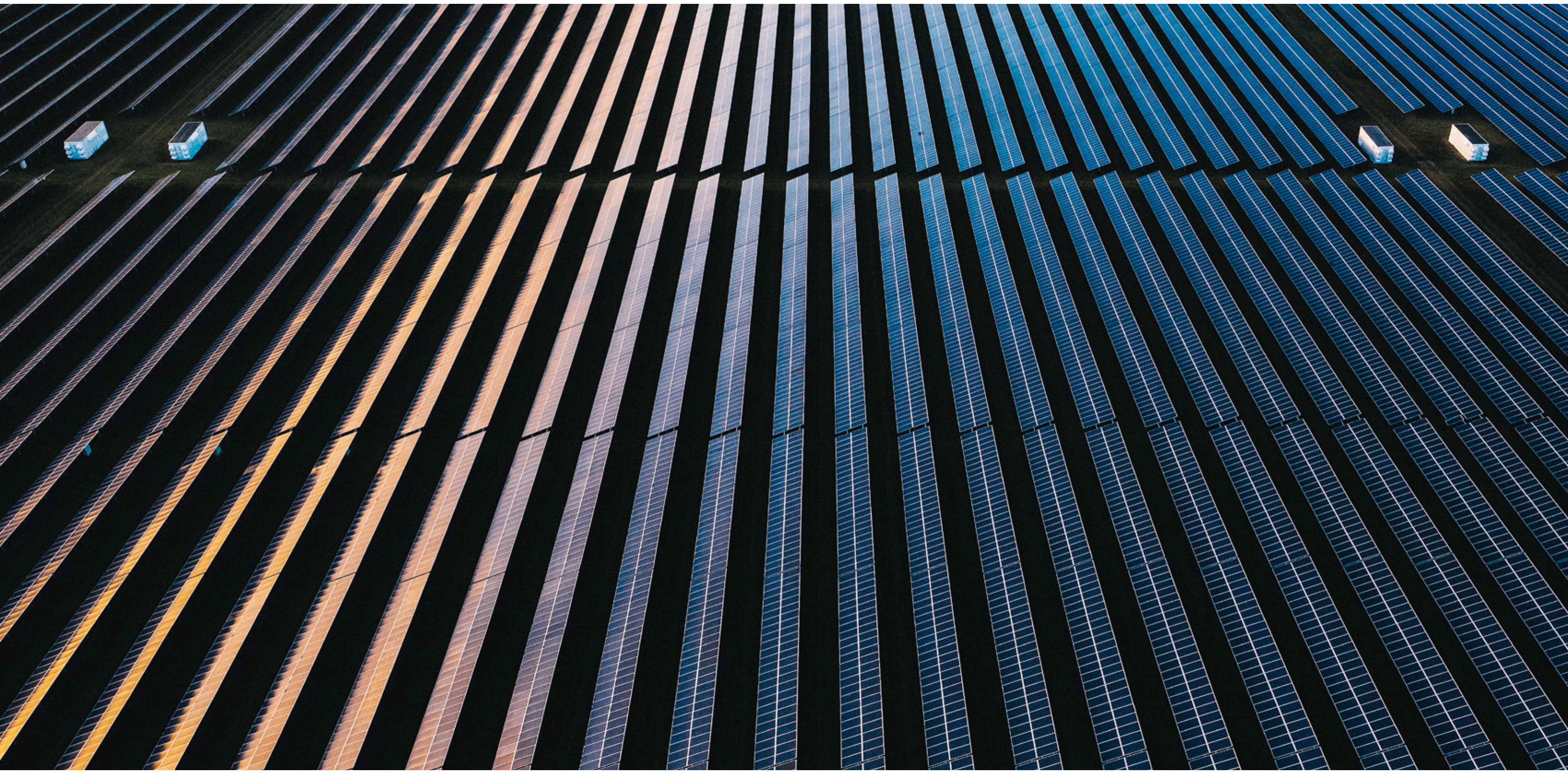
McKinsey & Company

Advanced Industries and Electric Power & Natural Gas Practices

Building resilient supply chains for the European energy transition

To ensure a timely and orderly energy transition, companies and other stakeholders urgently need to strengthen each step of the already-stretched supply chains of key technologies.

