CIRCULAR REPUBLIC

The Business Case for a Circular Economy

The growing fragility of global supply chains highlights the need for circular business practices

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Management Summary

This white paper shows the magnitude of supply chain risks, their associated costs and ultimately how those risks can be leveraged through investments in the circular economy. In many instances including opportunity costs of supply chain risks makes a positive business case for building circular value chains.
The modern landscape of global trade, characterized by a remarkable era of efficiency driven by globalization and industrialization, has seen supply chains evolve into complex, transnational networks. Simultaneously, this complexity has exposed a fundamental vulnerability, as recent events – from natural disasters to global health crises, such as the COVID-19 pandemic or Panama Canal drought – have demonstrated.
This white paper provides an analysis of historical crises and their impact on local and global economies. Our findings indicate that supply chain disruptions with global effects occur approximately every 1,4 years and the trend is rising. Those disruptions cause major economic damages, ranging up to 5-10% of product costs and additional downtime impacts.
It is also in response to these challenges, that the European Union (EU) has implemented strategies to reduce its dependence on non-EU countries for raw materials. Initiatives such as the Critical Raw Materials Act and the push towards a circular economy aim to strengthen European resilience by reducing the dependency on key global suppliers, particularly China, which is a major supplier of critical materials to the EU.

The Allianz Trade Survey 2024 (3.200 surveyed firms) finds that the risks posing the greatest threats to supply chains are risks related to geopolitics. Politics and protectionism come next, followed by ESG-related risks like natural desasters.
To understand the risks related to high supply chain dependencies, the paper provides two in-depth use cases focusing on the material composition of key components in a battery electric vehicle (BEV) and a power tool as well as their dependency on China. These cases quantify the monetary risks associated with this exposure and the potential additional purchase costs in the event of a supply chain disruption, shedding light on the economic stakes of such vulnerabilities.
Our analysis shows that a product's material dependency on China's supply can be as high as 91% and the risk in an industry product, despite the potential for material substitution, lies at >€1,300 per battery electric car or >€2,40 per power tool – for both a significant share of the costs, not even accounting for potential revenue losses from down-times.
To address these risks, the white paper recommends six investable strategies, emphasizing the importance of adopting circular operations to mitigate supply chain risks effectively. Investing into those six strategies mitigates the before-mentioned risks and provides companies with the insights and tools necessary to navigate the uncertain terrain of global supply chains, ensuring resilience and sustainability in their operations.

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Business context is changing

In recent decades, the increasing pace of globalization and industrialization has strongly transformed global trade dynamics, promoting an era of unique efficiency. Supply chains have evolved into complex networks that transcend national borders, making crossing geographical boundaries less relevant for multinational corporations.

Despite these advancements, recent events have underscored the fragility of these complex networks. Supply chain disruptions, ranging from unforeseen natural disasters at a supplier's site to extensive crises like the COVID-19 pandemic, red sea crisis or Panama Canal drought, have exposed significant vulnerabilities and highlight the increased dependencies on global supply.

The consequences of these disruptions encompass both monetary and non-monetary impacts. Monetary impacts manifest as increased production costs due to the need for alternative sourcing, higher logistic expenses and escalated inventory carrying costs. Simultaneously, constraints on material supply and subsequent production delays result in lost revenue, diminishing profit margins and operational inefficiencies. Non-monetary consequences include reputational damage, tarnished brand image and heightened customer dissatisfaction from delayed deliveries or product unavailability.

All these effects are immense, the costs of downtime [1] alone are huge: In the UK **manufacturing industry**, the cost of downtime is approximately $260k per hour. Health care is already at > $600k/h, retail at >$11 million/h. Also, in energy ($2 million/h) and telecommunications ($2 million/h) effects are huge. The largest effect can be found in the **automotive industry**, where downtime costs rise to about $3 million per hour. Our analysis indicates that significant crises with international economic implications occur, on average, every 1,4 years. While crises happen more frequently, this calculation specifically includes only those that cause substantial international damage or lead to widespread economic suffering – quantified exemplarily in the second chapter of this paper.

These disruptions have profound implications, affecting not only businesses but also national economies. Considering the impact of these disruptions this paper will explain in detail how companies can adress this changing context through six strategies paying into a circular economy. While forecasting future disruptions poses a challenge due to their unpredictable nature, a retrospective analysis of past incidents highlights the severity and increasing frequency of supply chain disruptions. Historical patterns reveal that supply chain disruptions can be broadly categorized into five main causes: **Macroeconomic factors, health crises, geopolitical tensions, trade restrictions and natural disasters**. These are each described in detail on the following five pages.

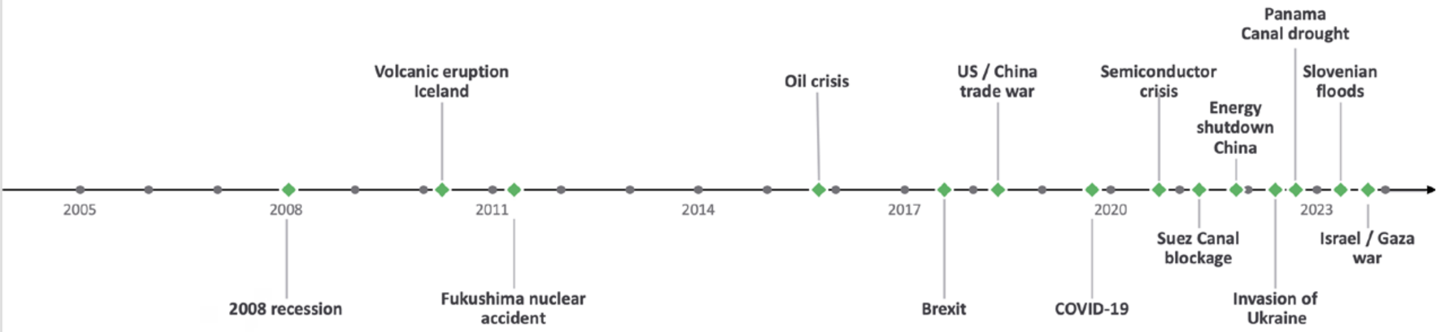


Figure 1: Frequency of global crises

Macroeconomic factors

Macroeconomic phenomena such as recessions and inflation introduce heightened volatility into labor markets and demand dynamics. These fluctuations can trigger cascading effects throughout supply chains, disrupting the production, distribution and consumption of goods and services. Given the interconnected nature of modern supply chains, the macro-economic conditions of one economy can rever-berate across borders, impacting global markets.

The 2008 recession serves as an illustrative example of how macroeconomic turbulence impacted global economies and production patterns. Triggered by the US subprime mortgage market collapse, it sparked a worldwide financial crisis, affecting various industries. Global trade suffered a significant decline, particularly impacting export-dependent economies. The recession led to a 14,6% decline in European industrial production in 2009 [2] (see figure 2), contributing to a substantial 4,4% contraction in European GDP [3] (see figure 3).
Germany, which accounts for the highest share of industrial production within Europe and is largely represented by its automotive industry, suffered production declines of 21,5%. Overall, the EU suffered production declines in the automotive industry of 25%. The industrial manufacturing sector was hit the hardest during the 2008 recession, as displayed in figure 4.

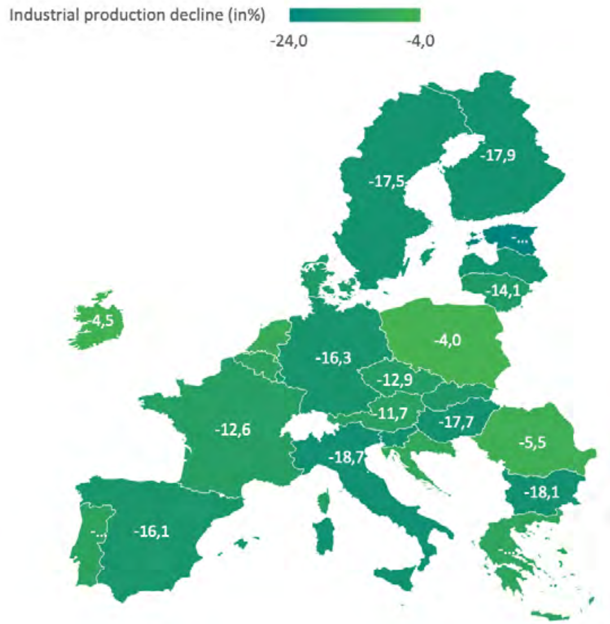


Figure 2: Industrial production decline EU 2009 vs. 2008

Figure 3: GDP decline EU 2009 vs. 2008

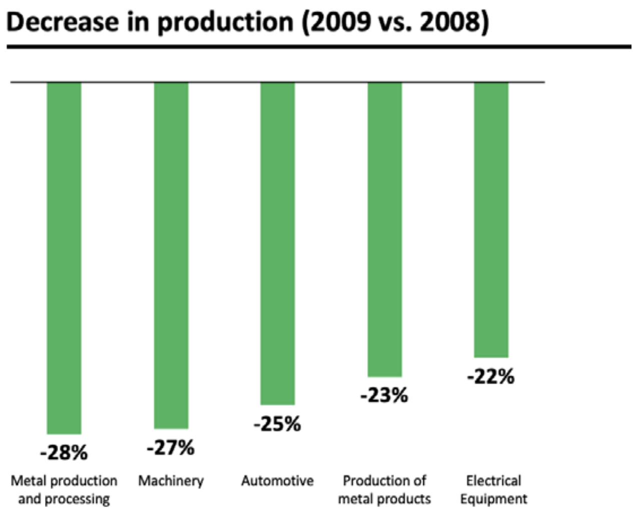


Figure 4: Effects of 2008 recession on selected EU industries [2]

Global health crises

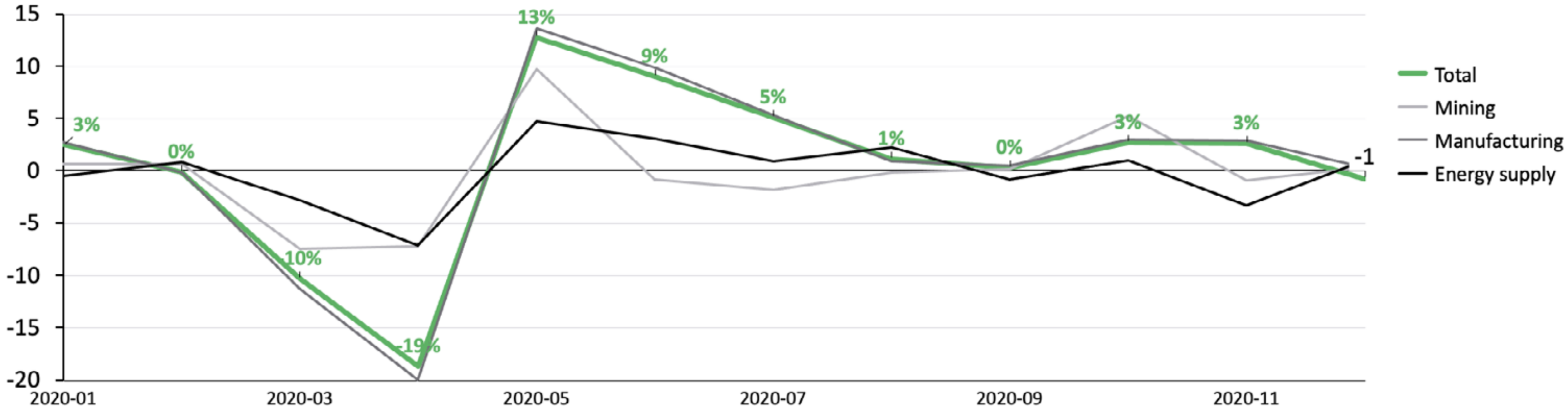


Figure 6: Impact of COVID-19 on industrial production [relative change in % to previous month] [6]

