Climate change threatens the world's most critical technology

Briefing for business leaders

US$1tn

The global semiconductor industry is tipped to hit US$1 trillion by 2030.

80,000

Processing copper ore from a single mine can consume enough water every seven weeks to fill an 80,000 seat stadium.

Executive summary

- A third of the global semiconductor supply could be disrupted by accelerating climate change within a decade, affecting all industries that rely on this critical technology.
- Climate change could harm semiconductor production because the mining of copper, a key material used to create semiconductor circuits, faces disruption from extreme weather and drought.
- None of the leading semiconductor-making countries and regions are spared from the growing risks. China, the US, Japan, Korea and Taiwan (Province of China) all face sharply rising risks to their semiconductor production.
- Semiconductors, often called chips, are the bedrock of the modern digital economy. They power critical systems from computers to energy grids, communication networks to transport. Semiconductors are required to transition to renewable energy and to seize the potential of AI and quantum computing. The global semiconductor industry is tipped to hit US$1 trillion by 2030.
- To make semiconductors, manufacturers need dependable supplies of materials like copper. Copper is used to create billions of microscopic wires that are the heart of semiconductor circuits – and without which semiconductors cannot function.
- Though researchers are seeking alternatives to copper for semiconductor production, it is difficult to find a readily available material that matches copper's advantages on performance and cost and can be used in production processes at industrial scale.
- Climate change can disrupt global supplies of copper by increasing the risk of severe drought at copper mines. Drought is problematic for copper mines because the mines require a steady water supply to function. Processing copper ore from a single mine can consume enough water every seven weeks to fill an 80,000 seat stadium.[1]

1 Processing ore from one mine requires about 30,000 m3 of fresh water a day which will fill an 80,000 seat stadium in about 7 weeks. Source: 'How can copper mines use less water,' Worley, 2023.

42%

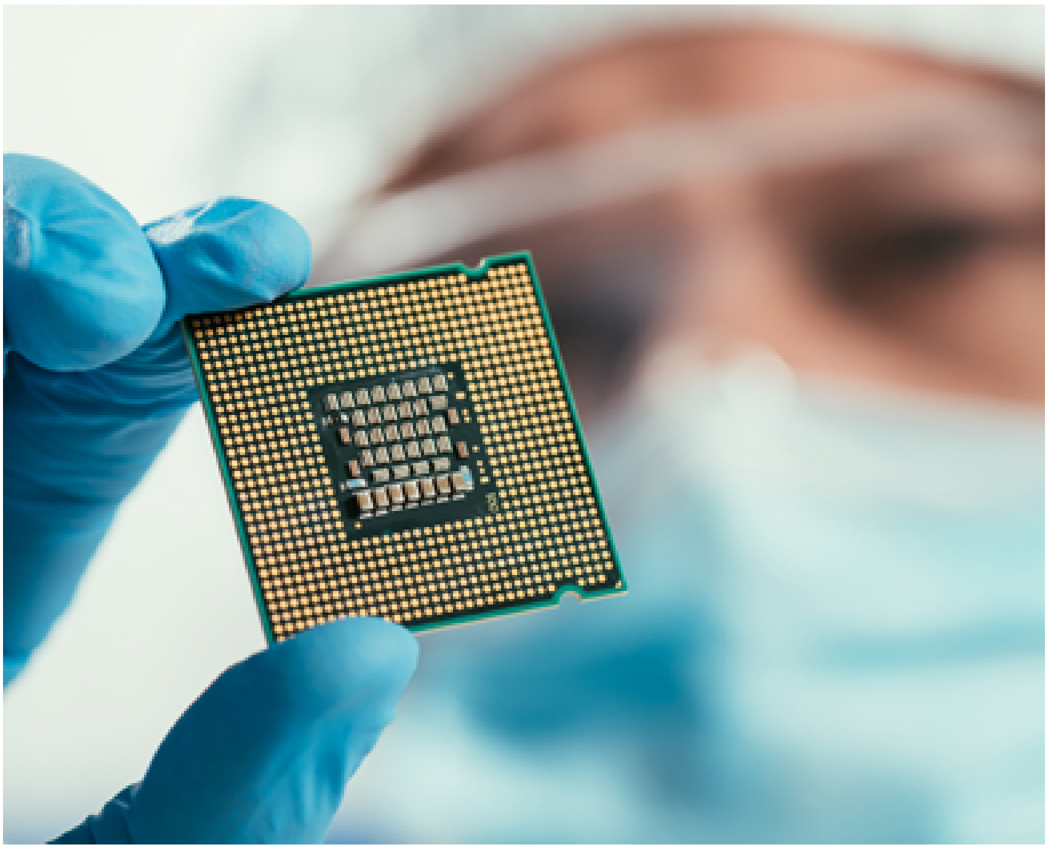
of global semiconductor production depends on an at-risk supply

- To understand the true scale of risks to semiconductor production, we traced the global semiconductor industry's copper supply back to copper mines across the world. Then we analysed how exposed those mines are to accelerating drought in coming years.
- We found that one-third of global semiconductor production is projected to rely on an at-risk copper supply within a decade. By 2050, even in an optimistic – and increasingly unrealistic - low carbon emissions scenario, 42% of global semiconductor production depends on an at-risk copper supply, rising to 58% by 2050 in a high emissions scenario.
- Today, all of the at-risk copper for the semiconductor industry comes from just one country, Chile, a nation which is taking assertive steps to protect its mines from drought. By 2035, however, copper from the majority of the 17 countries that supply the semiconductor industry is at risk. By 2050, in a high emissions scenario, copper from only three countries is *not* at risk. This means that far more countries may soon need to deploy drought management measures.
- Global temperatures are already exceeding 1.5°C above pre-industrial levels, meaning the world has probably already lost the battle to keep warming below 1.5°C. In fact, current estimates put the world on track for a temperature rise of over 3°C this century. As climate change continues to accelerate, climate threats to global supplies of critical commodities like copper are likely to grow at a steep rate.[2]
- Climate risks are accelerating rapidly and their future paths can be modelled, enabling companies to take steps to build resilience.
- Implications for business leaders in industries that rely on semiconductors: Leaders in these industries (automotive, telecom, healthcare, aerospace, energy, and more) should map and manage climate risks to their supplies. See the final section of this article, Next Steps for Business.
- Implications for all business leaders: This report highlights one type of climate risk to one critical global commodity – but this barely scratches the surface of the range of climate risks facing all companies. Leaders in all industries should map and manage the full scope of climate risks they face. See the final section of this article, Next Steps for Business.

