

[D5.3] Key drivers and disruptions by ecosystem

IDEALIST

3 INDUSTRIAL ECOSYSTEMS TACKLING SUPPLY CHAINS
DISRUPTIONS AND BOOSTING ADVANCED TECHNOLOGIES UPTAKE

DELIVERABLE INFORMATION

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Executive Summary

Funded under the HORIZON-CL4-2023-RESILIENCE-01 call, IDEALIST represents a consortium of 14 partners from across 7 European countries who have come together to enhance the resilience and technological adaptability of SMEs within the European Union.

This deliverable entitled D5.3 Key drivers and disruptions by ecosystem is linked to WP5 Beyond Strategic Foresight and discusses the process and outcomes of task T5.3 Horizon Scanning with the focus groups. The goal of D5.3 was to identify the most influential forces of change as well as current and future disruptions in the supply chains for each of the 3 IDEALIST industrial ecosystems. This deliverable synthesises the output of the online, collective intelligence gathering process, in which members of IDEALIST industrial clusters performed Horizon Scanning and sense-making activities.

1. Introduction

1.1. Project overview

IDEALIST stands for “3 InDustrial Ecosystems tAckLing supply chains dISrupTions and boosting advanced technologies uptake”. This ambitious initiative seeks to address the urgent challenges faced by SMEs in the Energy-Intensive Industries, Aerospace & Defence, and Mobility, Transport & Automotive sectors, promoting resilience, sustainable practices, and advanced technological adoption in the face of global disruptions such as the COVID-19 pandemic and geopolitical conflicts.

IDEALIST's core mission is to empower SMEs within these crucial industrial ecosystems to not only anticipate and withstand unexpected global challenges but also to emerge stronger and more competitive. This core part of the project is aimed at identifying supply chain disruptions and opportunities for the uptake of advanced technologies.

The project is composed around the following work packages:

- WP-WP3 Project Management
- WP4 Beyond Matchmaking
- WP5 Beyond Strategic Foresight
- WP6 Beyond Technological Uptake
- WP7 Beyond Supply Chains
- WP8 Beyond Pilot Projects
- WP9-WP10 Beyond Dissemination
- WP11 Beyond Communication

In WP5, in order to increase their organisational resilience, companies targeted by the IDEALIST will be equipped with concrete foresight tools and methodology enabling them to anticipate early signals of change in their strategic environment, to envision impacts of potential disruptions and prepare for future challenges.

The ultimate goal is to empower company representatives to make better-informed decisions by transforming uncertainty into a strategic advantage, enabling them to shape the future. This will be achieved through the development of a step-by-step foresight process methodology, which will be iteratively tested and refined with company representatives throughout the project lifecycle.

1.2. Scope of work

The tasks associated with the development of a step-by-step foresight process methodology, its testing and implementation within the IDEALIST project to identify supply chain disruptions and opportunities across the three industrial ecosystems - **Energy-Intensive Industries, Aerospace & Defence, and Mobility, Transport & Automotive sectors** - are taking place within WP5 Beyond Strategic Foresight. WP5 is structured along four main tasks, as follows:

- T5.1. Foresight needs assessment and toolbox design / M1-M6
- T5.2. Training the trainers / M5-M6
- T5.3. Horizon Scanning with the focus groups / M7-M12
- T5.4 Using Horizon Scanning outcomes for decision-making / M13-M36

This deliverable discusses the process and outcomes of task T5.3 Horizon Scanning with the focus groups. The goal of D5.3 was to identify the most influential forces of change as well as current and future disruptions in the supply chains for each of the 3 IDEALIST industrial ecosystems. This deliverable synthesises the output of the online, collective intelligence gathering process, in which members of IDEALIST industrial clusters performed Horizon Scanning and sense-making activities.

1.3. IDEALIST's Horizon Scanning approach

1.3.1. Definitions

Horizon scanning supports the process of building organisational resilience and is one part of a suite of tools which can help practitioners understand and prepare for future disruptions, both risks and opportunities. The goal of Horizon Scanning is to collect relevant information about the external environment of the topic under study. The collected information usually falls into three main categories: drivers, trends and signals of change.

Since in the IDEALIST project Horizon scanning serves as the main method to identify developments that could fundamentally change or disrupt the three industrial ecosystems in unexpected ways; the focus of Horizon Scanning was on the identification of drivers and signals.

- **Drivers** are influential forces of changes that are currently shaping or have the capacity to shape or transform a given system. They can take on different states and thus affect a system in many ways, therefore are often called uncertainties.
- **Signals** are early indications that disruptive change could be underway.

In this study Focus group experts assessed each signal using two metrics:

- **Earliest Time to Mainstream (ETM)**: this measures the minimum time needed for a signal to become mainstream defined as the point of peak impact on the ecosystem. Assessments ranged from 2 to 20 years in the future.
- **Impact**: the metric describes the nature (positive or negative) and the level of the signal's estimated impact on the ecosystem, using a scale of -5 to +5.

These assessments made it possible to identify signals of change as potential **disruptors**, indicating substantial shifts within the study area. A signal is classified as a potential disruptor if

its impact receives a score below -1 or above +1. This scoring system uses negative values to represent adverse effects and positive values for beneficial effects on the industrial ecosystem. A signal with a score of -4 or lower, or +4 or higher, is categorized as a potential hyperdisruptor, indicating a potential for extreme disruption, whether positive or negative.

1.3.2. Participants of the Horizon Scanning process

The main target group of the Horizon Scanning process of IDEALIST includes the representatives of the 11 industrial clusters and associations (Fig. 1).



Figure 1. Focus groups' composition

Source: Authors

Three international, cross-cluster focus groups, each implementing the Horizon Scanning process exclusively in its ecosystem were activated with the goal to « explore the future » via Foresight and Horizon Scanning. Each Focus Group was composed of up to 15 permanent representatives of selected organisations among clusters' members, mainly SMEs. During the meetings of the Focus Groups, a series of foresight tools were introduced and activities such as disruptions and driver mapping and weak signals' impact analysis were carried out. Overall, a total of 63 participants took part in the HS activities.

1.3.3. Overview of the results of Horizon Scanning

The Horizon Scanning results presented in this report consist of two main elements described by each IDEALIST's industrial ecosystem:

A map of drivers and disruptions: This illustrates (a) the most influential driving factors currently shaping or transforming the ecosystem, and (b) the most impactful signals of change (disruptions) with the potential to reshape the ecosystem. The signals (disruptions) are situated on the map according to their alignment with a specific driving factor and their estimated time to mainstream (the point of peak impact on the ecosystem).

A deep dive into key drivers and disruptions: This section portrays each signal (disruption) on the ETM, Impact Matrix while analysing the opportunities, risks, and challenges these drivers and disruptions may create for the ecosystem.

1.3.4. How to interpret maps of drivers and disruptions

Each map visually represents the key driving forces and potential disruptions within each IDEALIST's industrial ecosystem. It's designed to provide a clear overview of the factors shaping the future of each ecosystem.

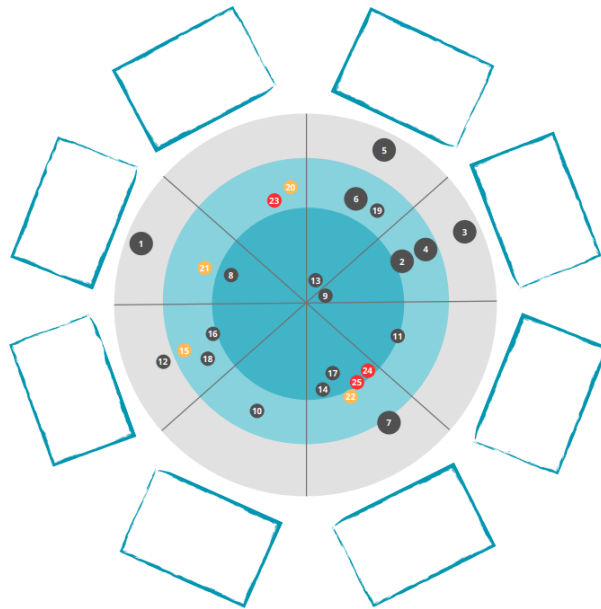
Here's how to interpret the map:

- **Driving Forces (drivers):**

The map is divided into eight segments, each representing a major driving force influencing the ecosystem's development. These forces are the overarching phenomena shaping the industry's future.

- **Signals of Change (Disruptions):**

Each segment contains colored dots representing individual disruptions or signals of change. These are specific events or early emerging trends that could significantly impact the ecosystem.



- **Impact and Timing:**

- **Color:** The color of a dot indicates its potential impact on the ecosystem:
 - Black: Positive impact
 - Yellow: Mild negative impact
 - Red: Strong negative impact
- **Size:** The size of a dot reflects the magnitude of the disruption's potential impact. Larger dots indicate a greater potential impact.
- **Position:** The position of a dot within its segment indicates the estimated timeframe for its peak impact on the ecosystem:
 - Innermost circle: 2-5 years
 - Middle circle: 6-10 years
 - Outermost circle: 11-20 years

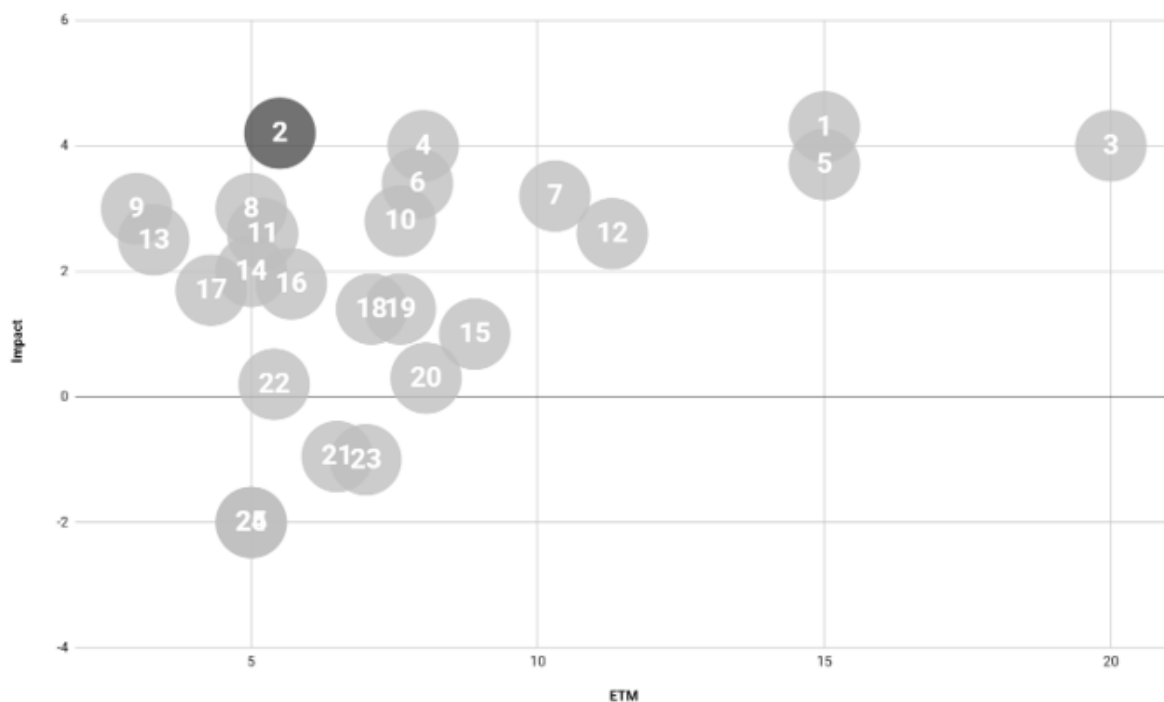
- **Positioning Logic:** Each signal is positioned on the map based on three factors:

- **Relevant Driving Force:** The signal is placed within the segment that represents the driving force it most closely aligns with.
- **Impact Level:** The size of the dot is determined by the estimated impact level of the signal, as assessed through a standardized metric.
- **Earliest Time to Mainstream (ETM):** The signal's distance from the center of the circle reflects its ETM rating, indicating how soon its impact is likely to become widespread.

1.3.5. How to interpret matrices of Impact and ETM

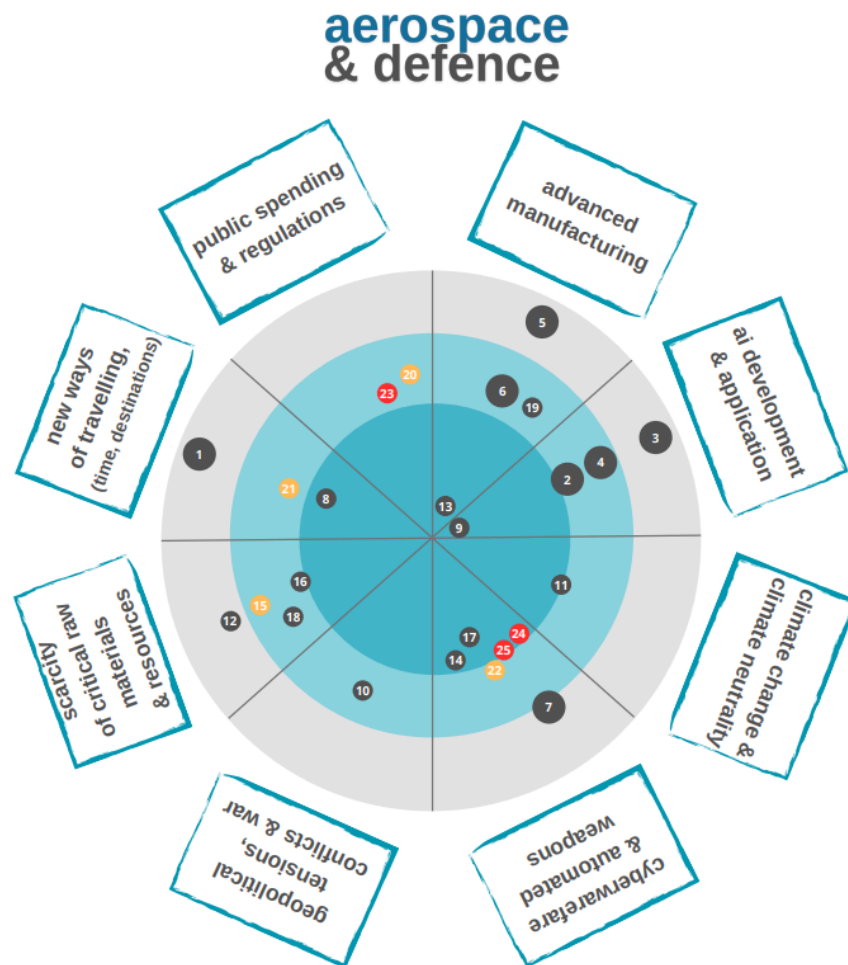
Each matrix visually represents the signals (disruptions) identified within a specific industrial ecosystem. The matrix shows the estimated strength of impact of a signal on the industry and the time (ETM), representing the earliest year when the disruption is expected to have its peak impact.

Both impact and ETM were assessed by the participants of IDEALIST's Focus Groups who took part in Horizon Scanning activities. Impact is assessed on a scale of -5 to +5, where negative values indicate a negative impact and positive values a positive impact. A signal is classified as a potential disruptor if its impact receives a score below -1 or above +1. A signal with a score of -4 or lower, or +4 or higher, is categorized as a potential hyperdisruptor, indicating a potential for extreme disruption. ETM assessments ranged from 2 to 20 years in the future.



In the above example matrix for the A&D ecosystem, the impact of signal 2 (AI in air traffic control) was estimated at 4.2. Its score of 4.2 categorizes it as a hyperdisruptor, which may positively influence the ecosystem's development. The estimated ETM is 5.5 years, which means that the signal may fully materialize by mid-2029.

2. Map of drivers and disruptions in Aerospace and Defence (A & D)



1. Supersonic jet engines, high-speed travel
2. AI- air traffic control
3. Commercialisation of passenger drones
4. AI in aviation and drones
5. Fully 3D printed large aircraft
6. Single-aisle & middle-range commercial aircraft fuselage made of 100% composite materials
7. Bionic models of drones penetrating deep into enemy controlled territories
8. Ariane 6 a technical success but needed alliances. New Space Paradigm
9. Digital twins in cockpits
10. More flexibility in production chains, more independence from China
11. Emissions as key indicator.
12. Synthetic Biology for Fuel Production
13. Additive Manufacturing (3D Printing)
14. Directed Energy Weapons (DEWs)
15. Some private companies (industrials) are shifting to other markets than commercial aviation i.e. implementing diversification strategy toward renewable energy
16. Focus on drone productions as war in Ukraine shows that it is a weapon of 21st century
17. End-users and clients are reluctant to buy products involving outsourced or rare materials
18. XaaS : everything as a service (energy, mobility, manufacturing)===> versatility, quick redeployment
19. Hydrogen fuel of the future
20. Increase of investment in defense application. Signal of need of sovereign materials and components
21. artificial intelligence (AI) in military
22. Flight shaming
23. EU defense technologies are highly dependent on non-EU countries, posing risks to strategic autonomy.
24. Cybersecurity Threats from Advanced Technologies
25. Internet of Military Things (IoMT)

3. Zooming in to examine key drivers and disruptions in A & D

The **Aerospace and Defence** ecosystem covers manufacturing companies in aeronautics, space, and defence; space operators and data and service providers; research institutes.

The sector is a significant contributor to the EU economy, with 3.92 million employees directly employed in the industry. This represents 1.99% of the EU's total value added, amounting to €241 billion. The sector comprises 3.2 million companies, with SMEs making up an overwhelming majority (99%) of this figure. This highlights the importance of small and medium-sized enterprises in driving innovation and growth within this technologically advanced sector.³

3.1. List of key drivers of A & D sector

Drivers are influential forces of changes that are currently shaping or have the capacity to shape or transform a given system. They can take on different states and thus affect a system in many ways, therefore are often called uncertainties.

A & D Focus group experts involved in the IDEALIST's Horizon Scanning identified the following key drivers of the sector: Public Spending and Regulations, Advanced Manufacturing, AI Development and Application, Cyberwarfare and Automated Weapons, Geopolitical Tensions, Conflicts, and Wars, Scarcity of Critical Raw Materials and Resources, New Ways of Travelling (Time & Destinations), Climate Change and Climate Neutrality.

3.1.1. Public Spending and Regulations

The **Public Spending and Regulations** driver of change for the European Aerospace & Defense (A&D) sector refers to the significant influence of public policy, defence budgets, and both international and national regulations on the development and operations of this sector.

- The stability and level of public funding are key drivers of growth in the A&D sector. Given the increasing geopolitical threats in Europe, countries are raising their defence budgets, leading to investments in new technologies, R&D programs, and the modernization of existing systems. Public spending enables the development of innovative solutions and technologies aimed at enhancing security and increasing defence autonomy.
- Regulations at both the EU and international levels impact safety standards, control of technology exports and imports, and production norms. The European Union aims to strengthen its position in the global market through regulations that promote collaborative projects and cooperation among member states (e.g., PESCO initiatives). At the same time, these regulations ensure sustainable development and adherence to environmental protection standards.
- EU support, such as the European Defense Fund (EDF), facilitates research projects and collaboration in developing new technologies. These initiatives aim to reduce Europe's dependence on external military technology providers and increase its strategic autonomy.
- Changes in member states' policies and potential tensions among them can affect the distribution or consolidation of defense spending and regulations. A united European defense policy plays a crucial role in the stable growth of the sector.

³ https://commission.europa.eu/system/files/2021-05/swd-annual-single-market-report-2021_en.pdf

Public Spending and Regulations will be crucial factors influencing Europe's ability to create innovative defense solutions and maintain global competitiveness. By increasing public spending and developing unified regulations, the European A&D sector stands to gain greater autonomy and agility in responding to emerging threats.

3.1.2. Advanced Manufacturing

The **Advanced Manufacturing** driver of change for the European Aerospace & Defense (A&D) sector encompasses modern production technologies that enhance efficiency, precision, and flexibility in manufacturing processes, impacting the sector's competitiveness and capacity for innovation.

- The implementation of advanced automation and robotics shortens production times and reduces costs while increasing production precision. In the A&D sector, this enables the manufacture of high-quality components that meet rigorous standards and ensure reliability under extreme conditions.
- 3D printing allows for the creation of lightweight, durable parts with complex geometries, essential for aerospace and military structures. Additive manufacturing enables rapid prototyping and customization of production to meet specific operational needs, shortening the time to market for new solutions.
- Advanced data analytics, supported by AI, optimizes production processes, identifies potential defects, and facilitates predictive maintenance. In A&D, this contributes to operational efficiency and enhances product safety and quality.
- There is a growing emphasis on manufacturing technologies that reduce resource and energy consumption and limit emissions, aligning with European climate goals. Sustainable production is particularly significant in A&D, where reducing environmental impact is prioritised without compromising quality and efficiency.
- Integrating IoT technology into manufacturing processes enables real-time monitoring and management of equipment, increasing production transparency and allowing for rapid response to any deviations from standard.

Advanced Manufacturing will be a crucial factor influencing the capabilities of the European A&D sector, enhancing its flexibility and ability to adapt to the rapidly changing demands of the market. With these modern production technologies, the A&D sector can achieve greater independence and responsiveness, which is essential in the face of increasing geopolitical and technological challenges.

3.1.3. AI Development and Application

The **AI Development and Application in General Aviation** driver of change for the European Aerospace & Defense (A&D) sector highlights the transformative potential of artificial intelligence in enhancing safety, efficiency, and adaptability within general aviation, from small aircraft operations to air traffic management.

- AI enables the development of autonomous flight capabilities and advanced pilot assistance systems, reducing pilot workload and supporting safer decision-making, particularly in adverse conditions. These systems enhance safety by providing predictive insights and automated responses to in-flight situations, making general aviation more accessible and reliable.

- AI-driven predictive maintenance tools allow for real-time analysis of aircraft health, reducing unexpected downtime and maintenance costs. By identifying potential issues before they arise, AI improves aircraft reliability and efficiency, optimising the operational lifecycle and cost-effectiveness of fleets in general aviation.
- AI-based air traffic management systems facilitate the safe and efficient coordination of increasingly crowded airspaces. AI enhances collision avoidance systems by processing vast amounts of data quickly, reducing the risk of mid-air incidents, and improving the safety of low-altitude and urban air mobility, especially with the growth of unmanned aerial vehicles (UAVs).
- AI-powered simulation and training platforms provide customised learning experiences for pilots, adapting to individual skill levels and learning speeds. This approach not only reduces training costs but also improves pilot readiness and adaptability by simulating complex scenarios and real-time responses.
- AI supports sustainability goals in aviation by optimising fuel consumption, flight paths, and environmental impact monitoring. By dynamically adjusting routes and energy use, AI contributes to greener aviation practices and aligns with European climate objectives for the aviation sector.

AI Development and Application in General Aviation will be a pivotal factor in advancing safety, accessibility, and sustainability within European aviation. Through enhanced autonomy, efficient maintenance, and innovative training solutions, AI not only bolsters the competitiveness of general aviation but also supports Europe's overarching goals of technological leadership and environmental responsibility.

3.1.4. Cyberwarfare and Automated Weapons

The **Cyberwarfare and Automated Weapons** driver of change for the European Aerospace & Defense (A&D) sector reflects the increasing role of cyber capabilities and automated weapon systems in shaping defense strategies and operational frameworks, with profound implications for security, ethics, and international stability.

- Automated weapons and drones, capable of identifying and engaging targets independently, are becoming crucial tools in modern warfare. These systems enhance battlefield efficiency by reducing response times and enabling precision strikes, while also raising ethical and legal considerations regarding decision-making in lethal operations.
- As military systems become more connected, cyber vulnerabilities increase, making cybersecurity a critical focus. Cyber defense capabilities are essential to protect A&D infrastructure and ensure resilience against cyber-attacks. Conversely, offensive cyber capabilities can disrupt enemy operations by targeting critical infrastructure or communications systems, marking a shift toward non-physical modes of warfare.
- Cyberwarfare tools enable sophisticated monitoring and intelligence gathering, providing real-time insights into adversarial activities. Enhanced reconnaissance capabilities are fundamental in identifying and neutralizing potential threats early, contributing to a more proactive defense stance in complex conflict scenarios.
- Artificial intelligence aids in processing vast amounts of data, offering real-time situational awareness and decision-making support. These systems provide military leaders with rapid insights and predictive analytics, enhancing command and control capabilities, especially in high-stakes, fast-evolving scenarios.

- The proliferation of automated and cyber-enabled weapons demands robust regulatory and ethical frameworks at both the national and international levels. Europe is at the forefront of these discussions, aiming to establish standards that mitigate risks associated with autonomy in warfare, uphold human rights, and reduce the potential for unintended escalation.

