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Reshoring and Resiliency in a Pandemic World

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Introduction

From the Rust Belt to the White House, policymakers, manufacturers, and consumers are debating the merits of reshoring, nearshoring, and building more resilient supply chains.[1] The previous administration maintained a sharp focus on strengthening manufacturing in the United States through trade remedies, tariff protection, and reshoring measures. President Joe Biden has largely followed suit, maintaining many of the previous administration's trade policies while outlining his own administration's commitment to "Buy American" and build more resilient supply chains.[2]

In the years between World War I and World War II, the rise of nationalist ideologies and crushing economic conditions ushered in an era of trade protectionism. In the interwar years, trade liberalization that had accelerated through 1913 essentially halted, dismantling previously established trading networks. However, these protectionist dynamics shifted with the signing of the Reciprocal Trade Act of 1934, which institutionalized tariff reduction reforms.[3] Then, the 1944 Bretton Woods Agreement at the end of World War II laid the groundwork for the postwar economic world through the establishment of the World Bank, the International Monetary Fund, and eventually the General Agreement on Tariffs and Trade and its successor organization, the World Trade Organization, which was intended to serve as the global promoter of trade liberalization. During this time, the world trading system witnessed a reduction in tariffs and a push toward regional and multilateral trade agreements. With newly realized access to foreign markets, multinational firms—especially those in the manufacturing sector—initiated a trend of offshoring, which allowed firms to pursue lower costs abroad and achieve higher productivity gains.

As trade liberalization expanded, companies began to reexamine their production processes and disaggregate them in order to take advantage of lower relative prices and high productivity abroad in a bid to reduce the overall costs of goods production. Significant declines in transportation and

communication costs were instrumental in this development. They enabled companies to develop supply chains that take advantage of low costs around the world to produce parts and components in different locations and then assemble them in a third location. International companies, particularly within the manufacturing sector, benefitted from decreased production costs and cheaper labor, but not without a cost to U.S. workers. Following a 30-year trend of offshoring, some firms have begun renationalizing their production chains, particularly since the 2008 recession. Meanwhile, the effects of globalization on manufacturing capacity and the U.S. trade deficit have grown to play a more prominent role in public discourse.[4]

The Covid-19 pandemic caused unique supply chain challenges and demand shocks for nearly every industry. Quarantines and border closures constricted imports from foreign producers, and manufacturers faced severe material and labor shortages, lengthy manufacturing delays, and decreases in consumer demand. As this daunting confluence of factors was exposed, policymakers began to sound alarm bells and warn that existing supply chains would be unable to handle the bottlenecks in production. In response, two different approaches to supply chains have emerged: resiliency and reshoring

Supply chain resiliency is defined as the capacity for a supply chain to resist and respond to disruptions, minimizing the time needed to recover operational capacity. In other words, resiliency measures a supply chain's ability to rebound to its pre-disruption production capacity. Reshoring, on the other hand, occurs when suppliers reduce their dependence on global supply chains by moving production within domestic borders.

These pandemic-induced dynamics have complicated industries' responses to supply chain issues. Should supply chains be built for resiliency or efficiency? What are the trade-offs between the two approaches? How are firms approaching supply chains? To answer these questions, this report conducts two case studies in increasingly critical industries: transformers and heating, ventilation, and cooling systems (HVACs). This report assesses how these industries have been affected by the pandemic and how they have responded, particularly whether firms have chosen to embrace resiliency or pursue reshoring. This research is informed by interviews with firms directly impacted by the pandemic and presents broader themes in the ongoing debate over how to rethink supply chains in a pandemic world.

1

Resiliency, Reshoring, and Nearshoring

As global value chains in the manufacturing sector became increasingly complex, debates began to arise over whether firms should prioritize resiliency or efficiency. This debate intensified as the Covid-19 pandemic upended supply chains across the manufacturing sector, highlighting clear vulnerabilities of many vital industries. Now, in a post-pandemic era, firms must grapple with differing approaches to supply chain management, most notably employing strategies of resilience, reshoring, or nearshoring.

DEFINING A STRATEGY OF RESILIENCE
Resiliency is a short-term effort within a firm's control to respond to sudden shocks. Depending on internal analyses or stress tests, firms can determine the most efficient way to invest their resources.

EXAMPLE
During the pandemic, the HVAC industry adopted digital tools—including the use of artificial intelligence (AI) technology—to facilitate consumer access to products.

BENEFITS	DRAWBACKS
This targeted approach gives firms the ability to reduce initial costs while retaining high output and worker capabilities in the near term. Proper resilience development involves redundancy that can provide different avenues to help mitigate sudden shocks, whether through increasing the number of suppliers, utilizing different risk assessments, or diversifying transportation methods.	The question remains whether resiliency can be utilized as a long-term strategy without sacrificing overall supply chain efficiency.[5] By sacrificing efficiency, the lower initial implementation cost could result in a long-term increase in costs.

DEFINING A STRATEGY OF RESHORING

Reshoring refers to efforts by firms to renationalize their production chains and decrease their reliance of foreign manufacturing capabilities.

EXAMPLE

In 2014, Universal Plastics reshored production from China to the United States due to factors including product quality and product differentiation in China.[6] One reason that reshoring to the United States became more attractive for the company was that its U.S. business became more efficient and cost-effective due to the deployment of new technology and automation.

BENEFITS	DRAWBACKS
While reshoring supply chains involves a larger upfront investment from companies, the move eliminates dependencies on foreign producers, reducing certain risks while increasing the reliance on domestic supply chains. As a result, transportation costs are reduced as manufacturing moves closer to domestic consumers. Additionally, as the pandemic underscores, reshoring can mitigate supply chain disruptions resulting from government actions, such as lockdown or quarantine directives that constrain labor in foreign countries or border closures that prevent the import of necessary inputs.	Reshoring can complicate access to necessary manufacturing inputs, especially raw materials. For example, within the United States, only six aluminum producers remain in operation. As a result, industries that rely on significant aluminum inputs, such as the HVAC industry, may struggle to operate under and adapt to the United States' limited aluminum production capacity.[7] Furthermore, reshoring is often more expensive for firms due to higher costs of both labor and material inputs.

DEFINING A STRATEGY OF NEARSHORING

Nearshoring is a derivative of offshoring where business operations are relocated to a nearby country. The country chosen depends on either its proximity to the business's consumer market (e.g., opening a factory in Germany to sell goods to German consumers) or its participation within a regional agreement (e.g., shifting production to Mexico due to its cheaper labor force and participation in the U.S.-Mexico-Canada Agreement).