This article is a collaborative effort by Stathia Bampinioti, Harald Bauer, Nadia Christakou, Luigi Gigliotti, Emil Hosius, Friederike Liebach, Lorenzo Moavero Milanesi, Humayun Tai, and Raffael Winter, representing views from McKinsey's Advanced Industries and Electric Power & Natural Gas Practices.



October 2022

In earlier research on solving the net-zero equation,[1] we described the nine key requirements we believe must be met for an orderly energy transition. These fall into three broad categories: physical building blocks; economic and societal adjustments; and governance, institutions, and commitments. This article focuses on the first area, particularly on the ability to create at-scale supply chains and support infrastructure for key decarbonization technologies.

The energy transition is already well under way in Europe, but it will need to accelerate significantly to meet the European Union's Fit for 55 targets and deliver on REPowerEU, an energy security action plan developed in response to events in Ukraine.[2] One measure in the REPowerEU plan, for example, mandates the installation of 320 gigawatts (GW) of new solar photovoltaics (PVs) by 2025 and 600 GW by 2030. Meeting this goal will require a threefold to fivefold increase in the solar PV installation rate.

Increased (and increasing) demand for the technologies that enable decarbonization—such as electrification technologies across industrial processes, buildings, power supply, and the mobility industry—creates many knock-on opportunities. Companies at each step of the affected value chain have the opportunity to benefit, as we discussed in a recent article focused on electrification.[3]

Those looking to take advantage of these opportunities will need to be cognizant of a number of risks and act to avoid them. Avoiding bottlenecks in already-stretched supply chains is particularly important, especially in the context of recent geopolitical events; bottlenecks create risks around volume shortages, price volatility, geographical-sourcing dependency, long lead times, and issues with quality. These risks can affect all key energy transition technologies and every step of the supply chain. Particular challenges are expected around the procurement of raw materials, manufacturing of components, and availability of labor for construction and installation.

Businesses and other key stakeholders looking to shore up supply chain resilience for an orderly energy transition can take a range of mitigation actions. Fast and decisive action to analyze and strengthen supply chains and a willingness to invest judiciously can help position Europe and its businesses to capture the substantial opportunities of an orderly energy transition. A lack of action will increase the risk that Europe may fall behind in achieving its important, ambitious energy goals—or even miss out on these opportunities entirely.

The energy transition is under way, and the pace of decarbonization will only increase

The drive toward decarbonization, increasing cost competitiveness, and geopolitical considerations have further accelerated the energy transition and significantly increased the pace of electrification.

But the rate of decarbonization will need to more than triple to meet the European Union's Fit for 55 target of a 55 percent emissions reduction from 1990 levels by 2030.[4] There will need to be a dramatic shift toward renewables in power supply and toward electrification technologies in demand.

These top-level targets have profound implications for the products and technologies that enable electrification and thus decarbonization. Renewable-energy sources (RES), for example, will need to constitute 70 percent of the generation mix by 2030.[5] Increased demand for electricity will further complicate the transition.

The result of these shifts will be a strong and growing demand for electrification-enabling technologies. These technologies include wind, solar PV, and battery storage in the power industry; heat pumps for buildings and industrial processes; and batteries and charging infrastructure for the mobility sector, to name just a few. This burgeoning demand will be synchronized along the entire

[1] For more, see "Solving the net-zero equation: Nine requirements for a more orderly transition," McKinsey, October 27, 2021.
[2] "Fit for 55," European Council, June 30, 2022; "REPowerEU Plan," European Council, May 18, 2022.
[3] For more, see "Unlocking opportunities from industrial electrification," McKinsey, July 18, 2022.
[4] "EU greenhouse gas emissions fell in 2019 to the lowest level in three decades," European Commission, November 30, 2020.
[5] *Global Energy Perspective 2022*, Achieved Commitments scenario, McKinsey, April 2022.

value chain, from raw and processed materials and manufacturing of components and assemblies all the way to logistics and construction.

Supply chains are facing significant—and growing—challenges

Supply chains for key energy transition technologies are already stretched, and recent geopolitical events have further exacerbated the situation. The global pandemic disrupted supply chains, resulting in multiple-month production halts while major supplier countries went into lockdown.

