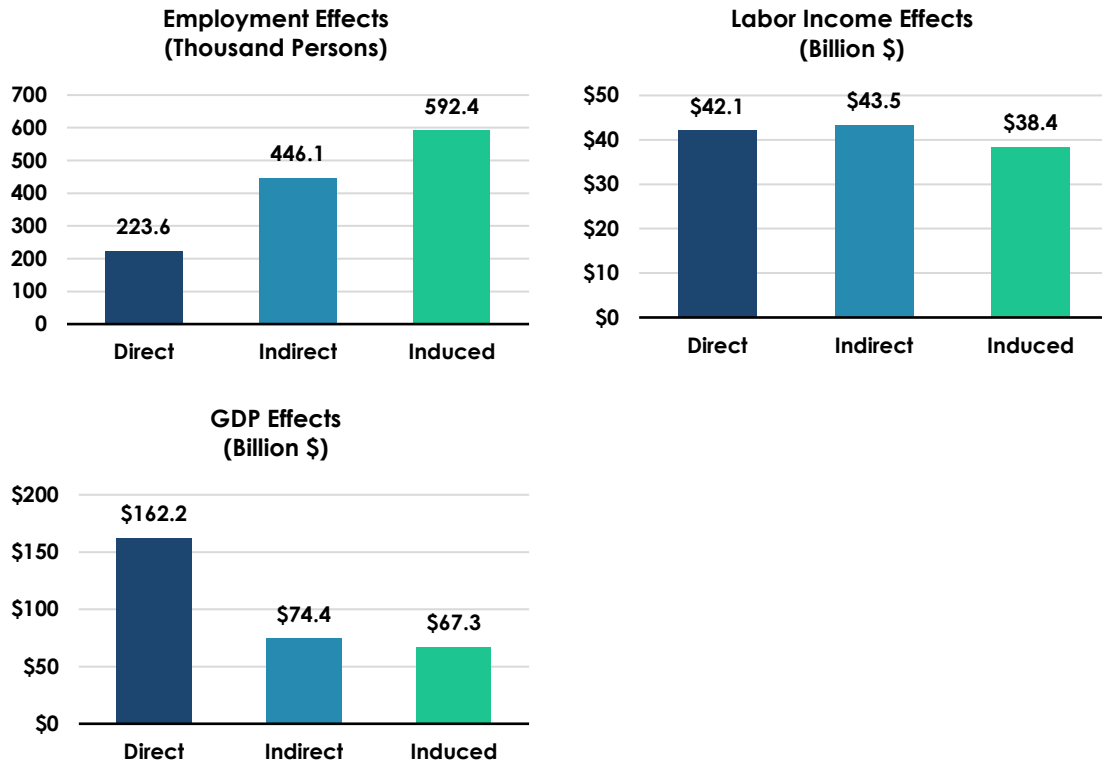


Table 8 displays the indirect GDP impacts associated with medicine and pharmaceutical manufacturing. These upstream industries help manufacturing firms by providing important goods and services. The top industry listed is 'Wholesale – Other durable goods' (\$15.8 billion); they are responsible for helping distribute the inputs needed to produce medicines and pharmaceuticals. 'Management of companies and enterprises' (\$9.0 billion) oversee the organization and provide strategic planning. Other top industries include 'Truck transportation' (\$2.2 billion) and 'Electric power transmission and distribution' (\$2.0 billion).

Table 8. Indirect GDP, Medicine and Pharmaceutical Manufacturing – Top 10 Industries
Units: Billion \$

Industry	Indirect GDP (Billion \$)
Wholesale - Other durable goods merchant wholesalers	15.8
Management of companies and enterprises	9.0
Truck transportation	2.2
Electric power transmission and distribution	2.0
Iron and steel mills and ferroalloy manufacturing	2.0
Other real estate	1.6
Wholesale - Machinery, equipment, and supplies	1.4
Monetary authorities and depository credit intermediation	1.4
Employment services	1.3
Semiconductor and related device manufacturing	1.3
All Other Industries	36.5
Total Indirect GDP	74.4