EXAMPLE

Los Angeles-based Motorcar Parts of America invested more than $30 million in a Mexican production facility to move manufacturing capacity from China and maintain a supply chain closer to its consumers in the United States.[8]

BENEFITS	DRAWBACKS
Nearshoring offers a more cost-effective method for supply chain management because of the lower transportation fees. It also offers some protection from content requirement policies and other supply chain infrastructure problems currently causing global bottlenecks.	Neighboring countries may not possess the same manufacturing bases and investment environments as the original foreign destination, thereby increasing costs or decreasing output for firms. For instance, U.S. companies seeking to relocate from China to Mexico must grapple with Mexico's manufacturing limitations and uncertain investment conditions.

These three general strategies represent different methods firms can employ to mitigate the constricting effects of shocks on supply chains. To assess the viability of these strategies, it is

important to study what actions companies have taken during the global pandemic. The following sections address the choices of the transformer and HVAC industries to either embrace resiliency or pursue reshoring—or to meet in the middle with nearshoring. Overall, firms interviewed for this project, both in the HVAC and transformer industries, rejected calls to reshore due to cost intensity and lack of feasibility, preferring strategies of resiliency and nearshoring instead.

Firms interviewed for this project, both in the HVAC and transformer industries, rejected calls to reshore due to cost intensity and lack of feasibility.

2

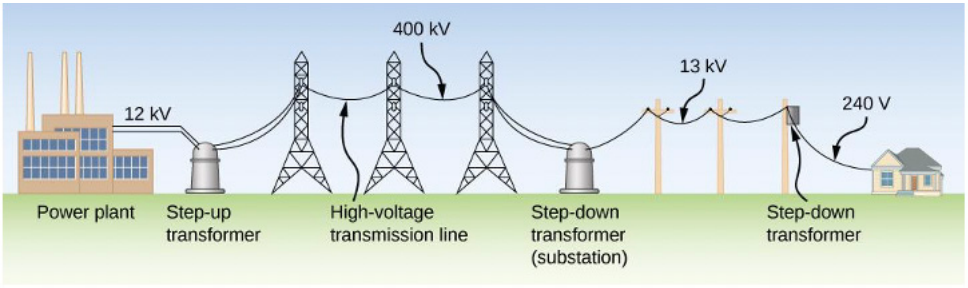
Industry Primers

Transformers and HVACs

What Are Transformers?

Power plant generators produce power by converting mechanical energy (usually a turbine powered by steam heated from burning fossil fuels) into electricity. The electricity is then transmitted from the power plant down transmission lines into the grid. Located along these lines are substations (which contain maintenance equipment and circuit breakers) and transformers. Transformers increase or decrease the outputted voltage level of the electrical current to match the voltage needed for the circuitry of electrical equipment or systems.

Step-up transformers increase the voltage of alternating current (AC) immediately after electricity generation at a power plant. This technology is necessary to attain a high voltage to minimize energy loss over many miles of power lines during power transmission. Step-up transformers can increase voltage to several hundred thousand volts. Step-down transformers, on the other hand, decrease the voltage of the AC to voltage levels usable by homes and businesses (usually 120 to 720 volts). Because low-volt current is more susceptible to energy loss along transmission lines, step-down transformers are usually located close to the end-use point of electricity.



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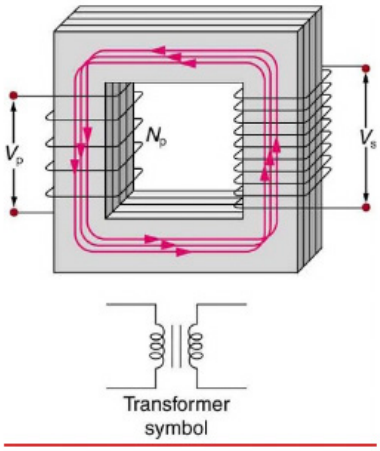

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Transformers consist of a steel core and two coils of wire: the primary winding and the secondary winding. The primary winding is the side of the transformer that takes power, and the secondary winding is the side that delivers power. Step-up transformers have more densely wound secondary winding, and the opposite is true for step-down transformers. The steel core can consist of Grain Oriented Electrical Steels (GOES), which are iron-silicon steel alloys that provide the low core loss and high permeability required for efficient and economical electrical transformers (this essentially lowers resistance for the current to flow). Energy conservation is critical, and GOES are designed to minimize heat loss at the core. GOES are used primarily to produce laminated cores for large and medium-sized power transformers, which handle high-voltage power from generation to the central source of distribution, and distribution transformers, which handle lower-voltage power from central points to the points of usage.

Transformers are one of the most critical components in delivering electricity to customers, without which the U.S. electric grid would not function.[9] In 2019, the global power transformer market size was valued at $27.7 billion, and it is expected to grow by 7.9 percent from 2020 to 2027 and reach $50.8 billion by 2027.[10] This growth is attributed to increasing electricity demands and the updating of aging transmission and distribution systems. The U.S. Energy Information Agency forecasts that electricity demand will increase by 2.8 percent in 2021 and by 1.0 percent in 2022.[11] At the same time, the nation's electric grid is rapidly aging. Analysts note that the average age of a transformer on the U.S.

electric grid is 35 years—near the end of its lifespan.[12] With the current push in the White House and among congressional Democrats toward clean energy infrastructure, some aging transformers are likely to be replaced by energy-efficient ones, advancing the agenda for clean electricity infrastructure.[13]

While transformers maintain a central function in the U.S. electric grid, their supply chain dynamics remain complex. Relying on an unhindered and affordable supply of raw materials, most notably steel and copper, and robust manufacturing capabilities, the transformer market was greatly impacted by raw material price increases and availability, manufacturing delays, and labor shortages during the Covid-19 pandemic. Thus, the transformer industry presents an interesting case study on how a vital U.S. industry approached supply chain resiliency and efficiency.

While transformers maintain a central function in the U.S. electric grid, their supply chain dynamics remain complex.

What Are HVACs?

HVAC systems regulate buildings' internal environments by maintaining temperature and air quality. HVAC products and components include furnaces, heat pumps, air conditioners, and duct work. Depending on whether the system is installed in residential or commercial buildings, the size and complexity of the HVAC system varies. In general, there are four primary HVAC systems: split systems, hybrid systems, duct-free systems, and packaged heating and air systems.