2 'Global Climate Highlights 2024,' European Commissions Copernicus agency. 'Hottest January on record shocks scientists,' Financial Times, 6 Feb, 2025. Prediction of temperature rise over 3C this century comes from the United Nations Environment Program projections published October 2024.

Most companies rely on semiconductors in some way

Semiconductors, commonly called chips, are the brains of critical systems from computers to energy grids. They are the bedrock of the modern digital economy and have been called 'the world's most critical technology.' Many nations consider them essential to economic growth and security.[3] PwC research projects the semiconductor industry will reach a value of $1 trillion just five years from now (in 2030), fueled by the growth of AI and the Internet of Things.



3 Semiconductors have been called 'the world's most critical technology' by the Financial Times. Additional sources: 'Semiconductors and National Defense – what are the stakes', Centre for Strategic &I International Studies, 2022; 'Semiconductors in the EU,' European Commissions, 2023.

Semiconductors underpin modern life from computers to planes, phones to satellites

‘Semiconductors are the hidden lifeblood of modern technology, embedded in everything from computers and phones to cars and washing machines. That means disruption to the semiconductor supply can have severe economic consequences. For example, the U.S. Department of Commerce estimated that supply chain disruptions in the pandemic of the early 2020's caused a chip shortage that cost the U.S. economy a full percentage point in GDP growth and Germany 2.4%. A reliable supply of semiconductors is essential to economic stability and growth.’

Glenn Burm
PwC Global Semiconductor Leader, Partner, PwC Korea

Just as electricity revolutionised the 20th century, semiconductors are the invisible force propelling the 21st. Semiconductors will fuel the next wave of breakthroughs in the energy transition, AI adoption, quantum computing, and biotechnology.

Global semiconductor production is threatened by accelerating climate change

Climate change could disrupt semiconductor production in many ways. For example, extreme weather can damage infrastructure, shut down plants, and play havoc with transportation and communication systems. Such harms could heighten geopolitical tensions, lift prices or constrict supplies of necessities from energy to insurance, and raise the cost of capital for businesses that are unprepared to adapt to a hotter world.

Building on our previous study of how a changing climate could disrupt global production of key commodities, we focus on one key climate threat to the semiconductor industry: disruption to copper supplies.[4] Copper is the standard material used to create billions of microscopic wires that are the heart of semiconductor circuits - and without which semiconductors cannot function.[5] While alternative materials are viable for some semiconductor applications, there is no substitute for copper's balance of performance and cost.[6]

A robust supply of copper requires a robust supply of water. Around 1,600 litres of water are required to obtain the amount of copper found in a single medium-sized family car (19 kilograms).[7] Processing copper ore from a single mine can consume enough water every seven weeks to fill an 80,000 seat stadium.[8]

Unfortunately, drought is increasing in many of the areas where the world's copper mines are located. Accelerating drought could make it harder for these copper mines to produce as usual and to continue to provide the steady supply of copper on which global semiconductor production relies.

4 Copper is not the only critical commodity for semiconductor production threatened by climate change. For example, the global silicon supply has been disrupted by hurricanes, and the mining of rare earth metals has been disrupted by droughts. This means that the true extent of climate threat to critical commodities for the global semiconductor industry is much broader than shown in this article.

5 Copper is used in many other ways in semiconductor production too – for example, in the copper lead frames used in chip packaging.

6 Centre for Strategic & International Studies, 'Mineral Demands for Resilient Semiconductor Supply Chains', May 2024

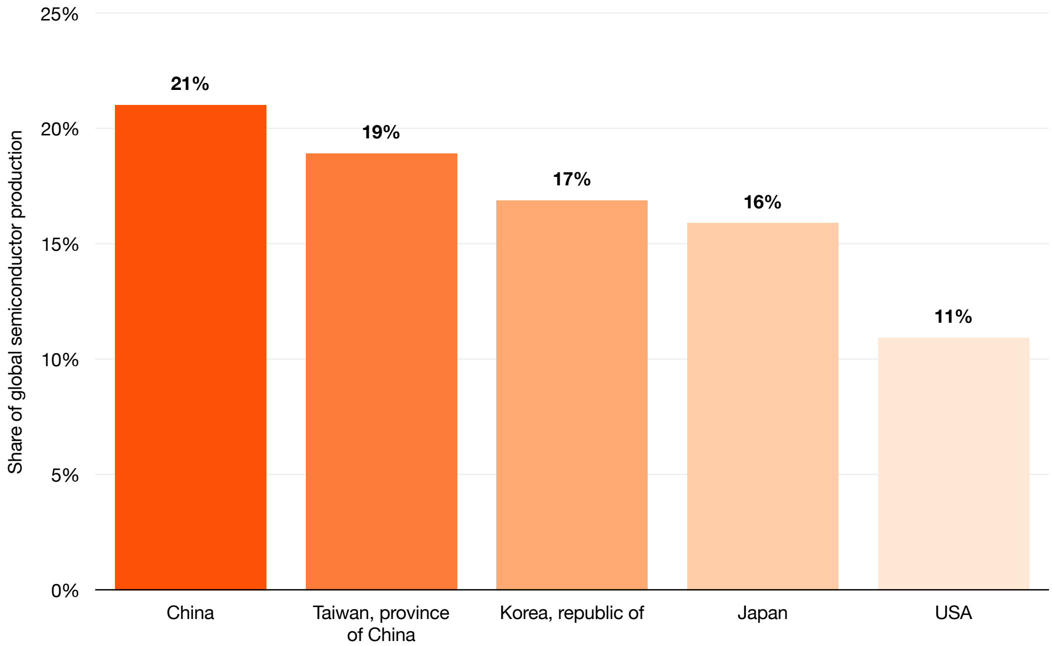
7 Commonwealth Scientific and Industrial Research Organisation, cited in 'Water considerations for copper mining in the Americas.' Refers to internal combustion engine car.

