2024

GUIDE

TO THE

ELECTROINDUSTRY

NEMA

Abstract

The Guide to the Electroindustry offers a detailed analysis of the U.S. electroindustry, providing various measures that help to gauge the vitality of individual sectors and segments. This publication highlights the U.S. electroindustry's integral role in the economy.

Zach Gilbert
Senior Economist
Zach.Gilbert@nema.org
(703) 841-3270

Don Leavens
Senior Vice President & Chief Economist
dleavens@nema.org
(703) 841-3263

Steve Wilcox
Senior Director, Business Intelligence
wilcoxs@nema.org
(703) 841-3223

THE BUSINESS OF THE U.S. ELECTROINDUSTRY

BY THE NUMBERS

Starting at the point of electricity generation, NEMA member products and systems transmit, distribute, and control the flow of electricity throughout the electric grid to myriad intermediate and end uses.

ELECTROINDUSTRY OUTPUT TOTALED

$248.2

BILLION in 2022

DIRECTLY PROVIDING

460,000

SKILLED AMERICAN JOBS

SUPPORTING LABOR INCOME OF

$51 BILLION

THE ELECTROINDUSTRY EXPORTED **$86.4 BILLION** WORTH OF GOODS IN 2023

VALUE ADDED OF **$74.3 BILLION**

WITH OVER **12,500** ESTABLISHMENTS IN ALL **50 STATES**

THE U.S. IMPORTED **$184.8 BILLION** WORTH OF ELECTROINDUSTRY GOODS IN 2023

U.S. ELECTROINDUSTRY MARKET SIZE OF

$340 BILLION

IN 2022

FOR EVERY JOB CREATED BY THE ELECTROINDUSTRY, 3.0 ARE GENERATED ELSEWHERE IN THE ECONOMY, TOTALING OVER

1.84 MILLION JOBS

CALIFORNIA, PENNSYLVANIA, TEXAS, WISCONSIN, and **ILLINOIS** have the largest number of electroindustry employees

ELECTROINDUSTRY INVESTMENT IN BUILDINGS AND EQUIPMENT IN 2021

$4.2 BILLION

Table of Contents

List of Tables

List of Figures

Executive Summary

Government climate policies are amplifying the electroindustry's national economic contribution

- The electroindustry contributes nearly $258 billion to the U.S economy—equivalent to one percent of Gross Domestic Product (GDP)
    - Wiring device manufacturing, relay and industrial control manufacturing, and copper rolling, drawing, extruding, and alloying are the sectors with the largest GDP contribution
- The electroindustry provides 460,000 jobs and supports labor income of $51 billion
    - For every job created by the electroindustry, three are generated elsewhere in the economy, totaling over 1.84 million jobs
    - Storage battery manufacturing, relay and industrial control manufacturing, and wiring device manufacturing provided the most electroindustry jobs in 2022
- The electroindustry has over 12,500 establishments in all 50 states, with California, Pennsylvania, Texas, Wisconsin, and Illinois having the largest number of electroindustry employees
- The US electroindustry market size, encompassing domestic output and net imports, reached $340 billion in 2022, and is rapidly growing and evolving in composition
    - Market size expanded by 39.4 percent over the period from 2018 to 2022, with a 22.5 percent increase from 2021 to 2022 alone
    - Storage battery manufacturing and miscellaneous electrical equipment and component manufacturing (e.g., inverters, rectifiers) experienced the fastest growth over the past five years, driven by accelerating trends in clean generation and electrification

The electroindustry is extensively globalized, creating a landscape marked by vulnerability to supply chain disruptions and geopolitics

- The electroindustry exported $86.4 billion of goods in 2023, and the US imported $184.8 billion of electroindustry goods in 2023, resulting in a trade deficit of $98.4 million

    - Miscellaneous electrical equipment & components, motors & generators, and switchgear and switchboard apparatus were the top contributors to the electroindustry's export value in 2023
    - Miscellaneous electrical equipment & components, batteries, and switchgear and switchboard apparatus represented the largest shares of the electroindustry's import value in 2023
- The electroindustry trade deficit grew each year between 2018 and 2023, rising $50.6 billion (+106%) across the period, not adjusted for inflation
    - The growing trade deficit has largely been driven by imports of other electrical equipment and components
    - Mexico, Canada, China, Germany, and the United Kingdom are the electroindustry's top five export destinations
    - The US imports the most electroindustry goods from Mexico, China, Germany, Japan, and South Korea
- Shortages of skilled labor and critical materials, often sourced from global markets, have created manufacturing delays for fundamental grid components such as transformers
- Policies, including imposition of tariffs and subsidies that require domestic product content, support for union labor, and pursuit of environmental justice, have introduced complexities that potentially impede the momentum towards increasing domestic energy transition investment
    - Trade barriers have led more to a change in the sources of imports than to a significant boost in domestic production

The electroindustry is at the epicenter of the energy transition, advancing technologies geared toward electrification, energy efficiency, and grid resilience

- The electroindustry has made over $12 billion in investments since 2020
- Efficiency improvements in motors, lighting, energy control systems, and electrical distribution, integrated into industries, businesses, and homes, have contributed to the flattening of electricity generation growth over the past two decades

    - Since 1973, U.S. energy intensity—the amount of energy consumed per unit of GDP—has declined at an annual rate close to 2.0 percent, reaching about half its 1990 level by 2020
- Electroindustry innovations are playing a pivotal role in propelling the energy transition by enhancing not only the efficiency but also the reliability and scalability of renewable energy systems and electrified technologies
    - Advances in smart grid technology, energy storage solutions, and power electronics are enabling a more effective integration of intermittent renewable resources into the electrical grid
    - On the energy end-use side, electroindustry developments are hastening electrification across areas like transportation, building heating, and manufacturing
    - The commercial and residential sectors are the most electrified, while the industrial and transportation sectors exhibit lower levels of electrification but also hold promise for significant improvements through the electrification of low-hanging fruit
- Between the Infrastructure Investment and Jobs Act (IIJA), the Inflation Reduction Act (IRA), and the CHIPS and Science Act, approximately $1.1 trillion has been made available to drive the energy transition over the next five to ten years
- Along with funding accelerators, the energy transition also faces numerous challenges, including siting and permitting constraints, aging infrastructure, long queues for grid connections, affordability, and policy disputes
    - Transmission capacity is expected to need to double by 2030 and potentially triple by 2050 to achieve full clean energy potential
- Given the challenges inhibiting the expansion of the electrical grid, a coordinated approach between the public and private sectors would help to allocate resources and advance the energy transition in a sustainable, cost-effective, and secure manner, without compromising living standards
- By investing in electrification, the electroindustry is creating a framework to ensure the technology and scalability needed for a modern, reliable, and resilient energy transition

Introduction

The electrical and medical imaging manufacturers that compose the electroindustry produce equipment and systems that manage electricity flow from the point of generation, through transmission and distribution, to end-uses such as automation, lighting, and medical imaging systems. The industry serves key markets such as manufacturing, utilities, mining, and construction. It also supplies consumer-oriented products like primary batteries, alongside home safety devices including arc fault circuit interrupters (AFCIs) and ground fault circuit interrupters (GFCIs).

The electroindustry is at a pivotal juncture where societal commitment to reduce greenhouse gases by phasing out fossil fuel consumption is driving a public/private partnership to electrify major energy end-uses, including automobiles, space heating and cooling systems, and household appliances. Simultaneously, the industry is advancing technologies designed to enhance energy efficiency, expand energy storage solutions, and strengthen grid resilience. Product digitalization is transforming the industry by generating ever-growing data streams that support more reliable, resilient, and efficient electricity supply and utilization.

Electrical manufacturers depend on a complex supply chain that is extensively globalized and vulnerable to supply chain disruptions. Shortages of skilled labor and critical materials, often sourced from global markets, have created manufacturing delays for fundamental grid components such as transformers. Also, policies, including tariffs and subsidies that require domestic product content, union labor, and environmental justice, have introduced additional complexities, potentially impeding the momentum towards increasing domestic investment to expand production capabilities for electrification and grid fortification technologies. Additionally, the role of maquiladoras—low-cost factories located in Mexico that assemble U.S. products and export them back—underscores the globalized nature of the electroindustry and highlights the challenges of securing the industry's supply chain.

Chapter 1: What is the Electroindustry?

The electroindustry is divided into five segments based on the North American Industry Classification System (NAICS) codes, which are managed collaboratively by Mexico, Canada, and the U.S. Within electrical manufacturing, these segments are electric lighting equipment, core electrical equipment, other electrical equipment & components, and miscellaneous. The latter includes six sectors not covered by the primary electrical manufacturing NAICS classification. Medical imaging manufacturing comprises three sectors: electromedical and electrotherapeutic apparatus manufacturing, irradiation apparatus manufacturing, and pharmaceutical preparation manufacturing. Figure 1.1 below presents the composition of each segment.

Figure 1.1: Electroindustry Breakdown

Electric lighting equipment

- Residential electric lighting fixture manufacturing (*NAICS = 335131*)
- Commercial, industrial, and institutional electric lighting fixture manufacturing (*NAICS = 335132*)
- Electric lamp bulb and other lighting equipment manufacturing *(NAICS = 335139)*

Core electrical equipment

- Power, distribution, and specialty transformer manufacturing (*NAICS = 335311*)
- Motor and generator manufacturing (*NAICS = 335312*)
- Switchgear and switchboard apparatus manufacturing (*NAICS = 335313*)
- Relay and industrial control manufacturing (*NAICS = 335314*)

Other electrical equipment & components

- Battery manufacturing *(NAICS = 335910)*
- Other communication and energy wire manufacturing (*NAICS = 335929*)
- Current-carrying wiring device manufacturing (*NAICS = 335931*)
- Noncurrent-carrying wiring device manufacturing *(NAICS = 335932)*
- Carbon and graphite product manufacturing (*NAICS = 335991*)
- All other miscellaneous electrical equipment and component manufacturing (*NAICS = 335999*)

Miscellaneous

- Copper rolling, drawing, extruding and alloying (*NAICS = 331420*)
- Speed changer, industrial high-speed drive, and gear manufacturing (*NAICS = 333612*)
- Welding and soldering equipment manufacturing *(NAICS = 333992)*
- Other communications equipment manufacturing (*NAICS = 334290*)
- Automatic environmental control manufacturing (*NAICS = 334512*)
- Electricity and signal testing instruments manufacturing (*NAICS = 334515*)

Medical imaging

- Electromedical and electrotherapeutic apparatus manufacturing (*NAICS = 334510*)
- Irradiation apparatus manufacturing (*NAICS = 334517*)
- Pharmaceutical preparation manufacturing (*NAICS = 325412*)

⚡ Electric lighting equipment

- **Residential electric lighting fixture manufacturing** *(NAICS = 335131)*
    - Comprises establishments primarily engaged in manufacturing fixed or portable residential electric lighting fixtures and lamp shades of metal, paper, or textiles. Residential electric lighting fixtures include those for use both inside and outside the residence.
    - E.g., residential chandeliers and desk lamps
- **Commercial, industrial, and institutional electric lighting fixture manufacturing** *(NAICS = 335132)*
    - Comprises establishments primarily engaged in manufacturing commercial, industrial, and institutional electric lighting fixtures.
    - E.g., commercial, industrial, and institutional ceiling lighting fixtures and luminous panels

Note: In data tables found in chapters 2, 3, and 4, 'residential electric lighting fixture manufacturing' and 'commercial, industrial, and institutional electric lighting fixture manufacturing' are consolidated under the category 'lighting fixture manufacturing'.

- **Electric lamp bulb and other lighting equipment manufacturing** *(NAICS = 335139)*
    - Comprises establishments primarily engaged in manufacturing electric light bulbs, tubes, and parts (except glass blanks for electric light bulbs and light emitting diodes (LEDs)), electric lighting fixtures (except residential, commercial, industrial, institutional, and vehicular electric lighting fixtures), and nonelectric lighting equipment.
    - E.g., LEDs, lanterns, flashlights

⚡ Core electrical equipment

- **Power, distribution, and specialty transformer manufacturing** *(NAICS = 335311)*
    - Comprises establishments primarily engaged in manufacturing power, distribution, and specialty transformers (except electronic components). Industrial-type and consumer-type transformers in this industry vary (e.g., step

up or step down) voltage but do not convert alternating to direct or direct to alternating current.
    - E.g., power transformers, distribution transformers, autotransformers
- **Motor and generator manufacturing** *(NAICS = 335312)*
    - Comprises establishments primarily engaged in manufacturing electric motors (except internal combustion engine starting motors), power generators (except battery charging alternators for internal combustion engines), and motor generator sets (except turbine generator set units). This industry includes establishments rewinding armatures on a factory basis.
    - E.g., integral horsepower motors, fractional horsepower motors, generators and sets, armatures, rotors, phase converters
- **Switchgear and switchboard apparatus manufacturing** *(NAICS = 335313)*
    - Comprises establishments primarily engaged in manufacturing switchgear and switchboard apparatus.
    - E.g., power circuit breakers, control panels, fuses, power switching equipment
- **Relay and industrial control manufacturing** *(NAICS = 335314)*
    - Comprises establishments primarily engaged in manufacturing relays, motor starters and controllers, and other industrial controls and control accessories.
    - E.g., control circuit relays, motor control centers, rheostats, solenoid switches

⚡ Other electrical equipment & components

- **Battery manufacturing** *(NAICS = 335910)*
    - Comprises establishments primarily engaged in manufacturing primary and storage batteries.
    - E.g., lithium storage batteries, rechargeable battery packs, alkaline cell batteries, flashlight batteries
- **Other communication and energy wire manufacturing** *(NAICS = 335929)*
    - Comprises establishments primarily engaged in manufacturing insulated wire and cable of nonferrous metals from purchased wire.
    - E.g., nonferrous coaxial cable, nonferrous communications wire and cable

- **Current-carrying wiring device manufacturing** *(NAICS = 335931)*
    - Comprises establishments primarily engaged in manufacturing current-carrying wiring devices.
    - E.g., bus bars, ground fault circuit interrupters, lightning arrestors and coils
- **Noncurrent-carrying wiring device manufacturing** *(NAICS = 335932)*
    - Comprises establishments primarily engaged in manufacturing noncurrent-carrying wiring devices.
    - E.g., conduits and fittings, face plates (i.e., outlet or switch covers)

Note: In data tables found in chapters 2, 3, and 4, 'current-carrying wiring device manufacturing' and 'noncurrent-carrying wiring device manufacturing' are consolidated under the category 'wiring device manufacturing'.

- **Carbon and graphite product manufacturing** *(NAICS = 335991)*
    - Comprises establishments primarily engaged in manufacturing carbon, graphite, and metal-graphite brushes and brush stock; carbon or graphite electrodes for thermal and electrolytic uses; carbon and graphite fibers; and other carbon, graphite, and metal-graphite products.
    - E.g., carbon or graphite fibers, carbon or graphite electrodes
- **All other miscellaneous electrical equipment and component manufacturing** *(NAICS = 335999)*
    - Comprises establishments primarily engaged in manufacturing industrial and commercial electric apparatus and other equipment (except lighting equipment, household appliances, transformers, motors, generators, switchgear, relays, industrial controls, batteries, communication and energy wire and cable, wiring devices, and carbon and graphite products). This industry includes power converters (i.e., AC to DC and DC to AC), power supplies, surge suppressors, and similar equipment for industrial-type and consumer-type equipment.
    - E.g., inverters, rectifiers, solid-state battery chargers

⚡ Miscellaneous

- **Copper rolling, drawing, extruding and alloying** *(NAICS = 331420)*
    - Comprises establishments primarily engaged in one or more of the following: (1) recovering copper or copper alloys from scraps; (2) alloying purchased copper; (3) rolling, drawing, or extruding shapes (e.g., bar, plate, sheet, strip, tube, wire) from purchased copper; and (4) recovering copper or copper alloys from scrap and rolling, drawing, or extruding shapes (e.g., bar, plate, sheet, strip, tube, wire).
    - E.g., copper wire, copper plates, copper bars
- **Speed changer, industrial high-speed drive, and gear manufacturing** *(NAICS = 333612)*
    - Comprises establishments primarily engaged in manufacturing gears, speed changers, and industrial high-speed drives (except hydrostatic).
    - E.g., power transmission gears, power transmission speed changers
- **Welding and soldering equipment manufacturing** *(NAICS = 333992)*
    - Comprises establishments primarily engaged in manufacturing welding and soldering equipment and accessories (except transformers), such as arc, resistance, gas, plasma, laser, electron beam, and ultrasonic welding equipment; welding electrodes; coated or cored welding wire; and soldering equipment (except handheld).
- **Other communications equipment manufacturing** *(NAICS = 334290)*
    - Comprises establishments primarily engaged in manufacturing communications equipment (except telephone apparatus, radio and television broadcast equipment, and wireless communications equipment).
    - E.g., car alarm manufacturing, traffic signals, smoke detectors
- **Automatic environmental control manufacturing** *(NAICS = 334512)*
    - Comprises establishments primarily engaged in manufacturing automatic controls and regulators for applications, such as heating, air-conditioning, refrigeration and appliances.
    - E.g., electric space heater controls, humidistats, thermocouples
- **Electricity and signal testing instruments manufacturing** *(NAICS = 334515)*

- Comprises establishments primarily engaged in manufacturing instruments for measuring and testing the characteristics of electricity and electrical signals.
- E.g., circuit and continuity testers, voltmeters, ohm meters, wattmeters, and multimeters

Medical imaging

- **Electromedical and electrotherapeutic apparatus manufacturing** *(NAICS = 334510)*
  - Comprises establishments primarily engaged in manufacturing electromedical and electrotherapeutic apparatus.
  - E.g., magnetic resonance imaging equipment, medical ultrasound equipment, pacemakers, hearing aids, electrocardiographs, and electromedical endoscopic equipment
- **Irradiation apparatus manufacturing** *(NAICS = 334517)*
  - Comprises establishments primarily engaged in manufacturing irradiation apparatus and tubes for applications, such as medical diagnostic, medical therapeutic, industrial, research and scientific evaluation. Irradiation can take the form of beta-rays, gamma-rays, X-rays, or other ionizing radiation.
- **Pharmaceutical preparation manufacturing** *(NAICS = 325412)*
  - Comprises establishments primarily engaged in manufacturing in-vivo diagnostic substances and pharmaceutical preparations (except biological) intended for internal and external consumption in dose forms, such as ampoules, tablets, capsules, vials, ointments, powders, solutions, and suspensions.
  - E.g., Nuclear medicine (e.g., radioactive isotopes) preparations manufacturing

Chapter 2: Electroindustry Economic Impact

The economic impact attributable to the U.S. electroindustry is based on data generated using the IMPLAN model—an economic model that relates different types of economic activity to one another through the industrial supply chain, the labor market, consumer expenditures, tax revenues, and public expenditures. The IMPLAN model accounts for industry-related direct impacts, indirect impacts (i.e., impacts stemming from supply chain relationships between industrial sectors), and induced impacts (i.e., impacts resulting from industry employees spending income in the economy). The electroindustry contributes one percent of U.S. Gross Domestic Product (GDP), directly providing nearly 460,000 skilled American jobs. Tables 2.A and 2.B below cover the electroindustry's total economic impact and direct GDP contributions by sector, respectively.

- *Labor Income*: Defined by IMPLAN as the sum of employee compensation (wages & benefits) and proprietor income. The electroindustry directly provided $51.1 billion in labor income in 2022 and contributed $105.3 billion through indirect and induced effects.
- *Value-added*: Defined by the Bureau of Economic Analysis (BEA) as the market value an industry adds in production. Direct value-added registered $74.3 billion in 2022 and indirect and induced value-added aggregated to $183.3 billion.
- The electroindustry's total impact on employment, labor income, and value-added was 1.84 million jobs, $156.4 billion, and $257.6 billion, respectively, in 2022.

Table 2.A: Electroindustry Economic Impact, 2022

Measure	Direct National Impact	Indirect National Impact	Induced National Impact	Total National Impact
Employment	460,000	638,000	743,000	1,841,000
Labor Income ($ billions)	51.1	56.9	48.4	156.4
Contribution to GDP ($ billions)	74.3	95.3	88.0	257.6

Table 2.B: GDP Contribution by Sector, 2022

Sector	GDP Contribution ($ billions)
Wiring device manufacturing	6.57
Relay and industrial control manufacturing	6.19
Copper rolling, drawing, extruding and alloying	6.14
Storage battery manufacturing	5.93
Switchgear and switchboard apparatus manufacturing	5.92
Motor and generator manufacturing	5.75
All other miscellaneous electrical equipment and component manufacturing	4.56
Electricity and signal testing instruments manufacturing	4.51
Lighting fixture manufacturing	4.25
Irradiation Apparatus Manufacturing	3.90
Electromedical and electrotherapeutic apparatus manufacturing	3.78
Power, distribution, and specialty transformer manufacturing	3.49
Other communications equipment manufacturing	2.74
Welding and soldering equipment manufacturing	2.52
Other communication and energy wire manufacturing	1.92
Automatic environmental control manufacturing	1.54
Speed changer, industrial high-speed drive, and gear manufacturing	1.44
Carbon and graphite product manufacturing	1.33
Electric lamb bulb and part manufacturing	0.84
Primary battery manufacturing	0.82
Pharmaceutical Preparation Manufacturing	0.14
Total	***74.28***

Chapter 3: Electroindustry Output

Electroindustry output data are derived from the IMPLAN model described above. IMPLAN output equals the value of industry production, equivalent to sales plus net inventory change, measured in producer prices. Tables 3.A and 3.B below break down electroindustry output by sector and state, respectively. Figures 1-6 present the composition of output within each overarching electroindustry segment.