Split Systems: One of the most common types of HVAC systems, the split system, consists of both indoor and outdoor units. This system utilizes two main units, one for heating and the other for cooling. The cooling, outdoor component expels hot air with a fan, while refrigerants, compressors, and coils cool air inside the building. The indoor heating unit disperses hot air through ducts with either a fan or an evaporator. Traditional units also include a thermostat to measure the temperature, as well as purifiers or humidifiers.

Hybrid Systems: Like split systems, hybrid systems incorporate two different units. The hybrid heating system, however, reduces overall energy costs because users can switch between gas and electric heating systems. The rest of the system reflects that of the split system, including the traditional ducts and thermostats for temperature control.

Duct-Free Systems: A third type is duct-free systems. Basic ductless systems utilize one outdoor compressor and one indoor electronic unit. The two components are connected by refrigerant tubing and electric wiring through a single hole in the wall. The indoor units are generally wall-mounted to deliver the heated or cooled air directly to the specified area. The outdoor compressor pumps chemical refrigerant through the tube connected to the indoor unit coil. This process transforms the refrigerant into a gas while removing heat and humidity from the room as the air blows along the coil.[14] The cooler air is sent into the room, and the refrigerant gas returns to the

outdoor compressor, where it is converted back into its liquid form and its heat energy is released via the compressor's coil. The process is reversed to produce warmer air.

Unlike the previous two systems, this system requires a larger upfront cost but does not require the installation of ducts, which can be costly in terms of labor and components. The removal of ducts allows for independent unit temperature control for each individual room. Furthermore, the duct-free system is easier to install and more energy efficient, mitigating the higher cost. These systems require routine maintenance and cleaning.

Packaged Heating and Air Systems: Finally, the fourth type is packaged heating and air systems, which are typically installed in warmer climates. These less powerful HVAC systems use electricity as a power source and can both heat and cool a house with a more compact unit. These units are usually installed outside of the home and connect to ductwork via holes in the wall.

From individuals to commercial industries, HVAC systems are widely utilized across the country. In 2020, the global HVAC market was valued at $127.4 billion, and the industry is expected to grow by 5.9 percent from 2021 to 2028.[15] The U.S. market remains one of the largest consumers of HVAC systems, second only to China, and several pressures may increase demand for HVACs. Furthermore, as climate change and pandemics alike put pressure on temperature and air quality, HVACs stand to grow in importance. First, the demand for comfort among consumers places upward pressure on consumer demand. Second, technological innovation within the industry, including real-time monitoring and controlling of systems, facilitates better management of HVAC systems, thereby increasing consumer demand. Third, the unpredictability of weather conditions and poor air quality during fire season, both exacerbated by climate change, increase the need for heating and cooling systems as extreme weather events lead to an increased demand for both residential and commercial investment in HVAC systems. Fourth, although the pandemic had a temporary negative impact on the HVAC market, the pandemic is expected to provide the impetus for future market growth as businesses and consumers demand better indoor air quality.

With increased awareness about the importance of clean indoor air, especially as many consumers transitioned to work-from-home environments, consumers are investing in HVAC systems for air purification purposes, which is likely to create additional market opportunities for existing firms and potential entrants. The combination of the workplace transition, adverse weather conditions, and health concerns regarding airborne viruses has compelled consumers to seriously assess indoor air quality. In a survey commissioned by Lennox Industries, a leading HVAC manufacturer, three out of five homeowners now prioritize their home air quality, while 61 percent were willing to spend more money to improve quality, underscoring the growing importance of the HVAC market.[16]

3

Industry Supply Chains

Transformers

The main actors in the transformer supply chain are component suppliers, manufacturers, and distributors. The component suppliers provide the raw materials, which are then used by the manufacturers to build the transformers. Manufacturers often sell to electrical utilities directly or go through distributors which have well-established logistical networks in various regions. A report by *Transformers Magazine* provides insight into the unique features of power transformer supply chains.[17] First, the power transformer industry is a relatively low-output business, as only about 20,000 power transformers are produced each year. As a result, the market size for transformer inputs is relatively small, and nearshoring within the industry is easier than in other comparable industries. In 2019, U.S. transformer sales amounted to $4.42 billion. Major players in the North American transformer industry include General Electric, Siemens, and Mitsubishi, and utilities, such as Pacific Gas & Electric, are the primary sources of demand. The Commerce Department's Bureau of Industry and Security surveyed 36 domestic transformer manufacturing and power handling companies in the United States. The report found that these U.S. companies employed 15,238 people and that labor represented an average of 36 percent of the overall costs for the industry.[18]

Second, power transformers are almost always tailor-made for the needs of specific utility companies, meaning the ability of the transformer market to adapt quickly to changes is more constrained and less flexible. Therefore, transformers employ numerous, highly tailored specifications, and thus, manufacturers' ability to maintain a large stock is difficult. Moreover, transformer components suppliers must adapt to the needs of the manufacturers; this significantly increases pressure on the supply chain, as component suppliers cannot simply mass produce inputs. Complicating matters further, suppliers are generally smaller firms with a local or regional

presence, and only standard components, such as GOES, maintain an expansive international marketplace.

The order and fulfillment process is also highly complex within transformer supply chains. Manufacturers operate with an inability to accurately predict customer preferences and demand. When a utility company places an order for a transformer, the manufacturer must first complete the design and receive the utility company's approval before placing an order for components. If there are design changes—including after an initial design may be agreed to—production schedules can change significantly because the tailor-made nature of transformers requires a lengthy components procurement process. Most power transformers require about 50 to 100 component shipments from around the world, including steel from China and copper from South America. This process is often difficult to synchronize, making ad hoc procurement measures common.

Finally, about 70 percent of power transformers are purchased by utility companies, with purchases often made in bulk.[19] This gives utility companies exceptional leverage over manufacturers, often limiting manufacturing flexibility. The remaining 30 percent of power transformers are utilized in many other industries, including charging stations for electric vehicles, electronic devices, and commercial aviation.

HVACs

The HVAC ecosystem is diverse, ranging from air quality in hospitals to temperature control in private households. The U.S. HVAC market is valued at $15.16 billion, but most large manufacturers have either pursued international mergers and acquisitions or international partnerships to remain competitive globally.[20] The main actors in HVAC supply chains are material suppliers, manufacturers, distributors, and contractors. Suppliers provide raw components and the intermediate goods required for HVAC systems. Manufacturers then utilize these components to build specific HVAC systems. Within the U.S. market, prominent HVAC manufacturers include the Carrier Corporation, Daikin Industries, Emerson Electric, Mitsubishi Electric U.S., Johnson Controls International, Lennox International, and Trane Technologies.