Cyberwarfare and Automated Weapons will be transformative forces for the European A&D sector, redefining defense strategies and operational dynamics. By investing in cyber capabilities and automated systems, Europe can strengthen its strategic resilience and deterrence capabilities. However, these advancements also necessitate careful consideration of ethical implications and the establishment of regulatory safeguards to ensure that technological progress in warfare aligns with European values of human rights and global stability.

3.1.5. Geopolitical Tensions, Conflicts, and Wars

The **Geopolitical Tensions, Conflicts, and Wars** driver of change for the European Aerospace & Defense (A&D) sector underscores the influence of global power struggles, regional conflicts, and rising defense demands on the sector's priorities, investments, and innovations.

- Heightened geopolitical tensions often lead governments to expand defense budgets and prioritize military modernization. This increase in funding supports the development of advanced technologies and the acquisition of new systems, such as cyber defense tools, autonomous weaponry, and next-generation aircraft, which are essential for maintaining strategic capabilities.
- In response to evolving security threats, European nations are strengthening alliances and fostering collaborative defense initiatives, such as PESCO and NATO partnerships. These collaborations aim to enhance interoperability and resource-sharing, allowing member states to respond more effectively to threats and ensure collective defense across the continent.
- Geopolitical instability has underscored the importance of resilient supply chains, especially for critical defense materials and technologies. Europe is increasingly focused on reducing dependency on external suppliers, fostering local innovation, and building a self-sufficient defense manufacturing base to secure supply chains against potential disruptions.
- Regional conflicts and instability lead to increased investments in border security, surveillance, and reconnaissance technologies. These systems, often enhanced by AI and advanced sensor capabilities, enable continuous monitoring and quick response to cross-border threats, migration flows, and illegal trafficking, contributing to regional stability.
- Conflicts today often involve hybrid warfare tactics, combining traditional military force with cyber attacks, disinformation, and economic disruption. Preparing for such threats requires the A&D sector to develop robust cybersecurity measures and hybrid warfare response capabilities, allowing Europe to protect critical infrastructure and mitigate non-conventional attacks.

Geopolitical Tensions, Conflicts, and Wars will continue to shape the European A&D sector, driving demand for advanced defense capabilities and self-reliant supply chains. By investing in cutting-edge technologies and strengthening defense alliances, Europe aims to secure its strategic position in an increasingly unpredictable global landscape. The sector will play a vital role in enhancing Europe's readiness for diverse threats while advancing collaborative efforts to foster stability and security across the region.

3.1.6. Scarcity of Critical Raw Materials and Resources

The **Scarcity of Critical Raw Materials and Resources** driver of change for the European Aerospace & Defense (A&D) sector highlights the impact of limited access to essential materials on production, supply chains, and strategic planning. This scarcity influences resource management, innovation, and policy decisions aimed at ensuring sustainable and resilient defense capabilities.

- The limited availability of critical materials, such as rare earth elements, metals, and composites essential for advanced aerospace and defense technologies, exposes the sector to supply chain disruptions. As a response, Europe is focusing on building strategic stockpiles and identifying alternative suppliers to reduce dependency on geopolitically unstable regions.
- The scarcity of essential materials is driving research into alternative materials and recycling technologies. These innovations aim to substitute critical raw materials with more accessible options or to reuse materials from decommissioned systems, thus reducing the demand for scarce resources and enhancing sustainability in production.
- To improve resource security, Europe is investing in the exploration and development of local resources. Expanding regional extraction and refining capabilities, especially for materials such as lithium, cobalt, and rare earth elements, aims to strengthen Europe's autonomy in the supply of materials crucial for defense manufacturing.
- Given the high energy demands in A&D production, the scarcity of resources also drives the adoption of energy-efficient manufacturing processes and conservation technologies. By minimizing energy use and waste, the sector can mitigate the environmental and financial impact of limited resources and align with Europe's sustainability goals.
- European nations and industries are increasingly collaborating to address resource scarcity through shared strategies, policies, and standards. The European Union's initiatives on raw material security focus on creating a coordinated approach to securing resources, promoting responsible sourcing, and fostering alliances with non-European resource-rich countries.

The Scarcity of Critical Raw Materials and Resources will significantly impact the European A&D sector by shaping the supply chain, fostering innovation in materials, and promoting sustainable practices. Addressing resource scarcity is essential for maintaining production stability and strategic autonomy. Through resource-efficient technologies, local sourcing efforts, and collaborative policies, the A&D sector can secure a reliable supply of critical materials and support Europe's long-term resilience in defense capabilities.

3.1.7. New Ways of Travelling (Time & Destinations)

The **New Ways of Travelling (Time & Destinations)** driver of change for the European Aerospace & Defense (A&D) sector reflects the transformative potential of emerging transportation concepts and technologies, which redefine travel efficiency, reach new destinations, and reshape global connectivity.

- The development of hypersonic and supersonic transportation offers the potential for ultra-fast travel, significantly reducing flight times for long-distance routes. These advancements would allow both military and civilian aircraft to operate at unprecedented speeds, creating possibilities for rapid-response missions, as well as for reducing travel times for commercial passengers.
- The expansion of commercial space tourism and potential orbital travel marks a new frontier in destinations. Aerospace companies are investing in spaceflight technology to enable trips to low-Earth orbit and beyond, paving the way for a new class of travel experiences and expanding the commercial market into outer space, with possible implications for military and scientific missions.
- Urban air mobility solutions, including Electric Vertical Take-Off and Landing Vehicles (eVTOLs), aim to create faster, more flexible travel within cities and metropolitan regions. This new mode of transportation could help reduce urban congestion, improve accessibility, and serve as a rapid-response tool for medical or security needs, providing versatile applications in both civilian and defense contexts.

New Ways of Travelling (Time, Destinations) will profoundly impact the European A&D sector by advancing fast, sustainable, and accessible travel options. Through innovations in high-speed travel, urban air mobility, and environmentally responsible aviation, Europe can redefine global connectivity and lead in the development of advanced, eco-friendly transportation solutions. As travel needs and expectations evolve, the A&D sector will play a critical role in creating the infrastructure and technologies that support new modes of transport, reinforcing Europe's strategic presence in the global aviation landscape.

3.1.8. Climate Change and Climate Neutrality

The Climate Change and Climate Neutrality driver of change for the European Aerospace & Defense (A&D) sector underscores the growing urgency to mitigate the environmental impact of defense activities and transition towards sustainable practices. This driver influences technological innovation, operational strategies, and policy decisions aimed at reducing greenhouse gas emissions, adapting to climate-related risks, and contributing to Europe's climate neutrality goals.

The A&D sector is a significant contributor to greenhouse gas emissions, primarily due to aircraft operations and energy-intensive manufacturing processes. To address this, the industry is actively developing and implementing sustainable aviation fuels (SAFs), exploring electric and hybrid aircraft propulsion systems, and optimizing flight operations to minimize fuel consumption and emissions.

Climate change poses operational challenges for the A&D sector, including increased turbulence, extreme weather events, and rising sea levels that can affect infrastructure and operations. As a response, the sector is investing in climate-resilient infrastructure, developing early warning

systems for extreme weather events, and adapting training and operational procedures to ensure mission effectiveness in a changing climate.

The drive towards climate neutrality is stimulating innovation in the A&D sector. This includes research into lightweight materials and advanced manufacturing processes to reduce the environmental footprint of production, as well as the development of renewable energy sources to power military bases and support operations.

3.2. List of key disruptions A & D

A & D Focus group experts involved in the IDEALISTss Horizon Scanning identified key signals that will shape the future of the sector. **Signals** are early indications that disruptive change could be underway.

Experts assessed each signal using two metrics:

- **Earliest Time to Mainstream (ETM):** this measures the minimum time needed for a signal to become mainstream defined as the point of peak impact on the ecosystem. Assessments ranged from 2 to 20 years in the future.
- **Impact** describes the nature (positive or negative) and the level of the signal's estimated impact on the ecosystem, using a scale of -5 to +5.

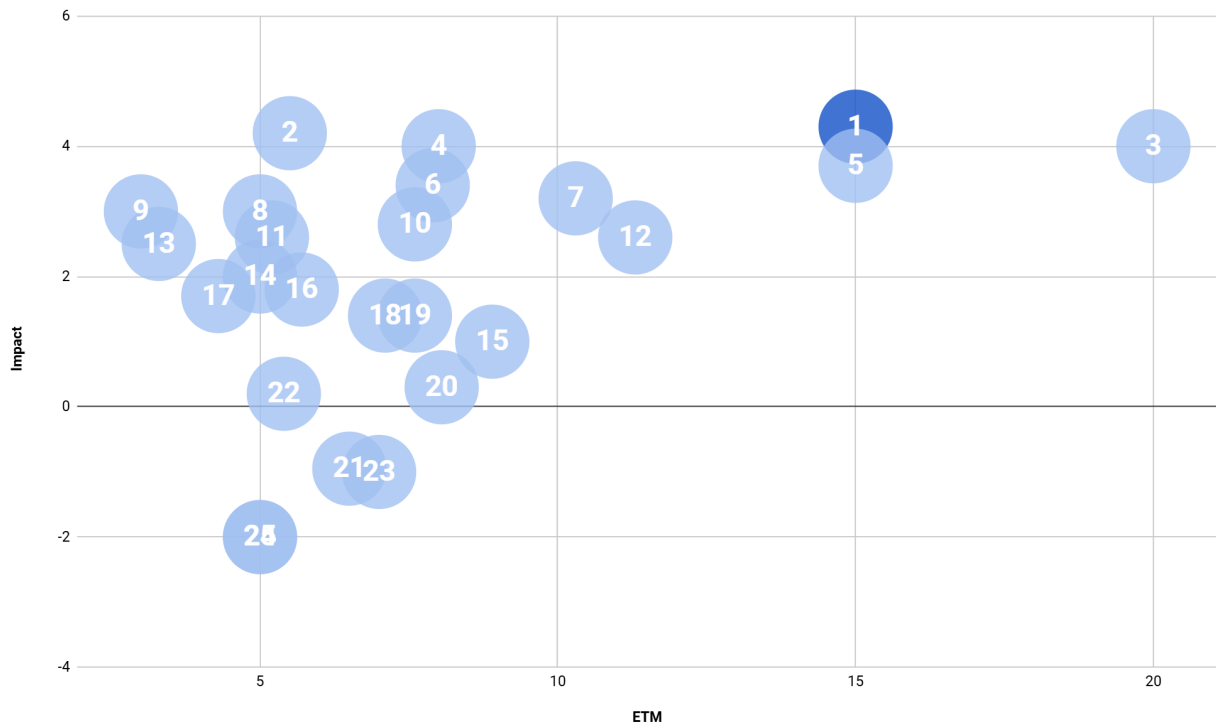
These assessments made it possible to identify signals of change as potential **disruptors**, indicating substantial shifts within the study area. A signal is classified as a potential disruptor if its impact receives a score below -1 or above +1. This scoring system uses negative values to represent adverse effects and positive values for beneficial effects on the industrial ecosystem. A signal with a score of -4 or lower, or +4 or higher, is categorized as a potential hyperdisruptor, indicating a potential for extreme disruption, whether positive or negative.

3.2.1. Signal 1: Supersonic jet engines and high-speed travel⁴

Innovative jet engine systems and advanced propulsion technologies enabling commercial supersonic and high-speed travel, representing a potential revival of faster-than-sound passenger transportation. These developments incorporate new materials, noise reduction technologies, and enhanced fuel efficiency to address previous limitations of supersonic flight.

3.2.1.1. ETM, IMPACT Matrix

⁴ Source: <https://mae.ucf.edu/a-new-type-of-jet-engine-could-revive-supersonic-air-travel/>

Figure 2. Impact and ETM analysis of Supersonic jet engines and high-speed travel in Aerospace & Defence.

The impact of signal 1 (Supersonic jet engines and high-speed travel) was estimated at 4.3. Its score of 4.3 categorizes it as a hyperdisruptor, which may positively influence the ecosystem's development. The estimated ETM is 15 years, which means that the signal may fully materialize by 2039.

3.2.1.2. How can it change our optics?

- It shifts attention towards a renewed era of supersonic commercial aviation, emphasizing the balance between speed and sustainability
- It underlines the importance of innovation in aerospace engineering and propulsion technology, particularly in noise reduction and fuel efficiency
- It brings a new element to the discussion about the future of long-distance travel and globalization, considering environmental impact
- It facilitates understanding of potential changes in aviation industry competition, including new market entrants and business models
- It highlights the need for updated regulatory frameworks to address supersonic flight over populated areas
- It draws attention to the intersection of luxury travel and environmental responsibility

3.2.1.3. How can it change the ecosystem?

- Drives innovation in multiple technical domains: Advanced materials science for heat-resistant components; Aerodynamics optimization for reduced sonic boom; Noise reduction technologies for community acceptance; Fuel efficiency improvements for economic viability;

- Transforms long-distance travel infrastructure requirements: Modified airport facilities for supersonic aircraft; New maintenance and service capabilities[Specialized training programs for crews;
- Creates new market segments and business models: Premium high-speed travel services; Specialized aircraft maintenance and support; Technology licensing and partnerships;
- Environmental considerations become central to design: Fuel efficiency optimization; Noise pollution mitigation; High-altitude emissions management.

3.2.1.4. What opportunities does the signal carry for the ecosystem?

- Reduced travel times enabling new business models and market opportunities
- Increased connectivity between distant global markets
- Development of new technical capabilities and expertise
- Creation of high-skilled jobs in advanced engineering
- Potential for technology spillover into other sectors
- New revenue streams from premium travel services
- International collaboration opportunities in R&D
- Development of sustainable aviation technologies

3.2.1.5. What risks does the signal carry for the ecosystem?

- Noise pollution affecting communities near flight paths.
- Higher environmental impact compared to subsonic aircraft:
 - Increased fuel consumption
 - Higher-altitude emissions
 - Greater carbon footprint
- Cost and accessibility creating market segregation.
- Regulatory challenges and potential restrictions.
- Public resistance to noise and environmental impacts
- Investment risks in unproven technology
- Competition from alternative transport modes
- Market volatility affecting premium travel demand

3.2.1.6. What challenges does the signal carry for the ecosystem?

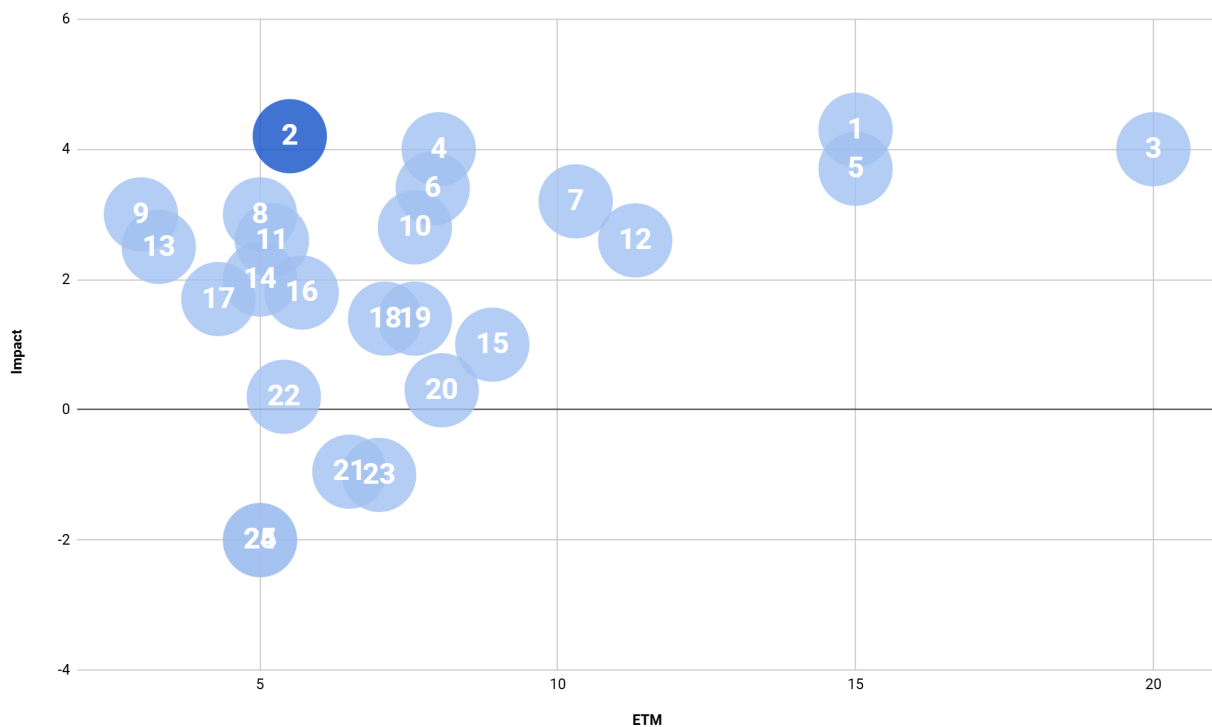
- Technical challenges: Noise reduction to acceptable levels; Fuel efficiency improvement; Emissions reduction; Materials durability and longevity
- Regulatory challenges: Certification requirements; Flight path restrictions; Environmental compliance
- Market challenges: Cost management; Customer acceptance; Infrastructure development; Competition with established travel modes
- Skills and workforce: Training requirements; Expertise development; Knowledge transfer

3.2.2. Signal 2: AI in air traffic control⁵

AI-powered air traffic control refers to the use of artificial intelligence and machine learning technologies to enhance the safety, efficiency, and capacity of air traffic management systems. This can involve using AI to optimize flight routes, predict and manage air traffic flow, assist air traffic controllers in decision-making, and automate certain tasks. By leveraging AI's ability to analyze vast amounts of data and identify patterns, AI-powered air traffic control aims to improve airspace utilization, reduce delays, and enhance the overall safety and efficiency of air travel.

3.2.2.1. ETM, IMPACT Matrix

Figure 3. Impact and ETM Analysis of AI in air traffic control in Aerospace & Defence.



The impact of signal 2 (AI in air traffic control) was estimated at 4.2. Its score of 4.2 categorizes it as a hyperdisruptor, which may positively influence the ecosystem's development. The estimated ETM is 5.5 years, which means that the signal may fully materialize by mid-2029.

3.2.2.2. How can it change our optics?

- Shifts perception of air traffic control from a primarily human-operated system to a human-AI collaborative environment
- Emphasizes the critical role of data-driven decision-making in aviation safety
- Highlights the evolution from reactive to predictive traffic management
- Demonstrates the potential for AI to handle increasing air traffic complexity
- Shows how technology can enhance rather than replace human expertise
- Illustrates the importance of system resilience and redundancy in critical infrastructure
- Underscores the need for continuous learning and adaptation in aviation systems

⁵ Source: <https://www.careeraroo.com/magazine/the-role-of-ai-in-future-air-traffic-management/>

3.2.2.3. How can it change the ecosystem?

- AI-powered air traffic control will drive innovation in areas such as machine learning, data analytics, and aviation communication systems.
- AI can improve the efficiency of air traffic management, reducing delays and fuel consumption, which can lead to cost savings for airlines and passengers.
- AI can enhance the safety and efficiency of air travel.
- AI can reduce fuel consumption and greenhouse gas emissions from aviation.

3.2.2.4. What opportunities does the signal carry for the ecosystem?

- Enhanced Safety through: Predictive risk assessment, automated conflict detection, real-time weather adaptation, and reduced human error.
- Increased Efficiency: Optimized flight paths, reduced fuel consumption, better capacity utilization, and fewer delays.
- Operational Improvements: Lower controller workload, improved decision support, enhanced situational awareness, and better emergency response.
- Economic Gains: Cost savings, increased airspace capacity, new technology markets, and reduced operational costs.

3.2.2.5. What risks does the signal carry for the ecosystem?

- Technical risks: System reliability concerns; Integration challenges; Data quality issues; Software vulnerabilities
- Security risks: Cybersecurity threats; Data privacy concerns; System manipulation potential; Communication interference
- Operational risks: Over-reliance on automation; Skill degradation; System failure impacts; Transition period challenges
- Human factors: Resistance to change; Training challenges[Trust in automation; Job security concerns

3.2.2.6. What challenges does the signal carry for the ecosystem?

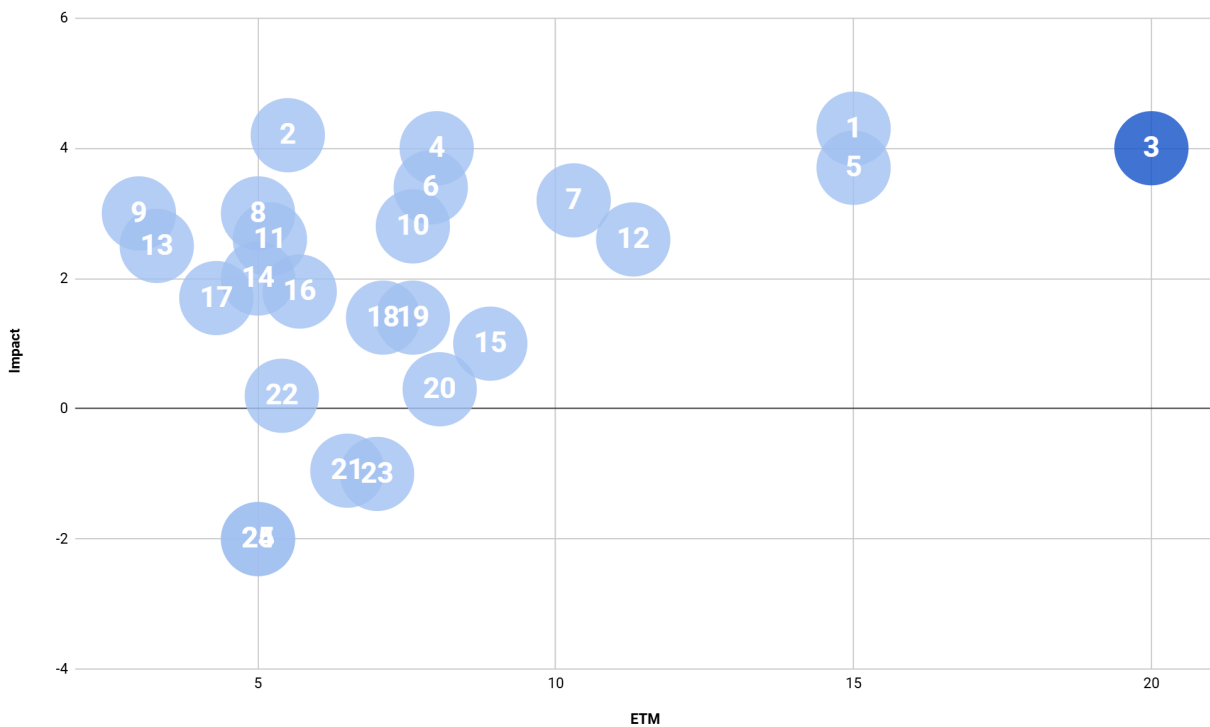
- Technical challenges: Data quality and availability; System integration complexity; Real-time processing requirements; Performance validation
- Regulatory challenges: Certification requirements; Safety standards adaptation; International harmonization; Liability frameworks
- Implementation challenges: Infrastructure updates; Training requirements; Change management; Cost management
- Human-AI interface: Interface design; Role definition; Trust building; Workflow optimization

3.2.3. Signal 3: Commercialisation of passenger drones⁶

The emergence of electric vertical takeoff and landing (eVTOL) aircraft and autonomous aerial vehicles designed for passenger transportation, representing a new category of urban air mobility. These passenger drones combine advanced automation, electric propulsion, and innovative design to offer point-to-point transportation, potentially revolutionizing urban and regional mobility while creating new patterns of air traffic.

3.2.3.1. ETM, IMPACT Matrix

Figure 4. Impact and ETM Analysis of Commercialisation of passenger drones in Aerospace & Defence.



The impact of signal 3 (Commercialisation of passenger drones) was estimated at 4.0. Its score of 4.0 categorizes it as a hyperdisruptor, which may positively influence the ecosystem's development. The estimated ETM is 20 years, which means that the signal may fully materialize by mid-2044.