8 'How can copper mines use less water,' Worley Engineering, 2023.

Climate-driven drought could disrupt the semiconductor industry's copper supply

Taiwan, Province of China, is perhaps best known as a leading semiconductor producer, but in fact a number of nations make semiconductors. According to the Semiconductor Industry Association, five countries and regions lead the world in semiconductor fabrication: China, Taiwan (Province of China), South Korea, Japan, and the USA.[9] During fabrication, semiconductors' intricate electrical circuits are created and wiring—typically of copper—is added.

Top 5 semiconductor producers



Source: trade data

9 Semiconductor Industry Association, 'State of the Industry Report', page 23. We use semiconductor wafer fabrication as a proxy for semiconductor fabrication. Europe is the sixth biggest producer with an 8% share of global production.

We used trade data to determine where the top five semiconductor-producing countries and regions get their copper (including both domestic sources and imports). (See Appendix for more detail on our methodology.)

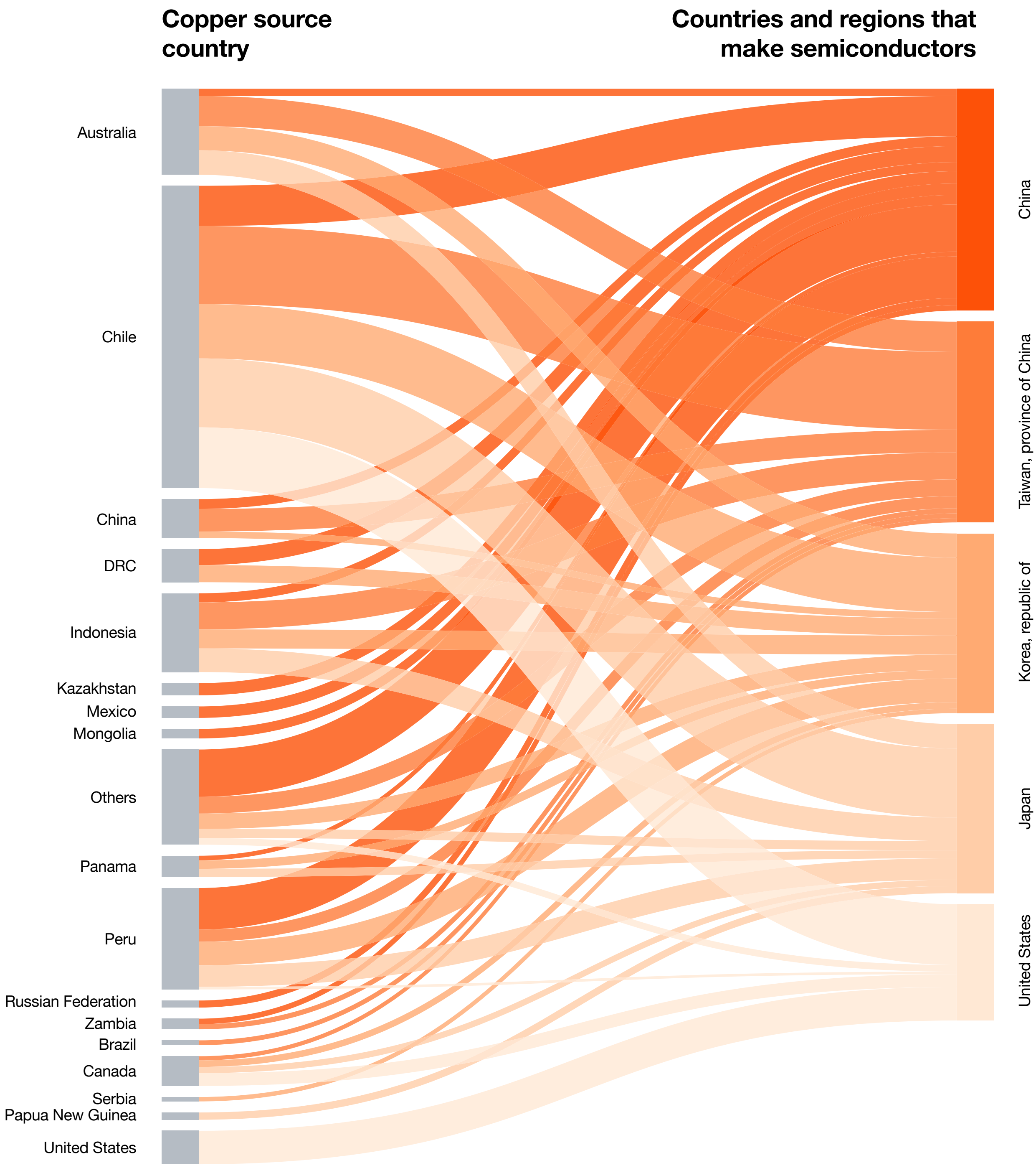


Chart notes: Width of each bar represents the share of a semiconductor producer's copper supply that is obtained from each copper source. 'Others' includes sources that supply less than 2% of a semiconductor producer's copper.

We located all major copper mines in each copper source country. We identified which copper mines are in a location projected to experience severe drought risk (defined as predicted to spend at least 20% of the time in severe drought; the true time in severe drought could be much higher).[10] This enabled us to identify the share of each country's copper production exposed to severe drought risk today, in 2035, and in 2050.[11]

For the latest year in our analysis, 2050, we tracked how drought risks vary according to how much progress the world makes in reducing emissions using two scenarios defined by the UN's Intergovernmental Panel on Climate Change.

- An (increasingly unrealistic) low-emissions scenario in which substantive action is taken to curb emissions, keeping global average temperature increase below 2°C (Scenario SSP1-2.6). The world is not on track to achieve this scenario.
- A high-emissions scenario in which no action is taken to follow a low-emissions pathway, resulting in a rise in global average temperature of 4.4°C by 2100 (Scenario SSP5-8.5).