Source: Inforum, IMPLAN

3.5 Refrigeration and Air Conditioning Manufacturing

The refrigeration and air conditioning manufacturing industry uses compounds, under some definitions described as PFAS, to help chill food, pharmaceuticals, and other temperature-sensitive goods. Additionally, they are utilized in the air conditioning systems of residential homes and nonresidential structures. For the purposes of this analysis, refrigeration and air conditioning manufacturing is defined to include a share of NAICS 333415¹³. The authors of the report, in consultation with subject matter experts, used detailed data to identify specific products which rely on PFAS compounds. Specifically, information within the 2017 Economic Census reveals that approximately 93% of the products produced by the overall 'Air-conditioning and warm air heating equipment and commercial and industrial refrigeration equipment manufacturing' industry utilize PFAS compounds¹⁴.

The refrigeration and air conditioning manufacturing industry directly employs over 86 thousand people who earn \$6.9 billion in labor income. On average these workers earn \$80,000 in labor income; this is nearly 10% greater than the U.S. economy's average labor income (\$73,100). The industry directly contributes \$14.1 billion to domestic GDP. Direct contributions can be seen on the first row of Table 9.

Importantly, the direct activity of refrigeration and air conditioning manufacturers generates indirect activity via upstream suppliers, who provide inputs for manufacturers. These firms employ an additional 91 thousand people and generate \$13.4 billion in indirect GDP impacts. Finally, a portion of the labor income earned by refrigeration and air conditioning manufacturing workers and their supply chains is spent on goods and services. This activity, seen in the third row of Table 9, supports another 105.7 thousand jobs, \$6.9 billion in labor income, and \$12.1 billion in GDP. In total, refrigeration and air conditioning manufacturing and related activity helps contribute 283 thousand jobs and just shy of \$40 billion towards GDP.

In total, refrigeration and air conditioning manufacturing activity helps contribute 283 thousand jobs and nearly \$40 billion towards GDP.

One refrigeration and air conditioning manufacturing job supports 2.3 jobs elsewhere in the economy.

The data shown in Table 9 reveals that one refrigeration and air conditioning manufacturing job helps support 2.3 other jobs in the economy¹⁵. Additionally, one dollar of the industry's GDP generates \$1.81 of GDP elsewhere in the economy¹⁶.

¹³ Please note this industry does not include home appliances (ex: household type refrigerators) or mobile air-conditioning units (motor vehicle air conditioning units). More details on the industry definition are available at: <https://www.census.gov/naics/?input=333415&year=2017&details=333415>

¹⁴ More information about North American Product Classification Codes is available at: <https://www.census.gov/naics/napcs/>

¹⁵ Employment multiplier = (Indirect + Induced Employment) / Direct Employment = (91.0 + 105.7) / 86.3 = 2.3

¹⁶ GDP multiplier = (Indirect + Induced GDP) / Direct GDP = (13.4 + 12.1) / 14.1 = 1.81

Table 9. Economic Contribution Summary – Refrigeration and Air Conditioning Manufacturing

Units: Thousand Jobs and Billion \$

	Employment (1,000 Persons)	Labor Income (Billion \$)	GDP (Billion \$)
Direct	86.3	6.9	14.1
Indirect	91.0	8.2	13.4
Induced	105.7	6.9	12.1
Total	283.0	22.0	39.6

Source: Inforum, IMPLAN

Figure 5. Economic Contribution Summary – Refrigeration and Air Conditioning Manufacturing