Distributors are nodes that manufacturers use to reach their target audiences. These companies determine which products to keep in stock for contractors or branch offices, including the sales team on the ground. Distributors vary by region within the United States. Smaller distributors might only serve several cities, while larger corporations can distribute to several states. Contractors, perhaps the most visible players within the HVAC supply chain, install, repair, and service HVAC systems both in residential and commercial buildings. In 2019, 376,800 mechanics and installers were employed within the U.S. HVAC industry.[21] The Bureau of Labor Statistics' national estimate indicates that 344,020 mechanics and installers were employed in May 2020, demonstrating a sudden decrease as the pandemic worsened.

The HVAC industry is divided into three different end-user sales markets: residential HVAC systems, small commercial HVAC systems weighing less than 25 tons, and large commercial HVAC systems weighing more than 25 tons.[22] Manufacturers tend to focus on a particular market area, although some crossover occurs between residential HVAC and small commercial systems. Like the transformer industry, the HVAC industry is reliant on both copper and aluminum, and the aluminum supply chain itself is heavily dependent on imports. Due to the cost and complexity of bauxite mining and alumina alloy production, the United States does not have a competitive advantage when it comes to producing raw aluminum. It is significantly cheaper to import the bauxite mined elsewhere and send it to aluminum smelters in the United States for processing. In 2020, only 49 percent of aluminum smelters in the United States were operating at capacity, meaning new smelters would not need to be built in order to fulfill increased demands. However, the majority of bauxite is concentrated abroad—including 32 percent in Africa alone—and the United States does not have adequate domestic resources to meet demand.[23] Due to labor, energy, and transportation costs, it can be cheaper to produce the aluminum abroad and import it into the United States, meaning reshoring would represent a costly strategy for the industry, which would in turn drive up costs for the HVAC industry.

Supply chain pathways vary depending on the manufacturers and distributors' target markets. Residential HVAC manufacturers ship their products to a regional distribution center, which then sends the products to each of its branch locations. There, HVAC contractors retrieve the equipment as needed. The contractor installs the final product for the individual residential or commercial project. For the residential HVAC supply chain, product availability depends on the supply stock held by the regional distributors. High numbers of contractors and steep market competition result in significant market fragmentation.

4

Covid-19 Supply Chain Challenges

The HVAC and transformer industries faced similar supply chain issues at the onset and throughout the pandemic. Both were affected by changes in input and commodity pricing, supply chain bottlenecks, and, perhaps most importantly in both industries, acute labor shortages. While some of the causes of supply chain disruptions have leveled off, bottlenecks and labor shortages continue to affect the industry. Nevertheless, HVAC and transformer firms interviewed for this project tended to eschew strategies of reshoring, viewing it as a costlier and riskier alternative to supply chain resiliency.

Labor Shortages

Labor shortages resulted in supply chain disruptions throughout the HVAC and transformer industries. In the HVAC industry, to mitigate the loss due to lower revenues, workers were let go or furloughed during the early months of the pandemic. Some workers chose to leave the industry voluntarily to prevent exposure to Covid-19 when entering households, especially if known virus cases were present. Moreover, an industry representative claimed that enhanced unemployment insurance has made junior HVAC positions less competitive, as businesses are unable to offer similar wage benefits.[24] Overall, the available workforce has decreased significantly, slowing down installations and production.

The labor shortage within the HVAC industry is not a novel problem. Even before the pandemic, the dearth of technicians and mechanics had plagued the industry. Industry experts explained that the 2008 recession pushed workers out of the industry who have not returned, meaning that the pandemic has put more pressure on an already stressed industry. Similarly, an expert in the

transformer industry noted the difficulty in recruiting talent to join the firm's manufacturing facilities, an issue that has long plagued the industry and was only exacerbated by the pandemic.

Early labor shortages during the pandemic largely related to health concerns. However, these labor shortages continued after most people in the United States were vaccinated, and they have been ongoing for numerous reasons, including ongoing government financial support, widespread change throughout the national labor market in general, and an ongoing reluctance to return to work amid a new wave of variant infections. Labor shortages have also caused disruptions in transportation logistics, which has affected both the transformer and HVAC industries. Experts interviewed for this report explained ongoing difficulties in finding drivers to ship their products or work in their factories. A firm in the transformer industry interviewed for this report explained that the company had sought to nearshore production away from East Asia to Latin America largely because the labor pool was substantially larger and cheaper than in the United States and because transportation costs and vulnerability to supply chain disruptions were reduced compared to East Asia.

HVAC and transformer firms interviewed for this report preferred resiliency as a supply chain strategy but were also willing to engage in limited nearshoring under certain circumstances, such as ongoing shipping delays, labor shortage problems, and supply chain bottlenecks. One transformer firm interviewed for this project preferred to maintain ongoing business ties with Southeast Asia but found that nearshoring to Mexico insulated the firm against supply chain bottlenecks in Asia and labor supply shortages in the United States. However, while one firm with operations in Mexico had experienced supply chain disruptions due to a recent border closure, the firm regarded supply chain risks in Mexico as significantly reduced in the long term when compared with running operations from East Asia. In both the transformer and HVAC industries, firms interviewed expressed greater confidence in the business benefits of nearshoring rather than reshoring.

Reduced Access to Consumers

Although the HVAC and transformer industries faced similar supply chain issues, one supply chain concern was exclusive to the HVAC industry: customer access. As the world moved online, customers no longer had access to in-store purchases, which shrank a key revenue source for HVAC companies. Furthermore, the HVAC industry relies on the ability to conduct on-site visits with potential customers. Businesses were suddenly forced to digitize their platforms in order to provide more channels for consumers to access products. This digitization ultimately helped firms build in additional supply chain resiliency, which allowed them additional room to maneuver amid pandemic circumstances, but it produced short-term dislocations.

The emergence of omni-channel retail strategies, such as curbside pick-up, e-commerce, and text-to-order services, became a staple for distributors and contractors during the pandemic.[25] To increase consumer access to their products and services, HVAC manufacturers began launching cloud-based online platforms. For example, Johnson Controls launched OpenBlue and Carrier launched BluEdge, both of which utilize AI systems to provide remote service solutions and personalization for consumers.[26] These platforms facilitate virtual visits, remote diagnostics, compliance monitoring, and real-time building monitoring. In other words, digitization in response to the pandemic provided easier access for consumers to HVAC manufacturers, distributors, and contractors. Moreover, these platforms also collect data, which assists businesses in predicting future supply chain disruptions.