For example, more than two years into the pandemic, the gap between chip supply and demand has widened across all semiconductor-enabled products. This semiconductor shortage will likely persist in selected technology nodes for the next three to five years. For mature node sizes, for example, shortages are expected to persist until 2026.[6]

More recently, the war in Ukraine has disrupted the supply of oil and gas and has driven many European countries to make decisions that will have a long-term impact on where and how they source their energy supply. There have also been disruptions around other key raw materials for which Russia and Ukraine are key suppliers. For example, 43 percent of the global production of palladium is sourced from Russia, 33 percent of global semifinished steel imports are supplied by Russia or Ukraine, and 17 percent of global class 1 nickel is produced in Russia.[7]

These events and trends could amplify five risk areas related to supply chains: volume shortage, price volatility, geographical-sourcing dependency, long lead times, and issues with quality (Exhibit 1).

Key industry players are increasingly aware of the need to act—and many have already started to do so. In 2022, for example, the World Economic Forum noted the risk of choke points in the supply of commodities such as lithium and copper and advocated for global standards as well as increased innovation to boost supply diversity.[8] In September 2021, the European Raw Materials Alliance introduced a plan calling for governments and manufacturers to support mining and processing through a mix of subsidies and sales quotas.[9]

Exhibit 1

Supply chains are associated with five areas of potential risk.

1

Volume shortage

Supply chain cannot deliver the quantity of material or component required at sufficient scale, either due to lead times required to scale up or fundamental limits (eg, constraints in mining capacities)

2

Price volatility

Material or component is exposed to market forces that lead to consistently rising or volatile prices

3

Geographical-sourcing dependency

Material or component production is significantly concentrated in a region where geopolitical, social, regulatory, or other factors could affect trade flows

4

Long lead times

Material or component takes a long time to be procured

5

Quality

Material or component may suffer from low quality due to massive increase of demand and decrease of quality controls to speed up the process

[6] Ondrej Burkacky, Johannes Deichmann, Philipp Pfingstag, and Julia Werra, “Semiconductor shortage: How the automotive industry can succeed,” McKinsey, June 10, 2022.
[7] “Share of global production and rank for selected minerals and metals in Russia, 2020,” IEA, last updated May 20, 2022; “List of exporters for semi-finished products of iron or non-alloy steel,” Trade Map, International Trade Centre (ITC), accessed September 10, 2022; McKinsey MineSpans.
[8] Joisa Saraiva and David G. Victor, “Rethinking global supply chains for the energy transition,” World Economic Forum, January 31, 2022.
[9] Elisabeth Behrmann, “EU makes $2 billion push to curb reliance on China’s rare earths,” *Bloomberg*, September 30, 2021.

Risks exist along each step of the supply chain

Supply chain risks can affect procurement, manufacturing, logistics, and construction. These risks have the potential to cause serious disruption for all key energy transition technologies (Exhibit 2). For a deep dive on how supply chain risks threaten every step of the value chain for heat pumps, see sidebar, "Vulnerabilities in the heat pump supply chain."

Individual risk profiles and the actions needed to minimize them vary for each step of the value chain, with particular challenges expected in raw materials, components, and labor.

Exhibit 2

Supply chains for key energy transition technologies are stretched.

Selected examples, nonexhaustive

Drivers of risk: Volume shortage; Price volatility; Geographical-sourcing dependency; Long lead times; Quality

Raw- and processed-material procurement

Wind turbines
EU provides only 1% of raw materials for wind turbines; expected supply shortage for neodymium and praseodymium

Batteries
1% of materials from EU; 74% dependence on China (lithium and cobalt), Russia (class 1 nickel), Africa (cobalt), and Latin America (lithium)

Grids
Potential shortage of copper driven by demand increase

Component manufacturing and assembly

Solar
China's role becomes quasi-monopolistic in solar-PV[1] components, providing > 70% of solar-cell and module components

Batteries
China supplies 66% of finished lithium batteries; EU fully dependent on battery cell imports, yet European capacity expected to ramp up

Wind turbines, solar, and batteries
High dependence on Asia for power electronics, with China, Japan, Korea, and Taiwan accounting for ~75% of global production

Logistics

Wind turbines
Potential shortage of XL vessels for offshore wind turbines after 2025

Construction and labor

Wind turbines, solar, batteries, and grids
Demand for construction workers will increase more than threefold by 2030; blue-collar workers are already scarce today

[1]Photovoltaic.
Source: *Critical raw materials for strategic technologies and sectors in the EU: A foresight study*, European Commission, September 3, 2020; expert interviews; Technologies and Innovations; *The raw-materials challenge: How the metals and mining sector will be at the core of enabling the energy transition*, McKinsey, January 10, 2022

Vulnerabilities in the heat pump supply chain

Heat pumps can be used to electrify both space and water heating in the residential- and commercial-buildings sector, where they replace gas and oil boilers. They can also be used to electrify industrial processes such as in the chemicals, pulp and paper, and food and beverage industries.

