Deliverable D1.1
Map of disruptions experienced so far by the Rail Supply industry and lessons for the future

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1. Executive Summary

The Rail Supply Industry (RSI) in the EU accounts for nearly half of the world market for rail products and has a market share of more than 80% in Europe, while – as top exporter – it accounts for approximately 20% of world trade with railway products. The world leadership of the European RSI is largely due to its research, development and innovation capacities, and these are strongly boosted and coordinated at EU level by the former Shift2Rail and now Europe's Rail programmes to transform the European railway system by 2030.
At the same time Europe – already today – is not producing around ¼ of the Railway supplies it needs; these include *raw materials*, *intermediate products* and *finished products* (the amount in Euros was around 2.500 billions in 2014, with increasing trend).[1]

The COVID-19 lockdowns and the set of following crisis and supply disruptions (both short ones such as the Suez Canal blockage in 2021, and long ones like the ongoing war in Ukraine) have taught that *the more you rely on Global Value Chains* (GVCs) for your supplies, *the more you are vulnerable*. And in too many cases, the supply of key components and raw materials is *not only* very far from Europe *but also* concentrated in a few places, which boosts vulnerability. As reported by McKinsey[2], in fact, "more than 50% of chip foundry production capacity of about 45 nanometer or smaller chips (typically focused on logic chips) is concentrated in ~15 facilities (factory modules) in Taiwan. About 98% of manufacturing capacity of 350 nanometer and smaller optoelectronic chips (for example, used in image sensors, lasers, LEDs) is in 9 facilities in southern Japan, and about 40% of memory chip capacity is in 10 facilities in Seoul and surrounding cities".
Not only: the greater frequency and severity of climate hazards is teaching that climate change is one more source of disruptions in Global Value Chains, interrupting production, raising costs and prices, and hurting corporate resilience. According to McKinsey estimations, for instance, "by 2040 a company using leading-edge chips [such as an OEM manufacturer of Autonomous trains], sourcing from geographies in Korea, Japan, Taiwan or other hubs in the Western Pacific, can expect that hurricanes sufficient to disrupt their suppliers will become 2 to 4 times more likely"[3], with lasting effects for several months. Also, "the probability heavy rare earths production is severely disrupted from extreme rainfall may increase 2 to 3 times by 2030"[4], as their production is concentrated in Southern China, which is increasingly exposed to such extreme climate events. McKinsey estimates for instance that "the manifestation of an extreme precipitation event, or series of events, could cause at least a 20% drop in heavy rare earth output, and potentially much more in a worst-case scenario. Damage mechanisms include excessive mud and landslides in mines, flooding treatment ponds, and disrupted logistics to and from mines (…) and a large landslide could disrupt production for up to 12 months in severely hit mines, though for most mines the disruption would be shorter if the landslide is shallow and only affects parts of the

[1] European Commission (2019), *Final Report: Study on the Competitiveness of the European Rail Supply Industry*.
[2] McKinsey (2020), *Could climate become the weak link in your supply chain?*, p. 17.
[3] Ibidem.
[4] Ivi, p. 23.

mine".

Europe's vulnerability can increase proportionally with the increasing demand for Advanced Technologies and Advanced Materials[5] necessary to deliver (also) the innovations targeted by the Europe's Rail Master Plan and Multi Annual Work Programme for 2030. This is posing a double challenge: in terms of **change in the *demand***, and in terms of ***actual* capacity of Europe to supply and produce** the necessary materials and components for such innovations, or to source them from more reliable and secure supply chains from oversea.

This has become definitely clear with COVID-19 effect on Global Value Chains, with the result of the European Commission having to revise in May 2021 its Industrial Strategy – that had only been launched in March 2020 and then based on *Twin Transition* and *Global Competitiveness* -, including in it the ***Resilience*** of Europe's economy as well as the need to identify where Europe's strategic dependencies lie, how they may develop in the future and the extent to which they could lead to vulnerabilities. To achieve this, the European Commission:

- is **monitoring strategic dependencies**, identifying from the first bottom-up report **137 products** in sensitive ecosystems for which the European Union (EU) is highly dependent on foreign sources. The report also offers an in-depth analysis of 6 **strategic areas** where the EU has dependencies, and **5 of them are key for delivering the target Europe's Rail innovations in 2030**: raw materials; batteries; hydrogen; semiconductors; cloud and edge technologies. In this framework also lies the EU **monitoring of Critical Raw Materials for resilience**[6];
- based on that, is **developing Europe's strategic capacities and autonomy** by supporting **new industrial alliances** in the above (and further) strategic areas - Raw Materials Alliance; Clean Hydrogen Alliance; Circular Plastics Alliance; Industrial Data, Edge and Cloud Alliance; Processors and Semiconductor Technologies Alliance – as well as relevant Technological Partnerships – High Performance Computing; Photonics;
- is **diversifying international partnerships** to use trade to sustain strategic diversification of supply and demand.[7] In this sense, among the most recent initiatives taken by the EU: (a) "closely working with the Biden administration right now (…) we face (…) for example the challenge together that we are developing an over-dependency on China regarding raw materials that are critical for our green transition. So, one of the possible solutions could be to create a raw materials club to overcome China's monopoly in this field"[8]; (b) Strategic Partnership MoU between EU and Kazakhstan in the field of raw materials, batteries, and renewable hydrogen[9]; (c) EU-Latin America Partnership on Raw Materials[10].

[5] Advanced Materials | Advanced Technologies for Industry (europa.eu).
[6] Critical raw materials (europa.eu).
[7] European Industrial Strategy (europa.eu).
[8] Keynote speech by the President von der Leyen on the occasion of the 120th anniversary of Bocconi University, 7 December 2022.
[9] Strategic Partnership between the European Union and Kazakhstan on sustainable raw materials, batteries and renewable hydrogen value chains (europa.eu).
[10] The partnership | MDNP (mineralplatform.eu).

In this highly complex framework, the "Map of disruptions experienced so far by the Rail Supply industry and lessons for the future" offers a starting point for giving – ultimately – answer to the key question: ***will Europe have enough materials and components to deliver the railway innovations needed to transform the European Railway sector in 2030, as defined at EU level?***

To pose the first building block that will lead to such final answer at the end of the LEADER 2030 project, the study provides:

- key insights from desk research on disruptions in supplies having impacted Europe in the most recent years
- the results of the European survey of the Rail Supply industry on disruptions experienced since 2018, launched by the LEADER 2030 project.

Section 5 introduces to the key topics of supply *disruptions* and *dependencies*, to help the readers better understand not only the terminology but also the complexity behind them.

Section 6 presents the **Desk research** that was conducted on the many available studies and reports produced in the recent years following to the impact of the COVID-19 pandemic, war in Ukraine and other major events having impacted on the flow of global supplies. The detailed list of consulted documents is provided in the *References* – **Section 9**.
The desk research phase not only provided a huge quantity of information, of which the key ones are highlighted in this study as necessary for drawing specific conclusions for the Railway sector, but also provided guidelines to better frame and select the questions for the survey phase.

Section 7 presents the **Survey** that was conducted through a multilanguage online European Consultation addressed to companies of the Rail Value Chain, and open from November to December 2023, and its results. Also it comments the survey results with **correlations** with the ones emerged in the Desk research phase.

Section 8 draws the final conclusions and introduces to the next project steps.

2. Abbreviations and acronyms

Abbreviation / Acronym	Description
CRMs	Critical Raw Materials
DG GROW	Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs of the European Commission
ECB	European Central Bank
ECCP	European Cluster Collaboration Platform
EIB	European Investment Bank
EISMEA	European Innovation Council and SMEs Executive Agency
EU	European Union
EU-RAIL / EU-RAIL JU	Europe's Rail Joint Undertaking
Eurostat	Statistical office of the European Union
GDP	Gross Domestic Product
GVCs	Global Value Chains
ISO	International Standards Organization
JRC	Joint Research Centre of the European Commission
LEADER 2030	"Learning for European Autonomy to Deliver Europe's Rail in 2030"
MoU	Memorandum of Understanding
OECD	Organisation for Economic Co-operation and Development
RSI	Rail Supply Industry
SME(s)	Small and Medium-sized Enterprise(s)
TTC	EU-US Trade and Technology Council
WTO	World Trade Organization

3. Background

The present document constitutes the Deliverable D1.1 “Map of disruptions experienced so far by the Rail Supply industry and lessons for the future” in the framework of the Exploratory Research Project LEADER 2030 as described in the EU-RAIL AWP 2022. Ultimately, it aims to contribute with intelligence information to the execution of all Flagship Projects.

4. Objective/Aim

The purpose of this Report is to:

- study the effects on the EU industrial ecosystems of the supply disruptions/distorsions driven by COVID-19 lockdowns and other recent supplies-disrupting/distorting crisis (e.g. Ukraine war, logistics disruptions and high rise of costs, rising and volatile energy and raw material prices, etc.), including the impact of climate change, and the overall key-lessons learnt;
- study how specifically the Rail supply chain (especially SMEs) was impacted by such crisis;
- compare the first study and the second to identify if specific characteristics regarding the Rail supply chain exist both in terms of “more disruption" and “more resilience” compared to other EU industrial ecosystems or general trends.

5. Setting the scene

5.1. Introduction to Supply Chain Disruptions

The continuous growth of Global Value Chains (GVCs) in the past decades – except for the decline caused by the 2008 global financial crisis – has seen the European Union (EU) as primary actor in such trade flows, as European producers rely heavily on imported parts and components from overseas.
The search for cost-based comparative advantage at each stage of the production process have in fact led the companies to move labour and capacity to very low-cost markets in Asia, first of all to China[11], making the supply chains increasingly complex as they span across a variety of geographical areas.
The GVCs can be in fact described as "fragmented networks of production-sharing", since "the different stages of the production process are located across different countries"[12]. Following the "specialisation of countries in tasks and business functions rather than specific products", in fact, "most goods and an increasing number of services are 'made in the world'"[13].

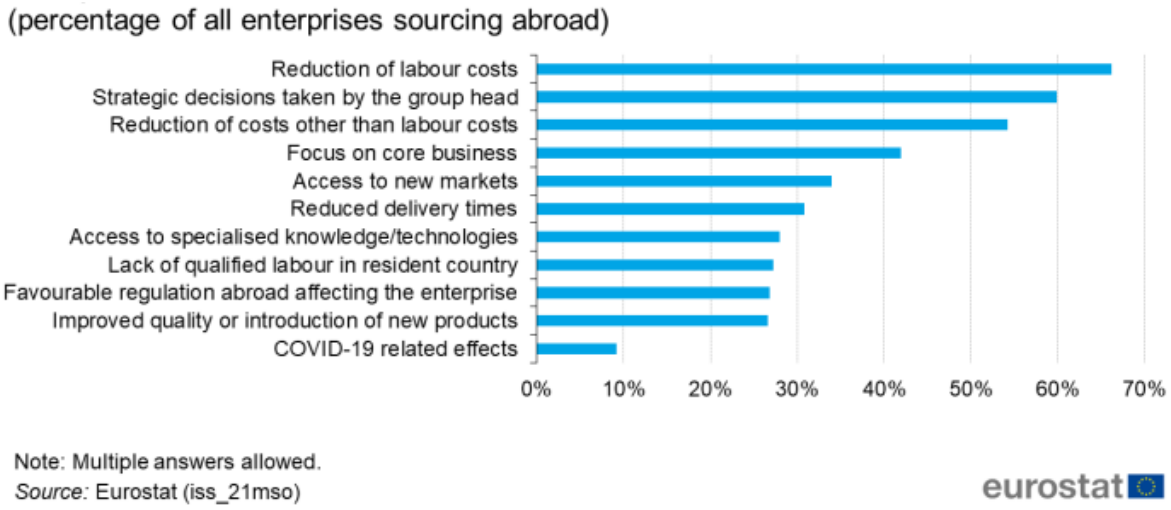
This phenomenon has been driven by large multinational enterprises, but small and medium-sized enterprises (SMEs) also have integrated the GVCs into their businesses.

> "Companies started developing single source supplier relationships with key contractors spread across just a few provinces in China. As years passed, these supply chains became more intertwined and integrated. The cost reduction focus brought in reduced inventory buffers, increased demand for shorter delivery windows and therefore shorter lead times. The logistics providers responded to market needs, and large mother ships with capacities of 10,000-plus containers became a norm. In an effort to keep the freight rates low, massive manufacturing of containers took off in China, just to keep the supply steady. Few thought about the vulnerabilities this introduced to businesses; risk assessments that pointed out supply disruptions were largely ignored".[14]

The reasons for

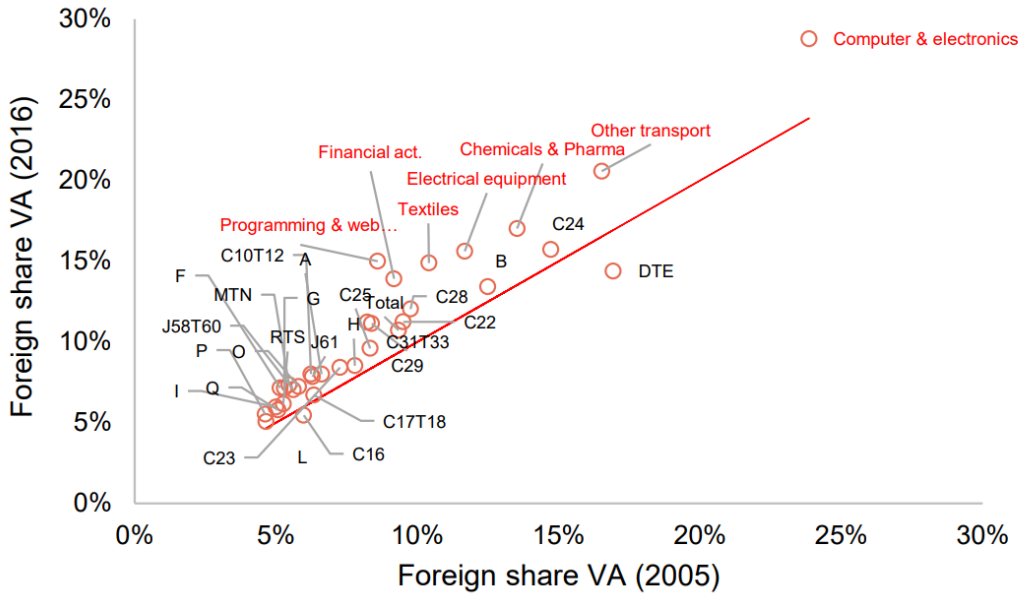
[11] According to Statista, China accounted for 28,7% as share of global manufacturing output in 2019, the second being the US with 16,8%. Available at Chart: China Is the World's Manufacturing Superpower | Statista.
[12] See respectively WTO (Global Value Chain Development Report 2021: Beyond Production (wto.org)) and OECD (Global value chains - OECD).
[13] De Backer K, Miroudot S (2014), "Mapping Global Value Chains", *Working Paper Series* n. 1677, European Central Bank, p. 4.
[14] Bhairavi J (2021), "Global supply chain dependencies and disruptions · Global supply chains, national resilience, and dependency on China", *Project for Peaceful Competition*.

Figure 1 | Motivational factors important for enterprises sourcing abroad (2018-2020) (source: Eurostat)[15]



Such industrial decisions have led the European market to become increasingly dependent on foreign supplies, with a trend shown in the following Figure:

Figure 2 | Share of EU foreign value added (comparison 2016 vs 2005)[16]



All this has multiplied business opportunities for European – and global – enterprises, but also

[15] Eurostat (2022), *Motivational factors important for enterprises sourcing abroad (2018-2020)*, 4 October.
[16] Benoit F, Connell García W, Herghelegiu C, Pasimeni P (2021), "Detecting and Analysing Supply Chain Disruptions", *Single Market Economy Papers*, European Commission, p. 8.

has multiplied the vulnerabilities and risks of disruptions suitable to affect the flow of supplies in the European market.

5.1.1. What triggers Supply Chain Disruptions

> "Supply chain disruptions are not exceptional, *per se*. They take place daily, given the multitude of factors that impact a supply chain. But when disruptions are systemic, like those which followed 9/11, an adjustment process is universal. In such a situation, there is a direct impact on the flow of goods and cargo carrying capacity, but also on the data flows and information that need to be shared across the chain. And, of course, cost parameters go through changes of a similar magnitude"[17].

5.1.1.1. Definition of Disruption

According to the ISO Standard 22301:2019 "Security and resilience – Business continuity management systems – Requirements", the **word *disruption* means**:

> "incident, whether anticipated or unanticipated, that causes an unplanned, negative deviation from the expected delivery of products and services according to an organization's objectives"[18].

Such meaning clearly highlights the ***incidental nature*** and the ***effects*** on business processes, at a clear **micro-economic scale**, i.e. at company/organisation level.

For a **macro-economic scale** analysis, which is the target here, we can refer to the following definition:

> "Supply chain disruptions are defined as **unexpected** and **unforeseen events** or **circumstances** that **disturb** the **regular flow** of goods and materials **along the value chain**"[19].

Other definitions of *disruption* can be found in many EU policy and research documents (e.g. *technological disruption*[20], *innovation disruption*[21], *productive disruption*[22], etc.), as well as in many documents of international organisations and Academia. However, the above mentioned

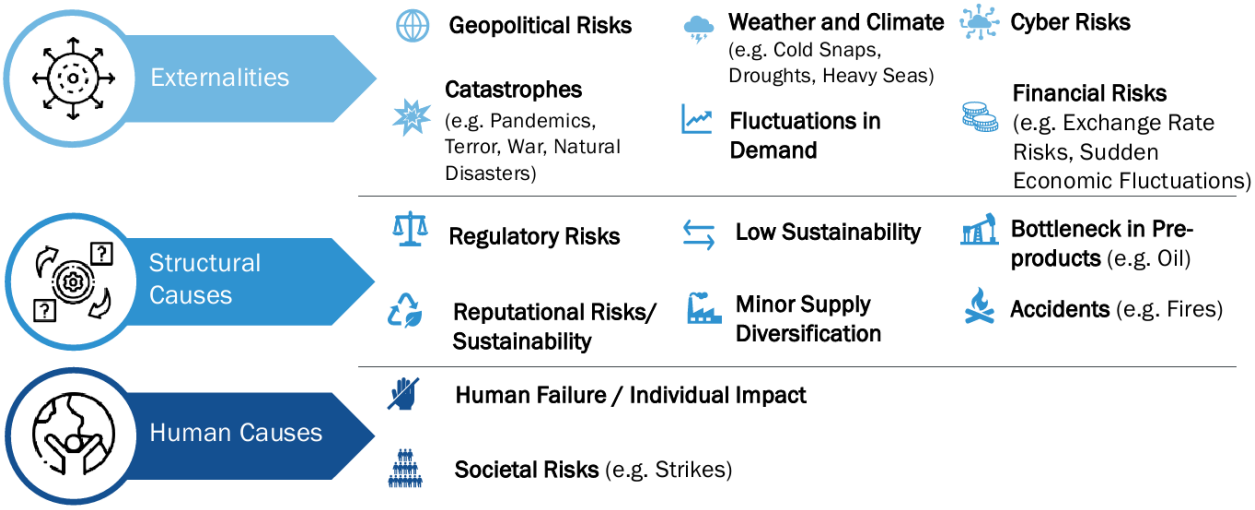
[17] Ibidem.
[18] ISO 22301:2019(en), Security and resilience — Business continuity management systems — Requirements.
[19] Novoszel L, Wakolbinger T (2022), "Meta-analysis of Supply Chain Disruption Research", *Operations Research Forum*, Springer, para. 2.3.3.
[20] Disruption by technology (europa.eu).
[21] Disruptive innovation - Publications Office of the EU (europa.eu).
[22] The Principle of Disruption. A Figure Reflecting Complex Societies | DISRUPTION | Project | News & Multimedia | FP7 | CORDIS | European Commission (europa.eu).

definitions (ISO standard and Novoszel-Wakolbinger, 2022) are closer to the concept under analysis in this study, for the fact that the *incident/event* triggering supply chains disruptions cannot be productive, and here the impact of a new *technology* introduction or *innovation* is not under focus; it will be analysed at a later stage of the project, but not here.

5.1.1.2. Nature of Disruptions

Concerning the ***nature*** of the incident/event, according to the ECCP-European Cluster Collaboration Platform, supply chains disruptions can be triggered through a **variety of factors**, where a **series of unrelated events** could effectively cause a shortage. Even though the risks might appear distinct from one another on the surface, it is the **culmination of different factors** affecting different stages and aspects of a business output that can constitute the disruption[23]. Such factors are summarized in the next Figure:

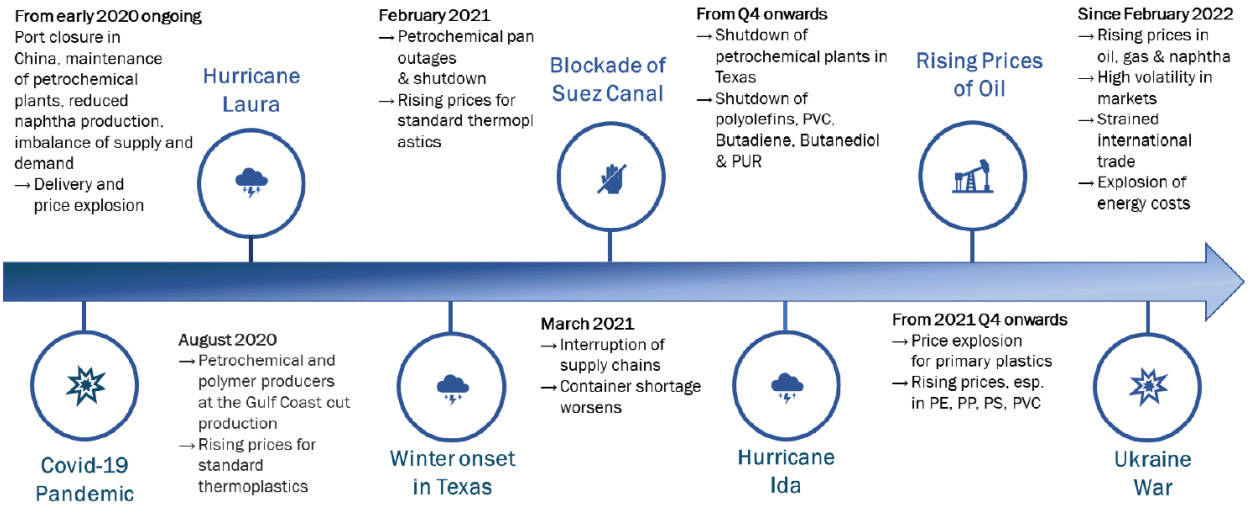
Figure 3 | Dimensions of risks to supply chains[24]



How a series of unrelated events of different nature can lead to a long period of supply disruptions is proved by the set of events mapped by ECCP between 2020 and beginning 2022:

[23] ECCP (2022b), *Report on the survey 'Solutions to Supply Chain Disruptions in the EU'*, p. 9.
[24] Ibidem.

Figure 4 | Events impacting the supply chains from 2020 to early 2022[25]



Of course, the list of events having an impact on the supply chains continued after the timeframe of Figure 3, and include:

- high rise of freight shipping rates by sea, air, truck along major global trade routes
- freight shipping delays
- continuous rise of energy prices
- food crisis
- rise of inflation at global level, and with double-digit in Europe
- up to the recent War in the Gaza Strip, with first impacts on freight shipping in the Red Sea and Suez Canal, having a fundamental role in global trades[26].

The variety of events/factors that may conduct to disruptions is – as shown – wide and complex. However, for the goal of this study, the events mainly taken into consideration are the ones which have a **lower level of predictability and of company preparedness** (i.e. excluding for instance regulatory risks, cyber risks, reputational risks/sustainability, etc., as companies can have time to comply with new rules, to implement cybersecurity solutions to reduce risks and mitigate impact, to implement sustainable actions, etc.).

5.1.2. Impacts of Disruptions

Each disruption produces a wide array of impacts, which ultimately "disturb the regular flow of

[25] Ibidem.

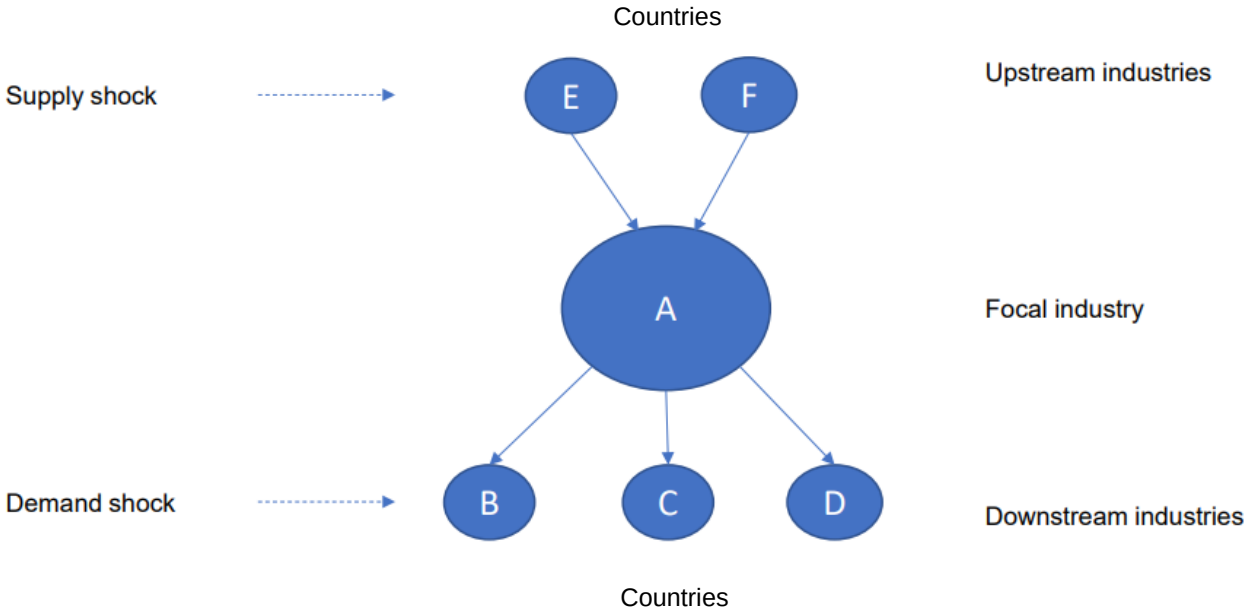
[26] See on the point After Covid and Ukraine war, another supply-chain disruption taking shape? - The Economic Times (indiatimes.com) and The Impact of the Israel-Hamas War on Global Logistics and Supply Chain (logisticsinsider.in).

goods and materials along the value chain", as per the definition given above.

This is what the majority of the literature reviews calls "**multiple supply chain disruptions"** – e.g. disruptions in the supply and demand stage together – or the "**ripple effect"**[27]. This means that an operational disruption propagates beyond its origin and across the entire network.

According to OECD-Organisation for Economic Co-operation and Development, the **propagation of a 'shock'** in GVCs follows this model:

Figure 5 | The propagation of supply and demand shocks through GVCs[28]



"Upstream supply shocks or downstream demand shocks can affect domestic output by percolating through GVCs [see Figure 4]. For instance, flooding in Thailand in 2011 disrupted the supply of electronics components (say upstream industry in country E) to Japanese and US carmakers and technology companies (focal industry in country

[27] References to papers diffusely addressing such key concept can be found in: Yuhong L, Kedong C, Collignon S, Ivanov D (2021), "Ripple effect in the supply chain network: Forward and backward disruption propagation, network health and firm vulnerability", *European Journal of Operational Research*, Vol. 291, Issue 3, pp. 1117-1131.

[28] Schwellnus C, Haramboure A, Samek L, Chiapin Pechansky R, Cadestin C (2023), "Global value chain dependencies under the magnifying glass", *OECD Science, Technology and Industry Policy Papers*, n. 142, OECD, p. 11.

A). By contrast, the global financial crisis of 2008-09 reduced final demand for the output of downstream producers (say downstream industries in country C), which in turn reduced demand for intermediate inputs addressed to upstream producers (focal industry in country A)"[29].

Following this model, it's easier to understand the *ripple effect* generated during crisis igniting disruptions. As example, such ignition at the beginning of the COVID-19 crisis worked as follows:

> "the pandemic caused the operations suspension in China in February and March 2020, which further disrupted US and European manufacturers and retailers because of supply shortage. Additionally, the stay-at-home order during the COVID-19 pandemic has caused demand disruption to the travel and tourism-related industries. Then the disruption diffuses to airline companies, hotels, and restaurants and further negatively influences their associated supply companies"[30].

Focusing on supply shocks, disruptions can impact **specific stages** of the supply chain.
The stages identified by the ECCP following its Survey "Solutions to Supply Chain Disruptions in the EU" in 2022 are the following, listed per magnitude of impact on European companies, from the most impactful to the least[31]:

- Inbound logistics – *of raw materials, intermediate inputs, storage*
- Procurement – *of such supplies* (supplier management, funding, specification, standardisation)
- Operations (manufacturing, processing, maintenance)
- Human Resource Management
- Outbound Logistics
- Research and Development
- Marketing & Sales
- Administrative, Finance infrastructure
- Services (e.g. post-sale services, upgrades, etc.).

The ECCP fact-finding results confirm similar trends observed in other reports on the COVID-19 shock and the following ones, i.e. that **the areas mostly impacted** by the supply chain shocks have been:

- Logistics breakdowns – *due to transportation bottlenecks, port closures, shipping rates skyrocketing, etc.*
- Lack of material supplies – *due to concentration of suppliers, export restrictions, closure of suppliers, climate events, etc.*

[29] Ibidem.
[30] Op. cit., Yuhong L, Kedong C, Collignon S, Ivanov D (2021).
[31] Op. cit., ECCP (2022b), p. 17.

- Energy security – *due to oil and gas skyrocketing prices, need to change sources and suppliers, etc.* [32].

In terms of crisis **impact on enterprises' export capacity**, it is interesting to report that "unlike during the global financial crisis [in 2008, where being part of GVCs and having diversified trade relationships was source of resilience for companies], during the pandemic GVC firms experienced a larger drop in exports compared with other exporters, suggesting that supply value chains can be either a source of vulnerability or a source of resilience, depending on the nature of the crisis"[33].

5.2. Introduction to Supply Dependencies

5.2.1. Definition of Dependencies and Strategic Dependencies

The European Commission defines *dependencies* as:

> "reliance on a **limited** number of **actors** for the supply of goods, services, data, infrastructures, skills and technologies combined with a **limited capacity** for internal production to substitute imports"[34].

The concept is valid *per se* also at micro-economic level (individual business level), but of course here the reference is made to the macro-economic level.

Similarly, the European Commission defines *strategic dependencies* as:

> "dependencies that are considered of critical importance to the EU and its Member States' strategic interests such as security, safety, health and the green and digital transformation"[35].

The reference to the green and digital transformation as strategic interest lies in the EU vision for 2050, therefore its actual achievement is strategic. However, its reference here is highly meaningful not just as 'exemplification' of EU strategic interests, but rather because the realisation of the so-called Twin Transition will require a huge quantity of materials and components for which the EU is totally or very highly dependent on third countries.
This point will be further detailed in Section 6.

[32] Accenture (2022), *From disruption to reinvention: The future of supply chains in Europe*, p. 7.
[33] Lebastard L, Serafini R (2023), "Global value chains and the pandemic: the impact of supply bottlenecks", *Economic Bulletin Boxes Issue 2-2023*, European Central Bank.
[34] European Commission (2021a), *Commission staff working document 'Strategic dependencies and capacities'*, p. 8.
[35] Ibidem.

5.2.2. …and their contrary: Autonomy and Strategic Autonomy

"Neither autarchy nor dependence - more European autonomy"

Thierry Breton, European Commissioner for Internal Market[36]

In order to counterbalance dependencies, which harm a country's (or regional power's - like in the case of EU) capacity to "produce, provide or rely on (strategic) goods, services, data, infrastructures, skills, industrial know-how and technologies"[37], there is the need to work for ensuring ***strategic autonomy***.
The concept is introduced in the EU for the first time *with an industrial meaning* in the European Industrial Strategy 2020[38], coupled with the word "industrial competitiveness" at point 2.1, and then in the dedicated chapter 4 "Reinforcing Europe's industrial and strategic autonomy":

> "Europe's strategic autonomy is about **reducing dependence on others for things we need the most**: critical materials and technologies, food, infrastructure, security and other strategic areas. They also provide Europe's industry with an opportunity to develop its own markets, products and services which boost competitiveness".

According to the literature, the term was coined by Charles De Gaulle in 1950, with a *defence* meaning[39]. 'Revamped' in the 90s, France was the first to officially use it in its "Livre Blanc sur la Défense" (White Paper on Defence)[40] in 1994, and then the EU Institutions followed in 1998 with usage referred to the EU's Common Defence Policy and NATO pillar (to mean conducting military crisis-management operations outside European territory autonomously but if necessary with the support of NATO resources), and then for the EU's Common Foreign and Security Policy (CFSP)[41].

The transition from a *defence* towards an *industrial* meaning usage could be well represented by the proposal and adoption in 2017 of the EU Regulation establishing a European Defence Industrial Development Programme, aiming at "enhancing the competitiveness and innovation of the EU defence industry including cyber defence" in order to "fully meet Europe's current and future security needs". The text concluded that this "would ultimately help to enhance the Union *strategic autonomy* and strengthen its ability to act with partners"[42].