More accurate data helps increase supply chain transparency, allowing firms to identify and predict potential problems across their supply chains. Data accumulation also helps firms make more accurate decisions that better prepare their supply chains for future shocks. In other words, enhanced adoption of digital tools during the pandemic allowed firms to embrace resiliency over reshoring.

Rising Prices and Shortages of Steel, Copper, and Other Raw Materials

Both industries are already relatively inflexible when it comes to supply chain disruptions. For example, the aluminum supply chain—an essential part of the HVAC supply chain—is heavily dependent on imports. Moreover, due to the cost and complexity of bauxite mining and alumina alloy production, the United States does not have a competitive advantage to specialize in aluminum production. It is significantly cheaper to import bauxite mined abroad and import it to aluminum smelters in the United States for processing. Furthermore, smelters specialize in certain alloy aluminum production, meaning it is more efficient to focus production efforts on a certain alloy and import other alloys for processing. Since the cost of building new smelters would be in the billions of dollars, reshoring would be a costly strategy to implement for the raw aluminum production industry.

Gaps in supply and demand are also emerging with steel. Steel prices have increased by over 200 percent since March 2020, and while prices have surged, demand has also increased, in part as a result of economies reopening and increased activity in the manufacturing and construction sectors.[27] The World Steel Association estimates that worldwide steel demand will grow by 5.8 percent in 2021.[28] At the same time, suppliers have struggled to keep pace, resulting in product backlogs in many industries, including transformers.

The rising price and limited supply of two crucial raw materials, steel and copper, during the pandemic presented a major problem for transformer manufacturers. While the price of copper plunged in March 2020, by April 2021 copper reached its highest price since 2011, fueled by the global economic recovery and demand generated by government efforts to promote clean energy transitions.[29] Analysts at Goldman Sachs believe it is likely that copper prices will reach $10,000 per ton by the first half of 2022, potentially reaching the record high of $10,170 set in 2011.[30] However, as the demand for copper has surged, supply has struggled to keep pace. Global copper production declined by 2.6 percent in 2020, as lockdowns and mine shutdowns severely disrupted supply, especially from copper-rich nations such as Chile and Peru.[31] Analysts predict copper demand in 2021 will rise by about 5 percent year-on-year, while supply is expected to grow by 2.3 percent year-on-year, resulting in a potential deficit of more than 200,000 tons of copper in 2021.[32] This remains a significant concern for the transformer industry, as it relies heavily on a steady supply of copper wiring.

The unpredictable pricing of input materials has increased stress on HVAC supply chains. From copper price increases to steel and aluminum tariffs, the price of HVAC materials and projects were less stable during the pandemic. For both the HVAC and transformer industries, one response has been to preorder materials and raise installation prices to counteract product and material shortages.[33] Although these changes have altered installation and repair timelines, they are valuable in erecting buffers that create flexibility within supply chain operations, which makes supply chains more resilient over time. In the HVAC market, firms

have begun switching to supply chain management (SCM) strategies from a "turn and earn" focus to prevent stockout—a situation in which there is no available product supply.[34]

Transportation Complications and Bottlenecks

In both industries, shipping costs and delays—especially for raw materials and manufactured products—continue to cause supply chain disruptions. Illustrating just how stark price increases have become, the average worldwide price to ship a 40-foot container has increased by more than 200 percent since the pandemic began.[35] Prices to ship from China to major ports on the U.S. West Coast average about $12,000 a container, while prices can reach $20,000 for last-minute shipments. Moreover, an average of 80 container ships a day have been stuck outside the Port of Long Beach, the second-largest port in North America in terms of inbound shipments and a major destination for inbound raw materials from China and Thailand for a transformer company interviewed for this project.[36] Complicating matters further, as port workers tested positive for Covid-19 during the height of the pandemic, there was an inadequate supply of workers to unload items onto trains and other delivery vehicles, further delaying when businesses could receive their goods, especially critical raw materials inbound from Asia.

Consequently, HVAC manufacturers have started to regionalize their supply chains, forming global partnerships and acquisition arrangements with suppliers and manufacturing businesses closer to their consumer bases. For example, Carrier launched its Alliance Supplier Program to extend its global reach and deepen its relationships with strategic suppliers.[37] With greater proximity to consumers, transportation logistics are lessened, leading to reduced costs and delivery time and a more profitable system.

The transformer industry experienced a similarly tumultuous year. The primary problem in the transformer industry related to early labor shortages caused by the pandemic. One firm interviewed for this project recalls petitioning local and federal governments repeatedly to obtain an "essential" designation in order to stay open. Similar to the HVAC industry, industry experts interviewed for this project regarded tariffs as the government policy that most threatened the industry.

Changing Demand

Overall, both industries experienced similar disruptions but have taken this opportunity to build more resilient supply chains, particularly since reshoring would not be cost effective for either. During the onset of the pandemic, the HVAC industry was quickly identified as an essential industry and remained largely operational throughout 2020.[38] While its designation as an essential industry did not restrict its functionality, demand decreased as customers' concerns grew regarding the spread of the virus. Residential demand dropped as customers became uncomfortable with strangers entering their homes. Moreover, due to the lockdowns, new commercial and multifamily construction projects plummeted, falling 22 percent below the levels recorded during the first half of 2019.[39]

Then, June 2020 brought about a drastic consumer demand increase for HVAC projects as people were stuck at home during the hottest summer on record.[40] However, firms had prepared for lower sales and accordingly ordered fewer materials and furloughed workers. When demand returned, distributors and suppliers were constrained by inadequate stock and fewer workers. Consequently, the distributors

and manufacturers needed to compensate for production slowdowns, additional lead time, and general coordination problems. In May 2020, only 11 percent of builders reported shortages of HVAC equipment.[41] However, the June 2021 survey released by the National Association of Home Builders shows that number increased to 68 percent, with 13 percent reporting "serious shortages." Economists interviewed for this project underscored that no one expected this type of "V-shaped" demand recovery. This drastic change within one year represents a confluence of factors that have disrupted supply chains—namely shortages, transportation problems, and an insufficient workforce.

A Department of Commerce report found that market consolidation was in large part responsible for changes in transformer markets, which resulted in "fewer, larger players that offer a wider product range and are able to benefit from economies of scale."[42] The report also noted that "during the consolidation process, many manufacturers moved their production offshore (e.g., Mexico, India, Colombia), taking advantage of lower labor costs, lower labor and environmental standards, and access to local markets with rapidly increasing demands for electricity."[43] Demand in the United States does not necessarily relate to new demand for electricity but in many cases is based on the need for upgrades and replacements of old infrastructure.