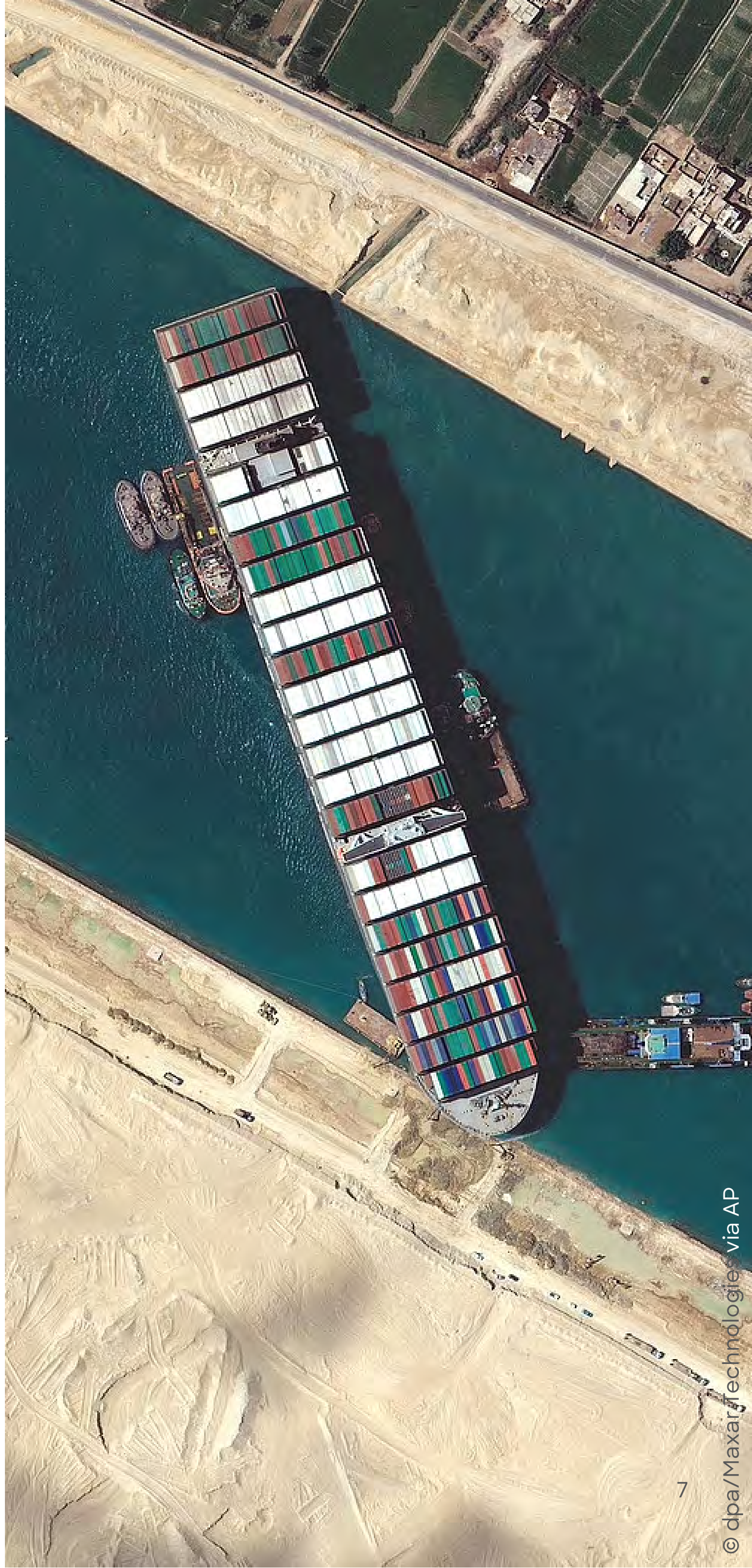
Health crises can be triggered by a variety of factors, including natural disasters or human-wildlife interactions and pose challenges in our interconnected world. The consequences of such health crises are far-reaching and multifaceted. At the forefront is the human cost, with increased mortality rates as the most immediate and tragic outcome. However, the impacts extend beyond the loss of human life. The strain on healthcare systems can lead to overwhelming costs and the disruption of global trade can result in significant economic downturns, affecting both local markets and the global economy.
The COVID-19 pandemic emerged as a prime exemplar of a global health crisis with profound economic ramifications. Its rapid spread instigated significant disruptions across global production networks, heightened by stringent lockdowns, social distancing protocols, stranded containers and travel restrictions. These measures, essential for mitigating the virus's transmission, had a cascading effect on the value chains of nearly all industries, severely affecting sectors such as airlines, automotive, energy, hospitality and retail. This illustrates the extensive impact health crises can wield on economic stability. The aviation industry, heavily hit by travel limitations, faced an estimated $370 billion in revenue losses in 2020 alone [4]. The European industrial production sector was also hit hard, albeit not as hard as during the 2008 recession, partly due to a significant 8,2% increase in pharmaceutical production compared to 2008 levels. Despite this uptick, overall production fell by 7,4%, with the textile industry bearing the brunt of the pandemic's economic fallout with a total production decline of 28% [5].

Looking ahead, the likelihood of global health crises is expected to increase, mainly due the ongoing degradation of our ecosystem, driven by deforestation, wildlife exploitation, greenhouse gas emissions and the relentless extraction of natural resources. Climate change, resulting from these activities, facilitates the expansion of disease vectors, such as mosquitoes, by enlarging their habitats. This, in turn, increases the risk of infectious diseases spreading uncontrollably as warmer conditions create ideal breeding grounds.

Geopolitical risks

Geopolitical risks, often emerging from political instability, trade disputes and military conflicts significantly challenge supply chain stability. The effects of geopolitical tensions can cause a range of disruptions, including sanctions, production halts and military actions, profoundly affecting global trade.
An illustrative example of such disruptions is the trade war between the US and China in 2019, along with a general block building between the US, China and the EU. Characterized by tariffs and retaliatory measures, this conflict disturbed supply chains across various industries, particularly impacting companies reliant on trade between these two major economies. Nations with strong economic connections to both the US and China, such as Germany and Japan, found their industries, especially automotive and electronics, strained.
A more severe example of geopolitical risks are wars and political escalation such as the Russian invasion of Ukraine which impacted a variety of sectors. Strategies like nearshoring and supplier diversification (as explained in detail later in this report) are typical reactions of companies to these threats. Especially, the European energy industry faced increasing costs resulting from embargos and price caps on Russian oil and gas [7]. Subsequently energy intensive industries such as the chemical and steel industry were facing higher prices which they in turn transferred to their customers, thus affecting a wide range of industries.

More recent tensions, such as the conflict between Israel and Hamas, once again highlighted the vulnerability of global supply chains.
Attacks by the Houthis, a Yemeni civil war party, on ships traversing the Red Sea have created significant hurdles for European companies dependent on Asian imports of raw materials and goods. These disruptions have led to delivery delays and increased logistic costs as shipping companies opt for longer, albeit safer, routes around the Horn of Africa. Car manufacturers operating in Europe, such as Volvo and Tesla, reported production stoppages of up to two weeks due to these logistical problems [8].
The strategic importance of the Red Sea trade route was already highlighted by the Ever Given incident in 2021, which blocked the Suez Canal for six days. Considering that 90% of global trade is conducted by sea [9] and 12% of global trade passes through the Suez Canal [10] disruptions like these have substantial economic consequences. Allianz estimated the economic losses caused by this incident to range between $6 bn - $10 bn per day [11]. As the Suez Canal was blocked during a total of 6 days the Economic losses may be as high as $60 bn.



Trade restrictions

Trade restrictive measures and policy barriers impede the cross-border flow of goods and services. These measures, exemplified by events such as Brexit or tightened export regulations in China, pose additional hurdles for companies operating in global supply networks. Export duties and taxes on imported goods, as well as restrictions on trade in cutting-edge technology, create uncertainty and increase operating costs for companies engaged in international trade. Brexit has complicated trade relations between the UK and the EU and led to delays in deliveries. Similarly, China's strict regulations, such as the introduction of tariffs on certain imports and exports, particularly of raw materials, have disrupted supply chains and required strategic adjustments by multinational companies operating in the region. Recently, China began restricting the export of gallium and germanium in the summer of 2023, followed by the control of graphite exports in the winter of 2023. Graphite anodes are an essential component of the lithium-ion batteries used in electric vehicles and are therefore crucial for the European automotive industry.

Such restrictions may lead to a reduced availability of graphite anode material and massively rising prices. Current trade restrictions are mainly targeting critical raw materials, as classified by the EU. An analysis of Allianz shows that within the last decade export restrictions on critical raw materials increased by a factor of five [12]. Especially countries accounting for the largest mining and processing shares for critical raw material such as China, heavily impose export restrictions. Allianz calculated that just removing tariffs on green goods could boost exports volumes by over +10% per year, which amounts to about $184 billion [13].

Natural disasters

The impacts of natural disasters, including earthquakes, hurricanes, floods and wildfires, on supply chains can be direct when impacting transportation networks and distribution channels or indirect when affecting specific production facilities. However, even while indirect impacts might initially seem localized, their effects frequently ripple across regional and national borders, as supply cannot be assured.

The 2010 Icelandic volcanic eruption is a prime example, where the resultant ash cloud led to widespread disruption of air travel across Europe, directly impacting distribution channels. This event caused notable delays in the delivery of goods and components, directly affecting various industries. The automotive industry was impacted, with BMW suspending production at three of its plants in Germany due to a shortage of parts [14]. Similarly, Nissan experienced production setbacks in Japan because air pressure sensors from Ireland could not have been delivered [15].

Recent disruptions to critical infrastructure, such as the Panama Canal drought and Red Sea tensions, highlight the vulnerability of global trade to climate change and conflict. These interconnected systems are essential for economic stability and any disruption can have severe consequences. For instance, climate-related damage to European infrastructure is projected to rise tenfold to €37 billion by 2100, while persistent low water levels in the Panama Canal could reduce global trade by nearly 7% by the end of 2024 [16]. The threat of climate change further intensifies these vulnerabilities. Data highlights an increasing trend in the frequency and economic impact of natural disasters over recent decades, with projections indicating a continuation of this trend (see figure 8). Allianz highlights that this comes with the risk that increasing parts of the world are not insurable any more [17].

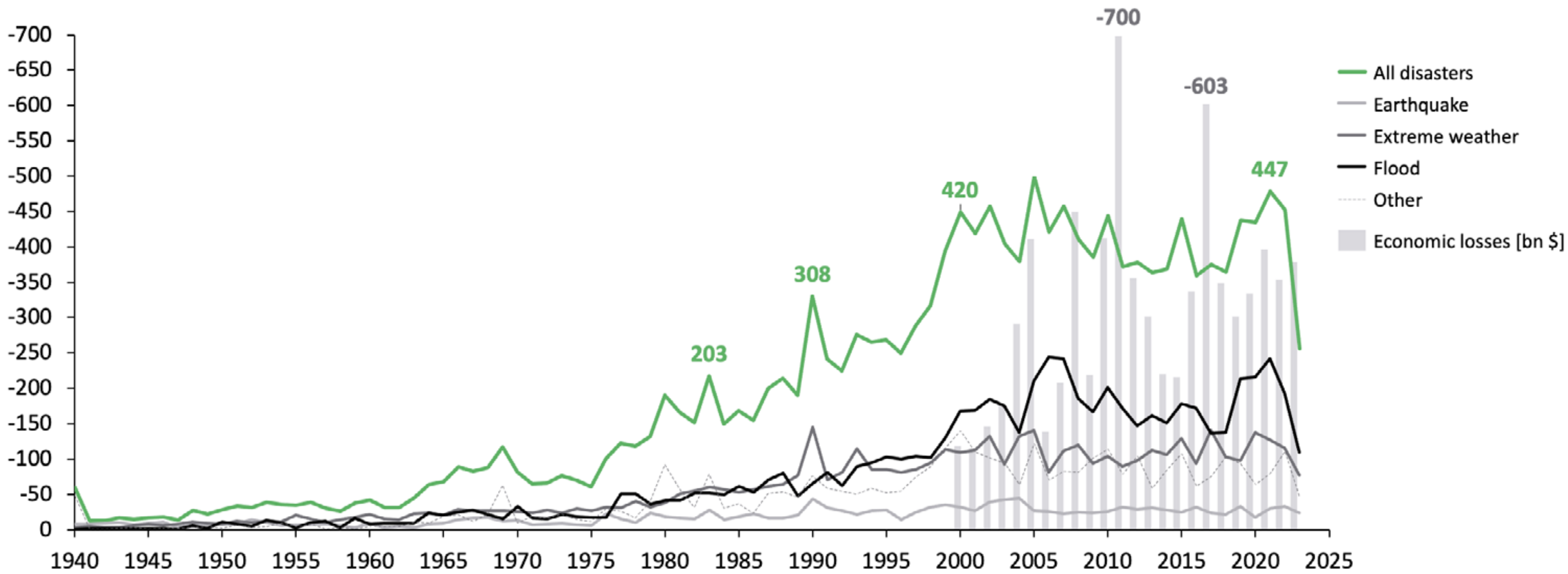
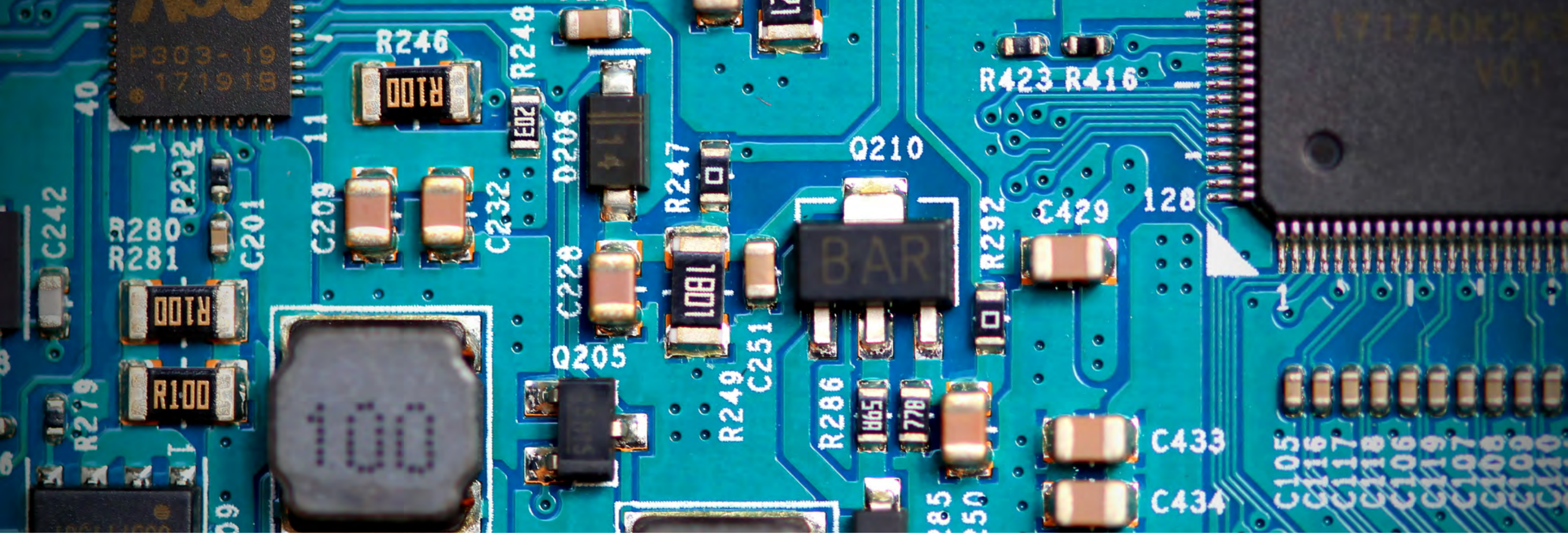


Figure 8: Number of yearly natural disasters and global economic losses [$ bn] [18], [19]



Connected crisis – example: Semiconductor crisis

Supply chain disruptions often unfold as bullwhip effect, where an initial incident triggers a series of related disruptions, escalating into broader crises. The semiconductor shortage during the COVID-19 pandemic illustrates this dynamic vividly. The pandemic caused widespread shutdowns or scale-backs of production facilities worldwide to limit virus spread, causing an economic downturn and subsequently shifting consumer demands.
A notable shift was the increased demand for electronic goods due to the rise of remote work, online learning and digital entertainment, which collided with the constrained supply from closed semiconductor factories.