- Electroindustry output totaled $248.2 billion in 2022.
- Copper rolling, drawing, extruding and alloying, motor and generator manufacturing, and wiring device manufacturing led electroindustry output in 2022, constituting 19.7%, 7.6%, and 7.6% of total output, respectively.
- California, Texas, and Pennsylvania led electroindustry output in 2022, accounting for 10.0%, 6.9%, and 6.4% of total output, respectively.
- The miscellaneous segment led electroindustry output in 2022, accounting for 33.2% of total output.

I. Output by Sector

Table 3.A: Output by Sector, 2022

Sector	Output ($ billions)
Copper rolling, drawing, extruding and alloying	48.79
Motor and generator manufacturing	18.97
Wiring device manufacturing	18.91
Switchgear and switchboard apparatus manufacturing	18.57
Storage battery manufacturing	18.14
Relay and industrial control manufacturing	16.27
Lighting fixture manufacturing	14.42
All other miscellaneous electrical equipment and component manufacturing	12.39
Irradiation apparatus manufacturing	11.66

Sector	Output ($ billions)
Electricity and signal testing instruments manufacturing	10.97
Power, distribution, and specialty transformer manufacturing	10.06
Electromedical and electrotherapeutic apparatus manufacturing	8.77
Other communication and energy wire manufacturing	8.68
Other communications equipment manufacturing	7.77
Welding and soldering equipment manufacturing	7.47
Carbon and graphite product manufacturing	4.23
Speed changer, industrial high-speed drive, and gear manufacturing	3.71
Automatic environmental control manufacturing	3.59
Primary battery manufacturing	2.32
Electric lamb bulb and part manufacturing	2.26
Pharmaceutical preparation manufacturing	0.26
Total	***248.22***

II. Output by State

Table 3.B: Output by State, 2022

State	Output ($ billions)	State	Output ($ billions)
California	24.94	Iowa	2.66
Texas	17.15	New Hampshire	2.59
Pennsylvania	15.89	Kansas	2.41
Illinois	15.19	Arkansas	2.32
Ohio	14.43	Colorado	2.31
Wisconsin	13.66	Arizona	2.27
Georgia	12.18	Rhode Island	1.61
New York	11.45	Oregon	1.59
North Carolina	9.05	Maryland	1.32

State	Output ($ billions)	State	Output ($ billions)
Indiana	8.23	Nebraska	1.19
Missouri	7.27	Oklahoma	0.91
Florida	6.53	Idaho	0.73
Massachusetts	6.48	Delaware	0.70
South Carolina	6.14	Louisiana	0.57
Nevada	5.96	New Mexico	0.53
Minnesota	5.88	Vermont	0.51
Michigan	5.51	West Virginia	0.31
Tennessee	5.47	South Dakota	0.28
Connecticut	5.21	Maine	0.23
New Jersey	4.71	Wyoming	0.19
Kentucky	4.14	Montana	0.10
Virginia	3.93	Alaska	0.06
Utah	3.92	North Dakota	0.05
Washington	3.33	Hawaii	0.03
Mississippi	3.20	District of Columbia	0.01
Alabama	2.88	***Total***	***248.22***

III. Composition of Output

Figure 3.1: Composition of Electric Lighting Equipment Output, 2022

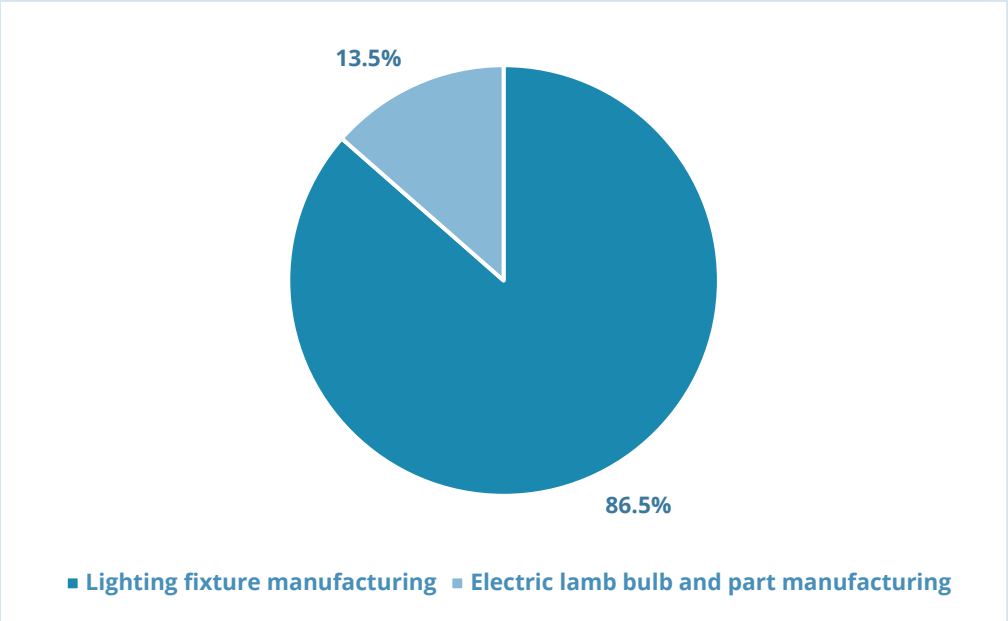


Figure 3.2: Composition of Core Electrical Equipment Output, 2022

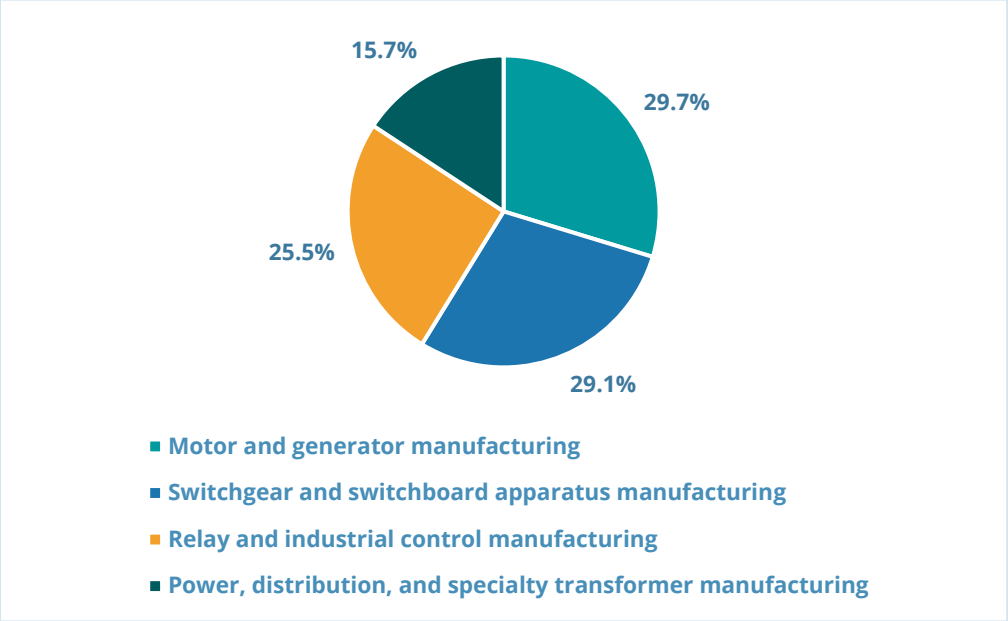


Figure 3.3: Composition of Other Electrical Equipment Output, 2022

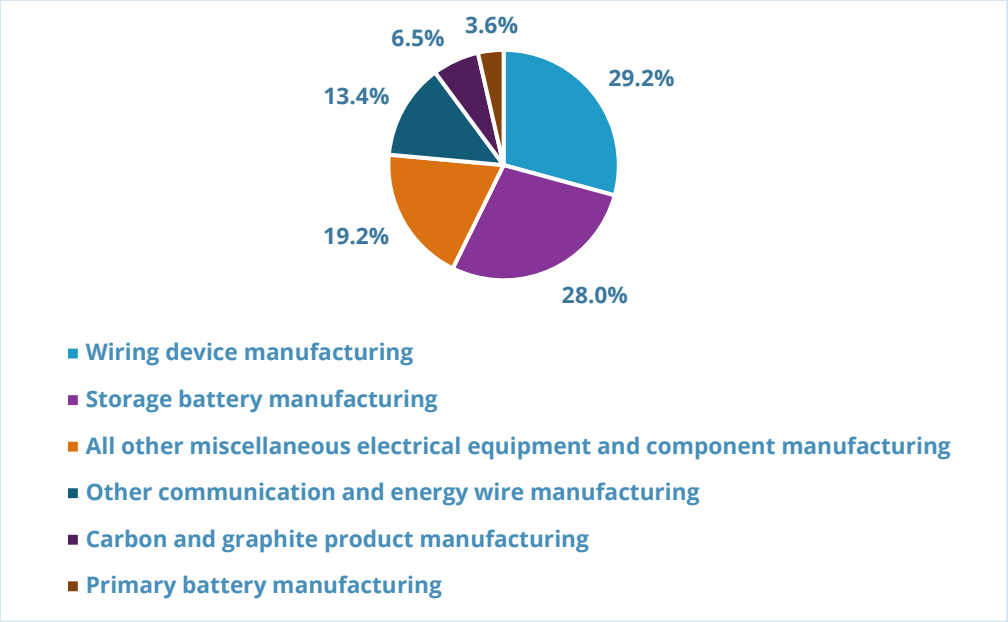


Figure 3.4: Composition of Miscellaneous Output, 2022

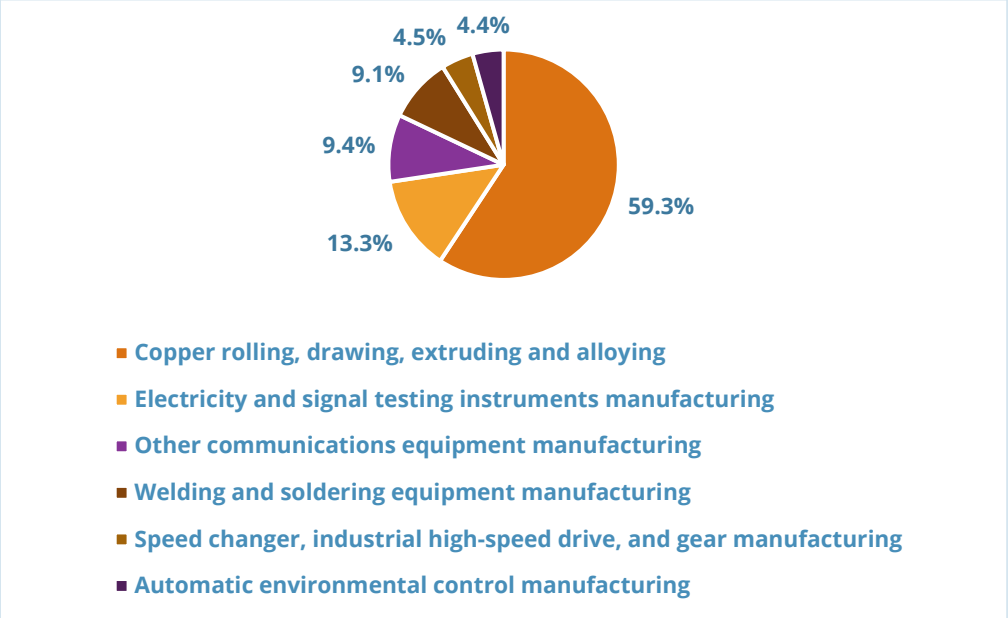


Figure 3.5: Composition of Medical Imaging Output, 2022

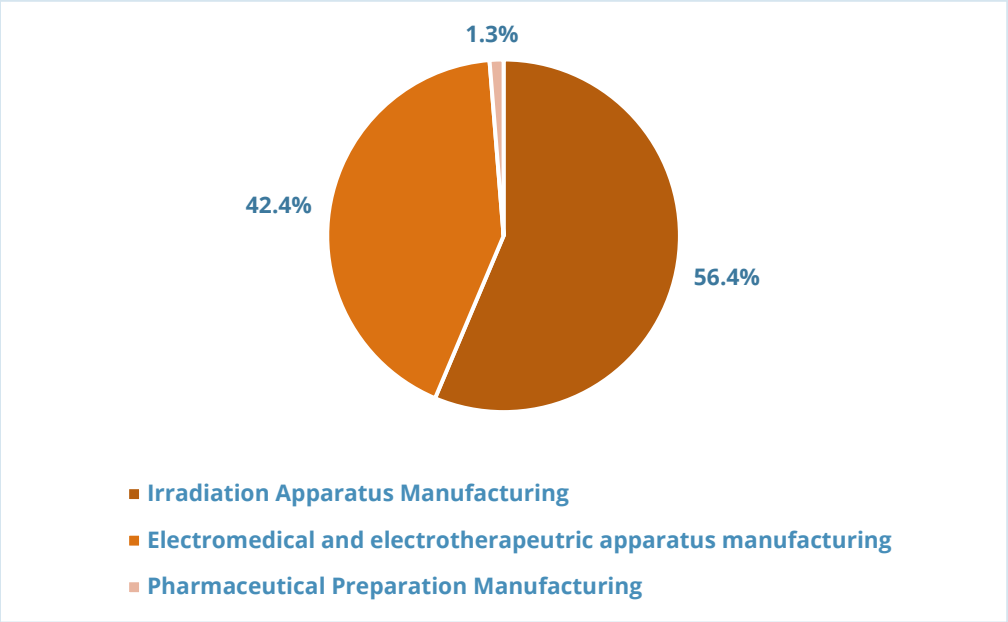
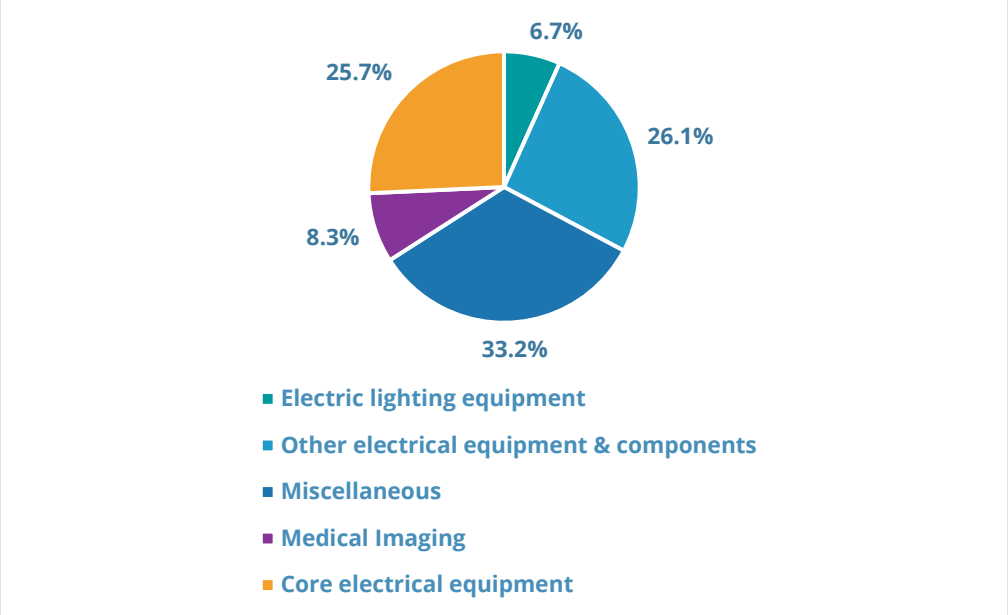


Figure 3.6: Composition of Electroindustry Output, 2022



Chapter 4: Electroindustry Employment & Labor Income

Employment and labor income for the U.S. electroindustry is derived from IMPLAN data and encompasses both full- and part-time employees. Labor income (as defined in Chapter 2) is the sum of employee compensation (i.e., wages and benefits) and proprietor income. Tables 4.A and 4.B below break down electroindustry employment and labor income by sector and state, respectively. Figures 1-6 present the composition of labor income within each major electroindustry segment.

- The electroindustry provided 459,679 jobs and $51.1 billion in labor income in 2022.
- Storage battery manufacturing, relay and industrial control manufacturing, and wiring device manufacturing provided the most electroindustry jobs in 2022, comprising 9.0%, 9.0%, and 8.8% of total employment, respectively.
- In 2022, the sectors relay and industrial control manufacturing, storage battery manufacturing, and all other miscellaneous electrical equipment and component manufacturing provided the most labor income, supplying 9.7%, 8.6%, and 8.1% of total labor income, respectively.
- The pharmaceutical preparation manufacturing, electricity and signal testing instruments manufacturing, and electromedical and electrotherapeutic apparatus manufacturing sectors supplied the most per capita income in 2022 at $183,791, $154,901, and $149,998, respectively.
- California, Pennsylvania, and Texas provided the most electroindustry jobs in 2022, contributing 10.7%, 6.6%, and 6.2% of total employment, respectively. The same three states also supported the most labor income, coming in at 13.4%, 6.5%, and 6.2% of total labor income, respectively.
- The core electrical equipment segment supported the most labor income in 2022, making up 30.4% of the electroindustry total.
- Per capita labor income by electroindustry segment in 2022:
    - Medical imaging: $145,387

- Miscellaneous: $113,974
- Core electrical equipment: $108,456
- Other electrical equipment & components: $107,195
- Electric lighting equipment: $101,855

I. Employment & Labor Income by Sector

Table 4.A: Employment & Labor Income by Sector, 2022

Sector	# of Employees	Labor Income ($ billions)
Storage battery manufacturing	41,508	4.38
Relay and industrial control manufacturing	41,312	4.96
Wiring device manufacturing	40,427	4.11
Motor and generator manufacturing	37,942	3.87
Switchgear and switchboard apparatus manufacturing	36,103	3.93
Lighting fixture manufacturing	34,752	3.49
All other miscellaneous electrical equipment and component manufacturing	34,286	4.14
Copper rolling, drawing, extruding and alloying	28,746	2.71
Power, distribution, and specialty transformer manufacturing	27,623	2.75
Electricity and signal testing instruments manufacturing	23,361	3.62
Welding and soldering equipment manufacturing	15,127	1.56
Electromedical and electrotherapeutic apparatus manufacturing	14,927	2.24
Irradiation apparatus manufacturing	14,182	1.99
Other communications equipment manufacturing	13,340	1.72
Other communication and energy wire manufacturing	13,121	1.26
Automatic environmental control manufacturing	11,327	1.17
Speed changer, industrial high-speed drive, and gear manufacturing	11,044	0.95
Carbon and graphite product manufacturing	9,383	0.97
Electric lamb bulb and part manufacturing	5,514	0.61

Sector	# of Employees	Labor Income ($ billions)
Primary battery manufacturing	5,457	0.58
Pharmaceutical preparation manufacturing	197	0.04
Total	***459,679***	***51.06***

II. Employment & Labor Income by State

Table 4.B: Employment & Labor Income by State, 2022

State	# of Employees	Labor Income ($ billions)
California	49,326	6.85
Pennsylvania	30,312	3.33
Texas	28,544	3.15
Wisconsin	27,504	3.09
Illinois	26,612	3.14
Ohio	25,341	2.72
New York	20,049	2.40
North Carolina	18,088	1.81
Georgia	17,943	1.90
Missouri	14,748	1.40
Florida	14,147	1.36
South Carolina	12,484	1.20
Michigan	12,398	1.32
Indiana	12,147	1.06
Minnesota	11,583	1.43
Nevada	11,065	1.29
Tennessee	11,053	1.16
Massachusetts	10,806	1.55
Virginia	8,927	0.83

State	# of Employees	Labor Income ($ billions)
New Jersey	8,681	0.99
Connecticut	8,111	0.94
Washington	7,333	0.87
Utah	6,509	0.78
Mississippi	6,197	0.47
Kentucky	5,708	0.57
Iowa	5,112	0.51
Colorado	4,729	0.60
Arkansas	4,558	0.38
Alabama	4,480	0.41
Arizona	4,466	0.49
New Hampshire	4,268	0.44
Kansas	4,142	0.38
Oregon	3,523	0.40
Maryland	2,964	0.37
Oklahoma	2,066	0.19
Nebraska	2,027	0.18
Idaho	1,895	0.17
Rhode Island	1,826	0.19
Louisiana	1,498	0.14
Delaware	1,455	0.16
Vermont	1,111	0.10
New Mexico	1,043	0.08
South Dakota	710	0.05
West Virginia	613	0.06
Maine	565	0.05
Wyoming	402	0.03
Montana	275	0.02

State	# of Employees	Labor Income ($ billions)
Alaska	129	0.01
North Dakota	115	0.01
Hawaii	67	0.01
District of Columbia	25	0.00
Total	***459,679***	***51.06***