Several interviewees in both sectors reiterated that government policies to encourage onshoring were not desirable because firms had gone to great lengths to cultivate relationships abroad, where prices are cheaper. Reshoring would not only damage those hard-won relationships overseas but would likely lead to increased prices and ongoing uncertainty within the market. Even with an additional influx of government funding, firms thought that reshoring would not be as cost effective or efficient as existing global supply chains. Many firms also underscored ongoing concerns about the domestic labor force and its ability to support increasing demand, preferring instead to nearshore by opening facilities in countries such as Mexico, where there is a larger and more affordable labor base.

5

Government Approaches and Policies

Executive Branch Clean Energy Initiatives

The Biden administration's clean energy initiatives, along with proposals in Congress, are likely to impact both industries. The Biden administration's second infrastructure plan—a "human infrastructure" plan—will invest in social programs such as paid family leave and clean energy development.[44] If passed, this plan will have profound effects on U.S. power infrastructure and will help meet the administration's goal of decarbonizing the power grid by 2035. In particular, the agenda includes a clean electricity standard (CES) and tax credits for clean transmission lines.[45] The CES would require utility companies to adopt a baseline amount of renewable energy (yet to be determined), with the amount increasing over the next 15 years.[46] While 30 states and the District of Columbia currently require utility companies to include some renewable energy in their operations, the administration's CES initiative is likely to accelerate this process. Utility companies, the largest customers in the transformer industry, may prefer one federal standard over the patchwork of state regulation standards they currently operate under, as this would promote efficiency in their operations and directly impact how they purchase and utilize transformers.

The administration also plans to create the Grid Deployment Authority as part of the Department of Energy, which would streamline the process of permitting and financing transmission projects. Furthermore, the Department of Energy announced in April 2021 that the Western Area Power Administration Transmission Infrastructure Program's $3.25 billion fund is accepting applications to support power transmission projects in the western United States.[47] The Department of Transportation also simultaneously announced the use of public highways and other public transportation avenues to expedite the permitting and installation of transmission lines. These grid-enhancing initiatives are likely to require the timely shipment and installation of custom-

made transformers, thereby increasing the importance of efficient and resilient transformer supply chains. Industry experts interviewed for this project note that the upgrading and expansion of transmission lines will provide a market expansion opportunity for their business, and they remain eager to supply the transformers necessary to implement the Biden administration's clean energy initiatives.

Nevertheless, experts in the transformer industry are concerned about what a potential influx of investment would mean since suppliers are already under tremendous pressure to deliver. This has led some firms to expand their supplier base, both within the United States and abroad. One transformer company interviewed for this project noted that the labor supply in Mexico surpassed the U.S. domestic labor supply, but another company with operations in Mexico was reticent to expand operations there over fears relating to border closures and uncertainty related to U.S. government policies.

Similarly, the HVAC industry would also benefit from the Biden administration's agenda. The American Jobs Plan includes the Neighborhood Homes Investment Act, which calls for the creation of a new federal tax credit that experts estimate would result in the construction of 500,000 new homes.[48] An additional $213 billion is slated to retrofit and preserve residential houses with more energy efficient technology. While the administration's agenda has focused on the HVAC industry, the final bipartisan infrastructure bill at the time of writing for this paper did not include these provisions.[49] However, the initial inclusion of an HVAC-related line item in the president's climate plan underscores the growing realization that HVACs will play an important role in both residential and commercial settings.

Legislative Branch

In Congress, Senator Martin Heinrich (D-NM) and Representatives Steven Horsford (D-NV) and Susie Lee (D-NV) introduced the Electric Power Infrastructure Improvement Act in April. The act would, in part, provide a 30 percent investment tax credit for the development and expansion of electricity transmission lines that would connect clean energy sources throughout the country and allow for a more resilient electric grid.[50] These tax credits are likely to provide the incentives for several large-scale transmission projects to move forward in the coming years, as it would allow a more cost-effective implementation of inter-regional transmissions systems.[51]

Other legislation is also intended to aid the HVAC industry. The HOPE for HOMES Act of 2021 incentivizes online training for residential contractors and creates rebates for energy-efficient upgrades of HVAC systems in homes and multifamily buildings.[52] Representative Roger Williams (R-TX) introduced an efficiency permanent tax credit (labeled the "25C" tax credit) for 10 percent of eligible expenses from installing energy-efficient appliances, such as energy-efficient HVAC systems.[53] The Air Source Heat Pump Act, cosponsored by Senators King and Collins, establishes a federal tax credit for new heat pump installations and associated costs.[54] Finally, the Workforce, Innovation and Opportunity Act Reauthorization supports training to help job seekers access education, training, and support systems to gain employment in certain trade sectors, including the HVAC industry.[55] Government promotion of energy-efficient systems has increased demand for greener technology, but the investment in employment resources has not substantially increased employment after the pandemic. These proposals, if passed, will help incentivize investment in new energy-efficient technology, increase demand for HVAC systems, and spur job seekers to consider the HVAC industry.

In the short run, recent legislation focuses mainly on increasing demand for clean energy in the HVAC and transformers industry and simultaneously increasing sectoral employment. Therefore, these legislative initiatives fit with industry goals of building in resiliency rather than pursuing reshoring policies. However, experts interviewed for this project expressed concern about Buy American and other content requirements since those tend to create uncertainty within the industry and threaten existing relationships that firms have around the world, which play an integral role in their supply chains.

National Security and Trade Barriers

The implementation of tariffs and national security concerns under both the Trump and Biden administrations have played a critical role in the transformer industry. After an investigation in 2018, President Trump applied 25 percent tariffs on imports of certain steel products and, in January 2020, expanded the tariffs to cover certain derivative steel products. The tariffs remain in place under the Biden administration, even as some members of Congress have raised concerns about the economic impact of increased tariffs. Meanwhile, other members have argued that the tariffs are inadequate since they do not cover GOES derivative products such as laminations and cores.[56] The Core Coalition, a network of companies active in the transformer industry, has disagreed with the decision to put tariffs on imports of transformers and transformer inputs, arguing that the United States does not have the domestic production capacity to adequately supply enough transformer inputs to power the electric grid.[57]