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[36] Breton T (2022), "Neither autarchy nor dependence – more European autonomy", *Blog of Commissioner Thierry Breton*, 25 August.
[37] Op. cit., European Commission (2021a), p. 8.
[38] European Commission (2020a), *Communication from the Commission 'New Industrial Strategy for Europe'*, Commission Communication, COM(2020) 102 final.
[39] Mauro F (2018), "Autonomie stratégique. Le nouveau Graal de la défense européenne", *Les rapports du Grip*, p. 4.
[40] Ibidem.
[41] Van den Abeele E. (2021), "Towards a new paradigm in open strategic autonomy", *ETUI Working Paper 2021.03*, p. 13.
[42] Regulation of the European Parliament and of the Council establishing the European Defence Industrial Development Programme aiming at supporting the competitiveness and innovative capacity of the EU defence

The 'way' the EU is pursuing its strategic autonomy is called ***Open Strategic Autonomy***, and is defined by the European Commission as:

> "the ability to shape the new system of global economic governance and **develop mutually beneficial bilateral relations**, **while protecting the EU** from unfair and abusive practices, including to **diversify and solidify global supply chains to enhance resilience to future crises**"[43].

The JRC shortly defines the concept as:

> "…equipping the EU to manage interdependence in line with its interests and values"[44],

but the best conceptual synthesis seems to be provided by the Research Service of the European Parliament:

> "Open strategic autonomy is about ensuring that the EU has the **capacity to cope alone if necessary** but **without ruling out cooperation whenever possible**. It goes some **steps beyond smart supply chain management** by taking into account geopolitics as well as economic factors. It relies on foresight to identify threats and ensures resilience by anticipating the required responses"[45].

Conceptually, *open strategic autonomy* is a result of the COVID-19 shock and of deep-rooted European values always aiming to foster growth by openness, but not only:

> "import openness from third-party countries remains crucial for various regions (…). (…) a European de-risking strategy, reducing the risk of dependence on third-party countries, is more desirable for (…) supply chain resilience compared to autonomy strategies and protectionist policies"[46].

Whereas the EU has chosen *openness* and *multilateralism* as way to *protect itself* – as "reshoring and decoupling mean that the EU's interdependencies could be turned against it"[47] - other major economic powers have addressed the need to protect own economic, industrial and social

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industry, COM(2017) 294 final, Exploratory Memorandum, point 1, para. 2.

[43] Op. cit., European Commission (2021), p. 7-8.

[44] JRC (2021), *Shaping and securing the EU's Open Strategic Autonomy by 2040 and beyond*, European Commission, p. 1.

[45] García Higuera A, Weichert C (2023), "What if open strategic autonomy could break the cycle of recurring crises?", *Scientific Foresight: What if*, European Parliamentary Research Service - Scientific Foresight Unit, p. 1.

[46] Orecchia M, Romeo G (2023), "Strategic autonomy in the cleantech rush: Europe, United States and China", *Orizzonti Politici*, p. 2.

[47] Op. cit, García Higuera A, Weichert C (2023), p. 1.

ecosystems focusing on 'pure' *resilience* of *supply chains* and *protectionist* policies[48].
It is the case of US, that in the latest years adopted protectionist acts defining generous subsidy schemes to companies who manufacture in the US or build infrastructures using US materials (i.e. in 2021 the "Infrastructure Investment and Jobs Act"[49] and in 2022 the "CHIPS and Science Act"[50] – further tightened in October 2023[51] - and the "Inflation Reduction Act"[52]), and where recently the "White House Council on Supply Chain Resilience" started its activities[53], unveiling the creation at the Department of Homeland Security of the "Supply Chain Resilience Centre" (SCRC):

> "a new U.S. government entity designed to collaborate with the private sector to better secure our supply chains. The SCRC will **analyze vulnerabilities** and conduct **scenario planning** with private sector stakeholders to help **mitigate** supply chain **disruptions**, **ensure** reliable and efficient **deliveries** of goods and services, and **lower costs** for the American people"[54].

It is also the case of Japan, which adopted measures to help supply chain resilience since early 2020 with investment subsidies to assist Japanese companies to relocate production back to Japan and to countries in Southeast Asia (i.e. the "Program for Promoting Investment in Japan to Strengthen Supply Chains", supporting the return of production bases to Japan for products, parts, and materials for which Japan is highly dependent on one country; the "Overseas Supply Chain Diversification Support Project", that promotes the establishment in ASEAN countries of multiple manufacturing bases to supply products and materials to Japan)[55]. On the security of supplies side, the "Economic Security Protection Act" adopted in 2022 and to be implemented in stages along 2023 and 2024, establishes: (i) a system to ensure stable supplies of critical materials; (ii) a system to ensure stable provision of services using critical infrastructure; (iii) a system to support the development of critical technologies; (iv) a secret patent system[56].

With a dose of realism, this introductory section is concluded with the following consideration

[48] Pros and cons of the two approaches are analysed by the European Commission Directorate-General Taxation and Customs Union: García Sánchez J J (2023) "American protectionism: can it work?", *Epicenter Blog*, Harvard University, 16 August.
[49] Final Build America, Buy America Act Guidance Released, Tightening U.S. Content Requirements For Federally Funded Infrastructure Projects | Baker Donelson - JDSupra.
[50] Fact Sheet: CHIPS and Science Act Will Lower Costs, Create Jobs, Strengthen Supply Chains, and Counter China | The White House.
[51] Public Information on Export Controls imposed on Advanced Computing and Semiconductor manufacturing items to the People's Republic of China (PRC) (doc.gov).
[52] Inflation Reduction Act Guidebook | Clean Energy | The White House.
[53] The White House (2023), *Issue Brief: Supply Chain Resilience*, 30 November.
[54] Biden-Harris Administration Announces Supply Chain Resilience Center to Protect U.S. Supply Chain from Evolving Threats | Homeland Security (dhs.gov).
[55] Government Initiatives | Manufacturing - Industries - Investing in Japan - Japan External Trade Organization - JETRO.
[56] Japan's economic security legislation (europa.eu).

that will be taken into account in commenting specific answers gathered in the Survey phase:

> "The ongoing debate surrounding strategic autonomy in Europe rests upon a **fundamental assumption**: when companies base their investment decisions and supply chains solely on their economic interests, they risk creating trade models that excessively depend on unreliable partners. Pursuing strategic autonomy thus implies reconsidering the trade-off between economic efficiency and geopolitical resilience"[57].

Far from being a theorical problem, 'diverging' behaviours in the supply chains from *what should be good to be done* and *what is actually done* is proven also in Japan:

> "Japan's ties with China have strengthened rather than decoupling amid the COVID pandemic. Japan's economy is supported by exports that have grown due to China's rapid economic recovery. (…) the primary driving force behind Japan's growing trade with China is **Japanese business and not the Japanese government**. Business circles are generally interest-driven and are unlikely to prioritize security considerations"[58].

[57] Op. cit., Orecchia M, Romeo G (2023), p. 5.
[58] ISPI (2022), *Japan's Initiatives to Secure Supply Chains and Its Key Challenges*, 17 March.

6. Desk research on Disruptions and Dependencies in Supplies in the European industrial ecosystems

"European industrial ecosystem" is the *approach* introduced by the European Commission in the Industrial Strategy 2020 - and further detailed in 14 specific *ecosystems for resilience* in the update 2021 to such a Strategy – *to look at Europe's economy* with a 'systemic lens', recognising **importance of "all the horizontal and vertical links among economic actors** (…) **often considered as ancillary to industry**, such as supply of raw material, research and innovation, the provision of business services, or access to distribution networks". The industrial ecosystems, therefore, encompass "all players involved in the achievement of a certain socioeconomic goal: from the smallest start-ups and the largest companies cooperating to satisfy a new market need, the research activities supporting industrial innovation, the regulators steering economic activity through conducive policies, to the services providers and suppliers" [59].

The process of identification of the 14 industrial ecosystems has been "based on their **economic and technological relevance**, and for **their expected contribution to the decarbonisation, digitalisation and resilience** of the EU economy" [60], although they don't represent the entire EU economy but approximately its 70%, and 80% of EU value added.

The Figure below shows them, and it is immediately clear that overlapping exist. The Rail Supply Industry, in fact, lies certainly in the *Mobility-Transport-Automotive* ecosystem, but part also in the *Construction* ecosystem, as well as in the *Electronics*, in the *Digital* and in the *Energy intensive industries* ones.

[59] European Commission (2021b), *Commission Staff Working Document, Annual Single Market Report 2021*, p. 72.
[60] Ibidem.

Figure 6 | The 14 Industrial Ecosystems identified in the EU Industrial Strategy 2021 (source: European Commission)[61]

6.1. Disruptions and Dependencies in Supplies in the EU

Fact-based information about **disruptions** having affected – and still affecting – European companies is quite rich. Since the beginning of COVID-19 shock, at various level it was tried to map *type* and *magnitude* of disruptions, also for the European and national institutions' need to fast-track support initiatives as much tailored as possible.

The most fact-based literature includes surveys, mapping and studies from:

- the ECCP-European Cluster Collaboration Platform, given cluster organisations' role to group "specialised companies and other kinds of actors (SMEs, academic institutions, research centres, training centres, etc.) which share a common vision, cooperate closely among themselves and form a connected network with a view to mobilising a representative critical mass in a particular area of activity" and "hold the EU's industrial policy together", hence being "the key channels for

[61] European industrial strategy - European Commission (europa.eu).

the strategic value chains"[62]. The author of this study represents a group of these in the railway sector

- the European Commission-DG GROW[63]
- the European Central Bank and other National Central Banks[64]

whereas more general statistics are certainly provided by:

- Eurostat[65]
- Statista[66]
- Consulting companies such as Accenture, McKinsey, Boston Consulting Group, etc..

For mapping **dependencies**:

- the fundamental analysis and studies are from the European Commission and mainly concern Critical Raw Materials[67]
- other more partial and/or with sectorial-focus analysis and studies are provided by plenty of sources, including:
  - International organisations, such as OECD[68], WTO[69]
  - The European Central Bank and other National Central Banks[70]
  - economic/policy research centres[71].

The following sub-chapters will focus on disruptions and dependencies relevant to the Rail Value Chain - hence not covering those concerning food supplies, medical supplies, etc..

6.1.1. Disruptions in EU Supplies

[62] Op. cit., Van den Abeele E (2021), p, 29.
[63] Internal Market, Industry, Entrepreneurship and SMEs - European Commission (europa.eu).
[64] Relevant European Central Bank publications can be found at: Publications by date (europa.eu). National studies on impacted value chains include, to name a few: *Assessments and expectations of firms in the pandemic: findings from the Bundesbank Online Panel Firms* by the National Bank of Germany; *Global supply chain bottlenecks and exporter performance: evidence from Italy* by the National Bank of Italy; *Banco de España survey on business activity - EBAE - Reports and statistical products* by the National Bank of Spain, etc..
[65] International sourcing, business functions and global value chains - Statistics Explained (europa.eu).
[66] Statista - The Statistics Portal for Market Data, Market Research and Market Studies.
[67] Critical raw materials - European Commission (europa.eu).
[68] OECD iLibrary (oecd-ilibrary.org).
[69] WTO | Publications by subjects.
[70] To mention a few: *Critical raw materials: the dependence and vulnerabilities of the EU* by the National Bank of France; *Critical raw materials : from dependency to open strategic autonomy?* by the National Bank of Belgium
[71] To mention a few: CEPR (*The EU's strategic dependencies unveiled*), CEPII (*EU Strategic Dependencies*), ECIPE (*A Forward-Thinking Approach to Open Strategic Autonomy: Navigating EU Trade Dependencies and Risk Mitigation*).

6.1.1.1. The first ECCP Survey (2022)

To map disruptions in the EU, on behalf of the European Commission-DG GROW the ECCP-European Cluster Collaboration Platform run the **Survey "Identification of disruptions in value and supply chains"** between March and April 2022[72]. It was aimed to focus on disruptions *on going* or *expected in the near future*, immediately after Russia invasion of Ukraine. Participated by 500 companies of all EU industrial ecosystems from 26 EU countries, it showed that:

- the most affected **ecosystems** were Agrifood (17,5%), Construction (14%), Health (10,8%) and Mobility-Transport-Automotive (9,8%)
- the most impacted **stages** of the supply chains and impact per company **size (all industrial ecosystems vs Mobility-Transport-Automotive ecosystem (MTA))** were the following in Table 1. The results show that: (i) SMEs were more impacted than large companies in each stage; (ii) Small and Micro companies were more impacted than Medium ones, except in one case; (iii) the MTA ecosystem was more impacted in Inbound logistics, less impacted in Procurements, and equally impacted in the other two stages than all the other ecosystems considered together:

Table 1 | Summary of relevant disruptions and impacts according to the first ECCP Survey (Author's re-elaboration of ECCP Survey Report data; in bold the worst performance per category)

Stage	*Large enterprises*	*SMEs*	*Detail per size intra-SME category*		*Total*	*Differentiation per industrial ecosystem*
			Medium-sized enterprises	*Small & Micro enterprises*		
Inbound logistics	9%	**19%**	*8%*	***11%***	28%	All
	13%	**17%**	*6%*	***11%***	**30%**	MTA
Outbound logistics	5%	**11%**	*4%*	***7%***	16%	All
	7%	**9%**	*2%*	***7%***	16%	MTA
Procurement	7%	**9%**	***5%***	*4%*	16%	All
	6%	**10%**	*4%*	***6%***	16%	MTA
Operations	5%	**10%**	*4%*	***6%***	15%	All
	2%	**7%**	*2%*	***5%***	9%	MTA

- the main **types** of disruptions at overall EU industrial ecosystems were: logistics (25%), energy (20%), raw material (16%), metals (12%), financing (8%), agri-food materials (5,4%), wood (4%), and electronic components (3,4%)
- **raw materials** disruptions have a high number of appearances in the MTA (22% out of the disruptions selected), Construction (10%) and Energy Intensive Industries (14%) ecosystems
- high level of **input loss** hit 61,24% of the large companies and 44% of SMEs, when considering all industrial ecosystems, while in the MTA the figures are 25% of the large companies and 22% of SMEs
- similarly, high level of **market loss** hit 40% of the large companies and 34% of SMEs, when considering all industrial ecosystems, while in the MTA the figures are 13% of the large companies and 19% of SMEs.

[72] ECCP (2022b), *Report on the survey Identification of disruptions in value and supply chains*.

6.1.1.2. The second ECCP Survey (2022)

A new **Survey "A Solution-Oriented Approach to Supply Chain Disruptions"** was launched by ECCP immediately after, from May to September 2022, having as central focus solutions and specific measures to build supply chain resilience. It was answered by 336 participants from all EU countries and all industrial ecosystems, of which 69% were enterprises.
The introductory questions of the Survey provide some data for comparison with the first Survey:

- 77% of survey participants suffered from external shocks; their majority is active in the ecosystem **Mobility–Transport–Automotive** (17%) followed by the ecosystem **Construction** (16%)
- per **type** of external shock, these mainly consisted in increased prices for supplies and services (56% of respondents were *very negatively* affected), delivery delays (42%), and increased transaction costs that originate in the search for new suppliers (40%)
- per **stage** of the supply chain, also here the most impacted were Inbound logistics (68%), Procurement (58%), Operations (53%), Outbound logistics (39%)[73].

6.1.1.3. The European Commission Chips Survey (2022)

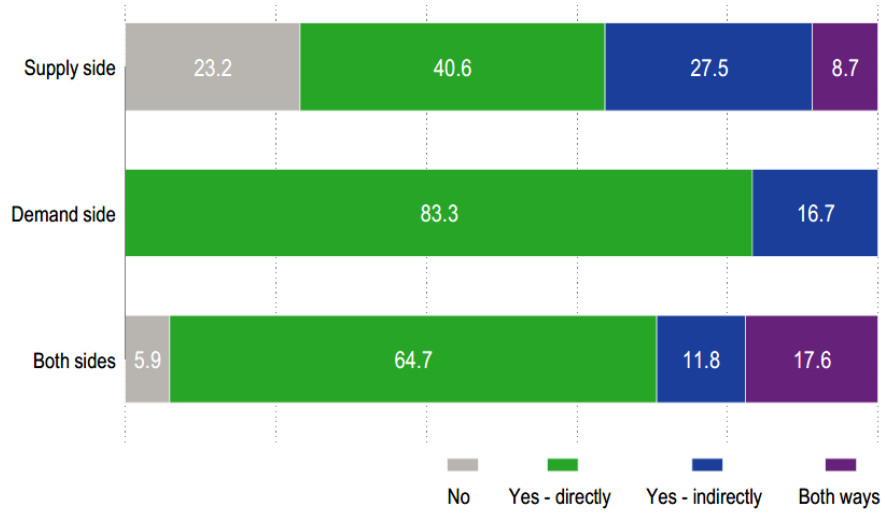
A **"European Chips Survey"** was run by the European Commission from 16 February to 20 March 2022[74] "to better understand current and forecast demand for chips and wafers, the complexity of the value chain, industry prioritisation for chip fabrication activities, the impacts of the chip supply crisis on European industry and the industry appetite for public support initiatives".
The Survey had 141 participants from 23 countries, of which 54,9% large enterprises, 17,3% medium-sized, 19,5% small, and 8,3% micro enterprises. 76 organisations had business activity on the supply side, 22 on the demand side, 16 were active on both the supply and demand side; the remaining ones didn't identify their role in the value chain. The ecosystems represented in the Survey include the Electronics, Mobility-Transport-Automotive, Digital, Renewable energy, Energy intensive industries, Construction, Defence, Aeronautics, and the chemicals sector.

The disruptions part of the Survey made emerge that the chips supply crisis:

- affects all ecosystems and all actors in the ecosystems
- has an impact of 100% on the demand side, of 76,8% on the supply side, on 94,1% on those organisations operating on both sides:

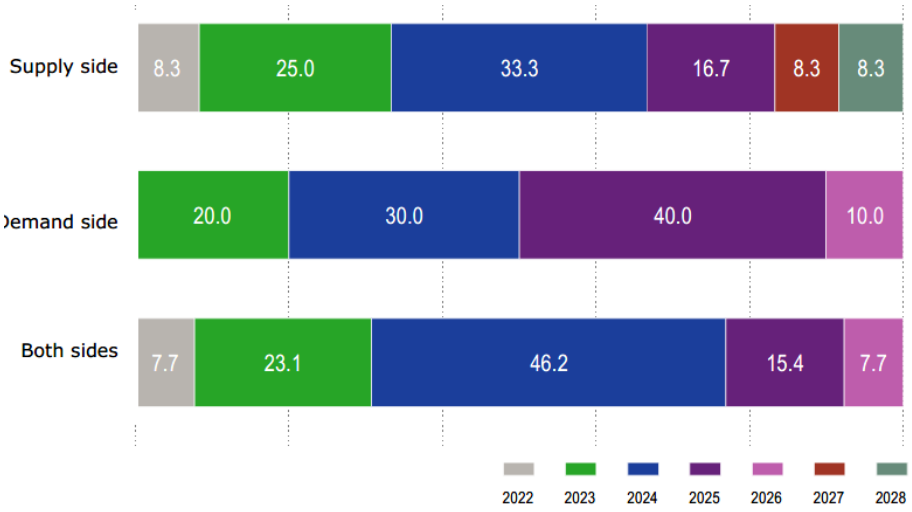
[73] The percentages highly differ from the ones in the first Survey as here the participants could select multiple choices. For all data: ECCP (2022b), *Report on the survey "Solutions to Supply Chain Disruptions in the EU*.
[74] European Chips Survey | Shaping Europe's digital future (europa.eu).

Figure 7 | Effect of supply chain shortage of chips on businesses (source: European Commission Survey Report)



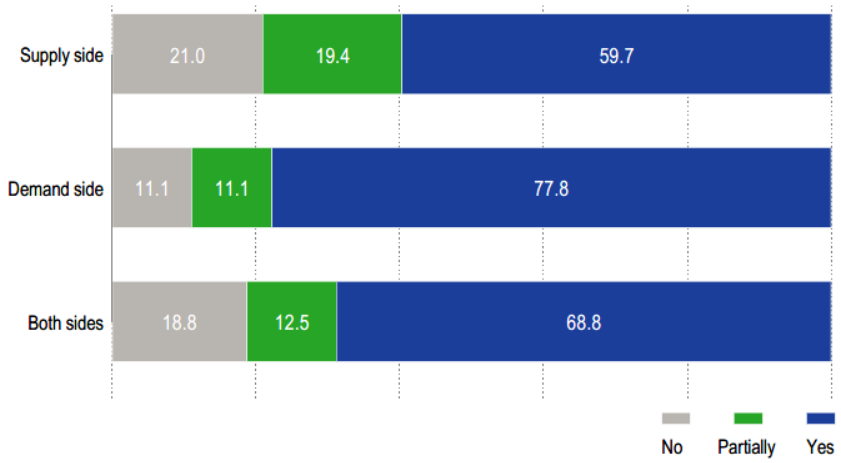
- it is expected to last until at least 2024, with the supply side more optimistic about an earlier end vs the demand side:

Figure 8 | Expectations for end of disruptions (source: European Commission Survey Report)



- is forcing companies to take costly mitigating measures, such as *Attaining new suppliers*, *Strategic investments*, *Reducing chip usage*, *Stockpiling* etc.

Figure 9 | Preparedness to take mitigating measures
(source: European Commission Survey Report)



Other interesting information about the chips' crisis emerge from the "European Chips Act - Shaping Europe's digital future"[75]:

- Within Europe, the automotive sector is a significant market (accounting for 37% of the semiconductor demand) as well as industrial manufacturing (accounting for 25% of semiconductor demand). Of the 5,1% shortfall in EU-wide industrial production in the first three quarters of 2021, the industrial manufacturing (machinery and equipment sector) bore 0,8%, just behind the automotive industry with 0,9%. Due to the chips crisis and insufficient global production capacity, delivery of **machineries and equipment** is expected to suffer severe delays (up to 3 years).
- Chips of >1 µm (1 micron = 1000 nm) are those used by the MTA industrial ecosystem, including specifically **trains**.

6.1.1.4. European Central Bank Survey (2023)

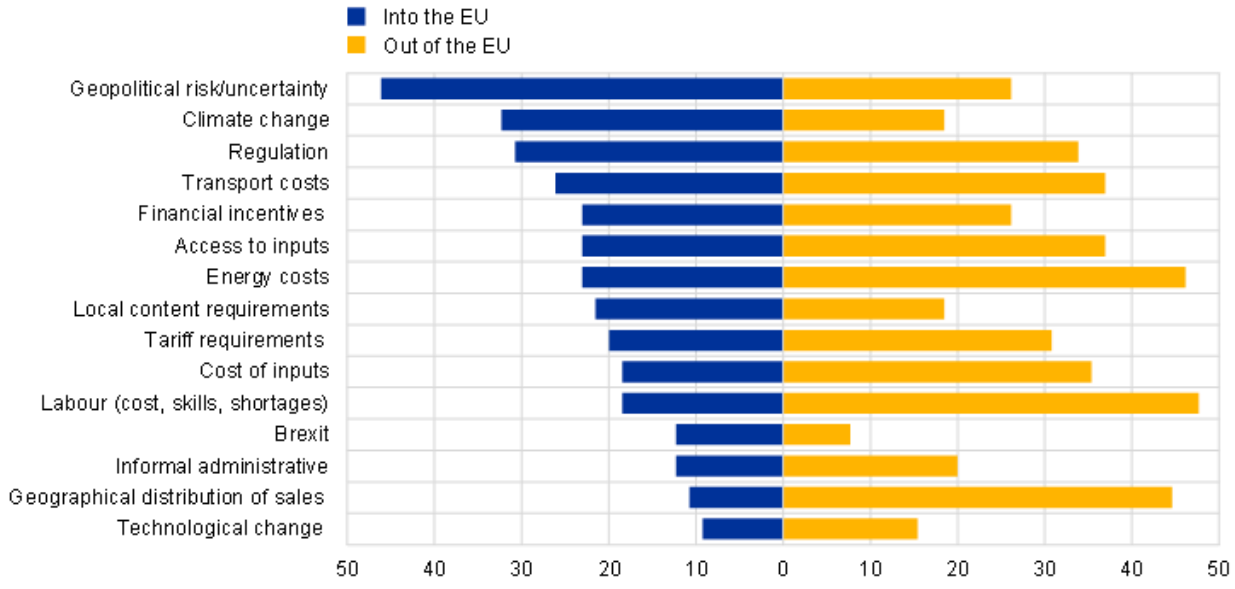
A **Survey on Global Production and Supply Chain risks** was run by the European Central Bank in July-August 2023, having as focus leading companies operating in Europe. A total of 65 responses were received, but the aggregate value added of these firms is equivalent to around 5% of euro area GDP.
The answers show important trends in terms of **production location** and **supply chains location**[76]:

- (production) higher shares of firms expect to (**re**)**locate** more production both *into* and *out* of the EU in the next five years than in the previous five years

[75] European Commission (2022a), *Commission Staff Working document "A Chips Act for Europe"*.
[76] Attinasi M G, Ioannou D, Lebastard L, Morris R (2023), "Global production and supply chain risks: insights from a survey of leading companies", *Economic Bulletin Boxes Issue 7-2023*, European Central Bank.

- (production) 74% of firms expect a tendency to (i) **relocate** more production geographically closer to the final production site or country of sales ('near-shoring'), (ii) **diversify** operations to a greater extent across countries, and/or (iii) (re)**locate** more production within/into countries politically closer to the main country of sales ('friend-shoring') in the *next* five years than in the *last* five years (42%):
    - "near-shoring" (or producing "local for local") alone was already a fairly common trend which is now expected to intensify: 28% or respondents had near-shored production already in the last five years, while 49% say they expect to do so in the next five years
    - "friend-shoring", by contrast, had not been so evident in the past but was expected to become much more commonplace: 42% of firms envisage pursuing such a strategy, up from just 11% in the previous five years.
    - It is primarily the firms that were already near-shoring or expecting to near-shore that now also anticipate diversifying and friend-shoring some of their operations.
- (production) ***Geopolitical risk*** was the most frequently cited factor behind decisions to (re)locate production into the EU, while ***Demand and cost factors*** motivate moves out of the EU. The other reasons for moving production *into* or *out* of the EU are:

Figure 10 | Importance of factors for moving production/operations into or out of the EU (source: European Central Bank)

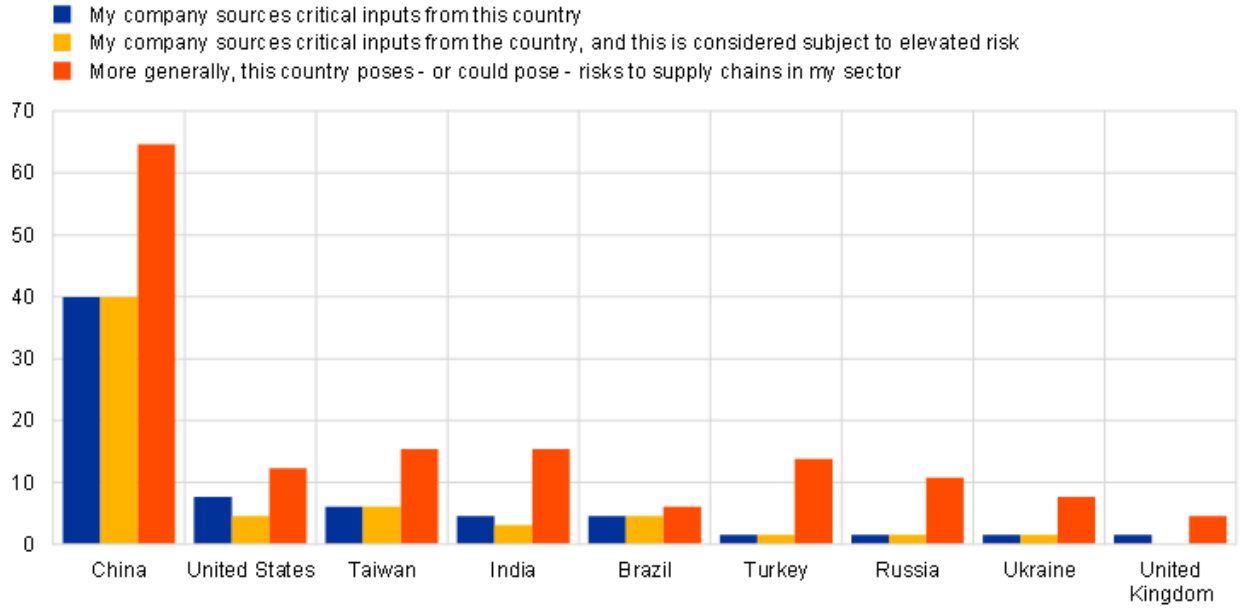


- (supply sourcing) respondents expect to increasingly near-shore, diversify and/or friend-shore their supply chains in the next five years, with some increase in the share of sourcing from inside the EU (from 55% to 80%):
    - diversifying and near-shoring the sourcing of inputs were already fairly common and were expected to become more so in the coming years
    - by contrast, the friend-shoring of input sourcing had, as was the case with the location of production, not been typical in the past but is expected to become much more so (with

42% of responding firms expecting to pursue such a strategy compared with just 9% having done so in the past).

- (supply sourcing) in terms of **perceived risks** as source of critical inputs for own supply chain or those of its sector, the following Figure shows the participants' answers:

Figure 11 | Supply chain dependency and risks, by country (source: European Central Bank)



- (supply sourcing) 65% of respondents said that it would be *very hard* for them to **substitute critical inputs** originating from countries deemed to be an elevated risk, and 29% said it would be *hard*. As sourcing modality, 66% thirds said that their company mainly sourced these critical inputs directly from firms located in the country concerned, 17% said that they mainly sourced them directly from their own facilities in the country concerned, with the remainder sourcing them mainly via distributors
- (supply sourcing) as **de-risking strategy to reduce country exposure**, 38% of respondents said they would shift sourcing of the same inputs to other countries outside the EU, 19% to other countries inside the EU, while 17% think to adopt a strategy in the near future and 15% will recur to other strategies.
- (production & supply sourcing) the impact of **changes** in production and supply sourcing *if* (re)located/shifted to the EU has been assessed by the respondents as (i) positive in terms of increase of shares of added value generated in the EU, but (ii) negative in terms of increasing costs and access to labour and skills, with this last one rated as the most important factor in their recent or planned future decisions to move production or operations out of the EU.

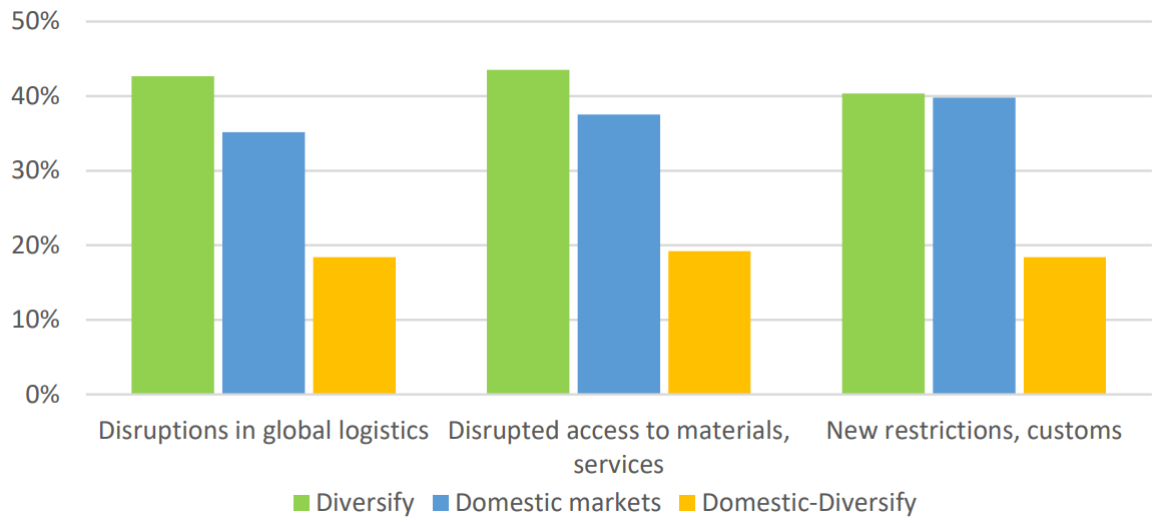
6.1.1.5. European Investment Bank Survey (2022)

The **European Investment Bank Investment Survey (EIBIS)** has surveyed more than 10 thousand

EU firms in 2022 on **Trade disruptions experienced**, in the framework of the European Investment Bank (EIB) interviews about their investment and business choices. The main results show that:

- the **majority** of the firms across the EU report experiencing major trade disruptions since 2021. At least a third of the firms perceived them as major obstacle to their business
- the most cited **disruptions** are related to global logistics (45%) and to raw materials or services access (42%), with a lower share of disruptions caused by new trade regulations, customs, or tariffs (15%)
- among the EU countries, the highest share of firms **complaining** about major trade disruption are in Cyprus, Italy, and the Netherlands, while the lowest share of firms reporting about major disruptions are in Hungary and Czechia
- severe problems with **material access** were relatively more likely to be reported in Hungary, France, and Slovakia
- trade disruptions affected more than 40% of **non-trading firms** as well. Firms that are not engaged in international trade in fact were affected via their difficulties with local suppliers (in turn hit by disruptions) or their imported inputs acquired via wholesalers
- trade disruptions are more likely to **discourage** non-traders from using imported inputs than trading companies
- more productive, innovative and digitalised firms were more likely to take action to **mitigate** the effects of trade related obstacles
- low productivity firms are more likely to choose focusing on domestic markets over not taking action. More productive firms and globally competitive firms are more likely to choose diversification as a **response strategy**.
- firms that have already taken action to **diversify** are expecting gains in terms of increased sales. Firms that focused on domestic markets do not share this positive outlook[77].