Historically, heat pumps have been significantly more expensive than alternatives in terms of total cost of ownership. At 2019 fuel prices, for example, the cost of heating an average German residential dwelling was about 50 percent higher with air-to-water heat pumps than with a condensing gas boiler.[1] However, rising commodity prices and direct subsidies are rendering these pumps increasingly cost competitive. In addition, carbon taxes and policies will further encourage the installation of heat pumps, which are both a short-term lever to reduce European dependency on Russian oil and gas and a key longer-term decarbonization lever.

As a result, the European Commission has set a target to double the rate of deployment of heat pumps over the next five years.[2] An analysis of heat pump supply chains, however, reveals a number of potential vulnerabilities:

Procurement of raw and processed material. Steel and copper are among the key raw materials for the creation of heat pumps. While steel production will likely not face bottlenecks in supply, increased demand for green steel and increasing energy prices might significantly drive up steel prices. There will also likely be a near-term undersupply of copper. Demand will increase as a result of grid expansion, increasing renewable energy, and the adoption of electric vehicles (EVs), while supply will be limited by aging mining assets and weak project pipelines.

Component manufacturing. While components such as fans and valves are highly commoditized, and therefore no sourcing constraints are expected, inverters and electrical components may fall victim to the semiconductor bottleneck.

Components assembly. Increased use can increase the output of existing assembly lines, but there are high barriers to entry for new players in the heat pump market; complex systems and licensing requirements in certain cases result in a lead time of up to 12 months to open new plants.

Construction and labor. While increasing worker shifts can provide some labor scale-up flexibility, labor shortages might slow down the uptake of heat pumps. To meet governmental targets, for example, the United Kingdom will need to add 5,000 to 7,000 heat pump installers per year from 2025 until 2035.[3]

Furthermore, the ability to retrofit heat pumps into existing buildings is restricted by space limitations in urban housing and bureaucratic hurdles, such as the need for owner communities' approval and preservation orders.

Enabling strong heat pump uptake may therefore require businesses and other relevant stakeholders to consider the following actions:

- Advocate for supportive policies (including subsidies and carbon taxes), launch awareness campaigns to increase local demand, and engage in large-scale skilling and reskilling efforts for technicians.

- Make corporate commitments in commercial real estate to accelerate the adoption of heat pumps in stakeholders' building portfolios.

- Create innovative designs to enable the retrofitting of buildings and allow for heat pump installation in small urban apartments.

- Scale up assembly-line production capacity with a focus on automated-manufacturing practices.

[1] "Are renewable heating options cost-competitive with fossil fuels in the residential sector?," IEA, December 1, 2021.
[2] "Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions," European Commission, May 18, 2022.
[3] "Shortage of trained heat pump installers could set back net zero," Nesta, July 7, 2022.

Procurement of raw and processed materials
The main supply chain risks that are likely to affect raw materials are supply shortages and geographical-sourcing dependency.