Integrated Device Manufacturers focused on meeting the booming demand in the consumer electronics market, sidelining other industries like automotive. This prioritization left the automotive sector grappling with production halts and delays, intensified as the immediate impacts of the pandemic settled but the semiconductor shortage persisted. European automakers, in particular, faced significant challenges, spotlighting the semiconductor supply chain's critical role in modern economies.
The crisis prompted regulatory actions aimed at strengthening supply chain resilience. Besides the Chips Act, aiming for the autonomy and robustness of semiconductor supply chains, the EU also introduced the European Critical Raw Materials Act. This aims to decouple Europe's dependency on mining materials crucial for green technologies such as batteries, wind turbines or photovoltaic. Similarly, the United States has also taken steps to not only encourage domestic semiconductor production but also to strengthen the local raw material extraction and processing. These measures reflect a growing recognition of the need for strategic planning and investment to secure supply chains against disruptive events, ensuring the continuity and reliability of critical sectors in the face of unforeseen challenges.

Role of insurers for managing these risks

by Michael Bruch, Allianz Commercial

Recent events, such as the semiconductor shortage that crippled the automotive industry, have highlighted the vulnerability of linear supply chains and the significant losses businesses can incur. These incidents underscore the necessity for robust risk management strategies and insurance solutions that address the complex nature of supply chain interruptions.

The role of the insurance industry goes beyond risk transfer. Insurers act as proactive partners in strengthening supply chain, enhancing product safety and promoting the circular economy. The circular economy is not only an environmental initiative, it is a risk mitigation imperative. By embracing circular principles, companies can reduce their exposure to supply chain disruptions, which can lead to significant financial losses and operational downtime.

However, new risks may emerge with circular economy, as the use of recycled materials in new products can introduce significant safety and quality risks, due to the potential retention and introduction of toxic chemicals, exacerbated by insufficient tracing and regulation.

To evaluate those interlinked risk landscape specialized risk consultants bring expertise in identifying and evaluating the complex risks associated with global supply chains and circular economy, helping businesses to understand and prepare for potential disruptions and new risk exposures. These professionals assist in resilience services and in crafting tailored insurance solutions that align with the unique challenges and opportunities presented by the circular economy. By doing so, insurers enable companies to confidently invest in sustainable practices, knowing they have the support to manage risks effectively. The strategic expertise combined with the protective layer of insurance empowers businesses to innovate and thrive in a circular economy while safeguarding against the financial impacts of unforeseen events.

This comprehensive approach demonstrates the insurance industry's commitment to not just insuring the present but navigating the complexities and embracing the opportunities of the 21st-century marketplace, with a clear focus on quality and safety in line with sustainability goals.

Use cases: Cracking the numbers

Due to increasingly complex and interdependent supply chains, we explored the potential financial impact on companies from supply chain disruptions in two case studies. These cases specifically address scenarios in which supply from Asia is disrupted. We analyzed key components and material groups for their mining, processing and production dependencies.
The selected components are either crucial to the product's functionality, such as electric vehicle batteries, contribute significantly to the product's weight, like metals and plastics in vehicles, or contain several critical raw materials as classified by the EU.

Our analysis involved examining the material composition and identifying the countries responsible for mining and processing these materials. For some components, such as batteries, we examined the entire value chain, beyond the material processing, as the manufacturing or assembly stages are also dominated by one single country.
The greatest dependence on Asia at one stage of the value chain was considered representative of the overall dependence because the dependency in one step in the value chain influences the dependency of the entire value chain.

The cost of the critical and dependent components and materials was calculated by multiplying the maximum percentage dependency (within the value chain) with the purchase price of the component or material.
This calculation quantifies the financial value share of a product which is dependent on Asia.

Finally, the additional procurement costs, factoring in a 13% price increase for sourcing components and materials from alternative locations was calculated. This 13% increase is based on reference projects from manufacturing companies during the semiconductor crisis, where the average price increase - or the average willingness to pay a price premium - was observed to be 13%. It is important to note that this estimate can be considered as relatively conservative, as actual price increases can exceed those 13% by far. Additionally, our calculations do not account for potential revenue losses resulting from production downtimes, which can significantly impact a company's financial performance.

The two cases involve products from two industries. First, a middle-class battery electric vehicle (BEV) and second a power drill was analyzed.

First example case: Automotive

8 key components of a middle-class BEV were analyzed. 7 of these are included in the overall calculation, as the 8th component is a fuel cell, which is currently not widely spread in European car manufacturing. In total the dependency of the components reaches a maximum of 91% towards China for certain components or materials. The potential additional purchase costs per vehicle sum up to a total of €1.300 to €1.600.

Figure 9: Case Study: Risk costs of an average battery electric vehicle

Battery

Costs	~10.000 €
Costs of critical materials	~ 7.500 €
Additional costs	~ 975 €

Electric engine

Costs	~ 900 €
Costs of critical materials	~ 470 €
Additional costs	~ 60 €

Fuel cell

Costs	*~ 10.000 €*
Costs of critical materials	*~ 6.700 €*
Additional costs	*870 €*

Wire harness

Costs	~ 1.200 €
Costs of critical materials	~ 460 €
Additional costs	~ 55 €

Total risk between

1.300€

&

1.600€

per car

Frame and Body

Costs	~ 2.550 €
Costs of critical materials	~ 1.870 €
Additional costs	~ 245 €

Aluminium rims

Costs	~ 600 €
Costs of critical materials	~ 340 €
Additional costs	~ 45 €

Plastics

Costs	~ 225 €
Costs of critical materials	~ 70 €
Additional costs	~ 10 €

Semiconductors

Costs	~ 800 €
Costs of critical materials	~ 320 €
Additional costs	~ 40 €

Battery

Materials – The most critical and relevant materials within a battery are Lithium, Nickel, Manganese, Cobalt, Copper, Aluminum, Iron, Phosphor as well as natural and synthetic graphite [20]. Europe is highly dependent on non-European countries for those materials. The highest raw material dependency, with a 79% dependency on China, in the processing stage is phosphorus [21]. However, the other materials also represent a high dependency towards China, ranging from 50% to 60% for the processing stages of lithium, aluminum and cobalt. For the latter, the dependency toward Congo for mining, being 63% [28], also represents a significant risk which is however not subject to this analysis.

Value chain – Unlike other components, batteries rely heavily on China throughout the production process, from mining raw materials to final assembly. An EU study found that even cell production is heavily dependent on China. This dependence is particularly high in final assembly (75%). Europe's low cell production capacity (3%) further limits battery availability [24].

Additional purchase costs – The average purchase cost of a Li-ion battery for a mid-range to small car ranges between €9.000 and €11.000. Of this, 75% is critical and dependent, which corresponds to approximately €7.500. With additional costs of 13%, this results in additional purchase costs of €975 per battery.

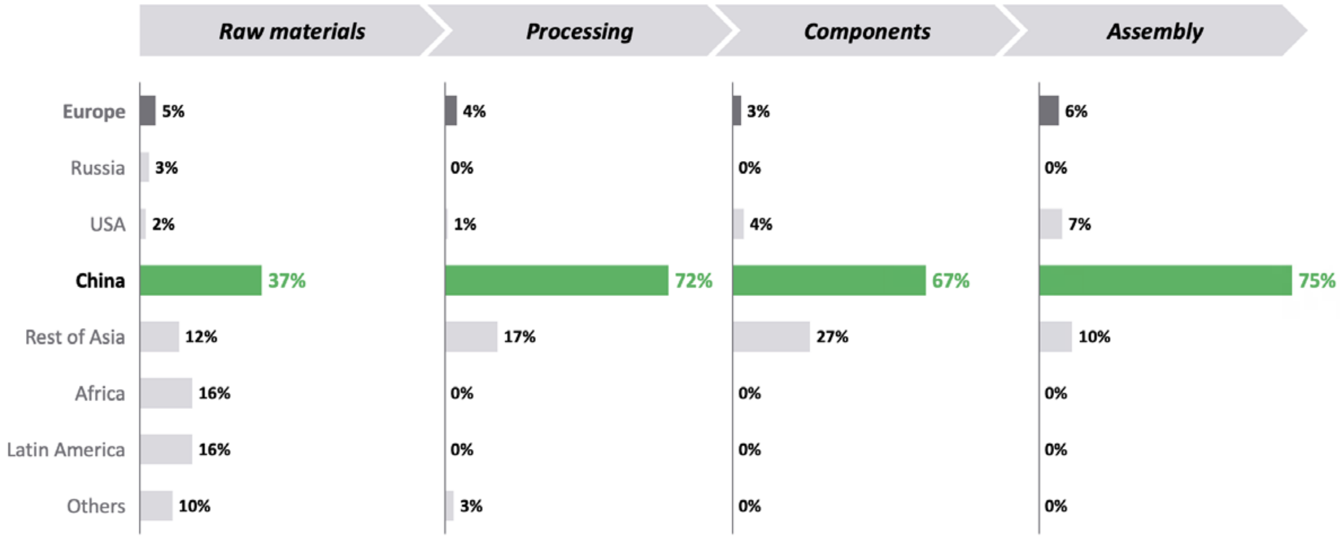


Figure 10: Li-ion battery value chain country dependency [27]

Electric engine – Permanent magnet synchronous motor

Materials – The most valuable and critical materials of the electric engine lie within the permanent magnets. The permanent magnets used today are generally neodymium-iron-boron magnets (NdFeB). Iron accounts for the largest proportion, followed by rare earth metals with approx. 30% and boron with only 1%. Two important rare earths in permanent magnets are dysprosium and neodymium. The rare earth elements are used, among other reasons, to increase the temperature resistance of magnets and China processes up to 90% of all rare earths. Another important material is silicon, which is found in printed circuit boards. Most of the silicon is also processed in China, accounting for around 76% of the market share.

Value chain – Similar to the battery analysis, the entire value chain for the electric motor is evaluated again to identify its dependency on China. This is due to the fact that the highest dependency towards China can be observed in the production of electric motor components, with a value of 52%.

Additional purchase costs – The average purchase cost of a permanent magnet synchronous motor for a mid-range to small BEV varies from €600 to €1.000. Of this, 52% is critical and dependent, which corresponds to approximately €470. With increased costs of 13%, this results in additional purchase costs of €60 per electric engine.

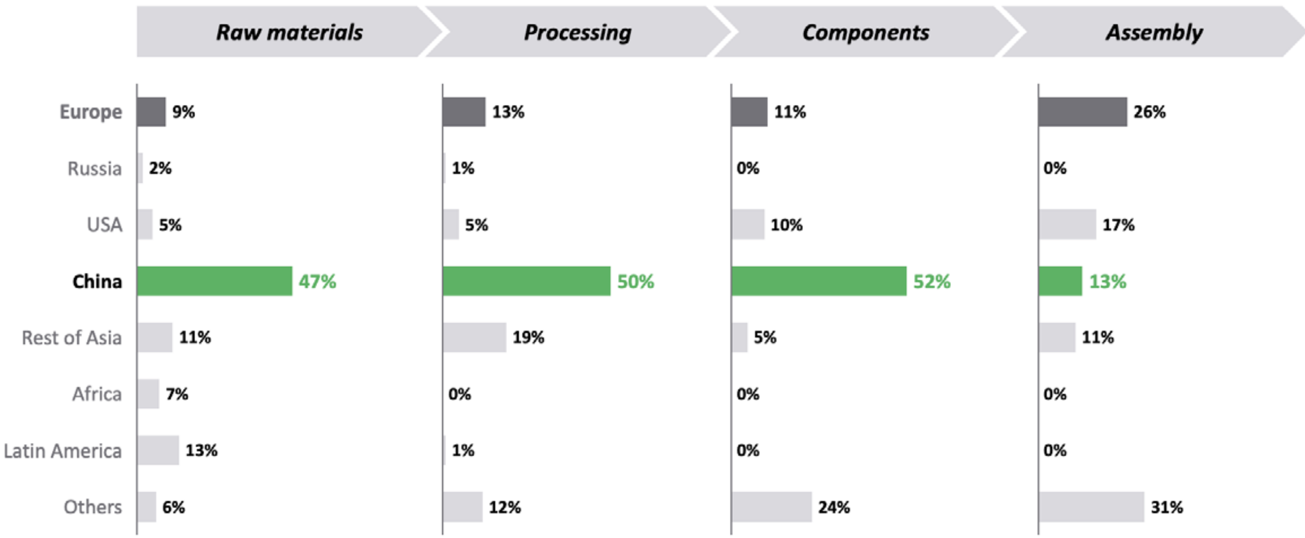
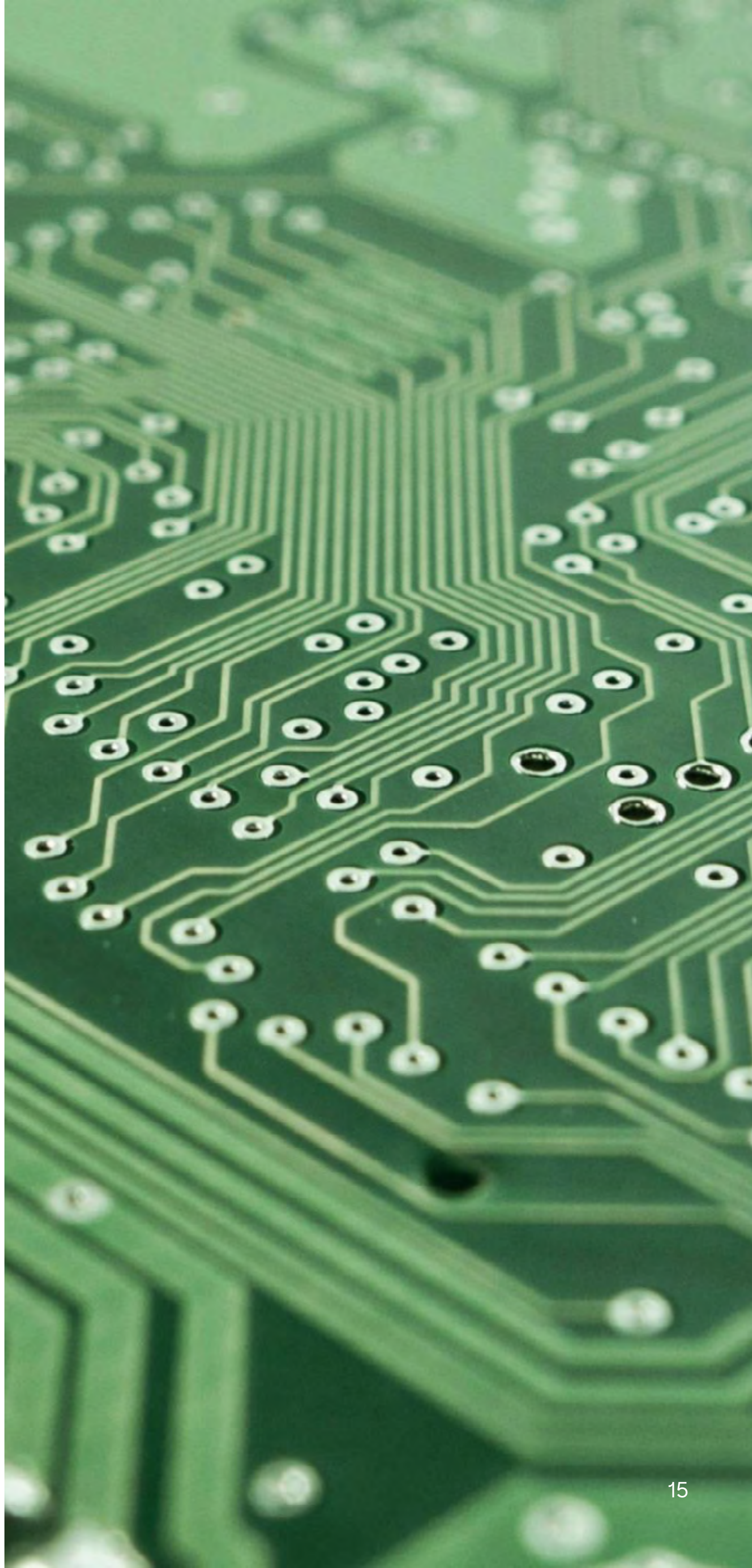