Units: Thousand Jobs and Billion \$

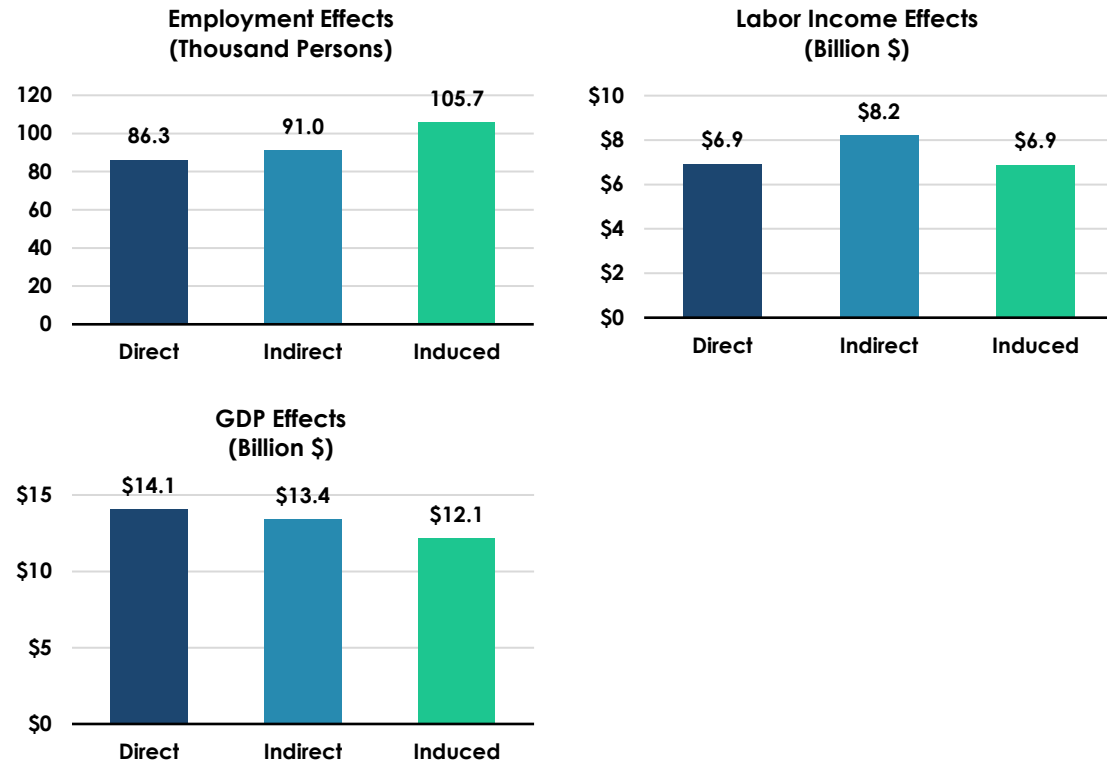


Table 10 displays the indirect GDP impacts associated with refrigeration and air conditioning manufacturing. These upstream industries help firms by supplying needed materials and services. Three of the top six industries listed are wholesalers; they are responsible for helping distribute the inputs, including machinery and raw materials, needed to produce refrigerators and air conditioning units. 'Management of companies and enterprises' (\$1.3 billion) oversee the organization and provide strategic planning. Other top industries include 'Copper rolling, drawing, extruding, and alloying' (\$0.3 billion) and 'Truck transportation' (\$0.3 billion).

Table 10. Indirect GDP, Refrigeration and Air Conditioning Manufacturing – Top 10 Industries
Units: Billion \$

Industry	Indirect GDP (Billion \$)
Wholesale - Other durable goods merchant wholesalers	2.1
Management of companies and enterprises	1.3
Wholesale - Household appliances and electrical and electronic goods	0.7
Copper rolling, drawing, extruding and alloying	0.3
Truck transportation	0.3
Wholesale - Machinery, equipment, and supplies	0.3
Iron and steel mills and ferroalloy manufacturing	0.3
Other real estate	0.3
Employment services	0.3
Monetary authorities and depository credit intermediation	0.2
All Other Industries	7.3
Total Indirect GDP	13.4

Source: Inforum, IMPLAN



3.6 Semiconductor Manufacturing

Semiconductors are vital components in nearly all electronics, from personal devices and telecommunications equipment to the data centers that make the internet possible. Semiconductor manufacturing is made possible by using PFAS as “photoacid generators, fluorinated polyimides, poly(benzoxazole)s, antireflection coatings, topcoats, and embedded barrier layers, fluorinated surfactants, and materials for nanoimprint lithography”¹⁷. At the time of this writing, the applications include critical manufacturing processes with no known alternatives. For the purposes of this analysis, semiconductor manufacturing is defined to cover NAICS 334413.