3.2.3.2. How can it change our optics?

- Transforms our understanding of urban mobility and transportation infrastructure
- Shifts focus from ground-based to three-dimensional urban transportation planning
- Highlights the convergence of aviation and urban planning disciplines
- Creates new perspectives on personal air transportation accessibility
- Raises questions about the democratization of air travel
- Changes perceptions of commuting distances and urban sprawl
- Emphasizes the role of autonomous systems in daily transportation

⁶ Source: <https://www2.deloitte.com/us/en/insights/focus/future-of-mobility/passenger-drones-flying-cars.html>

3.2.3.3. How can it change the ecosystem?

Infrastructure development:

- Vertiport networks
- Charging stations
- Air traffic management systems
- Maintenance facilities

Technology advancement:

- Battery technology
- Autonomous systems
- Safety mechanisms
- Noise reduction solutions

Market structure:

- New service providers
- Novel business models
- Changed competition dynamics
- Integration with existing transport

Urban planning:

- 3D transportation networks
- Landing site integration
- Noise management zones
- Emergency response systems

3.2.3.4. What opportunities does the signal carry for the ecosystem?

Transportation efficiency:

- Reduced travel times
- Decreased congestion
- New route options
- Better connectivity

Economic growth:

- New business models
- Job creation
- Technology development
- Market expansion

Urban development:

- Enhanced mobility options
- Reduced ground infrastructure pressure
- New urban planning possibilities
- Regional connectivity

Environmental benefits:

- Electric propulsion adoption
- Reduced ground traffic
- Lower emissions per passenger-mile
- Optimized routes

3.2.3.5. What risks does the signal carry for the ecosystem?

Safety concerns:

- System reliability
- Weather vulnerability
- Collision risks
- Emergency procedures

Environmental impacts:

- Noise pollution
- Visual pollution
- Wildlife disruption
- Energy consumption

Social issues:

- Privacy concerns
- Public acceptance
- Equity of access
- Community impact

Market risks:

- Investment uncertainty
- Technology limitations
- Regulatory barriers
- Competition issues

3.2.3.6. What challenges does the signal carry for the ecosystem?

Technical challenges:

- Battery technology limitations
- Range optimization
- Noise reduction
- Safety systems development
- Weather resistance

Infrastructure challenges:

- Vertiport development
- Power grid integration
- Navigation systems
- Maintenance networks

Regulatory challenges:

- Safety certification
- Air traffic integration
- Noise regulations
- Insurance frameworks

Social challenges:

- Public acceptance
- Privacy protection
- Noise management
- Community integration

Economic challenges:

- Initial investment costs
- Operating costs
- Market development
- Business model viability

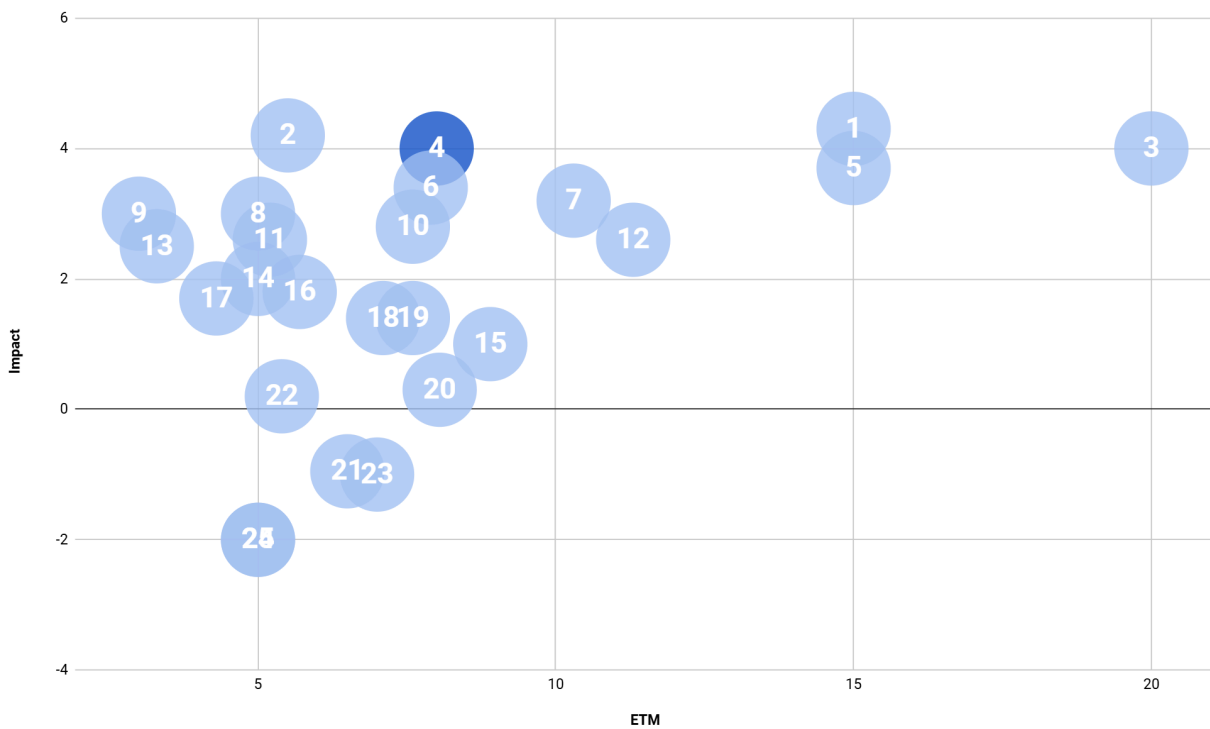
3.2.4. Signal 4: AI applications in aviation and drones⁷

Integration of artificial intelligence across aerospace and defense applications, including flight operations, maintenance, mission planning, and autonomous systems. This encompasses machine learning algorithms for predictive maintenance, AI-powered flight assistance, autonomous drone operations, and intelligent mission support systems, fundamentally transforming both civilian and military aviation capabilities.

⁷ Source: <https://www.easa.europa.eu/pl/light/topics/artificial-intelligence-and-aviation-0> and <https://dron.edu.pl/drony-a-sztuczna-inteligencja-rozwoj-algorytmow-ai/>

3.2.4.1. ETM, IMPACT Matrix

Figure 5. Impact and ETM Analysis of AI applications in aviation and drones in Aerospace & Defence.



The impact of signal 4 (AI applications in aviation and drones) was estimated at 4.0. Its score of 4.0 categorizes it as a hyperdisruptor, which may positively influence the ecosystem's development. The estimated ETM is 8 years, which means that the signal may fully materialize by mid-2032.

3.2.4.2. How can it change our optics?

Artificial intelligence can support the crew by advising on routine tasks to increase the operational efficiency of the flight. It can anticipate problems such as turbulence and icing conditions and help pilots make decisions when conflicts arise. By analyzing data on weather patterns, sector configurations, air traffic congestion and other factors, artificial intelligence could help optimize flight paths, reduce flight times, fuel consumption and costs. Such optimization would then lead to a more efficient air traffic management system, reduced delays and increased air travel capacity.

Applications based on artificial intelligence and machine learning (ML) could also help air traffic controllers make more informed and faster decisions in the face of conflict.

3.2.4.3. How can it change the ecosystem?

On the air operations side, artificial intelligence can help detect foreign object fragments on runways and illegal drones (e.g., drones) around airports, as well as assist in preventing bird collisions.

Inside the airport terminal, artificial intelligence can help with security screening, dangerous goods detection and surveillance.

3.2.4.4. What opportunities does the signal carry for the ecosystem?

- Development of new defense capabilities through autonomous systems
- Enhanced aircraft performance through AI-optimized operations
- Improved maintenance efficiency reducing aircraft downtime
- New revenue streams from AI-based services and solutions
- Competitive advantage through early AI adoption
- Export opportunities for AI-enabled aerospace systems

3.2.4.5. What risks does the signal carry for the ecosystem?

- Dependence on AI suppliers outside the traditional aerospace supply chain
- Vulnerability to AI-specific cyber threats
- Loss of traditional aerospace expertise as focus shifts to software
- International restrictions on AI technology transfer
- Ethical concerns limiting military AI applications
- Competition from tech companies entering the aerospace sector

3.2.4.6. What challenges does the signal carry for the ecosystem?

- Certification of AI systems for safety-critical applications
- Integration of AI with legacy aerospace systems
- Development of aerospace-specific AI expertise
- Protection of sensitive data used in AI training
- Standardization of AI applications across the industry
- Balancing automation with human control in critical operations

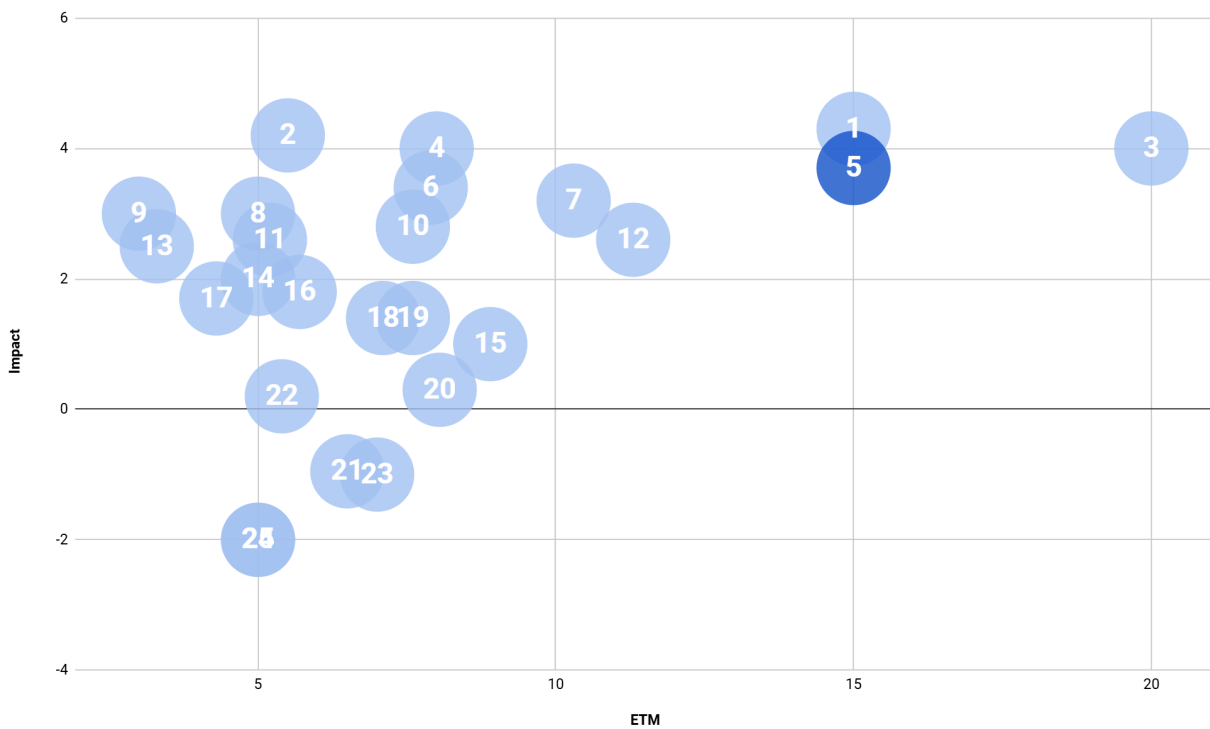
3.2.5. Signal 5: Fully 3D printed large aircraft⁸

Manufacturing of an airplane takes place in a fully automatic process using robotics & autonomous 3D printers, which are connected and work synchronously & asynchronously. 3D printers are able to print large components.

⁸ Source: <https://3dprint.com/137389/airbus-thor-3d-printed-plane/>

3.2.5.1. ETM, IMPACT Matrix

Figure 6. Impact and ETM Analysis of Fully 3D printed large aircraft in Aerospace & Defence.



The impact of signal 5 (Fully 3D printed large aircraft) was estimated at 3.7. Its score of 3.7 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 15 years, which means that the signal may fully materialize by mid-2039.

3.2.5.2. How can it change our optics?

- Transforms perception of aircraft manufacturing from assembly to integrated printing
- Shifts focus from component suppliers to digital design and material science
- Changes view of production facilities from sprawling assembly lines to compact printing centers
- Highlights importance of digital design validation over physical prototyping
- Emphasizes material optimization over traditional manufacturing constraints

3.2.5.3. How can it change the ecosystem?

- Less local transportation is needed.
- Centralised production
- Energy supply might be a challenge
- Production site should be localised near the airports
- Initial problems with quantity of products (materials, CAD designs)
- Less tools needed, everything is replaced by robots and additive manufacturing process
- Engineering paradigm shift
- More human supervisors needed

3.2.5.4. What opportunities does the signal carry for the ecosystem?

- Significant reduction in manufacturing waste
- Faster prototype-to-production transition
- Design freedom for performance optimization
- Lower inventory and storage costs
- Rapid production scaling capability
- Local production feasibility for remote locations
- Quick adaptation to design modifications

3.2.5.5. What risks does the signal carry for the ecosystem?

- High initial capital investment requirements
- Displacement of traditional component manufacturers
- Dependence on limited material suppliers
- Quality certification challenges for printed parts
- Intellectual property protection in digital designs
- Potential job losses in traditional manufacturing
- Flight safety

3.2.5.6. What challenges does the signal carry for the ecosystem?

- Development of aerospace-grade printing materials
- Certification of printed components for flight
- Energy supply for large-scale printing operations
- Training workforce for additive manufacturing
- Integration with existing production systems
- Quality consistency across printed components
- Scale-up of printing technology for large parts

3.2.6. Signal 6: Composite materials in single-aisle & middle-range aircraft fuselage⁹

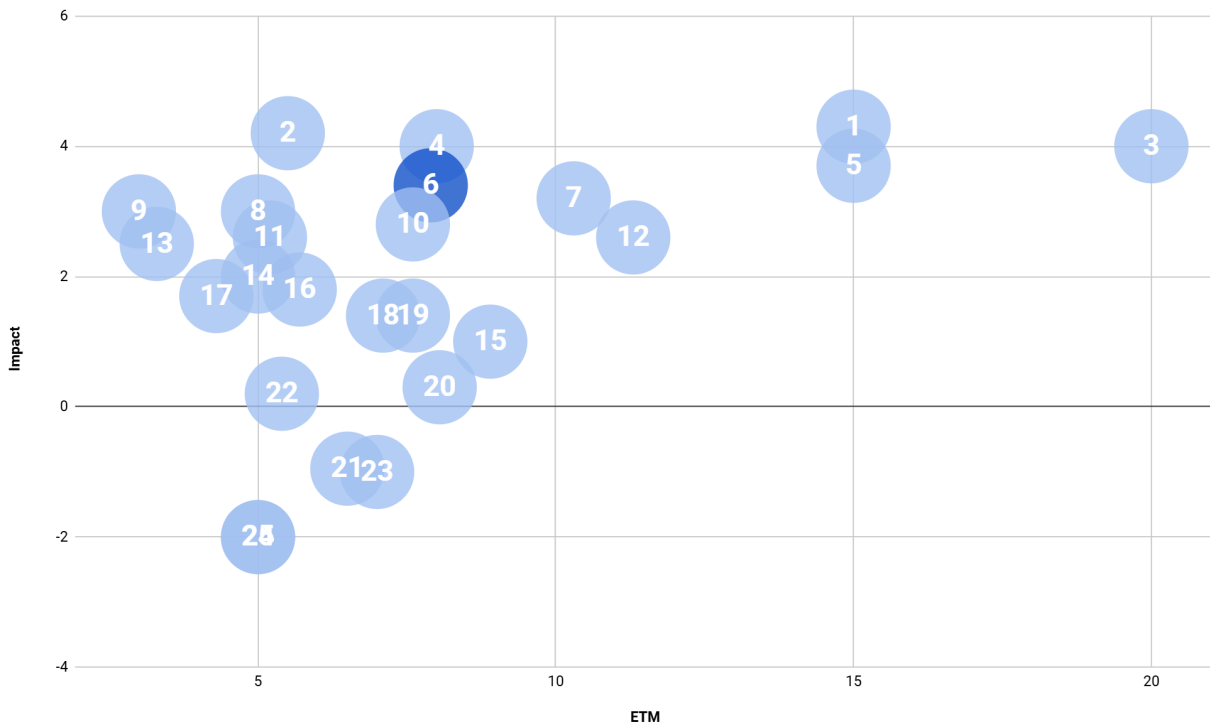
Currently, about 10% of aircraft materials consist of composites, with future designs potentially incorporating up to 60%. This shift could significantly impact the ecosystem, as increased composite use reduces weight, leading to improved fuel efficiency and lower emissions. Interestingly, while composites offer these energy advantages, their manufacturing lead times remain longer than those of traditional materials, posing a challenge for mass production. Despite this, the environmental and operational benefits of composites—particularly in large-scale manufacturing—represent a noteworthy and somewhat unexpected shift, as such extensive use of composites has been rare in mass-produced applications.

⁹ Source:

<https://www.compositesworld.com/articles/the-next-generation-single-aisle-implications-for-the-composites-industry>

3.2.6.1. ETM, IMPACT Matrix

Figure 7. Impact and ETM Analysis of Composite materials in single-aisle & middle-range aircraft fuselage in Aerospace & Defence.



The impact of signal 6 (Composite materials in single-aisle & middle-range aircraft fuselage) was estimated at 3.4. Its score of 3.4 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 7.9 years, which means that the signal may fully materialize by mid-2031.

3.2.6.2. How can it change our optics?

- Shifts industry focus from metallic to composite manufacturing expertise
- Changes perception of production efficiency from speed to material performance
- Highlights importance of specialized manufacturing capabilities
- Emphasizes long-term operational benefits over production speed
- Creates new perspective on supply chain strategic importance

3.2.6.3. How can it change the ecosystem?

The potential shift would have profound implications for raw materials suppliers and manufacturers of basic components. If confirmed, it would be highly disruptive, as many new factories would need to be built. Traditional manufacturers relying on metallic processes would be forced to transition to composite materials, necessitating significant investments in new manufacturing equipment and infrastructure. Not all existing players would have the capacity to adapt to these changes. This challenge is particularly pressing for industrial SMEs in Europe, which are often ill-equipped to handle such disruptions.

3.2.6.4. What opportunities does the signal carry for the ecosystem?

- Growth potential for composite specialists
- Development of new manufacturing technologies
- Creation of specialized composites workforce
- Export opportunities for composite expertise
- New material development possibilities
- Enhanced aircraft performance capabilities
- Reduced aircraft operating costs

3.2.6.5. What risks does the signal carry for the ecosystem?

It would signify heavy investments in manufacturing equipment and buildings. Some current players would not be capable of such an adaptation. For example, in Europe not many players are strong enough to raise 400M€ of investment to build new factories.

3.2.6.6. What challenges does the signal carry for the ecosystem?

- Raising funds for investment.
- Shifting mindsets and fostering innovation.
- Merging companies or collaborating.
- Implementing automation, optimizing tooling, and utilizing greener or functionalized materials to improve current manufacturing processes and move towards mass production.

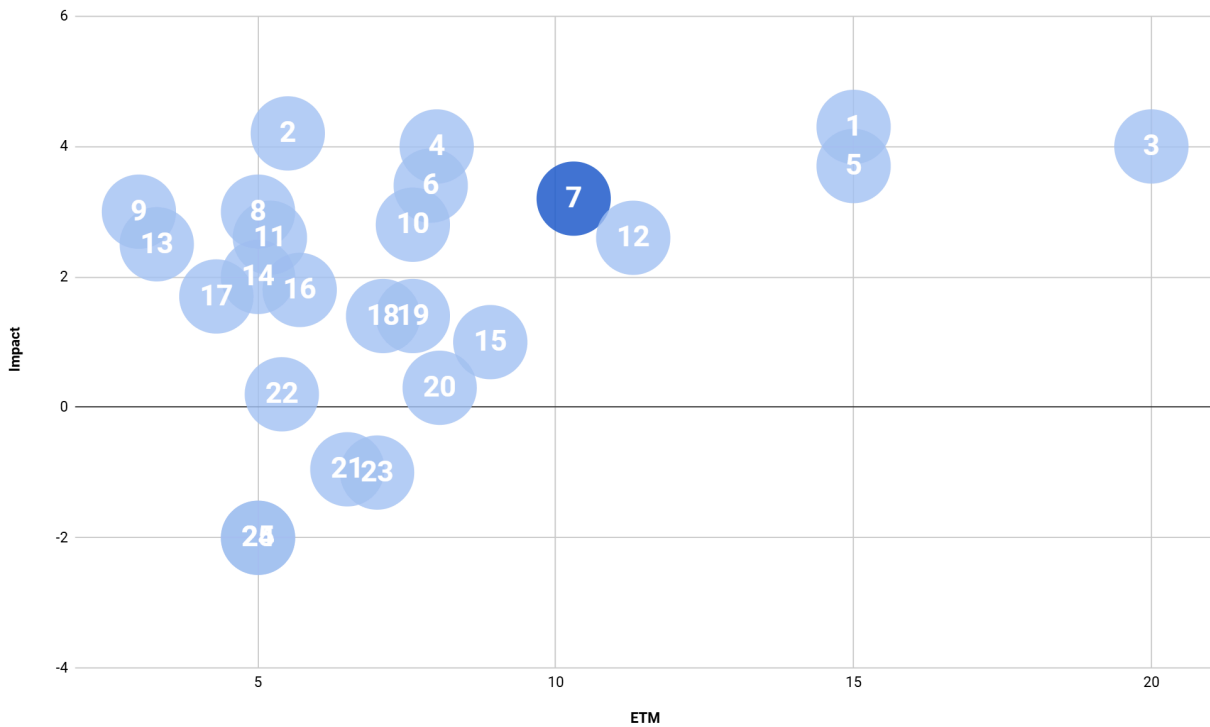
3.2.7. Signal 7: Bionic drones for deep penetration missions¹⁰

Bionic drones, inspired by the flight mechanisms of birds and insects, represent a new generation of unmanned aerial vehicles (UAVs) designed for stealth, manoeuvrability, and extended flight endurance. These drones mimic the aerodynamic principles and flight patterns of natural creatures, allowing them to penetrate deep into enemy-controlled territories for reconnaissance, surveillance, and potentially even offensive operations. Their ability to blend in with natural surroundings and navigate complex environments makes them a valuable asset for gathering intelligence and conducting covert missions.

¹⁰ Source: <https://www.cfr.org/article/how-drone-war-ukraine-transforming-conflict>

3.2.7.1. ETM, IMPACT Matrix

Figure 8. Impact and ETM Analysis of Bionic drones for deep penetration missions in Aerospace & Defence.



The impact of signal 7 (Bionic drones for deep penetration missions) was estimated at 3.2. Its score of 3.2 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 10.3 years, which means that the signal may fully materialize by mid-2034.

3.2.7.2. How can it change our optics?

- It shifts attention towards the potential for biomimicry to revolutionise drone technology.
- It underlines the importance of stealth and maneuverability in modern warfare
- It brings a new element to the discussion about the ethics and implications of autonomous weapons systems.
- It facilitates the understanding of a potential change in the balance of power in aerial warfare.

3.2.7.3. How can it change the ecosystem?

- Bionic drones drive innovation in areas such as aerodynamics, materials science, artificial intelligence, and sensor technology.
- The use of bionic drones in warfare raises ethical concerns about the potential for increased surveillance, autonomous decision-making, and the blurring of lines between human and machine control in combat.

3.2.7.4. What opportunities does the signal carry for the ecosystem?

- Bionic drones can penetrate deep into enemy territory undetected, providing valuable intelligence and situational awareness.
- Improved surveillance and reconnaissance
- Increased operational efficiency reducing the need for human intervention and potentially minimizing risks to personnel.
- The development of bionic drones can drive innovation in aerospace engineering, materials science, and artificial intelligence.

3.2.7.5. What risks does the signal carry for the ecosystem?

- Ethical concerns about accountability, proportionality, and the potential for unintended harm.
- Proliferation and misuse could destabilise regional conflicts and increase the risk of misuse by non-state actors or rogue states.
- Arms race, potentially leading to increased military spending and tensions.

3.2.7.6. What challenges does the signal carry for the ecosystem?

- Technological challenges related to miniaturisation, flight endurance, and autonomous navigation
- Ethical and legal frameworks
- Countermeasures and defence will be crucial to protect against their potential misuse.
- International cooperation and arms control agreements may be necessary to prevent the proliferation and misuse of bionic drone technology.