Figure 12 | Responses to major trade shocks by the type of trade shock (source: European Investment Bank)



[77] European Investment Bank (2023), *Trade disruptions in Europe: Evidence from the EIB Investment Survey 2022*.

6.1.1.6. Other Surveys run by private organisations

From the private sector, surveys show other specific useful elements about what is happening in Europe. The dates of survey execution and report release are also interesting to see the evolution of crisis and type of disruptions, and companies' concerns.

6.1.1.6.1. Deloitte (2022)

Deloitte run a **Survey to CFO in Europe** from October to December 2022[78] which shows that:

- Despite the rise in the costs of raw materials and transport that followed the Russian invasion of Ukraine, and the swings in supply and demand that took place during the pandemic, 13% of European CFOs say their companies are affected to a *large extent* by supply chain and delivery problems, 29% to a *moderate extent*, 34% to a *small extent*, 24% are not affected.
- Among CFOs who say supply chain issues have become acute for their companies, more than 40% identified ***Late delivery*** as their biggest problem (to a large or moderate extent); 35% say that a ***Lack of intermediate goods*** (i.e. those used as inputs in the production of other goods) is the biggest problem for their organisations.
- **Higher prices** for commodities or **intermediate goods** are a moderate or significant issue for almost 80% of CFOs, while **higher shipping costs** and **problems in the delivery of final goods** to customers (outbound logistics) are the most significant issue respectively for 70% and 77% of respondents.
- There is little significant difference between the sectors most substantially affected by supply chain problems, with the Construction sector the most impacted (21%).

6.1.1.6.2. McKinsey (2023)

McKinsey run the latest annual **"Supply Chain Pulse Survey"** over a four-week period from the middle of April to the middle of May 2023. The goal was to **track the efforts of supply chain leaders to overcome disruptions, mitigate risks, and build resilience in their operations**. 101 respondents from six continents answered. Not referring to Europe only, here are reported the results with a very high percentage of respondents, to increase the probability that European companies are in the samples:

- Almost every respondent reported significant **issues** over the previous 12 months
- 78% increased their **inventory** buffers
- 78% pursued **dual-sourcing** strategies for critical raw materials
- 66% were obtaining more inputs from suppliers located **closer** to their production sites *over the past 12 months*
- 64% are *currently* **regionalizing** their supply chains *(Europe is surely included here)*
- 50% (mostly representing Europe and South-East Asia) say that their supply chains are dependent on inputs from another region. 89% of this sample want to **reduce** that **dependency** over time[79].

[78] Deloitte (2023), *2023 Central Europe CFO Survey*.

6.1.2. Dependencies in EU Supplies

The updated EU Industrial Strategy adopted by the European Commission in 2021 was accompanied by the report "Strategic dependencies and capacities"[80]. This included an analysis of over 5,000 products, where **137 products in sensitive ecosystems were found to be highly dependent on foreign suppliers**, of which 34 (representing 0,6% of extra-EU import value of goods) could be considered as potentially more vulnerable given their possibly low potential for further diversification as well as substitution with EU production.
In addition, the European Commission made in-depth reviews of a number of **areas that can be considered strategic for Europe's interests where the EU faces dependencies**. With the first, included in the above-mentioned report, 6 areas were identified. With a second in-depth review of 2022[81], one was further deepened and 4 were added. All but one are relevant to the Railway Value Chain:

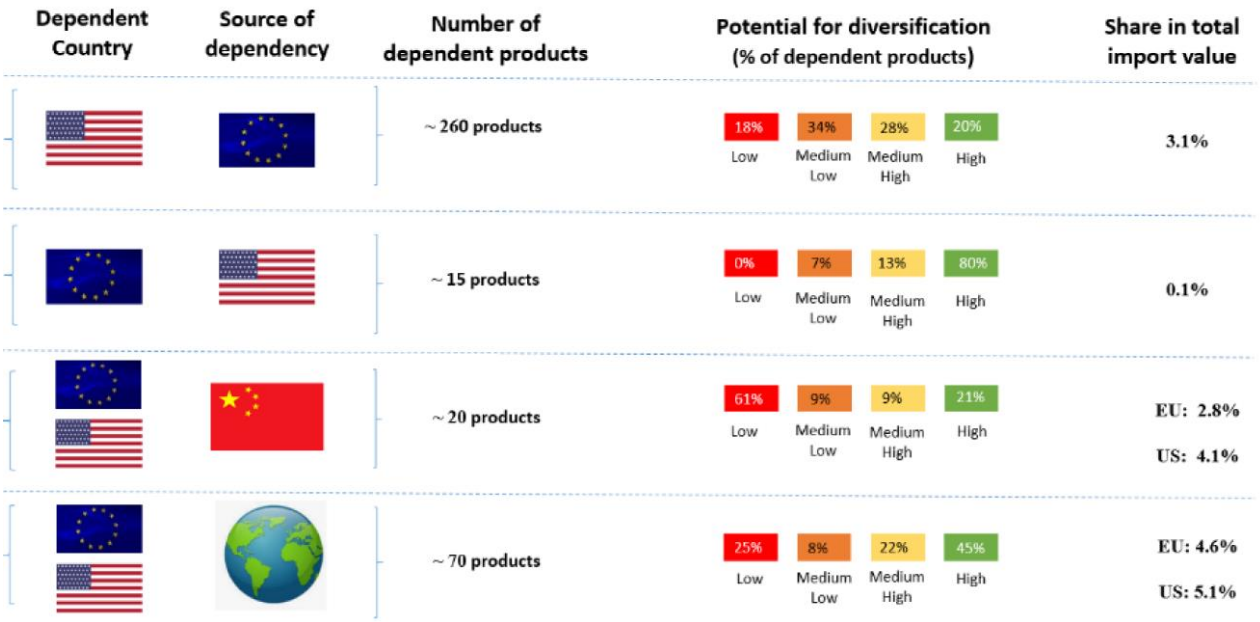
- **Raw and processed materials (in 2021 it was "Raw materials")**
  - **Rare earths and magnesium**
  - **Chemicals**
- **Lithium (Li-on) Batteries**
- **Hydrogen**
- **Semiconductors**
- **IT software (with a focus on cloud and edge software) (in 2021 it was "Cloud and edge computing")**
- **Photovoltaic panels and technologies**
- **Cybersecurity technologies and capabilities**
- Active pharmaceutical ingredients.

The overview of such dependencies was also compared – in 2021 report – with the dependency levels of the two EU's major trade countries. The following Figure shows the number of products where:

- the US can be considered dependent on the EU (first row)
- the EU can be considered dependent on the US (second row)
- common dependencies for the EU and the US on China (third row)
- common dependencies for the EU and the US on the world (fourth row).

[79] Alicke K, Foster T, Hauck K, Trautwein V (2023), *Tech and regionalization bolster supply chains, but complacency looms*, *McKinsey*, 3 November.
[80] Op. cit., European Commission (2021a).
[81] European Commission (2022b), *Commission staff working document – EU Strategic dependencies and capacities – second stage of in-depth reviews*.

Figure 13 | Overview of EU dependencies compared to US and China[82]



For many of these common EU/US dependencies vis-à-vis China, the potential for trade diversification to other countries (beyond China) appears limited given the current structure of world trade where China takes up a very central position for these dependent products.

Further in-depth economic analysis on dependencies is provided by the European Central Bank (ECB), that has analysed from a central banking perspective all EU external dependencies and interdependencies, also discussing the EU's policy agenda to address them[83].
The ECB identifies the following sources of external dependency:

- Trade dependencies
- Energy dependencies
- Critical raw materials dependencies
- Digital transition
- Financial interdependencies

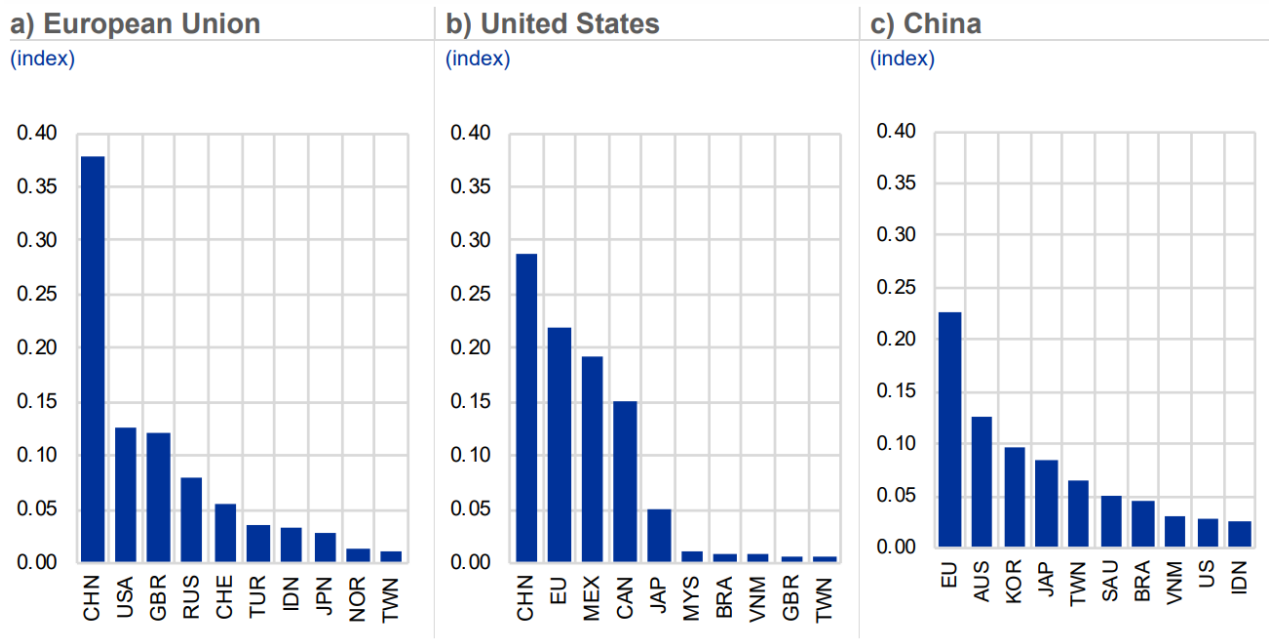
With reference to the Trade dependencies, interestingly the ECB identifies and measures the vulnerabilities both related to *import* and to *export*, as also the latter 'threaten' EU economy. However, given this study's focus on supplies, only the import part is taken into account here, and with reference to areas relevant for the Rail Value Chain.

Key findings of the ECB analysis are:

[82] Op. cit., European Commission (2021a), p. 26.
[83] European Central Bank (2023), *The EU's Open Strategic Autonomy from a central banking perspective. Challenges to the monetary policy landscape from a changing geopolitical environment*.

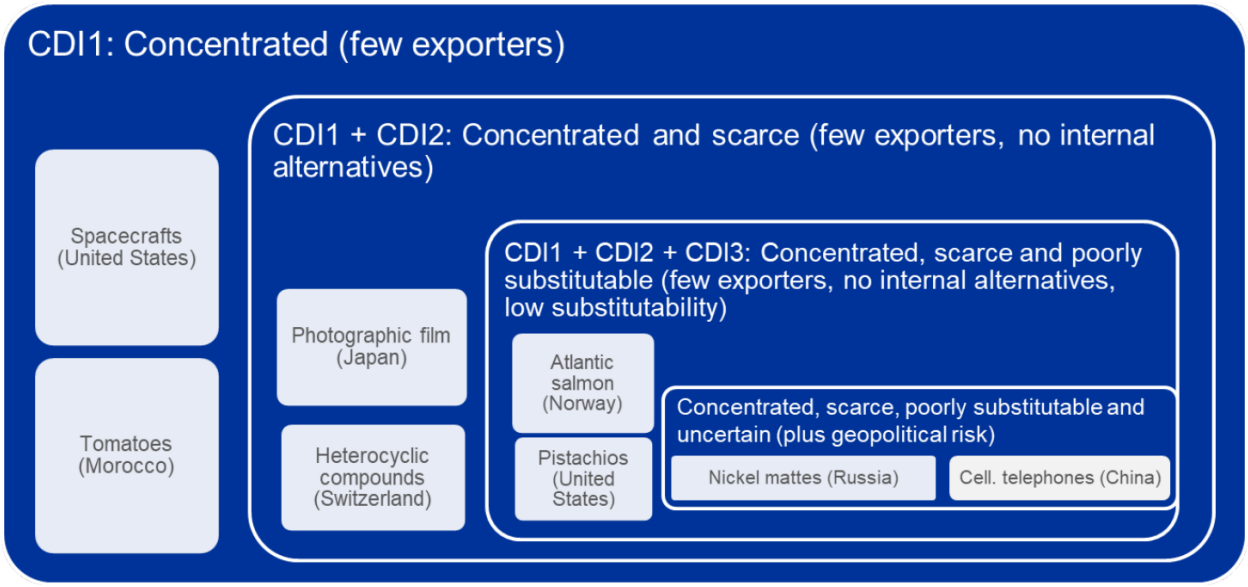
- EU import dependency on Chinese and US production is **very heterogeneous** at the sectoral level.
- By far the **highest bilateral import concentration** of the EU in goods trade is with China.
- Other trade partners with which the EU has high bilateral import concentrations are the **US**, the **United Kingdom** and also – because of the EU's dependencies on energy products and key commodities such as nickel or uranium – **Russia**.
- The reliance on Chinese imported value-added is highest for production in **computers and electronics** and the **basic metal sectors**.
- Dependency on US value-added is more concentrated in the **transport equipment** sector, the **services** sector, and **computer and electronics** sector.

Figure 14 | Imports concentration index of the EU, US and China from third countries (source: European Central Bank)[84]



[84] Op. cit., European Central Bank (2023), p. 42.

Figure 15 | Characteristics of import dependency at the product level and examples (source: European Central Bank)[85]



- Most **Critical Raw Materials** are scarce within the EU. Moreover, for some of them, EU imports are also highly concentrated in a few trading partners. However, also the US and China show a high level of dependency on Critical Raw Materials.
- Given the rising volume of data processed in cloud infrastructures, dependencies in the **Digital Technologies** sector (supplies and skills) will become even more important during the digital transition.

Out of the above list concerning access to supplies, but highly relevant to supplies autonomy, is China acquisition of stakes in several **strategic transport and energy infrastructure facilities** across the EU as a part of China´s Belt and Road Initiative (BRI), mentioned by the ECB among EU's financial dependencies. China has stakes in 14 ports across the EU[86] and handles about 10% of Europe's shipping container capacity. Given the logistics disruptions mentioned earlier in this study, such concentration - and control – of shipping of EU goods cannot but raise concerns. For this reason, more recently further attempts to acquire ports in Europe have been blocked.
A study by the European Parliament notes that "risks arise from the deliberate strategy by China to leverage its investments in European maritime infrastructure to its own advantage, and as a result of conflict scenarios (i.e. the Taiwan conflict, or disputes between the EU and/or Member States and China)" [87].

In the next paragraphs the main source of dependencies relevant to this study's objectives are introduced.

[85] Ivi, p. 81.
[86] See the map in Chambers S (2023), "China's European port interests mapped", *Splash247*, 20 September.
[87] Ghiretti F, Gunter J, Sebastian G, Gökten M, Pindyuk O, Zavarská Z, Tonchev P (2023), 'Chinese Investments in European Maritime Infrastructure', *At a glance*, European Parliament, pp. 1-2.

6.1.2.1. Critical Raw Materials

"Critical Raw Materials" are defined as:

> "a set of non-energy, non-agricultural raw materials that, due to their **high economic importance** and their exposure to **high supply risk**, often caused by a high concentration of supply from a few third countries, are considered critical" [88].

They are coupled with those called "Strategic Raw Materials", that are defined as:

> "the raw materials that score among the **highest** in terms of **strategic importance**, **forecasted demand growth** and **difficulty of increasing production**"[89].

The European Commission has been mapping the Critical Raw Materials (CRMs) for the EU since 2011, with updates every three years. The list of CRMs passed from 14 in 2011 to 34 in 2023.

Figure 16 | Critical and Strategic Raw Materials 2023 (source: European Commission)[90]

2023 Critical Raw Materials (*Strategic Raw Materials in italics*)			
aluminium/bauxite	coking coal	*lithium*	phosphorus
antimony	feldspar	*LREE*	scandium
arsenic	fluorspar	*magnesium*	*silicon metal*
baryte	*gallium*	*manganese*	strontium
beryllium	*germanium*	*natural graphite*	tantalum
bismuth	hafnium	niobium	*titanium metal*
boron/borate	helium	*PGM*	*tungsten*
cobalt	*HREE*	phosphate rock	vanadium
		*copper**	*nickel**

The demand for such Critical and Strategic Raw Materials will increase exponentially in the coming decades, given the key role of many of them in realising the green and digital transitions, as well as for defence and space applications. The **JRC Foresight study "Supply chain analysis and materials demand forecast in strategic technologies and sectors in the EU"** of 2023[91] assesses supply chain dependencies and forecasts materials demand until 2050 in the EU, as well as the EU's materials needs and vulnerabilities (CRMs, Strategic Raw Materials and others) and the potential supply chain bottlenecks in key strategic technologies, most of which relevant to the Rail Value Chain:

[88] European Commission (2023a), Proposal for a EU Regulation Establishing a framework for ensuring a secure and sustainable supply of critical raw materials, COM(2023) 160 final, Preamble, point 1.
[89] European Commission (2023b), A secure and sustainable supply of critical raw materials in support of the twin transition', Commission Communication, COM(2023) 165, p. 3, footnote 8.
[90] European Commission (2023c), *Study on the Critical Raw Materials for the EU 2023. Final Report*, p. 3.
[91] JRC (2023), *Supply chain analysis and material demand forecast in strategic technologies and sectors in the EU – A foresight study*, European Commission.

- **Li-on batteries**
- **Fuel cells**
- **Electrolysers**
- **Traction motors**
- **Data transmission networks**
- **Data storage and servers**
- **Additive manufacturing (3D printing)**
- **Robotics**
- **Drones**.

The **increasing demand**, suitable to create further bottlenecks in supplies and competition with other global industrial players, is coupled with a **heavy dependence** the EU has on CRMs imports from a few suppliers, concentrating global extraction and/or production, and many of which "non-like-minded", as shown in the next Figures. Such dependence affects in some cases several stages of the supply chains and, for some technologies, affects the complete value chain. And while in some technologies there is room for supply **diversification** measures, in many other cases this is not possible. Also, forecasts highlight the high risk of **demand outpacing supply** for selected materials and technologies relevant to the twin transition, as for raw materials the supply tends to grow much more slowly, as it takes a relatively long time to increase mine capacity and years to open a new operation. Also **ownership** of mining facilities in third countries is an issue, with foreign ownership and exclusive supplies. Ultimately, the development of capacity at one stage of the value chain cannot happen without ensuring **sufficiency** in the previous steps.

Table 2 | Critical and Strategic Raw Materials necessary in each Strategic technology, and individual Supply Risk (Author's re-elaboration of JRC data) [92]

Strategic technologies	*CRMs and Strategic Raw Materials necessary*	*Supply risk of each CRM/Strategic Raw Material*	*Leading countries per share of production stage (with values ≥3%)* *(RM: Raw Materials; PM: Processed Materials; C: Components; A: Assemblies; + where relevant: SA: Super Assemblies; S: Systems. In **bold** the leading stage of the country; in **brackets** the production share of the leading country per stage. For the EU, the value of every share is indicated to inform about the distance from other leaders)*
Li-on batteries	Lithium Natural graphite Cobalt Manganese Copper Phosphorus Aluminium	1,9 4 1,7 1,2 0,1 3,3 1,2	**China**: RM (37%), **PM** (72%), C (67%), A (75%) **Africa**: RM **Latin America**: RM **South Korea**: PM, **C**, A **Japan**: PM, **C**, A **US**: C, **A**

[92] Op. cit., JRC (2023), pp. 19-127.

			EU: PM (4%), **A** (6%) **Rest of Europe**: RM
Fuel cells	Rare earths (PM) Boron PGM Natural graphite Cobalt Silicon metal Manganese Nickel Copper Heavy rare earths (rest) Light rare earths (rest) Strontium Vanadium Feldspar Baryte Aluminium	4,0 3,8 2,7 1,8 1,7 1,4 1,2 0,5 0,1 5,3 3,5 2,6 2,3 1,5 1,3 1,2	**China**: RM (32%), PM, C, **A** (67%) **US**: PM (30%), **C** (44%), A **Africa**: RM **Latin America**: RM **Russia**: RM **EU**: PM (15%), **C** (25%), A (12%) **Rest of Europe**: RM, PM
Electrolysers[93] *They are based on 4 main technologies:* ▪ *Alkaline (AWE)* ▪ *Proton Exchange Membrane (PEM)* ▪ *Solid Oxide (SO)* ▪ *Anion Exchange Membrane (AEM)*[94]	Magnesium Rare earths (PM) Boron PGM Natural graphite Cobalt Silicon metal Manganese Tungsten Nickel Copper HREE (rest) Niobium LREE (rest) Strontium Scandium Vanadium Baryte Tantalum Aluminium	4,1 4,0 3,8 2,7 1,8 1,4 1,2 0,5 1,2 0,5 0,1 5,3 4,4 3,5 2,6 2,4 2,3 1,3 1,3 1,2	**China**: **RM** (31% **AWE**, 38% **SO**, 38% **AEM**), **PM** (24% **SO**), C, A **US**: **PM** (43% **PEM**; 27% **AEM**), C, A **EU**: RM (4% AWE, 5% SO), **PM** (29% **AWE**, 18% PEM, 14% SO, 20% AEM), **C** (35%), **A** (50%) **Rest of Europe**: **PM**, C, A **Africa**: **RM** (45% **PEM**), PM **Japan**: PM, **C**, **A** **Rest of Asia** (no China, Japan, South Korea, Taiwan): **RM**, PM **Latin America**: RM **Russia**: RM
Traction motors	REE (PM) Boron Silicon Metal Copper Aluminium	4,0 3,8 1,4 0,1 1,2	**China**: **RM** (47%), **PM** (50%), **C** (52%), A **US**: RM, PM, C, **A** **EU**: PM (12%), C (9%), **A** (19%) **Rest of Europe**: RM, A

[93] "Electrolysers, which use electricity to split water into hydrogen and oxygen, are a critical technology for producing low-emission hydrogen from renewable or nuclear electricity" (IEA (no date), '*What are electrolysers?*').
[94] For more details see Bernuy-Lopez C (2023), "Electrolysis technologies and LCOH: current state and prospects for 2030", *Hydrogen Tech World*, 13 April.

			Japan: **PM**, C, A **South Korea**: **PM**, C, A **Rest of Asia** (no China, Japan, South Korea, Taiwan): **RM**, PM **Latin America**: **RM** **Russia**: RM **Africa**: RM
Data transmission networks (*however, JRC didn't include in this assessment the ETCS-European Train Control System due to its high degree of hardware specialisation)	Gallium REE (PM) Boron PGM Lithium Bismuth Germanium Natural graphite Cobalt Silicon metal Manganese Nickel Copper HREE (rest) Niobium LREE (rest) Strontium Vanadium Antimony Arsenic Baryte Tantalum Aluminium Fluorspar Phosphate rock	4,8 4,0 3,8 2,7 1,9 1,9 1,8 1,8 1,7 1,4 1,2 0,5 0,1 5,3 4,4 3,5 2,6 2,3 1,8 1,6 1,3 1,3 1,2 1,1 1,0	**China**: **RM** (45%), PM, C, **A** (29%), **S** (41%) **EU**: **PM** (23%), C (17%), A (26%), S (24%) **Rest of Europe**: RM, PM, C **US**: RM, PM, **C** (19%), **A**, S **Japan**: PM, **C** **Taiwan**: PM, **C** **South Korea**: PM, **A**, S **Rest of Asia** (no China, Japan, South Korea, Taiwan): **RM**, PM **Russia**: RM **Africa**: RM **Latin America**: RM
Data storage and servers	Gallium Magnesium REE (PM) Boron PGM Bismuth Germanium Silicon metal Manganese Nickel Copper HREE (rest) Phosphorus Scandium Antimony	4,8 4,1 4,0 3,8 2,7 1,9 1,8 1,4 1,2 0,5 0,1 5,3 3,3 2,4 1,8	**China**: **RM** (42%), **PM** (23%), **C**, A, SA **US**: RM, PM, C, **A** (58%), **SA** (50%) **EU**: **PM** (13%), C (8%) **Rest of Europe**: **RM**, PM **Japan**: RM, **PM** (23%), C, A, SA **Taiwan**: PM, **C** (22%), A, SA **Rest of Asia** (no China, Japan, South Korea, Taiwan): **RM**, PM, C **Africa**: RM **Latin America**: RM **Russia**: RM

	Beryllium Arsenic Hafnium Baryte Aluminium	1,8 1,6 1,5 1,3 1,2	
Additive manufacturing (3D printing)	Magnesium Cobalt Titanium metal Silicon metal Manganese Tungsten Nickel Copper HREE (rest) Niobium Scandium Vanadium Hafnium Aluminium	4,1 1,7 1,6 1,4 1,2 1,2 0,5 0,1 5,3 4,4 2,4 2,3 1,5 1,2	**China**: **RM** (33%), PM (26%), SA **US**: RM, PM (26%), **SA** (38%) **EU**: RM (4%), PM (24%), **SA** (27%) **Rest of Europe**: RM, **PM** **Rest of Asia** (no China, Japan, South Korea, Taiwan): RM, PM, **SA** **Japan**: SA **Africa**: RM **Latin America**: RM
Robotics	Gallium Magnesium REE (PM) Boron PGM Lithium Natural graphite Cobalt Titanium metal Silicon metal Manganese Nickel Copper HREE (rest) LREE (rest) Vanadium Antimony Aluminium Fluorspar	4,8 4,1 4,0 3,8 2,7 1,9 1,8 1,7 1,6 1,4 1,2 0,5 0,1 5,3 3,5 2,3 1,8 1,2 1,1	**China**: **RM** (52%), PM (37%), C (43%), A **EU**: PM (15%), C (11%), A (10%), **SA** (41%) **US**: RM, PM, C, **A** (50%), SA **Rest of Europe**: RM, **PM**, C **Japan**: PM, C, A, **SA** (47%) **South Korea**: PM, **C**, A **Rest of Asia** (no China, Japan, South Korea, Taiwan): RM, PM **Africa**: RM **Latin America**: RM
Drones	Gallium Magnesium REE (PM) Boron PGM Lithium Natural graphite Cobalt Titanium metal	4,8 4,1 4,0 3,8 2,7 1,9 1,8 1,7 1,6	**China**: RM (50%), PM (34%), C (31%), A, **SA** (78%) **US**: RM, PM, C, **A (48%)**, SA **EU**: RM (4%), **PM** (18%), C (9%), A (11%), SA (6%) **Rest of Europe**: RM, PM, **A**, SA **Russia**: RM **Japan**: PM, C, A, **SA** (47%) **South Korea**: PM, **C**, A

	Silicon metal Manganese Tungsten Nickel Copper HREE (rest) Niobium LREE (rest) Vanadium Antimony Feldspar Hafnium Tantalum Aluminium Fluorspar	1,4 1,2 1,2 0,5 0,1 5,3 4,4 3,5 2,3 1,8 1,5 1,5 1,3 1,2 1,1	**Rest of Asia** (no China, Japan, South Korea, Taiwan): RM, PM **Africa**: RM **Latin America**: RM

Figure 17 | Major EU sourcing countries of CRMs per individual material (source: European Commission)[95]

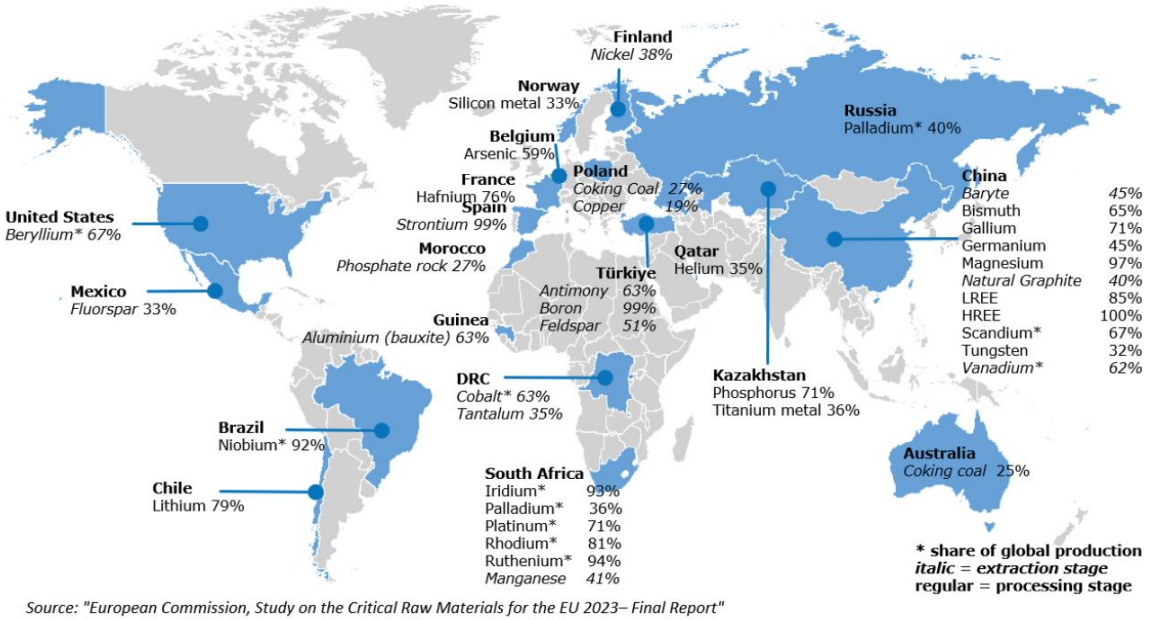
	Material	Stage *	Main EU supplier	Share		Material	Stage *	Main EU supplier	Share
1	aluminium	E	Guinea	63%	27	magnesium	P	China	97%
2	antimony	E	Türkiye	63%	28	manganese	E	S. Africa	41%
3	arsenic	P	Belgium	59%	29	natural graphite	E	China	40%
4	baryte	E	China	45%	30	neodymium	P	China	85%
5	beryllium	E	USA	60%	31	niobium	P	Brazil	92%
6	bismuth	P	China	65%	32	nickel	P	Russia	29%
7	boron	E	Türkiye	99%	33	palladium	P	N/A*	N/A*
8	cerium	P	China	85%	34	phosphate rock	E	Morocco	27%
9	cobalt	E	N/A*	N/A*	35	phosphorus	P	Kazakhstan	65%
10	coking coal	E	Poland	26%	36	platinum	P	N/A*	N/A*
11	copper	E	Poland	19%	37	praseodymium	P	China	85%
12	dysprosium	P	China	100%	38	rhodium	P	N/A*	N/A*
13	erbium	P	China	100%	39	ruthenium	P	N/A*	N/A*
14	europium	P	China	100%	40	samarium	P	China	85%
15	feldspar	E	Türkiye	51%	41	scandium	P	China	67%
16	fluorspar	E	Mexico	33%	42	silicon metal	P	Norway	33%
17	gadolinium	P	China	100%	43	strontium	E	Spain	99%
18	gallium	P	China	71%	44	tantalum	E	Congo, D.R.	35%
19	germanium	P	China	45%	45	terbium	P	China	100%
20	hafnium	P	France	76%	46	thulium	P	China	100%
21	helium	P	Qatar	35%	47	titanium metal	P	Kazakhstan	36%
22	holmium	P	China	100%	48	tungsten	P	China	32%
23	iridium	P	N/A*	N/A*	49	vanadium	E	China	62%
24	lanthanum	P	China	85%	50	ytterbium	P	China	0%
25	lithium	P	Chile	79%	51	yttrium	P	China	100%
26	lutetium	P	China	100%					

Grouped materials	Stage	Main EU supplier	Share
HREEs	P	China	100%
LREEs	P	China	85%
PGMs (iridium, platinum, palladium, rhodium, ruthenium)	P	N/A*	N/A*

Legend	
Stage	E = Extraction stage P = Processing stage
HREEs	Dysprosium, erbium, europium, gadolinium, holmium, lutetium, terbium, thulium, ytterbium, yttrium
LREEs	Cerium, lanthanum, neodymium, praseodymium and samarium
PGMs	Iridium, palladium, platinum, rhodium, ruthenium

[95] Ivi, p. 9.