Figure 11: Electric engine value chain country dependency [27]



Fuel cell

Materials – The materials most used in the proton exchange membrane fuel cells (PEMFC) and solid oxide fuel cells (SOFC) consist of platinum, graphite, zirconium, cobalt, manganese, iron ore, nickel and several rare earth elements. China dominates the mining of graphite, holding 65% of the market share. For other materials, China's mining share reaches only up to 15%. However, since fuel cells consist of rare earth elements, dependency on China becomes significant once again, as China dominates approximately 90% of global rare earth processing.

Value chain – The entire value chain has once again been evaluated for the fuel cell. The highest dependency towards China lies in the assembly process with up to 67% dependency on China.

Additional purchase costs – The average purchase cost of a fuel cell ranges between €9.000 and €11.000. Of this, 52% is critical and dependent, which corresponds to approximately €6.700. With increased costs of 13%, this results in additional purchase costs of €870 per electric engine.

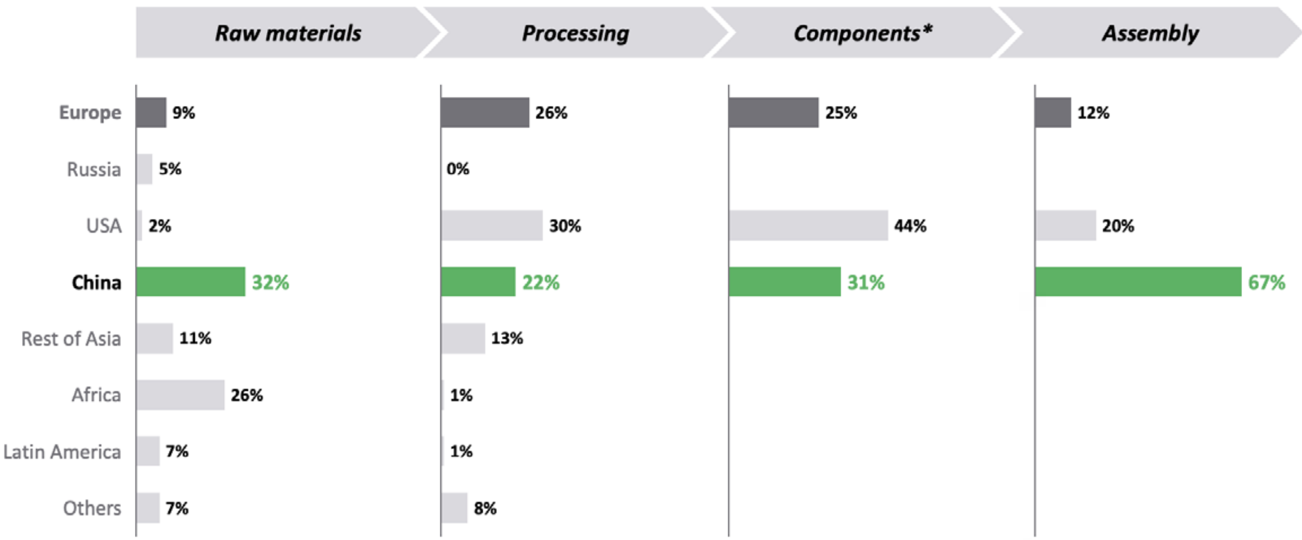
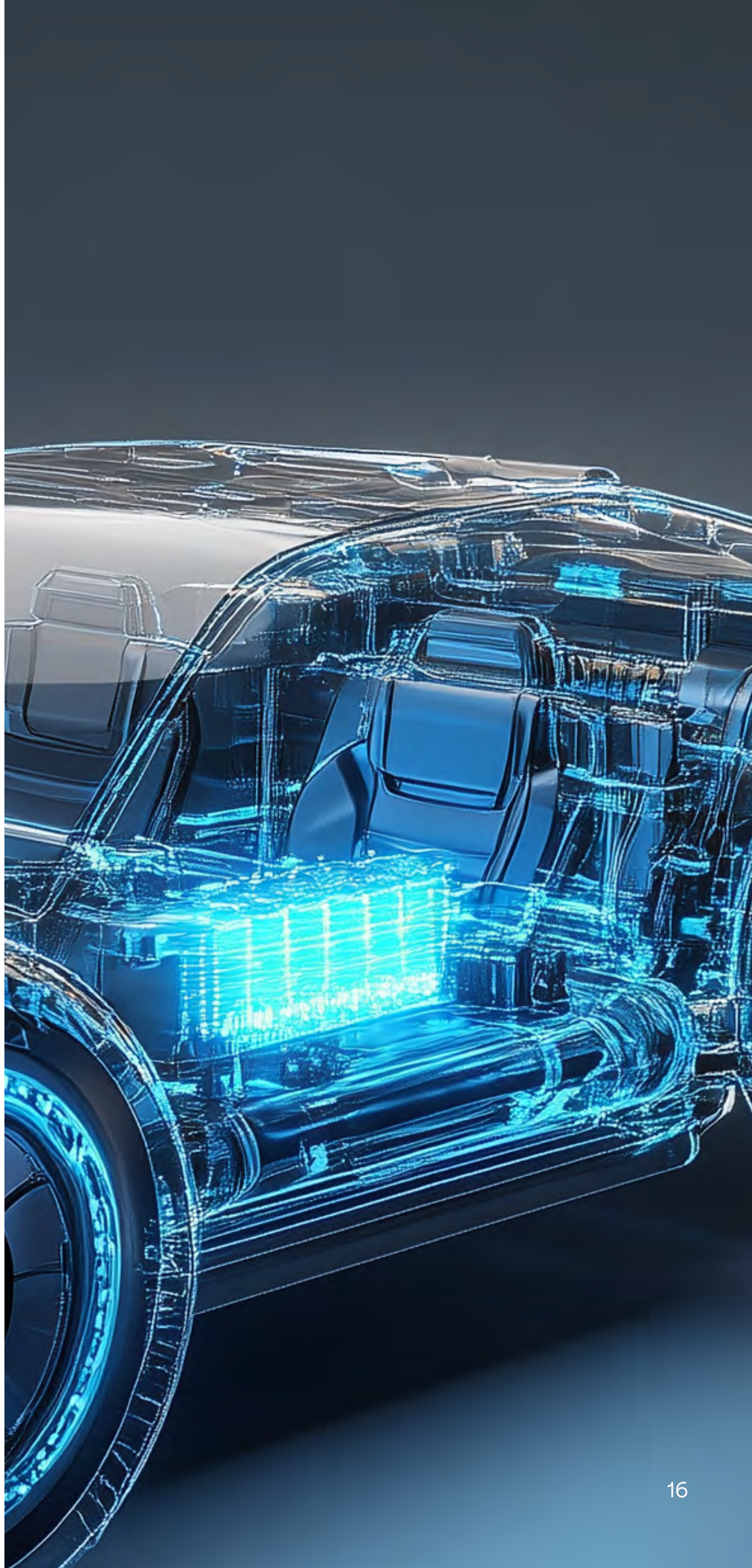


Figure 12: Fuel cell value chain country dependency [27]



Wire harness

Materials – A wiring harness consists of several materials, such as plastic (usually PVC or nylon), which is used to insulate the cables. However, the most valuable and critical material is copper. Plastic components are analyzed separately in a following chapter, which is why the focus when assessing the wire harness lies solely on copper. According to the International Copper Study Group, a BEV consists in average 23 kg of copper [22].

Value chain – China is not a big player in the production of wire harnesses, representing less than 1% in global market share. Therefore, the focus lies in the mining and processing stages of copper. While Chile is the largest mining country for copper (market share of 28%), China still processes the largest amount of copper (38%).

Additional purchase costs – The average purchase cost of a wire harness depends on the type of the wire harness. All vehicles are built with a low voltage wire harness, while electric vehicles additionally have a high voltage wire harness. As the case study analyzes a BEV, both wire harnesses are included in the calculation. A low voltage wire harness usually ranges between €700 and €800 while a high voltage wire harness ranges between €400 and €500, summing up to total purchase costs of €1.100 to €1.300. Of this, 38% is critical and dependent, which corresponds to €460. With increased costs of 13%, this results in additional purchase costs of €55.

Frame and body

Materials – Over the years the material composition of a vehicle's body and frame changed. Whilst it mostly consisted of steel in the 80s, nowadays the frame and body are a mixture of several materials, such as aluminum, magnesium and steel. The kind of steel used differs, ranging from soft steel to ultra-high strength steel. However, for this analysis steel is classified as one. The other two materials being considered are magnesium and aluminum.

Value chain – Magnesium is the material which represents the highest dependency on China. This not only applies to mining, in which China holds 88% of the total mining capacity but also to processing, in which China holds 91% of the global market share. China is not the largest miner for steel (15% of mining capacity) but, according to the world steel association [23], China produces 54% of the global steel. Like steel, China does not have the largest market share in mining for aluminum (24%) but processes 56% of global aluminum.

Additional purchase costs – The average purchase cost of the entire frame and body metals of a mid-range to small BEV ranges between €2.300 and €2.800. Of this, 91% of the magnesium, 65% of the aluminum and 54% of the steel is critical and dependent, which corresponds to €1.870. With increased costs of 13%, this results in additional purchase costs of €245 for each frame and body.

Aluminum rims

Materials – As seen in the previous component analyses, aluminum is a highly dependent and critical material, which is why the aluminum rims have been analyzed separately. The only material considered when analyzing the rims was in fact aluminum, as it represents 97% of the total weight.

Value chain – China holds 24% of the mining market share for aluminum and 56% of the processing.

Additional purchase costs – The average purchase cost of a set of aluminum rims ranges between €500 and €700. Of this, 56% is critical and dependent, which corresponds to €340. With increased costs of 13%, this results in additional purchase costs of €45 per set of aluminum rims. However, it must be noted that not all vehicles are equipped with aluminum rims. A large share of vehicles is equipped with plastic rims.

Plastics

Materials – A vehicle's interior components, especially, are made up of several types of plastic. Thermoplastics make up the largest share of plastics used within a vehicle, while other plastics, such as elastomers, polyurethane, also play a significant role. For this analysis, however, no differentiation has been made between the plastic types, when examining the value chain and calculating the costs. Thermoplastics are the most used plastic groups. However, those thermoplastics differ in terms of the used additives and fillers. For simplicity, all plastics, averaging 200 kg per vehicle, were treated the same in terms of criticality.

Value chain – In total, China has a market share of 32% of global plastic production.

Additional purchase costs – The average purchase cost of one ton of plastic is approximately €1.000. For the 200 kg of plastic used in a vehicle, the purchase cost ranges between €200 and €250. Of this amount, 32% is considered critical or dependent, corresponding to €70. Including additional costs of 13%, this results in an extra €10 in purchase costs for all plastics used in a vehicle.

Semiconductors

Materials – The most used materials within a semiconductor are silicon, germanium and gallium. However, the critical dependency of a semiconductor not only lies in the used materials but rather in the complexity of the value chain and production of a semiconductor.

Value chain – The semiconductor value chain is highly intricate, involving multiple specialized steps from material procurement to back-end manufacturing. These are often carried out by different companies across various countries, with semiconductors crossing international borders up to 70 times. This complexity is compounded by the fact that no single market possesses all the capabilities required for end-to-end semiconductor design and manufacturing.

The three crucial steps within the semiconductor value chain are the raw wafer production, the front-end production and the back-end production. China dominates a significant portion of the semiconductor market, holding 40% of the total market share, particularly in the back-end production.

Additional purchase costs – The overall value of semiconductors within a vehicle ranges between €600 and €1.000. Thereof China dominates up to 40% of the market for back-end production, which means that approximately €320 of the semiconductors used in a vehicle are critical and dependent. With additional costs of 13%, this results in additional purchase costs of €40 for all semiconductors in one vehicle.