3.2.8. Signal 8: Ariane 6: technical success and need for alliances. New Space Paradigm¹¹

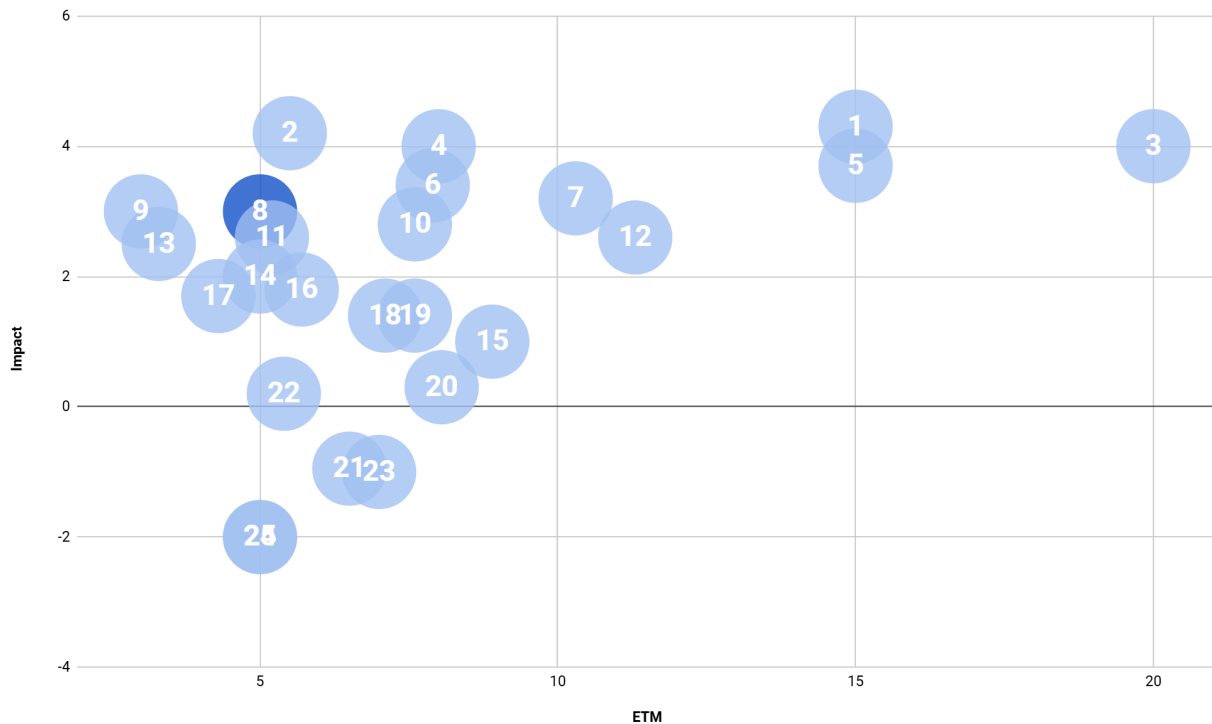
Despite Ariane 6's technical achievements, the space industry faces a paradigm shift where traditional 'Old Space' business models are challenged by 'New Space' approaches. This transition highlights the need for strategic alliances, agile development, and new business models in the European space sector, particularly affecting major players like Airbus Space Division.

¹¹ Source:

<https://www.theglobeandmail.com/business/article-airbus-to-restructure-space-systems-as-consolidation-talks-continue/>

3.2.8.1. ETM, IMPACT Matrix

Figure 9. Impact and ETM Analysis of Ariane 6: technical success and need for alliances. New Space Paradigm in Aerospace & Defence.



The impact of signal 8 (Ariane 6: technical success and need for alliances; New Space Paradigm) was estimated at 3. Its score of 3 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 5 years, which means that the signal may fully materialize by mid-2029.

3.2.8.2. How can it change our optics?

- Shifts perception from government-led to commercial-driven space ventures
- Changes view of space projects from long-term to rapid development cycles
- Emphasizes importance of failure tolerance in innovation process
- Highlights need for workshop and production reconfigurability
- Demonstrates value of commercial partnerships over sole-source contracts
- Shows importance of cost-effectiveness over technical perfection

3.2.8.3. How can it change the ecosystem?

The rise of commercial space ventures, exemplified by the Ariane 6 and the "New Space" paradigm, is poised to transform the European A&D ecosystem. Historically, space development has centered on large, government-funded projects characterized by long lead times and high costs. In contrast, the commercial space sector prioritizes agility, efficiency, and cost-effectiveness, driven by market-based incentives rather than governmental timelines.

While traditionally dominated by government agencies, the emergence of European original equipment manufacturers (OEMs) will necessitate a shift towards agility, efficiency, and

collaborative partnerships to succeed in this dynamic market. This means embracing new business models, investing in R&D, and forging alliances with startups and SMEs to ensure competitiveness and a prominent role for Europe in the evolving space industry.

3.2.8.4. What opportunities does the signal carry for the ecosystem?

Achieving flexibility in manufacturing while maintaining stringent part quality standards presents a pivotal opportunity in the commercial space sector. Controlling the manufacturing process is essential for meeting these standards, especially as OEMs and their partners navigate the challenges of rapid production scaling and market demands. Leveraging technological advancements offers several pathways to ensure component quality while potentially streamlining traditionally lengthy certification processes. Here are some key opportunities:

- **Automation and Precision Control:** Using automation technologies like robotics and advanced CNC machines can improve precision and consistency in parts production, reducing errors and defects.
- **Digital Twins and Simulation:** Digital twin technology allows for virtual testing and optimization of the manufacturing process, identifying potential issues early on.
- **Additive Manufacturing:** 3D printing offers flexibility for producing complex parts quickly, enabling rapid prototyping and potentially faster certification.
- **Advanced Quality Assurance:** Non-destructive testing and in-line inspection technologies can streamline quality assurance and catch defects early in the production process.
- **Machine Learning:** Machine learning can predict potential quality issues and optimize maintenance schedules to ensure consistent production quality.
- **Streamlined Certification:** Advanced tracking and digital documentation can significantly reduce certification times.
- **Collaborative Platforms:** Cloud-based platforms facilitate the sharing of quality standards and real-time feedback across the supply chain.

3.2.8.5. What risks does the signal carry for the ecosystem?

- Loss of traditional space expertise
- Increased competition from global players
- Reduced government funding stability
- Market oversaturation in launch services
- Technology transfer to competitors
- Loss of European strategic autonomy
- Investment uncertainty

3.2.8.6. What challenges does the signal carry for the ecosystem?

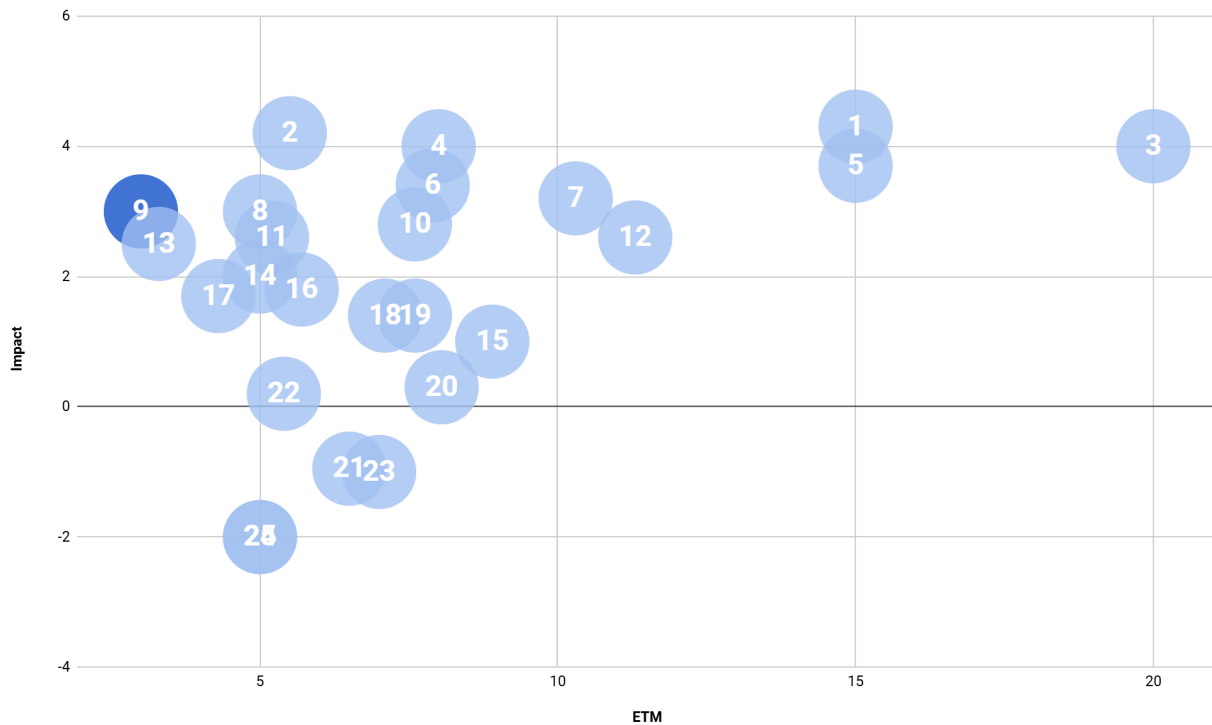
- Balancing quality control with rapid development
- Managing certification processes efficiently
- Developing cost-competitive solutions
- Building effective industry partnerships
- Maintaining European space sovereignty
- Adapting to commercial market demands
- Securing stable funding sources
- Training workforce for new paradigm

3.2.9. Signal 9: Digital twins in cockpits¹²

Implementation of digital twin technology in aircraft cockpits, creating virtual replicas of physical aircraft systems for real-time monitoring, predictive analysis, and enhanced decision support. These digital replicas integrate with flight systems to provide advanced safety features, performance optimization, and predictive maintenance capabilities.

3.2.9.1. ETM, IMPACT Matrix

Figure 10. Impact and ETM Analysis of Digital twins in cockpits in Aerospace & Defence.



The impact of signal 9 (Digital twins in cockpits) was estimated at 3.0. Its score of 3.0 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 3 years, which means that the signal may fully materialize by mid-2027.

3.2.9.2. How can it change our optics?

- It underlines the importance of Artificial Intelligence
- Shifts cockpit design focus from physical to digital interfaces
- Changes perception of pilot role from operator to systems manager
- Emphasizes predictive over reactive flight operations
- Highlights integration of virtual and physical aircraft systems
- Demonstrates evolution of aviation safety through digital technology

3.2.9.3. How can it change the ecosystem?

- This is particularly important for improving the safety of travellers.

¹² Source:

<https://www.economist.com/science-and-technology/digital-twins-in-cockpits-will-help-planes-look-after-themselves/21809110>

- Transforms aircraft system monitoring and maintenance approaches
- Creates new requirements for cockpit system suppliers
- Develops new standards for digital system certification
- Changes pilot training requirements and methods
- Establishes new cybersecurity priorities for cockpit systems
- Affects aircraft certification processes

3.2.9.4. What opportunities does the signal carry for the ecosystem?

- Enhanced safety: predict potential issues, assist in decision-making.
- Digital twins can improve fuel efficiency, reduce operating costs, and minimize aircraft downtime.
- Realistic flight simulations and training scenarios
- Data and insights from digital twins can inform aircraft design and development
- New revenue streams from digital services
- Advanced troubleshooting capabilities
- Enhanced flight data analysis
- Improved aircraft design feedback loops

3.2.9.5. What risks does the signal carry for the ecosystem?

- Overreliance on digital twins could potentially reduce pilots' situational awareness and decision-making skills in unexpected situations.
- Digital twins rely on data and connectivity, making them vulnerable to cyberattacks that could compromise flight safety.
- The collection and use of data from digital twins raise privacy concerns that need to be addressed to ensure responsible and ethical use of this technology.

3.2.9.6. What challenges does the signal carry for the ecosystem?

- Data integration and accuracy
- Designing intuitive and user-friendly interfaces for pilots to interact with digital twins
- Cybersecurity
- Regulatory framework
- Real-time data processing capabilities
- Digital twin accuracy validation
- Cross-platform compatibility
- Pilot acceptance and adaptation
- Legacy system integration
- International standardization

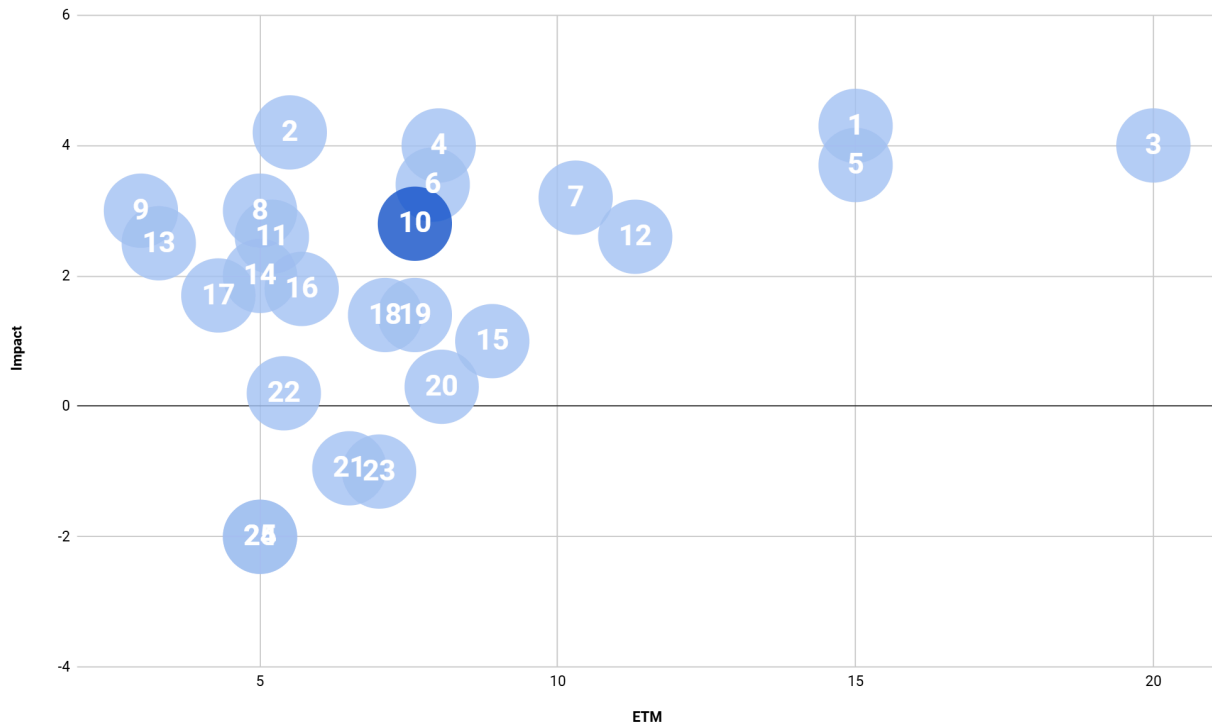
3.2.10. Signal 10: More flexibility in production chains, more independence from China¹³

Strategic shift in aerospace and defense supply chains driven by China's dominant position in 58% of defense-critical raw materials. This situation has prompted European OEMs to seek alternative sources, develop new production methods, and establish more resilient supply chains to reduce dependency on single-source materials.

¹³ Source:

3.2.10.1. ETM, IMPACT Matrix

Figure 11. Impact and ETM Analysis of More flexibility in production chains, more independence from China in Aerospace & Defence.



The impact of signal 10 (More flexibility in production chains) was estimated at 2.8. Its score of 2.80 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 7.6 years, which means that the signal may fully materialize by mid-2031.

3.2.10.2. How can it change our optics?

The recognition of critical material dependency is transforming industry perspectives on supply chain management and strategic autonomy. This shift is driving a fundamental reevaluation of sourcing strategies, with increased emphasis on supply chain transparency and ethical considerations. The industry is moving to a resilience-focused approach, where security of supply and geopolitical considerations take precedence. This change is also highlighting the strategic importance of developing domestic capabilities and alternative material solutions within Europe.

3.2.10.3. How can it change the ecosystem?

The aerospace and defence ecosystem will undergo a significant transformation driven by the need for supply chain independence. This will include the development of alternative material sources, enhanced recycling capabilities, and the establishment of new European supply networks. The change will catalyse innovation in material science and manufacturing processes, while also fostering the growth of new European suppliers and recycling facilities. This transformation will create opportunities for vertical integration and the development of domestic production capabilities.

3.2.10.4. What opportunities does the signal carry for the ecosystem?

- Development of new European material suppliers and processing facilities will emerge
- Creation of innovative recycling and material recovery technologies will advance
- Regional supply chain clusters will be established
- Research and development for material alternatives will expand
- New business opportunities in critical material production will arise

3.2.10.5. What risks does the signal carry for the ecosystem?

- Production costs could rise affecting competitiveness
- Transition period could disrupt current operations
- Geopolitical tensions could affect trade relationships
- Alternative suppliers could remain limited
- Investment uncertainty could challenge supply chain development

3.2.10.6. What challenges does the signal carry for the ecosystem?

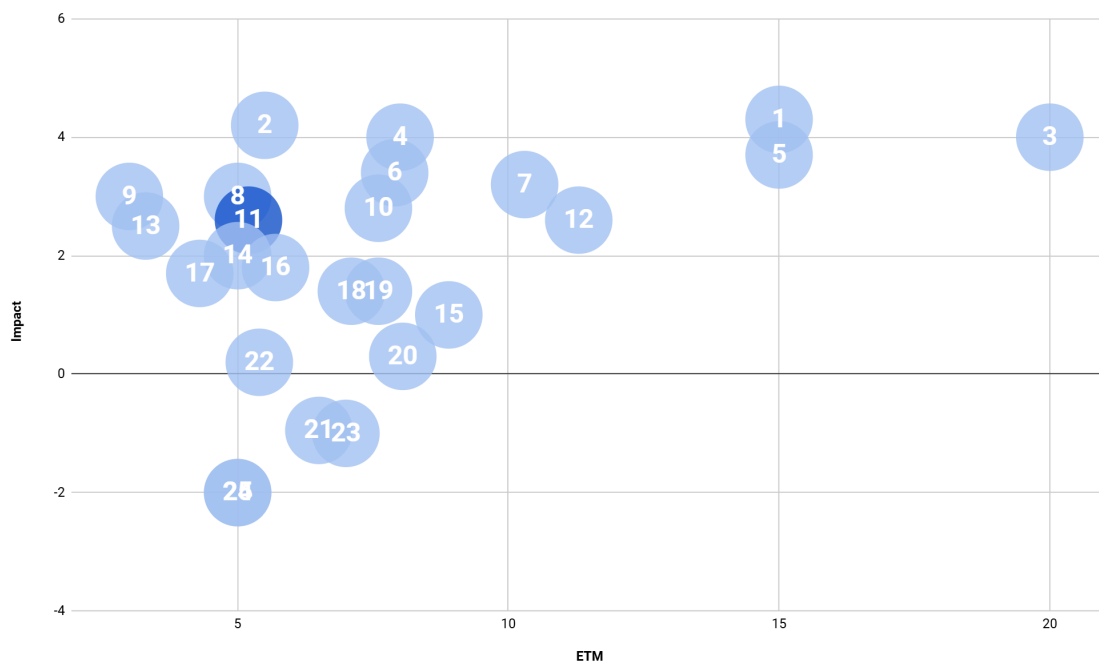
- Technical alternatives for critical materials will need development
- Skilled workforce for new technologies will require training
- Transition costs and timelines will need management
- New quality certification processes will need establishment
- International partnerships will require careful cultivation

3.2.11. Signal 11: Emissions as key indicator¹⁴

Emissions will become a critical factor in transportation decision-making, driven by differential taxation and environmental regulations. This shift will influence aircraft design, operations, and route planning, with emissions data becoming a standard feature in navigation systems and operational metrics.

3.2.11.1. ETM, IMPACT Matrix

¹⁴ Source: <https://www.wired.com/story/greener-is-getting-going/>

Figure 12. Impact and ETM Analysis of Emissions as key indicator in Aerospace & Defence.

The impact of signal 11 (Emissions as key indicator) was estimated at 2.6. Its score of 2.6 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 5.2 years, which means that the signal may fully materialize by mid-2029.

3.2.11.2. How can it change our optics?

The aerospace industry's perspective will fundamentally shift as emissions become a primary consideration in all operational decisions. This transformation will drive investment priorities toward green technologies and sustainable solutions. Banks' commitment to decarbonization will reshape project funding dynamics, with environmental performance becoming as crucial as financial returns. The integration of emissions data into navigation systems will create new transparency standards across the industry.

3.2.11.3. How can it change the ecosystem?

The A&D ecosystem will evolve to prioritize emissions reduction across its value chain. This will promote transparency in environmental impact reporting and encourage investment in green aviation projects. The shift will create new metrics for evaluating aircraft performance and operational efficiency. Manufacturing processes will be redesigned to minimize environmental impact, while new technologies for emissions reduction will become central to product development.

3.2.11.4. What opportunities does the signal carry for the ecosystem?

- Green aviation projects could attract preferential financing
- Emissions-tracking technologies could create new markets
- Sustainable aircraft designs could gain competitive advantage
- Environmental certification could open new revenue streams
- Low-emission operations could reduce operational costs

3.2.11.5. What risks does the signal carry for the ecosystem?

- False indicators and data manipulation could undermine trust
- Fabricating emission values could create unfair advantages
- Misrepresented environmental performance could mislead stakeholders
- Differential taxation could create market distortions
- Non-standardized measurement systems could lead to inconsistent reporting

3.2.11.6. What challenges does the signal carry for the ecosystem?

- Accurate emissions measurement systems will need development
- New environmental standards will require certification
- Infrastructure adaptation will demand significant investment
- Foster transparency across the industry ecosystem
- Educate users and community about emissions impact

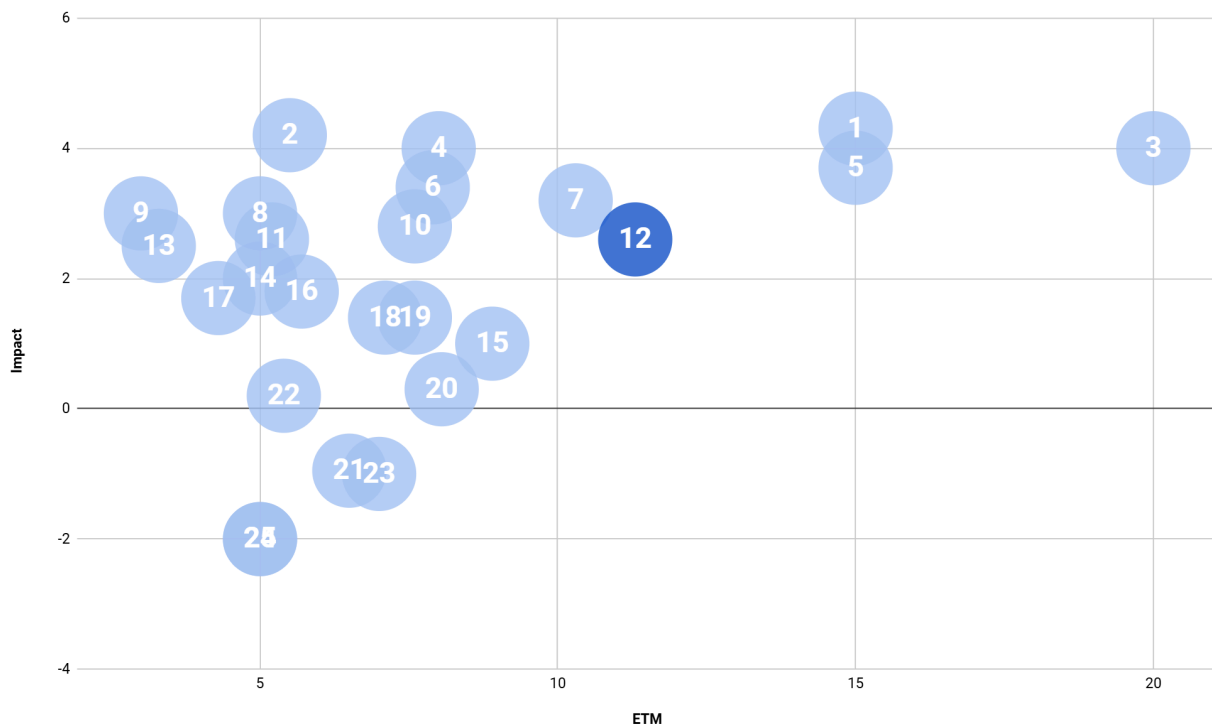
3.2.12. Signal 12: Synthetic Biology for Fuel Production¹⁵

Synthetic biology in fuel production focuses on redesigning biological entities—such as bacteria, algae, or yeast—to generate fuels like biodiesel, bioethanol, and hydrogen. Using tools from genetic engineering and metabolic design, this field enhances these organisms to produce fuel efficiently from renewable resources like biomass or sunlight. This approach offers a promising route to sustainable, renewable fuel alternatives to fossil fuels, potentially transforming the energy landscape in aerospace and defense.

¹⁵ Source: <https://www.sciencedirect.com/science/article/pii/S1369527421001466>

3.2.12.1. ETM, IMPACT Matrix

Figure 13. Impact and ETM Analysis of Synthetic Biology for Fuel Production in Aerospace & Defence.