III. Composition of Labor Income

Figure 4.1: Composition of Electric Lighting Equipment Labor Income, 2022

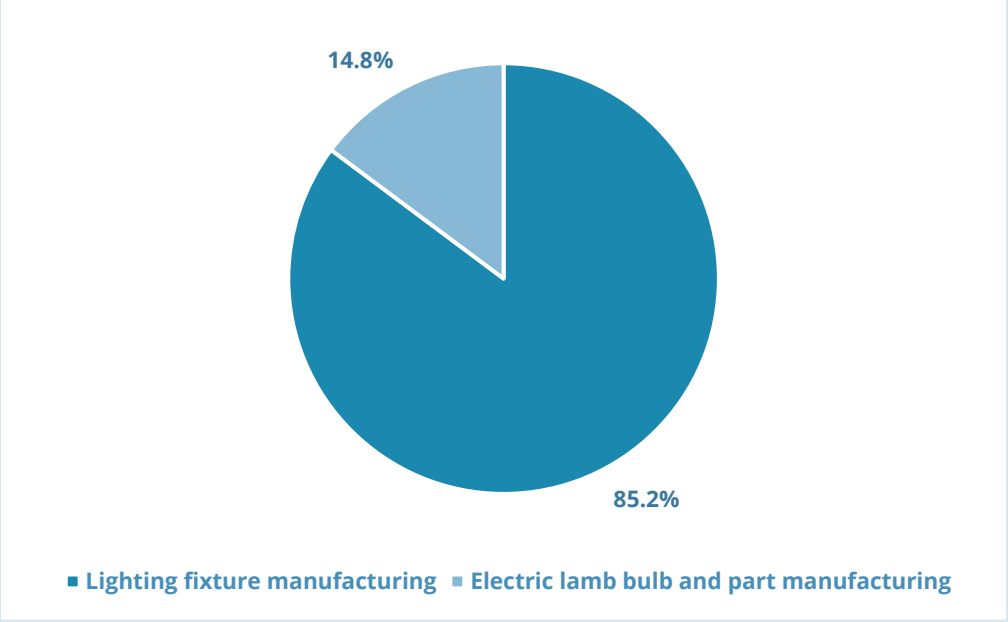


Figure 4.2: Composition of Core Electrical Equipment Labor Income, 2022

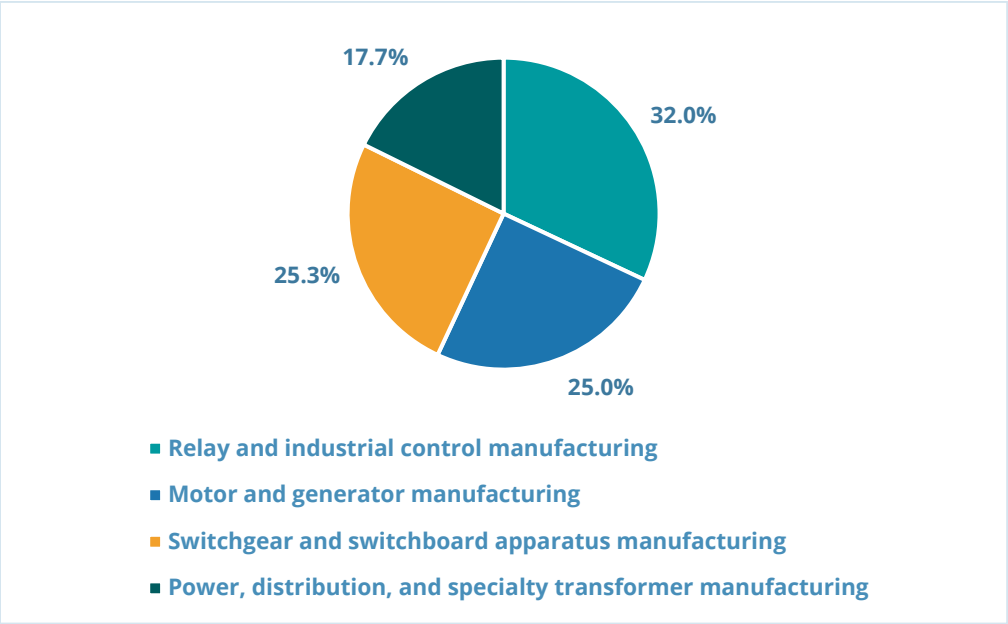


Figure 4.3: Composition of Other Electrical Equipment Labor Income, 2022

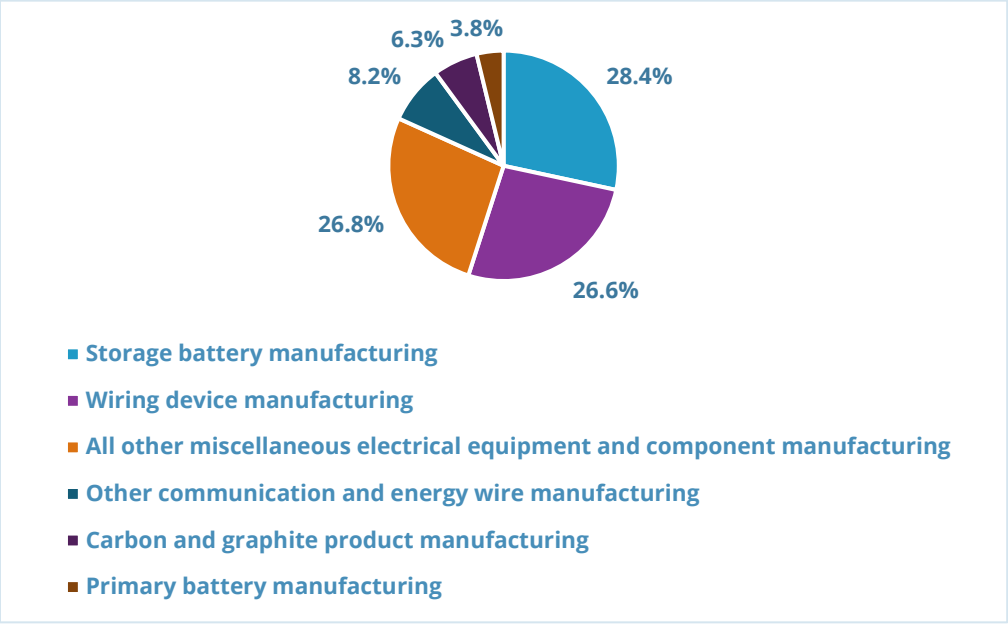


Figure 4.4: Composition of Miscellaneous Labor Income, 2022

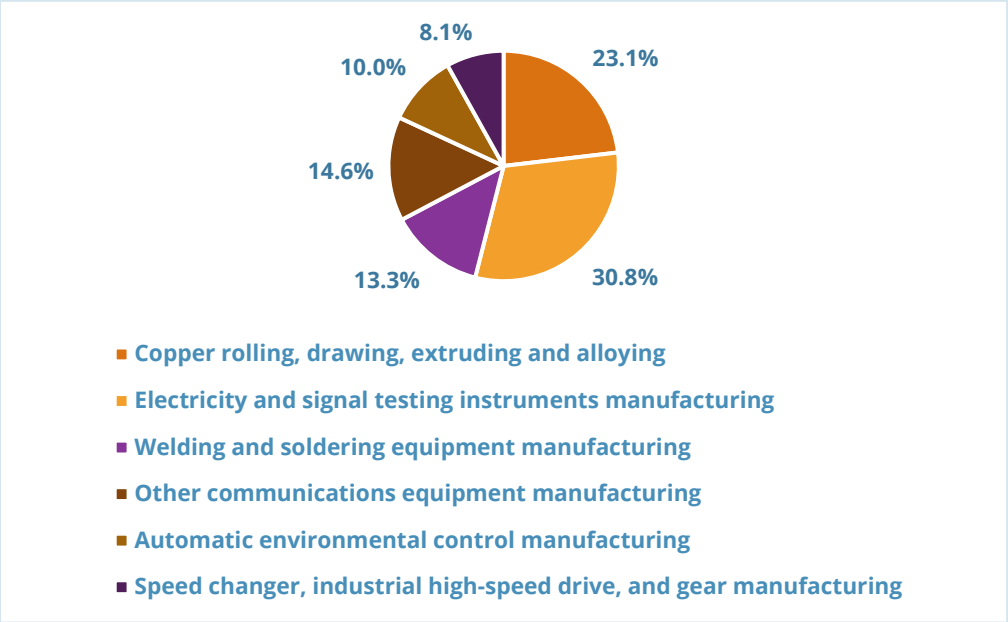


Figure 4.5: Composition of Medical Imaging Labor Income, 2022

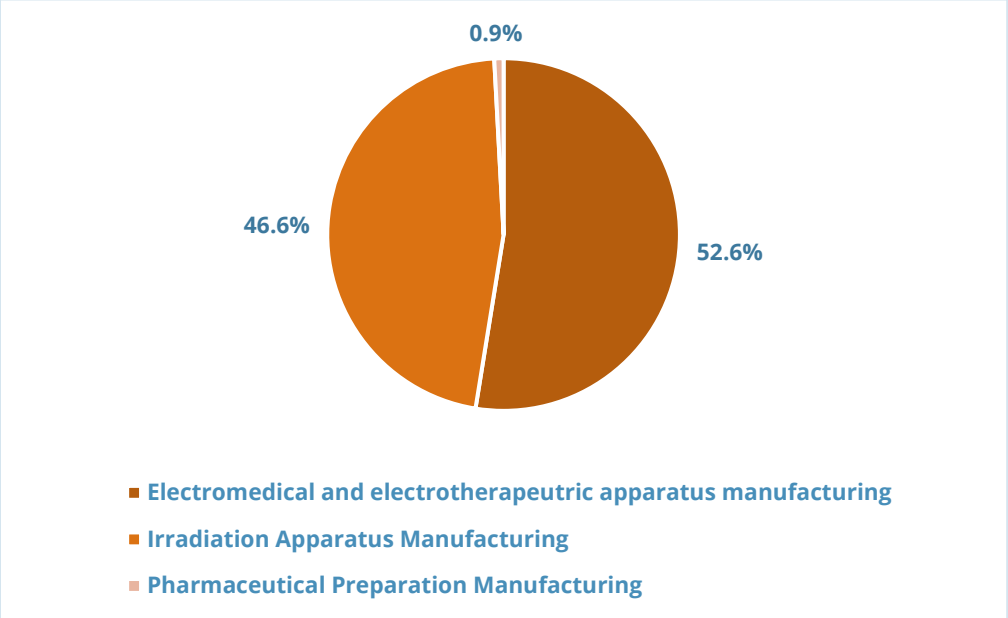
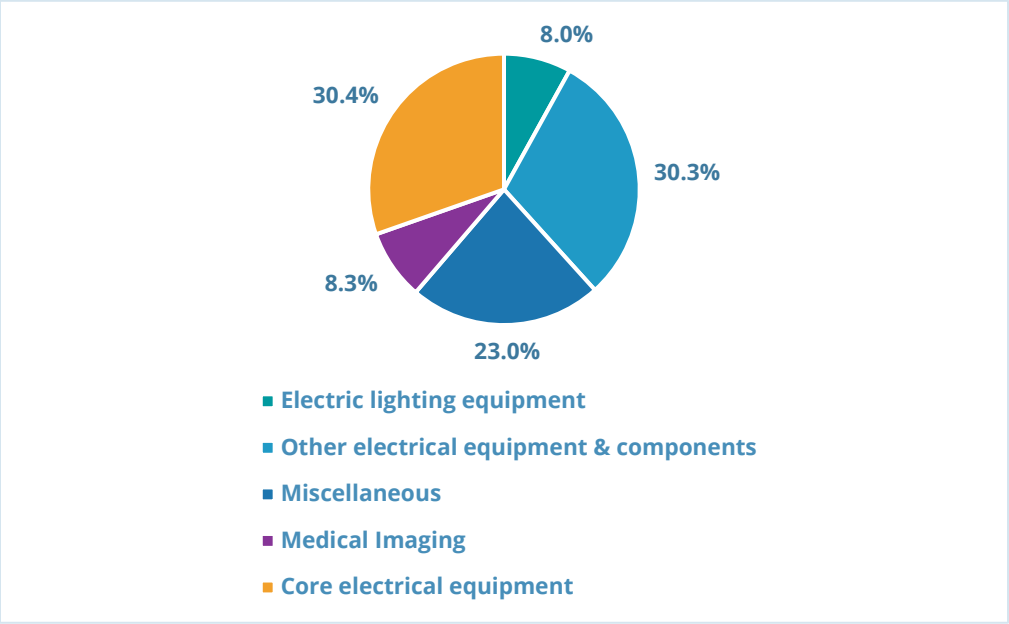


Figure 4.6: Composition of Electroindustry Labor Income, 2022



Chapter 5: Electroindustry Global Trade

The U.S. electroindustry's global trade picture is analyzed below. Tables A-G below break down export and import trends by sector, country, and region. Figures 1-2 present the composition of electroindustry trade and figures 3-8 display trade trends across 2018-2023.

- The electroindustry exported $86.4 billion and imported $184.8 billion of goods in 2023, resulting in a $98.4 billion trade deficit.
- Miscellaneous electrical equipment & components manufacturing, motors & generators manufacturing, and switchgear and switchboard apparatus manufacturing were the top contributors to the electroindustry's export value in 2023, accounting for 11.6%, 10.2%, and 9.5% of total exports, respectively.
- Miscellaneous electrical equipment & components, batteries, and switchgear and switchboard apparatus represented the largest shares of the electroindustry's import value in 2023, accounting for 19.6%, 16.5%, and 10.5% of total imports, respectively.
- Carbon & graphite products ($400 million) and current-carrying wiring devices ($380 million) were the only electroindustry markets that posted trade surpluses in 2023.
- The leading exporting sectors for the top five U.S. export destinations in 2023 were:
    - *Mexico*: Current-carrying wiring devices ($3,763 million)
    - *Canada*: Motors and generators ($2,024 million)
    - *China*: Irradiation apparatus ($780 million)
    - *Germany*: Electromedical and electrotherapeutic apparatus ($1,263 million)
    - *United Kingdom*: Motors and generators ($364 million)
- The leading importing sectors for the top five U.S. import countries in 2023 were:
    - *Mexico*: Switchgear and switchboard apparatus ($8,486 million)
    - *China*: Batteries ($15,995 million)
    - *Germany*: Electromedical and electrotherapeutic apparatus ($1,561 million)
    - *Japan*: Batteries ($3,191 million)
    - *South Korea*: Batteries ($4,363 million)
- Top U.S. export sector by region in 2023:
    - *Asia*: Miscellaneous electrical equipment & components ($3,163 million)

- *North America*: Current-carrying wiring devices ($4,974 million)
- *Europe*: Electromedical and electrotherapeutic apparatus ($3,599 million)
- *South/Central America*: Switchgear and switchboard apparatus ($802 million)
- *Australia & Oceania*: Batteries ($625 million)
- *Africa*: Motors and generators ($138 million)

- Top U.S. import sector by region in 2023:
  - *Asia*: Miscellaneous electrical equipment & components ($27,003 million)
  - *North America*: Switchgear and switchboard apparatus ($9,942 million)
  - *Europe*: Motors & generators ($4,245 million)
  - *South/Central America*: Electromedical and electrotherapeutic apparatus ($1,022 million)
  - *Australia & Oceania*: Miscellaneous electrical equipment & components ($86 million)
  - *Africa*: Switchgear and switchboard apparatus ($59 million)
- Other electrical equipment & components accounted for the largest portion of exports in 2023, contributing 40.1 percent of the industry total.
- Similarly, at 48.0 percent of the industry total, other electrical equipment & components represented the largest portion of imports in 2023.

I. Trade by Sector

Table 5.A: Exports by Sector, 2018-2023 ($ billions)

Sector	2018	2019	2020	2021	2022	2023
Misc Electrical Equipment & Components, Nesoi	8.77	8.47	7.25	7.61	8.89	10.02
Motors & Generators	6.56	6.94	6.36	6.87	7.20	8.84
Switchgear & Switchboard Apparatus	6.51	6.47	5.76	6.41	7.21	8.21
Current-carrying Wiring Devices	7.24	6.78	5.76	6.81	7.82	8.13
Relays & Industrial Controls	6.34	5.89	4.99	5.78	6.79	8.10
Communication & Energy Wire, Nesoi	6.58	6.22	5.24	6.32	7.58	7.80

Sector	2018	2019	2020	2021	2022	2023
Electromedical and Electrotherapeutic Apparatus Manuf	5.03	5.05	5.14	5.53	6.20	7.40
Battery Manufacturing	4.57	4.71	4.28	4.36	5.01	6.34
Irradiation Apparatus	4.32	4.05	3.73	3.74	3.76	4.33
Copper Rolling, Drawing & Extruding, & Alloying	3.03	2.70	2.33	3.44	3.68	3.63
Speed Changers/industrial High-speed Drives/gears	2.29	2.46	2.11	2.42	2.79	2.90
Electricity and Signal Testing Instruments Manuf	2.70	2.85	2.49	2.45	2.49	2.64
Carbon & Graphite Products	1.69	1.81	1.32	1.38	1.77	1.83
Electric Lamp Bulb And Other Light Equipment Manuf	2.02	1.94	1.54	1.80	1.83	1.75
Welding & Soldering Equipment	1.29	1.26	0.94	1.15	1.27	1.46
Other Communications Equipment	0.68	0.70	0.61	0.65	0.71	0.89
Power/distribution/specialty Transformers	0.54	0.49	0.41	0.42	0.49	0.57
Noncurrent-carrying Wiring Devices	0.37	0.36	0.31	0.33	0.42	0.48
Automatic Environmental Controls	0.38	0.39	0.35	0.39	0.46	0.48
Commercial,indust,institut Elec Light Fixture Manuf	0.35	0.32	0.27	0.32	0.38	0.37
Residential Elec Lighting Fixture Manufacturing	0.25	0.23	0.21	0.26	0.22	0.22
Total	***71.53***	***70.12***	***61.44***	***68.44***	***76.97***	***86.37***

Table 5.B: Imports by Sector, 2018-2023 ($ billions)

Sector	2018	2019	2020	2021	2022	2023
Misc Electrical Equipment & Components, Nesoi	15.71	17.21	18.79	20.93	30.27	36.27
Battery Manufacturing	8.79	8.85	10.20	15.71	24.37	30.54
Switchgear & Switchboard Apparatus	13.02	13.42	12.57	14.51	16.84	19.49
Motors & Generators	13.90	13.54	12.87	15.66	17.91	17.98

Sector	2018	2019	2020	2021	2022	2023
Communication & Energy Wire, Nesoi	8.72	8.24	8.24	10.42	12.67	12.17
Relays & Industrial Controls	6.18	6.48	5.81	6.63	7.97	8.65
Electromedical and Electrotherapeutic Apparatus Manuf	6.23	6.63	6.52	7.41	8.27	8.40
Electric Lamp Bulb And Other Light Equipment Manuf	10.46	9.05	8.20	9.77	9.57	7.81
Current-carrying Wiring Devices	6.35	6.10	5.58	6.94	7.96	7.75
Power/distribution/specialty Transformers	2.54	2.72	2.99	3.04	4.05	6.06
Copper Rolling, Drawing & Extruding, & Alloying	3.72	3.48	3.20	5.22	6.05	5.53
Speed Changers/industrial High-speed Drives/gears	4.50	4.63	3.82	4.58	4.77	4.77
Irradiation Apparatus	4.26	4.26	3.64	4.36	4.47	4.46
Electricity and Signal Testing Instruments Manuf	2.58	2.76	2.56	2.75	3.05	3.54
Commercial,indust,institut Elec Light Fixture Manuf	2.71	2.61	2.44	2.71	2.92	2.55
Residential Elec Lighting Fixture Manufacturing	2.81	2.30	2.37	2.78	2.51	1.89
Other Communications Equipment	1.67	1.70	1.45	1.60	1.80	1.74
Welding & Soldering Equipment	1.63	1.56	1.51	1.66	1.77	1.63
Automatic Environmental Controls	1.60	1.53	1.35	1.48	1.65	1.59
Carbon & Graphite Products	1.56	1.62	1.11	1.10	1.45	1.43
Noncurrent-carrying Wiring Devices	0.38	0.33	0.33	0.48	0.61	0.54
Total	***119.34***	***119.01***	***115.56***	***139.74***	***170.96***	***184.80***

Table 5.C: Trade Balance by Sector, 2018-2023 ($ billions)

Sector	2018	2019	2020	2021	2022	2023
Carbon & Graphite Products	0.13	0.19	0.21	0.28	0.32	0.40
Current-carrying Wiring Devices	0.89	0.68	0.18	-0.13	-0.14	0.38
Noncurrent-carrying Wiring Devices	-0.01	0.03	-0.02	-0.15	-0.19	-0.07