In both the HVAC and transformer industries, firms tended to view pandemic-related supply chain disruptions as a call to rethink how to build additional resiliency into their supply chains. In both industries, it is often unfeasible for firms to reshore parts of their supply chains. For example, electric utilities often rely on specialized steel inputs, such as GOES, for transformers, which are cheaper to obtain from abroad. There is currently only one producer of GOES in the United States, meaning producers largely import from abroad, primarily from Mexico and Canada. In a 2020 public comment to the Department of Commerce, the Edison Electric Institute warned against future trade remedies, claiming such sweeping measures "effectively would relegate an entire industry to reliance on a single domestic GOES supplier or an unreasonably small number of products suppliers."[58] In 2014, the U.S. International Trade Commission found that AK Steel's prices, 25 percent higher than similar grades of steel from other parts of the world, were responsible for the company's reduced competitiveness, despite a Department of Commerce finding that the industry was the victim of both dumping and foreign subsidies.[59]

The manufacturing of GOES remains a vital issue in transformer supply chains. AK Steel, which maintains manufacturing operations in Ohio and Pennsylvania, is currently the only domestic producer of GOES, and lawmakers have been keen to protect the company as a vital component of the U.S. transformer industry and, in effect, the nation's electric grid. Senators Sherrod Brown (D-OH), Bill Cassidy (R-LA), and Bob Casey (D-PA) proposed an amendment to the Bipartisan Infrastructure Framework, advanced in August, directing the U.S. trade representative to negotiate with Canada and Mexico in order to prevent transformer parts made with Chinese and Russian GOES from entering the United States tariff-free.[60] The senators note that jobs and U.S. national security are at risk if the U.S. electric grid becomes too reliant on foreign GOES. However, based on interviews with industry experts, the transformer industry views GOES tariffs as counter-productive since material costs would increase and cost-cutting measures, including eliminating jobs, would likely ensue. The amendment was ultimately stripped from the Bipartisan Infrastructure Framework.

Similarly, the Trump administration also argued that, given the importance of U.S. power grid equipment, including transformers, importing this equipment from countries such as China could pose national security risks to the United States. Thus, in December 2020, Secretary of Energy Dan Brouillette signed an order banning electrical utility companies that partner with critical defense facilities from importing certain power system equipment, including transformers, from China over fears of potential cyberattacks.[61] Industry leaders supported the goal of adequately addressing security risks within the U.S. power infrastructure but worried that costs could increase.[62] The Biden administration revoked the order in April after the administration conducted its own energy infrastructure security review.[63]

As part of the review, the Department of Energy released the second version of the Cybersecurity Capability Maturity Model (C2M2) in July, a tool created to assist companies, especially those critical to the U.S. energy infrastructure, to evaluate and enhance their cybersecurity capabilities.[64] Part of this C2M2 is to help organizations "strengthen their operational resilience" by digitizing supply chains and building in layers that prevent shutdowns and malicious attacks. However, industry experts interviewed for this project also note that increased cybersecurity regulations by the Department of Energy and other regulatory agencies could increase business costs and limit supply chain flexibility.

The Biden administration has so far been reluctant to alter many of the previous administration's trade policies, including steel and aluminum tariffs, due to pressure from organized labor and domestic industry. Unlike the previous administration, however, the Biden administration is embarking on a set of domestic policies that stand to benefit the HVAC and transformer industries, such as the 25 percent tax credit for energy-efficient HVAC systems.[65] Among firms interviewed for this project, frustration is ongoing regarding existing tariffs, though fears of new tariffs are more restrained. Instead, many firms indicated a growing realization that new production demand as a result of government spending initiatives would require firms to develop additional contingency and resiliency plans to ensure they would be able to meet future demand. While interviewed firms expressed strong desires to maintain the freedom to choose where they source their input materials, there is a growing realization that several of the proposed spending programs have Buy American requirements, which firms generally regarded as adding a new level of complexity to their supply chains.

The Biden administration has so far been reluctant to alter many of the previous administration's trade policies, including steel and aluminum tariffs, due to pressure from organized labor and domestic industry.

In March 2018, the Trump administration levied tariffs of 25 percent on all foreign steel and a 10 percent tariff on aluminum, resulting in widespread price increases and market uncertainty. In 2010, seven aluminum companies operated nine domestic smelters.[66] By 2020, that number had dwindled to three companies operating six primary aluminum smelters. Those primary aluminum smelters were operating at 60 percent capacity in 2019 but dropped to 49 percent capacity in 2020. An Economic Policy Institute report found that aluminum-producing industries "thrived" under tariffs, citing an

increase in U.S. primary aluminum production of 37.6 percent between 2018 and 2020 and a series of downstream expansion projects.[67] However, a 2021 Congressional Research Service report paints a different picture.[68] While the report says the 2018 imposition of a 10 percent tariff on aluminum imports "may have been a factor in sustaining some jobs domestically in aluminum manufacturing" between 2018 and 2019, data demonstrate that the total number of jobs in primary and secondary aluminum manufacturing shrank 9 percent between June 2019 and June 2020. Furthermore, while domestic production of primary aluminum increased by 12 percent from 2018 to 2020, total aluminum production, which includes secondary aluminum, fell by 9 percent overall.

Similar dynamics have played out within the industry. Alcoa Aluminum, which opposes Section 232 tariffs, has not restarted idled domestic production under the tariff, and it closed a smelter in Washington state in 2020 due to "uncompetitive smelting capacity" and "declining market conditions."[69] However, one of the chief proponents of the Section 232 tariffs is Century Aluminum. While only one of three of Century Aluminum's domestic smelters is operating at full capacity, the company has increased some domestic capacity under the tariffs and argues the company may be forced to close if the tariffs are removed.

With one exception, all firms interviewed for this project opposed executive branch tariffs on their industries. HVAC and transformer firms interviewed for this report repeatedly stressed that tariffs on inputs, namely steel and aluminum, were financially harmful, created uncertainty throughout the industry, and were ultimately ineffective in spurring reshoring. Firms interviewed for this project noted that their supply chains are relatively inelastic due to the high cost of either building new aluminum smelters on U.S. soil or restarting idled facilities, as well as the higher labor and electricity costs that would accompany increased capacity. Furthermore, as the case of AK Steel demonstrates, companies often suffer from a host of problems—whether foreign government support or increased labor prices at home—meaning a one-size-fits-all approach is ineffective. Another problem for the U.S. domestic industry is the cost of electricity for operating smelters, due in large part to the age of U.S. smelters, the newest of which was constructed in 1980. Electricity costs can account for 40 percent of primary aluminum production operating costs and have led firms to relocate production facilities to countries with cheaper electricity, namely Canada and Iceland.[70]

Overall, experts in both industries welcomed government intervention, particularly investment, if it would boost revenue without creating uncertainty. HVAC and transformer industry experts were wary of trade remedies, particularly tariffs, following several tumultuous years marked by trade wars and market fluctuations. As the United States seeks to modernize its grid and insulate against extreme weather, industry experts thought that government investment, coupled with resilient and global supply chains, would best benefit U.S. consumers and firms.