The impact of signal 12 (Synthetic Biology for Fuel Production) was estimated at 2.60. Its score of 2.60 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 11.3 years, which means that the signal may fully materialize by mid-2035.

3.2.12.2. How can it change our optics?

- It shifts attention towards the potential for biology to play a central role in energy production.
- It underlines the importance of interdisciplinary collaboration between biology, engineering, and aerospace sciences.
- It brings a new element to the discussion about energy security and independence.
- It facilitates the understanding of a potential change in the environmental impact of aviation and defence operations.

3.2.12.3. How can it change the ecosystem?

- Synthetic biology for fuel production will drive innovation in genetic engineering, metabolic engineering, bioreactor design, and downstream processing technologies.
- The development and deployment of synthetic biofuel production could create new economic opportunities in the biotechnology sector, agriculture, and renewable energy industries
- By offering a more sustainable alternative to fossil fuels, synthetic biofuels can contribute to reducing greenhouse gas emissions and mitigating climate change.
- Synthetic biofuels have the potential to significantly reduce the environmental impact of aerospace and defence operations by decreasing reliance on fossil fuels and lowering greenhouse gas emissions.

3.2.12.4. What opportunities does the signal carry for the ecosystem?

Diminished reliance on oil-producing countries (like Russia, Iran, Saudi Arabia, Venezuela, and others) enhances the sovereignty of European nations.

3.2.12.5. What risks does the signal carry for the ecosystem?

The scarcity of alternative resources such as fields for crops and the recycling of byproducts into Sustainable Aviation Fuel (SAF) is triggering a "gold rush" scenario and conflicts over land use.

3.2.12.6. What challenges does the signal carry for the ecosystem?

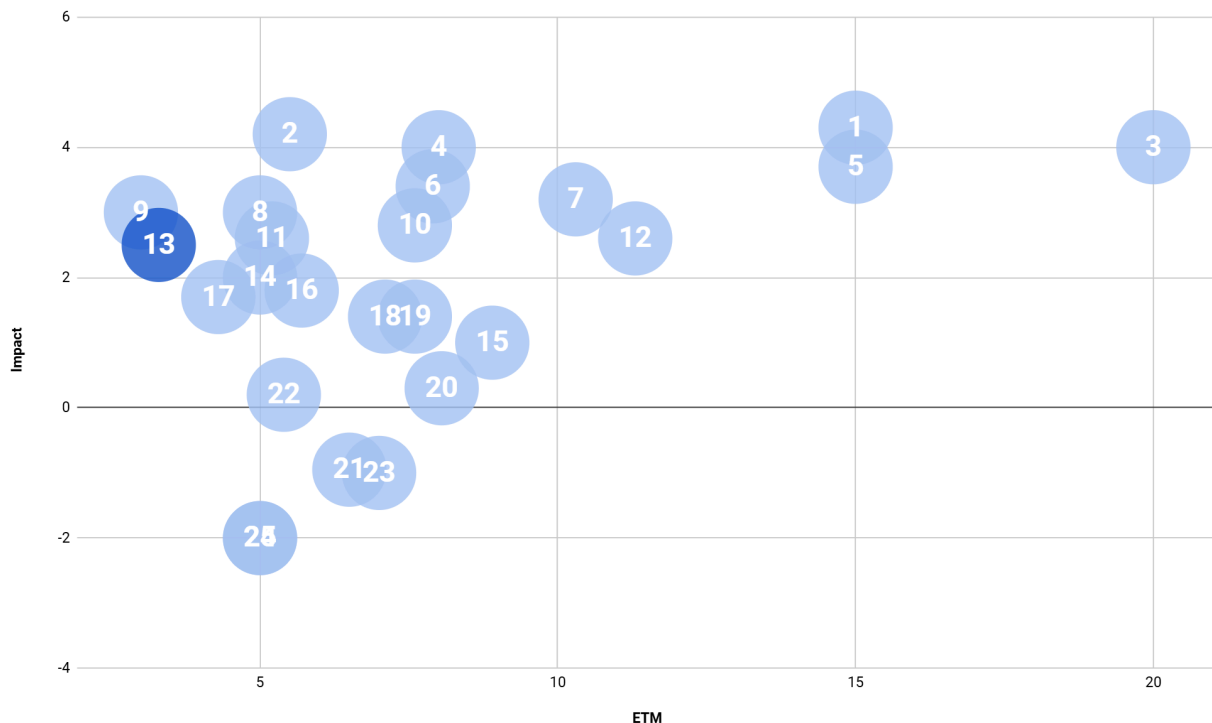
Given the substantial SAF requirement, it is crucial to address whether there will be sufficient supply to meet the needs of all flights.

3.2.13. Signal 13: Additive Manufacturing (3D Printing)¹⁶

In the military sector, additive manufacturing is increasingly utilized to fabricate lightweight and durable components. This technology encompasses on-site 3D printing, allowing for rapid prototyping and repairs in various field settings, enhancing operational efficiency and equipment readiness.

3.2.13.1. ETM, IMPACT Matrix

Figure 14. Impact and ETM Analysis of Additive Manufacturing (3D Printing) in Aerospace & Defence.



¹⁶ Source: <https://saabrds.com/top-technology-trends-in-aerospace-and-defense-for-2024/> and <https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/a-rising-wave-of-tech-disruptors-the-future-of-defense-innovation>

The impact of signal 13 (Additive Manufacturing (3D Printing)) was estimated at 2.5. Its score of 2.5 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 3.3 years, which means that the signal may fully materialize by mid-2027.

3.2.13.2. How can it change our optics?

This transformative technology prompts a shift towards localized and sustainable production, highlighting the significance of customization and rapid innovation. It offers fresh insights into the future dynamics of supply chains. Stakeholders who acknowledge and adapt to these transformations can better equip themselves to capitalize on the benefits of this technology, ensuring their readiness for the evolving landscape.

3.2.13.3. How can it change the ecosystem?

In the Aerospace & Defense ecosystem, Additive Manufacturing, commonly known as 3D Printing, has the potential to revolutionize operations and management. It presents opportunities for technological innovation, economic efficiency, societal advancement, and environmental sustainability. This technology not only strengthens existing capabilities but also opens doors for future developments that align with global objectives. By harnessing the power of 3D Printing, the defense industry can transform and adapt to meet the ever-evolving challenges of the modern era.

3.2.13.4. What opportunities does the signal carry for the ecosystem?

Through rapid prototyping, customization, and intricate geometrical production, technological advancements and cost reductions are driven. It not only boosts supply chain resilience and job creation but also promotes skill development. Additionally, sustainability is enhanced by minimizing waste and utilizing lightweight materials.

3.2.13.5. What risks does the signal carry for the ecosystem?

Quality control issues, intellectual property theft and cybersecurity threats, which could lead to compromised defence systems and operational failures. The high initial investment costs and the need for specialised technical expertise may hinder widespread adoption, while over-reliance on this technology could disrupt traditional supply chains and create economic instability. Additionally, the potential for unregulated production of weapons poses significant security challenges.

3.2.13.6. What challenges does the signal carry for the ecosystem?

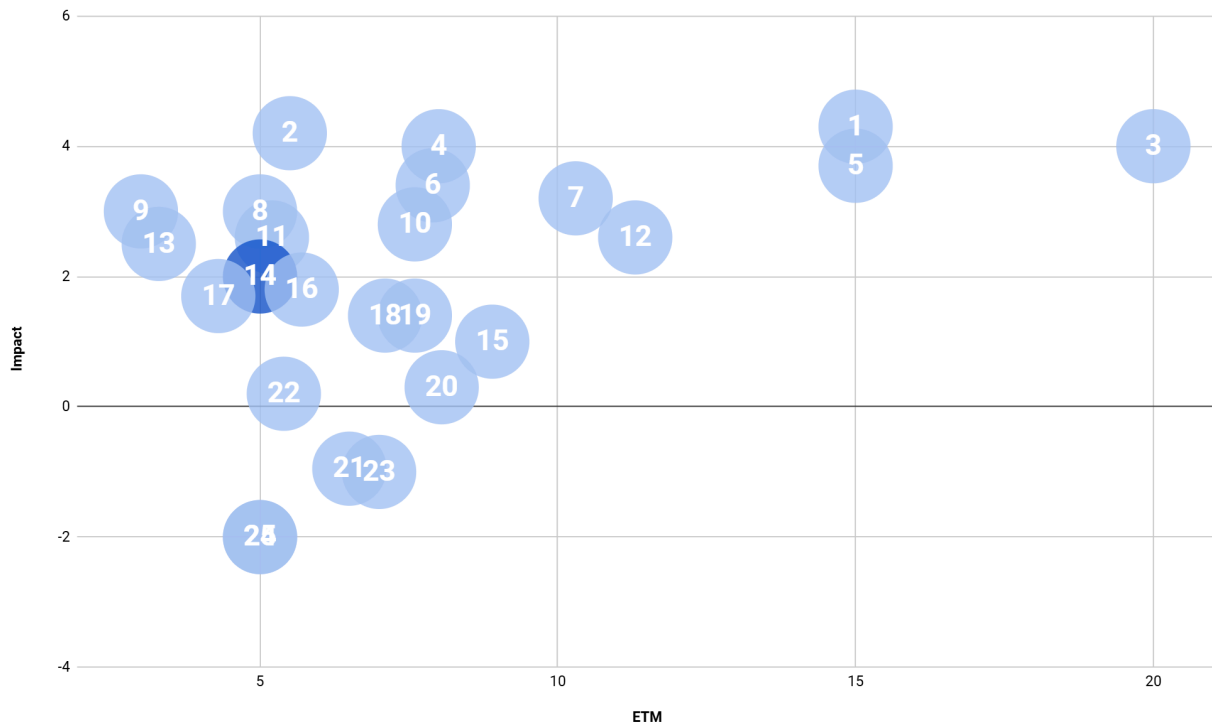
Ensuring consistent quality and reliability of printed parts is crucial to avoid mission-critical failures. The digital nature of designs increases the risk of intellectual property theft and cyber-attacks, potentially leading to compromised or sabotaged components. High initial investment costs and the need for specialised technical expertise can hinder adoption and integration, while over-reliance on this technology could disrupt traditional supply chains and create economic instability.

3.2.14. Signal 14: Directed Energy Weapons (DEWs)¹⁷

Directed Energy Weapons (DEWs) are a class of advanced weaponry that use highly focused energy, such as lasers or microwaves, to inflict damage on targets. DEWs offer precise, speed-of-light targeting capabilities, potentially replacing conventional munitions with more agile and adaptable offensive and defensive systems.

3.2.14.1. ETM, IMPACT Matrix

Figure 15. Impact and ETM Analysis of Directed Energy Weapons (DEWs) in Aerospace & Defence.



The impact of signal 14 (Directed Energy Weapons (DEWs)) was estimated at 2.0. Its score of 2.0 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 5.0 years, which means that the signal may fully materialize by mid-2029.

3.2.14.2. How can it change our optics?

The emergence of DEWs in the Aerospace & Defence ecosystem signals a significant shift towards non-kinetic warfare capabilities, potentially revolutionizing military strategy and tactics. This shift could lead to a decreased reliance on traditional explosive munitions, with implications for the entire supply chain and logistics of defense operations.

3.2.14.3. How can it change the ecosystem?

The rise of DEWs could revolutionize warfare, potentially rendering traditional kinetic weapons obsolete and reshaping defense industries towards prioritizing technological innovation in directed energy. The rise of DEWs could trigger a significant realignment within the Aerospace &

¹⁷ Source:

<https://ndupress.ndu.edu/Media/News/News-Article-View/Article/2053280/directed-energy-weapons-are-real-and-disruptive/>

Defence sector, pushing companies to invest heavily in R&D and acquire new technological capabilities to remain competitive.

3.2.14.4. What opportunities does the signal carry for the ecosystem?

It allows for the development of new, energy-based deterrents that could revolutionize defense strategies and potentially reduce reliance on traditional kinetic weapons. It opens up avenues for cutting-edge research in areas like laser technology, high-power microwaves, and particle beams, potentially leading to breakthroughs with civilian applications (e.g. telecommunications). It presents opportunities to develop advanced targeting and tracking systems, enhancing the precision and effectiveness of defense systems, which could also find applications in civilian areas like air traffic control and autonomous navigation.

3.2.14.5. What risks does the signal carry for the ecosystem?

Companies may face difficulties in securing sufficient and reliable energy sources to power these weapons, potentially hindering their deployment in remote or resource-constrained environments. Overcoming the technical challenges associated with generating, focusing, and controlling high-energy beams requires substantial investment in research and development, which may divert resources from other critical areas within the A&D sector.

3.2.14.6. What challenges does the signal carry for the ecosystem?

- It requires adapting existing doctrines, tactics, and training programs to incorporate the unique capabilities and limitations of these new weapons, potentially leading to significant organizational and logistical adjustments.
- It necessitates developing new command and control systems to effectively manage and coordinate the deployment of DEWs alongside traditional military assets, demanding complex integration efforts and potentially substantial financial investments.
- Ensuring the interoperability of DEWs with existing platforms and communication networks presents a significant technical challenge, requiring close collaboration between various stakeholders within the A&D ecosystem.

3.2.15. Signal 15: Hydrogen as the fuel of the future¹⁸

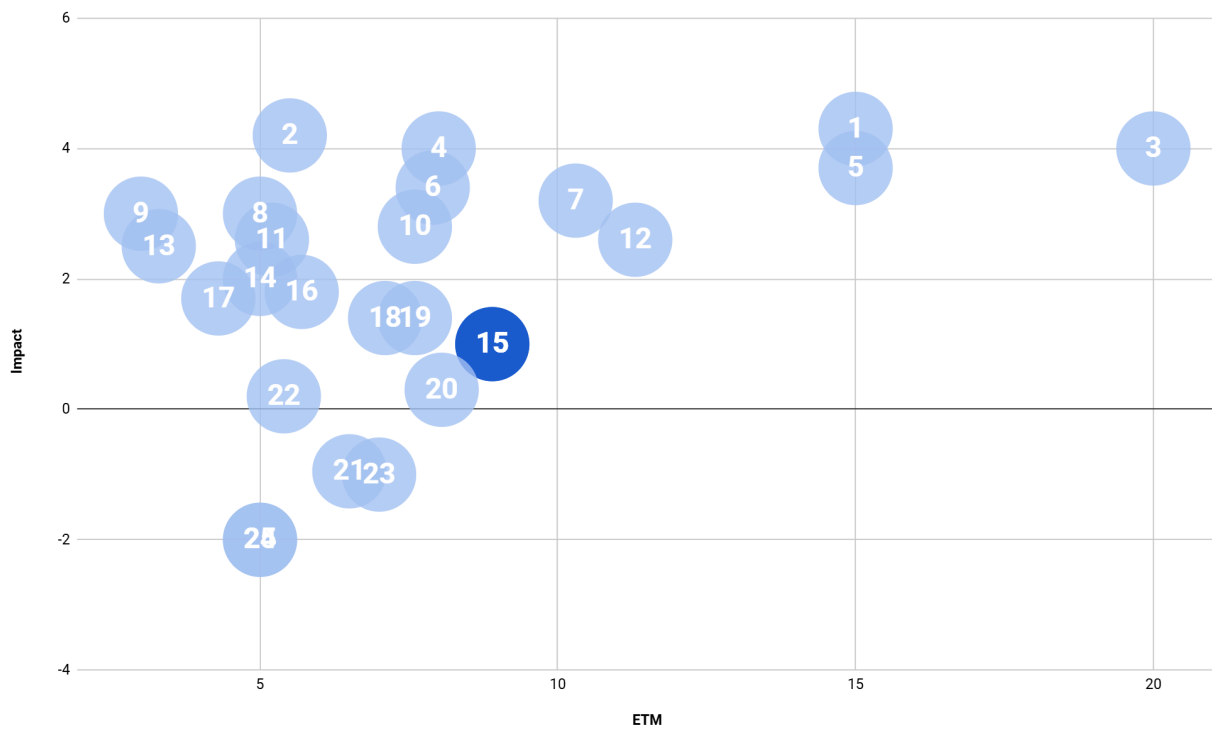
Hydrogen fuel, a clean energy source produced from various sources like natural gas, biomass, and water electrolysis, is gaining attention as a promising alternative to fossil fuels for decarbonizing transportation, including the aircraft industry. When consumed in a fuel cell, hydrogen produces only water as a byproduct, making it a highly attractive option for reducing emissions. While the use of cryogenic hydrogen, which involves storing hydrogen at extremely low temperatures to increase its density, holds potential for achieving environmental sustainability in aviation, significant logistical and technological hurdles remain before widespread adoption is feasible.

¹⁸ Source:

<https://www.national-geographic.pl/traveler/artykul/nadchodzi-przelom-lotniczy-gigant-przetestuje-loty-na-wodor-240819090055>

3.2.15.1. ETM, IMPACT Matrix

Figure 16. Impact and ETM Analysis of Hydrogen as the fuel of the future in Aerospace & Defence.



The impact of signal 15 (Hydrogen fuel of the future) was estimated at 1.0. Its score of 1.0 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 8.9 years, which means that the signal may fully materialize by mid-2032.

3.2.15.2. How can it change our optics?

Hydrogen fuel is generating significant interest as a key component in achieving the Green Deal's ambitious goals of transitioning away from fossil fuels and towards clean, renewable energy sources. Its appeal lies in the fact that it can be produced and consumed without generating CO₂ emissions, and its primary source, water, is abundant. This potential for dramatically reducing CO₂ emissions by up to 90% makes hydrogen a highly attractive solution.

However, despite the promise and significant R&D investment in recent years, there are growing concerns about the viability of hydrogen, particularly in the aviation sector. While sustainable aviation fuels (SAF) and electric batteries offer some solutions, they cannot fully address the industry's needs in terms of availability and performance. Cryogenic hydrogen, with its higher energy density, was considered a potential candidate to bridge this gap. Yet, progress in developing and implementing this technology for aircraft has been slow, raising doubts about its ability to deliver on its initial promise and fulfil the industry's decarbonization goals.

3.2.15.3. How can it change the ecosystem?

While cryogenic hydrogen offers the potential for reducing gross carbon emissions in aviation and enabling cheaper air travel, with applications extending to other industries, its failure to materialise as a viable solution could have negative societal implications. If, despite the promise of cryogenic hydrogen, the aviation industry continues to rely heavily on sustainable aviation fuels

(SAF), which, while greener than traditional fuels, still contribute to emissions, it could solidify the perception that aviation is a major contributor to environmental pollution. This could ultimately hinder public acceptance of air travel and undermine efforts to achieve sustainability in the sector.

3.2.15.4. What opportunities does the signal carry for the ecosystem?

The potential of cryogenic hydrogen extends far beyond aviation, with applications in various industries seeking to reduce their carbon footprint. Its successful implementation in aircraft could make air transport accessible to a wider social group by potentially lowering costs and expanding travel options. However, the current focus remains on carefully managing investments in this technology, balancing research and development with the need for clear signals from the entire value chain that cryogenic hydrogen is a suitable solution, both technically and logistically. This cautious approach reflects the desire to ensure that resources are allocated effectively and that the technology aligns with the broader needs and capabilities of the aviation ecosystem.

3.2.15.5. What risks does the signal carry for the ecosystem?

The main risk associated with cryogenic hydrogen for aviation is the potential for the technology to be deemed unfeasible and ultimately abandoned. This could occur if it proves too expensive, ineffective, or impractical to implement on a large scale. If this happens, the industry will be forced to explore and invest in alternative solutions to achieve its decarbonization goals, potentially delaying progress towards sustainable aviation.

3.2.15.6. What challenges does the signal carry for the ecosystem?

A significant challenge facing the adoption of cryogenic hydrogen in aviation is the potential need to redesign aircraft to accommodate this new fuel source and its unique storage requirements. This raises the question of how to build sufficient confidence among stakeholders across the entire value chain – from aircraft manufacturers and airlines to fuel producers and regulators – to invest in and commit to this potentially transformative, yet still uncertain, technology.

3.2.16. Signal 16: Industrial companies diversify beyond aviation into renewables¹⁹

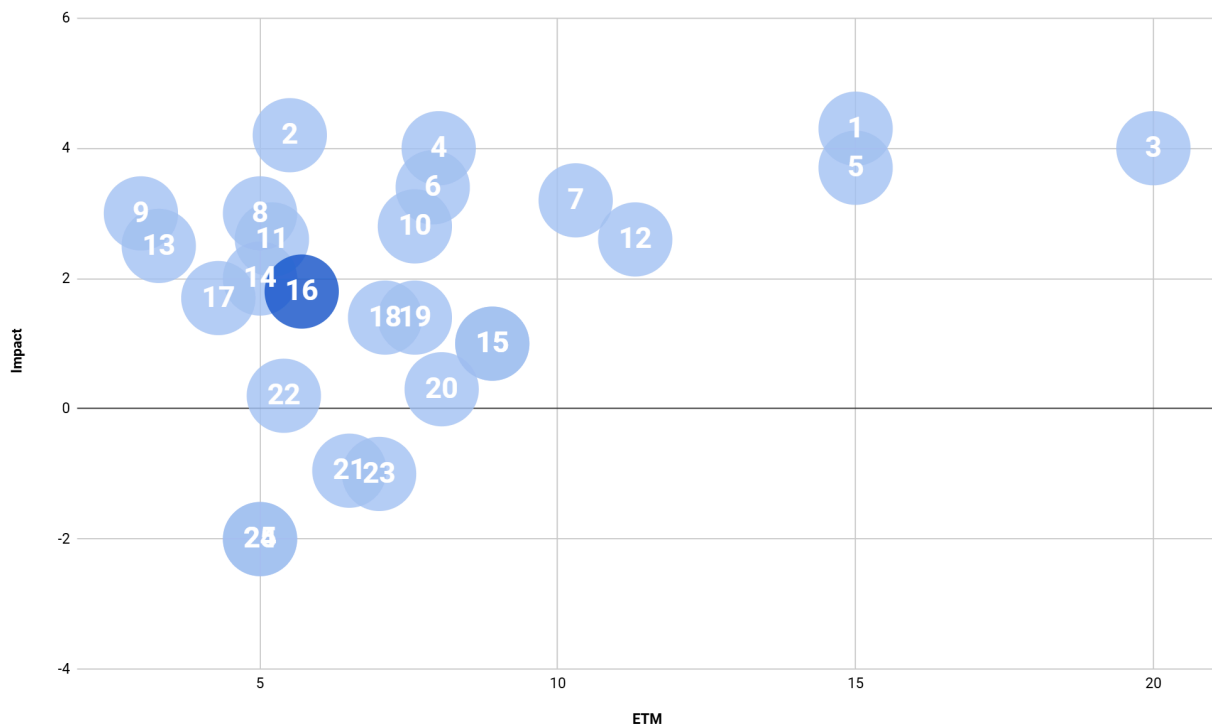
Companies are moving away from activities with a higher environmental impact (traditional industrial processes and commercial aviation) towards those with a lower impact (renewables within aerospace and defense). This shift is starting to take place in several companies, addressing aerospace market as a result of several drivers :

- Lessons learned from COVID where aviation was severely hit endangering too specialised companies.
- Pressure from employees willing to work in a meaningful, sustainable sector.
- Leaders with other values than just "money"
- Pressure from the public and regulation (Quality Hygiene Safety & Environment...)

¹⁹ Some private companies (industrials) are shifting to other markets than commercial aviation i.e. implementing diversification strategy toward renewable energy in Aerospace & Defence. Source: Experience testimony from a company selling chemical products (coatings, surface treatments).

3.2.16.1. ETM, IMPACT Matrix

Figure 17. Impact and ETM Analysis of Industrial companies diversify beyond aviation into renewables



The impact of signal 16 (Industrial companies diversify beyond aviation into renewables) was estimated at 1.8. Its score of 1.8 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 5.7 years, which means that the signal may fully materialize by mid-2029.

3.2.16.2. How can it change our optics?

This shift could lead to a cross-pollination of knowledge between the Aerospace & Defence and wind turbine industries. As aerospace companies diversify into renewable energy, they bring expertise in aerodynamics, materials science, and advanced manufacturing, which can be applied to improve wind turbine efficiency and durability. This knowledge transfer could accelerate advancements in wind energy technology, leading to more cost-effective and reliable renewable energy solutions. Moreover, this convergence could create new partnerships and supply chains, further strengthening the renewable energy sector. Ultimately, this shift could position the Aerospace & Defence industry as a key driver of innovation in the broader renewable energy ecosystem.

3.2.16.3. How can it change the ecosystem?

This shift towards renewables in Aerospace & Defence can trigger a broader positive transformation.

- Firstly, increased public acceptance and support from decision-makers can create a favorable policy environment for renewable energy investments, accelerating the industry's growth.
- Secondly, access to innovative funding sources, like green funds and ethical financial initiatives, can unlock significant capital for research and development, driving technological breakthroughs.