Sector	2018	2019	2020	2021	2022	2023
Irradiation Apparatus	0.06	-0.21	0.09	-0.63	-0.72	-0.13
Welding & Soldering Equipment	-0.34	-0.30	-0.56	-0.52	-0.50	-0.17
Relays & Industrial Controls	0.16	-0.59	-0.82	-0.85	-1.18	-0.56
Other Communications Equipment	-0.99	-1.00	-0.84	-0.95	-1.09	-0.85
Electricity and Signal Testing Instruments Manuf	0.12	0.09	-0.07	-0.31	-0.56	-0.90
Electromedical and Electrotherapeutic Apparatus Manuf	-1.20	-1.58	-1.38	-1.87	-2.08	-1.00
Automatic Environmental Controls	-1.22	-1.14	-1.00	-1.09	-1.19	-1.11
Residential Elec Lighting Fixture Manufacturing	-2.56	-2.07	-2.16	-2.52	-2.29	-1.67
Speed Changers/industrial High-speed Drives/gears	-2.21	-2.17	-1.71	-2.16	-1.98	-1.87
Copper Rolling, Drawing & Extruding, & Alloying	-0.68	-0.78	-0.86	-1.78	-2.38	-1.90
Commercial,indust,institut Elec Light Fixture Manuf	-2.36	-2.28	-2.17	-2.39	-2.55	-2.18
Communication & Energy Wire, Nesoi	-2.15	-2.02	-3.00	-4.10	-5.09	-4.37
Power/distribution/specialty Transformers	-2.00	-2.23	-2.59	-2.61	-3.56	-5.49
Electric Lamp Bulb And Other Light Equipment Manuf	-8.44	-7.11	-6.66	-7.98	-7.74	-6.06
Motors & Generators	-7.34	-6.60	-6.51	-8.78	-10.71	-9.14
Switchgear & Switchboard Apparatus	-6.51	-6.94	-6.81	-8.10	-9.64	-11.28
Battery Manufacturing	-4.21	-4.14	-5.92	-11.35	-19.37	-24.20
Misc Electrical Equipment & Components, Nesoi	-6.95	-8.73	-11.54	-13.32	-21.38	-26.25
Trade Balance	***-47.81***	***-48.89***	***-54.12***	***-71.30***	***-94.00***	***-98.43***

II. Trade by Country

Table 5.D: Exports – Top 5 Countries, 2023 ($ millions)

Sector	Mexico	Canada	China	Germany	UK
Copper Rolling, Drawing & Extruding, & Alloying	2,106.3	817.0	86.5	57.6	29.8
Speed Changers/industrial High-speed Drives/gears	412.0	859.9	185.7	174.5	54.2
Welding & Soldering Equipment	418.8	504.8	64.2	37.5	21.9
Other Communications Equipment	114.3	220.8	25.6	27.9	57.0
Automatic Environmental Controls	160.1	143.8	24.3	23.3	7.0
Irradiation Apparatus	331.1	274.1	780.1	459.0	100.1
Residential Elec Lighting Fixture Manufacturing	28.9	136.6	1.8	0.9	8.0
Commercial,indust,institut Elec Light Fixture Manuf	31.9	263.8	2.1	2.6	5.9
Electric Lamp Bulb And Other Light Equipment Manuf	297.3	583.6	90.0	71.0	49.4
Power/distribution/specialty Transformers	131.4	200.5	21.5	4.8	5.4
Motors & Generators	2,000.2	2,024.1	386.4	458.3	364.0
Switchgear & Switchboard Apparatus	2,374.0	1,923.2	348.8	521.9	237.0
Relays & Industrial Controls	3,261.4	810.7	573.7	280.4	288.0
Battery Manufacturing	1,288.9	1,762.6	98.7	202.0	267.8
Communication & Energy Wire, Nesoi	2,993.2	1,521.2	280.3	176.3	172.7
Current-carrying Wiring Devices	3,763.0	1,211.2	339.0	264.8	223.2
Noncurrent-carrying Wiring Devices	132.7	117.6	12.3	16.5	6.4
Carbon & Graphite Products	176.5	132.9	212.1	220.6	163.8
Misc Electrical Equipment & Components, Nesoi	2,150.9	1,633.1	684.9	559.9	308.9
Electromedical and Electrotherapeutic Apparatus Manuf	350.9	710.5	719.8	1,263.3	139.1

Sector	Mexico	Canada	China	Germany	UK
Electricity and Signal Testing Apparatus Manuf	402.0	359.7	281.0	87.4	98.7
Total	***22,925.7***	***16,211.8***	***5,219.0***	***4,910.4***	***2,608.2***

Table 5.E: Imports – Top 5 Countries, 2023 ($ millions)

Sector	Mexico	China	Germany	Japan	South Korea
Copper Rolling, Drawing & Extruding, & Alloying	750.3	112.0	585.8	93.8	351.5
Speed Changers/industrial High-speed Drives/gears	261.8	573.2	568.2	510.2	134.3
Welding & Soldering Equipment	163.7	157.8	257.9	250.4	67.2
Other Communications Equipment	728.8	386.0	36.1	27.7	4.7
Automatic Environmental Controls	807.1	135.8	47.0	17.6	47.0
Irradiation Apparatus	342.2	333.1	1476.6	330.9	179.9
Residential Elec Lighting Fixture Manufacturing	19.1	1357.3	2.7	0.3	4.5
Commercial,indust,institut Elec Light Fixture Manuf	1085.2	479.6	35.2	1.2	6.0
Electric Lamp Bulb And Other Light Equipment Manuf	761.3	4251.8	289.1	126.4	74.6
Power/distribution/specialty Transformers	2372.5	239.7	175.9	25.3	756.9
Motors & Generators	5200.3	2616.9	1508.7	1886.2	586.6
Switchgear & Switchboard Apparatus	8486.4	1410.0	1036.1	671.4	868.0
Relays & Industrial Controls	2703.0	869.6	737.5	531.6	93.4
Battery Manufacturing	1402.5	15995.1	646.5	3191.2	4363.0
Communication & Energy Wire, Nesoi	3848.2	2685.8	347.2	192.2	598.1
Current-carrying Wiring Devices	2340.0	1563.4	569.4	421.5	198.6
Noncurrent-carrying Wiring Devices	164.2	110.1	37.1	12.3	7.4
Carbon & Graphite Products	254.4	129.9	162.2	225.0	149.0

Sector	Mexico	China	Germany	Japan	South Korea
Misc Electrical Equipment & Components, Nesoi	4888.4	3547.6	1401.2	1248.1	1711.1
Electromedical and Electrotherapeutic Apparatus Manuf	1399.3	533.5	1560.7	789.9	204.4
Electricity and Signal Testing Apparatus Manuf	1112.3	214.9	266.9	90.6	126.8
Total	***39,091.0***	***37,703.0***	***11,748.0***	***10,643.8***	***10,533.1***

III. Trade by Region

Table 5.F: Exports by Region, 2023 ($ millions)

Sector	Africa	Asia	Australia and Oceania	Europe	North America	South/Central America
Copper Rolling, Drawing & Extruding, & Alloying	4.1	438.6	5.5	178.9	2,923.3	75.3
Speed Changers/industrial High-speed Drives/gears	61.4	501.3	98.8	623.7	1,271.9	347.0
Welding & Soldering Equipment	13.0	252.0	33.7	129.1	923.6	107.0
Other Communications Equipment	20.3	214.4	28.8	185.2	335.1	104.4
Automatic Environmental Controls	2.5	73.4	6.6	66.3	303.9	22.7
Irradiation Apparatus	54.0	1,896.9	115.2	1,372.0	605.2	287.9
Residential Elec Lighting Fixture Manufacturing	0.9	12.6	4.9	23.4	165.5	11.0
Commercial,indust,institut Elec Light Fixture Manuf	2.0	21.0	4.9	25.3	295.6	20.1
Electric Lamp Bulb And Other Light Equipment Manuf	12.9	369.6	30.3	299.3	880.9	153.1
Power/distribution/specialty Transformers	5.1	98.2	4.4	50.9	331.9	78.5
Motors & Generators	138.5	2,010.5	226.9	1,888.8	4,024.3	547.1
Switchgear & Switchboard Apparatus	63.5	1,423.8	114.6	1,508.5	4,297.2	801.6

Sector	Africa	Asia	Australia and Oceania	Europe	North America	South/Central America
Relays & Industrial Controls	87.1	1,817.2	130.0	1,420.0	4,072.1	570.4
Battery Manufacturing	38.9	986.2	624.8	1,282.9	3,051.6	352.6
Communication & Energy Wire, Nesoi	92.5	1,364.4	89.9	1,196.0	4,514.4	544.1
Current-carrying Wiring Devices	64.2	1,422.7	66.8	1,085.7	4,974.3	515.9
Noncurrent-carrying Wiring Devices	3.5	125.5	7.6	49.4	250.3	41.7
Carbon & Graphite Products	6.1	563.8	26.3	833.0	309.4	93.1
Misc Electrical Equipment & Components, Nesoi	84.2	3,162.5	179.5	2,212.7	3,784.1	599.6
Electromedical and Electrotherapeutic Apparatus Manuf	54.3	2,066.4	157.2	3,599.5	1,061.4	463.7
Electricity and Signal Testing Apparatus Manuf	16.7	1,113.6	67.1	554.2	761.7	125.8
Total	***825.5***	***19,934.3***	***2,023.9***	***18,584.8***	***39,137.8***	***5,862.5***

Table 5.G: Imports by Region, 2023 ($ millions)

Sector	Africa	Asia	Australia and Oceania	Europe	North America	South/Central America
Copper Rolling, Drawing & Extruding, & Alloying	18.3	1,184.4	0.8	1,138.0	2,761.8	422.6
Speed Changers/industrial High-speed Drives/gears	10.1	2,080.1	18.4	2,117.4	513.1	30.5
Welding & Soldering Equipment	5.0	584.4	3.2	629.0	405.3	5.4
Other Communications Equipment	1.6	642.3	16.0	258.3	819.0	4.5
Automatic Environmental Controls	5.3	536.0	0.5	123.1	904.0	20.5
Irradiation Apparatus	3.4	1,193.1	6.7	2,806.3	440.7	8.1
Residential Elec Lighting Fixture Manufacturing	2.2	1,715.6	3.3	124.0	47.6	0.5

Sector	Africa	Asia	Australia and Oceania	Europe	North America	South/Central America
Commercial,indust,institut Elec Light Fixture Manuf	0.8	818.1	2.3	198.4	1,529.5	2.8
Electric Lamp Bulb And Other Light Equipment Manuf	3.6	6,009.2	18.8	691.8	1,075.6	6.3
Power/distribution/specialty Transformers	5.1	1,338.4	0.6	990.9	3,240.0	485.6
Motors & Generators	15.4	7,328.8	7.7	4,245.3	5,787.8	594.5
Switchgear & Switchboard Apparatus	59.5	5,027.3	67.2	3,529.3	9,942.1	867.3
Relays & Industrial Controls	19.6	3,002.4	20.6	2,429.9	3,082.8	99.4
Battery Manufacturing	0.9	25,978.9	2.8	2,906.6	1,574.8	75.2
Communication & Energy Wire, Nesoi	46.1	6,000.6	6.5	1,281.9	4,526.0	306.3
Current-carrying Wiring Devices	26.4	3,245.7	10.2	1,761.6	2,524.2	184.5
Noncurrent-carrying Wiring Devices	0.8	229.5	0.6	74.4	236.7	1.9
Carbon & Graphite Products	2.2	588.4	2.8	548.7	280.2	9.0
Misc Electrical Equipment & Components, Nesoi	37.5	27,002.7	85.7	3,549.3	5,549.3	48.9
Electromedical and Electrotherapeutic Apparatus Manuf	0.3	2,473.0	10.4	3,093.6	1,799.2	1,022.0
Electricity and Signal Testing Apparatus Manuf	3.1	1,524.5	11.0	734.7	1,261.6	6.8
Total	***267.1***	***98,503.6***	***296.2***	***33,232.5***	***48,301.2***	***4,202.7***

IV. Composition of Trade

Figure 5.1: Composition of Electroindustry Exports, 2023

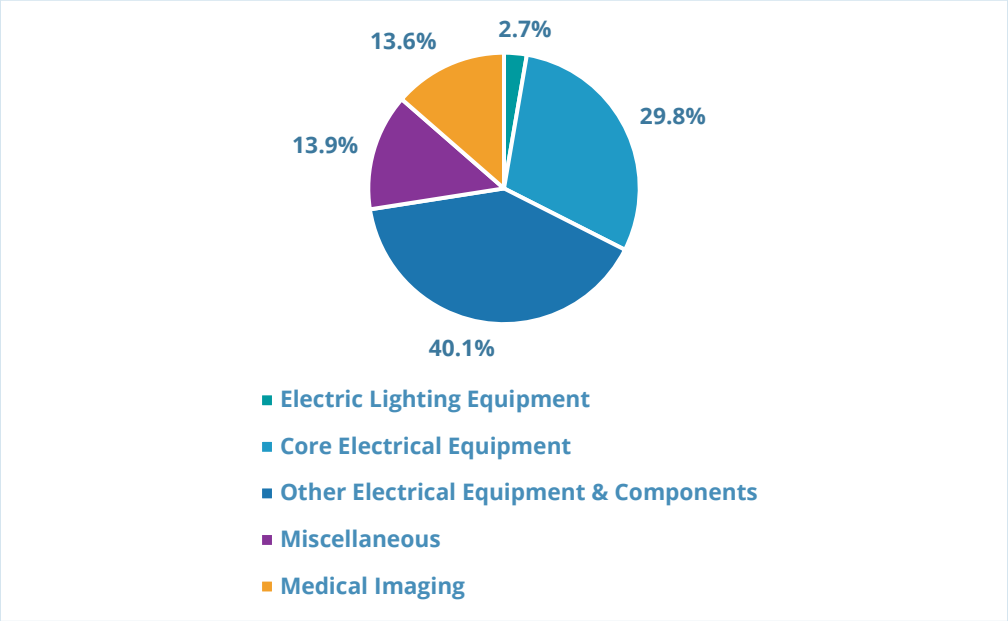
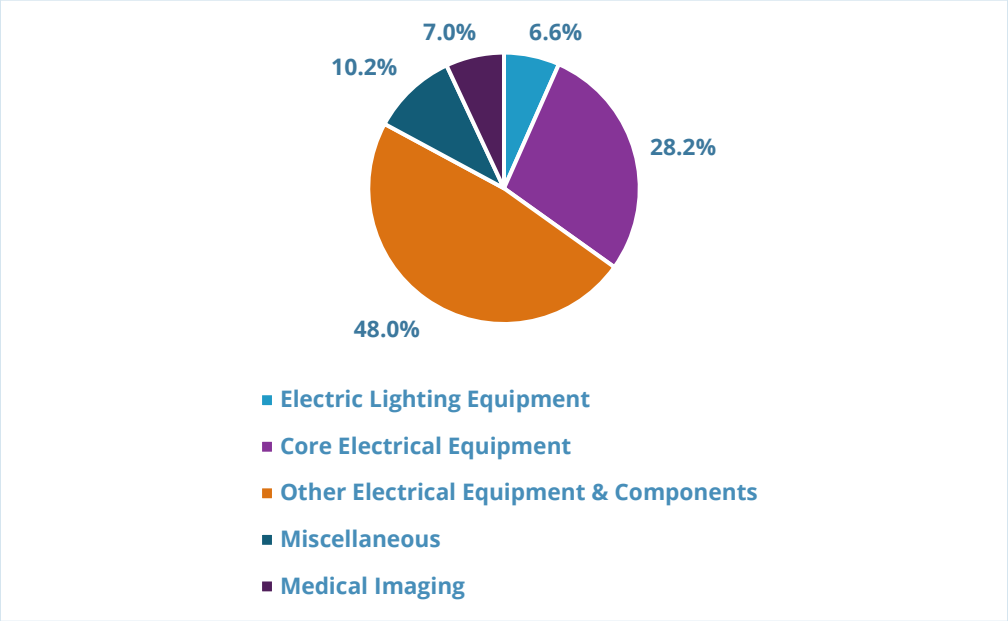


Figure 5.2: Composition of Electroindustry Imports, 2023



V. Trade Trends

Figure 5.3: Total Electroindustry Trade, 2018-2023 ($ billions)

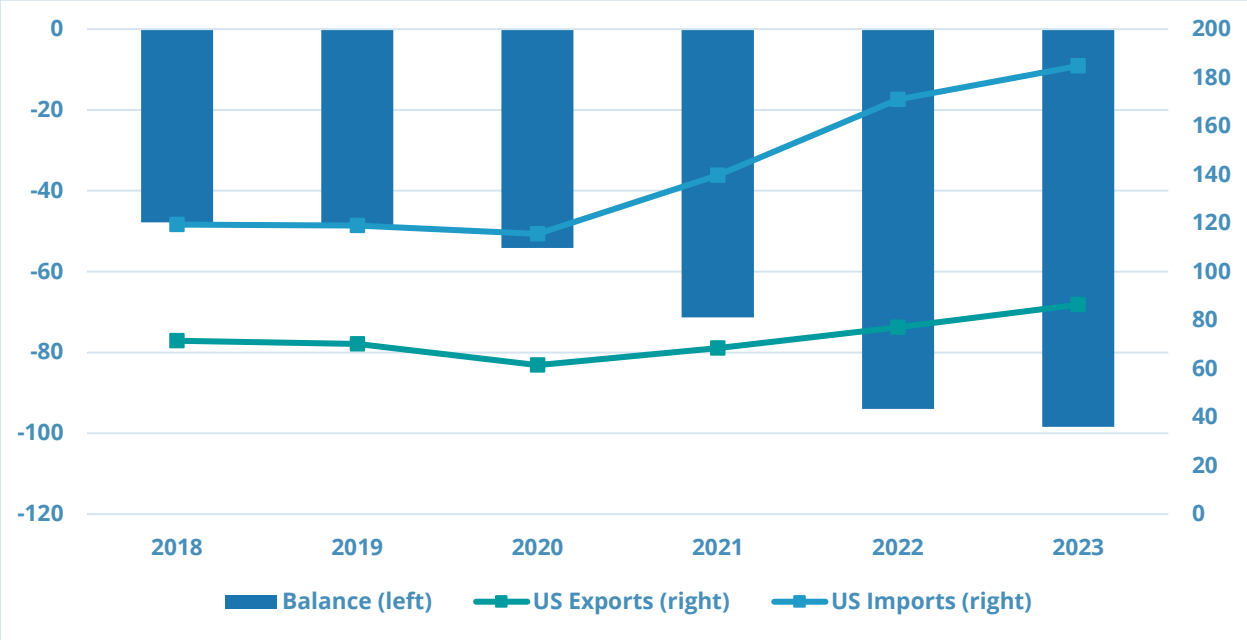


Figure 5.4: Electric Lighting Equipment Trade, 2018-2023 ($ billions)

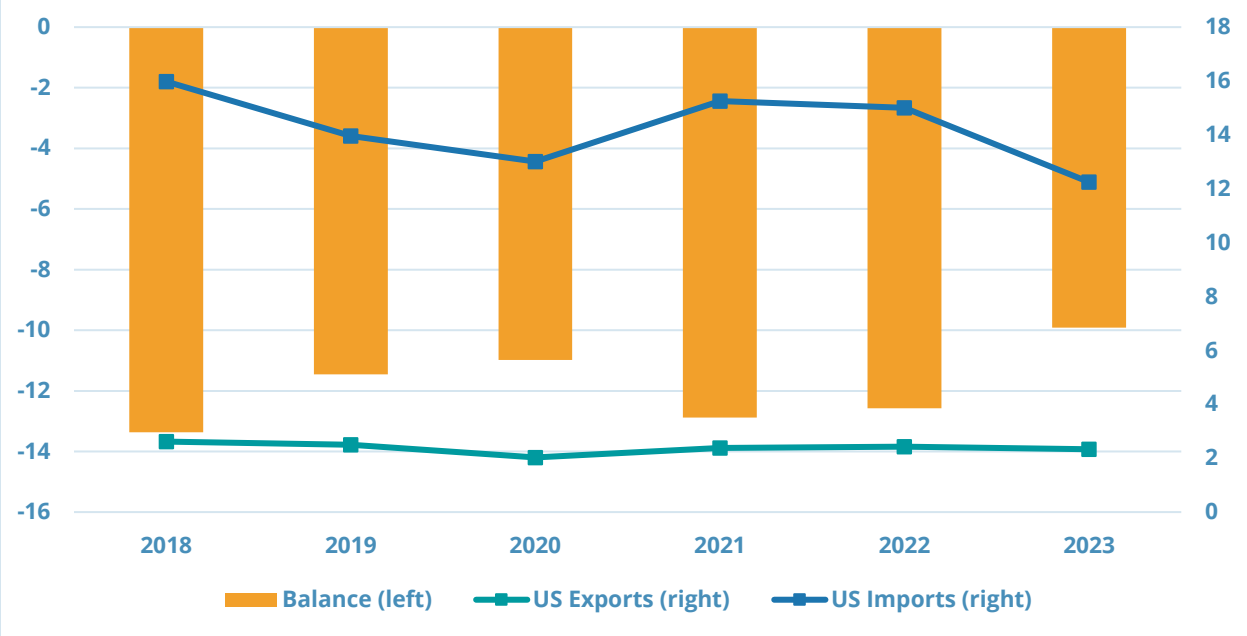


Figure 5.5: Core Electrical Equipment Trade, 2018-2023 ($ billions)