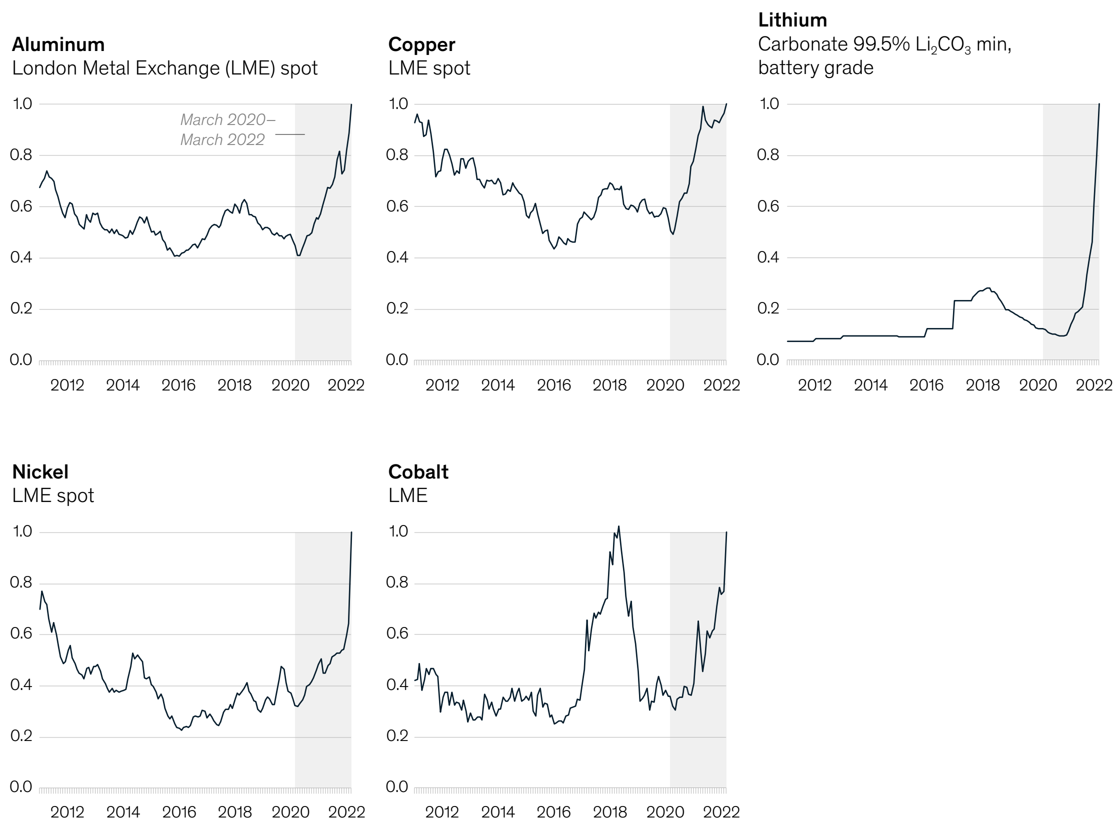
These risks will be particularly severe for rare-earth materials. Neodymium and praseodymium, for example, are key components of the permanent magnets used in wind power and electric vehicles (EVs) and will see a surge in demand in the coming years. Substitution options are limited, which may create risks in the future because the industry is highly dependent on China's refining capacity. Recycling will therefore be a key focus area, but based on expected capacity growth plans, we nevertheless predict an undersupply of 50 to 60 percent in 2030, leading to significant price spikes.[10]

Other raw materials will also be affected. For example, the energy transition and electrification will significantly increase demand for metals such as nickel, lithium, cobalt, aluminum, and copper. Demand is already rising, which has driven price increases (Exhibit 3). We expect that opportunities for increasing supply, recycling, and substitution will maintain a relative equilibrium between supply and demand for aluminum, copper, and cobalt, but we expect to see supply shortages of class 1 nickel and lithium in 2025.

Exhibit 3

There is an unprecedented extent of price increases across commodities.

All prices indexed to March 2022 = 100, VAT exclusive



Source: MySteel Global; *Metal Bulletin*; S&P SBB

[10] Dolf Gielen, "Engineering is key to easing the supply crunch of critical materials for clean energy," Engineering for Change, October 20, 2021.