We include these two scenarios to demonstrate that even in an increasingly unlikely low emissions scenario, climate risks still rise sharply. Businesses cannot rely on future emissions reductions to protect them from climate risks and should prepare now to operate in a world in which critical commodities will be increasingly threatened.[12]

10 Severe drought is defined as values below -1.5 on the Standardised Precipitation-Evapotranspiration Index, a multiscalar drought index. 20% of time in severe drought is measured over a 20 year time period centred on the year analysed.

11 For more on our methodology, please see our first report on global climate risks. We use the year 2020 as a baseline measure for today.

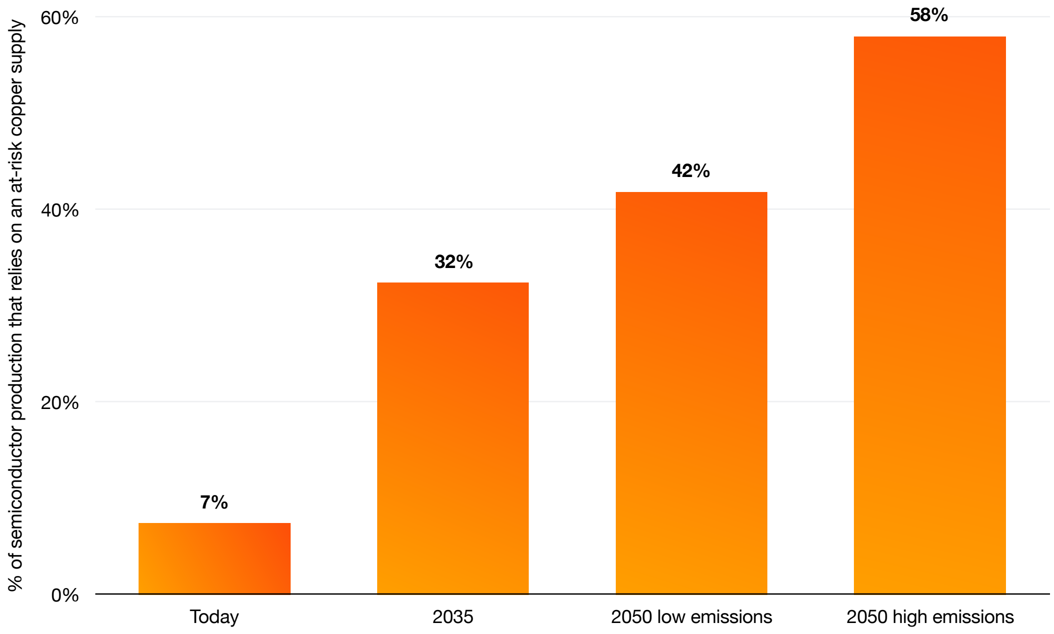
12 We combine our findings on risks in the top 5 semiconductor producing countries and regions to create a measure of global risk.

One-third of global semiconductor production is projected to rely on an at-risk copper supply within a decade

Today, only 7% of global semiconductor production relies on a copper supply that is exposed to severe drought risk. All of today's at-risk copper supply comes from Chile, a country that has taken assertive steps to manage drought risks to its mines. In future years, copper supplies are at risk in far more copper mining countries – not all of which may have taken the steps Chile has.

In 2035, the share of semiconductor production reliant on an at-risk copper supply more than quadruples to around a third (32%). By 2050, even in an optimistic low emissions scenario, 42% of global semiconductor production depends on an at-risk supply, rising to 58% in a high emissions scenario.