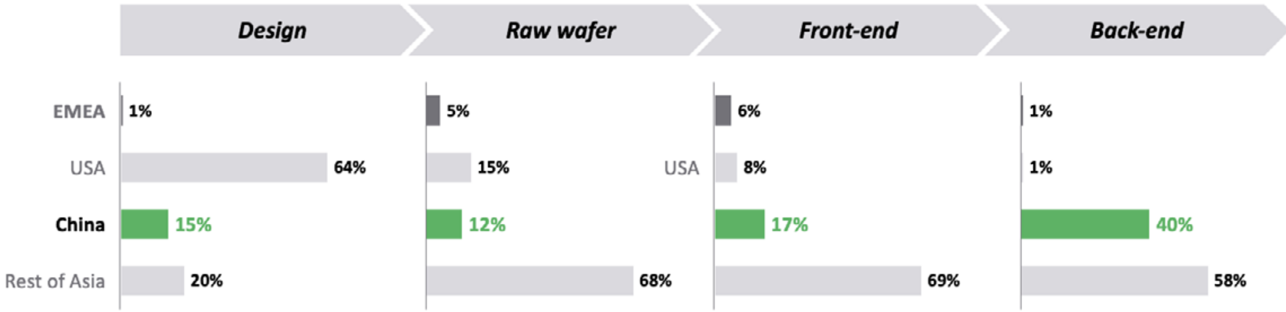
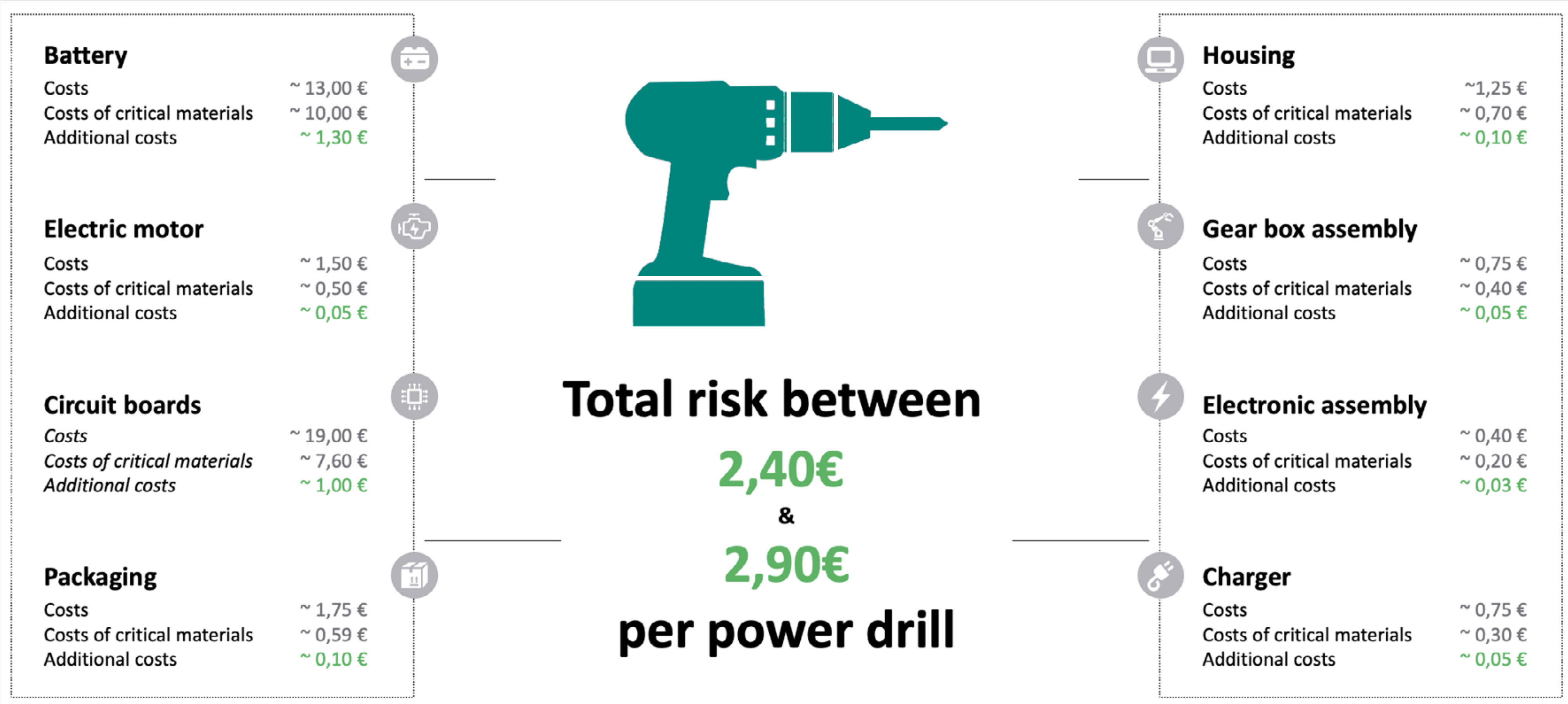


Figure 13: Semiconductor value chain country dependency

Second example case: Power drill

In the initial analysis of an average power drill, eight key components were evaluated, with a primary focus on the material value, largely neglecting the value added in subsequent processing steps. The analysis revealed a significant dependency on China, with up to 75% of the materials for these components being sourced from there. This dependency underscores the potential vulnerabilities in the supply chain. The estimated additional purchase costs for these critical components range between €2,40 and €2,90.

Figure 14: Case Study: Risk costs of an average power drill



Packaging

Materials – The packaging of a power drill consists solely of paper and plastics. Even though none of those materials is classified as critical by the European Commission, those materials may also have a dependency on China.

Value chain – According to Cepi [24] Asia produced approximately 48% of the world's paper. Due to the lack of specific data on China's paper production, the paper production share for Asia was used to estimate dependency on China. For plastics, China holds a total market share of 32% of global production.

Additional purchase costs – The purchase costs for paper and plastics within the packaging are approximately €1,50 – €2,00. With China dominating the market for these materials, accounting for an average of 34%, this results in additional purchase costs of approximately €0,10, assuming a price increase of 13%.

Housing

Materials – The housing of a power drill is primarily composed of plastics and steel. The plastic components form the outer casing and handle, providing the essential insulation and protecting internal components from impact and wear. Steel is utilized in the structural framework, ensuring the drill's overall strength, stability and longevity.

Value chain – Although China holds a 32% share of the global plastic production market, it does not dominate the production of iron ore, which is essential for steel manufacturing. According to the US Geological Survey (USGS) [25] Australia is the top producer of iron ore mines. When examining the upstream value chain, China's dominance reemerges in steel production, where it holds a 52% share of the global market.

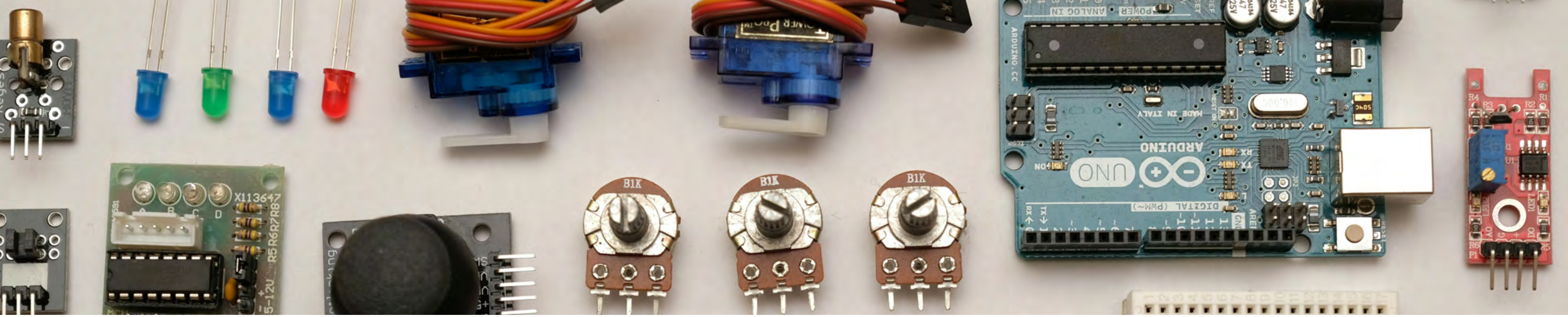
Additional purchase costs – The overall value of the plastics and steel within the housing unit ranges between €1,00 and €1,50. With China dominating the market up to 52%, this results in additional purchase costs of approximately €0,10, when assuming a price increase of 13%.

Motor

Materials – The electric motor of a power drill consists of several materials such as alloyed steels. However, the most valuable materials and parts within the motor are the copper wires and permanent magnets. The criticality of these materials can vary significantly depending on whether rare earth elements are used in the magnets or not. If rare earth elements are utilized, the dependency on China increases considerably. In this analysis, it is assumed that no rare earth elements are used in the magnets of the power drill.

Value chain – The motors' value chain relies on China for up to 38% of copper processing and up to 52% of alloyed steel processing.

Additional purchase costs – The overall value of the materials and parts within the motor are estimated to range between €1,00 and €2,00. On average, China dominates approximately 30% of the value chain for all materials used in the component. With an estimated price increase in case of a crisis of 13%, this results in additional purchase costs of €0,05.



Gear box

Materials – The gear box of a power drill is primarily made out of sintered steel and some plastics.

Value chain – The gear box and housing unit share the same value chain, with China dominating approximately 32% of global plastic production and 52% of steel production.

Additional purchase costs – The overall value of the materials used in the gear box, with steel being the primary weight contributor, is relatively low, with costs ranging from €0,50 to €1,00. Given that China dominates the market for across these materials up to 52%, this dominance results in additional purchase costs of approximately€0,05, assuming a price increase of 13%.

Electronic assembly

Materials – The materials used for making the electronic assembly parts of a power drill include various metals such as aluminum, copper, plastics and steel.

Value chain – Aluminum and copper represent critical materials as classified by the European Commission. China controls 24% of the bauxite mining market, the raw material required to produce aluminum. China's dominance in processing bauxite into aluminum becomes even more significant, holding a market share of approximately 58%.

Additional purchase costs – Due to the relatively low weight of the electronic assembly parts, the overall value of the materials used in these parts is also low, ranging from €0,35 to €0,50. Up to 58% of this value is dominated by China. Assuming a price increase of 13%, this results in additional purchase costs of approximately €0,03.

Battery

Materials – The critical and most valuable materials in the battery of a power drill are lithium, nickel and manganese. These materials are considered critical because their mining and processing are highly concentrated in a few countries and the demand for these materials is rising significantly due to the increasing trend of electrification.

Value chain – The entire component of the battery has been examined, similar to the approach used for calculating the cost of an automotive battery. The dependency on China encompasses not only the mining and processing of raw materials but also the production of the battery cells. The highest dependency on China, at 75%, is observed in the final assembly of the battery. This extensive dependency highlights China's substantial influence in the battery supply chain.

Additional purchase costs – The total purchase costs of the battery, including the battery packs, range between €11,00 and €15,00. Up to 75% of the production is dominated by China which represents approximately €10,00. With additional costs of 13%, this results in additional purchase costs of approximately €1,30.

Charger

Materials – The charger is composed of various materials, including plastics and metals, with copper being the most critical material due to its crucial role in electrical conductivity. Additionally, the charger includes a circuit board as a vital subcomponent, responsible for managing and regulating the electrical flow. The materials of the circuit board are not included in the analysis of the charger, as it is analyzed within the accumulated circuit boards.

Value chain – China processes 38% of global copper.

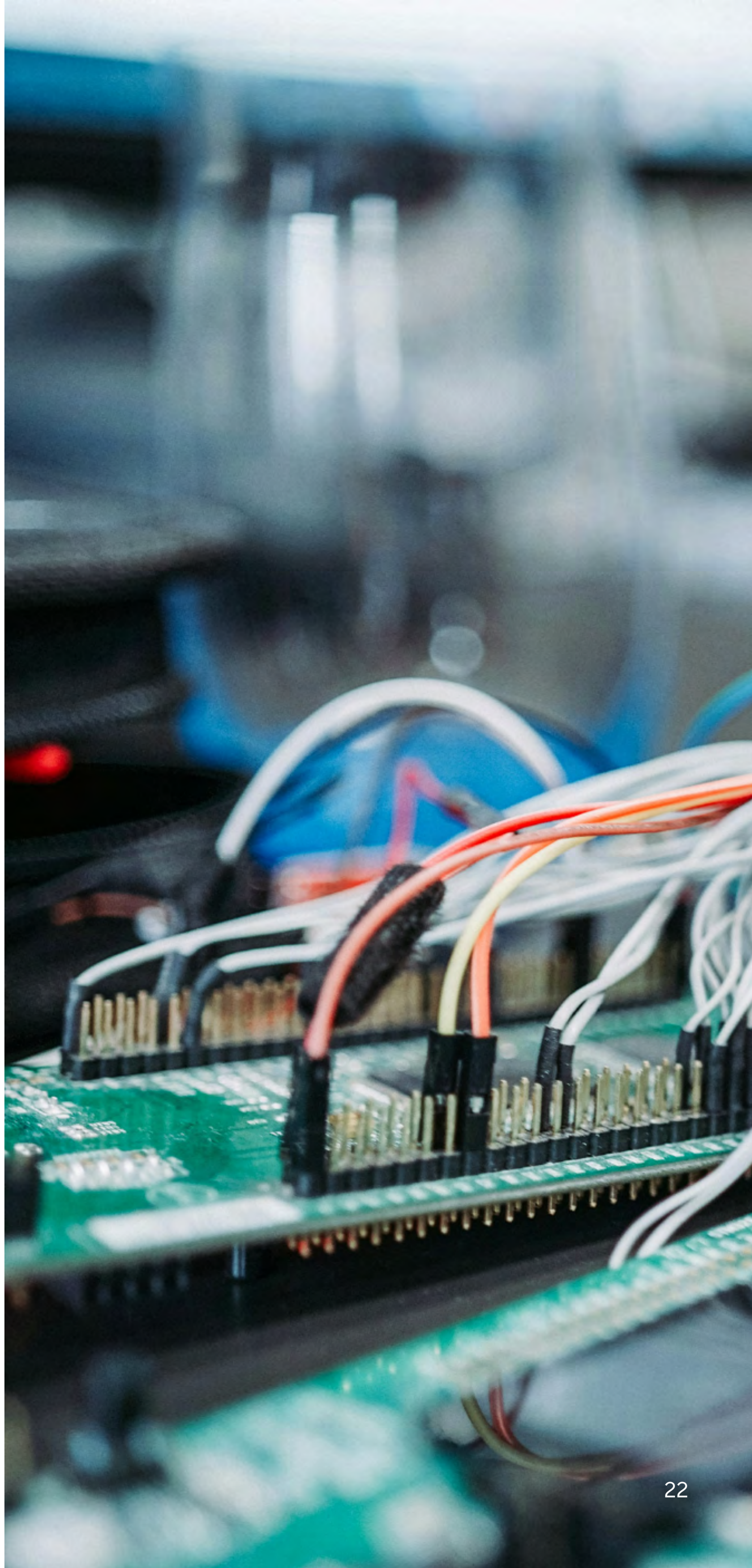
Additional purchase costs – The overall value of the materials and parts within the charger are estimated to range between €0,50 and €1,00. Thereof China dominates approximately 35% of the value chain on a weighted average basis. In the event of a 13% price increase due to a crisis, this would result in additional purchase costs of approximately €0,05.