- Thirdly, improved availability of a dedicated and committed workforce, attracted by the industry's commitment to sustainability, can fuel innovation and accelerate the transition.

This combination of factors can create a virtuous cycle, where progress in renewable energy within Aerospace & Defence stimulates further investment, public support, and talent attraction, ultimately contributing to a more sustainable future for the entire ecosystem.

3.2.16.4. What opportunities does the signal carry for the ecosystem?

- Firstly, it confirms the potential for companies to diversify their activities and increase their robustness by venturing into renewable energy markets, reducing reliance on traditional revenue streams.
- Secondly, opening to new markets like wind energy fosters cross-industry collaboration and knowledge transfer, allowing aerospace companies to learn from the experience of established renewable energy players. This exchange can lead to technological advancements and accelerate the development of sustainable solutions.
- Additionally, this diversification can attract new talent and investment, breathing fresh life into the ecosystem.
- Finally, it might position the Aerospace & Defence industry as a key player in the global transition towards sustainable energy, enhancing its reputation and long-term growth prospects.

3.2.16.5. What risks does the signal carry for the ecosystem?

- Companies accustomed to the highly regulated and relatively slow-paced Aerospace & Defence industry might struggle to adapt to the dynamic and rapidly evolving renewable energy market, potentially leading to missed opportunities or failed ventures.
- Existing company cultures, often characterized by rigid hierarchies and risk-averse decision-making, could hinder the agility and innovation needed to succeed in the renewables sector.
- Over-reliance on established standards and technologies within Aerospace & Defence could make it difficult to embrace the disruptive innovations driving the renewable energy transition, leaving companies vulnerable to being overtaken by more nimble competitors.

3.2.16.6. What challenges does the signal carry for the ecosystem?

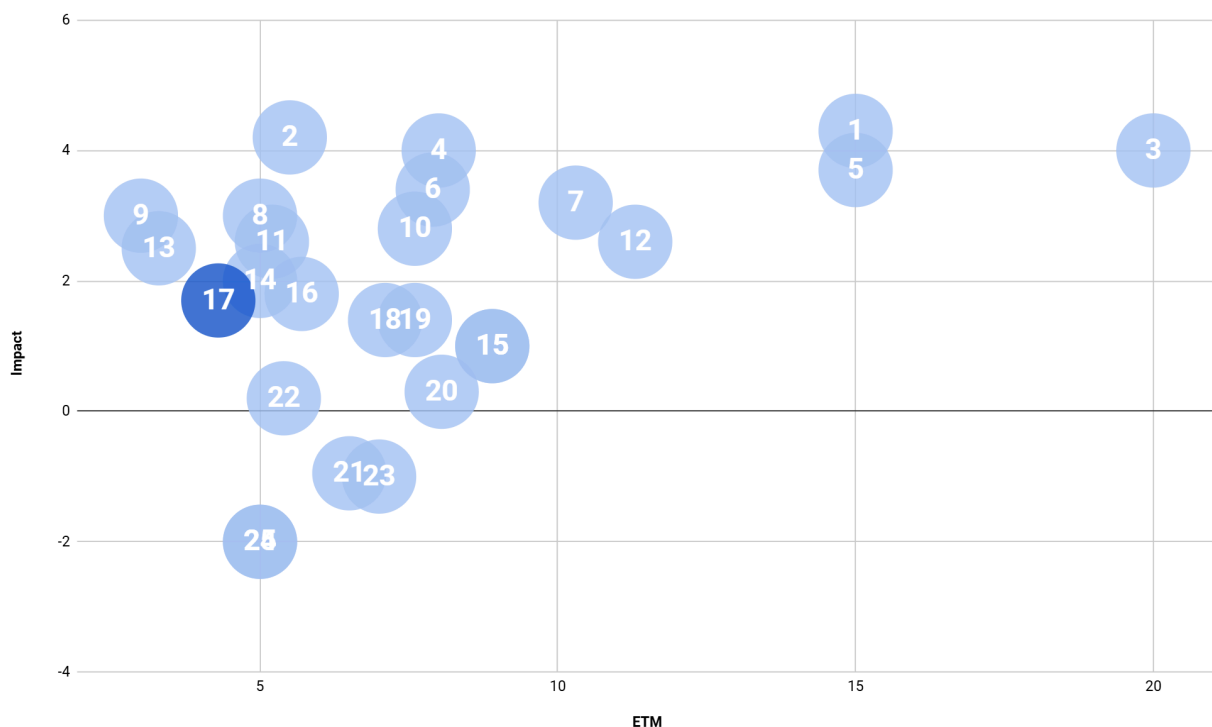
- Motivating individuals to embrace alternative perspectives, thought processes, and value systems will be crucial to foster a transformative cultural environment that can adapt to the demands of the renewable energy sector.
- Companies will need to overcome internal resistance to change and break down traditional silos to facilitate the cross-functional collaboration and knowledge sharing essential for success in this new market.
- Finally, attracting and retaining talent with expertise in renewable energy technologies will be critical, requiring competitive compensation packages and a compelling vision for a sustainable future.

3.2.17. Signal 17: Focus on drone productions as war in Ukraine shows that it is a weapon of 21st century²⁰

The ongoing conflict in Ukraine has highlighted drones as crucial tools in modern warfare, showcasing their versatility for surveillance, precision strikes, and logistical support on the battlefield. This signal reflects an accelerated focus on developing and scaling drone technologies within the defense sector, as military strategies increasingly rely on drones for tactical advantage, real-time intelligence, and cost-effective operations. As a result, drone production is becoming a priority, with investments directed toward enhancing their autonomy, durability, and capabilities to meet the evolving demands of 21st-century conflict.

3.2.17.1. ETM, IMPACT Matrix

Figure 18. Impact and ETM Analysis of Focus on drone productions as war in Ukraine shows that it is a weapon of 21st century in Aerospace & Defence.



The impact of signal 17 (Focus on drone productions as war in Ukraine shows that it is a weapon of 21st century) was estimated at 1.7. Its score of 1.7 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 4.3 years, which means that the signal may fully materialize by mid-2028.

3.2.17.2. How can it change our optics?

Two potential paths could shape the future of aviation: a peaceful world where planes transport people and goods, or a world in crisis where aircraft serve as tools of warfare, transporting bombs. Drone development enhances the industry's resilience to both of these contrasting scenarios, with technology capable of serving dual purposes: drones can contribute to a better

²⁰ Source:

world (e.g., delivering postal services to remote areas, aiding agriculture) or a more hostile one (e.g., facilitating warfare).

Drones also have a greater potential for public acceptance, particularly in educated, Western societies, due to their unmanned nature, which reduces the risk of human casualties in conflict situations. This adaptability positions drones as valuable assets across diverse applications, allowing the industry to pivot depending on future needs.

3.2.17.3. How can it change the ecosystem?

New Market Segment:

- Defense companies forming partnerships with technology firms to leverage innovation and integrate advanced tech solutions.
- Regulatory measures for airspace management to ensure safe and controlled drone and aircraft operations.

Accelerated Development:

- Faster progress driven by smaller, agile companies operating with fewer regulatory constraints, enabling rapid prototyping and deployment.

3.2.17.4. What opportunities does the signal carry for the ecosystem?

Small companies can make a significant impact, creating opportunities for newcomers. Relocating manufacturing to Europe to produce new devices and products could lead to job creation and economic growth, fostering innovation and strengthening local industries.

3.2.17.5. What risks does the signal carry for the ecosystem?

A lack of unified standards and control over development could lead to potential health and safety risks for the public. Weapons, including drones, pose significant dangers to civilians, with the risk of impacting urban areas and causing unintended harm.

3.2.17.6. What challenges does the signal carry for the ecosystem?

Effective lobbying is needed to engage with authorities and prevent the implementation of inadequate regulations. Focus on developing reusable drones and designing defence-oriented weapons that prioritise conflict avoidance over offensive action.

3.2.18. Signal 18: End-users and clients are reluctant to buy products involving outsourced or rare materials²¹

A growing trend highlights the reluctance of European clients, both civilian and military, to purchase products reliant on rare raw materials, components from competitor countries (e.g., China, Russia), or critical parts (e.g., military ships from the U.S.). This hesitation is driven by two key factors:

- Lack of Sovereignty – Dependence on foreign suppliers raises the risk of supply disruptions due to political decisions, such as reliance on rare earth elements from China.

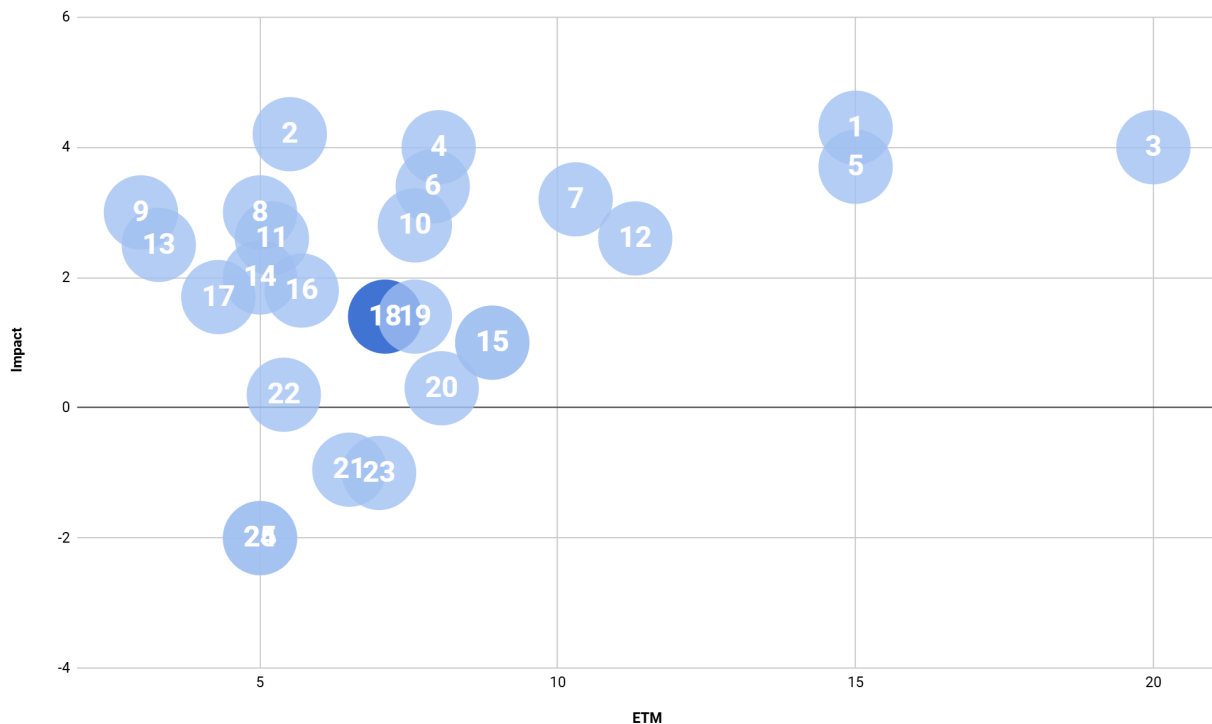
²¹ Source:

- Sanctions or Trade Restrictions – Materials from countries under sanctions or blockades (e.g., titanium from Russia) may be difficult or impossible to procure, creating vulnerabilities in supply chains.

In response, public funding initiatives are emerging to support re-industrialization and local production within Europe, promoting resource security and industry autonomy.

3.2.18.1. ETM, IMPACT Matrix

Figure 19. Impact and ETM Analysis of End-users and clients are reluctant to buy products involving outsourced or rare materials in Aerospace & Defence.



The impact of signal 18 (End-users and clients are reluctant to buy products involving outsourced or rare materials) was estimated at 1.4. Its score of 1.4 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 7.1 years, which means that the signal may fully materialize by mid-2031.

3.2.18.2. How can it change our optics?

This shift emphasises the importance of materials used in the manufacturing of final products, highlighting the need for traceability across the entire supply chain. For manufacturing companies, this introduces a new element: procurement departments are now required to investigate the country of origin for semi-finished products, components, and raw materials.

3.2.18.3. How can it change the ecosystem?

It compels industry players to offer alternative material solutions. Governments are supporting the development of domestically-based alternatives, such as providing grants to build factories focused on locally designed and manufactured components. Establishing a European standard for materials could also reduce dependence on U.S. certifications (e.g., NCAMP).

3.2.18.4. What opportunities does the signal carry for the ecosystem?

Introducing new interesting alternatives and gaining an advantage this way.

3.2.18.5. What risks does the signal carry for the ecosystem?

Failing to adapt the industry to the new requirements.

3.2.18.6. What challenges does the signal carry for the ecosystem?

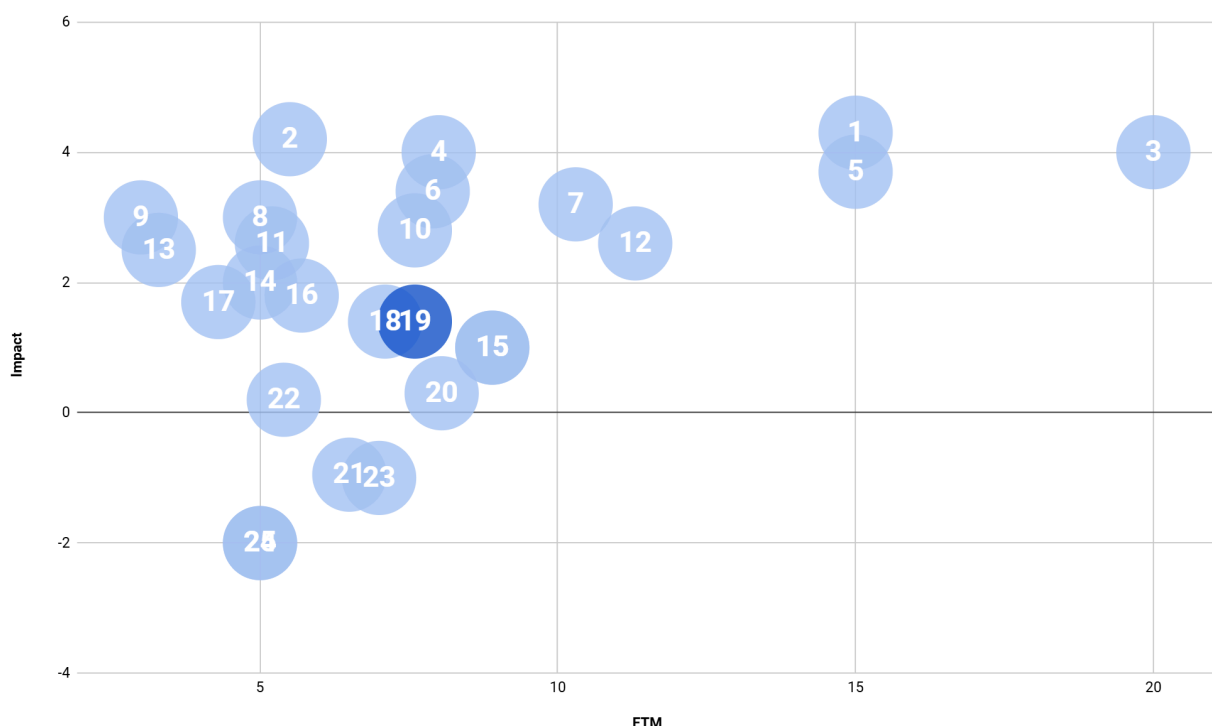
Finding solutions and having transparent communication with clients with enough data.

3.2.19. Signal 19: XaaS: everything as a service for versatility and quick redeployment²²

Companies are shifting from selling products to charging for usage or outcomes. The "XaaS" (Anything as a Service) model is emerging across various industries, emphasising "As a Service" solutions to streamline resources, financing, and technology through shared access and mutual benefits.

3.2.19.1. ETM, IMPACT Matrix

Figure 20. Impact and ETM Analysis of XaaS: everything as a service for versatility and quick redeployment in Aerospace & Defence.



The impact of signal 19 (XaaS: everything as a service for versatility and quick redeployment) was estimated at 1.4. Its score of 1.4 categorizes it as a disruptor, which may positively influence the

²² Source:

ecosystem's development. The estimated ETM is 7.6 years, which means that the signal may fully materialize by mid-2031.

3.2.19.2. How can it change our optics?

This trend is set to transform B2B relationships, requiring companies to enhance versatility and reconfigurability. The rise of XaaS models may lead to increased waste due to low-risk trials, as they don't require significant upfront investments. However, this shift also supports the democratisation of technology, making advanced solutions more accessible across industries.

3.2.19.3. How can it change the ecosystem?

Shift in commercial approach: a strong emphasis on collaboration replaces isolated development, fostering cost and operational efficiency within a more agile ecosystem.

3.2.19.4. What opportunities does the signal carry for the ecosystem?

Use of external technologies, cost-sharing, and accelerated technology development: New business models enable reductions in energy consumption and raw material usage.

3.2.19.5. What risks does the signal carry for the ecosystem?

Emergence of low-performing service providers: the novelty of the trend will attract many followers. Technology sharing may not be fully compatible with high-tech requirements, raising concerns about over-dependence on advanced technology and specialised software.

3.2.19.6. What challenges does the signal carry for the ecosystem?

Adoption of a new working mindset with a focus on external teams, integrated collaboration, and enhanced transparency.

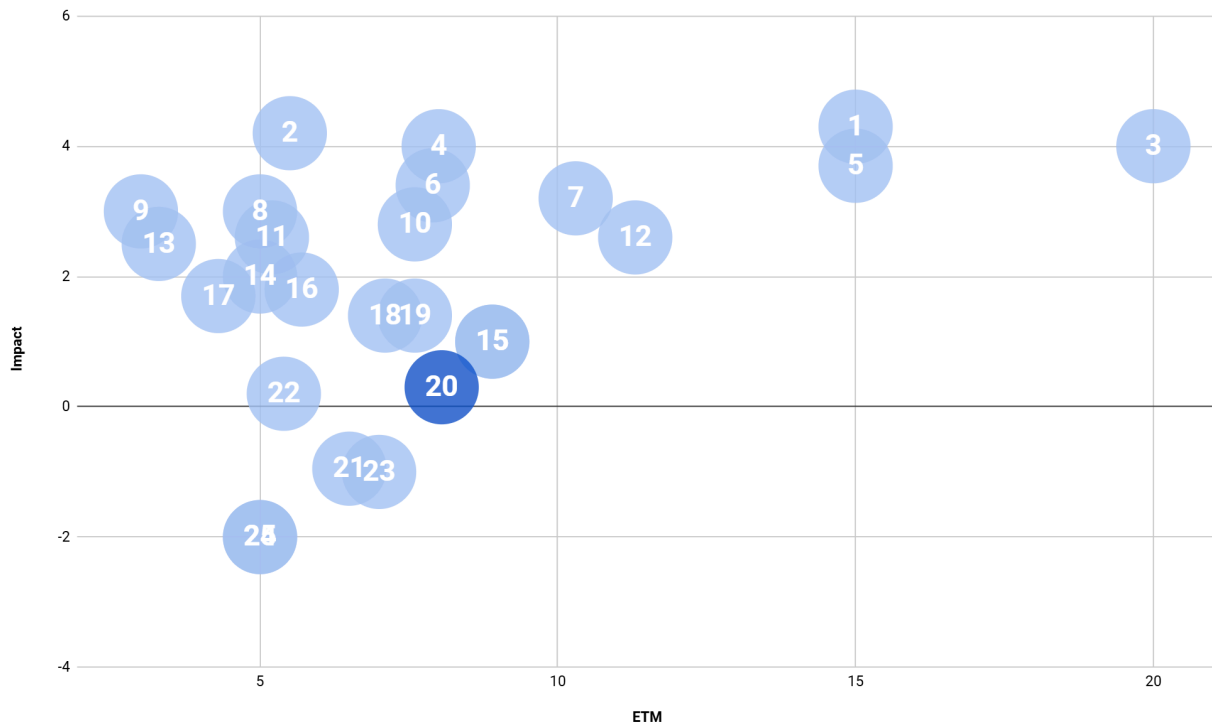
3.2.20. Signal 20: Rising Investment in Defense Applications and Demand for Sovereign Materials²³

Emerging conflicts and geopolitical tensions are prompting European countries to discuss mutual defence and shared interests in developing equipment and weapons. However, EU defence industries are facing a scarcity of essential raw materials, posing risks to production capabilities and innovation.

²³ Source: Requests by clients as well as new topics about drones by EU players (observing and tactical) https://rmis.jrc.ec.europa.eu/uploads/CRMs_for_Strategic_Technologies_and_Sectors_in_the_EU_2020.pdf

3.2.20.1. ETM, IMPACT Matrix

Figure 21. Impact and ETM Analysis of Rising Investment in Defense Applications and Demand for Sovereign Materials in Aerospace & Defence.



The impact of signal 20 (Rising investment in defense application and Demand for Sovereign Materials) was estimated at 0.3. Its score of 0.3 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 8.0 years, which means that the signal may fully materialize by mid-2032.

3.2.20.2. How can it change our optics?

The supply and manufacturing of composite parts should be relocated to “friendly” countries, such as those within the European Union, emphasizing the importance of certified materials. This shift highlights the need for industry independence and self-reliance, along with diversified sources for critical raw materials like certified resin for composites. It presents opportunities to establish factories within Europe, reducing reliance on overseas suppliers (e.g., from the USA or China) and raising awareness about geopolitical dependencies and the importance of resource diversification.

3.2.20.3. How can it change the ecosystem?

It will strengthen the supply chain within Europe, though it also introduces challenges related to innovation and intellectual property. Notably, it opens opportunities for exporting military aircraft equipment; for example, the French Rafale aircraft competes strongly with U.S. models due to France’s mastery over its supply chain. While this shift could reshape the ecosystem dynamics, it requires a clear strategic vision and objectives from European states. Some EU member-states may invest billions in these areas, supported by existing public R&D funding. For instance, France could secure the necessary investment to establish new factories for producing and certifying

composite materials. Private funding is also increasingly interested in strategic, low-risk investments, offering further financial resources for such initiatives.

This shift may encourage the development of alternative materials or recycling solutions, impacting supply chains and driving new R&D directions.

3.2.20.4. What opportunities does the signal carry for the ecosystem?

It creates significant opportunities for European manufacturers as overseas sourcing becomes less viable, even from the USA. If this shift continues, it will drive innovation, job creation, and the development of high-value products within Europe. Additionally, it offers the chance to establish strategic geopolitical independence, fostering sovereignty. More self-sufficient economies and industrial ecosystems enhance resilience in the face of global crises. This movement also encourages investment in recycling and material innovation, further strengthening Europe's industrial base.

3.2.20.5. What risks does the signal carry for the ecosystem?

The primary risk lies in an over-reliance on the defense and weapons market, which is limited in scope with a small client base (primarily national governments). This market dependency creates high interdependence among industry players, posing a threat to the entire ecosystem if a key player fails or if geopolitical tensions ease, leading to reduced state procurement. Additional risks include potential supply chain disruptions and rising costs.

3.2.20.6. What challenges does the signal carry for the ecosystem?

Defense markets are highly confidential, requiring industrial players to adopt a more open and collaborative mindset. Progress can be slow due to concerns about confidentiality and information security, which extends timelines for development and partnership.

Building factories for new technologies (e.g., innovative composite materials) requires strong political support and influence. Currently, there is a lack of political vision at this level in some countries, such as France, where government involvement is limited.

Additional challenges include securing stable supply chains and developing alternative materials and sources to ensure resilience.