The semiconductor manufacturing industry directly employs nearly 163 thousand people who earn roughly \$37 billion in labor income. On average these workers earn almost \$228,700 in labor income; this is roughly three 3.1 times greater than the U.S. economy's average labor income (\$73,100). The industry contributes roughly \$70 billion to domestic GDP. These numbers can be seen on the first row of Table 11.

This direct activity described above generates indirect activity within the economy. These upstream suppliers, who provide inputs for manufacturers, employ nearly 336 thousand people and generate an additional \$47.5

In total, semiconductor manufacturing activity helps contribute just shy of one million jobs and over \$173 billion towards GDP.

billion in GDP impacts. Finally, a portion of the labor income earned by semiconductor manufacturing workers and their supply chains is spent on goods and services. This activity, seen in the third row of Table 11, supports an additional 487 thousand jobs, almost \$32 billion in labor income, and \$56 billion in GDP. In total, semiconductor manufacturing and related activity helps contribute just shy of one million jobs and over \$173 billion towards GDP.

One semiconductor manufacturing job helps support over five other jobs in the economy.

Economic multipliers describe the ratio of the sum of indirect and induced impacts to direct impacts. The data shown in Table 11 indicate that one semiconductor manufacturing job helps support 5.1 other jobs in the economy¹⁸. Additionally, one dollar of the industry's GDP generates \$1.48 of GDP elsewhere in the economy¹⁹.

¹⁷ <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?SSO=1>

¹⁸ Employment multiplier = (Indirect + Induced Employment) / Direct Employment = (335.9 + 487.0) / 162.6 = 5.1

¹⁹ GDP multiplier = (Indirect + Induced GDP) / Direct GDP = (47.5 + 55.8) / 69.8 = 1.48

Table 11. Economic Contribution Summary - Semiconductor Manufacturing
Units: Thousand Jobs and Billion \$

	Employment (1,000 Persons)	Labor Income (Billion \$)	GDP (Billion \$)
Direct	162.6	37.2	69.8
Indirect	335.9	32.6	47.5
Induced	487.0	31.7	55.8
Total	985.5	101.5	173.1

Source: Inforum, IMPLAN

Figure 6. Economic Contribution Summary – Semiconductor Manufacturing
Units: Thousand Jobs and Billion \$



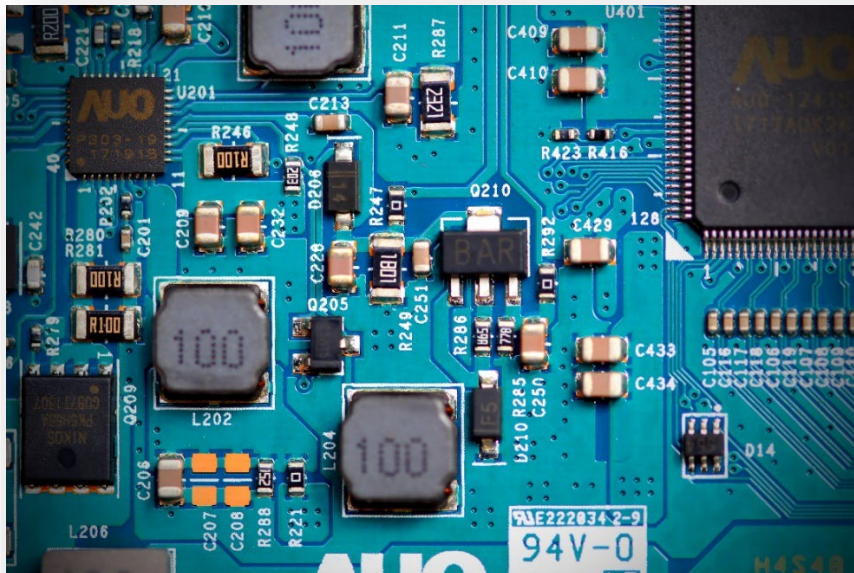
As previously mentioned, the activity of semiconductor manufacturing companies stimulate business in industries upstream in the supply chain. This network of transactions helps support jobs and generates economic contributions in a unique set of industries.