Circuit boards

Materials – Similar to the automotive case, the analysis of the circuit boards does not focus on the origin and processing of raw materials but rather on criticality of the semiconductor value chain.

Value chain – Even though the semiconductor value chain is very complex and highly dependent on China, semiconductors used in power drills are not considered as critical as those used in vehicles. This is because power drills use less complex and therefore less critical semiconductors. Both case studies share the same simplified value chain for semiconductors, with China controlling a significant portion (around 40%).

Additional purchase costs – The total purchase costs of the Circuit boards ranges between €17,00 and €21,00 representing the most valuable component of the power drill. Up to 40% of a circuit board's value chain is dominated by China which represents approximately €7,60. With additional costs of 13%, this results in additional purchase costs of approximately €1,00.



Vision: AI enabled Risk Management Tool

Understanding the material supply risks within interconnected supply chains does not automatically imply that a company has considered these risks in their strategy or operational actions. Since the COVID-19 pandemic, most companies have become aware that the abstract risk of disrupted supply chains can cause production downtimes and revenue losses. However, the general awareness of such a risk does not necessarily lead to operative actions of prevention, especially if those actions cost money.

Therefore, a critical initial step in addressing supply risk factors is the ability to quantify them, as demonstrated in the previous chapters. Only then can the potential costs of these risk factors be compared to current sourcing costs and new sourcing strategies. Additionally, quantifying this risk can serve as a motivation to introduce innovative circular business models aimed at reducing dependencies from international resource markets. A rough estimate of material supply risks may suffice for initiating strategic changes at the top level. However, justifying additional costs for sourcing or risk reduction requires in-depth analysis at the operational level. Therefore, a second critical step is to perform calculations based on company-specific data, ideally updated daily, considering the location and diversification of the company's own supply chain.

Reliable risk calculations face various barriers, including non-transparent or outdated supply chain data and the sensitivity of product-related data that companies often do not want to share in a public cloud such as digital product passports. Additionally, the real supply risk for a certain material might change daily with new geopolitical or climate developments. One example is the effect of the presidential elections in the US on a trade war with China. Even the mere visit by a US president in China, along with an ill-considered statement and subsequent diplomatic upheavals, could potentially become a major cause for later export restrictions. Additionally, impending weather catastrophes in a region crucial for sourcing a particular material can immediately alter the supply risk with that material.

Therefore, an elaborated risk management tool would be the optimal approach to address material supply risks in a company. Our vision includes an AI-based risk management tool connected to a personal and an external IT environment. The personal environment provides daily updated company-specific material/component prices and sensitive product data. New product designs and material price changes are automatically integrated in the personal cloud, which is connected to both the company's and the suppliers' IT systems. In the external cloud, macro data are scanned in real time and new global risk factors are identified from press releases, weather forecasts and similar sources. The risk management tool can process these data and directly adapt its underlying risk assessment. Data from the external cloud could be provided for whole industries without requiring company-specific information. The integration of personal and external environments is secured with respective IT measures to avoid data leaks.

The tool's risk assessment can facilitate improved negotiations with suppliers and proactive changes in a company's sourcing activities due to external risk-relevant developments without any delay. Additionally, the tool can provide long-term insights for strategic and product development decisions by generating forecasts using historical data and predicting political actions that may be indirectly signaled in advance. Furthermore, it could facilitate the initiation of new circular activities with external stakeholders or transfer data to insurance for hedging production downtime risks.

The biggest challenge for companies is not the material composition of their products, as this information is documented by the Bill of Material and tested through increasingly important life cycle assessments and product carbon footprints.

The difficulty begins with determining the exact locations where raw materials are extracted. However, a more significant gap exists when identifying where these raw materials are further processed in the value chain. This often results in white spots, which, given current geopolitical crises, leads to significant risks that are currently not covered by any risk management system.

To adress this situation, there are many tools available – for example also Porsche Consulting has developed a quick check tool that assesses a product's risk based on a Bill of Material (BoM). This tool utilizes several data sources, such as S&P Global, governmental reports and spot market prices. In the future, an integrated solution based on the respective company's ERP data will be crucial for identifying and managing supply chain risks at an early stage.

> **"This is a core topic for all large companies but very few are mastering it."**
>
> Prof. Dr. Gunther Friedl
> Dean of the School of Management at Technical University of Munich

QUICK-CHECK TOOL

Material dependency analysis at product level, based on the uploaded BoM

Securing global supply chains

by Fabian Vetter and Friederike von Bargen, Agora Strategy

Agora Strategy

Globalization is entering a new era with growing geopolitical uncertainty. In the last 10 years alone, the number of conflicts has almost doubled, while the strategic rivalry between the world powers is growing. China and Russia, for example, are fundamentally challenging the westernised world order. Global supply chains, access to raw materials and cutting-edge technology are caught up in the maelstrom of this hegemonic conflict. The primacy of free trade is coming under pressure as international trade dependencies are increasingly being used to assert geopolitical interests. Industrial policy instruments such as sanctions, export and import restrictions are being used in a targeted manner to gain national advantages in geo-economic competition. The fact that the law of the jungle prevails, even if this undermines the sovereignty of allied states, is demonstrated by the example of the Dutch chip supplier ASML, which had to stop exports to China due to US extraterritorial influence. China's explicit export and import bans as well as the US Inflation Reduction Act and the most recent tariffs on Chinese electric cars are just a few examples of how large nations do not consider themselves bound by the free trade standards of the World Trade Organization.

Against this backdrop, strategic business decisions can no longer be made without taking geopolitical factors into account. Global supply chains in particular have weak points if primary products are sourced from risk regions, depend on a small number of producers or if sources of supply are concentrated in one country.

Supply chain transparency, or at least a high degree of flexibility in procurement in order to be able to react quickly across all areas of the company, has become a strategic competitive advantage. But exports are also affected. Where companies are overly dependent on one sales market, the consequences of trade barriers are severe.

Logistics and transport routes are currently still underrepresented in the debate on a resilient supply chain. However, the recent attacks by Houthi militias on merchant ships in the Red Sea, China's long-established dominance of the global container shipping fleet and the strategic expansion of Chinese-occupied infrastructure hubs around the world show that logistics must also be seen as a volatile geopolitical factor. The Straits of Hormuz, Malacca and Taiwan as well as the Suez Canal and the Horn of Africa are considered to be the most geopolitically vulnerable sea routes. If one of these „chokepoints" fails, detours cost a lot of time and money - if they are possible at all. In any case, the consequences for companies are far-reaching.

But what can European companies do in the face of this serious increase in geopolitical risk factors? Friendshoring, i.e. the relocation of the supply chain, production and sales to allied regions, is on everyone's lips. However, complete decoupling is neither realistic nor sensible. The costs of such a model would not be competitive, nor is it possible to source raw materials regardless of geological conditions.

Instead, a targeted diversification of risks is needed where dependencies exist. Input products for which sources of supply cannot be diversified must be identified and prioritized.

Strategies for achieving sustainable competitive advantage

Having discussed the roots and nature of risk costs, it becomes evident that there is one common element in all mitigation strategies: the concept of circular economy, which presents possible solutions to these issues. Within this process, capitalizing on the circular economy opens new ways for companies to emerge more independent and future-proof whilst cutting costs.

The following section presents six recommendations that leverage different aspects of the circular economy. Implementing these comes with challenges, but we showcase successful examples to guide the way.

1. Transparency
2. Nearshoring / Friendshoring
3. Material loops
4. Product and components loops : Repair, Refurbish, Reuse
5. Design for circularity
6. Total cost of ownership and lifecycle costs

Driving forces of circular business making. Own illustration by CIRCULAR REPUBLIC

Transparency

The Bill of Material (BoM) is known for every product in every company, although the quality and depth of data can vary significantly. The BoM is often used for life cycle assessments, purchasing orders and legal obligations, but it embodies major pitfalls. Firstly, material data lacks information about the origin of materials, which is the first indicator for assessing scarcity and supply security. Even more critical and frequently unknown is the processing step of each specific material. This is where geopolitical complexities play a crucial role in conducting a holistic and valid risk evaluation.
Secondly, data is too generic to evaluate the material's health and recyclability potential. For instance, a commonly used plastic like PP-GF20 does not only consist of PP and GF; it includes additives, pigments, stabilizers and many other ingredients typically treated as trade secrets by supplying companies.
Not all detailed material data is necessary to assess supply risks and facilitate material-loop activities. However, additional data has to be included in the BoM. While it's never possible to achieve a complete picture, transparency throughout the entire supply chain has to be increased to enable a further analysis of risk factors and adapt the sourcing and material loop-strategy later on.

Recommended action

1. Increase data transparency throughout the entire supply chain to cover processing steps and relevant risk factors.
2. Closely collaborate with Tier 1 suppliers and n- Tier suppliers further upstream to jointly develop intersections for an exchange of relevant data, depending on the later intended actions (e.g. changing sourcing strategy, increasing recyclability)
3. Initiate data platforms like Catena-X to increase transparency at material level in order to evaluate the material health and circularity potential.

Benefits

- Through higher transparency, concrete actions for new sourcing strategies and for material loop approaches can be derived.
- Enable calculation of supply-chain-related risk factors to be included in decision process for new sourcing strategies
- Create valid calculation basis to introduce design for recycling in the development process of new products

Case example

Regarding the lack of transparency in material supply, a fitting example is the rapid changes within the European paper industry in the 2010s. The global market's reliance on only a few pulp suppliers such as Szuano and Smurfit Kappa has enabled these players to dictate prices for pulp. Simultaneously, the low collection rates for waste paper in China prompted Chinese paper producers to capitalize on periods of reduced shipping costs between Europe and China, sourcing waste paper from Europe. This consequently induced a higher price of waste paper on European markets. In the following, these two factors greatly impacted the European paper industry. Fully-integrated pulp producers such as Stora Enso, Metsä, UPM and Essity (formerly SCA) managed to emerge more independent from the price increase of waste paper, remaining consistent in pricing whilst reinforcing their competitive position.
Within this transformation, the remaining European small- and medium-sized producers can be categorized into two groups. The first group includes businesses that produce special paper products serving a niche market. Whilst being under increasing pressure, these companies managed to forward the inflated price to their customers. In contrast, the second group, containing classic pulp producers that heavily relied on waste paper as input material, were greatly affected by the increased price level. The European market has subsequently seen many of these producers go bankrupt, being split off or sold to private equity.
These developments have resulted in the European paper industry losing several players and further concentrating on only a few European players.
As mentioned earlier, amongst others, the Swedish paper producer Essity has managed to emerge stronger from this transformation. Since its spin-off from the SCA group in 2017, the company has grown to encompass 46.000 employees and attained €13,09 bn in revenue (2023). In addition to being a fully integrated pulp and paper producer, the company has increased transparency of their supply chain and thereby mitigate the associated risks through several initiatives, which are presented on the companies website and supposed to contribute to SDG12: responsible consumption and production.
Essity demonstrates its efforts to increase transparency throughout the supply chain by mandating its suppliers to adhere to the Global Supplier Standard (GSS). This standard encompasses requirements on quality, code of conduct, product safety and environmental impact. Strategic suppliers are required to perform risk assessments whenever changes are made in their production processes, ensuring continuous evaluation of the impact on supplied goods and raw materials. Furthermore, suppliers must develop contingency plans to address potential shortages in raw material supply, while also implementing processes that enable traceability and identification of delivered goods. Safety assessments are bolstered by external independent toxicologists and life science experts, which increases data transparency. Essity also processes new cellulose derived from straw into hygiene products, thereby enhancing their business model's circularity and diversifying production.

Nearshoring/Friendshoring

Driven by cost reduction potentials, globalization incentivized firms to source materials from all over the globe and diversify their suppliers significantly. Globalized, complex supply chains inherently contain a risk for delayed material deliveries or even unfulfilled orders due to logistical issues, supplier operations etc., but beyond this, material sourcing in general is considerably more under pressure than a few years ago. Companies in distributed supply chains face difficulty reacting flexibly due to complex procurement processes, long delivery times and production risks.
Furthermore, today's supply chains are often characterized by a lack of transparency, difficult access to supplier data (e.g. sustainability data) and general low control over supplier operations, especially beyond Tier 1 suppliers. This creates a heightened risk exposure to external crises, as collective problem-solving with those Tier 1 suppliers does usually not prove to be successful if issues arise further upstream. In this case, a mere re-location of Tier 1 suppliers to Europe cannot reduce material dependencies from non-European markets either, as the material risk is not directly related to them but rather to Tier 2 or 3 suppliers. Hence, a more strategic way to design the value chain is imperative. To address global crises and restructure supply chain approaches, it is crucial to analyze the potential of new sourcing possibilities compared to the status quo, also to improve end-to-end transparency of material sourcing and to avoid single supplier value chains.

Recommended action

1. Analyze potential and feasibility of EU-based raw material sourcing for current bill of material and, if beneficial, re-locate sourcing for selected materials to countries less affected by crisis
    a. Analyze BoM based on risks for fallouts and criticality for production, as well as costs and probability for supply issues.
    b. Calculate risk-related costs and compare them to (higher) material costs for sourcing materials (beyond Tier 1 suppliers) locally, including the complexity of adapting a specific value chain stream and implications for production or products in general, taking into account options for subsidies, e.g., for capital intensive or specialized value chains, or if re-location might not be feasible
    c. Start changing procurement processes for materials and build local relationships with key material as well as Tier 1 suppliers to increase flexibility in case of supply chain disruptions. Also consider partnerships in the field of with EU mining projects (e.g. Sweden, Norway, Greenland) to support refineries within the EU or others.
2. Beyond the local-to-local approach, a holistic restructuring of value chains and the integration of 'risk guardrails' can create even more resilience and protection.
    a. Evaluate potential for vertical integration or joint business undertakings (e.g. through contractual agreements or joint ventures) with suppliers. Particularly for specialized, difficult to substitute but essential materials or goods, vertical integration (e.g. through supplier acquisitions) can ensure future-readiness in the face of crisis and increase ability to control the value chain.
    b. Where vertical integration is not possible, additional risk guardrails can be integrated to increase resilience. For example, ensuring multiple supplier sourcing, including supplier 'resilience audits' (e.g. ESG & certification criteria, geospatial risks) and diversifying supplier locations in the case of climate change impacts or geopolitical events

3. Develop dynamic overall concept for the company's global sourcing planning with sufficient alternatives to enable a switch to new and local sourcing options in case of crisis. Weigh proactive vs. reactive change of sourcing concepts, based on the related costs and change supplier contracts accordingly.