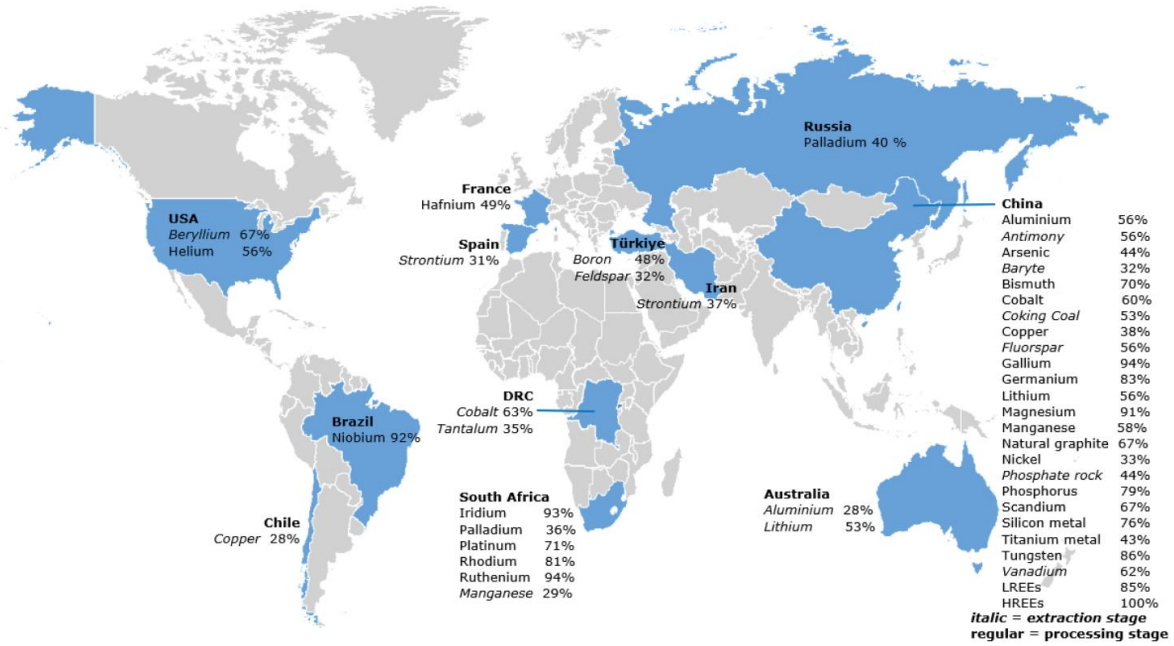
Figure 18 | Major EU suppliers of CRMs per country (source: European Commission)[96]



Source: "European Commission, Study on the Critical Raw Materials for the EU 2023– Final Report"

Key suppliers of the EU are also the largest suppliers globally, as shown in the next Figure. This further explains the level of dependency for such CRMs.

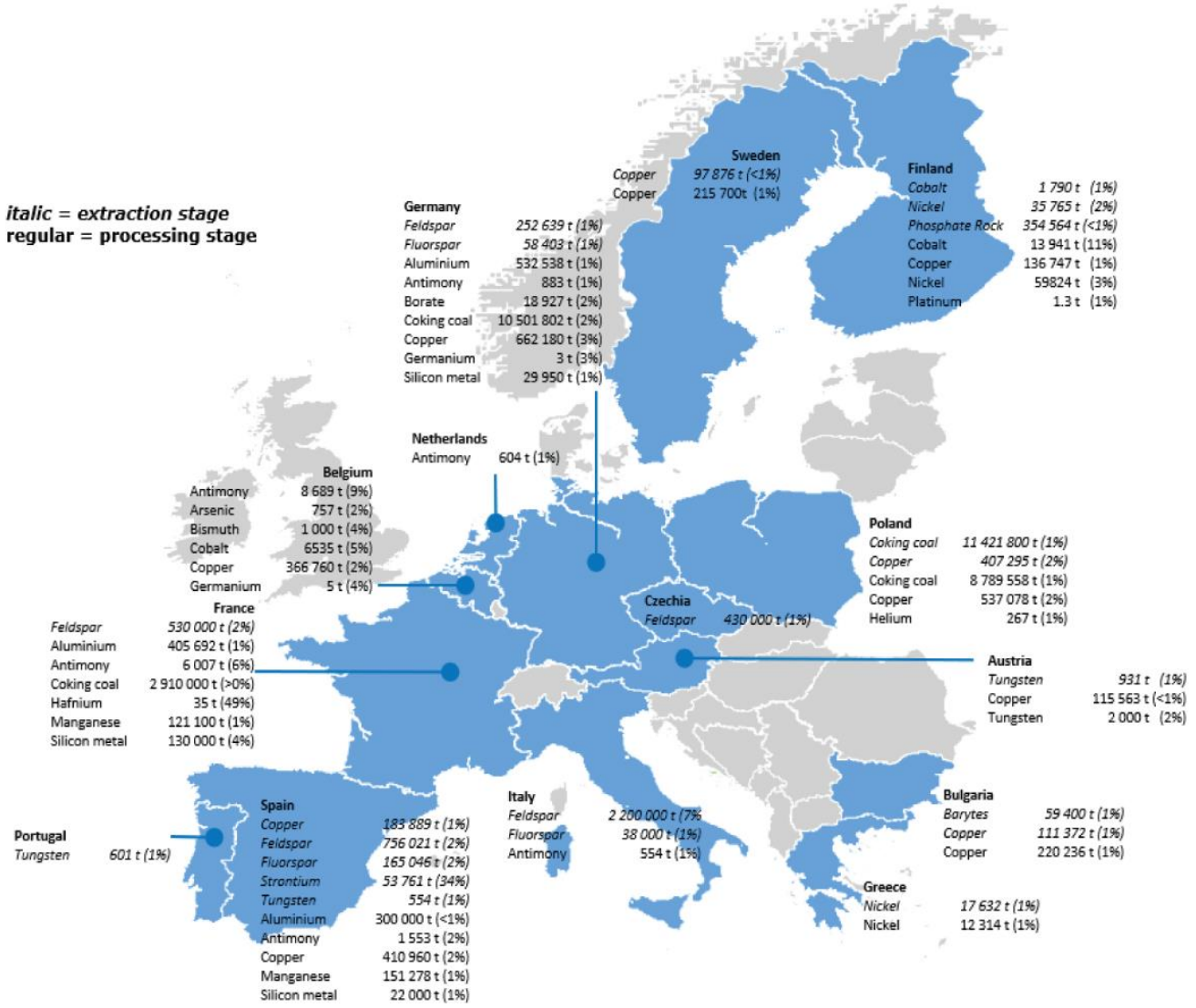
Figure 19 | Countries accounting for largest share of global supply of CRMs (source: European Commission)[97]



[96] Ivi, p. 10.
[97] Ivi, p. 7.

In-wards looking, EU Member States extract and/or produce the following CRMs and amounts:

Figure 20| EU producers of CRMs 2016-2020 (in brackets shares of global supply) (source: European Commission)[98]



6.1.2.2. Semiconductors

"Semiconductors – tiny chips composed of miniaturised electronic circuits layered on thin (often silicon) wafers – are the essential components that power virtually every digital or digitalised sector of the economy (…) [as well as] of the transformative

[98] Ivi, p. 8.

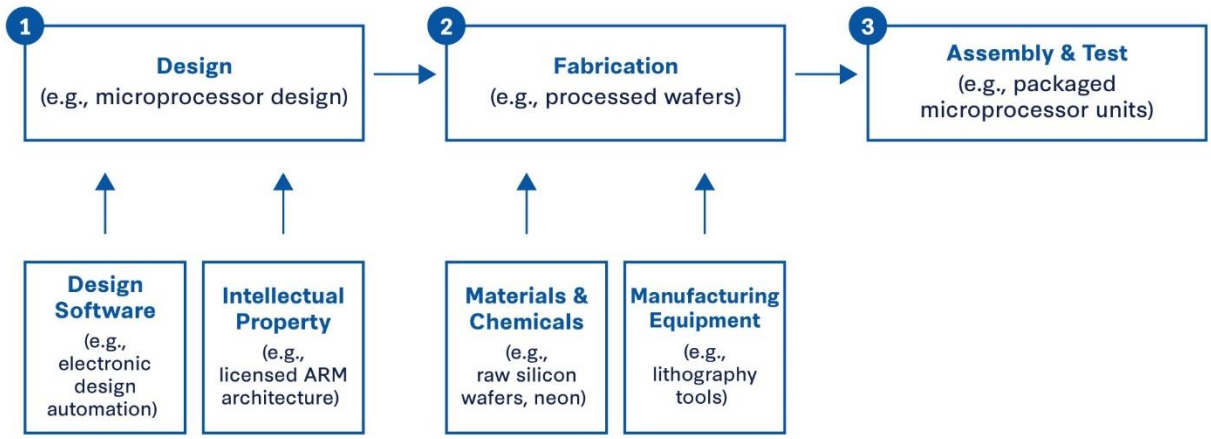
digital technologies of the future, including artificial intelligence, 5G/6G, autonomous electric vehicles, cloud/quantum/ edge computing and the internet of things".[99]

Interest in semiconductors has increased further in the wake of the COVID-19 pandemic, when a combination of shifts in consumer demand, chip factory closures, a faster than expected economic recovery and strategic stockpiling induced chip shortages that reverberated throughout the various supply chains.

The European Chips Act clearly describes all factors determining Europe's dependency for semiconductors[100]:

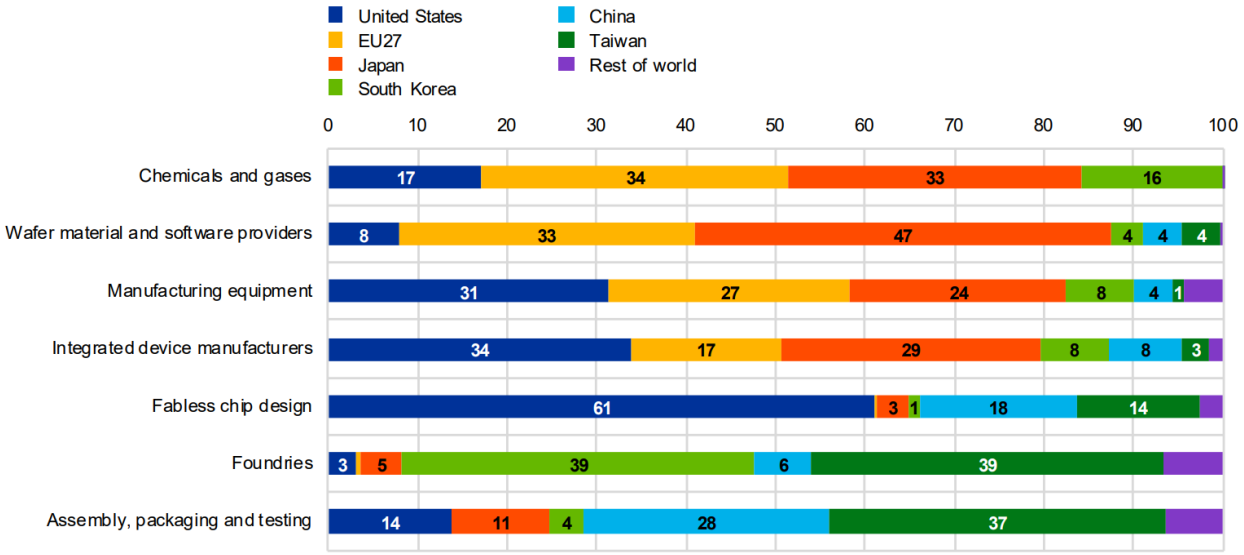
- The **production** of chips relies on collaboration and trade between the major semiconductor-producing regions.
- Complex **interdependencies** across the value chain and **concentration** of essential technologies or activities within particular companies or geographies, makes Europe prone to disruption: failures or shortages at any point in the value chain can have repercussions across the full supply chain. The Figures below show this situation:

Figure 21 | Simplified description of the Semiconductor Value Chain (source: CSIS) [101]



[99] Op. cit., European Central Bank (2023), p. 83.
[100] Op. cit., European Commission (2022a), p. 57.
[101] Thadani A, Allen G C (2023), *Mapping the Semiconductor Supply Chain: The Critical Role of the Indo-Pacific Region*, CSIS, 30 May.

Figure 22 | Turnover for the year 2020 in different segments of the semiconductor value chain, broken down by location of the global ultimate owner of the company (percentage of global turnover in the value chain segment) (source: European Central Bank)[102]



- The level of **consumption** of semiconductor components in Europe is higher around twice the value of components produced in the EU or even the value of components produced by European companies globally: in 2021, the EU's trade deficit for semiconductors was almost EUR 20 billion (exports EUR 31,5 billion; imports EUR 51 billion), despite in 2021 fabs were operating at full capacity.
- Roughly 50% of **capacity** in the EU is concentrated at nodes of 180nm and above. Design competences are largely concentrated on analogue, power, microcontrollers and MEMS - important for systems operating in the real world; for processors and memory components - central to computing - competences are scattered and confined to niche applications. This is reflected in industrial research efforts which have focussed on the former, rather than equipping the Union for digital transition. These are major concerns in light of the fact that future market growth is forecast to be concentrated below 10 nm nodes, where chips are needed to process ever-higher volumes of data, perform at higher speed and with less energy consumption.
- Open-source **approaches** and open platforms can reduce dependencies on a limited number of suppliers and European companies are attempting to make strides in design with open hardware platforms to generate IP for accelerators and processors, and open-source EDA tools. However more can be done, for example in advanced packaging. In terms of technology capacity, the EU clearly has strengths that it can build on but has serious gaps which if not addressed could even lead to current strengths being eroded.

6.1.2.3. Cybersecurity technologies

[102] Op. cit., European Central Bank (2023), p. 86.

Given the strategic importance of cybersecurity and its relevance for several of the EU's strategic interests including the Digital Transition, there is a need for strong generation and uptake of state-of-the-art cybersecurity technologies in Europe. This is necessary in particular to minimise technological dependencies on third countries in this critical area.

However, indicators show that while research in the EU stands up among the big cybersecurity players, this does not translate in an equally relevant industrial prominence: when looking at EU imports of products that have a link with cybersecurity technologies, the EU faces a particularly strong negative trade balance in the area of cybersecurity. This is in line with other estimates, which highlighted that about 70% of imports by Member States of goods and services in the area of cybersecurity are from outside the EU (30% being intra-EU imports).

The EU's capacity in the area of cybersecurity also depends on its access to certain essential inputs for which it currently depends on third countries, among which semiconductors: they are an essential input in the area of cybersecurity, with many of the security/authentication features on critical but also day-to-day activities being implemented through security chips requiring silicon to produce.

While the EU has some strengths in specific areas, only 14% of the world's top-500 cybersecurity companies are EU based. Also, the large majority of EU cybersecurity companies are SMEs (74%), which nevertheless only represent a small size of the overall market. The majority of these companies are not able to cover the full surface of the cybersecurity industry value-chain. Instead, they are often covering the last mile, as system integrators that put together products purchased by third parties (often non-EU). Furthermore, the smaller scale of EU industry also implies lower influence in the standardisation setting-process at international level in the area of cybersecurity[103].

6.2. Solutions for Supply Chain Resilience and Autonomy in the EU

The value chains recovery and resilience-building process in the EU after COVID-19 crisis and the following ones has been marked by a mix of initiatives aiming to address the disruption causes both in the short/medium-term and in the long-term.

Shorter-term initiatives aimed to re-connect broken value chains have spanned from the development of Academia-led models stressing the role of *networks* ("resilience an intrinsic property of the network"[104]), to the use of cluster organizations to support companies by facilitating new connections to rebuild their supply chains. One concrete example of such role is the set-up of the "Supply Chain Resilience Platform" in collaboration with the European

[103] Op. cit., European Commission (2021a), pp. 48-53.
[104] See quotation of Konstandopoulos A G (2020) in *Clusters: Driving the Green and Digital Twin Transitions*, ECA-European Cluster Alliance, p. 2.

Commission, EISMEA and matchmaking platforms dedicated to disruptions[105].

In the private sector, consultancies have strongly fostered companies' adoption of new supply chain models, with the result that also smaller companies have started to introduce strategies and operational modalities already well in use in the larger ones.

More strategic and longer-term initiatives have been adopted by the EU Institutions, the Member States and the regional authorities, according to own level of action and competence, to reduce the causes of vulnerability in the European industrial ecosystem and increase the level of autonomy in critical supplies. In fact, as recognised by the European Commission, although "in most cases, industry itself is best placed – through its corporate policies and decisions – to improve resilience and reduce any dependencies that may lead to vulnerabilities, including through diversification of suppliers, increased use of secondary raw materials and substitution with other input materials (…) [t]here are however situations where concentration of production or sourcing in only one single geographical area results in the unavailability of alternative suppliers"[106]. This calls for a public, targeted, and proportionate intervention.

Here below a summary of the main relevant measures adopted by the EU with the direct purpose to foster autonomy or however deploying a positive impact on that.

6.2.1. Policy level solutions

A set of long-term, strategic solutions of different nature (regulatory, industrial, research and innovation, skills, trade cooperation etc.) have been launched by the European Commission to reduce the risks of strategic dependencies, and therefore of value and supply chain disruptions, to increase overall Europe's resilience.

6.2.1.1. Critical Raw Materials Act

The steady increase in CRMs demand, together with the growing geopolitical tensions involving countries where the extraction and/or processing of CRMs is very highly if not totally concentrated (mostly "non-like-minded"), brought the European Commission to adopt a series of initiatives to reduce its dependency and ensure a secure and sustainable supply of CRMs[107].

The European Commission adopted in 2023 the "Critical Raw Materials Act", defining a set of

[105] See the "Supply Chain Resilience Platform" launched in 2022 by the EEN-Enterprise Europe Network in collaboration with the European Cluster Collaboration Platform, with the support of the European Commission and EISMEA.

[106] European Commission (2021d), *Questions and Answers on the update of the 2020 Industrial Strategy*, 5 May, Question 10.

[107] See for the overview: European Critical Raw Materials Act (europa.eu).

tools aimed to ensure the EU's access to a secure and sustainable supply of critical raw materials:

- Release of the **list** of Strategic raw materials, which are crucial to technologies important to Europe's green and digital ambitions and for defence and space applications, while being subject to potential supply risks in the future.
- Monitoring of critical raw materials supply chains and coordination of strategic raw materials stocks among Member States.
- Definition of **benchmarks** for domestic capacities along the strategic raw material supply chain and to diversify EU supply by 2030:
    - At least 10% of the EU's annual consumption for **extraction**
    - At least 40% of the EU's annual consumption for **processing**
    - At least 15% of the EU's annual consumption for **recycling**,
    - **Not** more than 65% of the EU's annual consumption of each strategic raw material at any relevant stage of processing **from a single third country**.
- Member States will have to develop national programmes for exploring geological resources.
- **Reduction** of the administrative burden and **simplification** of permitting procedures for critical raw materials projects in the EU.
- **Selected Strategic Projects** will benefit from support for access to finance and shorter permitting timeframes (24 months for extraction permits and 12 months for processing and recycling permits).
- Certain large companies will have to perform an **audit** of their strategic raw materials supply chains, comprising a company-level stress test.
- Establishment of a large-scale **skills partnership** on critical raw materials and of a Raw Materials Academy to promote skills relevant to the workforce in critical raw materials supply chains.
- Efforts to improve **sustainable development** of critical raw materials value chains.
- Strengthening the uptake and deployment of **breakthrough technologies** in critical raw materials.
- Member States will need to adopt and implement national measures to improve the collection of **critical raw materials rich waste** and ensure its recycling into secondary critical raw materials.
- Member States and private operators will have to investigate the potential for recovery of critical raw materials from **extractive waste** in current mining activities but also from historical mining waste sites. Products containing permanent magnets will need to meet circularity requirements and provide information on the recyclability and recycled content.
- Strengthening EU **global engagement** with reliable partners to diversify the EU's imports of critical raw materials, in particular with emerging markets and developing economies, notably in the framework of its Global Gateway strategy[108].
- The Global Gateway will be used also as a vehicle to **assist partner countries** in developing their own extraction and processing capacities, including skills development.
- Stepping-up trade actions**,** including by establishing a **Critical Raw Materials Club** for all like-minded countries willing to strengthen global supply chains, strengthening the World Trade

[108] Global Gateway - European Commission (europa.eu).

Organization (WTO), expanding its network of Sustainable Investment Facilitation Agreements and Free Trade Agreements and pushing harder on enforcement to combat unfair trade practices.

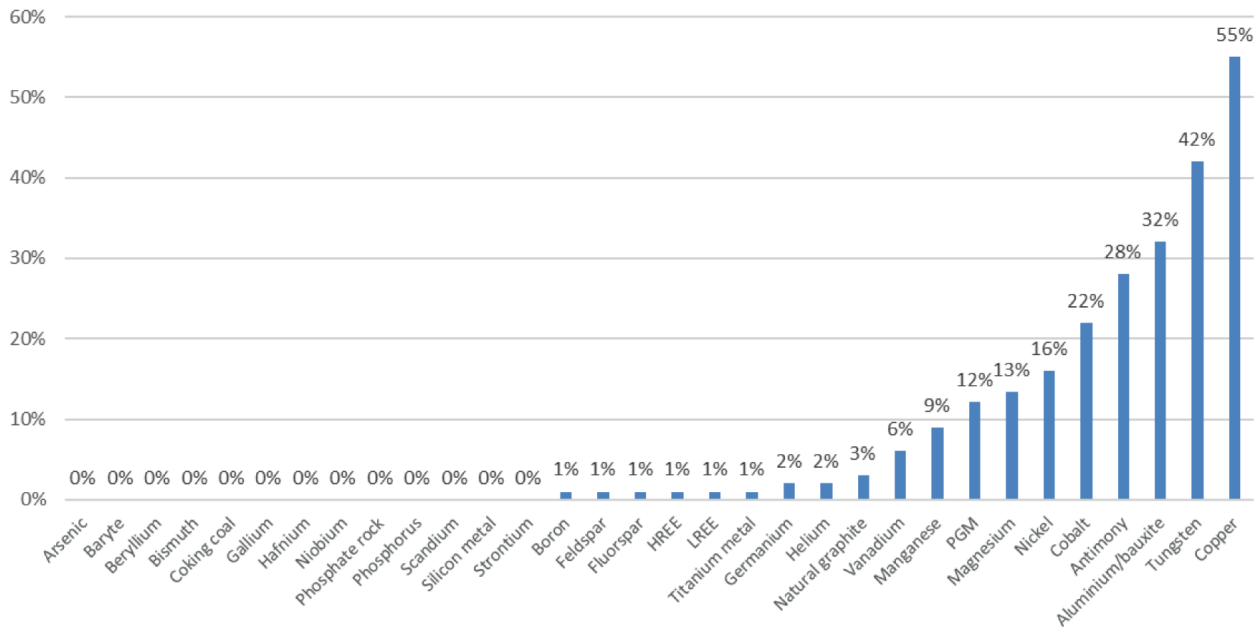
6.2.1.2. EU Action Plan for the Circular Economy

The EU Circular Economy Action Plans (the first adopted in 2015, the second in 2020) have brought the EU at the forefront of circular economy, this including the use of **Secondary Raw Materials** (SRMs), that – re-entering the production value chain – reduce EU's dependency on primary resources.

Nowadays more than 50% of some metals such as **iron**, **zinc**, or **platinum** are recycled, and they cover more than 25% of the EU's consumption. For others, however, especially those needed in renewable energy technologies or high-tech applications such as **rare earths**, **gallium**, or **indium**, secondary production makes only a marginal contribution[109].

The Action Plan 2020 aims to create a well-functioning market of SRMs, addressing the open issues (e.g. safety, performance, availability, cost), including preventing the mismatch between supply and demand of SRMs, and ensuring a smooth expansion of the recycling sector in the EU[110].

Figure 23 | EU End-of-Life Recycling Input Rate (%) of CRMs (source: European Commission)[111]



[109] Op. cit., European Commission (2023c), p. 11.
[110] European Commission (2020b), *A new Circular Economy Action Plan For a cleaner and more competitive Europe*, Commission Communication, COM(2020) 98 final, para. 4.3.
[111] Op. cit., European Commission (2023c), p. 11.

6.2.1.3. European Chips Act

The European Commission adopted in 2022 the European Chips Act package to address semiconductor shortages and strengthen Europe's technological leadership in this field, mobilising public and private funds of at least €43 billion up to 2030, to reach at least 20% - in value terms - of the world's production of cutting-edge and sustainable semiconductors.
Based on three main pillars, it sets measures to prepare, anticipate and swiftly respond to any future supply chain disruptions:

- strengthening existing EU semiconductor research, design and manufacturing **capacities** (mostly consisting in research and equipment manufacturing, analogue chip design and low-power technology), as well as developing skills training and reaching a better understanding of global semiconductor value chains
- supporting **"first-of-a-kind" production facilities**, in order to achieve the goal of producing at least 20% of the world's cutting-edge and most energy-efficient chips in the EU by 2030
- setting up systems for **monitoring** supply chain risks as well as for crisis response, with a toolbox including measures such as mandatory information gathering, the prioritisation of orders for critical sectors, common purchasing schemes and perhaps even export controls.

The Chips Act proposes:

- Investments in next-generation technologies
- Providing access across Europe to design tools and pilot lines for the prototyping, testing and experimentation of cutting-edge chips
- Certification procedures for energy-efficient and trusted chips to guarantee quality and security for critical applications
- A more investor-friendly framework for establishing manufacturing facilities in Europe
- Support for innovative start-ups, scale-ups and SMEs in accessing equity finance
- Fostering skills, talent and innovation in microelectronics
- Tools for anticipating and responding to semiconductors shortages and crises to ensure security of supply
- Building semiconductor international partnerships with like-minded countries, of which one example is provided in the paragraph 6.2.1.5.

On the operational point of view, the "Chips Joint Undertaking"[112] just launched is charged with the implementation of the above actions referring to the so called "Chips for Europe Initiative"[113], i.e. those aiming at strengthening Europe's semiconductor ecosystem and economic security, bridging the gap between research, innovation and industrial activities, w.
Among the initiatives it will fund:

- Set-up pre-commercial, innovative pilot lines, providing industry state-of-the-art facilities to test, experiment and validate semiconductor technologies and system design concepts
- Deploy a cloud-based Design Platform for design companies across the EU

[112] Commission launches Chips Joint Undertaking (europa.eu).
[113] European Chips Act: The Chips for Europe Initiative | Shaping Europe's digital future (europa.eu).

- Support the development of advanced technology and engineering capacities for quantum chips
- Establish a network of competence centres and promote skills development.

6.2.1.4. European Industrial Alliances

The Industrial Alliances are a tool of the European Commission Industry Strategy to facilitate stronger cooperation and joint action in highly strategic products and value chains necessary to deliver the EU strategic objectives for the future.
Among their founding principles, the openness and inclusiveness: the scale of the challenges addressed by the Industrial Alliances, in fact, can only be reached with the wide involvement of all relevant public and private stakeholders, such as Member States, regions, industry, financial institutions, private investors, innovation actors, academia, research institutes, civil society, trade unions, and others along the value chain.
The current Industrial Alliances created by the European Commission are the following:

- **European Raw Materials Alliance**[114]: it aims to build resilience and strategic autonomy for Europe's rare earth and magnet value chains. It will identify barriers, opportunities and investment possibilities in the raw materials value chain, while also addressing sustainability and social impact.
- **Industrial Alliance for Processors and Semiconductor Technologies**[115]: it aims to identify the existing gaps and the technology developments necessary for the competitiveness of companies and research and technology organisations active in the sector in the EU, including smaller European actors, including overcoming entry barriers, achieving critical mass and reducing dependencies in a concentrated industry.
- **European Alliance for Industrial Data, Edge and Cloud**[116]: it aims to strengthen the position of EU industry on cloud and edge technologies, meet the needs of EU businesses and public administrations that process sensitive categories of data, and foster the development and deployment of the next-generation cloud and edge capacities for the EU.
- **European Battery Alliance**[117]: it aims to make Europe a global leader in sustainable battery production and use.
- **European Clean Hydrogen Alliance**[118]: it supports the large-scale deployment of clean hydrogen technologies by 2030. It brings together renewable and low-carbon hydrogen production, demand in industry, mobility and other sectors, and hydrogen transmission and distribution.
- **European Solar Photovoltaic Industry Alliance**[119]: it aims to build resilience and strategic autonomy for Europe's solar photovoltaic (PV) value chain, identifying barriers, opportunities and

[114] European Raw Materials Alliance - European Commission (europa.eu).
[115] Industrial Alliance on Processors and Semiconductor Technologies - European Commission (europa.eu).
[116] European Alliance for Industrial Data, Edge and Cloud - European Commission (europa.eu).
[117] European Battery Alliance - European Commission (europa.eu).
[118] European Clean Hydrogen Alliance - European Commission (europa.eu).
[119] European Solar Photovoltaic Industry Alliance - European Commission (europa.eu).

investment possibilities while also addressing circularity and sustainability and the impact on skills.

- **Circular Plastics Alliance**[120]: it aims to boost the EU market for recycled plastics. The alliance covers the full plastics value chains.
- **Renewable and Low-Carbon Fuels Value Chain Industrial Alliance**[121]: it aims to boost production and supply of renewable and low-carbon fuels in the aviation and waterborne sectors.
- **Alliance for Zero-Emission Aviation**[122]: it aims to prepare the entry into commercial service of hydrogen-powered and electric aircraft.

The Industrial Alliances are a 'stakeholders' mobilisation' tool, as there is no direct funding for them. The actual implementation of the objectives each Alliance has is funded by other relevant tools, such as the "IPCEI-Important Projects of Common European Interest"[123]. IPCEI are identified in the EU Treaty but are promoted and funded by the Member States jointly, and undergo the European Commission approval under the State Aid rules. IPCEI are worth of billion euros investments each (public funding mobilising private ones), and concern predominantly research and development and first industrial deployment. All the current IPCEIs approved by the European Commission are in the critical fields where EU has dependencies:

- 2 on **Micro-electronics value chain**[124]:
  - The first (2018) aims to enable research and develop innovative technologies and components (e.g., chips, integrated circuits, and sensors) that can be integrated in a large set of downstream applications.
  - The second (2023) aims to enable the digital and green transformation by (i) creating innovative microelectronics and communication solutions, and (ii) developing energy-efficient and resource-saving electronics systems and manufacturing methods.
- 2 on **Batteries value chain**[125]**:**
  - The first (2019) aims to deliver beyond the state-of-the-art innovation across the batteries value chain, from mining and processing the raw materials, production of advanced chemical materials, the design of battery cells and modules and their integration into smart systems, to the recycling and repurposing of used batteries.
  - The second (2021) aims to contribute to the development of a whole set of new technological breakthroughs, including different cell chemistries and novel production processes, beyond the achievements of the first IPCEI, covering the entire battery value chain from extraction of raw materials, design and manufacturing of battery cells and packs, and finally the recycling and disposal in a circular economy, with a strong focus on sustainability.
- 2 on **Hydrogen value chain**[126]:

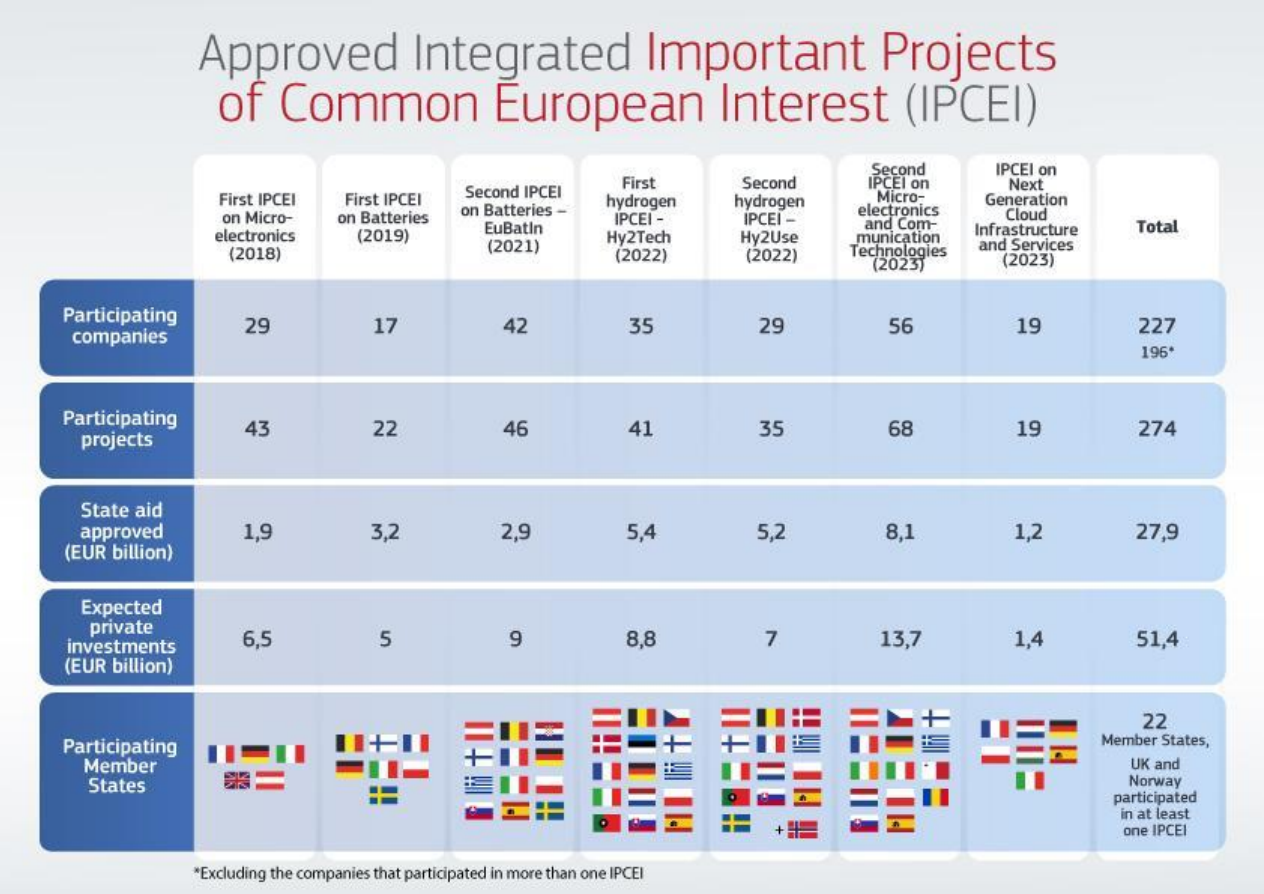
[120] Circular Plastics Alliance - European Commission (europa.eu).
[121] Renewable and Low-Carbon Fuels Value Chain Industrial Alliance - European Commission (europa.eu).
[122] Alliance for Zero Emission Aviation (europa.eu).
[123] IPCEI - European Commission (europa.eu).
[124] Microelectronics value chain - European Commission (europa.eu).
[125] Batteries value chain - European Commission (europa.eu).
[126] Hydrogen value chain - European Commission (europa.eu).