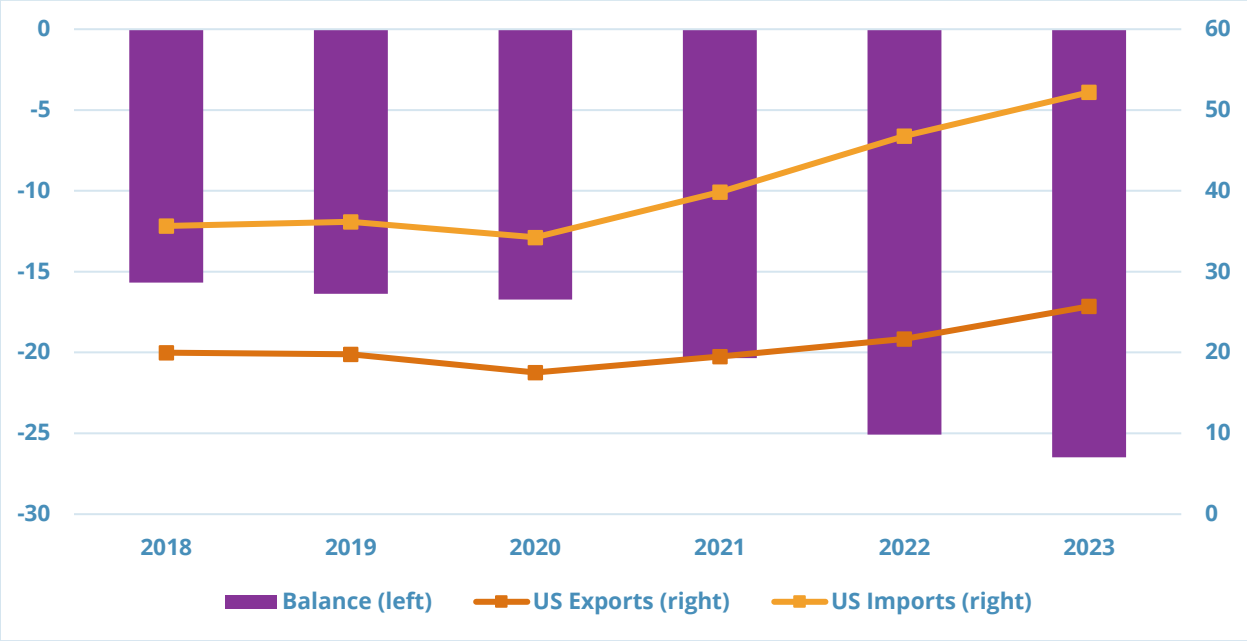


Figure 5.6: Other Electrical Equipment Trade, 2018-2023 ($ billions)

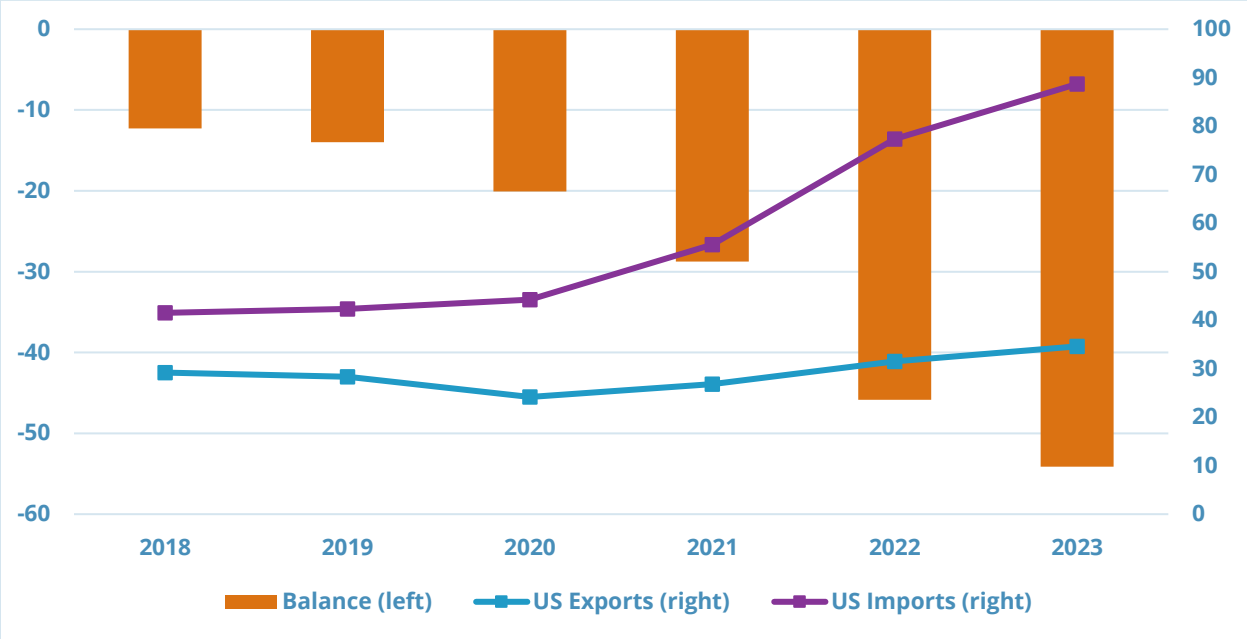


Figure 5.7: Miscellaneous Trade, 2018-2023 ($ billions)

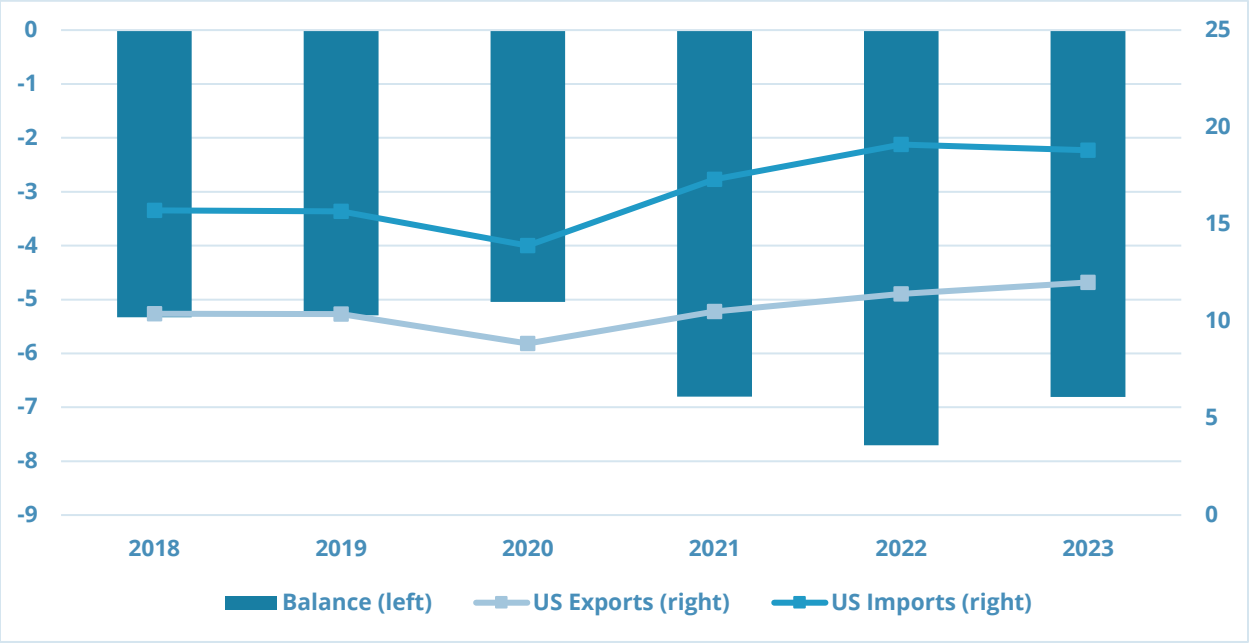
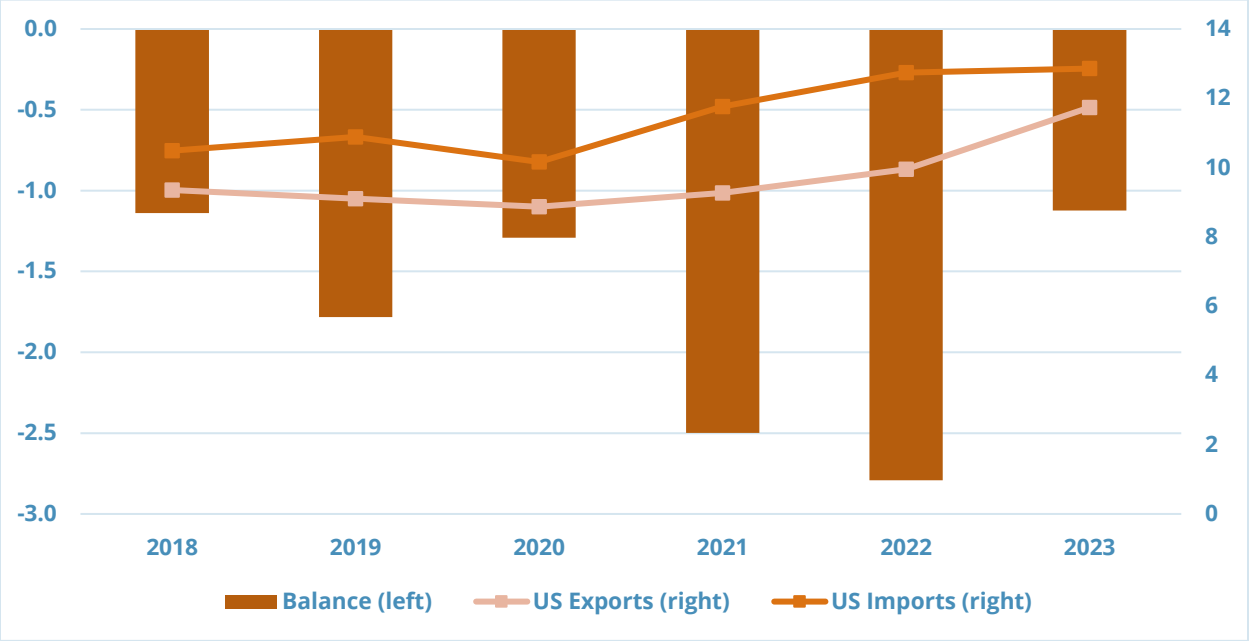


Figure 5.8: Medical Imaging Trade, 2018-2023 ($ billions)



The electroindustry trade deficit grew each year between 2018 and 2023, rising $50.6 billion (+106%) across the period, not adjusted for inflation. Imports have increased significantly across many sectors, while exports have exhibited slower growth. The other electrical equipment and components segment is primarily driving the growing trade deficit, with imports increasing $47.2 billion over the five years, while exports grew just $5.4 billion. Within other electrical equipment and components, imports of storage batteries and miscellaneous electrical equipment and components (NAICS = 335999) have risen substantially in recent years.

The electroindustry supply chain has recently been shifting, moving primarily from China to Mexico and to other Southeast Asian countries. This shift is largely due to increased trade barriers such as tariffs (e.g., S.301 tariffs) and friend-shoring strategies. Between 2018 and 2023, electroindustry imports from China fell by 6.7%, while imports from all other countries combined increased by 67.6%[1]. As a share of total electroindustry imports, the percentage from China decreased from 28.2% in 2018 to 17.9% in 2023. An S&P Global analysis supports these findings, stating that electrical equipment imports (HS 85) from Mexico have averaged 6.3% annual growth over the past five years, while imports from China have decreased by an average of 0.8% annually during the same period (Sevilla-Macip & Marris, 2023). Moreover, soft indicators point to nearshoring as a growth opportunity, with over 50% of electrical and electronic equipment companies expecting increased growth opportunities due to nearshoring in the next year, according to the S&P analysis.

Tables H-L below show the five Harmonized System (HS-6) codes that have experienced the largest shifts away from China between 2018 and 2023, along with the countries to which those products have predominantly shifted. The data show the change in imports over the period from 2018 to 2023, as well as each country's share of US imports in both 2018 and 2023.

[1] Information sourced from a NEMA electroindustry trade analysis at the HS-6 trade code level. The HS-6 scope is broader than the trade scope considered above.

Table 5.H: Static Converters & ADP Power Supplies (HS 850440)

Country	Change 2018-2023	% Change	2018 US Import Share	2023 US Import Share
Mexico	$1,780,622,246	189.8	9.2%	15.4%
Thailand	$1,608,046,292	526.7	3.0%	10.9%
Vietnam	$1,257,499,445	894.9	1.4%	7.9%
Spain	$820,097,020	656.2	1.2%	5.4%
Taiwan	$608,059,400	177.3	3.4%	5.4%
India	$575,878,258	450.5	1.3%	4.0%
Japan	$495,909,723	80.8	6.0%	6.3%
Malaysia	$477,476,338	266.3	1.8%	3.7%
Italy	$395,070,882	257.0	1.5%	3.1%
South Korea	$338,381,981	250.5	1.3%	2.7%
China	-$1,975,330,483	-38.9	50.0%	17.6%
All Other	$1,062,708,191	52.5	19.9%	17.5%
World Total	$7,444,419,293	73.2	-	-

Table 5.I: Electrical Machines & Apparatus (HS 854370)

Country	Change 2018-2023	% Change	2018 US Import Share	2023 US Import Share
Mexico	$1,777,439,167	81.4	27.4%	29.2%
Malaysia	$1,287,721,641	690.6	2.3%	10.9%
Indonesia	$1,140,005,998	12958.9	0.1%	8.5%
Thailand	$765,514,534	1041.3	0.9%	6.2%
Vietnam	$444,869,563	979.3	0.6%	3.6%
Taiwan	$346,725,329	209.4	2.1%	3.8%
Japan	$296,290,748	64.0	5.8%	5.6%
Germany	$267,700,384	49.9	6.7%	5.9%

Country	Change 2018-2023	% Change	2018 US Import Share	2023 US Import Share
Romania	$196,179,278	1097.7	0.2%	1.6%
South Korea	$183,955,898	97.7	2.4%	2.7%
China	-$1,796,292,279	-61.2	36.9%	8.4%
All Other	$676,676,189	58.7	14.5%	13.5%
World Total	$5,586,786,450	70.2	-	-

Table 5.J: Low-Voltage Electrical Conductors with Connectors (HS 854442)

Country	Change 2018-2023	% Change	2018 US Import Share	2023 US Import Share
Mexico	$627,875,367	46.7	24.0%	29.5%
Vietnam	$500,299,628	1090.9	0.8%	8.2%
Taiwan	$217,423,008	149.7	2.6%	5.4%
Thailand	$112,901,148	852.1	0.2%	1.9%
Philippines	$103,877,090	137.8	1.3%	2.7%
Indonesia	$97,889,763	285.0	0.6%	2.0%
India	$68,851,605	464.7	0.3%	1.3%
Germany	$68,824,133	44.7	2.7%	3.3%
Canada	$48,856,441	54.2	1.6%	2.1%
Malaysia	$48,638,628	192.6	0.5%	1.1%
China	-$1,075,219,934	-34.0	56.5%	31.3%
All Other	$245,247,290	49.2	8.9%	11.1%
World Total	$1,065,464,167	19.0	-	-

Table 5.K: Electrical Control Apparatus Under 1000V (HS 853710)

Country	Change 2018-2023	% Change	2018 US Import Share	2023 US Import Share
Mexico	$3,214,346,112	71.1	38.1%	43.7%
Canada	$598,160,809	85.1	5.9%	7.4%
Germany	$320,183,363	42.1	6.4%	6.1%
South Korea	$319,852,669	105.2	2.6%	3.5%
Taiwan	$299,593,445	216.3	1.2%	2.5%
Malaysia	$271,403,782	139.7	1.6%	2.6%
Vietnam	$234,248,501	142.6	1.4%	2.3%
Thailand	$206,488,185	118.6	1.5%	2.2%
Hungary	$142,847,066	203.0	0.6%	1.2%
Ireland	$133,495,957	527.9	0.2%	0.9%
China	-$797,180,593	-37.7	17.8%	7.4%
All Other	$870,276,462	32.1	22.8%	20.2%
World Total	$5,813,715,758	48.9	-	-

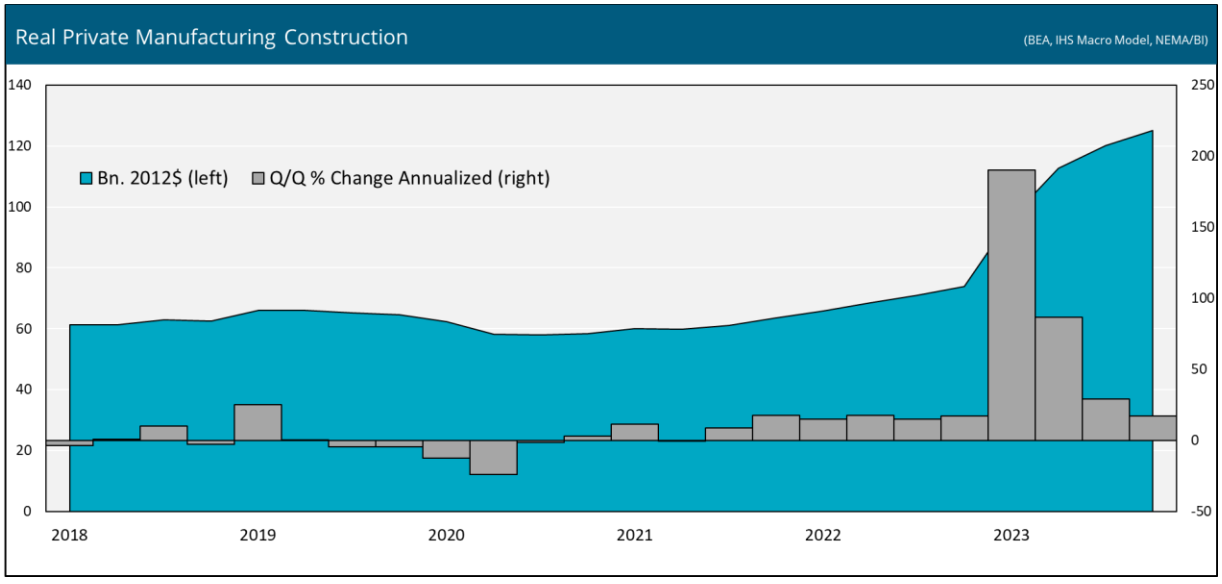
Table 5.L: Parts for Specialized Electrical Machines & Apparatus (HS 854390)

Country	Change 2018-2023	% Change	2018 US Import Share	2023 US Import Share
Japan	$98,319,773	29.3	16.2%	25.7%
Vietnam	$67,649,984	7145.7	0.0%	4.1%
Mexico	$53,148,311	42.5	6.0%	10.6%
Taiwan	$47,857,583	135.3	1.7%	4.9%
Germany	$30,525,657	37.1	4.0%	6.7%
Canada	$28,226,375	89.4	1.5%	3.5%
Indonesia	$23,918,226	251.1	0.5%	2.0%

Country	Change 2018-2023	% Change	2018 US Import Share	2023 US Import Share
United Kingdom	$22,304,942	57.1	1.9%	3.6%
Malaysia	$18,927,626	53.9	1.7%	3.2%
Belgium	$16,652,783	459.4	0.2%	1.2%
China	-$780,893,779	-67.7	55.8%	22.0%
All Other	-$6,208,591	-2.9	10.5%	12.5%
World Total	-$379,571,110	-18.4	-	-

Except for HS 854390—parts for electrical machines and apparatus with individual functions—the U.S. has substantially increased its imports of each of these products since 2018. Meanwhile, domestic output of electrical equipment and components (excluding appliances) increased by just 1.5% between 2018 and 2023. In effect, trade barriers have led to a greater change in the sources of imports rather than significantly boosting domestic production. Nonetheless, U.S. manufacturing construction has recently been thriving amid reshoring activity, with nearly 63% real growth in 2023 (see figure 5.9 below). This implies that U.S. factories may begin to compensate for some of the production losses from China in the upcoming years.

Figure 5.9: Private Manufacturing Construction, 2018-2023



Chapter 6: Electroindustry Market Size Trends

U.S. electroindustry market growth varies by sector. Market size is calculated as the sum of domestic output and imports, minus exports, presented in nominal dollars. Table 6.A below presents market size estimates for each electroindustry sector between 2018 and 2022, as well as the percentage changes over the five-year period and the last year. Figures 1-6 below display market size trends for each major electroindustry segment from 2018-2022.