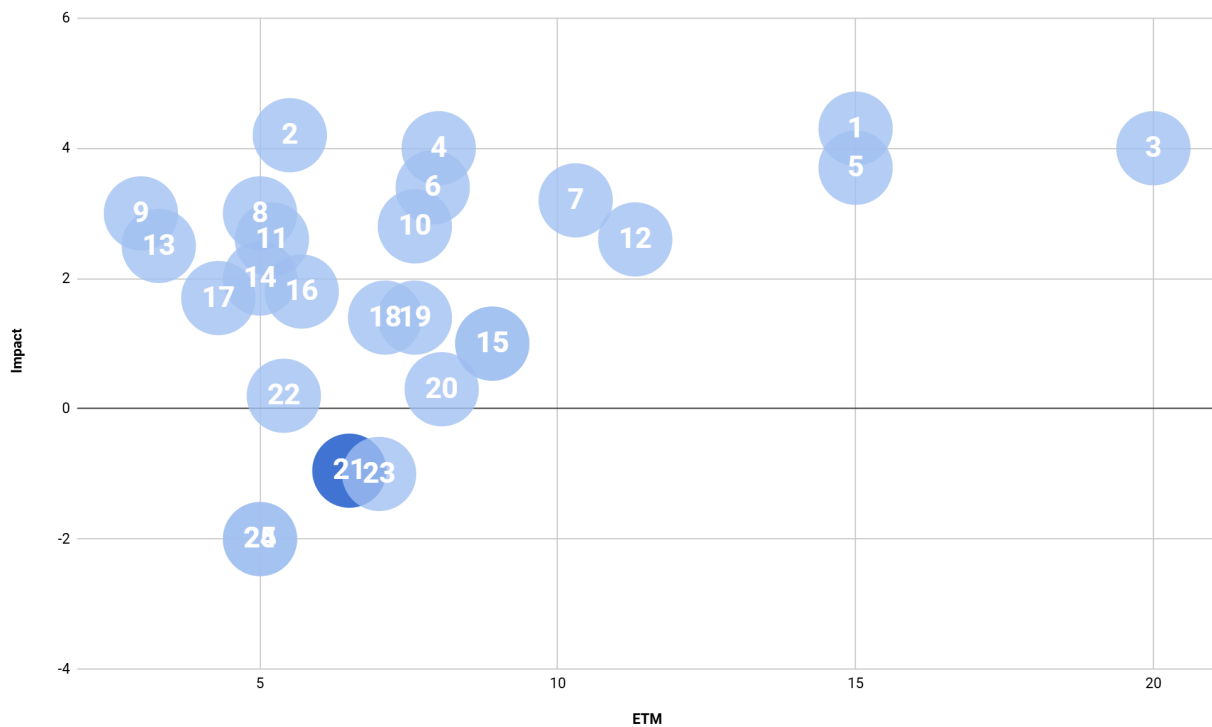
3.2.21. Signal 21: Flight shaming²⁴

This involves stigmatizing or shaming the practice of air travel, particularly when alternative modes of transport are available, and the choice to fly is driven primarily by convenience and time savings.

²⁴ Source: <https://fortune.com/europe/2024/10/11/why-europeans-suffer-flight-shame-swapping-plane-for-train/>

3.2.21.1. ETM, IMPACT Matrix

Figure 22. Impact and ETM Analysis of Flight shaming in Aerospace & Defence.



The impact of signal 21 (Flight shaming) was estimated at -0.95. Its score of -0.95 categorizes it as a disruptor, which may negatively influence the ecosystem's development. The estimated ETM is 6.5 years, which means that the signal may fully materialize by mid-2030.

3.2.21.2. How can it change our optics?

Changes to laws and regulations may be necessary: restrictions could be introduced, such as limits on the number of flights an individual or social group can take annually, or guidelines on who is permitted to travel by plane.

Implementation of a credit or points system that restricts the frequency of air travel per person.

3.2.21.3. How can it change the ecosystem?

Widening social status disparities

Slowing or halting of technological advancement

Positive environmental impact

3.2.21.4. What opportunities does the signal carry for the ecosystem?

New modes of transportation may emerge, such as hyperloop technology.

3.2.21.5. What risks does the signal carry for the ecosystem?

Companies may face bankruptcy, necessitating changes in business models.

3.2.21.6. What challenges does the signal carry for the ecosystem?

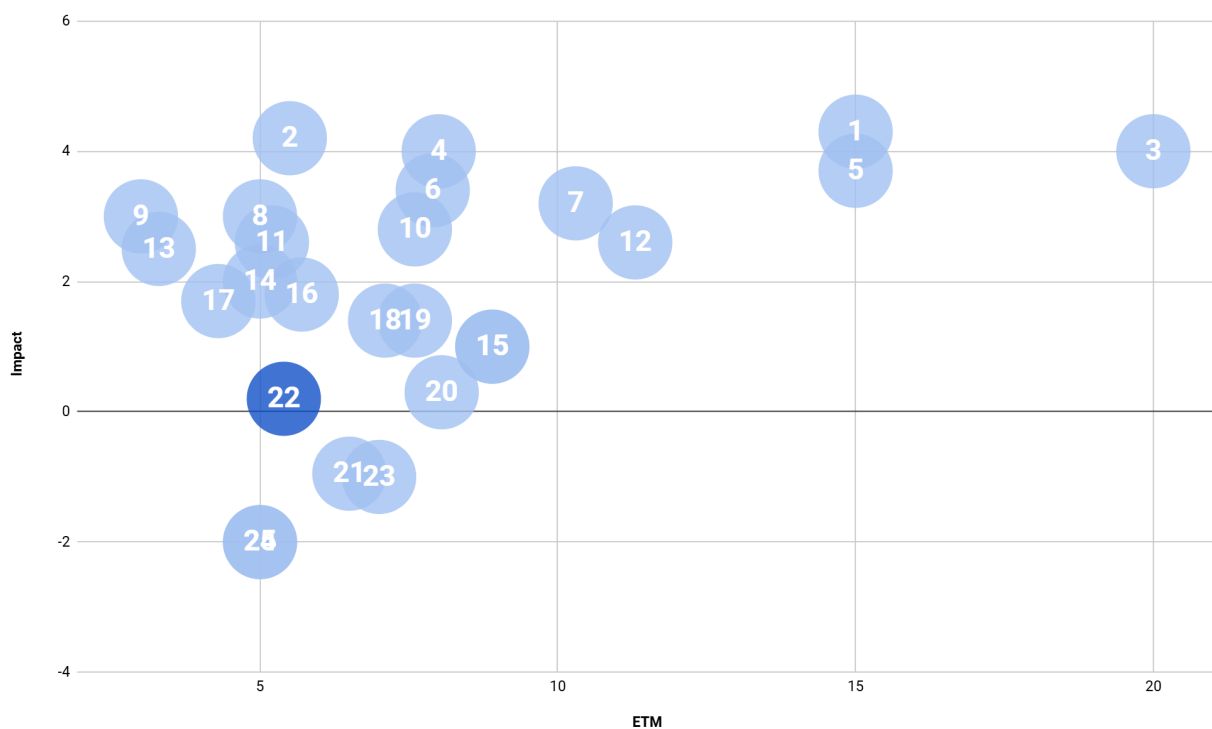
Innovative green technologies are paving the way for sustainable travel. However, this shift presents significant challenges for the aviation industry. Activist actions, such as strikes at airports and incidents involving protesters attaching themselves to planes or splashing them with paint, are already occurring. If these actions intensify, they could potentially paralyze air traffic entirely.

3.2.22. Signal 22: Artificial intelligence (AI) in military applications²⁵

Artificial intelligence (AI) will play a decisive role in human security and survival. Its integration into military decision-making is transforming strategic operations and battlefield tactics.

3.2.22.1. ETM, IMPACT Matrix

Figure 23. Impact and ETM Analysis of Artificial intelligence (AI) in military applications in Aerospace & Defence.



The impact of signal 22 (Artificial intelligence (AI) in military applications) was estimated at 0.2. With a score below 1.0, it was not categorized as a disruptor, and its influence on the ecosystem's development is expected to be rather marginal. The estimated ETM is 5.4 years, which means that the signal may fully materialize by mid-2029.

3.2.22.2. How can it change our optics?

This introduces a new dimension to the discussion of human responsibility for the fate of humanity and the world. Wars are increasingly fought remotely, distanced from the locations

²⁵ Source:

<https://www.technology.org/2024/08/30/japans-military-embarks-on-ai-powered-revamp-to-combat-recruitment-crisis-and-improve-unmanned-capabilities/>

where they are controlled. This shift heightens reliance on AI, potentially reducing human error in critical situations.

3.2.22.3. How can it change the ecosystem?

With increasingly advanced combat drones, soldiers will require a different skill set than before, with no direct "opponent-to-opponent" contact. This shift could lead to the automation of warfare, significantly impacting military training and raising ethical considerations.

3.2.22.4. What opportunities does the signal carry for the ecosystem?

Potential for reduced collateral damage and more precise operations, with enhanced decision-making speed and accuracy.

3.2.22.5. What risks does the signal carry for the ecosystem?

A lack of understanding of the true nature of war among those who influence its course, alongside ethical concerns and an over-reliance on AI.

3.2.22.6. What challenges does the signal carry for the ecosystem?

A redefined concept of a soldier with new required competencies, alongside the growth of drone companies (expanding beyond purely combat-focused applications). Emphasis on ensuring AI systems are robust and secure.

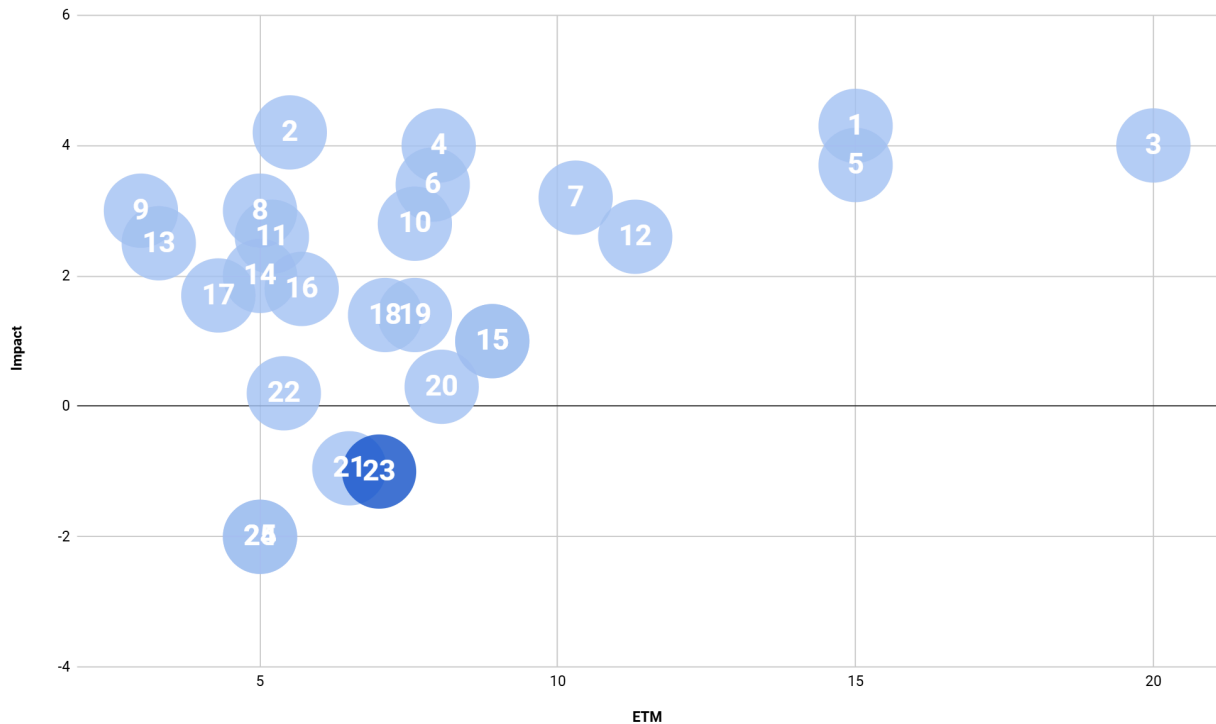
3.2.23. Signal 23: EU defense technologies are highly dependent on non-EU countries, posing risks to strategic autonomy.²⁶

The European Aerospace and Defence (A&D) industry faces a critical challenge: a significant dependence on non-EU countries for essential defense technologies. This reliance creates vulnerabilities in the supply chain, potentially hindering the EU's ability to act independently in defense matters. Furthermore, it limits technological sovereignty and may expose the EU to political influence from external suppliers. To mitigate these risks, the EU needs to diversify its supply chains, invest in domestic production capabilities, and strengthen collaboration among member states to achieve greater strategic autonomy in defense technology. This signal signifies a potential shift towards a more self-reliant European defense industry.

²⁶ Source: https://commission.europa.eu/system/files/2021-05/swd-strategic-dependencies-capacities_en.pdf

3.2.23.1. ETM, IMPACT Matrix

Figure 24. Impact and ETM Analysis of EU defense technologies are highly dependent on non-EU countries, posing risks to strategic autonomy. in Aerospace & Defence.



The impact of signal 23 (EU defense technologies are highly dependent on non-EU countries, posing risks to strategic autonomy) was estimated at -1.0. Its score of -1.0 categorizes it as a disruptor, which may negatively influence the ecosystem's development. The estimated ETM is 7.0 years, which means that the signal may fully materialize by mid-2031.

3.2.23.2. How can it change our optics?

This signal highlights the vulnerability of relying on external sources for critical defense technologies, emphasizing the need for increased self-reliance and potentially leading to a shift in priorities towards strengthening domestic capabilities. It also raises awareness of the potential geopolitical risks associated with technological dependence, prompting a reassessment of strategic partnerships and international collaborations within the A&D sector.

3.2.23.3. How can it change the ecosystem?

Recognizing the risks associated with dependence on non-EU sources could drive greater investment in domestic research and development, fostering innovation and strengthening the European defense industry's technological base. This shift could lead to the emergence of new domestic champions in critical technology areas, reducing reliance on external suppliers and potentially boosting economic growth within the EU.

3.2.23.4. What opportunities does the signal carry for the ecosystem?

This signal presents a significant opportunity for the European A&D ecosystem to boost EU-based technology and innovation. By investing in research, development, and manufacturing of critical defense technologies, the EU can reduce its reliance on external suppliers, create new jobs, and foster a more competitive and resilient defense industry. This could also lead to greater collaboration among EU member states, strengthening the European defense technological and industrial base.

3.2.23.5. What risks does the signal carry for the ecosystem?

Over-reliance on non-EU countries for critical defense technologies carries the risk of supply disruptions due to geopolitical instability or international conflicts, potentially hindering the EU's ability to maintain its defense capabilities. Furthermore, reducing dependence could lead to rising costs in the short term as the EU invests in domestic production and alternative supply chains, potentially impacting the affordability of defense equipment.

3.2.23.6. What challenges does the signal carry for the ecosystem?

Reducing dependency on non-EU sources while maintaining technological advancement in the A&D sector presents a significant challenge. The EU needs to strike a balance between investing in domestic capabilities and maintaining access to cutting-edge technologies from international partners. This requires careful planning, strategic investment, and fostering a collaborative environment within the European defense industry to ensure a smooth transition towards greater self-reliance.

3.2.24. Signal 24: Cybersecurity Threats from Advanced Technologies²⁷

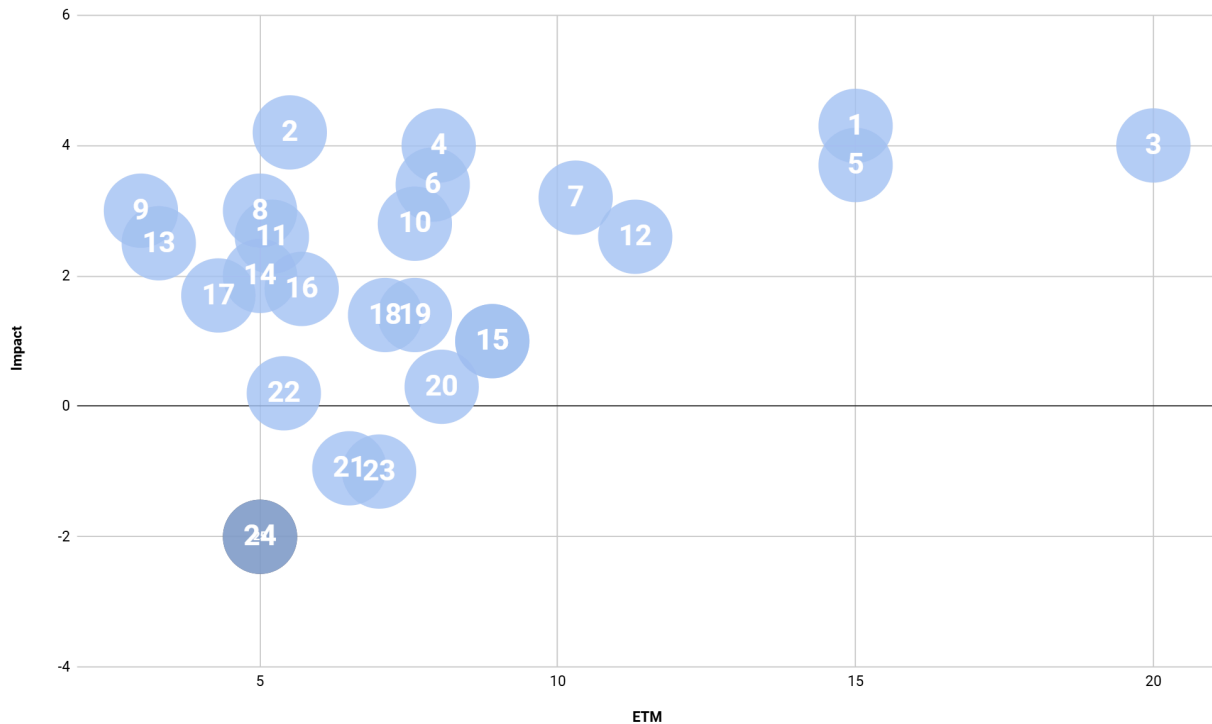
The rise of advanced technologies significantly amplifies the complexity of cybersecurity threats, creating new challenges for the defense sector. As systems become more interconnected and reliant on AI, automation, and data-driven processes, vulnerabilities increase, exposing defense networks to sophisticated cyberattacks. This evolving threat landscape demands continuous innovation in cybersecurity measures to protect critical infrastructure and ensure operational resilience.

²⁷ Source:

<https://monitor-industrial-ecosystems.ec.europa.eu/sites/default/files/2023-12/EMI%20Methodological%20Report.pdf>

3.2.24.1. ETM, IMPACT Matrix

Figure 25. Impact and ETM Analysis of Cybersecurity Threats from Advanced Technologies in Aerospace & Defence.



The impact of signal 24 (Cybersecurity Threats from Advanced Technologies) was estimated at -2.0. Its score of -2.0 categorizes it as a disruptor, which may negatively influence the ecosystem's development. The estimated ETM is 5.0 years, which means that the signal may fully materialize by mid-2029.

3.2.24.2. How can it change our optics?

The growing reliance on digital and networked systems in defense operations expands the focus on cyber threats within military strategies. Cybersecurity is now a critical component of defense planning, as military assets and communications systems become prime targets for cyberattacks, espionage, and data manipulation. This shift requires integrating advanced cyber defenses, real-time threat monitoring, and rapid response protocols to protect sensitive information and maintain strategic advantage. Consequently, military strategies are increasingly prioritizing cybersecurity as a foundational element of national defense, addressing both offensive and defensive cyber capabilities.

3.2.24.3. How can it change the ecosystem?

The rising emphasis on cyber threats within military strategies is prompting the development of more robust cybersecurity measures across defense networks. This shift has multiple impacts on the Aerospace and Defense (A&D) ecosystem:

- **Increased Investment in Cybersecurity Infrastructure** - defense organizations and contractors are likely to invest heavily in advanced cybersecurity tools and infrastructure (such as: next-generation firewalls, AI-driven threat detection, encryption, and secure data-sharing platforms) to protect critical systems, data, and communications.

- Integration of Cyber Defense in Product Development - cyber-resilient architectures are now a priority, ensuring that new products are not only effective in combat but also resistant to cyber infiltration and attacks.
- Enhanced Workforce Training and Recruitment in Cybersecurity - defense organizations are focusing on equipping their workforce with knowledge in areas such as threat intelligence, cyber risk management, and ethical hacking.
- Development of Cybersecurity Standards and Compliance - these standards aim to ensure that all defense contractors, suppliers, and partners meet high-security benchmarks to prevent vulnerabilities across the supply chain.
- Strengthened Public-Private Cybersecurity Collaboration - as cybersecurity becomes a national security priority, collaboration between government agencies, defense contractors, and technology firms is intensifying.
- Increased R&D in Cyber-Resilient Technologies - the emphasis on robust cybersecurity is likely to drive research and development in cyber-resilient technologies, including quantum encryption, autonomous threat response, and cyber attack simulation platforms.

3.2.24.4. What opportunities does the signal carry for the ecosystem?

The push for advanced security measures opens up a variety of areas for technological development and new market opportunities:

- Leveraging artificial intelligence for real-time threat detection and autonomous response mechanisms is a promising area for innovation.
- Defense sectors are beginning to invest in quantum encryption²⁸ technologies for securing sensitive military communications and data; providing fertile ground for research, development, and commercialization.
- To protect sensitive data, A&D organizations need advanced Identity and Access Management (IAM) solutions with multi-factor authentication and biometrics to ensure only authorized personnel access critical networks. This prompts innovation opportunities for solutions specifically designed for high-security environments, addressing the unique needs of defense operations.
- As autonomous systems and IoT devices become more prevalent in defense, building cyber-resilient embedded systems is crucial. These systems must detect and respond to attacks even when isolated, ensuring military assets remain secure and operational in hostile environments. Innovations in this field may include secure boot processes, self-healing capabilities, and autonomous isolation protocols.
- Blockchain technology presents an opportunity to enhance data integrity and traceability across defense supply chains. By using blockchain, defense organizations can ensure that data is immutable and verified at each stage of a product's lifecycle, from design to deployment.
- Simulation-based platforms that mimic real-world cyber threats and attacks can offer a hands-on environment for cybersecurity training. These platforms enable defense teams to practice responses to various scenarios, including malware attacks, phishing schemes, and ransomware, in a controlled setting, improving overall cybersecurity readiness.
- Developing advanced Zero Trust²⁹ solutions that can dynamically monitor, authenticate, and authorize entities based on continuously assessed security parameters is a critical

²⁸ Quantum encryption offers an unprecedented level of security by making intercepted data almost impossible to decipher without the correct quantum key.

²⁹ Zero Trust is a security model that requires strict verification for every individual and device attempting to access resources, regardless of their location within the network.

area for innovation. For the A&D sector, Zero Trust Architecture would mean enhancing security by ensuring that no network segment or user is inherently trusted.

- Platforms that facilitate cyber threat intelligence sharing between government agencies, defense companies, and technology partners offer a strategic advantage. These systems can enable secure, real-time information sharing on potential cyber threats, vulnerabilities, and attack methods.

Each of these areas provides a pathway for cybersecurity advancements that not only improve defense sector security but also have broader applications across critical infrastructure, healthcare, and other industries requiring high-security standards. This landscape of innovation holds potential for both established companies and startups to develop cutting-edge solutions and shape the future of cybersecurity.

3.2.24.5. What risks does the signal carry for the ecosystem?

The increasing reliance on digital systems, data connectivity, and advanced technologies in the Aerospace and Defense (A&D) sector heightens vulnerability to cyberattacks. As more critical assets—from communication networks to autonomous vehicles and operational control systems—are integrated into connected environments, they become prime targets for cyber adversaries. This expanded digital footprint exposes defense networks to risks such as unauthorized data access, system infiltration, malware, and ransomware attacks, potentially compromising national security and sensitive information.

The complexity and sophistication of cyber threats continue to evolve, posing a challenge for existing cybersecurity frameworks and requiring constant updates and vigilance. A successful cyberattack could disrupt essential military operations, damage critical infrastructure, and lead to significant financial and reputational losses, emphasizing the need for resilient, adaptive, and layered defense strategies to counter these risks effectively.

3.2.24.6. What challenges does the signal carry for the ecosystem?

The pace of change in cyber threats demands a proactive approach, including real-time threat intelligence, continuous training for cybersecurity teams, and adaptive strategies that can quickly respond to emerging risks. Additionally, the sector must navigate complex regulatory requirements, maintain interoperability with allied nations' defense systems, and secure vast networks of connected assets, all while balancing limited resources and budgets. Meeting these challenges requires a resilient cybersecurity infrastructure that can evolve as quickly as the threats it faces, ensuring the defense ecosystem remains secure and operational in a dynamic digital landscape.

3.2.25. Signal 25: Internet of Military Things (IoMT)³⁰

The Internet of Military Things (IoMT) is enabling autonomous decision-making systems in defense, using vast networks of devices and AI to execute decisions without human input. This shift streamlines military operations and allows for rapid responses to threats, providing a strategic advantage in time-critical situations. This speed and efficiency provide a strategic advantage, particularly in high-stakes scenarios where timing is critical, enabling forces to react faster than human operators could.