Component manufacturing and assembly

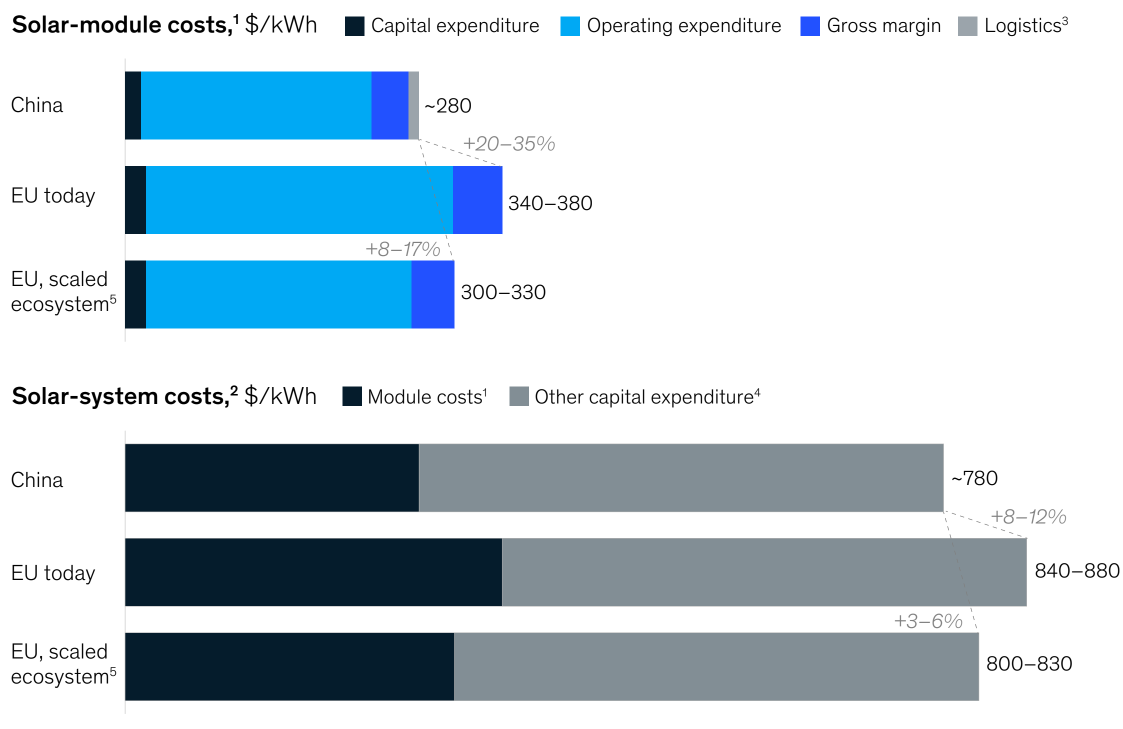
Increased demand for assets will increase demand for components, but the share of components that are made in Europe is decreasing. Dependency on non-EU countries for the sourcing of key components could therefore become a major risk, particularly for solar PV, batteries, and power electronics.

China is (and is set to remain) the dominant producer along the value chain; it currently provides more than 70 percent of solar-cell and module components and 66 percent of finished lithium batteries.[11] Most semiconductors are also produced in Asia—22 percent in China, 19 percent in Taiwan, 17 percent in Korea, and 16 percent in Japan—with France and Germany together accounting for only 5 percent of global front-end production.[12]

The steady decrease in the number of domestic EU production facilities for many components has mainly been driven by commoditization, which has led to competition based predominantly on price with few opportunities for product differentiation. European companies will struggle to compete on price; solar PV module costs are currently 20 to 35 percent higher in Europe than in China, primarily driven by higher costs for labor, materials, and CO_2.[13] Scaling the local manufacturing ecosystem could decrease price differences by eight to 17 percentage points, but this will take at least three to five years (Exhibit 4).

Exhibit 4

Regionalizing solar-module manufacturing can close the cost gap between European and Chinese solar-PV systems.



[1]Like-for-like comparison for Tier-1 Mono PERC modules. [2]For utility-scale projects. [3]Assuming logistics costs reach prepandemic levels in the medium term. [4]Includes balance of system, grid connection, installation, and soft costs, which are independent of module costs. [5]Benefits of scaled ecosystem expected once annual manufacturing capacity in Europe reaches 10–20 GW, which will take at least 3–5 years.
Source: Expert interviews; International Renewable Energy Agency (IRENA); *McKinsey Global Energy Perspective 2022*; National Renewable Energy Laboratory (NREL)

---

[11] "Critical raw materials for strategic technologies and sectors in the EU," European Commission, September 3, 2020.
[12] "World Fab Forecast," SEMI, Q4 2021.
[13] *Global Energy Perspective 2022*; McKinsey analysis.