- The electroindustry market size expanded by 39.4% over the period from 2018 to 2022, with a 22.5% increase from 2021 to 2022 alone.
- Copper rolling, drawing, extruding, and alloying ($50.8 billion), storage battery manufacturing ($37.2 billion), and miscellaneous electrical equipment and component manufacturing ($33.8 billion) were the largest domestic electroindustry markets in 2022.
- Likewise, storage battery manufacturing (+164.7%), miscellaneous electrical equipment and component manufacturing (+99.7%), and copper rolling, drawing, extruding, and alloying (+99.5%) experienced the largest growth over the past five years.
- Conversely, market size decreased over the five years for primary batteries (-56.9%), electric lamp bulb and parts (-22.5%), speed changers, industrial high-speed drives, and gears (-4.6%), electricity and signal testing instruments (-2.9%), and lighting fixtures (-2.9%)
- Five-year percentage market growth by major electroindustry segment:
    - Miscellaneous: +36.2%
    - Other electrical equipment & components: +33.8%
    - Medical imaging: +32.9%
    - Core electrical equipment: +29.2%
    - Electric lighting equipment: -5.1%

Table 6.A: Electroindustry Market Size by Sector, 2018-2022 ($ billions)

Sector	2018	2019	2020	2021	2022	% Chg (2018-2022)	% Chg (2021-2022)
Storage Battery Manufacturing	14.06	14.10	15.80	25.24	37.22	164.7%	47.4%
Misc Electrical Equipment & Components, Nesoi	16.91	19.60	22.20	24.52	33.77	99.7%	37.7%
Copper Rolling, Drawing & Extruding, & Alloying	25.48	31.37	27.32	30.64	50.84	99.5%	65.9%
Communication & Energy Wire, Nesoi	9.25	8.35	8.90	10.34	13.78	49.0%	33.2%
Irradiation Apparatus	8.53	9.10	11.02	13.27	12.20	43.0%	-8.1%
Motors & Generators	21.27	23.63	22.78	24.29	29.64	39.3%	22.0%
Switchgear & Switchboard Apparatus	20.65	23.41	23.44	24.88	28.15	36.3%	13.1%
Carbon & Graphite Products	2.96	3.87	3.73	3.04	3.91	31.9%	28.6%
Welding & Soldering Equipment	6.21	6.84	6.39	6.34	7.99	28.6%	26.1%
Electromedical and Electrotherapeutic Apparatus Manuf	8.71	9.20	10.38	10.98	10.71	23.0%	-2.4%
Other Communications Equipment	6.61	7.33	6.81	6.74	8.04	21.7%	19.4%
Power/distribution/specialty Transformers	11.67	13.43	12.65	11.53	13.59	16.5%	17.8%
Relays & Industrial Controls	15.13	18.08	17.27	16.27	17.41	15.0%	7.0%
Wiring Device Manufacturing	17.35	17.95	17.24	17.43	19.24	10.9%	10.4%
Automatic Environmental Controls	4.70	4.39	4.34	3.96	4.73	0.5%	19.4%
Lighting Fixture Manufacturing	27.15	24.80	23.47	25.29	26.35	-2.9%	4.2%
Electricity and Signal Testing Instruments Manuf	11.71	13.53	11.72	12.06	11.36	-2.9%	-5.8%
Speed Changers/industrial High-speed Drives/gears	5.98	6.22	5.07	5.38	5.70	-4.6%	5.9%
Electric lamb bulb and part manufacturing	3.44	3.95	3.07	3.35	2.66	-22.5%	-20.5%
Primary Battery Manufacturing	6.05	4.35	4.64	2.01	2.61	-56.9%	30.2%
Total	***243.81***	***263.51***	***258.24***	***277.56***	***339.90***	***39.4%***	***22.5%***

Figure 6.1: Total Electroindustry Market Size, 2018-2022 ($ billions)

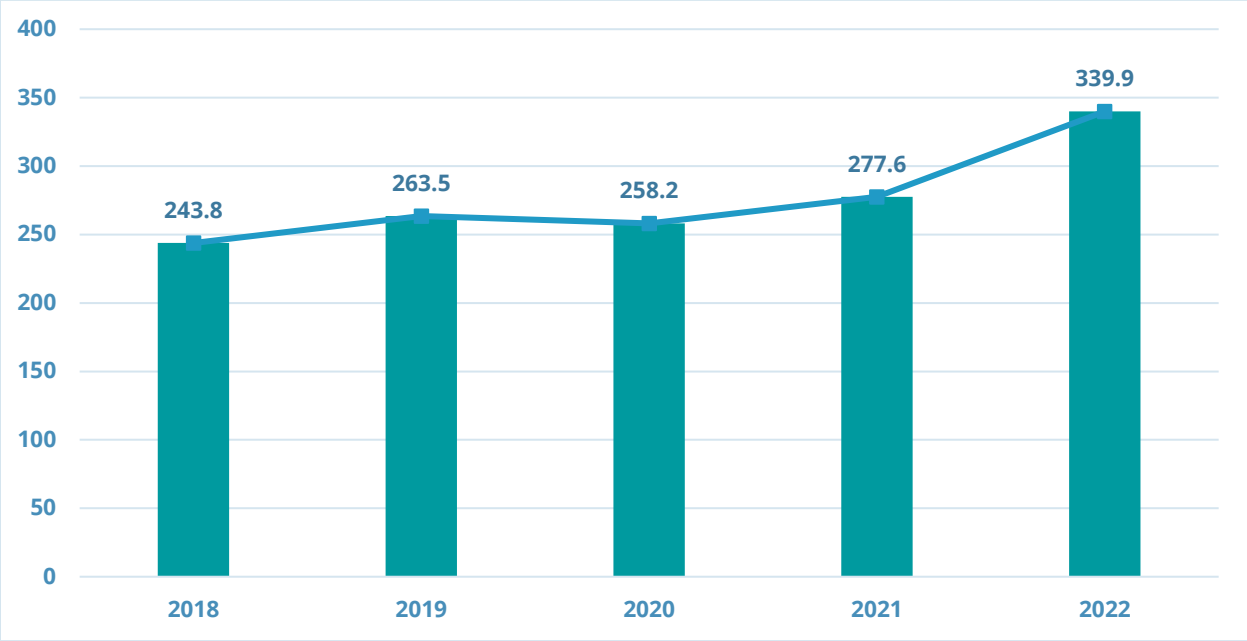


Figure 6.2: Electric Lighting Equipment Market Size, 2018-2022 ($ billions)

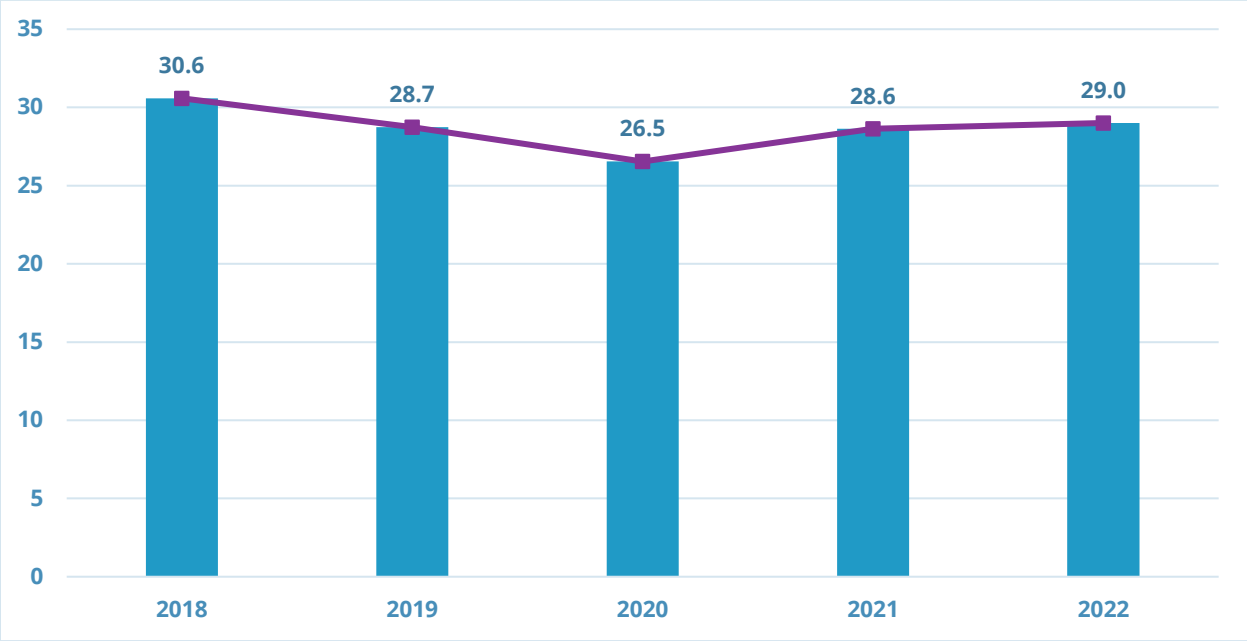


Figure 6.3: Core Electrical Equipment Market Size, 2018-2022 ($ billions)

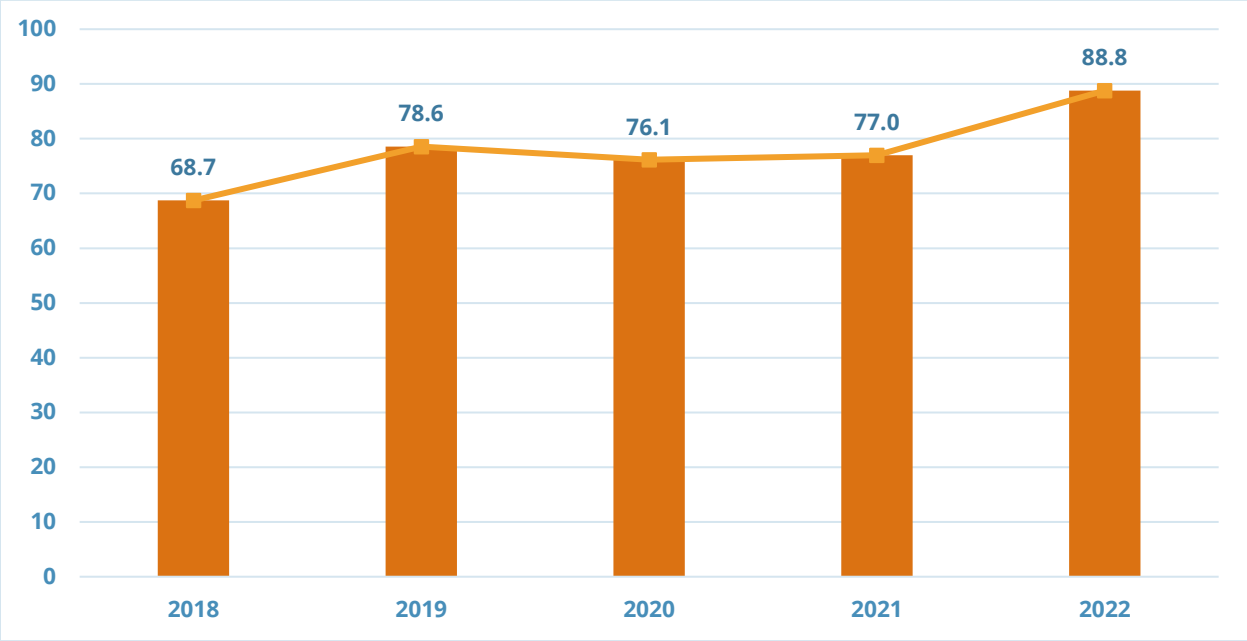


Figure 6.4: Other Electrical Equipment Market Size, 2018-2022 ($ billions)

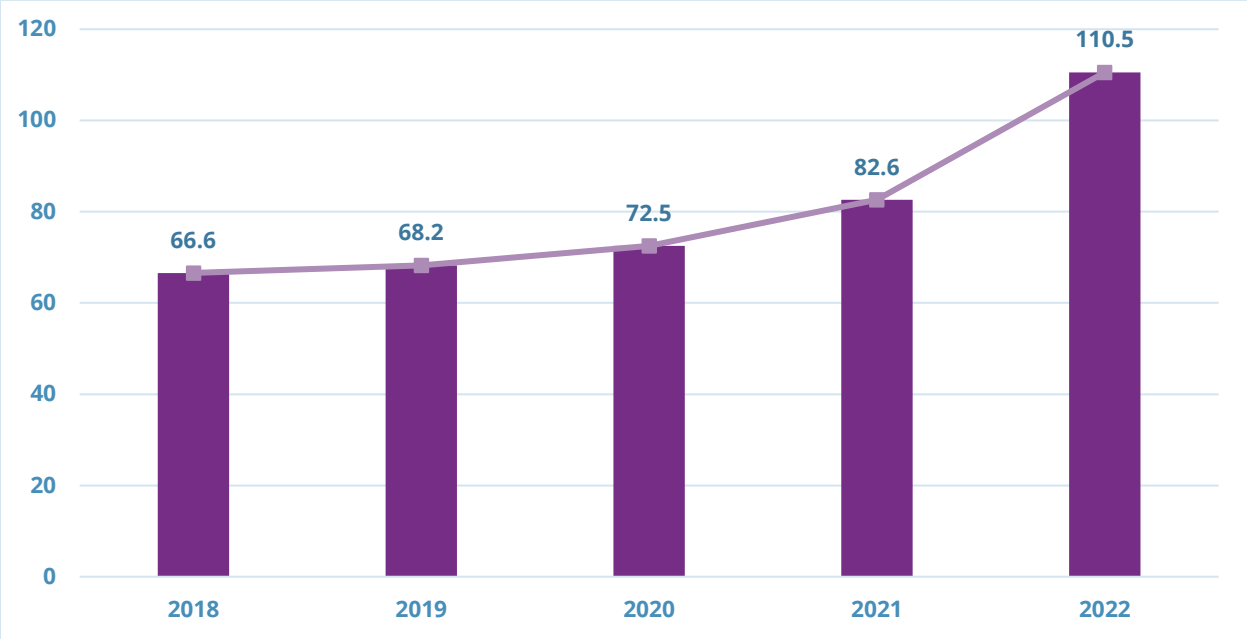


Figure 6.5: Miscellaneous Market Size, 2018-2022 ($ billions)

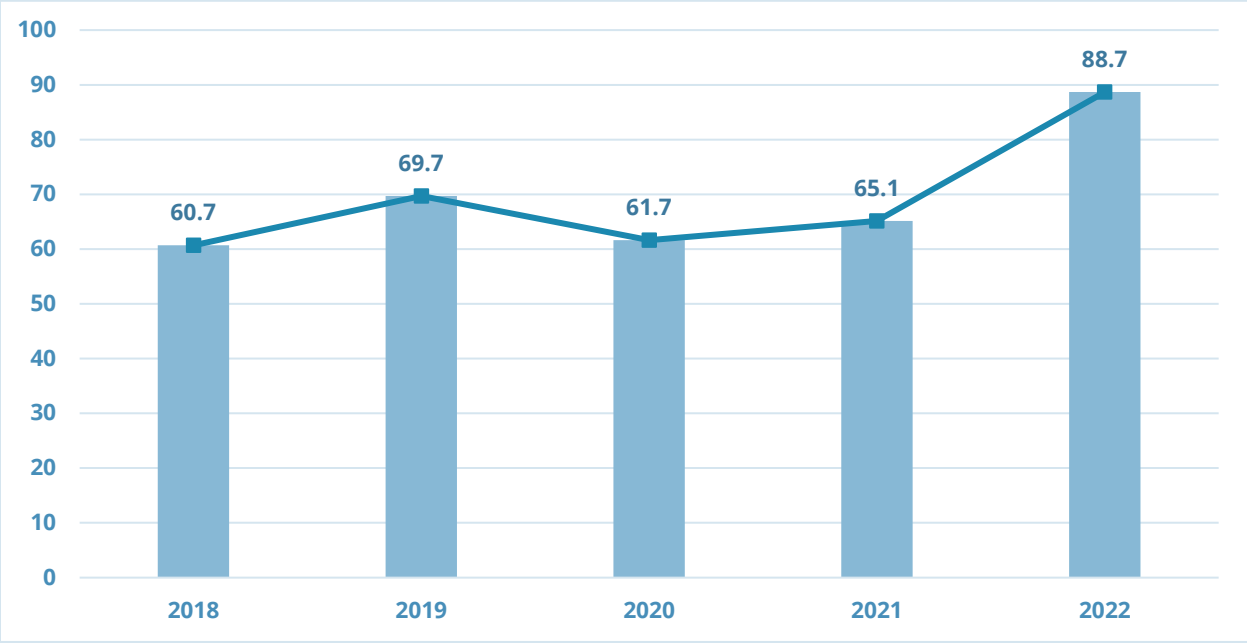
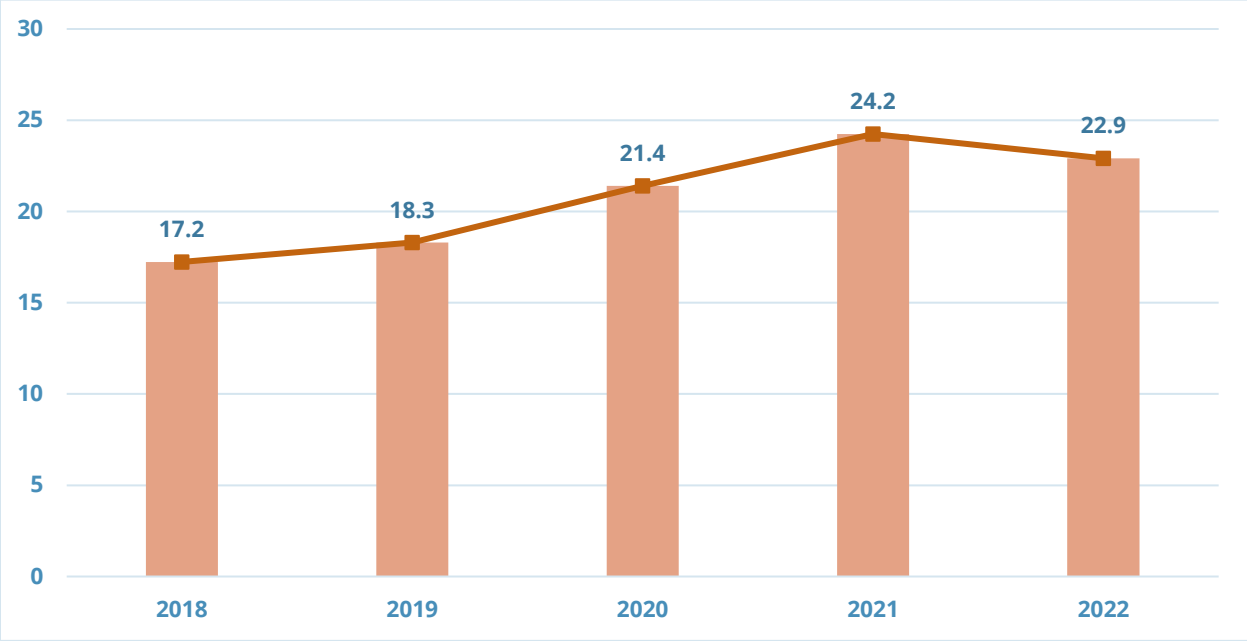


Figure 6.6: Medical Imaging Market Size, 2018-2022 ($ billions)



Chapter 7: Electroindustry Energy Efficiency Gains

Electroindustry firms excel at devising cutting-edge innovations that safeguard the reliable flow of electricity throughout the grid. In addition, they work collaboratively to adopt standards that bolster the efficiency and safety of electrical and medical imaging equipment. For instance, technological advancements in electric motors, which consume nearly 50 percent of the electricity used in manufacturing, have reduced carbon emissions significantly (EPA, 2022).

The electroindustry has facilitated the transition to more energy-efficient forms of lighting, such as LED. Developments in control systems have helped to manage electricity usage for indoor climates, lighting, and appliances—which has assisted in reducing energy consumption. The electroindustry has also spurred advancements that have improved efficiency in the electricity distribution process. Currently, out of the 37.7 quads of electricity generated annually in the U.S., 13.4 quads (35.5%) are usable—a significant improvement over the 32.5% that was usable just a decade ago. (LLNL, 2022). As the electroindustry becomes more efficient, less waste per unit is generated, leading to a reduction in the total electricity production needed. As a result, fewer greenhouse gas (GHG) contributors are required as inputs.

I. Motors

Improvements in motor efficiency help to save energy and reduce emissions, curb operating costs, and ultimately enhance the nation's productivity. Pioneering advancements such as variable frequency drives, inverter protection, and designs that minimize air gaps have revolutionized the modern motor. The posited environmental benefits for improvements in motor efficiency are immense. For example, the U.S. Department of Energy (DOE) estimated that the NEMA premium motor program saved 5,800 gigawatts of electricity and prevented the release of nearly 80 million metric tons of carbon into the atmosphere across its first ten years—equivalent to keeping 16 million cars off the road (NEMA, n.d.). By another estimation, a premium efficiency 50 horsepower (HP) motor would be expected to result in 8,630 kWh of

energy savings annually over a comparable standard efficiency motor—akin to the amount of electricity consumed annually in a typical U.S. household (DOE, 2012). [2]

In addition to curtailing negative externalities, motor efficiency improvements also boost business profitability by reducing variable costs. The main outlay pertaining to industrial motors is the cost of electricity to run them, accounting for nearly 95 percent of total motor expenditures (Constantinides, 2018). So, while newer and more efficient motors usually command a higher initial capital cost, they typically result in savings over time—often rather quickly—as operating expenses are significantly reduced. It is estimated that a one percent increase in motor efficiency for every motor in North America would translate into cost savings of $1.4 billion annually ("The Efficiency of AC Motors: Past, Present, and Future", 2022). A premium efficiency 50 HP motor (equivalent to the one discussed above) would be expected to result in $690 of cost savings per year over a comparable standard efficiency motor (DOE, 2012). The electroindustry's commitment to replacing older, less efficient motors with newer, more efficient motors has played a large role in curbing emissions.