Global semiconductor production at risk

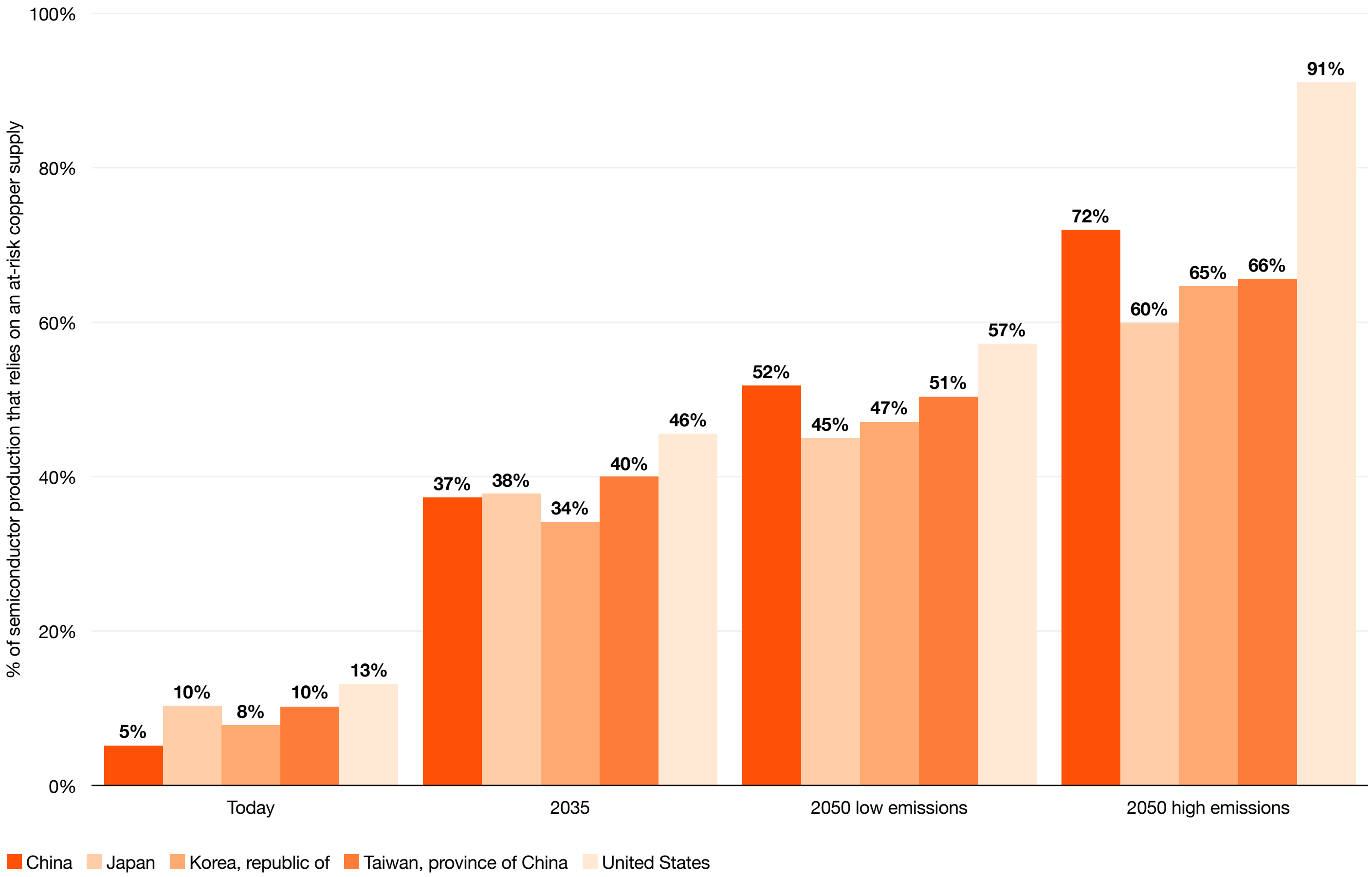


Source: PwC

No semiconductor-making country is spared from the rising risks

Today, 13% of each country's copper supply is at risk. As soon as 2035, at least 34% of every country's copper supply is at risk, and around half of every country's copper supply is at risk by 2050 – no matter how fast the world reduces carbon emissions.