- The first (2022) aims to develop important technological breakthroughs, including new highly efficient electrode materials, more performant fuel cells, innovative transport technologies, covering a wide part of the hydrogen technology value chain, including (i) the generation of hydrogen, (ii) fuel cells, (iii) storage, transportation and distribution of hydrogen, and (iv) end-user applications, in particular in the mobility sector.
- The second (2022) aims to support (i) the construction of hydrogen-related infrastructure, notably large-scale electrolysers and transport infrastructure, for the production, storage and transport of renewable and low-carbon hydrogen; and (ii) the development of innovative and more sustainable technologies for the integration of hydrogen into the industrial processes of multiple sectors, especially those that are more challenging to decarbonise, such as steel, cement and glass.

- 1 on **Cloud and edge computing value chain**[127]: it aims to (i) develop the first interoperable and openly accessible European data processing ecosystem, the multi-provider cloud to edge continuum (ii) data processing capabilities, and software and data sharing tools that enable federated, energy-efficient and trustworthy cloud and edge distributed data processing technologies and related services.

[127] Cloud - European Commission (europa.eu).

Figure 24 | The IPCEIs approved up to 2023 (source: European Commission)[128]



6.2.1.5. EU-US Trade and Technology Council (TTC)

The EU and the US are key geopolitical and trading partners: taken together, the economies of both territories account for one third of global trade in goods and services and close to one third of world GDP in terms of purchasing power. The size of trade in services and goods between the EU and the US is matched by their mutual investments, which are the biggest in the world and which are a substantial driver of the transatlantic relationship. The EU-US bilateral trade is at historical highs, increasing year on year: over €1.55 trillion in 2022 (in 2021 they were 1,22 trillion, and this had already surpassed pre-pandemic levels by more than 10%)[129].

For this reason, in June 2021 the "EU-US Trade and Technology Council" (TTC) was created as a forum "coordinate approaches to key global trade, economic, and technology issues and to deepen transatlantic trade and economic relations based on these shared values"[130].

[128] Approved IPCEIs - European Commission (europa.eu).

[129] See EU trade relations with United States (europa.eu) and EU-US Trade and Technology Council (europa.eu), 31 May 2023.

[130] EU-US Trade and Technology Council - European Commission (europa.eu).

The TTC works through 10 working groups, co-led by relevant departments, agencies, and services of the US Government and the European Commission. Among these, the security of supply chains, export controls, investment screening, and global trade challenges are topics related to this study.
In particular, Working Group 3 "Secure Supply Chains" is tasked to focus on advancing supply chain resilience and security of supply in key sectors for the green and digital transitions and for securing the protection of citizens. A priority track has been established for:

- **Semiconductors**: both US and the EU lead in specific stages of the value chain, but each party relies heavily on third parties for highest-end chip manufacture; critical materials; and assembly, packaging and testing. The WG could provide a mechanism through which EU and US could exploit their respective strengths and reduce their respective dependencies within semiconductor supply chains. The 4th TTC meeting (May 2023) has advanced the work on semiconductors, implementing agreements on **supply chain early warning** and **subsidies transparency**. TTC has also put in place a **mechanism to prevent subsidy races**, **deepened cooperation on their respective Chips Acts** and **forces will be joined in research to replace PFAS in semiconductor supply chains**.
- **Critical materials:** the issue is particularly sensitive because the EU and the United States are each excessively dependent on China for many critical materials (e.g. the EU depends on China rare earths imports for 98% and US for 80%). Moreover, China's massive state subsidies for Chinese firms have priced European and US companies out of the market in these areas, and it has sometimes used its exports as a trade weapon[131].

6.2.1.6. Miscellaneous

Ultimately, the type of measures adopted by the EU to offer long-term solutions to disruptions and dependencies in Europe can be very broad and diversified.

International organisations and the European banking system offer, through their analysis, suggestions on *what* public policies *should* cover, and what they *shouldn't*.
For OECD, "in the overwhelming majority of value chains, public policies should focus on measures to promote a rapid rebound following shocks rather than mitigating risk by reducing foreign exposures"[132].
For the Banking system, "the capacity of the production system to react autonomously is not to be underestimated"[133], as enterprises are already adopting measures to make their supply lines more resilient. Therefore, "it would seem advisable for public policies to focus on areas where

[131] Taylor M (2023), "EU endeavors to secure and strengthen its supply chain", *MRS Bulletin*, Springer, 23 May.
[132] Schwellnus C, Haramboure A, Samek L (2023), "Policies to strengthen the resilience of global value chains: Empirical evidence from the COVID-19 shock", in *OECD Science, Technology and Industry Policy Papers*, n. 141, p. 10.
[133] Signorini L F (2023), *Globalisation and fragmentation*, Banca d'Italia. Speech at Meeting hosted by the Polo Universitario delle Scienze Sociali of the University of Firenze 'Geopolitics, Geodemography and Tomorrow's World', p. 7.

private sector responses are expected to be less satisfactory, owing to externalities (for example, the network spillovers of disruptions in supplies) or to the specific nature of interventions (for example, sunk costs that are too high). It is in any case to be hoped that, on a global scale, safeguarding national interests does not translate into indiscriminate protectionism and trade wars"[134].

The following Figure offers an overview – however still partial – of the many measures through which EU's *open strategic autonomy* is *de facto* deploying:

Figure 25 | (Broad) taxonomy of strategic autonomy policies and proposed initiatives by major category (source: ECIPE)[135]

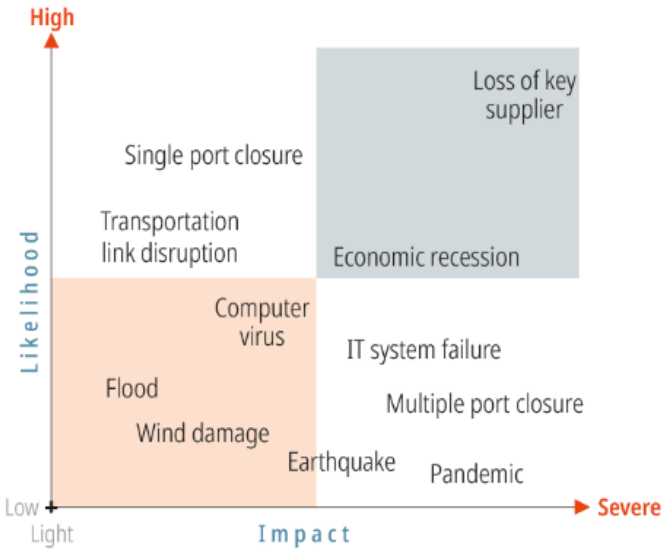
Category 1	Category 2	Category 3	Category 4
Measures aimed to achieve long-term industrial and trade policy objectives (including geo-strategic objectives)	Measures aimed at correcting market failures in the EU associated with products and activities	Measures primarily aimed at correcting market failures related to production and processing methods, with extra-territorial reach	Contingent measures in response to trade measures or behaviour by non-EU jurisdictions
• EU Foreign Investment Screening Mechanism • EU Chips Act • EU Emergency Framework Regarding Medical Countermeasures • EU Dual Use Regulation • EU Hydrogen Strategy • EU Pharmaceutical Strategy • EU Revised Renewable Energy Directive • EU Space Package • EU Standardisation Strategy • EU State Aid and IPCEI (Important Projects for Common European Interest) exemptions	• EU Artificial Intelligence Act (AI) • EU Digital Levy • EU Cybersecurity Certification Scheme for Cloud Services (EUCS) • EU Green Bond Standard • EU Data Governance Act • EU Data Act • EU Digital Markets Act (DMA) • EU Digital Services Act (DSA)	• EU Corporate Sustainability Due Diligence Regulation • EU Deforestation Free Products Regulation • EU Sustainable Batteries Regulation	• EU Anti-coercion instrument • Carbon Border Tax Adjustment Mechanism (CBAM) • Amendment of the EU Blocking Statute • EU Foreign Subsidy Instrument • EU International Procurement Instrument • Review of the EU Enforcement Regulation for trade Disputes

According to the European Parliamentary Research Service, "there is a policy gap regarding measures that can be used to address severe risks with a low likelihood of occurrence", referring to this Figure:

[134] Ibidem.

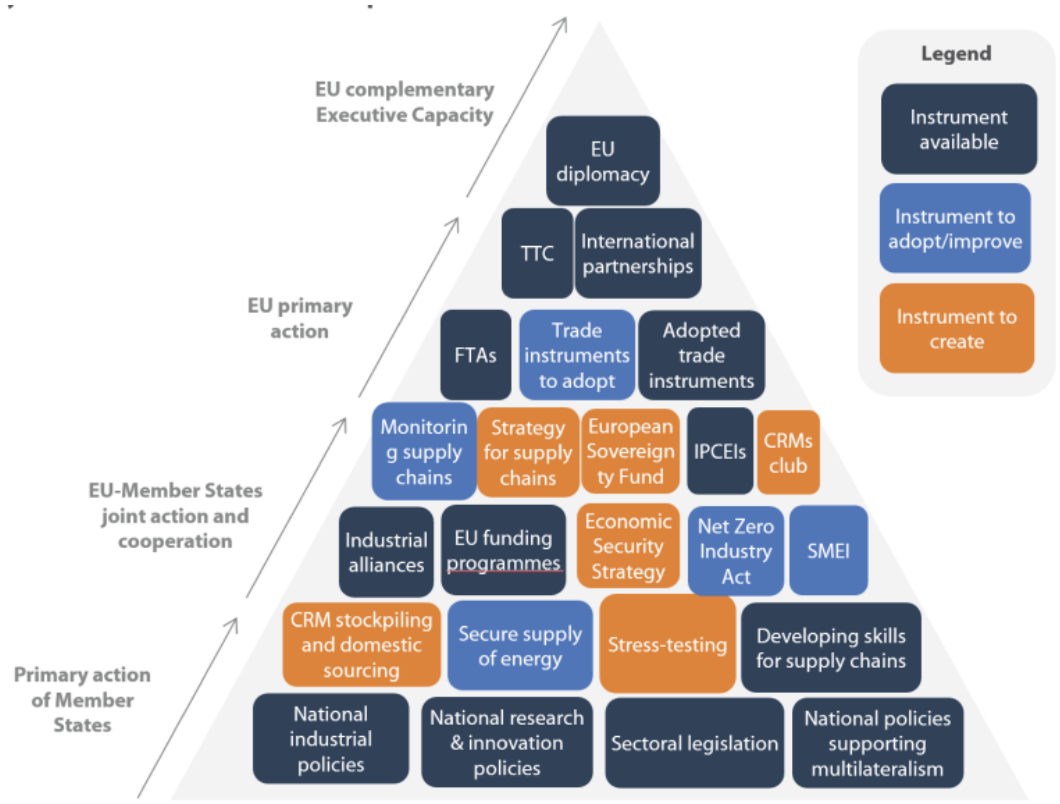
[135] Bauer M, du Roy O, Sharma V (2023), "A Forward-Thinking Approach to Open Strategic Autonomy: Navigating EU Trade Dependencies and Risk Mitigation", *ECIPE*, November.

Figure 26 | Likelihood vs Impact of disruptive events (source: OECD)



and continues: "All in all, supply risks are compounded by the evolving wider circumstances, such as escalating tensions among the great powers (…), challenges to multilateralism, crisis at the WTO, slowing globalisation, the rise of protectionism, weaponisation of energy dependencies, growing demand, and the increasing use of economic tools to advance geopolitical objectives", proposing the following Figure, that shows instruments at disposal. Given the EU functioning rules, some measures are to be adopted at EU level and others are to be adopted at Member States level:

Figure 27 | De-risking Europe's global critical supply chains. Pyramid of instruments at the disposal of the EU and its Member States (source: European Parliamentary Research Service)[136]



The Spanish Presidency of the Council of the European Union 2023 has dedicated to EU's *open strategic autonomy* a specific report - "Resilient EU2030"[137] - and dedicated the Informal European Council meeting in Granada (5 October 2023) to the future of the EU also through the lenses of such autonomy. The "Granada Declaration" officially adopted at the end of the meeting mentions:

> "We will work on our resilience and our global long-term competitiveness, making sure that the EU has **all the necessary tools** to secure sustainable and inclusive growth and global leadership in this crucial decade. We will address vulnerabilities and strengthen our crisis preparedness, not least in the context of growing climate and environmental risks and geopolitical tensions. We will anticipate potential challenges and seize the opportunities for our Union in the green and digital transitions, in order to ensure the sustainability of our economic model, leaving no one behind. We will concentrate particularly on energy and resource efficiency,

[136] European Parliamentary Research Service (2023), *Future Shocks 2023: De-risking Europe's global critical supply chains*, 18 August.
[137] Spain's National Office of Foresight and Strategy (2023), *Resilient EU2030*.

> circularity, decarbonisation, resilience to natural disasters and adaptation. to climate change. (…) We will ensure access to affordable energy, increase our energy sovereignty and reduce external dependencies in other key areas where the EU needs to build a sufficient level of capacity to guarantee its economic and social welfare, such as digital and net-zero technologies, critical medicines and raw materials, as well as sustainable agriculture. (…) We will mobilise and develop our external action instruments. It is now more important than ever to cooperate on strengthening and diversifying our supply chains, fostering partnership, trade and investment agreements, promoting sustainable development to meet our agreed goals towards net-zero emissions, and enhancing health emergency preparedness. This work also requires reinvigorating global trade, in which the WTO plays a fundamental role"[138].

Therefore, more measures – *specific*, *proportionate* – are to be expected to reduce European dependencies through a stronger industry, research and development, international cooperation.

6.2.2. Industrial level solutions

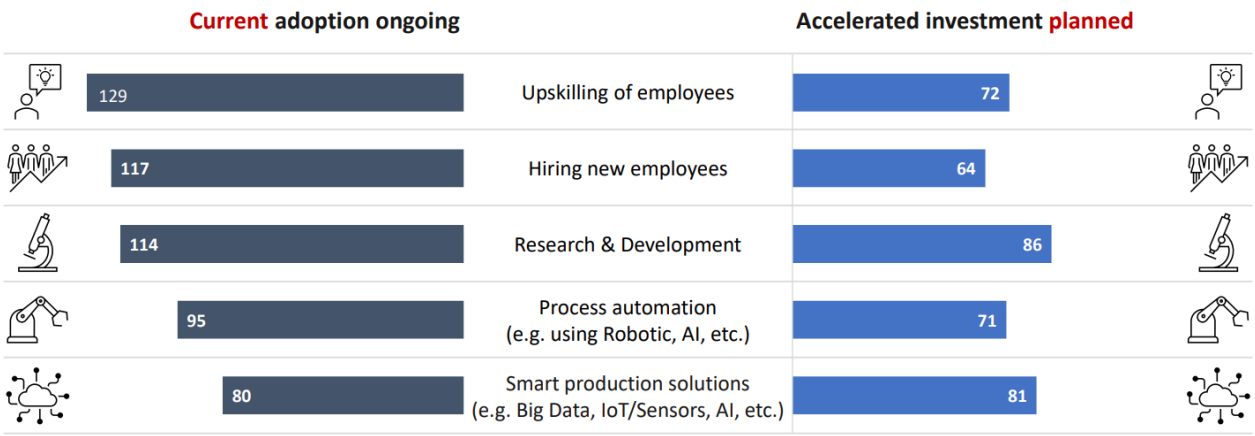
To cope with disruptions in supplies, several types of actions have been increasingly adopted by the European enterprises in the latest years.

ECCP[139] reports that the European companies it surveyed in 2022 responded to their supply disruptions by:

- (near team) **diversification of the supplier base**
- (near term) **building redundancies** (e.g., through safety stocks)
- (near term) **regionalisation of the supplier base**
- (near term) **acceleration of planned investments** to enhance supply chain resilience
- (longer term) **upskilling & hiring of employees**
- (longer term) **research and development**
- (longer term) **adoption of smart production solutions**.

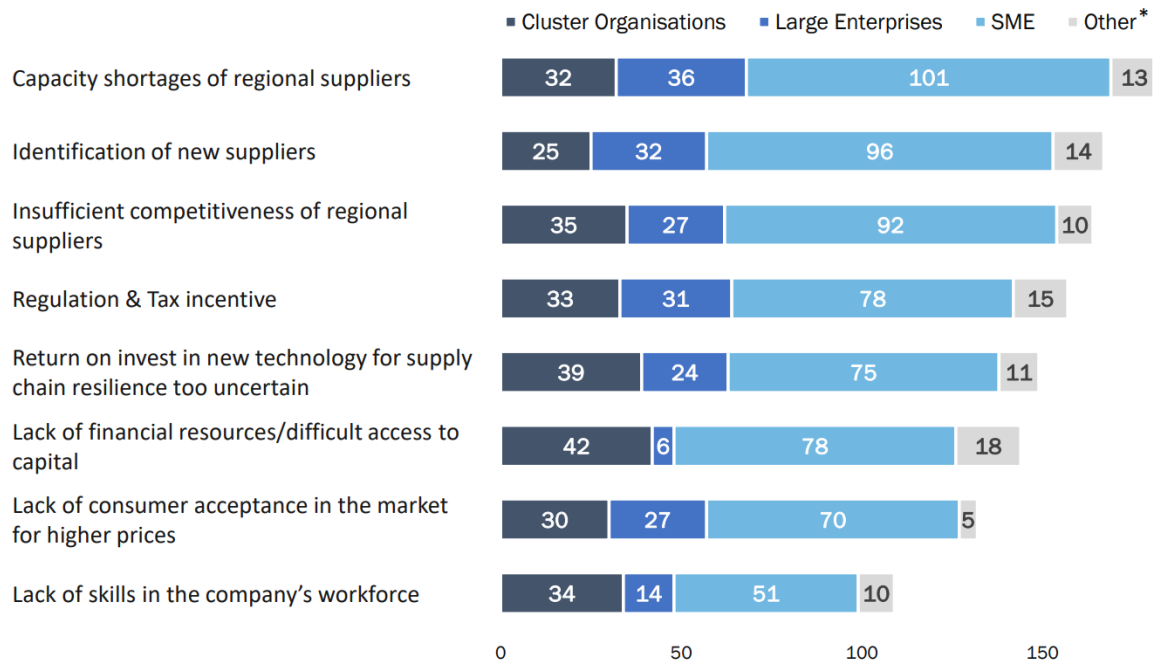
[138] The Granada declaration - Consilium (europa.eu).
[139] Op. cit., ECCP (2022b).

Figure 28 | Solutions adopted vs planned by the Survey respondents (source: ECCP)[140]



Against the background of these solutions to improve supply chain resilience, Survey participants were also asked about the difficulties they experienced in increasing supply chain resilience. The answers vary among the different entity types[141].

Figure 29 | Difficulties faced in making own supply chains more resilient (source: ECCP)[142]



[140] Ivi, p. 21.
[141] The answers provided by the Cluster organisations are generally provided in representation of samples of their members, of which the situation is directly known (A/N).
[142] Ivi, p. 22.

Deloitte[143] reports that the European companies it surveyed in 2023 are responding to their supply chain challenges by:

- ***Increasing collaboration with suppliers*** (56%)
- ***Diversifying their suppliers and supply routes*** (55%)
- ***Increasing use of digital planning tools*** (40%)
- ***Increasing parts and supplies inventories*** (32%)
- ***Increase local procurement*** (20%)
- ***Stress testing/scenario testing*** (20%)
- *Re-**evaluation/Relocation of production locations*** (11%).

The survey also providing a segmentation of answers per sector of operations, makes it possible to identify patterns in the two sectors suitable to represent the Rail Supply Industry – *Manufacturing* and to a smaller extent *Construction* – in terms of priority actions for resilience:

Table 3 | Resilience actions activated by the Deloitte Survey's respondents
(Author's re-elaboration of Deloitte Survey Report data; in bold the priority choice per each sector)

Resilience actions	***Average all surveyed sectors***	***Manufacturing sector***	***Construction sector***
Increasing collaboration with suppliers	***56%***	60%	**76%**
Diversifying their suppliers and supply routes	*55%*	**68%**	66%
Increasing use of digital planning tools	*40%*	47%	31%
Increasing parts and supplies inventories	*32%*	43%	17%
Increase local procurement	*20%*	24%	14%
Stress testing/scenario testing	*20%*	14%	10%
Re-evaluation/Relocation of production locations	*11%*	20%	3%

These results will be further commented in Section 7, where they will be compared to the results of the LEADER 2030 Survey concerning these aspects.

6.3. Conclusions

In the last four years the EU industry has been hit by several crisis impacting supply chains, of different nature and with different type of impact: *I can't produce because I can't find the necessary materials as borders are close*; *I can't produce because I can't find the necessary materials at my previous suppliers*; *I can't produce because the materials I need are delayed for logistics reasons*; *I can produce but supply costs/stockpiling costs/manufacturing costs/logistics costs have increased, my customer doesn't accept to pay for such increase and I have no more margins, which threatens my company's sustainability*; and so on.

[143] Op. cit., Deloitte (2023).

Many surveys have been run globally in these years to map and track all this on a pretty continuous basis, to understand such a complex situation not only for statistical reasons but rather for customising governments policies as well as for suggesting operational recipes for resilience to companies. The ones run on behalf of the European Commission discovered that main disruptions having hit European companies concerned Inbound logistics, Outbound logistics, Procurement and Operations, with the first much more prominent. Among the industrial ecosystems most affected in Europe by such disruptions there is the Mobility-Transport-Automotive, with data showing that SMEs were far more hit than larger companies. On the other hand, the MTA industrial ecosystem was less hit by *High-level Input loss* and *High-level Market loss* than the average of all ecosystems together, which suggests a relative higher capacity to recover from the disruptions.

The survey of the European Central Bank shows a high increase in the enterprises' decisions about near-shoring / friend-shoring / diversifying both the production and the supply chains in the next five years. Similar trends on supply chains regionalisation emerges also from McKinsey's.
Diversification is also reported by the European Investment Bank survey as response strategy to trade disruptions – these mainly driven by logistics and access to materials and services. The kind of mitigation actions, however, depend on the level of trade openness, productivity, innovation and digitalisation of the enterprise: the lower they are, the more enterprises become 'in-wards looking'.
Late deliveries and issues in accessing materials are also reported by Deloitte's as enterprises' biggest problems, together with higher shipping costs and – in general – higher prices for commodities or intermediate goods.
As resilience actions, according to McKinsey's almost all companies have increased their inventory buffers and pursued dual-sourcing strategies for critical raw materials. Similar results from ECCP and Deloitte, which show the role of regionalisation of supplies (although this is not without its difficulties) and the importance of stronger collaboration with suppliers.

Although the cause of all this has been blamed on Global Value Chains and their excessive use driven by cost efficiency only, and this has led to hard debates about geopolitical risks and their effects on global production and trade as well as the need to de-globalise, according to the European Central Bank "little empirical evidence has emerged of increased fragmentation in global value chains. (…) Most analysis to date does not find evidence of significant changes in aggregate European trade patterns". In fact, "the ways that firms are adjusting their trading relations and supply chain management may take time to unfold, given the challenges and costs involved in modifying business models, supply chains and contracts" [144].

Not being enough to leave the markets re-balance automatically, the largest economies have adopted strategies to increase their autonomy and to reduce vulnerability of key supplies, but their global impacts can be completely different. EU choice for *open strategic autonomy* and the

[144] Op. cit., Attinasi M G, Ioannou D, Lebastard L, Morris R (2023).

adoption of many varied policies in support remains the single case, while US opted for protectionism, suitable to produce not only internal but rather global effects. The measurement of estimated *direct effects* – e.g. – of the US "IRA Act" shows in fact an increase in production of electrical and optical equipment in US (concentrated mostly in the green sectors) by 6% to 30%, and production losses in the EU between -0,5% and -3%, in China between -1% and -5%, in Malaysia -up to -18%, in Vietnam up to -13%, but other *longer-term or indirect effects* may include up to slowing down the EU Green Transition processes, as US increased domestic production could hinder the international diffusion of knowledge in green technologies[145].

Enterprises' decisions about *where to source* and *where to invest/manufacture* will play a decisive role. States may offer strategies, implementation tools, subsidies, but ultimately it will be up to the enterprises to decide what is worth for them under *pure* business considerations.
So far, "both the theory and the empirical evidence suggest that there is inertia in the [enterprises'] localisation choices for factories and suppliers, owing to the considerable fixed costs of setting up in other countries and of creating stable trade relationships" [146].
The European Central Bank in fact shows that shocks perceived as being temporary don't bring enterprises to change their habits in supplies ("shocks to the Chinese supply chain lowered manufacturing production in the euro area by up to 7% in the spring of 2020" and their effect "quickly faded with the reopening of the Chinese economy", although, however, "the main contributions to the recession [in Europe] came from domestic sources") and in manufacturing location, while those perceived as long-lasting may encourage a search for alternative suppliers and manufacturing locations[147].
Therefore, *if not* requested by customers willing to recognise more value to closer and less vulnerable supply sources, and *if not* obtained through indirect policies such as the new EU Directive for Corporate Responsibility Due Diligence[148] - which aims to foster sustainable and responsible corporate behaviour throughout Global Value Chains -, European enterprises will hardly move supplies away from China and/or other Far-East countries *unless* a long-lasting risk is perceived. To name two: China's invasion of Taiwan and the even stronger impact of climate change in China and South-East Asia suitable to disrupt productions.

[145] Attinasi M G, Boeckelmann L, Meunier B (2023), *Unfriendly friends: Trade and relocation effects of the US Inflation Reduction Act*, CEPR.
[146] Op. cit., European Central Bank (2023), p 92.
[147] Ibidem.
[148] Corporate sustainability due diligence (europa.eu).

7. Survey phase on Disruptions and Dependencies in Supplies for the Rail Value Chain

In order to gather fact-based information on the specific disruptions and dependencies the Rail Value Chain suffers, a LEADER 2030 survey was launched on 6th November 2023 as online Consultation, available in 9 languages: English, French, German, Italian, Polish, Spanish, Swedish, Serbo-Croatian, Turkish – i.e. the national languages of the Railway Cluster organisations members of ERCI[149]:

Table 4 | The multi-language versions of the Consultation

▪ English	**European Consultation "Disruptions and Dependencies in the European Rail Supply Chain"**
▪ French	**Consultation Européenne "Perturbations et dépendances dans la chaîne d'approvisionnement ferroviaire européenne"**
▪ German	**Europäische Konsultation zu "Störungen und Abhängigkeiten in der Eisenbahn-Wertschöpfungskette"**
▪ Italian	***Consultazione Conoscitiva Europea "Disturbi e Dipendenze nella Filiera Ferroviaria Europea"***
▪ Polish	**Europejskie konsultacje w "Sprawie zakłóceń i zależności w kolejowym łańcuchu wartości"**
▪ Spanish	***Consulta Europea sobre "Interrupciónes y Dependencias en la Cadena de Valor Ferroviaria"***
▪ Swedish	**Undersökande Europeiska "Samrådet Om Störningar Och Beroenden I Järnvägens Värdekedja"**
▪ Serbo-Croatian	***Evropska Konsultacija o "Poremećajima i Zavisnosti u Železničkom Vrednosnom Lancu"***
▪ Turkish	**"Demiryolu Değer Zincirindeki Kesintiler ve Bağımlılıklar Üzerine Avrupa İstişaresi"**

The answers analysed in this Section are the ones received until 22nd December. The Survey will remain however open for the next few months, to gather any emerging information. The lessons learnt from the previous sections indicate that – unfortunately - disruptions emerge on a continuous basis and for different reasons. Keeping the survey open will make it possible, in case of emerging crisis, to include such information in the project intelligence activities.

7.1. Methodology and approach

The Survey aiming to provide a fact-based analysis of disruptions and dependencies experienced by the European Rail Value Chain, the target audience was represented by:

[149] ERCI members - ERCI (eurailclusters.com).

- Transport Operators
- Infrastructure Managers
- OEMs
- Tiers from 1 to 3

from the EU Member States and from European countries not member of the European Union home to a national Rail Supply Industry.

The Survey is composed of a set of conditional questions: i.e., according to the respondent's answers, sets of questions are presented or by-passed. As a result, the participants having no disruptions to report had to answer 11 questions, and those having disruptions in all the four categories covered for supply-related disruptions (*Raw materials*, *Processed materials*, *Components*, *Assemblies*) had to answer 28 questions.
The questions presented were however all mandatory, except the last one for a possible final comment. The reason for this choice was to ensure that all the questions thoroughly selected could all be answered. For this, the pdf version of the survey questions was made available and suggested for pre-download, to provide transparency and reassure.

Based on previous project experiences with companies' surveys, during the preparation of the survey much attention was paid to:

- ensure the **clarity** of the questions (not only through the use of national languages, but rather for how they were formulated, and the wording used)
- keep the **number** of questions to the minimum quantity necessary to gather the information sought by the project, in order to propose a survey answerable in maximum 5 minutes
- avoid questions whose answers could have been considered by the companies 'too **strategic'** (e.g. about supply strategies and practices, specific supply countries, etc.)
- gather a certain amount of information about the **responding company**, necessary to the Author to draw better conclusions, but at the same time ensure the maximum confidentiality of the answers provided. In this regard, a specific Policy was defined and made available in all survey links
- make clear, in introducing the survey, that also answers from companies having suffered **no disruptions** were valuable for the project purposes.

The survey was composed of **10 parts**:

- Company information: email and role of the responding person, name of the company, size of the company, website, country location, region location
- Company positioning in the Rail Value Chain: Infrastructure Manager, Transport Operator, OEM, Tier 1, Tier 2, Tier 3
- Company positioning in the Rail business segments: Rolling stock + 4 sub-segments, Command Control Signalling + 3 sub-segments, Infrastructure + 7 sub-segments, Operations + 3 sub-segments

- Disruptions suffered since 2018: Yes / No (if No, a question about the reason for this is posed, and the last question on a final comment is then presented; if Yes, the survey continues)
- Type of supplies affected: Standard/state-of-the-art, Innovative, Both
- Type of disruptions ranking: Supply-related, Demand-related, Manufacturing, Economic/Financial, Logistical
- Focus on Supply-related disruptions: 4 specific focuses on *Raw Materials*, *Processed Materials*, *Components*, *Assemblies*[150], Reasons for disruptions, Provenance of affected supplies, Potential for substitution, Average price difference between EU and out of EU supplies
- Demand-related disruptions: Reasons for disruptions
- Logistical disruptions: Type
- Adoption of long-term strategies for risk mitigation: Yes / No / Which ones.

The strategic project goals behind each question will be discussed along with the presentation of the results in the following sub-chapters.

7.2. Results

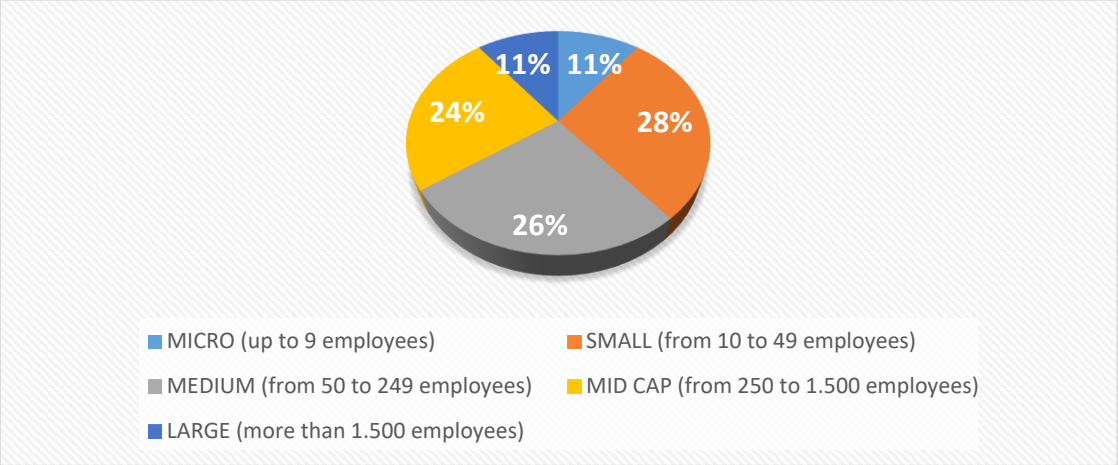
7.2.1. Value Chain represented

95 companies from 37 regions in 16 countries (Austria, Belgium, Croatia, France, Germany, Italy, Montenegro, Netherlands, North Macedonia, Poland, Serbia, Slovenia, Spain, Sweden, Türkiye, United Kingdom) answered the Survey.

Concerning the participants' **size**, all are represented in a balanced manner, with SMEs (Micro + Small + Medium sized enterprises, including some start-ups) totalling 62 (**65**% of the respondents). **SMEs involvement** in the entire intelligence-gathering process was **a key objective** of the EU-RAIL Call funding this project.