II. Lighting

Lighting is another key area where the electroindustry is fostering efficiency. Energy-efficient lighting not only reduces electric bills, but it also alleviates the load on power grids and lowers GHG emissions. The diffusion of LED technology increased rapidly as manufacturing costs dropped. LED light sources are between 25 and 40 percent efficient (LampHQ, n.d.). For each traditional halogen lamp replaced by a comparable LED, $4.10 is saved and 11 pounds of CO2 are prevented from entering the atmosphere annually (Devenish, 2021). Since the average U.S. house has 45 light sockets, replacing all incandescent lamps with LEDs could potentially save as much as $180 annually and prevent 495 additional pounds of CO2 from being discharged, assuming equal usage for all replaced lamps. Electroindustry firms have been helping to spearhead the transition to efficient lighting by reallocating production. The share of LED lamp sales is expected to continue to grow as the new, more stringent DOE rules for lamp

[2] Assumption: 1,800 RPM TEFC motor operating 8,000 hrs/year at 75% load at an electrical rate of $0.08 kWh

efficiency, implemented in July 2022, serve as a de facto ban on incandescent and halogen lighting products.

III. Energy Control Systems

Control systems have become an integral piece of the puzzle concerning minimizing energy usage and related costs. For example, sensors located in specific zones within buildings make it possible for lamps to illuminate only when an area is occupied. Controls are increasingly being integrated into appliances (e.g., timers, sensors) to mitigate excess energy consumption. In warehouses and manufacturing facilities, the cost savings potential from implementing lighting control systems is generally thought to be in the 45 to 80 percent range. (Armstrong, 2017). Other costs—such as lighting maintenance costs—tend to decrease when lighting controls are incorporated. Additional smart lighting controls developed and advanced by the electroindustry include daylight harvesting, auto scheduling, load shedding, and task tuning. Control systems mitigate power-generation pollution as well as provide many helpful auxiliary effects, such as enabling wireless connectivity between structures without additional infrastructure.

IV. Electrical Distribution

Each stage in the electricity distribution process—step-up transformers, transmission lines, substations, distribution lines, step-down transformers, and secondary lines that connect power to end-users—is prone to energy loss, known as line-loss. Line-losses average 5 percent on US utility grids—a level large enough that it could satisfy the electricity consumption of South Africa (Chen & Worden, 2018). There have been several leading innovations brought forward by the electroindustry concerning distribution that have minimized energy losses. Innovations related to transformers have helped to boost distribution efficiency. For example, the invention of voltage regulators—i.e., transformers with multiple taps installed along distribution circuits to alter voltage at various points—delivered improved efficiency, especially along lengthy distribution lines as they allow voltage to be stepped-up at distant points, thereby counteracting reduced voltage from line resistance. Another tactic developed by the electroindustry is installing pools of transformers at substations. This allows some transformers

to be de-energized during low-demand periods and re-energized during high-demand periods, a practice that diminishes energy losses.

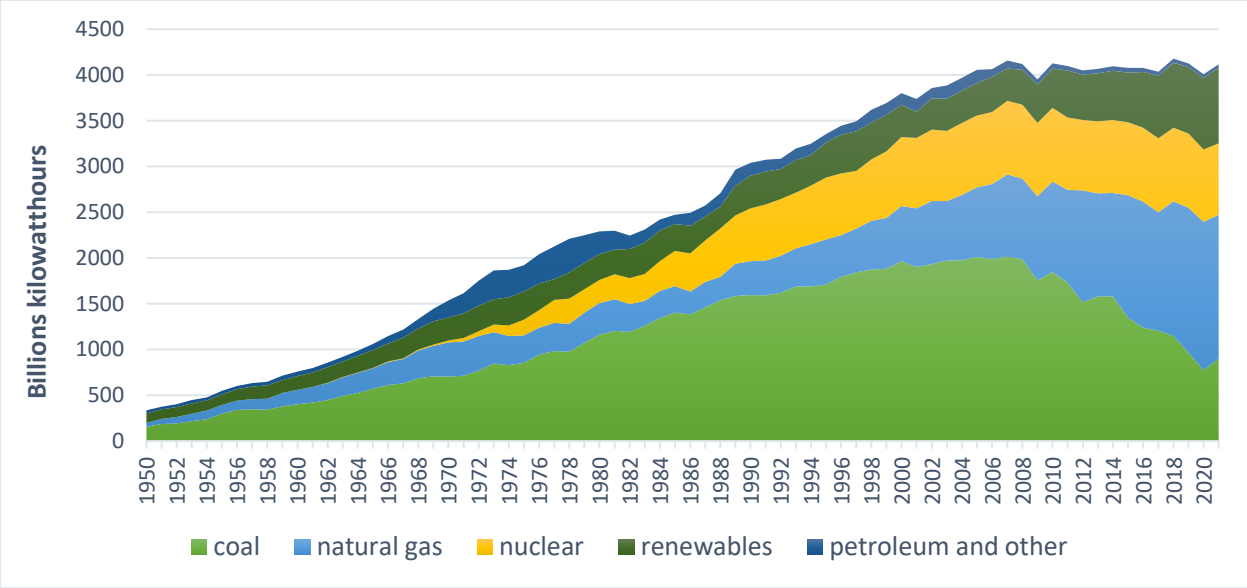
Various inventions and tactics have also reduced conductor-related energy losses. Modern wiring—which is lighter, stronger, and more effective than old-technology wiring—has strengthened the capacity of transmission lines. One tactic used is distributed generation (e.g., solar photovoltaics and wind) to source power closer to its end-use. This alleviates some of the need to deliver power over long distances where losses can be substantial and avoids grid congestion.

Lastly, breakthroughs in modern metering have permitted utilities companies and end-users to compute the difference between power supplied and power consumed. This enables utility companies to charge consumers for the actual power they require (factoring in reactive power) rather than just the power they use. In turn, modern metering provides incentives for end-users to invest in power factor correction technology. This typically involves capacitors that supply reactive power directly to a customer's equipment (rather than drawing it from the grid).

V. Aggregate Impact

The aggregate impact of these electroindustry innovations that have been increasingly integrated into industry, businesses, and homes has been a reduction in the growth of electricity generation in the U.S. Figure 7.1 breaks down electricity generation in the U.S. between 1950 and 2021.

Figure 7.1: U.S. Electricity Generation by Major Energy Source, 1950-2021



Source: Electricity generation, capacity, and sales in the United States (U.S. EIA)

U.S. electricity generation has plateaued since around 2006. To put this in perspective, between 1990 and 2005, electricity generation grew around 2.0 percent annually, but from 2006 to 2021, electricity generation grew an average of 0.1 percent. Since 1973, U.S. energy intensity—the amount of energy consumption per unit of GDP—has been declining at a rate close to 2.0 percent annually. By 2020, U.S. energy intensity was about half of what it was in 1990 (EIA, 2021). Thus, many of the technological breakthroughs and tactics developed by the electroindustry to promote efficiency and lessen the tug on the power grid have had noteworthy positive impacts.

Chapter 8: Energy Transition

Fueled by an urgency to combat climate change and reduce GHG emissions, the energy transition represents a transformative movement that is reshaping how societies produce, distribute, and consume energy. The energy transition is characterized by a shift away from fossil fuels towards renewable energy sources, such as solar and wind, along with the electrification of major energy end-uses, including e-mobility. Technology advancements, policy reforms, and evolving consumer preferences are accelerating this shift, positioning it as a key priority for governments, businesses, and communities alike. The energy transition is poised not only to mitigate adverse environmental impacts but also to offer opportunities for economic growth and energy security.

Electroindustry innovations are playing a pivotal role in propelling the energy transition by enhancing the efficiency, reliability, and scalability of renewable energy systems and electrified technologies. Advances in smart grid technology, energy storage solutions, and power electronics are enabling a more effective integration of intermittent renewable resources into the electrical grid. These technological innovations not only improve the management and distribution of electricity but also support the decentralization of energy production, allowing for greater use of local renewable sources and reducing reliance on fossil fuels. On the energy end-use side, electroindustry developments are hastening electrification—a cornerstone of the energy transition—across various sectors, including transportation, heating, and industry. For instance, breakthroughs in electric vehicle (EV) battery technology and EV charging infrastructure have significantly lowered the costs of these technologies, enabling broader adoption of EVs. Furthermore, technologies like heat pumps and ‘smart’ energy management systems are optimizing energy use for sustainability.

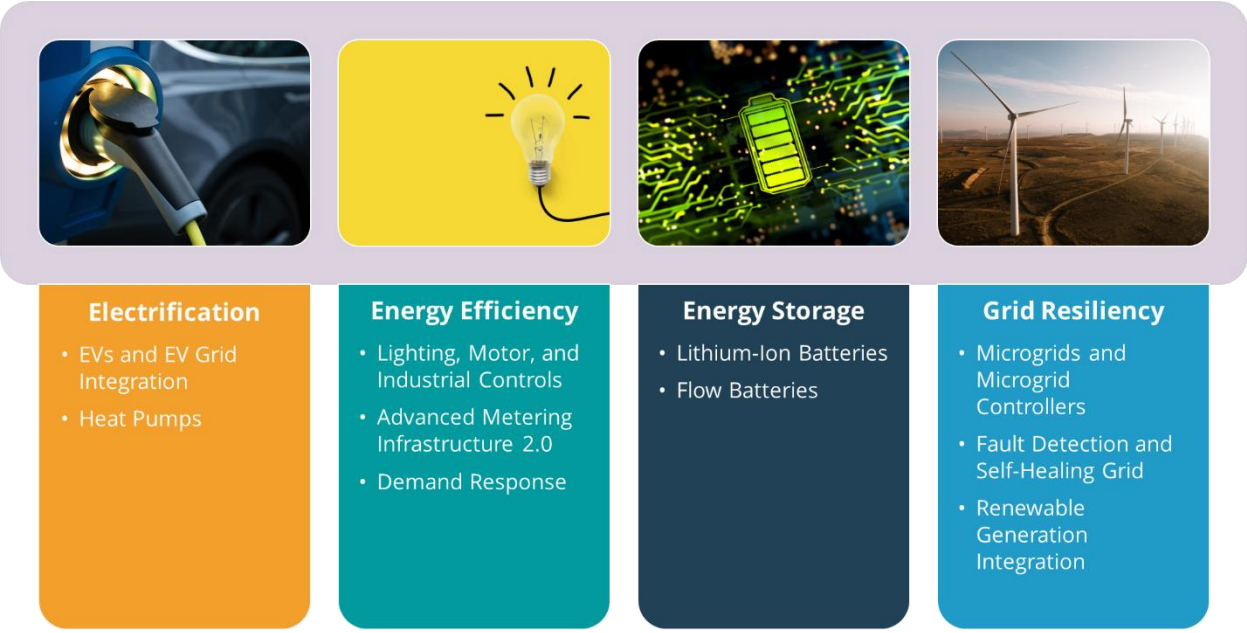
In many respects, the energy transition is still in its infancy, presenting a landscape ripe with both challenges and opportunities. Despite the growing adoption of renewables and the technological leaps in energy efficiency and storage, fossil fuels remain the backbone of the energy system. Moreover, electricity’s share of final energy consumption has hardly budged over the past decade, indicating that even though electricity demand has ticked up, the demand for fossil-fuel energy in end-use applications has also risen. In the US, the transportation sector

is by far the least electrified, with less than 1% electrification, sharply below the electrification rates in the commercial, residential, and industrial sectors. This disparity not only signals the transportation sector's vast potential for electrification but also underscores the embryonic stage of the energy transition. Amid the push towards EVs, recent years have seen a mix of enthusiasm and resistance. After two boom years in 2021 and 2022, during which eager buyers scooped up vehicles, EV sales growth softened in the second half of 2023, leading some automakers to scale back on EV-related investments. Nonetheless, EVs are still projected to grow as a share of total vehicle sales, and the electroindustry will continue to play a vital role in ensuring that EVs and EV charging infrastructure are available, safe, and efficient for consumers, suggesting a promising path forward.

Buttressing the energy transition is a substantial amount of public funding, along with evolving and sometimes complex rules and regulations. Between the Infrastructure Investment and Jobs Act (IIJA), the Inflation Reduction Act (IRA), and the CHIPS and Science Act, approximately $1.1 trillion has been made available to drive the energy transition over the next five to ten years. Additionally, the US government has implemented numerous key goals, mandates, and regulations that are expected to advance the energy transition. However, some policies aimed at bolstering domestic production capabilities, such as S.301 tariffs and the Buy American provisions in the IIJA, might be inadvertently hampering progress by leading to shortages of crucial components and creating ambiguity regarding the eligibility of finished products for federal funding. Since China is a major supplier of components and raw materials that are essential for energy-transition technologies, S.301 tariffs increase the expenses associated with electrifying end uses and developing renewable energy infrastructure in the US. This, in turn, makes the transition away from fossil fuels more costly.

While not all-encompassing, NEMA has narrowed down a list of 10 technologies that are crucial for driving the energy transition. Figure 8.1 below presents the 10 identified technologies, grouped into four categories: electrification, energy efficiency, energy storage, and grid resiliency. Each technology will be covered in detail in its respective section.

Figure 8.1: Ten Technologies Accelerating the Energy Transition & Hardening the Grid



I. Electrification

EVs and EV Grid Integration

Overview: EVs pose significant potential for producing tangible energy transition progress. Despite EV sales growth in recent years, the transportation sector remains overwhelmingly dominated by fossil-fuel powered engines, especially in heavy trucks, ships, and aviation.

The electroindustry manufactures numerous key products integral to the EV ecosystem, including, but not limited to:

- Electric motors
- Battery packs
- Power electronics (e.g., inverters, converters, and controllers)
- EV Supply Equipment (EVSE)
- Connectors and cables
- Power distribution equipment (i.e., switchgear, panelboards, transformers, etc. to distribute power safely to charging stations)

- Energy storage systems
- Smart chargers and management systems

EV Factoids:

- US EV sales grew 40% in 2023, capturing 9.5% of the total sales share
- EVs on US roads are expected to surpass 26 million by 2030
- US EV charging points are projected to reach 920,000 by 2030, up from 130,000 today
- Annual US electricity demand for EV charging is forecasted to grow from 11 billion kWh now to 230 billion kWh in 2030
- The EV market is projected to grow 30% annually over the next decade
- The US critical mineral supply must rise by 1/3 to meet EV battery demand in 2030
- EVs are expected to comprise 4% of final electricity demand by 2030
- The US transportation sector is expected to be 29% electrified by 2050

Heat Pumps

Overview: Heat pumps are a pivotal technology in the energy transition, offering a highly efficient, electrified solution to meet both heating and cooling needs, while also playing a significant role in reducing carbon emissions. These systems work by transferring heat from the external environment into buildings during colder seasons, and reversing the process to provide cooling in warmer seasons. The dual functionality of heat pumps is one of their key advantages, enabling year-round temperature control with a single system. Heat pumps are also remarkably energy efficient, typically delivering 3 – 4x more energy than electricity consumed. Electricity fuels the heating and cooling cycles by powering the compressor and the fans or pumps that circulate materials through the system.

Heat Pump Factoids:

- Heat pump capacity is expected to nearly triple by 2030
- Heat pumps' share of building heating needs is projected to double to 20% by 2030
- Global heat pump employment is forecasted to grow 3x to over 1.3 million by 2030

- In 2022, heat pump sales increased by 11% globally
- Heat pumps bring annual energy savings of around $300/year
- Small, energy efficient heat pumps reduce peak energy demand growth
- Heat pumps reduce GHG emissions by at least 20% compared with a gas boiler
- Heat pumps are projected to comprise ½ of global reductions in fossil-fuel use for heating in buildings by 2030

II. Energy Efficiency

Lighting, Motors, and Industrial Controls

Overview: Lighting, motors, and industrial controls play a crucial role in driving the energy transition by bolstering efficiency and promoting sustainability. Lighting controls, such as dimmers, motion sensors, and smart systems, are optimizing lighting use, considerably reducing energy consumption and environmental impact. Motor controls, including variable frequency drives and soft starters, enhance the efficiency of electric motors by tailoring operation to demand, which not only saves energy but extends equipment life. Industrial controls help to fine-tune industrial operations by integrating automation, process controls, and monitoring tools. Collectively, these control technologies play a critical role in reducing energy usage and GHG emissions.

Energy Efficiency/Controls Factoids:

- Past energy efficiency actions lowered global energy bills by 15% in 2022, reflecting 24 EJ of avoided energy demand
- Global energy efficiency investment rose 16% in 2022, and is expected to increase a further 50% from 2026 to 2030
- Lighting control systems have a cost savings potential of 45%-80% in warehouse or manufacturing areas
- A 1% increase in motor efficiency for every motor in North America would spell $1.4 billion in cost savings annually
- According to the International Energy Agency, "The accumulated effects of efficiency have been so large that final energy demand for IEA countries as a group has remained

relatively steady at about 140 EJ for 20 years. This was achieved even as the economies of the group grew by 40% in real terms and overall economic structure only slightly shifted towards less energy-intensive activities."

Advanced Metering Infrastructure 2.0

Overview: Advanced Metering Infrastructure (AMI) 2.0 represents a significant leap forward in the evolution of smart metering and energy management systems. AMI 2.0 enhances the capabilities of smart metering by incorporating two-way communication, improved data analytics, and integration with distributed energy resources (DER), facilitating a more interactive and efficient energy management system. This next-generation infrastructure supports the seamless integration of renewables and EVs, offering dynamic pricing and demand response programs. By providing detailed insights into energy usage and enabling a more resilient grid, AMI 2.0 is key in advancing the energy transition towards sustainability, empowering consumers and utilities to optimize energy consumption and contribute to a more flexible energy ecosystem.

AMI 2.0 Features:

- Enhanced cybersecurity to offset increased exposure in software-centric grid systems
- Supports advanced technologies like cloud, microgrid, and intelligent automation
- Distributed intelligence improves operational efficiency and enables fluid data aggregation
- Smart grid enablement helps address difficult-to-reach areas
- Real-time communications network facilitates rapid data exchange
- Improved customer engagement through pricing and data-driven insights
- Edge computing quickens response times and saves bandwidth
- DER enablement improves grid demand-side flexibility

Demand Response

Overview: Demand response is a critical energy management strategy that encourages consumers to adjust their power usage during peak demand periods in response to price signals or incentives from utility providers. By temporarily reducing or shifting energy consumption in response to grid needs or electricity market prices, demand response helps balance supply and demand, enhances grid reliability, and mitigates the need for expensive, carbon-intensive peak power plants. This not only contributes to a more efficient and sustainable energy system but also allows consumers to play a significant role in the energy transition by actively managing their energy use, leading to cost savings and a reduction in overall carbon emissions. Demand response programs leverage smart technologies and advanced metering infrastructure to enable this interactive grid management approach, marking a shift towards more dynamic and participatory energy networks.

Demand Response Factoids:

- U.S. demand response program participation totaled 10.3 million in 2022
- U.S. demand response programs resulted in over 13,800 MW of peak demand energy savings in 2022
- In 2022, U.S. demand response programs provided nearly $1.15 billion in customer incentives
- The residential sector accounts for 97% of customers, with average energy savings of 100 KWh and $26 in customer payout annually
- The commercial sector accounts for 2.3% of customers, with an average financial incentive of $1,220 annually
- Commercial customers saved on average 538 KWh of energy in 2022
- Industrial customers comprise less than 1% of total customers enrolled
- Industrial customers have an average financial incentive of over $15,000 annually

III. Energy Storage

Lithium-Ion Batteries

Overview: Lithium-ion batteries represent a cornerstone energy-transition technology. With their high energy density and rechargeability, lithium-ion batteries are vital in enabling the use of EVs, storing renewable energy, and powering portable electronics. They address the intermittency of renewables, ensuring a stable energy supply and supporting the shift towards a low-carbon future. Advances in capacity, safety, and recycling of these batteries are enhancing their role in the energy transition, making them crucial for reducing reliance on fossil fuels and promoting sustainability.

Lithium-Ion Battery Factoids:

- Lithium-ion battery pack costs have dropped by more than 80% over the past decade
- There are currently 7.8 GW of battery storage operating in the U.S., and another 20.8 GW expected over the next two years
- The global energy storage market is projected to grow 15-fold by 2030
- Deployments of energy storage capacity are expected to grow about 200 GW by 2050

Flow Batteries

Overview: Flow batteries, a type of rechargeable battery where energy is stored in liquid electrolyte solutions, offer a promising answer for large-scale energy storage applications. Distinguished by their scalability, long cycle life, and quick response times, flow batteries excel in stabilizing the grid, integrating renewables, and providing long-duration storage. Their ability to independently scale energy capacity and power output makes them particularly suited for applications requiring extended storage periods, such as bridging gaps in renewable generation or enhancing grid resilience. As the demand for sustainable and reliable energy storage solutions grows, flow batteries are increasingly recognized for their potential to support a transition to a more sustainable and efficient energy infrastructure.

Flow Battery Factoids:

- Flow batteries are electrochemical devices ideal for large-scale energy storage applications like utilities and microgrids
- Flow batteries can be cycled daily for up to 30 years, nearly 4x the life span of lithium-ion batteries
- Flow batteries have up to a 40% lower levelized cost of storage than lithium-ion batteries
- Flow batteries are larger and have less power density than lithium-ion batteries, making them ideal for long, consistent energy delivery
- In September 2021, the U.S. Department of Energy (DOE) announced nearly $18 million in funding for four R&D projects to scale up American manufacturing of flow battery and long-duration storage systems

IV. Grid Resiliency

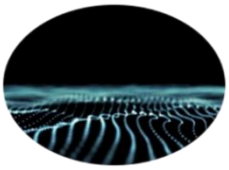
Microgrids and Microgrid Controllers

Overview: Microgrids, underpinned by advanced controllers, serve as self-sufficient energy networks that can disconnect from the main grid to operate independently. Microgrids empower communities, campuses, and businesses to manage their own energy resources, including renewable energy, storage, and conventional generators, with unparalleled efficiency and reliability. Microgrid controllers manage these transitions and energy flows, ensuring stability and continuous supply, thus providing essential support in outage situations. This capability positions microgrids as key to a resilient, decentralized, and sustainable energy framework, enhancing security and promoting diverse energy integration.