Semiconductor production at risk by country



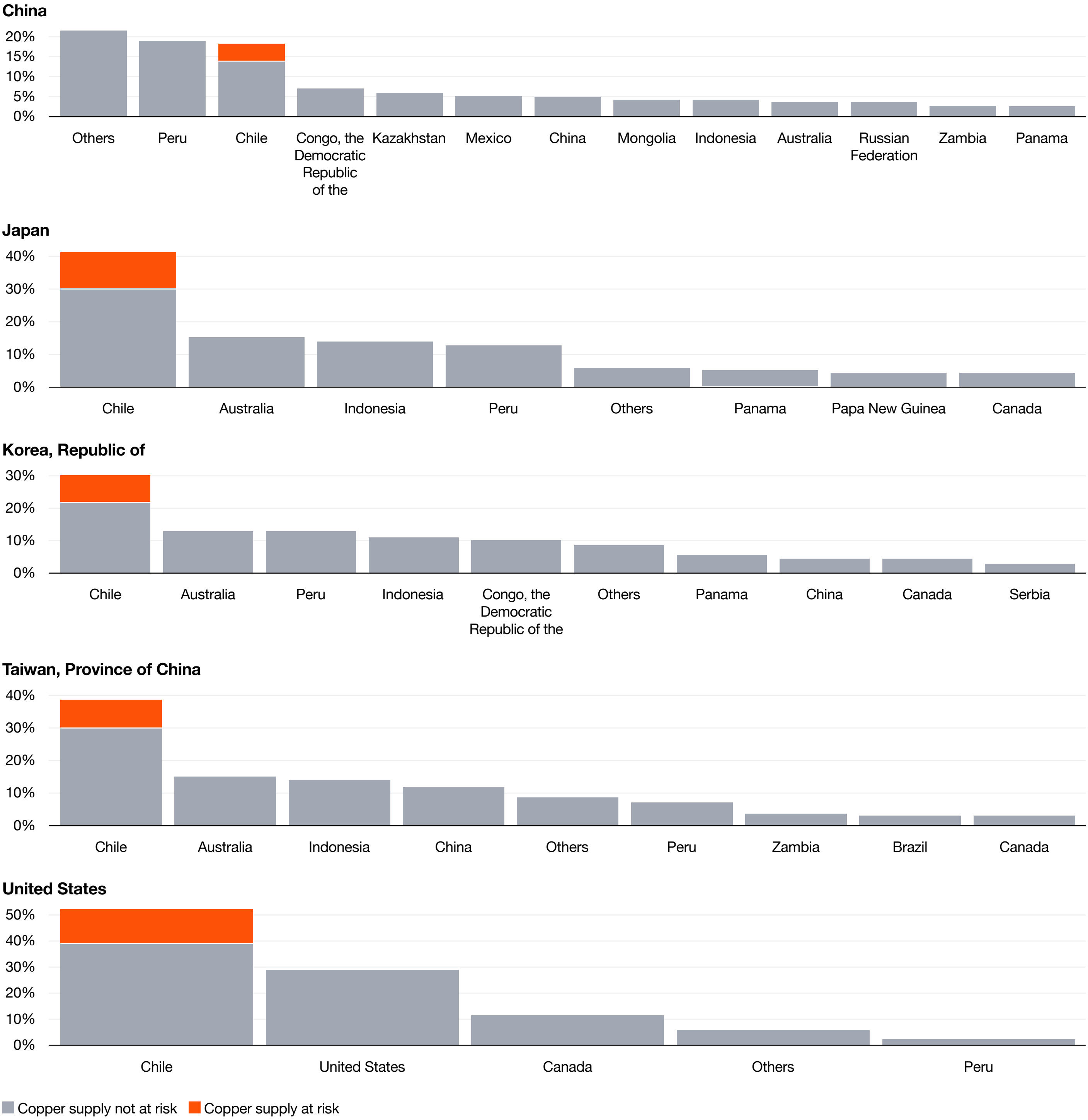
Source: PwC

Risk to copper supplies is spreading across the world

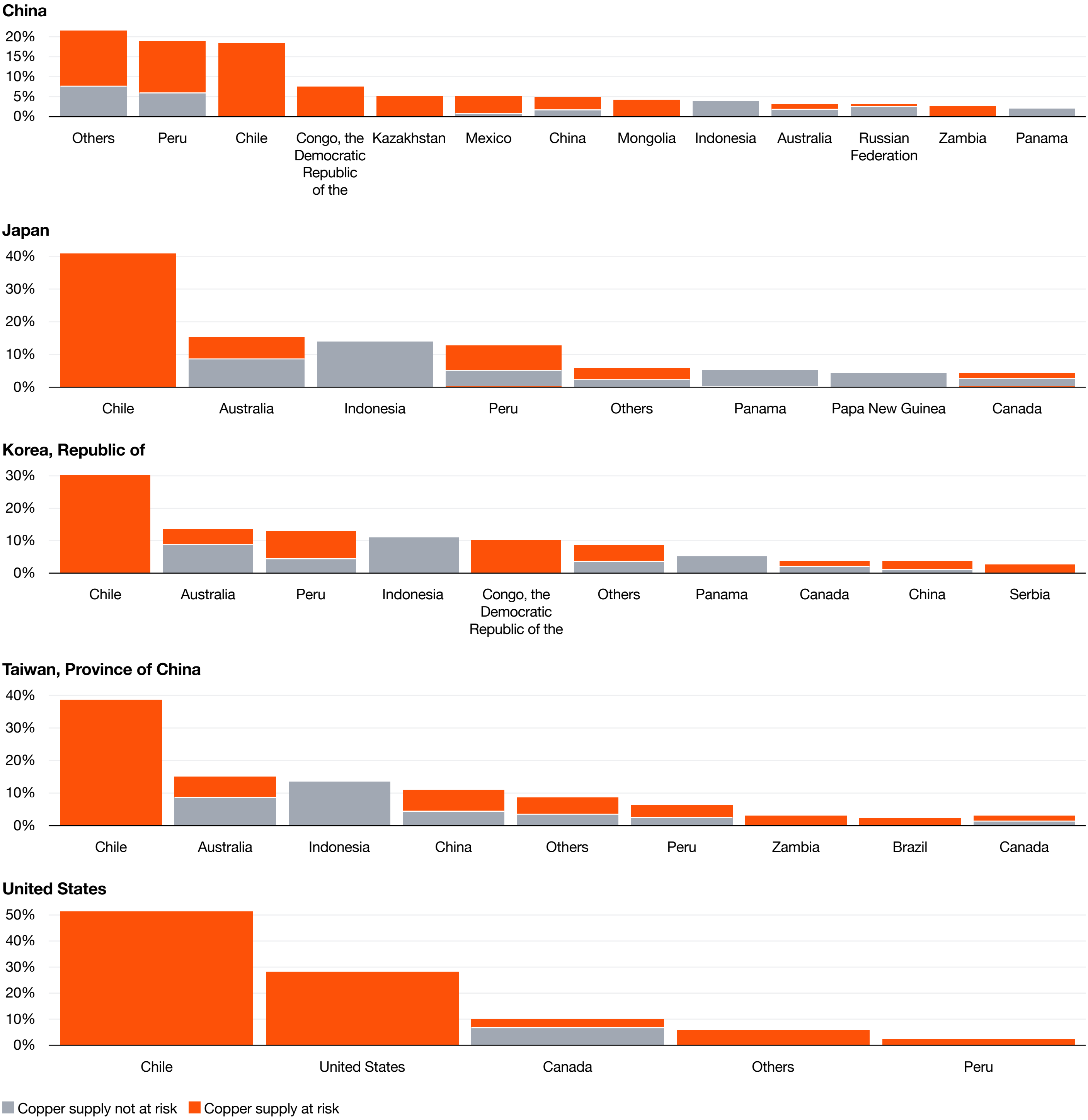
Today, all at-risk copper comes from Chile. By 2035, however, copper from China, Australia, Peru, Brazil, the US, Democratic Republic of Congo, Mexico, Zambia, and Mongolia is also at risk. By 2050, in a high emissions scenario, copper from only three copper mining countries is *not* at risk of drought (Papua New Guinea, Panama, and Indonesia).[13]

13 Excluding 'Others' which is an amalgamation of countries that each supply less than 2% of a semiconductor-producing nation's copper supply.

Today's sources of at-risk copper



2050 sources of at-risk copper (high emissions scenario)



Chile, a country already experiencing severe drought, continues to deploy measures to protect its copper and other mining production from water shortages. For example, to reduce its reliance on freshwater, Chile has built 22 seawater desalination plants with more under construction. The plants include a US$2 billion plant launched in March 2024 which will supply water to Chile's second largest copper mine. In addition, Chilean mining companies are investing heavily in technology to reduce water use.[14]

Soon, more countries may need to use similar methods to protect their ability to produce essential commodities as climate change accelerates. Chile too may need to make more widespread use of these methods as drought risks to its copper production rise sharply from 25% of production at risk today to 75% at risk within a decade and 90-100% by 2050.[15]

14 Global Business Reports, 'Mining, Water, and Climate Change: Desalination and recirculation preserve Chile's scarcest resource,' Oct 2024

15 90% of Chile's copper production is at risk by 2050 in low emissions scenario, and 100% in a high emissions scenario.

Next steps for business leaders

‘Threats to the semiconductor supply affect companies in a vast range of industries. For example, thousands of semiconductors are needed to build a single car. Accelerating climate change is a clear and present threat to semiconductor supply chain security. That makes it urgent for all companies involved in the semiconductor value chain to proactively track and manage climate risks as assiduously as any other supply chain issue.’

Tanjeff Schadt
Partner, Strategy&, PwC Germany

Next steps for copper miners

Some copper miners – especially in Chile – are taking actions to protect their operations from drought. Miners are, for example:

- **Improving water efficiency:** Innovations like dry-stack tailings minimise the amount of water needed for copper mining.[16] Managing evaporation and investing in alternative water treatment technologies can also help. Newer copper ore processing technologies like coarse particle recovery can more than triple the amount of copper recovered from ore, reducing the amount of water required to generate a given amount of copper.[17]

16 Dry stack tailings are a method of mine waste disposal in which tailings (the materials left over after extracting metals like copper from ore) are dewatered to create a dry, sand-like material. This is in contrast to conventional tailings storage where waste is mixed with water to form a slurry and stored in tailings ponds or dams. Source: ’How can copper mines use less water?’, Worley Engineering, April 2023

17 ‘Impact of copper shortages on the semiconductor industry,’ Stellarix 2022. ‘Water supply for mining industry: the Chile case,’ Arthur Little, 2023.