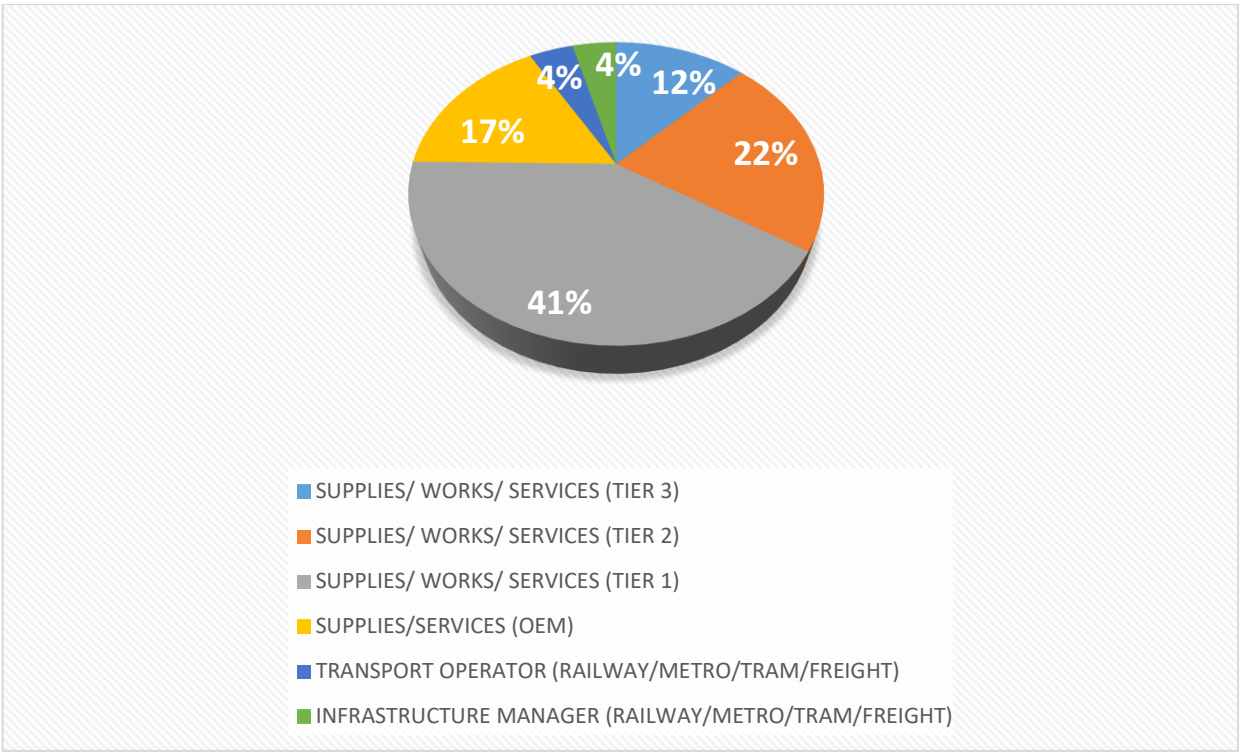
[150] Out of the several possible wordings for segmenting the production stages, the Author decided to use the wording used by JRC (2020), *Critical Raw Materials for Strategic Technologies and Sectors in the EU – A Foresight Study*, European Commission, p. 12.

Table 5 | Participants' size (n=95; source: Author)



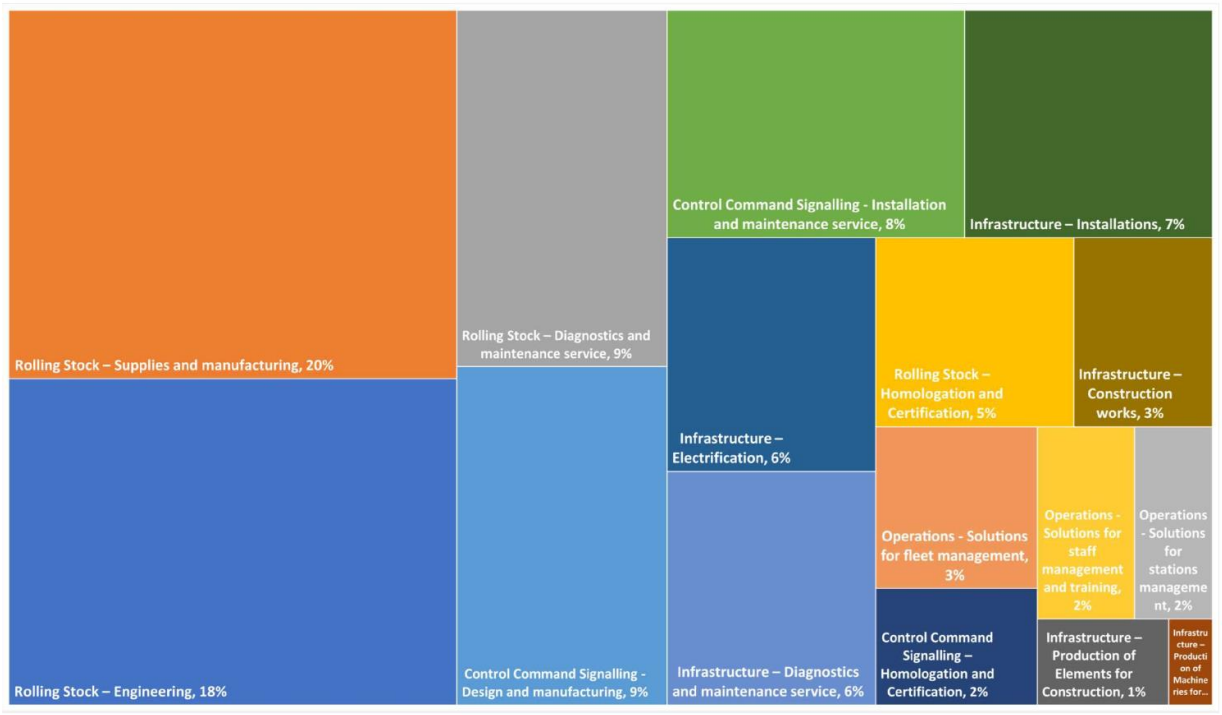
Concerning the **role in the Rail Value Chain**, all parties are represented, with more participation of Tier 1 suppliers:

Table 6 | Role in the Rail Value Chain of the Participants (n=95; source: Author)



Concerning the **railway business segment**, out of the 17 macro-categories proposed, the participants represent all but one ("Infrastructure Homologation and Certification"), with more participation (>50%) from companies operating in the Rolling Stock segment – as is easily understood, given the larger size of this segment.

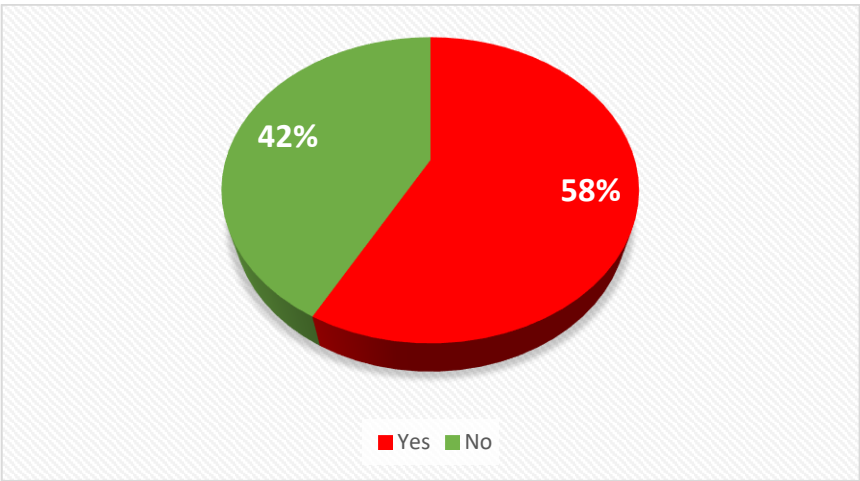
Table 7 | Railway business segments of the Participants
(n=95; multiple options were possible: tot=223; source: Author)



7.2.2. Disruptions

The Survey shows that **58% of respondents has suffered/is suffering disruptions** in the supply system.

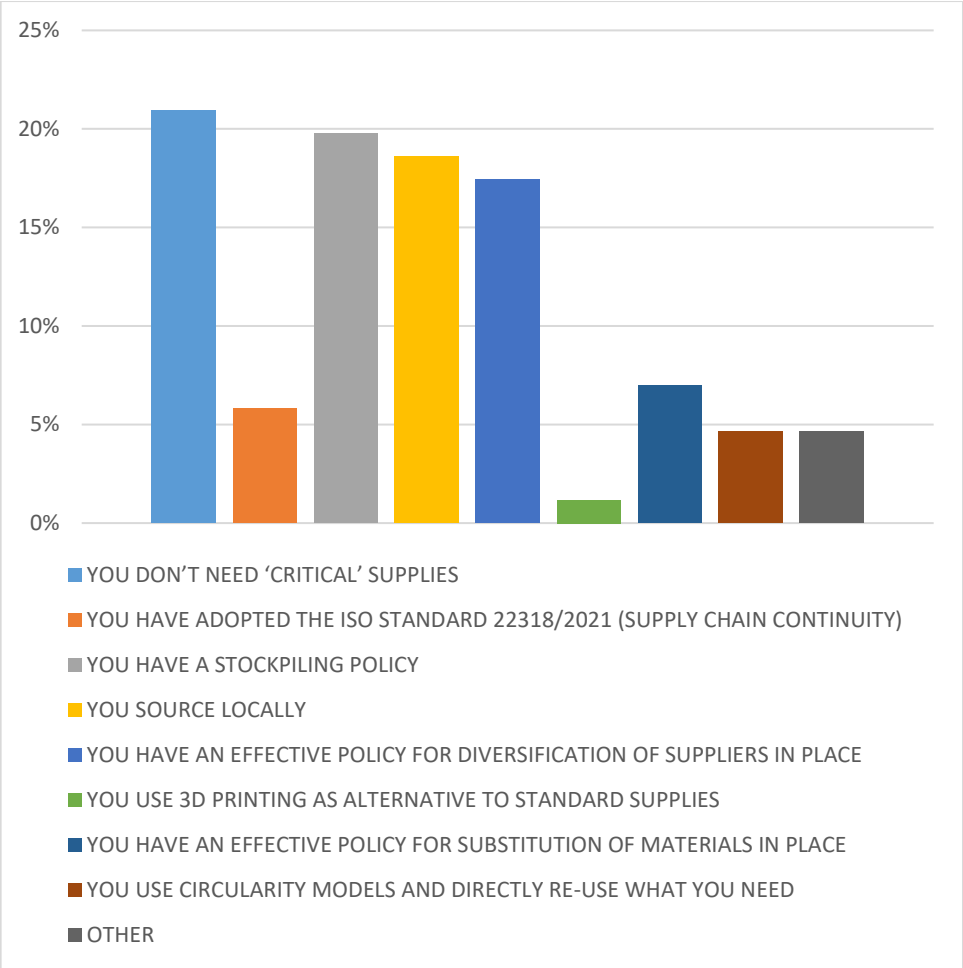
Table 8 | "Did you suffer/Are you suffering disruptions in supplies?" (n=95; source: Author)



Those **not having suffered any disruption** represent in a balanced way both immaterial supplies

(e.g. Engineering for Rolling Stock, IT-based solutions for Diagnostics) and material ones in all segments.
They were offered a set of options identified from the Desk research phase to understand **why** they didn't suffer any disruption.

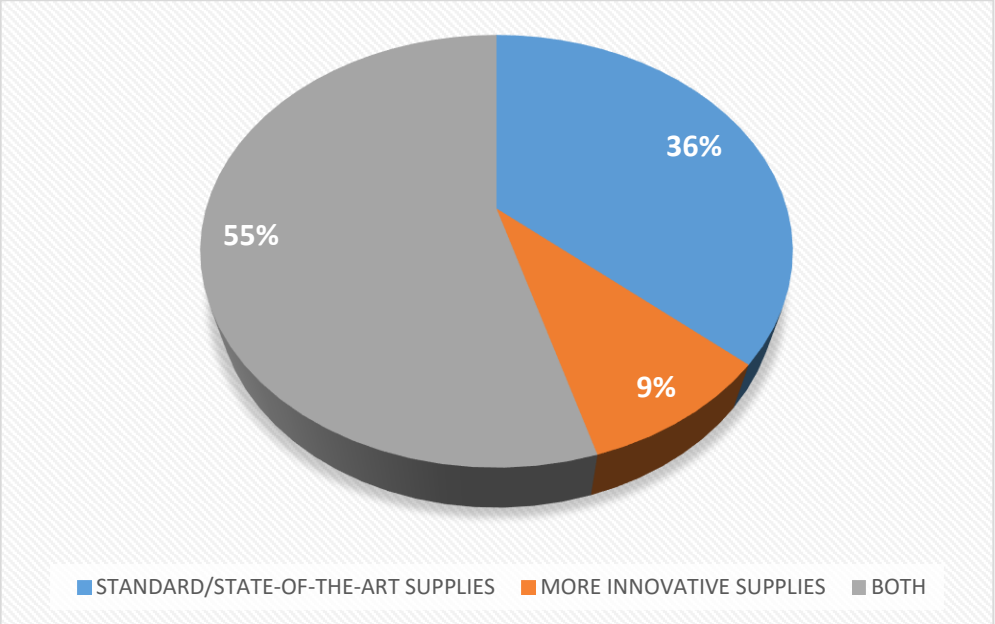
Table 9 | Why the companies not affected by disruptions could make it possible (n=40; multiple answers possible: tot=86; source: Author)



Among the "Other" answers: "*Autonomous production and sound relationships with suppliers*"; "*We provide engineering services at the manufacturer's request, contracted directly by the manufacturer and without dependence on third parties to perform our work*".
In 20 cases, **more than two resilience policies are adopted simultaneously**.
Interestingly, all those having adopted the **ISO standard on Business Continuity are all from the same country**; plus, they represent 1 Micro, 3 Small and 1 Large company, showing that not the size – as it usually is – explains the attention to international standards.
The analysis on the answers in comparison with the data from the desk research will be made in the sub-chapter "**Errore. L'origine riferimento non è stata trovata.**".

Concerning **what type of supplies suffered disruptions**, the answers show that in most cases both the standard supplies and the more innovative ones suffered problems. This is an important information as it confirms – on the one side – the need to not underestimate the access to supplies for the *ordinary functioning* of the Railway system, and – on the other side – that ***railway innovations*** **are already disrupted in terms of supplies** – which is a key information given the ultimate objective of the LEADER 2030 project.

Table 10 | Type of supplies disrupted (n=55; source: Author)



As the Desk research suggests, disruptions can be caused by different types of events and can have different impacts on companies' operations. For this reason it was asked to **rate the impact per different types of companies' operations**, focusing on the ones not having to do with internal skills'/organisational aspects, as this is out of the scope of the project:

- *Supplies*: this is the key focus of the project
- *Demand*: its evolution – also driven by innovation – is highly meaningful for the project objectives, as it impacts on European companies' capacity to deliver what requested
- *Manufacturing*: also this is related to innovation, in particular with the adoption of advanced technologies such as Advanced Materials, Additive Manufacturing, Robotics, etc.
- *Economic/Financial*: this is expected to be mostly driven by skyrocketing prices of energy and logistics in the most recent years, however it is an enabling factor for any company to afford any transformation the railway market is living
- *Logistics*: it impacts directly on companies' capacity to deliver correctly and on time own productions.

Table 11 | Level of impact of Supply-related disruptions (n=55; source: Author)

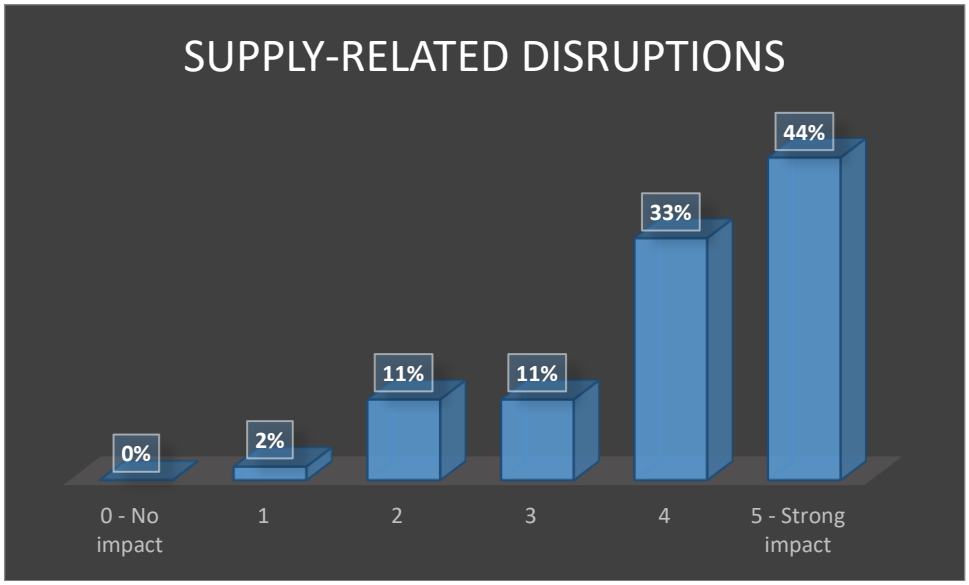


Table 12 | Level of impact of Demand-related disruptions (n=55; source: Author)

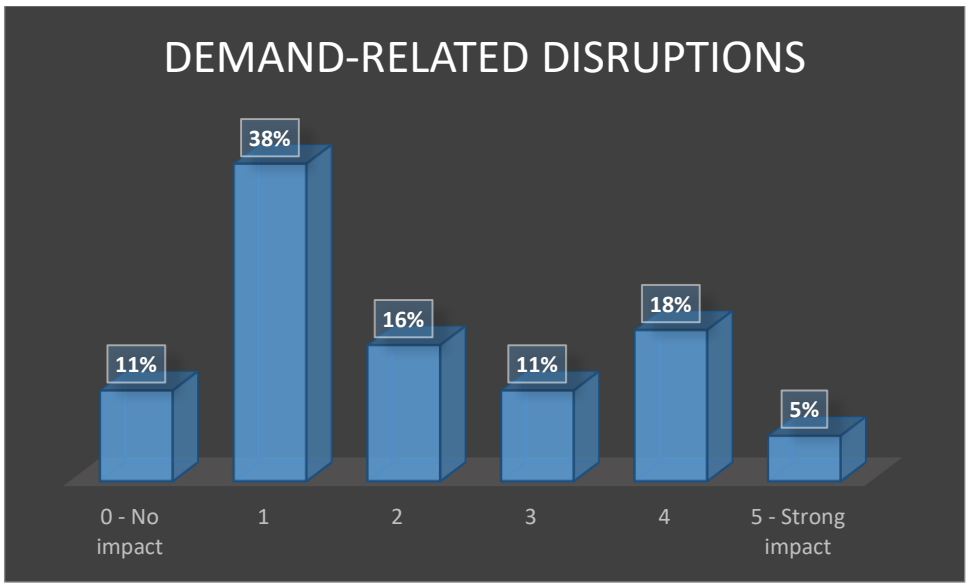


Table 13 | Level of impact of Manufacturing-related disruptions (n=55; source: Author)

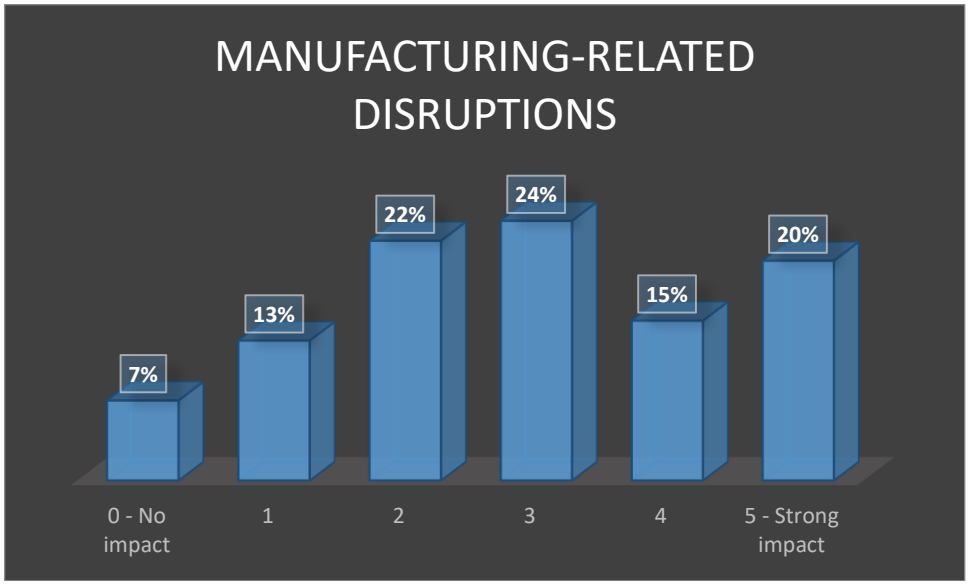


Table 14 | Level of impact of Economic/Financial disruptions (n=55; source: Author)

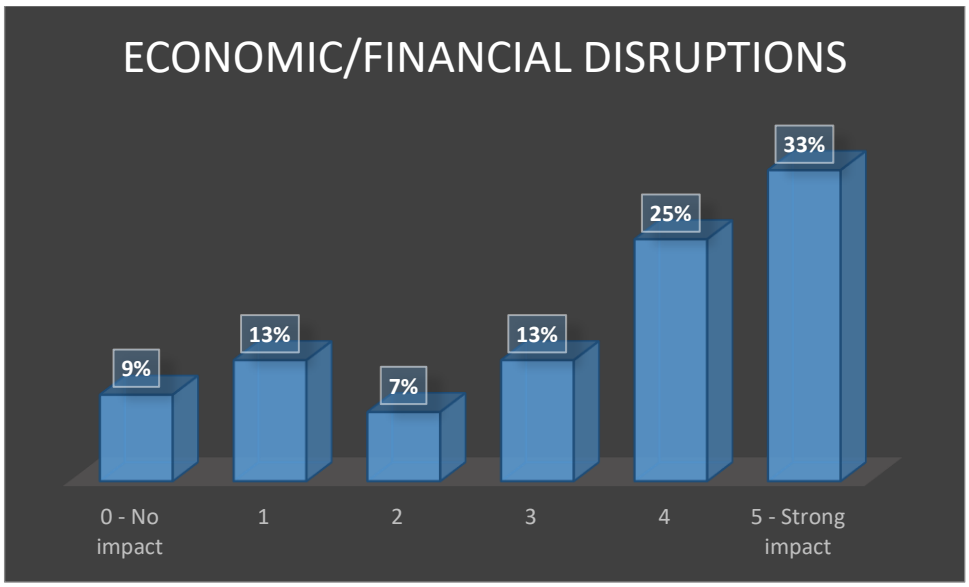
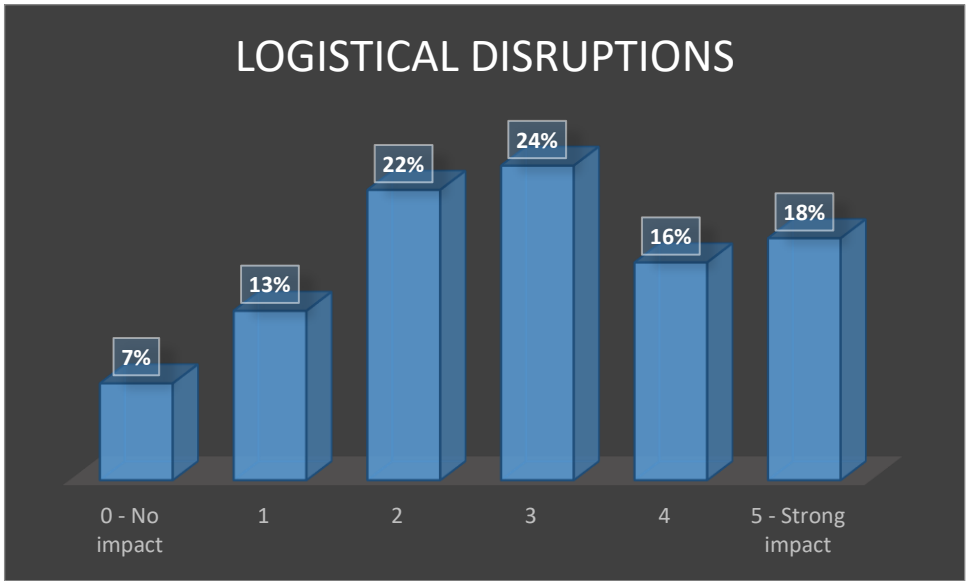
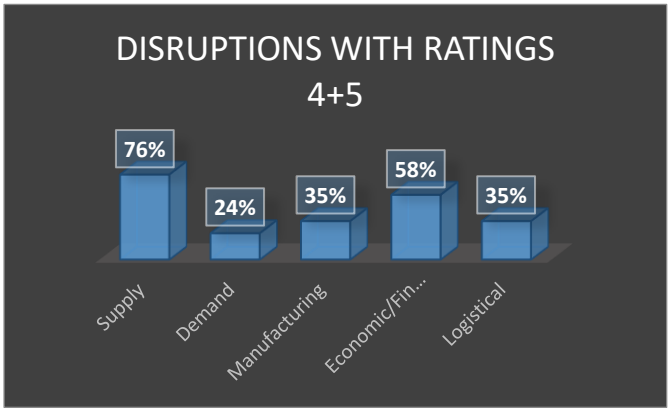


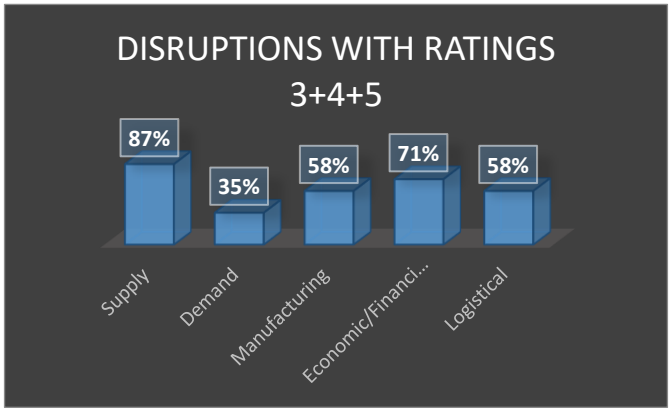
Table 15 | Level of impact of Logistical disruptions (n=55; source: Author)



The results show a very strong impact on companies' supplies but also on other aspects of their operations. A direct comparison focused on the **highest impact ratings** (answers "ratings 4 + 5") and **high+very high ratings** (answers "ratings 3 + 4 + 5") of the five types of companies' operations under focus offer the following pictures:

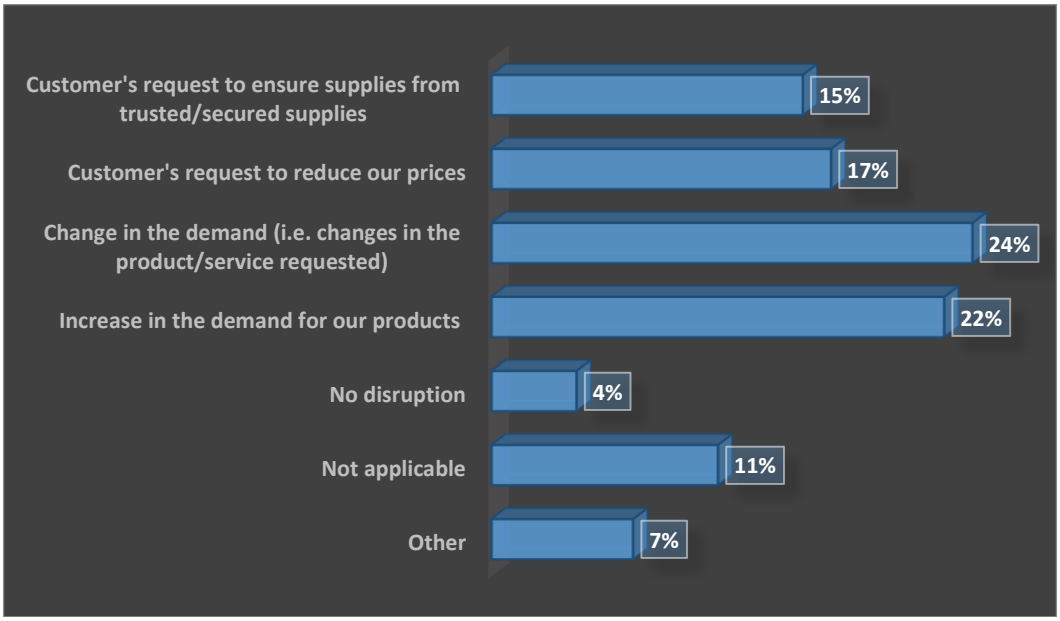
Table 16a-b | Comparison per types of disruptions (n=55; source: Author)





Supplies are by far the highest source of disruptions in the surveyed companies, followed by **Economic/Financial** disruptions; **Manufacturing** and **Logistical** ones are however an important source of disruption, that needs to be taken into consideration for the following project analysis and forecasts. **Demand-driven** disruptions are less impactful. Here below their specific nature:

Table 17 | Reasons for Demand-related disruptions (n=55; multiple answers possible: tot=72; source: Author)



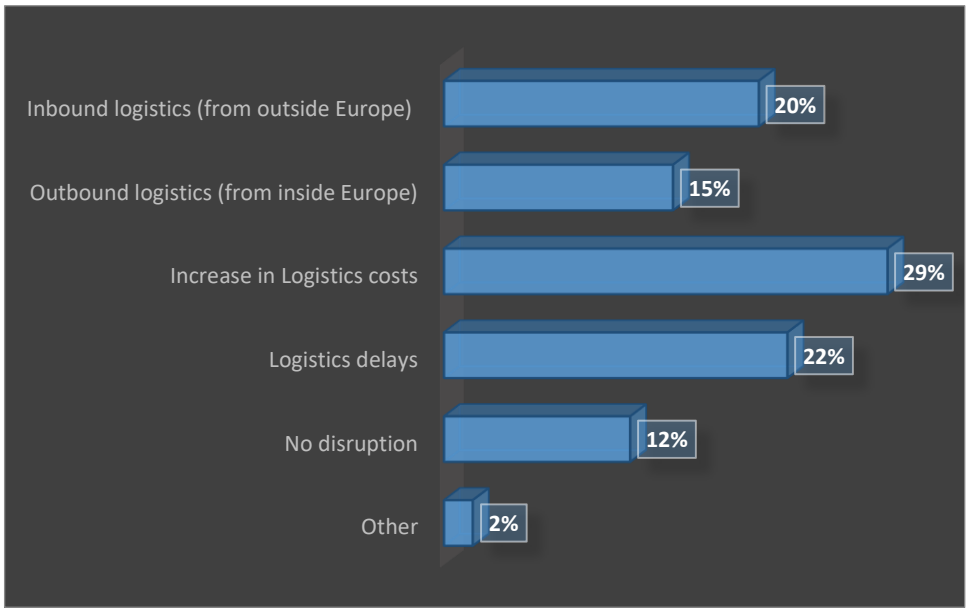
Among the "Other" answers: "*Product recall times not compatible with materials supply*"; "*Request for schedule changes*"; "*Reduced demand for our products*".

The analysis of the answers shows that:

- The highest reason for disruption (24%) is the **change in the products/services requested**. Out of the possible options, this represents the one more related to the impact of future expected innovations on the Rail Supply Industry. This calls for the **need to be ready for such transformation**, which is the ultimate objective of this project.
- Customers' **increased demand** for suppliers' products may lead to disruptions (22% of cases), given the times we are living in. All respondents with this type of disruptions but one also suffered logistics problems, and this could be one reason for, while the other could be materials'/components' scarcity.
- The customers in the Rail Value chain have already started to ask own direct suppliers to **source from trusted/secured suppliers** in order to reduce disruptions risks. Such an action, however, *if* introduced on short notice, can have the effect to reduce customers' disruptions but also to increase suppliers' ones. To avoid this, agreed terms of change between customers and stable suppliers should be pursued. Despite the rather low percentage is not worrying, however all this needs to be thoroughly taken into consideration in the next project analysis and forecasts with reference e.g. to the mentioned EU Directive for Corporate Responsibility Due Diligence expected to enter into force in 2025, as this will surely lead to important changes in the Rail supply chain.
- Customers' request to suppliers to **reduce prices** can 'threaten' the possibility to substitute – when possible – supplies from outside the EU with EU supplies to increase resilience. Next answers will elaborate this point.