Benefits

- Proactive design of a future-proof value chain will not only avoid revenue losses or cost increases but especially ensure competitiveness amongst a group of companies all exposed to similar risks. It can even be used as a competitive edge, signal to financial institutions etc.
- Vertical integration/joint ventures can additionally harness innovation as new production processes or even only lab-scale tests can be managed much faster and without IP issues
- Regulatory requirements are much easier to implement in a transparent & collaborative supply chain
- Decarbonization potential in addition, as European projects tend to have lower GHG emissions than international supplies and there might be a potential business case due to avoidance of the carbon border adjustment mechanism

Case example

The fashion industry's transition towards nearshoring is exemplified by several key players who have realigned their production strategy to capitalize on the benefits of manufacturing closer to the point of sale. One such example is C&A, a German fashion brand, which has started production at its Germany-based facility, aiming to ramp up the production of sustainable textiles, particularly denim. This move not only improves the brand's ability to deliver on sustainability goals but also reduces their risks to volatile global supply chains. Inditex has long leveraged nearshoring to swiftly respond to fast-changing consumer preferences and reduce its overproduction, with over 50% of its sales coming from Spain, Morocco and Turkey. Similarly, Benetton has strategically diversified its production locations to include Serbia, Croatia, Turkey, Tunisia and Egypt, aiming to reduce dependence on global supply chains [26]. By nearshoring their production, Benetton not only aims to mitigate supply chain risks but also enhances its ability to cater to regional market demands efficiently.

This diversified approach to production not only bolsters resilience but also allows for the development of a circular fashion ecosystem, as circular value chains can be easier realized if the production site, recycling facility and end-of-life location are close. In addition, the industry's overproduction of on average 20% [27] can be reduced significantly due to shorter delivery times. However, there remains a critical need for concerted action to address the environmental challenges associated with increased consumption and textile waste, as nearshoring might lead to lower fashion item wear times by consumers and hence increased textile waste.

Material loops

The use of recycled/secondary materials for industrial producers remains low. However, virgin material prices are increasing, demand is rising, and external shocks threaten global supply chains. Therefore, regulation pipelines will further mandate the use of recycled content and the business case to increase the use of recycled materials. Moreover, it is likely that the access to secondary or regenerative materials will be highly competitive in the next years as production still has to scale up to industrial capacities. It now becomes highly important to secure access to avoid lagging behind competitors. For example, off-take agreements between recyclers and producers have been announced several times in the past years showcasing the increasing market dynamics towards the use of recycled materials.

Recommended action

1. Explore potential for sourcing new/different materials in the EU, e.g. regenerative materials (see N. 6). The start-up Exomatter, for example, offers a material research platform that helps to identify more sustainable material alternatives through data mining.
2. Analyze most critical materials based on the price/availability of secondary materials, material specifications and suitability.
3. Compare these analyses to risk exposure (e.g. regulatory requirements, geopolitical events) and select materials which require the most secure strategic access to recycled materials at this point and in the future.
4. Change specifications and/or suppliers where access to secondary materials is not critical. Build relationships and collaboration with suppliers where access to secondary materials is difficult or competitive or where production has not been scaled yet. Possible actions are off-take agreements or joint ventures (e.g., Gigafactory joint venture between Stellantis and Samsung) to support market building for these materials.
5. Partner with innovation and entrepreneurship hubs to receive early access and contacts to new innovative recycling start-ups, such as e.g. Cylib and tozero in the field of battery recycling. Building alliances to support a scaled production of those materials is central. The creation of an own closed loop within a certain industry, as approached for car batteries by CIRCULAR REPUBLIC, can be a viable option.

Benefits

- Diversification of material suppliers reduces exposure and vulnerability to crisis and decreases supply risk-related costs
- Sustainable material sourcing strategy mitigates risks of CO2 price effects and supports the preparation for regulatory compliance with upcoming recycled content mandates
- Potential for building a competitive advantage is becoming a 'market builder for secondary materials'
- Ability to react flexibly to supply issues caused by external crises can be increased. Shorter lead times allow for a better demand predictability.
- Innovative approaches for recycled materials can improve its quality, especially where the current market does not provide sufficient high-quality secondary materials (e.g. plastics)
- Higher CO_2 taxes can be foregone in cases where recycled materials come with a lower emission footprint (e.g. steel).
- EU laws for recycled content and extended producer responsibility can be fulfilled (see EU's sustainable products initiative or battery regulation).

Case example

When discussing material loops, there are several lighthouses across various industries that already achieve high levels of circularity. Within the pump industry, there is certainly one German player that stands out: WILO SE. Founded 1872, Wilo is a German manufacturing company specialized in pumps and pump systems and is active worldwide. As of 2023, Wilo has 8,974 employees with net sales at €1,974.8 million.
Just a few years back, Wilo found itself under increasing pressure caused by shortages of one rare earth material used as permanent magnet in their pumps. They were far from securing a reliable supply of permanent magnets whilst maintaining costs. A few years down the line, they have achieved just that. Rethinking their business model led to the implementation of several circularity approaches.
Wilo's efforts with regards to circularity center around maintaining access to material used in pumps that have reached end of life (EoL). To achieve this, Wilo now relies on a EoL takeback scheme that enables securing material supply on a broader level. Through leveraging existing sales channels, old pumps can be handed in at specialist wholesalers and at Wilo for free, regardless of make, type, age or condition. Required rare earth materials are subsequently extracted by Wilo to be reused if possible or recycled by a recycling partner. All other remaining parts are supplied to recycling partners to extract other materials.
In terms of Wilo's business model, these measures proved to be highly effective. With regulation pipelines mandating the use of recycled material, such as the Electrical Equipment Act, customers are increasingly seeking an environmentally friendly way of exchanging old pumps whilst ensuring legal compliance. Depending on the state of the product, Wilo provides repair and refurbishment services (for such strategies, see N.4) as well as in-house recycling.
Therefore, supply chain resilience, profitability and legal compliance increases. Wilo has drastically increased access to rare earth materials whilst 30,000 components are currently reused each year and old pumps are replaced with newer, more efficient ones, saving clients power and cutting costs. Wilo now follows the vision of achieving the use of rare earth materials exclusively from legacy products in their in-house production.

Product and components loops : Repair, Refurbish, Reuse

If products or components are reused or materials are recycled, it is usually steered by different players than the producer who then makes profit from the feedstock initially purchased by the producer. One central reason for this development is the lack of transparency about the product lifetime and location, as the producer gives up ownership at the point of sale in most business models today.
However, many markets see material prices rising due to increased demand, scarcity and external crises such as the COVID-19 pandemic (e.g. prices for steel bars increased by 40% on average in 2022 [28]). Therefore, materials are set to be more and more valuable in the future. In addition, policy-interventions will increasingly mandate companies to take regulatory responsibility for their products' impact and further promote closed material loops. Therefore, producers should review their current operating model, thinking of ways to make recycling not the only circular imperative.
One prominent example is producers of white goods rarely having access to their sold products (e.g. washing machines) at the end of life. Selling products to retailers and not directly to customers hinders them from getting into contact with the end user. Old appliances are usually taken back by retailers or take-back-systems/container parks who then transfer them to recycling partners. However, some of the returned white goods might still be refurbished or single components might be reused for repairs.

As the described process still prevails, it rules out the possibility of remanufacturing, refurbishment and repair. This equally implies that product value is currently lost in the established process. Being in this position, new business models can help producers regain access to these values.
The circular economy, often misconstrued as merely enhancing recycling, focuses on maximizing product usage and lifespan through repair and reconditioning. Products-as-a-Service (PaaS) is an interesting approach that allows companies to maintain ownership or control over products, thereby promoting longer usage and sustainable practices. Repair is usually more cost-effective and environmentally friendly: A result supported by an Allianz study investigating GHG emissions from repairing versus replacing damaged vehicle parts (see figure 16). [29]

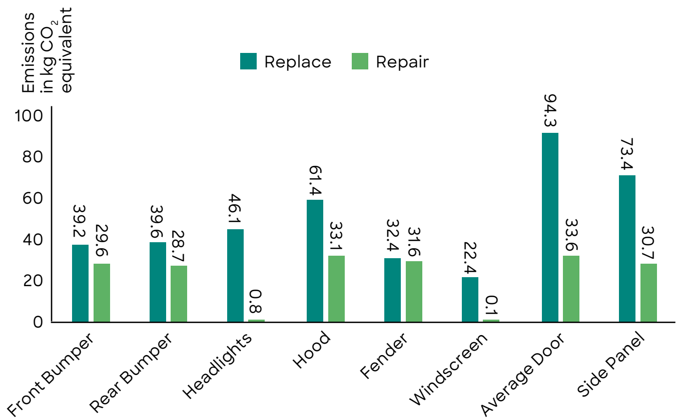


Figure 16: Emissions from repair and replacement (EU average, Volkswagen ID.3)

Recommended action

1. Increase transparency over sold products and materials through digital product passports or other tracing/tracking applications
2. Implement producer-driven take-back systems and incentivization mechanisms (such as deposit schemes or discounts for new products) for customers to return old products. Such mechanisms enable producers to gain direct access to their products at the end of life. Building effective reverse logistic processes presents an important success factor for take-back-systems. They should be established in a way to prevent logistic costs from jeopardizing the underlying business case.
3. Evaluate the potential for rental or as-a-service models, where producers retain ownership of the product and customers only purchase the 'service/performance' of a product, ranging from pay-per-use to pay-per-part approaches.

Benefits

- Enabling second life of products / components compares with value creation without requiring new raw materials and thus reduces the volatility to external crises that affect sourcing
- The ability to implement circular business models (e.g. selling remanufactured parts or second hand items) can create a strong competitive advantage and enables growth whilst addressing new customer segments
- Legal compliance with national closed-loop policies such as a refurbishing rate for electronic appliances in Spain or the requirement to provide used spare parts in France can be secured.
- EU laws for extended producer responsibility (see EU's sustainable products initiative) can be fulfilled.

Case example

Lorenz Meters is a leading manufacturer of flow measurement technology, whose smart water meters are installed in millions of households or in public networks throughout Germany and other European countries, enabling consumption monitoring and billing, management of public supply networks and control of industrial plants. Founded in 1963, Lorenz today produces around 2 million metering devices annually with a team of 350 employees at a turnover of around 50 million Euros. As a pioneer of circular Economy, Lorenz has received several awards for corporate sustainability, research and development and business ethics, including the German Innovation Prize for Climate and Environment and the German Resource Efficiency Prize.

However, while still fully "linear", the early 2000s presented challenges. Facing industry pressures to cut costs, many companies turned to cheaper materials and relocated production. This often came at the expense of quality and environmental impact. Lorenz took a different path. They chose to stand by their commitment to quality and durability, designing water meters with take-back and refurbishment in mind. This wasn't just an ecological decision; it proved to be a win-win. Reduced material and processing costs benefited Lorenz, while customers enjoyed the savings passed on.

This dedication to circularity wasn't a one-off solution. It became the foundation for a complete transformation. Lorenz went beyond simply refurbishing existing products. They designed their new generation of smart meters in a circular manner, maximizing product lifetime and updateability and realized circular business models such as renting or PaaS together with their customers. Used meters are taken back and refurbished and/or remanufactured, with entire recalibrated products or their components reintegrated into the production process.

Lorenz's journey exemplifies the power of aligning business models with circular economy principles. Instead of focusing on single-use products, they prioritized maximizing the service life and reusability of their meters. This focus on product-service systems, where ownership is secondary to service delivery, ensures long-lasting performance and minimizes waste. Lorenz's success story is a showcase to the fact that when business strategy and product design work hand-in-hand with sustainability principles, the circular economy can unlock significant environmental and economic benefits.

5

Design for circularity

Innovative circular activities in repair, reuse, recycling, refurbishing, or remanufacturing often reach their limits because of a linear product design. If a product is not designed for disassembly, a component might not be taken out without breaking it or causing tremendous costs. Furthermore, in the field of recycling, the quality of recycled materials strongly depends on the material composition in a product. Mixed and composite materials lead to worse recycling results than mono materials. Screwed material connections are usually better recyclable than glued materials. Especially in plastic recycling, sorting after the shredding process is often not good enough to separate different plastic fractions in a way that they can be upcycled. For this reason, in the recycling process of electronic waste, plastics are usually incinerated instead of reused. However, as sorting technologies are getting better, this might change in future.

To avoid this loss of material value, a design for circularity is a crucial lever. However, to achieve the optimum result at the end of life, it is important to already consider in the design phase which circular activities exactly will happen to the product in the end, as a product designed for refurbishing and the same product designed for recycling might have a different architecture.

Three barriers are to be considered in this context: First, design changes usually pay off only long after the investment decision is taken. Especially products with a long life span are therefore often not sufficiently attractive for circular design changes from a business point of view. Second, even with a long-term perspective in mind, circular product designs might only be economically viable if material supply risks are included in the investment decision, but this is currently not the usual practice. Third, profits from the end-of-life treatment are often obtained by different stakeholders than the ones responsible for the product design. Whereas the producer is the only stakeholder capable of changing the product design, the recycling process is usually steered by the recycling industry. This problem can only be solved in an ecosystem innovation approach involving various stakeholders in joint circular business models.