- **Recyling water:** Some companies have implemented advanced water recycling and reuse systems to minimize mines' demand for water. For instance, the Los Bronces copper mine in Chile has recycled more than 70% of the water it uses.[18]

- **Increasing water supply:** Many copper mining companies in arid regions such as Chile and Peru are, as we have seen, investing in desalination plants. For example, the Escondida Water Supply project pumps desalinated seawater over 100 km from the coast to the Minera Escondida copper mine.[19] Desalination plants have pros and cons so will not be the right solution for all mines. The plants provide a consistent and drought-proof water supply, but they also require high capex investment, incur significant ongoing costs for energy, and can only be built in locations where they can be linked by pipes to a large body of water.

Next steps for semiconductor makers

Semiconductor makers are increasingly recognising the risks posed by climate change and taking steps to address them. Here are some steps they are pursuing to manage risks to their copper supply.

- **Material Innovation:** Alternative materials, such as silver or carbon-based nanomaterials (like graphene and carbon nanotubes), are being researched for their potential to replace copper in certain semiconductor applications. However, there are challenges. Silver has better conductivity than copper but is less durable and much more expensive. Carbon-based materials, though promising, face significant challenges in terms of large-scale production and integration into existing semiconductor fabrication processes. Also, it is important to remember that these alternative materials too may face their own risks from climate change.

- **Efficiency Improvements:** Semiconductor manufacturers are seeking to design more efficient and compact circuits which can reduce the amount of copper needed while enhancing performance.

- **Diversification of Suppliers:** Semiconductor manufacturers can mitigate supply chain disruptions by diversifying their sources of copper. This reduces reliance on a single supplier or geographic region.

18 'Defining our water future,' by Hubert Fleming, Head of Water Management at Anglo American, 2017

19 'Sustainable water supply for Chile's copper mines,' Engineering and Mining Journal, 2020.

- **Recycling and Circular Economy:** Copper is one of few materials that can be reused with no decline in performance, making it an excellent candidate for recycling.[20]

Next steps for all business leaders

This report highlights one type of climate risk to one critical global commodity – but this barely scratches the surface of the range of climate risks facing all companies. Leaders in all industries should map and manage the full scope of climate risks they face throughout the value chain: risks to commodity supplies, transport disruption, insurance price spikes, and more.

For example, PwC traced climate risks along the value chain of a hypothetical smartphone maker from the mines that provide essential commodities through factories, ports, and all the way to end consumers:

Case study

Tracing climate risks to the global supply chain of a smartphone maker

Global supply chains can be highly vulnerable to the impact of physical climate risks, sometimes in ways we may not even be aware of. To highlight the wide range of physical climate risks that businesses face, PwC looked at their potential impact on the manufacture and supply of a typical smartphone. Researchers mapped the value chain of a notional smartphone and used this to create a simplified composite view of the physical climate risks involved at each step. They then studied the impact of seven climate hazards - floods, extreme rainfall, extreme wind, high heat, hail and thunderstorms, droughts, and wildfires - on these locations.

At every stage of the value chain, they found increased signs of physical climate risk that threatened the ability of the business to function reliably, even when the average global temperature was just 2C° higher. Higher temperatures at mines where the raw materials are sourced, for example, increase the likelihood of heat-related illness amongst workers, potentially raising the mine's operating costs as it seeks new ways to cool the mine and keep workers safe. Manufacturing and assembly of the smartphones in countries such as Japan and China, meanwhile, could be affected by heat and extreme rainfall, causing extensive flooding which damages factories and workers' homes. Extreme heat could also affect the transportation of the smartphones by disrupting the operations of a port, while drought-fueled wildfires are a risk to warehouses.

Finally, high wind poses a risk to distribution and retail sites, such as on Florida's Gulf Coast. At each stage of the value chain the physical climate threat comes both from the direct effects of the peril itself, such as a flood that knocks out a manufacturing site, and the indirect effects which arise for example from a flood destroying bridges to the manufacturing site.

20 International Copper Association, 'Copper Recycling.'

PwC supported a global consumer products company to precisely model the value at risk from climate change under both low and high emissions scenarios:

Case study

PwC quantified the value at risk and impact on future prices for a global consumer products company

The procurement team at a global consumer packaged goods company asked PwC to help it understand the potential impact of climate change on its ability to source 12 priority crops, including maize, soybeans and oranges. It also wanted to understand the potential impact of climate change on future orange yield and orange juice prices. PwC performed extensive research, data acquisition and statistical analysis to arrive at future climate impacts for each of the 12 crops. To develop value at risk metrics, PwC identified crop-specific growing regions through satellite imagery and client-provided data. We then identified regions highly exposed to drought, extreme heat and extreme cold under low and high emissions scenarios by 2050 using output from IPCC climate models. PwC then quantified the value at risk to the client by incorporating the client's procured volume and procurement spend for each crop and the climate exposure of their respective sourcing countries.

The client also had growing concerns about oranges due to their exposure to climate change and Citrus Greening disease, which is linked to rising temperatures caused by climate change. To address this PwC developed climate metrics for orange growing seasons in both Northern and Southern hemispheres as well as for the future prevalence of Citrus Greening disease. We then projected these metrics using IPCC climate model output under low and high emissions scenarios to map the changing suitability of growing oranges in different regions and the future likelihood of Citrus Greening disease. PwC also developed a model using historical country-level yield data and projected changes in orange juice prices due to a potential spread in Citrus Greening disease under different climate scenarios to represent the financial impact of the disease on the future orange juice prices.

With a clear picture of climate risks in hand, companies are equipped to prioritise and manage the risks, as PwC supported client Mosaic to do:

Case study

PwC helped Mosaic manage climate change risks to its operations

Mosaic is a leading producer of concentrated phosphate and potash and wanted to better understand how physical climate change risks could potentially impact its global operations. The PwC US team of climate risk specialists began by undertaking a broad qualitative risk assessment that outlined some of the most important potential climate-related risks to Mosaic's operations. Using future climate scenarios from a variety of established models and third party expert data sources, they then evaluated the potential business impact of each risk.