Western turbine manufacturers dominate the European market for wind power. In the past several years, however, Western OEMs have faced profitability issues due to lower-than-expected build-out and increased price competition driven by a shift to purely cost-driven tender design in many countries. As a result, many European countries—including Denmark, Germany, and Spain—have experienced job losses and factory closures.[14]

More recently, rising commodity prices have further eroded profitability. Many OEMs are fully exposed to increasing prices, resulting in double-digit negative EBIT margins for some European OEMs in the first quarter of 2022.

The Western world should build on learnings from the solar industry and strive to maintain a strong domestic industry and supply chain. As an example, refining tender designs to also incorporate more qualitative criteria—such as sustainability, carbon footprints, and system integration—could help ease pressure on the wind supply chain.

Logistics

There are also risks to an orderly energy transition related to the transportation of key technologies to the location of installation. These risks generally manifest as volume shortages.

Logistics is likely to become increasingly challenging in offshore wind. Increases in both capacity installation and, as a result of rapid technological advancement, turbine size are likely to lead to a shortage of appropriate installation vessels starting in 2025. We project that in 2026, about three GW of planned capacity will not be able to be installed because of the undersupply, and the size of this gap will increase over time.[15] The lead time for supersized installation vessels is considerable, which means that without prompt action, this mismatch between supply and demand is likely to be of considerable duration.

Construction and labor

Skilled labor to work on RES in the European Union is already scarce today, and employers experience a high level of competition from adjacent sectors. In 2019, for example, there were 1.8 job vacancies in Germany for every unemployed energy technician.[16]

This labor scarcity will get significantly worse: the demand for blue- and white-collar workers to develop and construct wind and solar assets in the European Union, for example, is expected to increase by a factor of between three and four by 2030 (Exhibit 5).[17] Labor shortages will be further exacerbated by an increasing demand for workers to operate and maintain these wind and solar projects; the lack of technicians is expected to be a particular pain point.

Stakeholders can act to minimize supply chain risks—and seize the opportunities

Businesses and other relevant stakeholders could take a range of mitigation actions to guard against supply chain risks. These actions are not just about mitigating risk, however: building supply chain resilience can also be an opportunity and a catalyst for collaboration and partnerships, as well as a driver of innovation—for example, to replace materials and increase productivity.

Potential actions for businesses

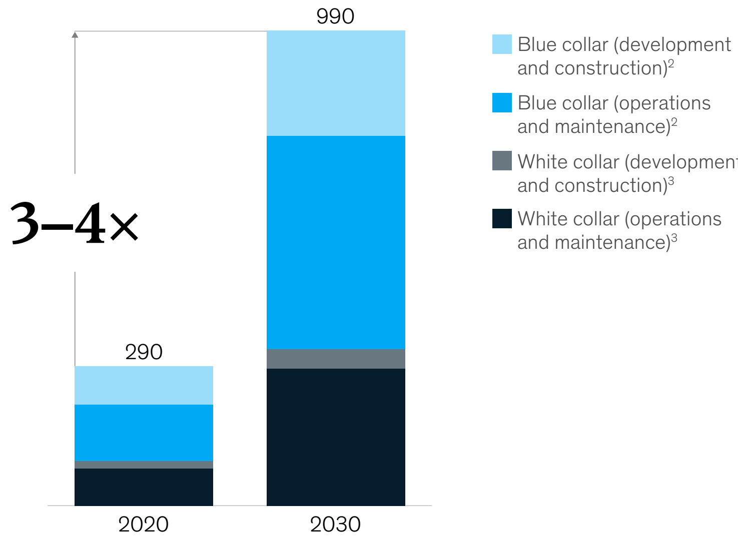
The right next steps will vary by the type and the specifics of individual businesses, but the following resilience-boosting actions can be beneficial to businesses along the supply chain:

[14] Maz Plechinger, "Nordex to lay off a fifth of staff in Germany," *EnergyWatch*, March 1, 2022.
[15] *Global Energy Perspective 2022*, Achieved Commitments Scenario; "Installation Vessel Supply and Demand Q1 2022," 4C Offshore, April 2022; McKinsey analysis.
[16] "Bottleneck Analysis," Federal Employment Agency, December 2019.
[17] *Renewable energy benefits: Measuring the economics*, IRENA, January 2016; *Global Energy Perspective 2022*, Achieved Commitments Scenario.

Exhibit 5

Demand for workers to develop and construct wind and solar assets in the European Union is set to increase by a factor of between three and four by 2030.