Concerning Logistical disruptions, here below their specific nature:

Table 18 | Reasons for Logistical disruptions (n=55; multiple answers possible: tot=108; source: Author)

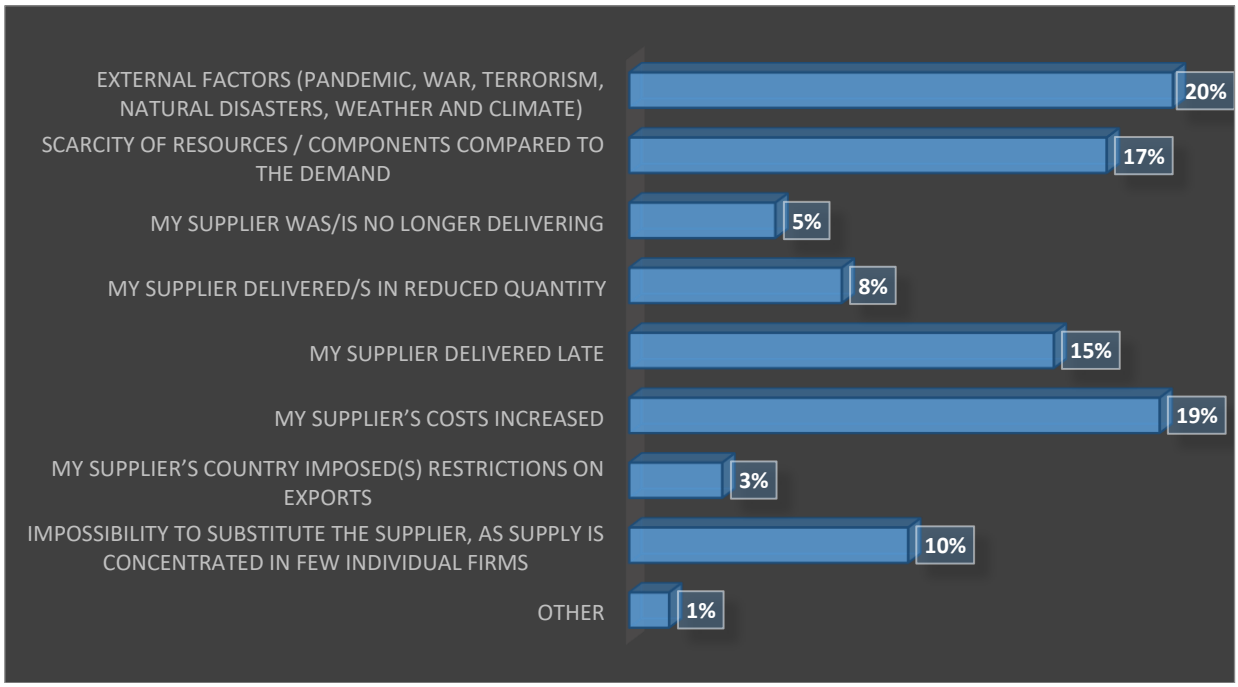


Among the "Other" answers: "*Generally fragile deadline situation in projects*"; "*Brexit*".
The analysis of the answers shows that all elements have an impact on the supply capacity of European companies, with:

- **Inbound logistics** (20%) more disrupted than Outbound one (15%), this explaining further the disruptions in supplies of materials, components, etc.
- the increase in logistics **costs** (29%) being the highest reason for disruption, followed by **delays** (22%); both contribute to problems in supplies, but the former explains the increase in supplies' costs and subsequent economic/financial disruptions as highlighted above, and the latter explains the delays in sourcing. In most cases, the respondents reported both problems together, this **triggering multiple disruptions**. This matches the results from the Desk research phase, i.e. that late deliveries are reported by Deloitte as enterprises' biggest problems, together with higher shipping costs.

Concerning Supply-related disruptions, here below their specific nature:

Table 19 | Reasons for Supply-related disruptions
(n=55; multiple answers possible: tot=208; source: Author)



Among the "Other" answers: "*Short age electronic components and their obsolescence*"; "*Costs and lead-times soared*"; "*Our company experiencing payment difficulties to the supplier*".
The analysis of the answers shows that:

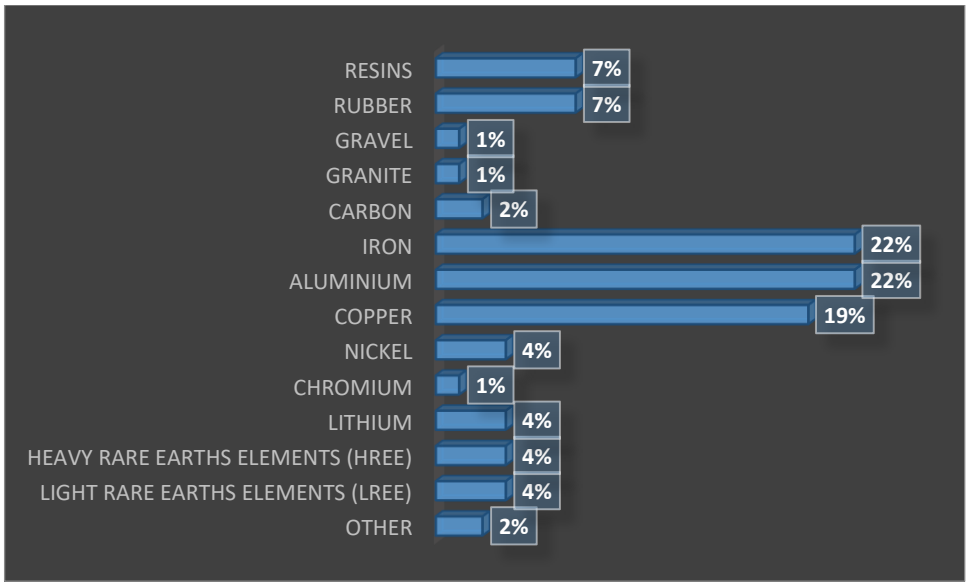
- **factors directly attributable to own suppliers** (with *increased costs* as the main one, followed by *delays*), if summed up, represent the major cause of disruption (47%)
- **major external factors** such as COVID-19 pandemic, war in Ukraine, etc. played and continue to play a major role in disruptions suffered (19%)
- **scarcity of resources/components** compared to the demand (17%) is one of the key aspects that **needs to be analysed by the project**, as this entails 'competition' not only among 'economic global powers' but also among different sectors in the same country/continent
- the **impossibility to substitute the supplier** as supply is concentrated in few individual firms, although limited as percentage (10%), represents a major threat that **needs to be further analysed in the next project studies**
- **protectionist measures** from third countries have – so far – very limited impact on disruptions suffered (3%).

A set of questions was then aimed to better focus on supply-related disruptions, detailing between those affecting *Raw Materials*, *Processed Materials*, *Components* and *Assemblies*.

For **Raw Materials**, the full list of *Critical* and *Strategic Raw Materials* as per the official EU list

was proposed, integrated with other types of raw materials used in the Railway sector, totalling 36 options plus "Other" option. One third of these materials interested the respondents having reported disruptions in such a field, with the following overview:

Table 20 | Raw materials affected by disruptions in sourcing
(n=34; multiple answers possible: tot=83; source: Author)



The "Other" option includes: "*Graphite*"; "*Crushed stone*".
This overview, compared with the list of Critical and Strategic Raw Materials in *Figure 16* | Critical and Strategic Raw Materials 2023 (source: European Commission) and with the Supply risk assigned by the European Commission to each Critical/Strategic Raw Material as reported in *Table 2* | Critical and Strategic Raw Materials necessary in each Strategic technology, and individual Supply Risk (Author's re-elaboration of JRC data) , shows that:

- **Iron**, one of the two most disrupted Raw Materials (22%), is not considered either a Critical or a Strategic Raw Material by the EU, i.e. it is not considered to have *high economic importance* and *high supply risk* (for being *Critical*) or *highest strategic importance*, *forecasted demand growth* and *difficulty of increasing production* (for being *Strategic*); vice versa, it is included in the similar list made of strategic minerals by China. The desk research about iron suppliers shows that the top iron ore exporting countries collectively shape the global iron ore market, and these are – from the largest - Australia, Brazil, China, India, Russia, Ukraine, South Africa, Iran, Kazakhstan, Canada[151]. The reported disruptions can therefore be explainable with stopped/drastically reduced supplies from Ukraine and from Russia and, in general, with the need to have to mostly source iron from outside the EU (the cited list doesn't include Sweden, which is however ranked eleventh at global level and whose production represents 1% of global one and is set as

[151] Pistilli M (2023), "Top 10 Iron-producing Countries", *Investing News Network*, 18 October.

increasing[152], despite extraction and production costs in Europe are far higher. The highest share of Swedish production is exported to Germany; however also German companies reported disruptions in the Survey).

- **Aluminium**, although having a *Supply risk* not very high (1,2), is - with iron - the material more disrupted (22%).
- **Copper**, although having the lowest *Supply risk* (0,1), is very disrupted (19%).
- **Lithium**, **Nickel** and **Rare Earths** (both Heavy and Light ones), far from being a problem hitting only major industrial/technological players, report disruptions (4% each) hitting also smaller companies.

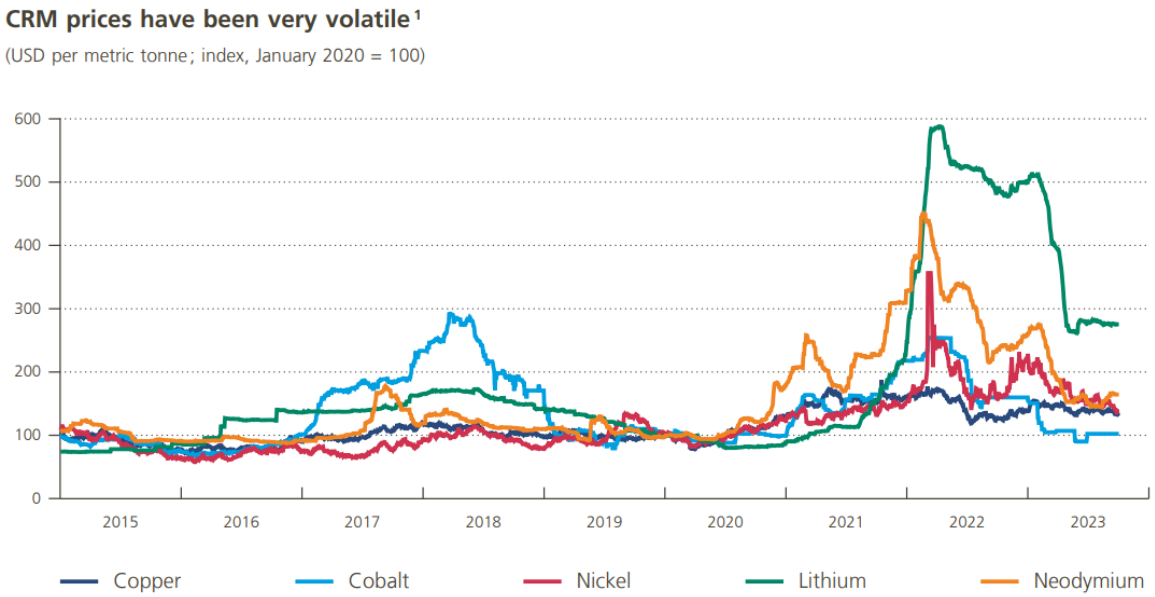
OECD confirms that the three traditional metals iron, aluminium and copper represent the highest dependencies of OECD countries, with iron and steel corresponding to 40% of all OECD dependencies in Critical Raw Materials, and copper and aluminium corresponding to 8% each[153]. The National Bank of Belgium confirms that "copper is already considered to be the most intensively traded industrial metal, and due to its extraordinary thermal and electrical conductivity, it is difficult to substitute – although aluminium and silver are sometimes used as alternatives for wiring"[154] – but we see that aluminium is disrupted as well. Its use across a wide range of technologies and in all clean energy technologies is pushing the large increase in its demand. Looking at copper price variations, the following figure shows that it was much less affected than other Critical Raw Materials, such a fact proving that disruptions reported mostly refer to *scarcity/access problems* than skyrocketing price problems – these latter instead hitting lithium, and with some peaks nickel.

[152] Iron ore in Sweden (mining-technology.com).

[153] OECD (2023), Raw Materials Critical for the Green Transition. Production, International Trade and Export Restrictions, *OECD Trade Policy Paper N. 269*, p. 33.

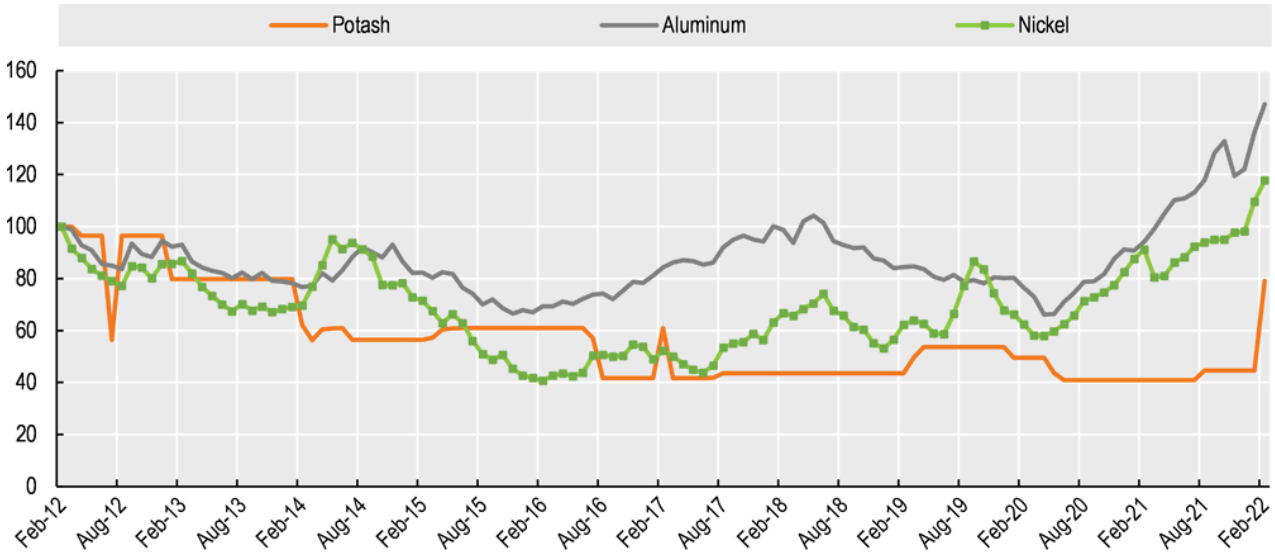
[154] Buysse K, Essers D (2023), "*Critical raw materials : from dependency to open strategic autonomy?*", *NBB Economic Review, 2023 N° 13*, p. 8.

Figure 30 | Price trends of five Critical Raw Materials (source: National Bank of Belgium)[155]



The following Figure, instead, shows price volatility of aluminium driven the Russian aggression of Ukraine but also by increased energy prices, which impact high on aluminium extraction and production process.

Figure 31 | Monthly aluminium, nickel and potash prices, February 2012-February 2022 (source: OECD)[156]

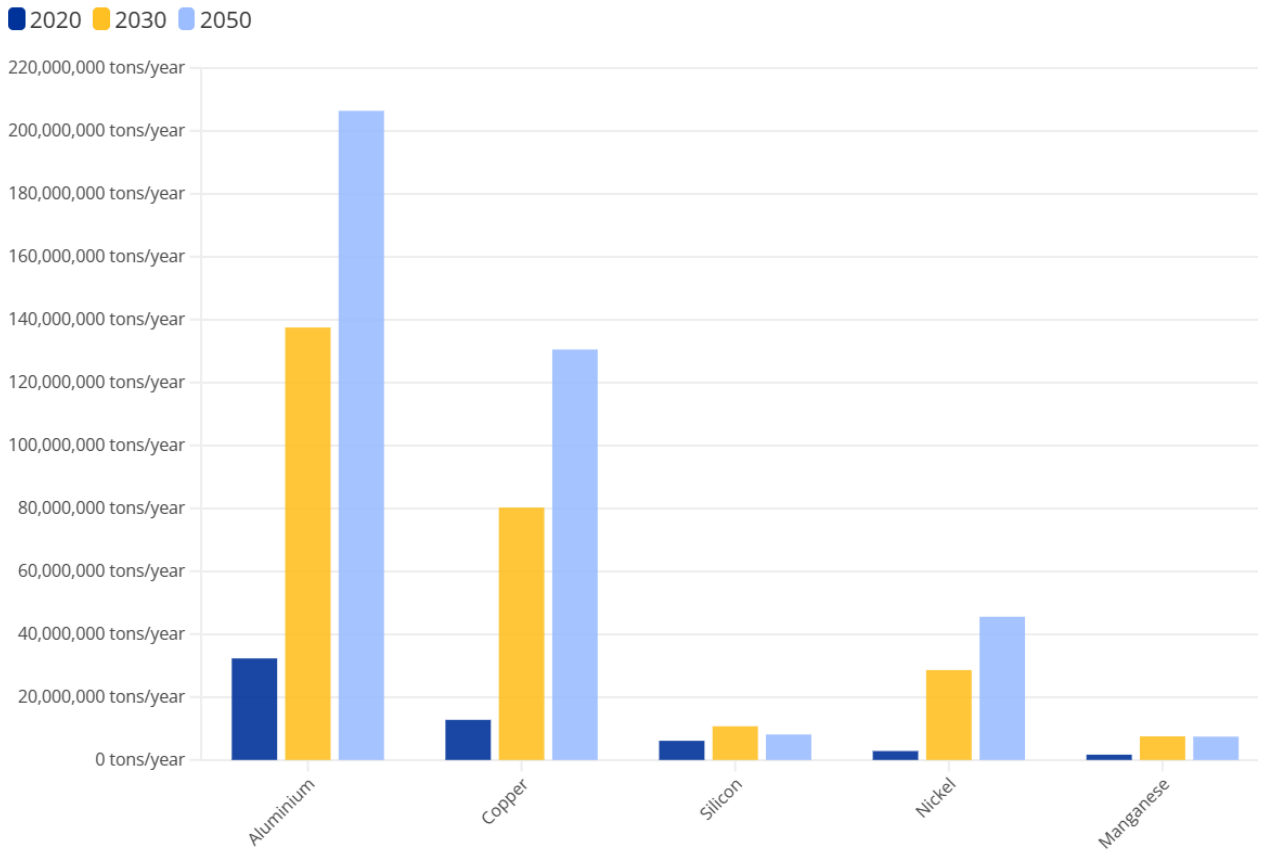


In terms of expectations, the situation cannot but worsen in the next years if looking at these forecasts, that see the **demand for aluminium multiplied 4,6 times by 2030 and the demand for**

[155] Ivi, p. 16.
[156] OECD (2022), *The supply of critical raw materials endangered by Russia's war on Ukraine*, 4 August.

copper multiplied by 8 times by 2030:

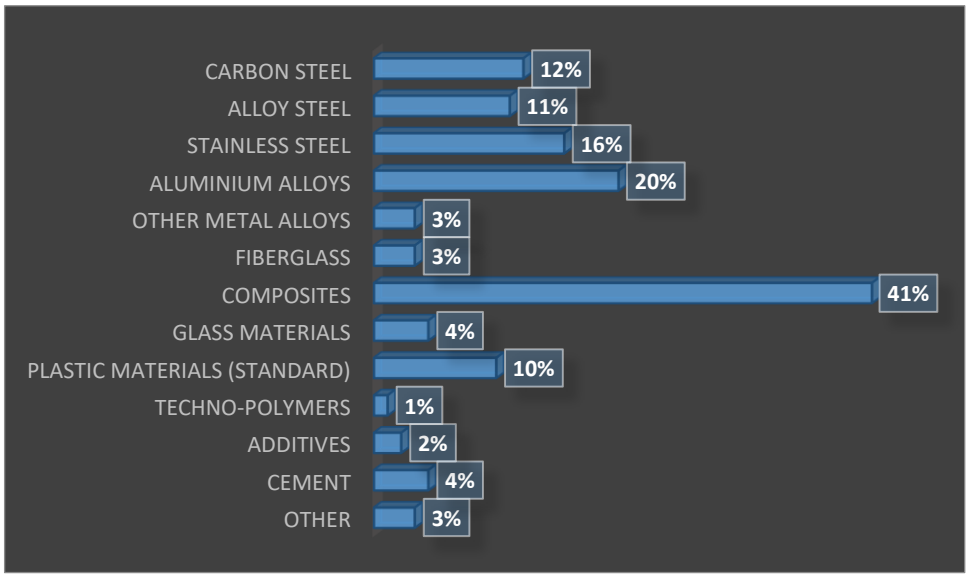
Figure 32 | Material demand in the European Union (high demand scenario; source: European Commission)[157]



For **Processed Materials**, a list of 14 options plus "Other" were offered, based on the most used in the Railway sector. All but two of these interested the respondents having reported disruptions in such a field, with the following overview:

[157] Council of the European Union (2023), *Infographic - An EU critical raw materials act for the future of EU supply chains*, November, point 5.

Table 21 | Processed materials affected by disruptions in sourcing
(n=37; multiple answers possible: tot=89; source: Author)



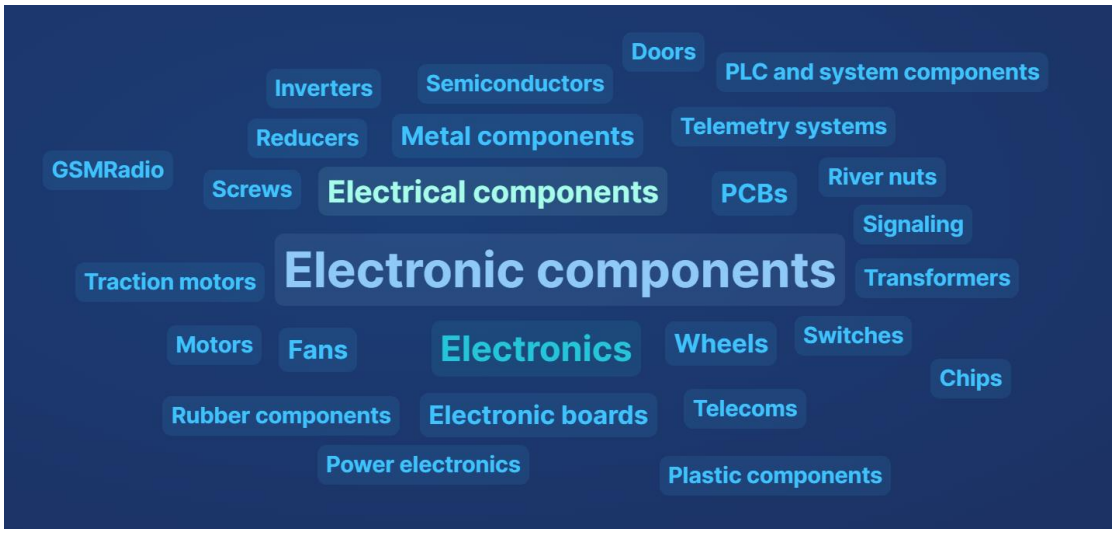
The "Other" option includes: "*Wood*"; "*Wood (birch) multiplex panels*"; "*Asphalt, Beton*".
This overview shows:

- The high level of disruptions suffered by **composites** (41%)
- The effect of disruptions in Raw Materials concerning iron and aluminium, impacting all types of **steels** (39%) as well as **aluminium alloys** (20%).
- Although just mentioned as "Other" options, also **wood** raises attention. In fact, price pressures and ongoing shortages were reported already by the European Commission in November 2021 and explained by a pronounced increase in global demand and supply bottlenecks given the high import concentration of some wood-related products in Russia, Ukraine and China. The Commission concluded that "[c]onsequently, international factors affecting important producers such as Russia, Ukraine or China can affect EU supply chains"[158]. The dramatic events started a few months later well explain the further disruptions in wood and wood-related supplies.

Concerning the **Components**, 37 out of 55 respondents were disrupted by this type of supplies.

[158] Op. cit., Benoit F, Connell García W, Herghelegiu C, Pasimeni P (2021), p. 12.

Table 22 | 'Word cloud' of disrupted Components mentioned at least twice (n=37; multiple open answers possible: total=85; source: Author)



Components mentioned once include:

- ETCS balises
- Communication components
- Control and communication systems
- Electronic chips
- Microchips
- Circuit board
- Microcontrollers
- Batteries
- Electrical motors
- Electrification components
- Optoelectronic equipment
- Electrical equipment
- Electromechanical components
- Magnetic components
- Converters DC/DC
- Rubber components
- Bogies
- Directional gears
- Axles
- Braking systems
- Air conditioners
- B&R controllers
- Moulded articles
- GRP articles
- Castings GGG
- Chemicals.

Concerning **Assemblies**, 18 out of 55 respondents were disrupted by this type of supplies. Disruptions hit the following (multiple open answers were given):

- Assemblies for complete production
- PCB-A Boards
- Assembled printed circuit boards
- Electrical assemblies
- Metal assemblies
- Control panels
- Electric motors
- Solenoid valves
- Electronic switches (contactors)
- Braking systems
- IT devices
- Cloud access
- Mechanical processing and wiring
- Electromechanical assemblies

- Wiring and Spinning
- Industrial Computers
- Construction, testing and similar
- Aerostructures.

Concerning the **provenance of supplies disrupted**, it was asked to rate the relevant impact. The results show this overview:

Table 23 | Level of impact of disruptions on supplies coming from own region (n=55; source: Author)

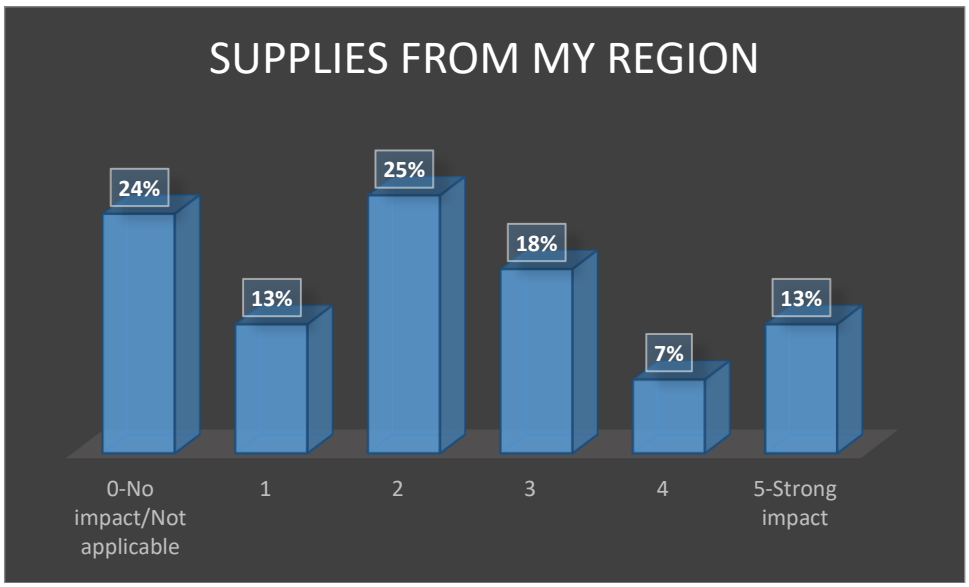


Table 24 | Level of impact of disruptions on supplies coming from own country (n=55; source: Author)

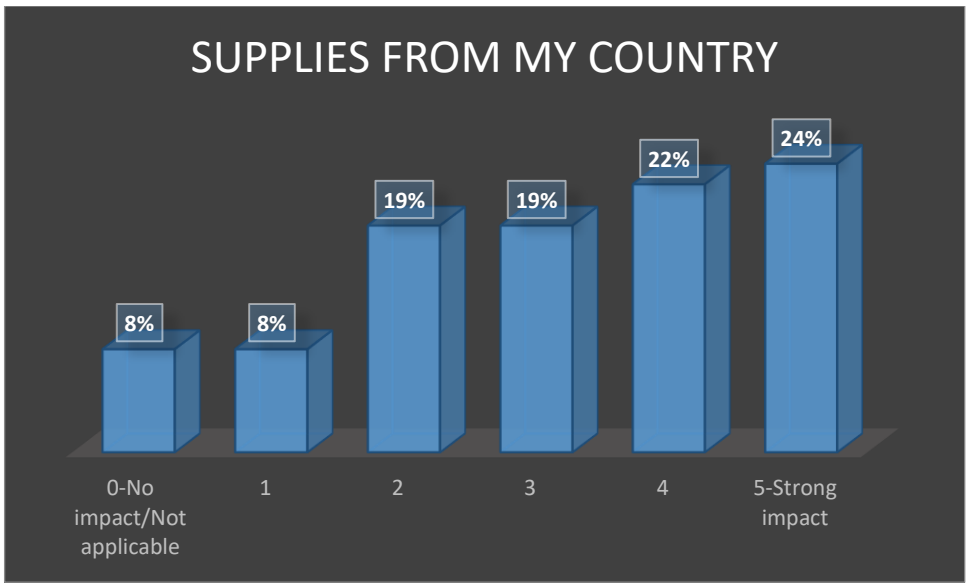


Table 25 | Level of impact of disruptions on supplies coming from other European countries (n=55; source: Author)

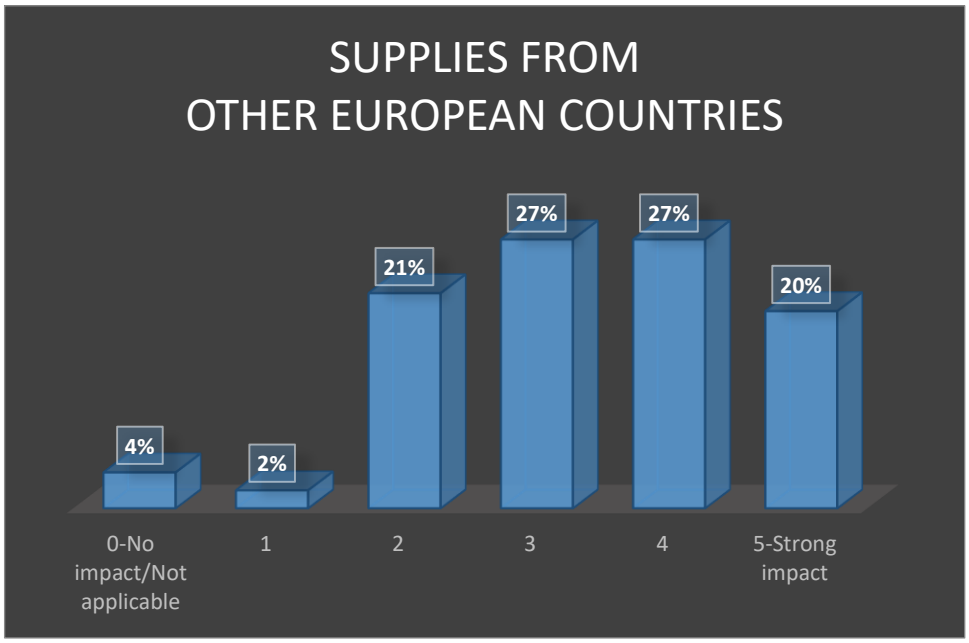


Table 26 | | Level of impact of disruptions on supplies coming from Asia (n=55; source: Author)

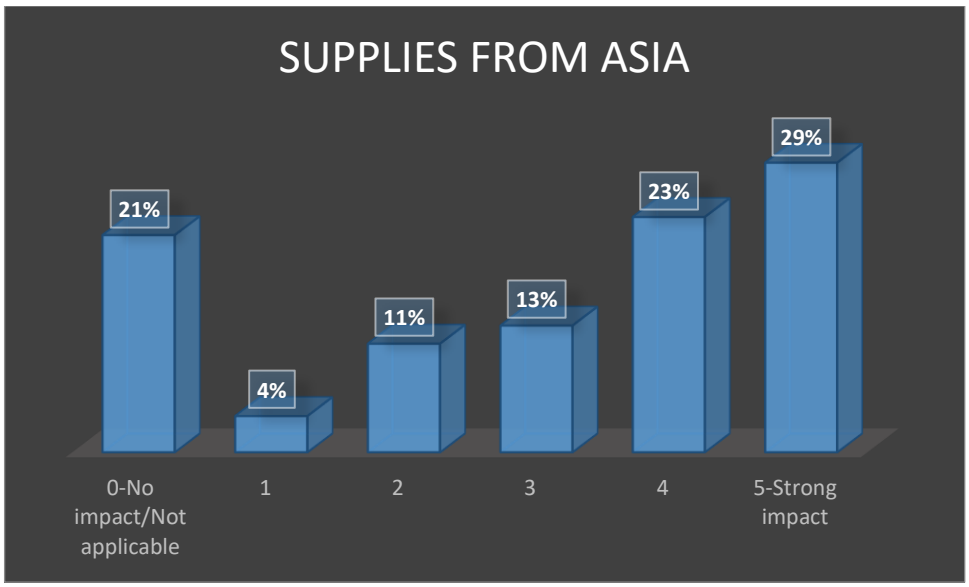


Table 27 | Level of impact of disruptions on supplies coming from Americas (n=55; source: Author)