Table 12 describes indirect GDP impacts by detailed industries. The largest affected industry by a wide margin is 'Management of companies and enterprises' (\$12.6 billion). This industry helps support manufacturing firms by assisting in strategic or organizational planning. The second-largest industry, 'Wholesale – Household appliances and electrical and electronic goods' (\$2.0 billion), supports the distribution of needed components. Other top affected industries include 'Legal services' (\$1.6 billion), 'Custom computer programming services' (\$1.6 billion), and 'Employment services' (\$1.5 billion).

Table 12. Indirect GDP, Semiconductor Manufacturing – Top 10 Industries
Units: Billion \$

Industry	Indirect GDP (Billion \$)
Management of companies and enterprises	12.6
Wholesale - Household appliances and electrical and electronic goods	2.0
Custom computer programming services	1.6
Legal services	1.6
Employment services	1.5
Electric power transmission and distribution	1.3
Warehousing and storage	1.1
Accounting, tax preparation, bookkeeping, and payroll services	1.1
Other real estate	1.0
Internet publishing and broadcasting and web search portals	0.9
All Other Industries	22.7
Total Indirect GDP	47.5

Source: Inforum, IMPLAN



4. Conclusion and Main Findings

This analysis quantifies the economic contribution of several key industries which use PFAS as vital inputs, either as a component of the final product itself or as an essential tool during the manufacturing process. In addition to the direct impacts reported by government statistics, contributions grow in size when upstream supply-chain (indirect) and income-related (induced) effects are considered.

The contributions described earlier in this analysis are noteworthy. To put them into context, the table below compares each industry's total (direct + indirect + induced) GDP contribution against a similar metropolitan statistical area (MSA) in the United States. For example, economic activity related to automotive manufacturing is slightly greater than the total GDP of the Phoenix-Mesa-Chandler region. Similarly, aerospace manufacturing and semiconductor manufacturing make GDP contributions comparable to that of Tampa-St. Petersburg-Clearwater and Cincinnati, respectively.

Table 13. GDP Contribution Comparison, PFAS Industry vs. Similar MSA
Units: Billion \$

PFAS-Related Industry	Total GDP (Direct + Indirect + Induced) (Billion \$)	Similar MSA
Aerospace Manufacturing	191.0	Tampa-St. Petersburg-Clearwater, FL
Automotive Manufacturing	358.7	Phoenix-Mesa-Chandler, AZ
Battery Manufacturing	15.3	Atlantic City-Hammonton, NJ
Medicine and Pharmaceutical Manufacturing	303.9	Minneapolis-St. Paul-Bloomington, MN-WI
Refrigeration and AC Manufacturing	39.6	Toledo, OH
Semiconductor Manufacturing	173.1	Cincinnati, OH-KY-IN

Source: Inforum, IMPLAN, BEA

The table below provides a summary of the overall total (direct + indirect + induced) contribution of the industries described in this analysis. In total, the analyzed PFAS-related industries help contribute nearly 6.2 million jobs, approximately \$560 billion in labor income, and more than \$1 trillion towards domestic GDP.

In total, the PFAS-related industries analyzed in this report contributed more than \$1 trillion toward domestic GDP in 2021.

Table 14. Contribution Summary, Analyzed PFAS Industries
Units: Thousand Jobs and Billion \$

PFAS-Related Industry	Employment (1,000 Persons)	Labor Income (Billion \$)	GDP (Billion \$)
Aerospace Manufacturing	1,127.3	107.7	191.0
Automotive Manufacturing	2,421.2	192.5	358.7
Battery Manufacturing	117.3	10.0	15.3
Medicine and Pharmaceutical Manufacturing	1,262.1	124.0	303.9
Refrigeration and AC Manufacturing	283.0	22.0	39.6
Semiconductor Manufacturing	985.5	101.5	173.1
Total	6,196.4	557.7	1,081.5

Source: Inforum, IMPLAN

The magnitude and types of impacts described in this report are an important piece of the discussion surrounding PFAS. Importantly, the list of industries included in this report is not exhaustive; numerous other industries currently rely on PFAS to produce their goods, employ workers, and make economic contributions. Looking ahead, this work could be extended to analyze these other industry segments, quantify economic contributions at the state-level, as well as estimate impacts of proposed legislation.