Estimated[1] annual full-time-equivalent (FTE) needs for development, construction, and operation of wind and solar assets in the EU, thousands



Note: Figures may not sum, because of rounding.
[1]Estimate based on current and expected build-out, and full-time-equivalent workers per GW estimates based on different publications from IRENA; learning rates have not been applied.
[2]Practical workers (eg, construction workers, technicians, ship crew, and operators).
[3]Remaining workers (eg, electrical, industrial, mechanical, and telecommunication engineers, and safety and regulation experts, financial analysts, and lawyers).
Source: *McKinsey Global Energy Perspective 2022* Accelerated Transition scenario; *Renewable energy benefits: Measuring the economics*, IRENA, January 2016

— *Diversify and localize supply chains* for critical raw materials and components across multiple suppliers and geographies.

— *Explore opportunities for cross-industry pooled procurement* of raw materials.

— *Invest in recycling, innovation, and research around substitutes* for critical materials.

— *Explore opportunities for vertical integration* to secure critical raw materials and decrease price volatility, either through alliances and partnerships or through targeted acquisitions.

— *Optimize procurement strategies* by targeting long-term supply agreements or developing streaming agreements with advance lump-sum payments for future production.

— *Send clear demand signals* via long-term target and volume commitments, such as by announcing target developments in offshore wind to drive the upgrade of vessels.

— *Attract and retain workers* from the European Union and beyond by conducting early outreach in schools and offering targeted reskilling programs.

— *Reduce labor demand* through automation and digitalization.

Potential actions for other stakeholders
Other stakeholders could consider the following actions:

— *Scale up regional supply chains* to a critical minimum; for example, use incentives (including both taxes and subsidies) or insert sustainability and local content criteria into tenders and policies.

— *Encourage innovation,* including around substitutes for critical and scarce raw materials.

— *Harmonize regulations* and streamline permitting processes.

— *Introduce intra-European Union alliances to source strategic raw materials,* including rare-earth materials.

— *Increase OEM recycling of raw materials* such as aluminum, lithium, and cobalt by creating financial incentives and setting standards regarding higher levels of reuse.

— *Communicate and commit* on growth plans to build the confidence that will allow businesses to make proactive investments.

— *Invest in labor programs* for blue-collar energy transition jobs focused on metallurgy and RES manufacturing capabilities. Programs could include skilling and reskilling while also facilitating international and cross-sector utilization.

— *Attract and retain workers* from the European Union and beyond—for example, by facilitating migration, activating passive workforce segments, and ensuring a predictable and steady project pipeline.

The supply chains for crucial energy transition and electrification technologies are only as strong as their weakest links. Therefore, businesses and other relevant stakeholders may benefit from plotting out and mitigating potential risks along every step of the supply chain. This is a significant endeavor, but it is also a real opportunity for innovation and collaboration among stakeholders. Those that can build resilient, future-ready supply chains will be well positioned to reap significant benefits as the energy transition continues to gather momentum.

Stathia Bampinioti is a consultant in McKinsey's Athens office; **Harald Bauer** is a senior partner in the Frankfurt office, where **Friederike Liebach** is a consultant; **Nadia Christakou** is an associate partner in the Geneva office, where **Luigi Gigliotti** is an associate partner; **Lorenzo Moavero Milanesi** is a partner in the Milan office; **Humayun Tai** is a senior partner in the New York office; and **Raffael Winter** is a partner in the Düsseldorf office, where **Emil Hosius** is a consultant.

This article represents views from McKinsey's Advanced Industries and Electric Power & Natural Gas Practices and McKinsey's initiatives on orderly energy transition and industrial electrification.

The authors wish to thank Marcelo Azevedo, Patricia Bingoto, Stefan Burghardt, Greg Callaway, Tommaso Cavina, Spencer Dowling, Tamara Gruenewald, Alessandro Gentile, Magda Handousa, Blake Houghton, Jake Langmead-Jones, Simon Norambuena, Philipp Pfingstag, Hamid Samandari, Eivind Samseth, Namit Sharma, Erlend Spets, Paolo Spranzi, Fabian Stockhausen, Christer Tryggestad, Antonio Volpin, Alexander Weiss, and Jakub Zivansky for their contributions to this article.

Designed by McKinsey Global Publishing