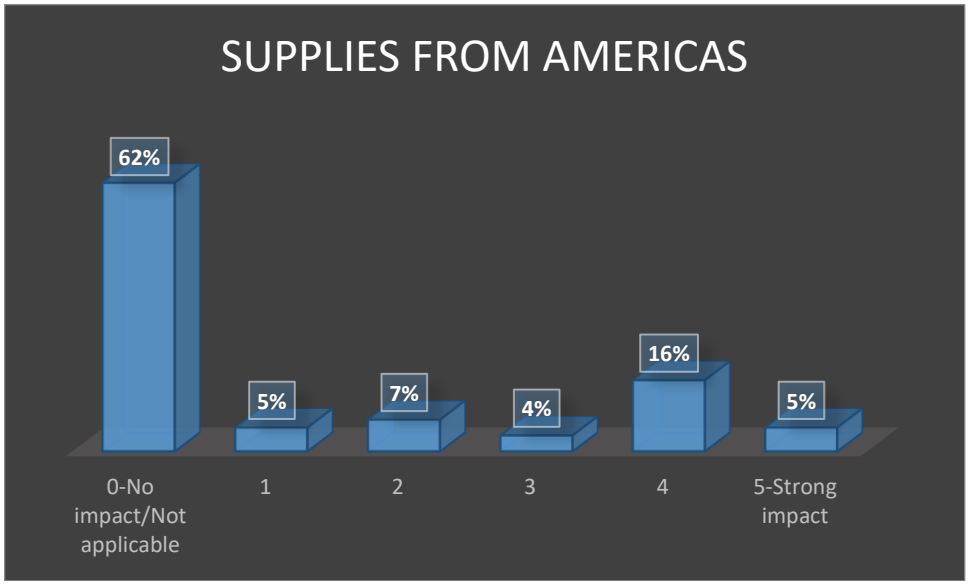
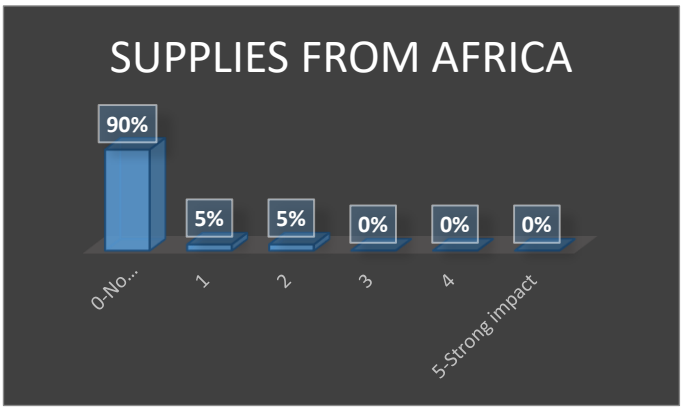
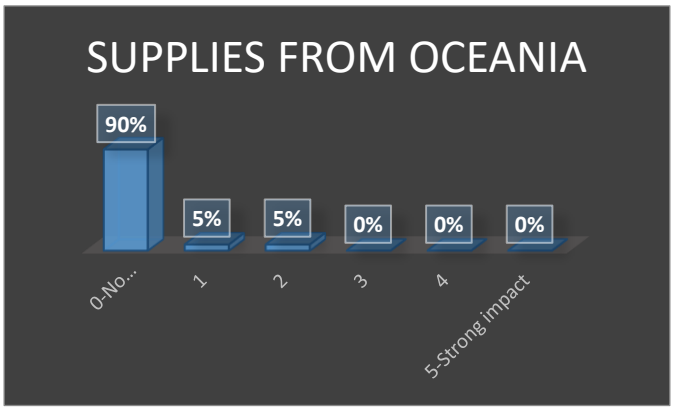


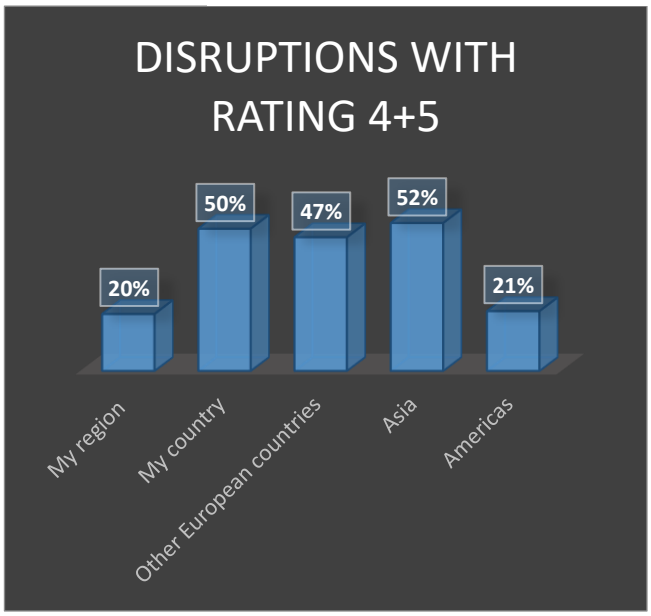
Table 28a-b | Level of impact of disruptions on supplies coming from Africa and from Oceania (n=55; source: Author)

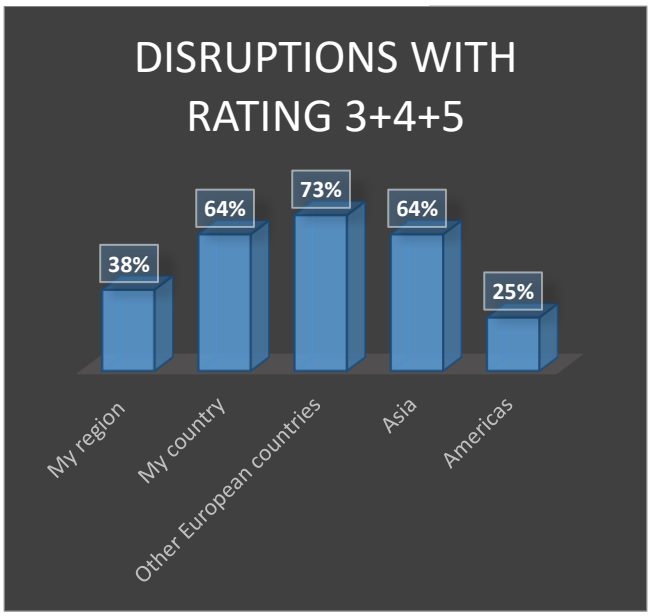




A direct comparison focused on the **highest impact ratings** (answers "ratings 4 + 5") and **high+very high ratings** (answers "ratings 3 + 4 + 5") of the main five provenances of supplies offer the following pictures:

Table 29a-b | Comparison per provenance of disruptions (n=55; source: Author)





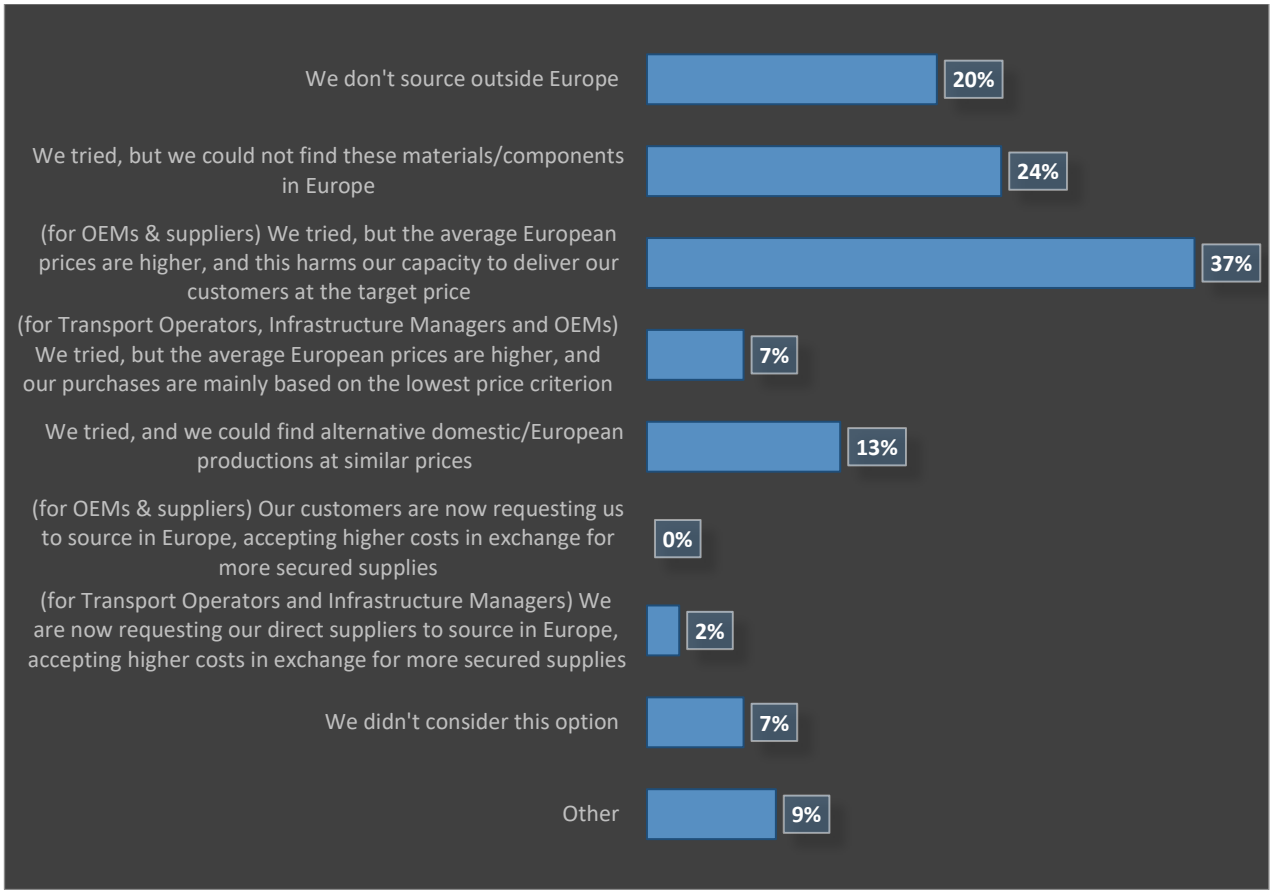
The overall picture offers the following comments:

- The surveyed companies don't source directly – if not at a minimum level (10%) – from **Africa** and **Oceania**. Despite these continents are key global producers of certain Raw Materials, it is quite evident that the surveyed companies – considering their size and the quantities needed - don't source directly from the direct producers rather from brokers in Europe.
- 38% of the surveyed companies source materials and components from **Americas**, and also these have been disrupted. It is interesting to highlight that **companies of all sizes** source – and report disruptions – from Americas.
- Also supplies **from the same region** suffered/are suffering disruptions. The overall level is quite high considering that *regionalisation of supplies* is one of the industrial actions that could be undertaken to reduce disruptions. This data probably shows ***systemic problems***, driven by the set of global crises we have been experiencing for the latest years. However, if compared to disruptions concerning supplies **from the same country**, the former perform much better.
- Supplies **from the same country** show a probably unexpected very high level of disruptions, equalling the figures **from Asia**, which expectations would have given for the highest.
- **Under a *Single Market* point of view,** supplies **from other countries in Europe** totalling the highest ranking in disruptions in the surveyed companies *is* a problem. Such fact had also been highlighted by the European Central Bank: "the main contributions to the recession [in Europe] came from domestic sources"[159]. A better functioning of the European Single Market to avoid disruptions is in the scope of the EU Industry Strategy and must also be resolved from the perspective of possible future reshoring or replacing 'made in Europe' supplies with non-EU supplies.

[159] Op. cit., European Central Bank (2023), p 92.

Related to the last comment are the next two questions posed to the surveyed companies, aiming to understand *if there is room* for 'made in EU' supplies to substitute non-EU supplies, and *under what conditions*.

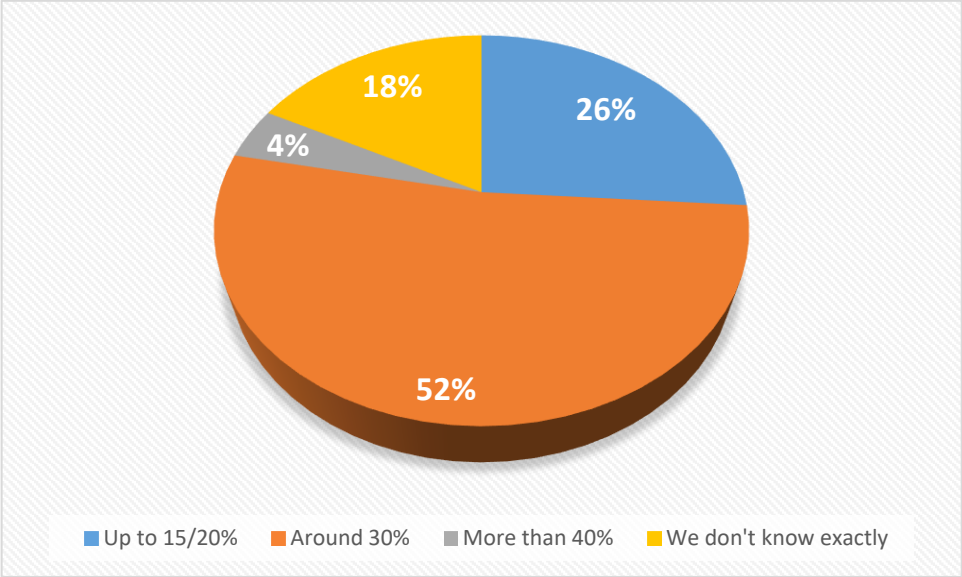
Table 30 | "Is there a potential for substitution of your extra-Europe supplies with domestic/European production, based on your experience?" (n=55; source: Author)



The respondents having selected one of the four answers referring to higher cost of European supplies were then asked to give an idea about such a difference. The options provided aimed to verify the data of the European Commission according to which "the distribution of price differences between extra-EU imports and total EU exports shows that the median price difference is 30%"[160]. For this reason also the option "We don't know exactly" was offered, to avoid the respondents 'randomly' choosing one of the three options with percentages.

[160] Op. cit., European Commission (2021a), p. 28.

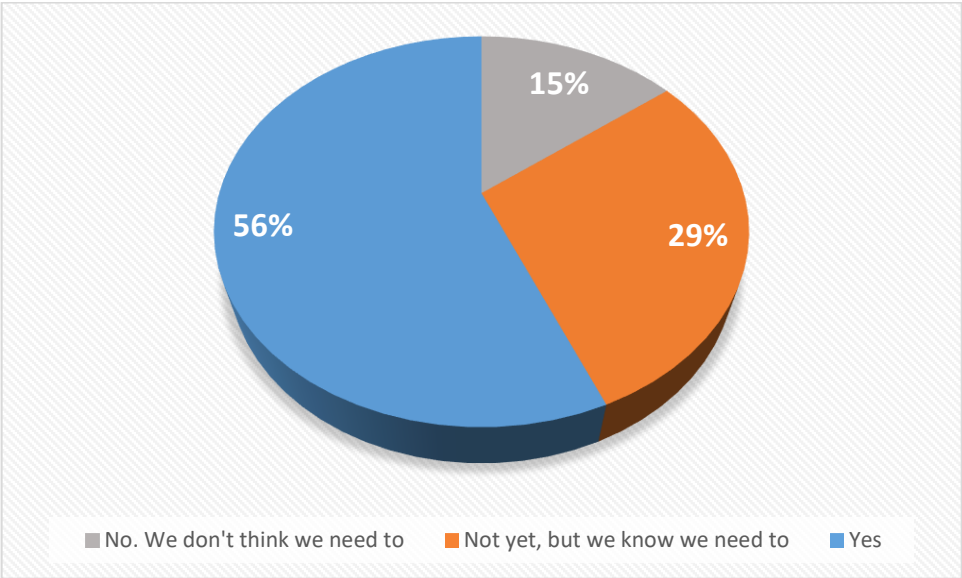
Table 31 | "How much is the average price difference between extra-Europe and European supplies you are referring to?" (n=26; source: Author)



The result confirms the European Commission data, with 52% of respondents confirming that the **average price difference is around 30%**.

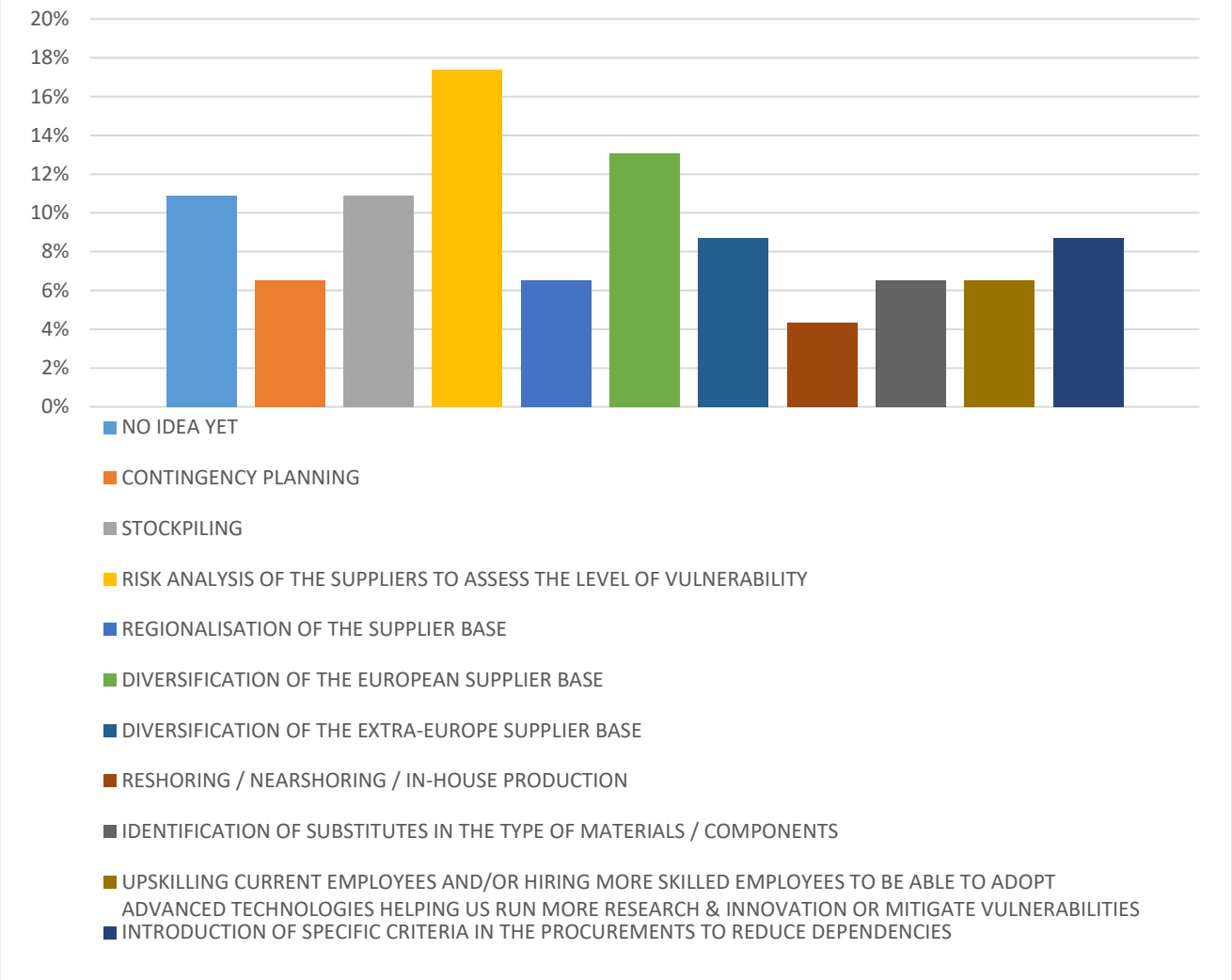
Coming to the adoption of **resilience policies**, these are the answers of respondents having suffered/suffering disruptions.

Table 32 | "Did you adopt long-term strategies to mitigate the risk of new disruptions?" (n=55; source: Author)



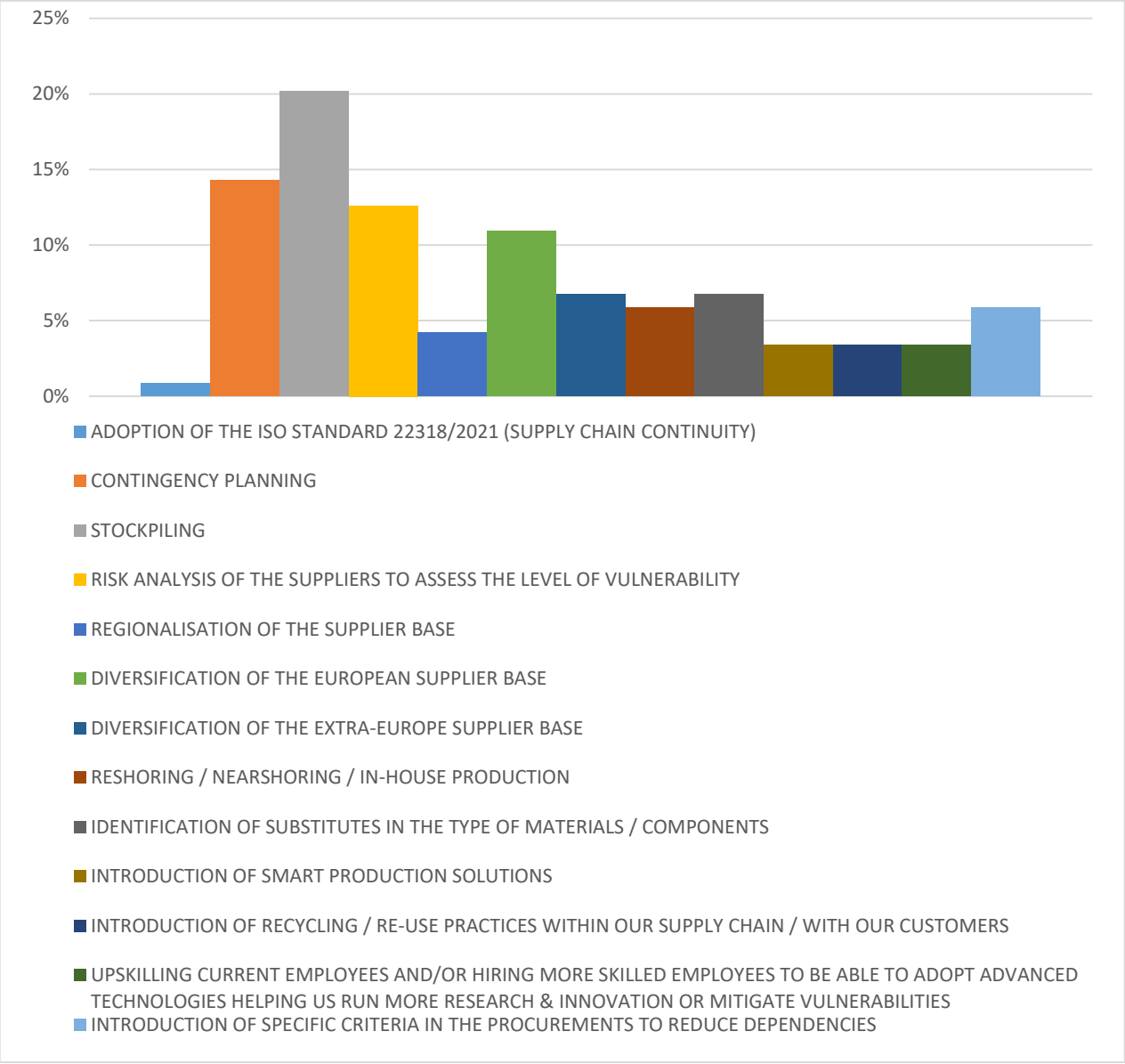
Details about the **policies** that **respondents not having any yet would adopt** shows the following results:

Table 33 | "What long-term strategies would you adopt?"
(n=16; multiple answers possible: tot=46; source: Author)



Details about the **policies already adopted by respondents** shows the following results:

Table 34 | "What long-term strategies did you adopt?"
(n=31; multiple answers possible: tot=119; source: Author)



This last Table, coupled with the answers from the respondents not having suffered any disruption (see *Table 9* | Why the companies not affected by disruptions could make it possible (n=40; multiple answers possible: tot=86; source: Author); therefore, the sample for the following calculations becomes n=40 of *Table 9* + n=31 of *Table 34*), shows that:

- **stockpiling** is the most preferred method adopted to increase resilience, corresponding to 58%. This matches the results emerged in the Desk research phase, i.e. that almost all companies have increased their inventory buffers

- **sourcing locally / regionalisation of the supplier base** represents an option chosen by 30% of the sample
- **diversification policies** are used by 51% of the sample. Also this matches resilience actions chosen by almost all companies according to the Desk research phase
- **substitution of materials / components disrupted** is used by 20%, showing a good potential for scaling up substitution policies
- **circularity policies** are used by 11%. Also this data shows a very good potential for scaling up circular business models along the Rail Value and Supply chain.

7.3. Conclusions

The surveyed European companies represent a well-balanced sample in terms of size, provenance, role in the Rail Value Chain and business segment. 58% of them suffered/is suffering disruptions, in most cases concerning both standard and innovative supplies (55%), which calls for a **first 'alert'** to be considered in the next project analysis, as this – summed to the 9% of disruptions hitting "more innovative supplies only" – is exactly the 'fear' behind the EU-RAIL call funding this project.

Disruptions are mainly supply-related (87% of respondents reported them with high+very high impact); the main ones concern Raw Materials (with iron, aluminium and copper the most hit), followed by Processed Materials (all steel types, composites and aluminium-based alloys the most hit) and Components (Electronic components of all types by far the most disrupted, however followed by a broad range of components related to rolling stock, signalling and communication systems, infrastructure); Assemblies are the least disrupted.
The demand forecasts for 2030 of aluminium, copper and electronic components of all types – to name some – represent the **second big alert** to be considered in the next project analysis, as global demand will soar for these supplies, which are already suffering disruptions.

Disruptions concerning Economic/Financial aspects are the second most important problem suffered by the Rail Value Chain (71% of respondents reported them with high+very high impact), followed by Logistics (increased costs and delays) and by Manufacturing-related disruptions (both with 58% of respondents reporting them with high+very high impact). While the first and the last go beyond the key focus and objective of the project, Logistics is strictly related to supply chain management and will be further analysed in the next project studies. In such a view, a **third big alert** to be considered in the assessment of future Rail supply vulnerabilities is the frequency of logistic disruptions with global impact. The surveyed companies source in large majority also from outside Europe, hence the likelihood that this type of disruptions will continue to impact them is very high.

Given that major disruptions in supplies however concerned sourcing from own country and from inside Europe, a **fourth big alert** – and indication for action – concerns the need to 'reconstruct'/connect as much as possible European value chains. Such a role is strongly

embedded in the DNA and operational modalities of cluster organisations, therefore project exploitation activities will also include activities in this sense.
Demand-driven disruptions exist (35% of respondents reported them with high+very high impact) and represent a **fifth alert** about disruptions that could affect the Rail supply industry as result of the upcoming innovation-driven transformations in the Railway sector. The main reason for such disruptions was in fact *change in the products/services requested*.

The low substitution potential of many supplies and the price gap between substitutable supplies 'made outside the EU' vs 'made in the EU' (worth of an average +30%) represents a **sixth alert** to be considered in identifying possible policy and industrial mitigation/solution strategies the project will have to work on, such as boosting circularity along the Value Chains or fostering the adoption of criteria in customers' procurements/purchases rewarding the 'made in EU'. In fact, in the background remains the risk that the deployment of all the (macroeconomic) policies and actions useful and necessary to increase the autonomy and resilience of European supplies in the years to come will be frustrated by the (microeconomic) policies and actions of the firms that determine the supply and demand for those supplies. Supply chain policies that continue to focus on the lowest price, moreover in parallel with the demand to source - however - from reliable suppliers, run the risk of appearing like 'having your cake and eating it'. This is a **seventh alert** to be considered. A crucial work should be done for bringing such considerations into the Procurement process of Public Buyers such as the State Railways, first, and as a beneficial consequence this would go all along the value chain purchases. Some EU policies and tools are already there to avoid the 'misuse' of lowest price criterium (see the several guides and best practices to boost use of the MEAT-Most Economic Advantageous Tender principle[161]) and of the awarding procurements under such a criterium to foreign-influenced companies receiving hidden State Aids (see the recent EU Foreign Subsidies Regulation[162]). Strategic considerations to make the best use of this and other tools to enable the best performances for the target users while helping EU industry long-term resilience should be done at Value Chain level.

The companies with resilience policies in place (both the ones not having suffered any disruption and those affected) are the huge majority (75%) of the surveyed companies. On average, more than one policy is adopted by each company, this showing that to mitigate *different* types of disruptions produced by *different* types of crises, companies need to put in place a set of solutions. For example, stockpiling is a good practice to reduce (i) risks of scarcity due to wars (because productions are suspended) or inbound logistics bottlenecks (whatever their reason), as well as (ii) risks of high fluctuations in prices (analysing the price trends and global trends, one can decide to buy larger stocks when prices are lower). However, the participants' answers also show a major attention to diversification of supplies both inside and outside Europe, for redundancy reasons. Stockpiling and diversification/duplication of suppliers, however, are both

[161] For the Rail Value Chain, see e.g. CER-EIM-UNIFE (2019), *Recommendation to apply the Most Economically Advantageous Tender (MEAT) & Good practices in the domain of railway procurement*; EFCA (2019), *Introducing quality criteria in public procurements*, with application to engineering services, contractors and architects. Also, for its general part, see Dor V, Musschebroeck Y (2020), *Guidance on Economic Most Advantageous Procurement of Innovative Solutions*, EURIPHI project (Horizon 2020 CSA).
[162] Foreign Subsidies Regulation - European Commission (europa.eu).

expensive choices: this raises an **eighth alert** concerning the economic sustainability of such policies in the long-term. Companies may think of them as *temporary* practices, but we are living in times in which crises follow one another *continuously*. The logistical one that had driven freight costs to unbelievable figures has recently ended, and another one is starting up again as a 'side effect' of the war between Israel and Hamas, with Yemeni Houti rebels attacking with missiles and drones cargo ships in transit to the Suez Canal, resulting in cargo ships from Asia to circumnavigate Africa, which means +14 days of travel, thus increasing transport costs and delivery times to Europe[163]. While this is happening due to a *war*, *climate change* is creating the drought that more than halved the operations at the Panama Canal, forcing vessels to circumnavigate South America or to pay 'crazy' costs at the Canal's auctions 'to jump the queue' (now worth 4 million dollars per slot on average)[164]. Such drought has become 'typical' from December to March/April each year, but climate change is worsening the situation and the dry seasons started two months earlier this year. The impact on delays and higher shipping costs - that will be passed on to customers – is there to stay...
So, if all this is becoming *non temporary*, companies need to make the most of Advanced technologies such as Internet of Things (IoT), Big Data analytics, Artificial Intelligence (AI), Robotics etc. to reduce the increased costs for stocks and supply management.
According to a survey by Reuters-JLL[165], the supply chain technologies necessary to understand and predict supply chain behaviour and disruptions ranking high for investment in 2024 are:

- **Supply chain monitoring, tracking and visibility solutions** - 68%
- **Forecasting** - 48%
- **Process automation** - 47%
- **Facility automation and robotics** - 37%
- **Analytics** - 37%.

The companies of the European Rail Supply industry should definitely include these as policies for resilience. As seen in the LEADER 2030 survey, in fact, the size doesn't help in resilience (large industrial leaders, smaller Tiers and start-ups are on average equally impacted) and invest on this **to achieve an optimised balance between *resilient-only* and *lean-only* status** should be a must for all companies.

Overall, the results from the LEADER 2030 survey confirm the trends emerged from the Desk research, which offered not only general data but also data concerning companies operating in the "Mobility-Transport-Automotive" European industrial ecosystem. Among the trends confirmed there is that **size doesn't count** to avoid disruptions, as the crises hitting Global Value Chains are nowadays not only 'endemic' as likelihood but also systemic as severity.

[163] See Hassan M (2023), "The Suez Canal is being attacked by the Houthis by default", *Middle East Monitor*, 27 December, and Eavis P (2023), "Shipping Giant Maersk Is Returning to the Red Sea After Houthi Attacks", *The New York Times*, 27 December.
[164] See Liao R and Bloomberg (2023), "Panama Canal has gotten so dry and backed up after brutal drought that shippers are paying up to $4m to jump the queue", *Fortune*, 4 December.
[165] Hadvick A, Ruegheimer V, Illi R, Graham L (2023), "The state of European Supply Chains 2023", *Reuters Events-JLL*, 2 March.

8. General conclusions and next steps

All the previous Sections draw a picture showing that the ongoing industrial transformations, driven by the Twin Digital and Green Transitions and other global mega-trends, will need a radical boost in the European supply capacity. Many of the fundamental production inputs to make Europe digital, green and fit for the future, have in fact already shown a very high vulnerability level due to structural dependencies or 'temporary' disruptions, and the disruptions risk grows to the nth power *if* …specific policies and industrial decisions are not adopted or are not able to deliver their promises; …the geopolitical situation worsens; …protectionism prevails on multilateralism; etc. etc..

Railway digitalisation and the transformation driven by EU-RAIL Plans for 2030 are part of this complex picture.

At the end of this study, what we know already is that *some* key supplies for digitalising, greening and innovating European Railways will require raw materials and components whose supply is already disrupted and whose demand is expected to at least double by 2030: it is the case for chips, which will be at the core of everything, expected to double between 2022 and 2030, with significant increases in future demand for leading-edge semiconductor technologies; it is the case for aluminium, expected to multiply more than 4 times by 2030, and copper, expected to multiply 8 times by 2030.

The next project step will then be:

- to study in detail *what specific* raw materials and components will be required by the *specific* innovative solutions that EU-RAIL plans to bring to the market by 2030 through its projects
- to study *what specifically* the European supply capacity of such components and raw materials will be
- to study *what* elements will impact on such supply capacity (enablers, obstacles)
- to study *how* enablers can be further boosted, and obstacles can be fixed/mitigated to foster autonomy and resilience
- to study *what* will go out from the Rail supply chain in terms of demand in 2030, and (i) *whether* this can be used to free-up components and raw materials useful to the new innovations (ii) *how* to support the reconversion (total/partial) of affected companies
- to understand *how* to get the Rail supply industry ready for 2030 demand, with specific attention to SMEs and start-ups
- to propose/recommend policy-level actions and industrial-level actions as result of all the intelligence analysis made during the project, to foster the *actual* achievement of EU-RAIL vision for a radically transformed European Railway system by 2030.

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