Recommended action

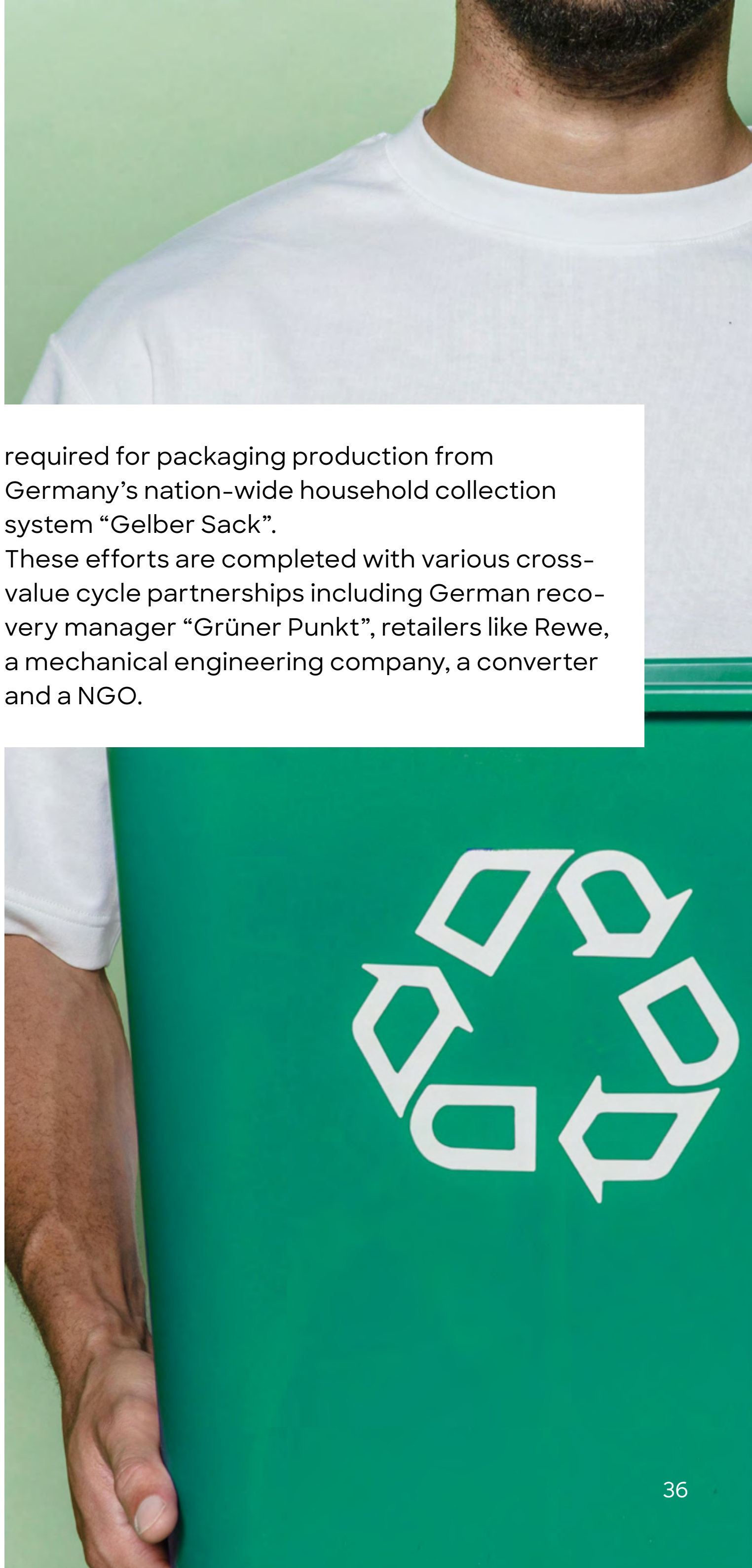
1. Include material supply risk calculations in the product development process for a valid business case assessment.
2. Participate in circular ecosystem innovations as a producer to share profits from new circular activities between all relevant players.
3. Develop your product design with regards to future circular activities in the end-of-life phase.
4. Include external stakeholders such as recyclers in the product development process to improve the design for circularity.

Benefits

- Circular ecosystem innovations that involve all relevant players enable a fair sharing of profits for new end-of-life activities.
- A circular product design enables the maximum gain of material value from a product.
- Joint collaborations between all relevant players to improve both product design and end-of-life process can ensure the availability of recycled materials in future in a sufficiently high quality and quantity to reduce the dependency from international resource markets.

Case example

Across several industries, numerous companies already incorporate elements of design for circularity. One of them is Werner & Mertz GmbH. The German producer of detergent and other related consumer household chemicals introduced the Frosch brand in 1986.
Since the last few years, the brand has started redesigning their range of packaging. This stems from the motivation to initiate the circularity of the products' packaging right from the design phase. As a result, the product portfolio now features packaging that is certified with the Cradle to Cradle quality certification. Rethinking the packaging of their products has led Frosch to a point where all of their newly produced detergent bottles are produced from 100% recycled polymers. The recycled polymer mix is composed of 75% polymers from household collection and 25% polymers from returnable bottles. Many more products within the company's range now incorporate high levels of recycled content during their production and Frosch is focused on further increasing this figure. The goal here is to redesign every product's packaging using insights from the already existing PET, PE and PP recycling streams. The fact that the brand's recycling streams are not brand exclusive and therefore not strictly proprietary represent another important detail. For instance, this allows Frosch to source polymers required for packaging production from Germany's nation-wide household collection system "Gelber Sack".
These efforts are completed with various cross-value cycle partnerships including German recovery manager "Grüner Punkt", retailers like Rewe, a mechanical engineering company, a converter and a NGO.



Total cost of ownership and lifecycle costs

The Key Performance Indicators (KPIs) used in a company are often oriented at linear business models and thus hinder a transition towards the circular economy. One example is short-term profitability playing the most important role for investment decisions, a strategic orientation disregarding new business models that only pay off in the long run.
Which KPIs play the most important role in a company, strongly depends on the strategic targets. Relevant questions are, for example, if the circular economy is integrated in the corporate strategy, how relevant a long-term focus is and how seriously risk factors, such as geopolitical material supply risks, are taken. "Revenue from circular business models" is not only a cross-functional and end-to-end TOP-KPI, it anchors the philosophy of 10R (recover, recycle, repurpose, repair, remanufacture/refurbish, revitalize, reuse, reduce, redesign and refuse) at all leadership levels. It connects sustainability, profitability and resilience holistically.
If steering mechanisms for risk factors are already established in a company, it has a strong influence on the possibilities to consider material supply risk factors in operative business.
Material supply risks should ideally be part of the Net present Value calculations in the product development process, but the calculation method is not specific enough to regard this risk perspective sufficiently. One suitable approach would be target costing, which is already wide-spread in the product development process to avoid over-engineering and could easily be also applied for material supply risks and for KPIs such as carbon footprint. Another suitable approach would be total cost of ownership, relating to all costs which occur in a product's lifetime. The use phase and especially the end-of-life recycling phase is typically not yet considered – economically and ecologically. The "ownership" in Total Cost of Ownership needs to be reconsidered and adjusted to a circular mindset with conservation of resources in focus.

Recommended action

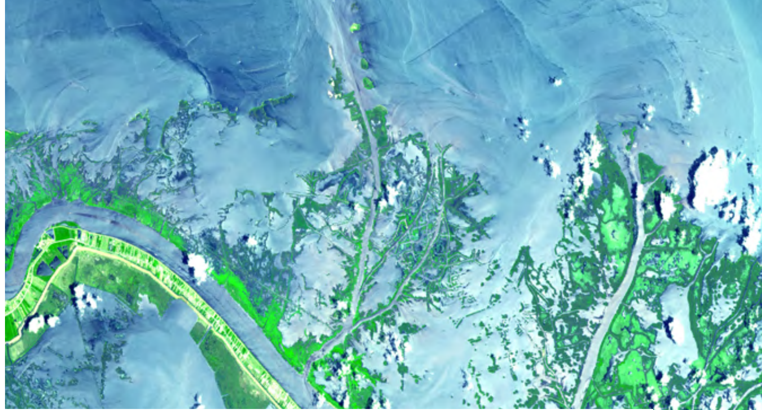
1. Increase awareness for material supply risk at top management level, also in companies that are not publicly listed and include long-term strategic targets in corporate strategy.
2. Establish steering mechanisms for risk factors in the company to enable operational decisions connected to supply risks.
3. Approach risk assessment in the product development process with target costing or total cost of ownership.
4. Provide training for employees to change thought patterns from merely cost-oriented to cost-/risk-oriented sourcing strategies.

Benefits

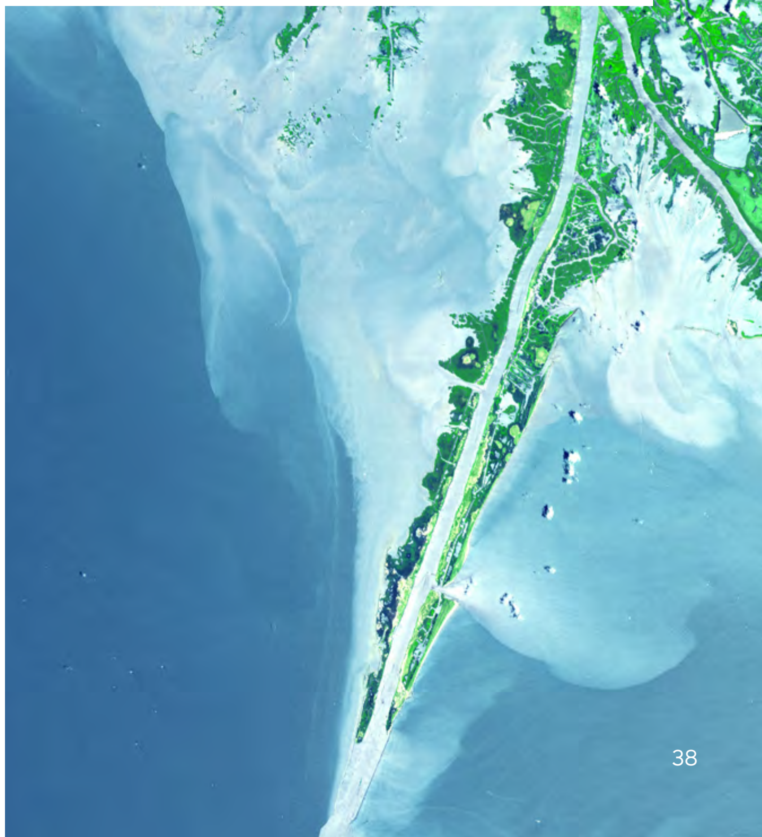
- Risk management systems enable a steering of operational decisions based on important risk factors.
- A clear strategic prioritization of long-term aspects and circular economy approaches can set the guardrails to reduce material supply risks.
- Suitable calculation methods for risk factors enable a direct consideration of risk factors in the product development process.

Case example

In this context, one important example is the German venture capital fund Planet A. Starting off in 2020, their first fund included investments in 14 impact start-ups. Only a few years later, in early 2023, the impact investor set out to build a new fund to boost European greentech start-ups and ended up collecting €160 mn from investors including BMW, KfW Capital, Rewe and many more. Within the process of performing the due diligence for their newest fund, Planet A increased the depth of analysis regarding four key areas: climate change mitigation, resource savings, biodiversity protection and waste reduction. With analysis including life cycle assessments amongst others, Planet A aimed at demonstrating intentional, positive and quantifiable impact in at least one of these four areas. After having performed the analysis, scientists from within the team were granted the right of veto if any nonconformity in the assessment is detected.
Therefore, the investment decision is centered around the ambition to quantify positive net effects of a product or service throughout its lifecycle, including all resource and material streams as well as emissions. In contrast to other impact investors, Planet A aims at assessing all effects of its investments on the planet and not only emissions. The result is a new, comprehensive approach and investments in ventures that offer



not only scalability but also positive net effects on the planet.
These intensive assessments result in investments in start-ups such as unwritten, makersite, optimal and the upright project. All of these ventures strive to increase data availability and transparency with regards to climate change mitigation and limiting resource extraction.



Conclusion and Outlook

The landscape of global trade has been significantly transformed by globalization and industrialization, fostering an era of unparalleled efficiency. However, this efficiency has come at a cost, exposing the vulnerabilities inherent in complex, transnational supply chains. Recent disruptions, ranging from natural disasters to global health crises, have underscored the fragility of these networks and the critical need for companies to build resilience.

This white paper has highlighted the significant economic and operational risks associated with over-reliance on global supply chains, particularly those heavily dependent on a single source for critical raw materials. The increasing frequency of supply chain disruptions necessitates a paradigm shift towards more robust and sustainable business models.

While it comes with significant hurdles in implementation, the concept of circular economy offers a compelling solution. By prioritizing resource recovery, reuse and remanufacturing, companies can significantly reduce their dependency on virgin materials and external suppliers creating a more resilient and cost-effective business model in the long run. This not only mitigates supply chain risks and business case opportunities but also fosters environmental sustainability by minimizing resource extraction and promoting closed-loop systems.

Transitioning towards a circular economy requires a multi-pronged approach. Companies should prioritize strategies such as:

- Increasing data transparency throughout the entire supply chain to cover processing steps and relevant risk factors
- Nearshoring and reducing reliance on distant suppliers by sourcing materials and components from geographically closer locations.
- Material looping through open-loop and closed-loop recycling: Incorporating recycled content into products while accepting used products back at the end-of-life for disassembly and reintegration into the production cycle.
- Repair, Refurbish or Reuse products focuses on maximizing product usage and lifespan leveraging the circular economy principles.
- Designing for circularity: Developing products from the outset with disassembly and recyclability in mind, facilitating the extraction and reintroduction of valuable materials at the end-of-life stage.
- Adopting Key Performance Indicators (KPIs) for Circularity & Resilience: Establishing metrics to track progress towards circularity goals and measure the effectiveness of implemented strategies in enhancing supply chain resilience.

By embracing these principles, companies can not only mitigate supply chain risks but also contribute to a more sustainable future. The circular economy presents a win-win scenario, fostering business continuity, environmental responsibility and long-term economic prosperity.

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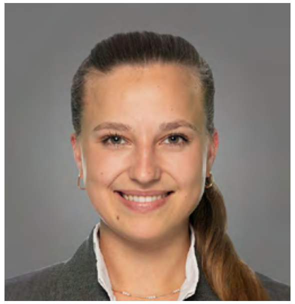
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CIRCULAR REPUBLIC is a pacesetter for the transformation towards a circular economy. Find out how we support you.

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