Conclusion

In 2020, the Covid-19 pandemic sent shockwaves through the global economy, threatening livelihoods, supply chains, and the world economy. In particular, the pandemic raised fundamental questions about the health of U.S. supply chains and their ability to meet the country's needs, highlighting the policy differences between increased resiliency, reshoring, and nearshoring. From component suppliers and manufacturers to port workers and distributors, the pandemic threatened to upend supply chains in industries critical not only to fighting the pandemic but also keeping the economy healthy amid increasing climate risks.

Aluminum and steel are not only required for both the HVAC and transformer industries but also are among the most critical manufacturing materials for many products and have become focal points of U.S. trade policy. Tariffs enacted by the Trump administration—alongside a Biden administration requirement that aluminum importers obtain a license in order to import—have resulted in renewed discussions about the health of the U.S. aluminum and steel sectors.[71] These trade restrictions were enacted under the guise of protecting the domestic steel and aluminum industries and to encourage domestic production, although interviewees for this project almost unanimously rejected the idea that protectionist policies—whether tariffs, tariff rate quotas, or content requirements—were helpful to long-term industry health.

In addition to back-to-back administrations that have made protecting U.S. workers a hallmark of their agendas, the pandemic resulted in a fresh look at the health of U.S. supply chains, as illustrated by the Biden administration's 100-day review of supply chains in four critical sectors. Throughout the pandemic, labor shortages, rising commodity prices, changing demand, and transportation bottlenecks have created far-ranging disruptions throughout both the HVAC and transformer supply chains. However, due to the critical role of the HVAC industry in protecting air quality and thus

combating airborne virus spread, it was quickly deemed an essential industry and remained largely operational throughout 2020. Indicating how important HVAC systems became during the pandemic, demand for HVAC installations and repair skyrocketed in June 2020. Furthermore, as weather patterns continue to change and climate pressures increase, the importance of the HVAC industry will likely grow over time.

Transformers were less prone to supply chain shock by the very nature of the industry. However, ongoing shipping costs and delays, especially for steel and copper, and the rising prices and limited availability of raw materials continue to cause supply chain disruptions within the industry. If core elements of the Biden administration's ambitious climate agenda come to fruition—namely the Clean Electricity Standard—a massive infusion of government funds into the electricity sector will likely have a profound effect on the transformer market. In the United States, demand for transformers is currently double what manufacturers are able to produce.[72] Some firms interviewed for this project expressed concern about the ability of manufacturers and suppliers, who are already under stress due to Covid-related supply chain disruptions, to fulfill an uptick in new orders. This concern about the future potential of manufacturers and suppliers to fulfill orders has led several firms to increase the number of suppliers in the network as a back-up plan for future bottlenecks, denoting a concerted effort to build more resilient supply chains.

From component suppliers and manufacturers to port workers and distributors, the pandemic threatened to upend supply chains in industries critical not only to fighting the pandemic but also keeping the economy healthy amid increasing climate risks.

Overall, the HVAC and transformer industries have embraced supply chain resiliency over reshoring. In the transformer industry, given the increased manufacturing costs associated with domestic production, reshoring remains an undesirable proposition. Moreover, concerns remain within the industry that crucial components, specifically GOES, could not be supplied domestically in adequate quantities to meet industry demand. Access to affordable and abundant raw materials, most notably from Asia and South America, remains the most crucial component for the industry's viability and profitability.

Rather than reshoring, both industries have focused on proactive measures to reduce supply chain bottlenecks, including preordering materials in bulk, accessing raw materials outside traditional markets, and instituting long-term planning mechanisms. Nevertheless, challenges remain, especially given rising demand on the HVAC and transformer supply chains from consumers focused on environmentally sound systems and government clean energy initiatives.

As both the transformer and HVAC industries illustrate, protectionist measures, namely tariffs, have proven ineffective in encouraging reshoring. In both industries, shifting production to the United States would be very expensive due to higher labor and electricity costs. Similarly, the United States is not able to produce all of the specialized steel components necessary for HVAC and transformers at a globally competitive cost due to higher labor and electricity costs. As demonstrated by the U.S. International Trade Commission's 2014 determination regarding AK Steel, higher costs are in part what accounted for the company's problems. The U.S. government should therefore avoid policies that raise costs on domestic firms, including blanket tariffs that create uncertainty and raise prices. Furthermore, firms have been reluctant to surrender the competitive advantage of Asian markets' low-cost manufacturing capabilities and their supply chain resilience. Asian exports rebounded fastest during the pandemic, surpassing pre-pandemic levels in 2021 due in large part to successful "coronavirus-mitigation measures" undertaken while the rest of the world went on lockdown. Most firms interviewed for this project pointed to one government policy that would increase certainty within their industries: tariff reduction. Whether passed on to manufacturers, suppliers, or firms, transformer and HVAC experts repeatedly underscored that protectionist policies, particularly those intended to encourage onshoring, would lead to efficiency losses over time.

Both industries must contend with a set of overlapping problems. Transformer and HVAC systems rely on foreign-produced inputs, ranging from copper wire to processed aluminum, which the United States does not produce in sufficient quantity at a competitive cost. Both industries have also had to contend with waxing and waning periods of protectionist government policies that have caused pervasive uncertainty in markets. Additionally, both industries experienced similar stresses during the outset of the Covid-19 pandemic that affected supply chains worldwide. As with firms around the world, the transformer and HVAC industries experienced shutdowns, reopenings, new regulations, persistent labor shortages, price changes, and transportation bottlenecks. While 2020 was significantly more disruptive than 2021, this year's pandemic-related impacts are different. Now, the transformer and HVAC industries are experiencing extended lead times and significant price increases due to large demand and more limited supply. Furthermore, the labor market has not bounced back, causing shortages throughout both industries.

While ongoing pandemic-related disruptions continue to affect both the HVAC and transformer industries, the pandemic has encouraged a fresh look at how to maintain resilient supply chains as pressures mount. As extreme weather threatens the electrical grid, as it did during the deep freeze in Texas, or encourages more widespread use of air conditioning systems, both industries will be crucial to ensuring a more resilient future for the United States. As the world thinks ahead about how to build that future, these industries are also thinking about how to weather the next storm, whether it is pandemic or climate induced. So far, the conclusion is that more openness and more supply chain resiliency is best suited to weather the storms of the future.

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