Together, Mosaic and PwC identified some of the highest-priority climate-related risks across the business, ranked by estimated likelihood of occurrence and severity of impact. Following this initial workshop, Mosaic identified four physical risks to study further. PwC analysed potential risk levels and associated business impacts of the largest physical risks to Mosaic. It leveraged 2°C and 4°C warming scenarios to examine the potential risks to the business under both a low-carbon economy and a high emissions scenario, creating a risk spectrum for the company's assets. PwC then integrated Mosaic's future plans and mitigation efforts to give increased focus to the analysis. The exercise helped Mosaic refine its estimates of the potential impacts that certain physical risks could have on its global operations. It will also enable it to make more informed decisions in the future.

Organisations can manage climate risks by collaborating with suppliers and other partners across the value chain to build climate resilience. For example, PepsiCo has worked with its critical suppliers to protect their operations from climate change:

Case study

PepsiCo supports its suppliers to build climate resilience

PepsiCo, one of the world's largest food companies, relies on a secure supply of more than 30 agricultural crops and ingredients - including maize, wheat and rice - from approximately 60 countries. In order to enable these supplies to be protected from the impact of climate-related risks PepsiCo works with its farmers to adopt regenerative agriculture practices — a set of techniques designed to improve and restore ecosystems in areas which could be affected by climate change to make soil healthier, capture carbon, improve watershed health, protect and enhance biodiversity and strengthen farmer livelihoods by optimizing their long-term yields and farm income.

The company supports a wide range of regenerative practices including planting cover crops to protect the soil, reducing tillage to maintain soil health and fertility, and encouraging livestock and other diversity onto farms. These practices help maintain and add nutrients, improve fertility, maintain soil carbon, control pests and weeds through sustainable management, improve biodiversity, maintain water quality and protect watersheds. By supporting farmers in this way, PepsiCo aims to help secure its supply while helping farmers address the challenges of climate change and prepare for agricultural challenges of the future.

For a detailed framework of next steps and many more examples of business action to enhance resilience to climate change, please see PwC's report developed in partnership with the WEF.

In conclusion

For some business leaders, the effects of climate change may seem either too far in the future to pose imminent risks, or too unpredictable to accurately foresee.[21] But climate change risks are accelerating rapidly and their future path can be modelled, enabling companies to take practical steps to build resilience.

What does all this mean for the semiconductor industry and companies that rely on it? Governments are taking action to secure national supplies of semiconductors (for example, the US CHIPS Act, EU Chips Act, or South Korea's "K-Semiconductor Belt" strategy aimed at building the world's largest semiconductor supply chain by 2030). These programs are driving billions in public and private investment, but their ultimate success depends on factors such as securing skilled workers, accessing sufficient materials, navigating regulatory hurdles, and securing continued political support. Companies that rely on semiconductors would be wise to consider the security of their own supply.

The world's average temperature has already exceeded 1.5C, and warming is continuing to accelerate at an alarming rate.[22] This means that climate threats to the semiconductor industry's supply of copper (and other commodities) are unlikely to decrease.

Making matters tougher, demand for copper is predicted to explode in coming years as a growing global population, skyrocketing demand for computing power, and the energy transition all increase demand for copper (according to some sources, achieving net-zero emissions targets will require as much new copper as humanity has produced in all of recorded history).[23]

The actions of Chile's copper mines offer an example of how climate risks can be managed and commodity supplies protected. Proactive efforts to understand and manage climate risks – while continuing to accelerate emissions reductions – is the right approach.

21 PwC's 27th Annual Global CEO Survey in 2024 finds that 47% of CEOs are taking proactive measures to safeguard their workforces and physical assets from climate change – which of course means the majority are not.

22 'Global Climate Highlights 2024,' European Commission Copernicus agency.

23 Mineral demands for resilient semiconductor supply chains,' Centre for Strategic and International Studies, May 2024

Appendix: How we trace sources of copper

BACI is the Analytical Database of International Trade that provides yearly data on bilateral trade flows at the product level for over 5,000 products and 200 countries.

We filtered BACI data for the following HS codes corresponding to copper ore, unrefined copper and refined copper.

HS Code	Copper Category	Multiplier
260300	Copper Ore	1
740200	Unrefined Copper	3.3
740311	Refined Copper	3.4
740312	Refined Copper	3.4
740313	Refined Copper	3.4
740319	Refined Copper	3.4

Multipliers were attached to the trade volume based on estimated copper content in the HS codes to homogenize traded volumes to the ore level.

30-40% for ore (the ore that is traded does undergo some refining/processing and % purity is around the 30% mark); **99% for unrefined copper; 99.99% for refined**

(Source: Copper Mining and Processing: Processing Copper Ores, Superfund Research Center)

To get to the source of traded copper and eliminate middlemen countries from the data as much as possible, we check the exporting country against the list of copper mining countries.

1. If exporting country is present in this list, then it is assumed to be the source country of that copper ore
2. If exporting country is not present in this file ("middleman" scenario):
    a. Use the copper ore HS code and BACI data to identify the source of copper ore and calculate percentage share of the copper ore imports by source country for the "middleman" country
    b. Distribute the exported volume of copper from the "middleman" country to its source countries in the same proportions as their share of the "middleman" country's copper ore imports
    c. Example: Country A exports 1000 units of copper to country B but Country A does not mine any copper itself. Country A gets 30% of its copper ore from Country C, 50% of its copper ore from Country D, 20% of its copper ore from Country E. The 1000 units that country A exports to country B are now instead distributed (credited as source country) to countries C (300 units), D (500 units) and E (200 units)
3. For the domestic mining output of in-scope countries:
    a. Domestic mining data is filtered for the in-scope countries which are major producers of semiconductors
    b. Filtered domestic mining data is modified to make it compatible to the trade data. New columns 'import country' and 'export country' are the same (i.e., mining country). Domestically mined quantity is considered equivalent to trade volume.
    c. Modified domestic mining data is then appended to the trade data

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