Microgrid Factoids:

- Microgrids can operate in grid-connected or island mode
- There are nearly 700 operational US microgrids in the US
- Microgrids provide estimated net operational benefits of $260,000/year per 10-MW investment
- Microgrid costs range from $2-4 million/MW depending on market segment

Fault Detection and Self-Healing Grid



Overview: Fault detection and self-healing grid technologies are transforming the resilience and efficiency of electrical grids by swiftly identifying and isolating faults, then rerouting power to minimize disruption. These smart systems leverage advanced sensors, analytics, and automated controls to detect issues in real-time, reducing outage times and enhancing grid stability. By enabling grids to recover automatically from faults, these technologies not only improve service reliability but also support the integration of renewables by managing their variability and distributed nature. Crucial for maintaining an uninterrupted power supply, these technologies are pivotal in an increasingly complex and renewable-dominant energy landscape.

Fault Detection and Self-Healing Grid Factoids:

- Fault location, isolation, and service restoration (FLISR) technologies are key for grid resiliency
- FLISR technologies encompass automated feed switches and reclosers, line monitors, communication networks, and DMS, OMS, & SCADA systems
- FLISR technologies reduce the number of customers interrupted by up to 45% for an outage event
- FLISR technologies reduce the customer minutes of interruption by up to 51% for an outage event

Renewable Generation Integration

Overview: Renewable generation integration, facilitated by smart inverters, is key to a sustainable energy transition, enabling the seamless incorporation of solar, wind, and other renewable resources into the grid. Smart inverters play a pivotal role by converting the variable direct current (DC) output of renewable energy sources into the stable alternating current (AC) required by the grid, while also managing voltage and frequency, enhancing grid stability. Additionally, these advanced inverters support grid services such as voltage regulation, reactive power control, and dynamic response to grid disturbances, ensuring reliability amidst the variability of renewable generation. Inverters are essential for maximizing the potential of

renewables, promoting a cleaner energy mix, and moving towards a more flexible, resilient, and sustainable energy system.

Renewable Generation Integration Factoids:

- Energy generation from renewables is expected to grow 150% over the next decade
- Centralized utility-scale renewables are 5-7 times less expensive than distributed generation renewables
- Smart inverters convert DC electricity from renewables to grid-compatible AC power and provide grid services
- Smart inverters provide voltage and frequency regulation, ride-through, dynamic current injection, and anti-islanding
- According to McKinsey & Company, "Renewables are projected to account for more than 30% of the global investments in the next 15 years."

V. Energy Transition Map

NEMA has developed an Energy Transition Map to model the appearance and dynamics of a modern, electrified energy system, pinpointing both accelerators and challenges to progress. This map encompasses several critical nodes: generation, transmission, distribution, and end-use, the latter of which spans the residential, commercial, industrial, and transportation sectors. Figure 8.2 below is the map. Each node is discussed in its designated section, accompanied by identified accelerators and challenges.

Figure 8.2: NEMA's Energy Transition Map

Generation

Overview: Clean, intermittent electricity generation plays a crucial role in the energy transition. The shift from fossil fuels to renewable sources, such as wind, solar, and hydro, is essential for reducing carbon emissions. This transition involves adopting technologies that can efficiently harness renewable energy, including photovoltaic cells, wind turbines, and hydroelectric power plants. Hydrogen fuel represents another alternative energy source that can help industries reduce emissions in sectors that cannot immediately electrify, such as aviation, steel, rail, and chemicals. While renewables and hydrogen are gaining prominence in the energy mix, baseload generation—which provides grid electricity to meet around-the-clock power needs—will continue to be dominated largely by coal-fired and natural gas plants near-term.

Accelerators:

- Federal funding of $369 B for clean generation and $65 B for grid reliability
- Programs encouraging energy management tech in new buildings

Challenges:

- Long queue to connect to grid
- Siting/permitting constraints
- Land availability
- Intermittent generation impact on grid reliability
- Affordability and policy disputes

Transmission

Overview: For the energy transition to gain full momentum, it is expected that a significant amount of transmission infrastructure buildout is needed. The electric grid, a vestige of the previous century, is characterized by aging infrastructure. According to the DOE's National Transmission Needs Study (2023), achieving full clean energy potential in the US requires more than doubling the existing regional transmission capacity and expanding existing interregional transmission capacity by more than fivefold by 2035. An NREL study estimates that transmission capacity will need to grow by 2x by 2030 and potentially triple by 2050 (Denholm et al., 2022). To prevent region-wide blackouts and ensure consistent, equitable access to electricity as the energy transition progresses, updated transmission infrastructure and advanced transmission technologies—such as dynamic line rating, topology optimization controls, and power flow controllers—are needed.

Accelerators:

- Federal funding of $2.5 B for high-capacity transmission projects
- Energy improvements in rural/remote areas

Challenges:

- Siting and permitting
- Aging infrastructure
- High infrastructure and technology costs
- System congestion

Distribution

Overview: Distribution plays a crucial role in facilitating the energy transition by serving as the final link in delivering electrical power to end consumers. Distribution systems include step-down transformers, which reduce the high-voltage power from transmission lines, above ground and underground transmission lines that move power around the area, and a final network of lower voltage lines that connect each user to the grid. Furthermore, distribution automation technologies, smart meters, and DER are key technologies in the distribution space, enhancing flexibility and resilience.

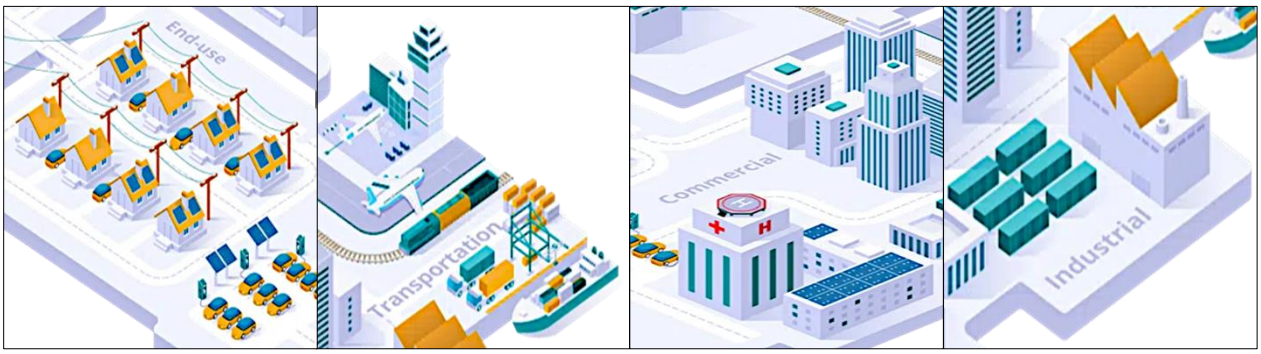
Accelerators:

- Federal funding of $13 B for grid hardening resiliency technologies
- Federal/state programs supporting a smart, two-way local distribution system
- Robust demand reduction markets

Challenges:

- Scale of the challenge
- Balkanization
- Siting and permitting issues
- Increased frequency and intensity of weather events from climate change

End-Use



Residential Transportation Commercial Industrial

Overview: End-use electrification is a critical component of the energy transition because it leads to reduced GHG emissions at the point of final energy consumption across various sectors, including transportation, industry, and buildings. Electric light-duty vehicles and heat pumps are two technologies at the forefront of the energy transition. However, others, such as electric stoves, electric water heaters, and e-bikes and e-scooters, are also important. Each end-use sector is at a different stage of electrification. In terms of electricity sales to ultimate customers over total end-use energy consumed by sector, the two most electrified sectors are commercial and residential, at 49% and 43% electrification, respectively. Conversely, the industrial (13%) and transportation (<1%) sectors exhibit low levels of electrification but also hold promise for significant improvement through the electrification of low-hanging fruit. Another integral component is grid-scale energy storage, which is likely to enhance industrial electrification and facilitate renewables adoption. Overall, while clean generation often captures the spotlight, end-use electrification is equally crucial, promising significant prospects for the electroindustry.

Accelerators:

- Federal funding includes $369 billion as part of the IRA, alongside allocations such as $7.5 billion for EV infrastructure, $2 billion for EV semiconductors, $9 billion towards residential energy efficiency and electrification financial assistance programs, and $505 million for developing long-duration energy storage demonstrations

- Initiatives to modernize building codes and energy markets, integrating automated demand reduction in homes and offices, coupled with initiatives for consumer education and full market participation
- Establishment of city and state objectives for achieving net-zero emissions in building construction
- Funding for large-engine solution development, and the extension of the Smart Grid to the transportation system

Challenges:

- Infrastructure and Market Integration: Lack of demand response automation infrastructure, difficulties in integrating with wholesale energy markets, inadequate incentives for demand reduction, and slow commercialization of technological advancements
- Technological and Economic Barriers: Higher costs of industrial manufacturing, constraints on capital and critical minerals, uncertain support from utilities (especially regarding batteries and microgrids), and slow turnover of existing technologies, such as gas appliances
- Transportation Electrification Headwinds: Lack of EV charging stations, charging capacity constraints, and limited options to electrify freight transport

As the foregoing sections have shown, the energy transition holds substantial promise, especially with rapidly accelerating technology and policy support, but also presents many challenges. A coordinated approach between the public and private sectors is essential to allocate resources appropriately and advance the energy transition in a sustainable, cost-effective, and secure manner, without compromising living standards. Expanding public awareness of available clean energy technologies and providing appropriate incentives can further accelerate the energy transition. Naturally, the electroindustry is at the epicenter of this energy transition. By investing significantly in electrification, the electroindustry is creating a framework to ensure the technology and scalability needed for a reliable energy transition.

Conclusion

The preceding chapters offer an in-depth analysis of the electroindustry, highlighting its critical importance to the economy and its central role in driving the energy transition. Energy efficiency, grid resilience, and electrification are cornerstones of the energy transition—as well as cornerstones of the electroindustry. However, the electroindustry is facing turbulent times, confronted with an unusual mix of opportunities and challenges, with the future of the energy transition at a crossroads amid economic, political, and societal opposition. Predictions of future electricity demand could not be more varied, even among the most reliable sources. Nonetheless, the electroindustry is investing to deliver a more efficient, reliable, and resilient energy sector, adding more than $12 billion in domestic capacity since 2020 to help secure vital future US electrical infrastructure.

Despite shifting landscapes, the electroindustry remains on stable footing, experiencing historically strong growth in recent years, even with supply-chain constraints. Growth drivers include booming sectors like data centers, energy storage, and manufacturing construction, all fueling robust demand for electrical equipment. These positive trends in the electroindustry will help to support higher living standards.

References

Armstrong, L. (2017, August 4). *Industrial Lighting Controls eGuide*. Acuity Brands. Retrieved from https://insights.acuitybrands.com/industrial/industrial-lighting-controls-eguide

Blair, Nate, Chad Augustine, Wesley Cole, et al. (2022). *Storage Futures Study: Key Learnings for the Coming Decades*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-81779. https://www.nrel.gov/docs/fy22osti/81779.pdf

Bloomberg NEF. (2022, October 12). *Global Energy Storage Market to Grow 15-Fold by 2030*. Retrieved from https://about.bnef.com/blog/global-energy-storage-market-to-grow-15-fold-by-2030/

Chen, J., & Worden, K. (2018, July 2). *Lost in Transmission: World's Biggest Machine Needs Update*. Natural Resources Defense Council (NRDC). Retrieved from https://www.nrdc.org/experts/jennifer-chen/lost-transmission-worlds-biggest-machine-needs-update

Cleary, K., & Palmer, K. (2022, March 24). *Renewables 101: Integrating Renewable Energy Resources into the Grid*. Retrieved from https://www.rff.org/publications/explainers/renewables-101-integrating-renewables/

Constantinides, S. (2018, July 18). *The Changing Landscape of Electric Motor Efficiency Standards*. Magnetics Business & Technology. Retrieved from https://magneticsmag.com/the-changing-landscape-of-electric-motor-efficiency-standards/

Deloitte. (n.d.). *Enabling the clean energy transition with next-gen advanced metering infrastructure*. Retrieved from https://www2.deloitte.com/us/en/pages/energy-and-resources/articles/next-gen-advanced-metering-infrastructure.html

Denholm, Paul, Patrick Brown, Wesley Cole, et al. (2022). *Examining Supply-Side Options to Achieve 100% Clean Electricity by 2035*. Golden, CO: National Renewable Energy Laboratory. Retrieved from https://www.nrel.gov/docs/fy22osti/81644.pdf

Devenish, B. (2021, March 23). *The Evolution of Energy Efficient Lighting*. Hampshire Light. Retrieved from https://www.hampshirelight.net/blog/the-evolution-of-energy-efficient-lighting

Edison Electric Institute (EEI). (2022, June 20). *EEI Projects 26.4 Million Electric Vehicles Will Be on U.S. Roads in 2030*. Retrieved from https://www.eei.org/News/news/All/eei-projects-26-million-electric-vehicles-will-be-on-us-roads-in-2030

Giraldez, J., Flores-Espino, F., et al. (2018, October). *Phase 1 Microgrid Cost Study: Data Collection and Analysis of Microgrid Costs in the United States*. NREL. Retrieved from https://www.nrel.gov/docs/fy19osti/67821.pdf

Gregus, N. (2021, December 13). *5 Key Differences Between Flow Batteries and Lithium Ion Batteries*. Energy Link. Retrieved from https://goenergylink.com/blog/differences-between-flow-batteries-and-lithium-ion/

IMPLAN Model. (2024). Data, using inputs provided by the user and IMPLAN Group LLC, IMPLAN System (data and software). Retrieved from https://implan.com/

International Energy Agency (IEA). (2022, December). *Energy Efficiency 2022*. Retrieved from https://www.iea.org/reports/energy-efficiency-2022

International Energy Agency (IEA). (2022, May). *Global EV Outlook 2022*. Retrieved from https://www.iea.org/reports/global-ev-outlook-2022

International Energy Agency (IEA). (2023, April). *Global EV Outlook 2023*. Retrieved from https://www.iea.org/reports/global-ev-outlook-2023

International Energy Agency (IEA). *Global EV Data Explorer*. Retrieved from https://www.iea.org/data-and-statistics/data-tools/global-ev-data-explorer

International Energy Agency (IEA). (2022). *The Future of Heat Pumps*. Retrieved from https://www.iea.org/reports/the-future-of-heat-pumps

LampHQ. (n.d.). *All About Energy Efficiency And Efficacy of Modern LED Lighting*. Retrieved from https://lamphq.com/led-energy-efficiency/

Larson, A. (2021, May 27). *The Benefits Of Flow Batteries Over Lithium Ion*. Retrieved from https://www.powermag.com/the-benefits-of-flow-batteries-over-lithium-ion/

Lawrence Livermore National Laboratory (LLNL). (2022). *Estimated U.S. Energy Consumption in 2022: 100.3 Quads*. Retrieved from https://flowcharts.llnl.gov/sites/flowcharts/files/2023-10/US%20Energy%202022.png

Mai, Trieu, Paige Jadun, Jeffrey Logan, Colin McMillan, Matteo Muratori, Daniel Steinberg, Laura Vimmerstedt, Ryan Jones, Benjamin Haley, and Brent Nelson. (2018). *Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-71500. https://www.nrel.gov/docs/fy18osti/71500.pdf.

McKinsey & Company (2022, April 18). *Building the electric-vehicle charging infrastructure America needs*. Retrieved from https://www.mckinsey.com/industries/public-sector/our-insights/building-the-electric-vehicle-charging-infrastructure-america-needs#/

McKinsey & Company. (2022, April). *Global Energy Perspective 2022*. Retrieved from https://www.mckinsey.com/industries/oil-and-gas/our-insights/global-energy-perspective-2022

Monschauer, Y., Delmastro, C., Martinez-Gordon R., *Global heat pump sales continue double-digit growth*. IEA. Retrieved from https://www.iea.org/commentaries/global-heat-pump-sales-continue-double-digit-growth

NAICS Association. (n.d.). *NAICS & SIC Identification Tools*. Retrieved from https://www.naics.com/search/

National Renewable Energy Laboratory (NREL). (n.d.,) *Advanced Power Electronics and Smart Inverters*. Retrieved from https://www.nrel.gov/grid/power-electronics-inverters.html

NEMA. (n.d.). *Lamp Indices*. Retrieved from https://www.nema.org/analytics/lamp-indices

NEMA. (n.d.). *NEMA Premium Motors*. Retrieved from https://www.nema.org/directory/products/nema-premium-motors

Office of Energy Efficiency & Renewable Energy. (2021, September 23). *Department of Energy Invests $17.9 Million in Long-Duration Energy Storage Technologies*. Retrieved from https://www.energy.gov/eere/articles/department-energy-invests-179-million-long-duration-energy-storage-technologies

Parag, Y., & Ainspan, M (2019, October). *Sustainable microgrids: Economic, environmental and social costs and benefits of microgrid deployment*. Energy for Sustainable Development. Volume 52, pages 72-81. Retrieved from https://doi.org/10.1016/j.esd.2019.07.003

S&P Global Market Intelligence. (n.d.). *U.S. Macroeconomic Model*. Retrieved from https://www.spglobal.com/marketintelligence/en/

Sevilla-Macip, J., & Marris, J. (2023, October). *Nearshoring to Mexico: National trends and regional disparities*. Retrieved from https://www.spglobal.com/marketintelligence/en/news-insights/blog/nearshoring-to-mexico-national-trends-and-regional-disparities

The Efficiency of AC Motors: Past, Present, and Future. Emotors Direct. (2022, August 15). Retrieved from https://www.emotorsdirect.ca/knowledge-center/article/the-future-of-ac-motors-advances-in-energy-efficiency

The White House. (2023, February 15). *Fact Sheet: Biden-Harris Administration Announces New Standards and Major Progress for a Made-in-America National Network of Electric Vehicle Chargers*. Retrieved from https://www.whitehouse.gov/briefing-room/statements-releases/2023/02/15/fact-sheet-biden-harris-administration-announces-new-standards-and-major-progress-for-a-made-in-america-national-network-of-electric-vehicle-chargers/

U.S. Bureau of Labor Statistics (2022). *Quarterly Census of Employment and Wages*. Retrieved from https://www.bls.gov/cew/home.htm

U.S. Census Bureau. (2022). *2021 Annual Survey of Manufactures* [Data set]. Retrieved from https://www.census.gov/programs-surveys/asm.html

U.S. Census Bureau. (2024). *Value of Construction Put in Place Survey (VIP)*. Retrieved from https://www.census.gov/construction/c30/c30index.html

U.S. Census Bureau. (n.d.). *USA Trade Online*. Retrieved from https://usatrade.census.gov/

U.S. Department of Energy (DOE). (2014, December). *Fault Location, Isolation, and Service Restoration Technologies Reduce Outage Impact and Duration*. Retrieved from https://www.smartgrid.gov/files/documents/B5_draft_report-12-18-2014.pdf

U.S. Department of Energy (DOE). (n.d.). *Microgrids Fact Sheet*. Retrieved from https://www.energy.gov/sites/default/files/2021-03/Microgrids_Fact_Sheet_01.pdf

U.S. Department of Energy (DOE). (2023, October 30). *National Transmission Needs Study*. Retrieved from https://www.energy.gov/gdo/national-transmission-needs-study

U.S. Department of Energy (DOE). (2012, November). *When to Purchase Premium Efficiency Motors*. Energy Tips: Motor Systems. Retrieved from https://www.energy.gov/sites/prod/files/2014/04/f15/whentopurchase_nema_motor_systemts1.pdf

U.S. Energy Information Administration (EIA). (2023, October 5). *Annual Electric Power Industry Report, Form EIA-861 detailed data files*. Retrieved from https://www.eia.gov/electricity/data/eia861/

U.S. Energy Information Administration (EIA). (2021). Annual Energy Outlook 2021. Retrieved from https://www.eia.gov/outlooks/aeo/tables_side.php

U.S. Energy Information Administration (EIA). (2023, March 16). *Annual Energy Outlook 2023*. Retrieved from https://www.eia.gov/outlooks/aeo/

U.S. Energy Information Administration (EIA). (2022, February). *Electric Power Monthly*. Retrieved from https://www.eia.gov/electricity/monthly/

U.S. Energy Information Administration (EIA). (2022, January). *Monthly Energy Review*, Table 7.2a. Retrieved from https://www.eia.gov/totalenergy/data/monthly/

U.S. Energy Information Administration (EIA). (2022, December 8). *U.S. battery storage capacity will increase significantly by 2025*. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=54939

U.S. Environmental Protection Agency (EPA). (2022, March 2). *Electricity Customers*. Retrieved from https://www.epa.gov/energy/electricity-customers

Woodward, M., Hamilton, J., & Walton, B. (2020, July 28). *Electric Vehicles: Setting a Course for 2030. Deloitte*. Retrieved from https://www2.deloitte.com/us/en/insights/focus/future-of-mobility/electric-vehicle-trends-2030.html