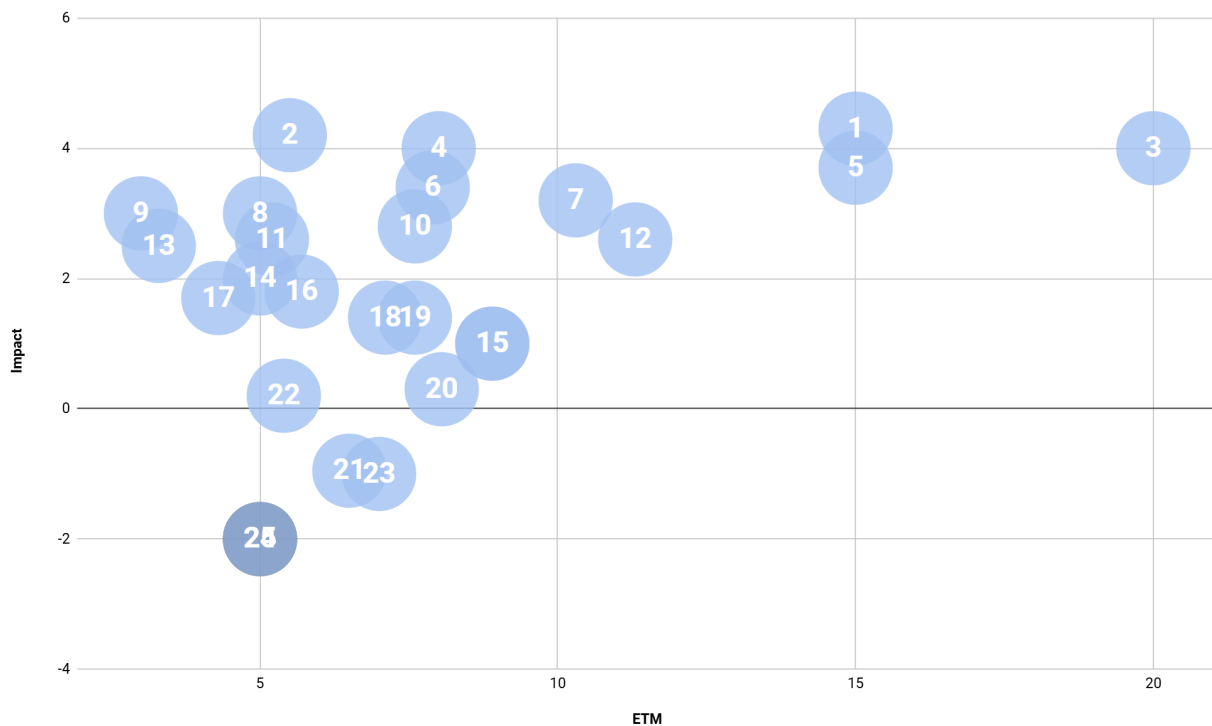
However, the rise of machine-led decisions in military contexts introduces critical challenges. The reliability of these systems depends on the quality and security of the data they receive, as

³⁰ Source: <https://www.taaltech.com/5-leading-trends-in-internet-of-military-things-iomt/>

compromised data could lead to flawed or even dangerous decisions. Ethical concerns also come into play, as decisions made by AI-driven systems in combat scenarios may lack the human judgment needed to assess moral considerations and the broader implications of action versus inaction. Balancing the benefits of autonomous systems with these risks is crucial as IoMT reshapes military technology.

3.2.25.1. ETM, IMPACT Matrix

Figure 26. Impact and ETM Analysis of Internet of Military Things (IoMT) in Aerospace & Defence.



The impact of signal 25 (Internet of Military Things (IoMT)) was estimated at -2.0. Its score of -2.0 categorizes it as a disruptor, which may negatively influence the ecosystem's development. The estimated ETM is 5.0 years, which means that the signal may fully materialize by mid-2029.

3.2.25.2. How can it change our optics?

IoMT is revolutionizing military operations by enabling real-time automation, enhancing situational awareness, and allowing for rapid responses to threats. This shift towards machine-led decisions and automated responses provides a strategic advantage but also raises cybersecurity and ethical concerns. The increased connectivity of IoMT systems demands robust cybersecurity to protect critical information. Ethical challenges arise as autonomous systems make life-or-death decisions, requiring transparency and human oversight. This technology shift challenges traditional military structures and requires a rethinking of doctrines and leadership approaches. Ensuring the reliability and resilience of automated systems is crucial, demanding redundancy and adaptability to maintain functionality in challenging situations.

3.2.25.3. How can it change the ecosystem?

IoMT is transforming the A&D ecosystem by enhancing cybersecurity, fueling economic growth, redefining ethical standards, driving educational evolution, and promoting environmental

sustainability, ultimately shaping a more resilient and technologically advanced defense landscape. In particular:

- The A&D sector faces a growing demand for robust cybersecurity measures to protect sensitive information and operational integrity. The complexity of interconnected systems also necessitates industry-wide standardization, ensuring interoperability across diverse IoT devices and platforms. This necessitates collaboration across defense contractors, tech firms, and regulatory bodies.
- IoMT is fueling economic expansion within the A&D ecosystem by driving investments in IoT, AI, and automation technologies leading to innovation and job creation. This strengthens the A&D industry's technology base, workforce and resilience.
- IoMT introduces new ethical considerations around autonomous decision-making in defense, prompting the need for transparent policies and accountability frameworks. The shift towards IoMT requires updates to educational programs and training to cultivate skills in cybersecurity, AI, and IoT within the A&D workforce.
- By enabling precise monitoring of resource use, energy consumption, and logistics, IoMT can reduce waste and optimize resource allocation, minimizing the environmental footprint of military operations. This aligns the A&D with sustainability goals.

3.2.25.4. What opportunities does the signal carry for the ecosystem?

It fosters economic growth through investments in AI, IoT, and cybersecurity, driving innovation and expanding the tech industry. IoMT also promotes skill development and advances education, preparing a workforce proficient in next-generation technologies. Furthermore, it optimizes resource management, supporting sustainability goals by reducing the environmental impact of military operations.

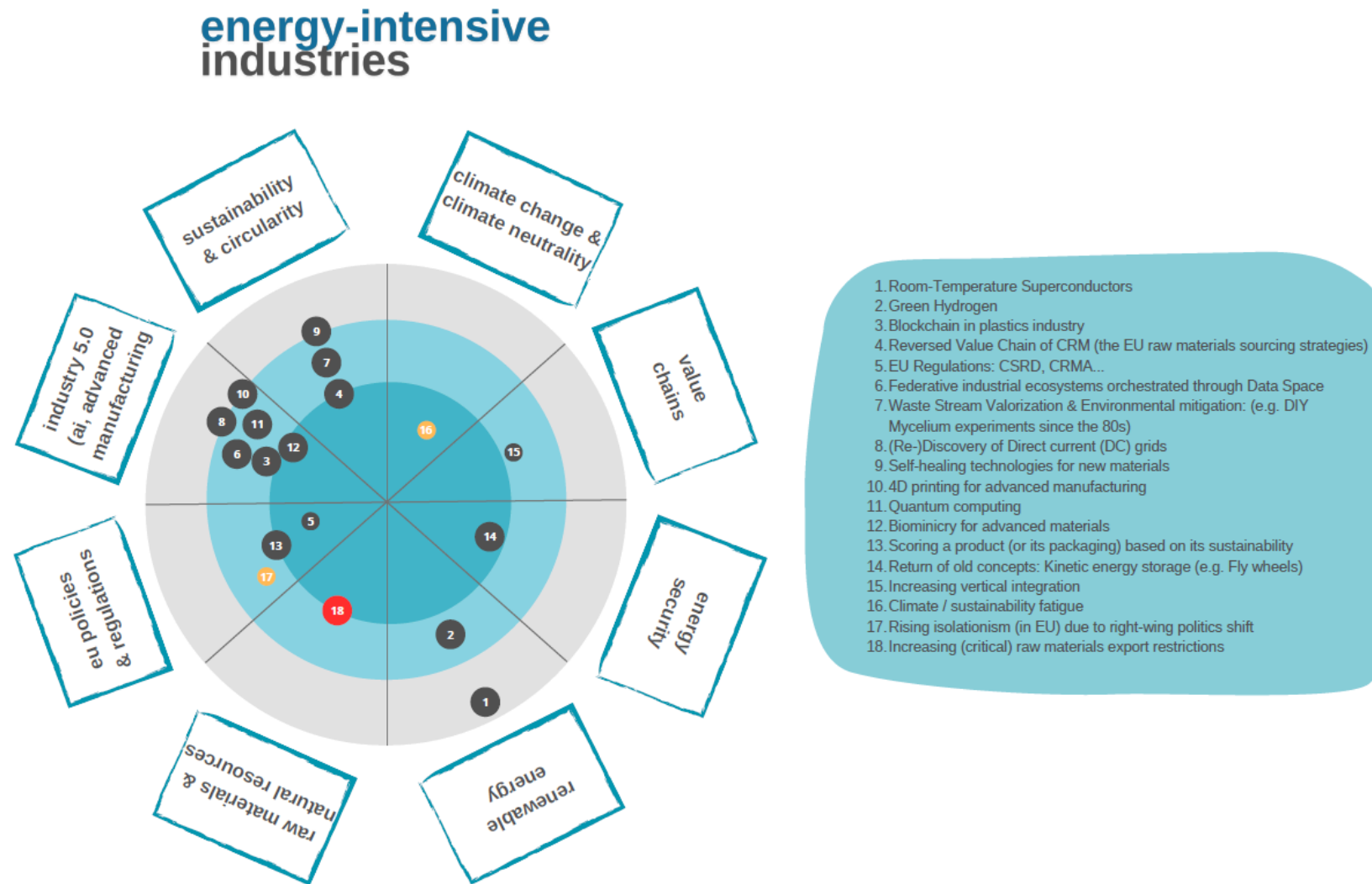
3.2.25.5. What risks does the signal carry for the ecosystem?

Increased connectivity introduces heightened cybersecurity threats, as it creates more entry points for potential attacks and data breaches. Integrating diverse IoT devices can lead to interoperability issues, highlighting the need for industry-wide standardization and collaboration. The reliance on automated decision-making systems also raises ethical concerns and risks of data overload, making advanced analytics essential for managing vast amounts of information effectively. Additionally, the high initial investment and the need for specialized technical expertise present significant barriers to widespread adoption.

3.2.25.6. What challenges does the signal carry for the ecosystem?

While autonomous decision-making systems offer advantages, they raise ethical concerns and can potentially lead to data overload. Therefore, advanced analytics are crucial for effectively managing the vast amounts of information generated by these systems.

4. Map of drivers and disruptions in Energy-Intensive Industries (EII)



5. Zooming in to examine key drivers and disruptions in EIs

The Energy-Intensive Industries (EIs) ecosystem covers chemicals, Steel, Paper, Plastics, Mining, extraction and quarrying, Refineries, Cement, Wood, Rubber, Nonferrous metals, Glass, Ceramics. They supply intermediate products to each other and to many downstream sectors of the economy, are closely integrated with energy providers as well as with the waste and recycling industries due to their need for secondary raw materials.

Energy-intensive industries play a crucial role in the European economy, employing 7.8 million people. These industries contribute significantly to the EU's value added, representing 4.55% (€549 billion). The sector comprises 548,000 companies, with an overwhelming majority (99.4%) being SMEs. This demonstrates the significant contribution of small and medium-sized enterprises to this vital sector.³¹

5.1. List of key drivers of EIs

Drivers are influential forces of changes that are currently shaping or have the capacity to shape or transform a given system. They can take on different states and thus affect a system in many ways, therefore are often called uncertainties.

EIs Focus group experts involved in the IDEALIST's Horizon Scanning identified the following key drivers of the sector: Industry 5.0 (AI, Advanced Manufacturing), EU policies and regulations, Sustainability and circularity, Climate change and climate neutrality, Value chains, Energy security, Renewable resources, Raw materials & natural resources.

5.1.1. Industry 5.0 (AI, Advanced Manufacturing)

Industry 5.0 is emerging as a transformative force within EU Energy-Intensive Industries (EIs). Building upon the foundations of Industry 4.0, it goes beyond automation and efficiency, placing human-centricity and sustainability at its core. This means leveraging advanced technologies like AI and collaborative robots (cobots) not just to optimize processes, but also to enhance worker well-being, promote environmental responsibility, and create a more resilient and adaptable industrial sector.

- Industry 5.0 envisions a future where humans and machines work together seamlessly. This involves utilizing AI-powered systems to assist workers with complex tasks, provide real-time insights, and create a safer work environment. Cobots can take over physically demanding or repetitive tasks, freeing up human workers for more creative and value-added activities.
- AI plays a crucial role in optimizing energy consumption, minimizing waste, and improving overall efficiency in EIs. Machine learning algorithms can analyze vast amounts of data to identify patterns and optimize processes in real-time, leading to significant reductions in energy use and environmental impact.
- Technologies like additive manufacturing (3D printing), digital twins, and advanced robotics enable greater flexibility and customization in production. This allows EIs to respond more effectively to changing market demands, produce highly specialized components, and minimize waste by creating only what is needed.

³¹ https://commission.europa.eu/system/files/2021-05/swd-annual-single-market-report-2021_en.pdf

- Industry 5.0 emphasizes building resilience into industrial operations, enabling EIs to better withstand disruptions like supply chain shocks or natural disasters. This involves diversifying supply chains, leveraging digital technologies for real-time monitoring and risk assessment, and adopting circular economy principles to reduce reliance on finite resources.
- The transition to Industry 5.0 requires a workforce equipped with the skills to operate and interact with advanced technologies. This necessitates investment in upskilling and reskilling initiatives to ensure workers can thrive in a human-machine collaborative environment and contribute to the digital transformation of EIs.

Industry 5.0 is not merely an incremental upgrade but a paradigm shift in how EIs operate. By embracing this human-centric and sustainable approach, the sector can enhance its competitiveness, reduce its environmental footprint, and contribute to a more prosperous and equitable society.

5.1.2. EU policies and regulations

EU policies and regulations are acting as a powerful catalyst for change within Energy-Intensive Industries (EIs). Driven by ambitious climate targets and sustainability goals, these policies are reshaping operations for EIs, encompassing a wide range of legislation aimed at reducing environmental impact and promoting innovation.

- The EU's commitment to climate neutrality requires significant emissions reductions from EIs. Policies like the ETS and CBAM incentivize decarbonization by putting a price on carbon and promoting cleaner technologies and renewables. This pushes EIs to adopt carbon capture solutions and transition towards a circular economy.
- Regulations aimed at improving energy efficiency are pushing EIs to optimize energy consumption and reduce waste. This includes implementing energy management systems, investing in energy-efficient technologies, and participating in energy audits. These requirements drive innovation in process optimization, waste heat recovery, and digital technologies for energy monitoring.
- Growing concerns about resource scarcity are leading to policies that promote resource efficiency and sustainable material use. This includes regulations on waste management, extended producer responsibility, and eco-design. EIs are responding by adopting circular economy principles, optimizing supply chains, and exploring alternative materials.
- The EU's Industrial Strategy aims to strengthen European industry's competitiveness while promoting its green transformation. This involves supporting innovation and fostering a level playing field for EIs. These policies encourage investment in R&D, adoption of advanced manufacturing technologies, and participation in collaborative projects.
- EU policies emphasize the social dimension of the green transition, ensuring fairness and inclusivity. This includes initiatives to support workers, promote social dialogue, and ensure equitable benefit sharing. EIs are increasingly expected to demonstrate social responsibility by investing in their workforce and engaging with communities.

EU policies and regulations are not merely constraints but catalysts for change within EIs. By providing a clear framework and incentives for sustainable development, these policies are shaping the future of the sector, driving its transition towards a cleaner, more efficient, and globally competitive industry.

5.1.3. Sustainability and circularity

Sustainability and circularity are core principles driving a profound transformation within EU Energy-Intensive Industries (EIs). Growing environmental awareness and stricter regulations are pushing these industries to minimize their impact, optimize resource use, and contribute to a circular economy.

- EIs are increasingly focused on optimizing their use of raw materials and energy. This involves implementing resource-efficient technologies, minimizing waste through process optimization, and adopting closed-loop systems where waste is a valuable resource. This reduces environmental impact and enhances competitiveness.
- The transition to a circular economy is a key priority for EIs. This involves moving away from linear models towards closed-loop systems that prioritize reuse, remanufacturing, and recycling. EIs are designing products for disassembly, collaborating to optimize resource flows, and investing in waste valorization technologies.
- The use of renewable energy is closely linked to sustainability in EIs. By transitioning to renewables, these industries can reduce reliance on fossil fuels and contribute to climate neutrality. This involves investing in on-site generation, participating in power purchase agreements, and adapting processes to accommodate renewable sources.
- EIs are adopting a life cycle perspective, considering the environmental impacts of their products throughout their entire life cycle. This involves conducting life cycle assessments, identifying hotspots of impact, and implementing strategies to minimize these impacts at each stage.
- Transparency and stakeholder engagement are increasingly important for EIs. This involves actively engaging with customers, suppliers, and communities to build trust and collaborate on sustainable solutions. EIs are also increasingly expected to report on their environmental performance.

Sustainability and circularity are a fundamental shift in how EIs operate. By embracing these principles, the sector can enhance its competitiveness and reduce its environmental footprint. This transition requires continuous innovation and a commitment to responsible practices.

5.1.4. Climate change and climate neutrality

Climate change and the urgent need for climate neutrality are driving major transformations within EU Energy-Intensive Industries (EIs). These industries face increasing pressure to decarbonize, adopt sustainable practices, and contribute to the EU's climate goals.

- Achieving climate neutrality requires EIs to drastically reduce their carbon footprint. This involves transitioning away from fossil fuels towards renewables, improving energy efficiency, and implementing CCUS technologies. EIs are exploring electrification, hydrogen use, and bio-based feedstocks.

- Improving energy efficiency is crucial for reducing emissions. EIs are investing in advanced process technologies, optimizing operations to minimize energy consumption, and implementing energy management systems for real-time monitoring. This focus on efficiency reduces environmental impact and lowers costs.
- Circular economy principles are closely aligned with climate neutrality goals. By minimizing waste and maximizing resource utilization, EIs can reduce their reliance on virgin materials and lower their environmental footprint. This involves implementing strategies for waste prevention, reuse, and recycling.
- Technological innovation is key to enabling EIs to achieve climate neutrality. This includes R&D in renewable energy, energy storage, CCUS, and sustainable materials. EIs are collaborating to accelerate the development of innovative solutions for decarbonization.
- EIs need to adapt to the impacts of climate change to ensure resilience. This involves assessing climate-related risks, implementing adaptation measures to protect infrastructure, and developing strategies to manage extreme weather events and resource scarcity.

Climate change and the pursuit of climate neutrality are fundamentally reshaping EIs. By embracing sustainable practices and investing in innovation, these industries can contribute to a cleaner, more resilient European economy.

5.1.5. Value chains

The evolution of value chains is reshaping EU Energy-Intensive Industries (EIs). Globalization, digitalization, and sustainability pressures are driving these industries to adapt and optimize their positions within increasingly complex networks.

- EIs are seeking greater control over their value chains through vertical integration and closer relationships with suppliers and customers. This allows for better coordination and resilience. Collaboration is also essential, with EIs partnering to share knowledge and optimize resource flows.
- Digital technologies are transforming value chains, enabling greater transparency and efficiency. EIs are leveraging data analytics to gain operational insights, optimize processes, and make informed decisions. This includes implementing digital platforms for supply chain management and using AI to analyze data.
- Circular economy principles are being integrated into value chains. EIs are focusing on minimizing waste, maximizing resource utilization, and extending product lifecycles. This involves designing for disassembly, implementing closed-loop systems, and collaborating to recover materials.
- Consumers demand sustainable products. EIs are responding with traceability systems to track the origin and impact of their materials. This enhances transparency and allows EIs to demonstrate their commitment to responsible sourcing.
- Global value chains are vulnerable to disruptions. EIs are strengthening resilience by diversifying supply chains, implementing risk management strategies, and leveraging digital technologies to monitor and respond to potential disruptions.

Evolving value chains present both challenges and opportunities for EIs. By adapting, embracing digital technologies, and prioritizing sustainability, these industries can enhance their competitiveness and contribution to a circular economy.

5.1.6. Energy security

Energy security is paramount for EU Energy-Intensive Industries (EII), shaping their strategies and operations. Reliable access to affordable energy is crucial for competitiveness. This driver encompasses efforts to diversify energy sources, enhance efficiency, and ensure resilience.

- Reducing reliance on single suppliers and volatile fossil fuel markets is key. EII are diversifying their energy mix by increasing renewable sources like solar and wind. This involves investing in on-site generation and supporting renewable energy infrastructure.
- Improving energy efficiency is crucial for cost reduction and energy security. EII are implementing energy management systems, investing in efficient technologies, and optimizing processes to minimize energy consumption. This reduces reliance on external sources and lowers costs.
- A reliable energy infrastructure is essential. EII are investing in modernizing their infrastructure, including grid upgrades, energy storage, and demand-side management. This enhances their ability to manage fluctuations in supply and demand, ensuring operational continuity.
- Technological advancements are vital for energy security. EII are supporting the development of smart grids, advanced energy storage, and energy management platforms. These technologies enable greater flexibility and efficiency within their energy systems.
- A supportive policy framework is crucial. EII are engaging with policymakers to advocate for policies that promote energy diversification, support investments in efficiency and renewables, and ensure a stable energy market.

Energy security is a multifaceted challenge with significant implications for EII. By addressing this challenge through diversification, efficiency, and innovation, these industries can enhance their resilience and competitiveness.

5.1.7. Renewable energy

The rise of renewable energy is profoundly impacting EU Energy-Intensive Industries (EII). Driven by climate concerns, falling costs, and technological advancements, renewables are becoming increasingly integrated into industrial energy consumption. This requires EII to adapt, innovate, and invest in new infrastructure and technologies.

- Renewable energy sources like solar, wind, hydro, and biomass offer a pathway for EII to significantly reduce their greenhouse gas emissions and contribute to climate neutrality. This involves transitioning from fossil fuels to renewable energy for electricity generation, process heat, and transportation.
- Increasing reliance on renewable energy sources enhances energy independence and reduces vulnerability to volatile global fossil fuel markets. This provides greater price stability and protects EII from geopolitical risks associated with energy imports.
- The renewable energy sector is a hotbed of innovation, driving the development of new technologies and business models. EII are investing in on-site renewable energy generation, participating in power purchase agreements, and exploring innovative solutions like green hydrogen production and energy storage.

- Integrating variable renewable energy sources like solar and wind requires grid modernization and investments in energy storage and smart grid technologies. EIs are actively participating in these efforts to ensure a reliable and stable energy supply.
- The transition to renewable energy creates new business opportunities for EIs. This includes developing expertise in renewable energy technologies, partnering with renewable energy developers, and exploring new markets for green products and services.

Renewable energy is not just an alternative energy source but a key enabler of a sustainable and competitive future for EIs. By embracing renewables, these industries can reduce their environmental impact, enhance their energy security, and unlock new opportunities for innovation and growth.

5.1.8. Raw materials & natural resources

The availability and sustainable management of raw materials are critical for EU Energy-Intensive Industries (EIs). These industries face challenges like price volatility and growing environmental concerns associated with resource extraction.

- EIs are focused on optimizing raw material use and minimizing waste. This involves implementing resource-efficient technologies, adopting circular economy models, and designing products for durability and recyclability. By maximizing resource productivity, EIs can reduce their environmental impact and enhance competitiveness.
- Ensuring responsible sourcing is a growing priority. This involves diversifying supply chains, tracing material origins, and engaging with suppliers to promote sustainable practices. Building resilient supply chains that can withstand disruptions is also crucial.
- Exploring alternative materials and innovative production can reduce reliance on critical raw materials. EIs are investing in R&D to identify substitutes and exploring new technologies like 3D printing for more efficient material use.
- EIs are expected to demonstrate responsible practices throughout their value chains. This includes minimizing the environmental impact of resource extraction, ensuring worker safety, and respecting the rights of local communities.
- A supportive policy framework is crucial for promoting sustainable raw material management. EIs are engaging with policymakers to advocate for policies that encourage resource efficiency and responsible sourcing.

Responsible raw material management is essential for the long-term sustainability of EIs. By embracing resource efficiency and sustainable sourcing, these industries can contribute to a more circular economy.

5.2. List of key disruptions in EIs

EIs Focus group experts involved in the IDEALIST's Horizon Scanning identified key signals that will shape the future of the sector. **Signals** are early indications that disruptive change could be underway.

Experts assessed each signal using two metrics:

- **Earliest Time to Mainstream (ETM):** this measures the minimum time needed for a signal to become mainstream defined as the point of peak impact on the ecosystem. Assessments ranged from 2 to 20 years in the future.
- **Impact** describes the nature (positive or negative) and the level of the signal's estimated impact on the ecosystem, using a scale of -5 to +5.

These assessments made it possible to identify signals of change as potential **disruptors**, indicating substantial shifts within the study area. A signal is classified as a potential disruptor if its impact receives a score below -1 or above +1. This scoring system uses negative values to represent adverse effects and positive values for beneficial effects on the industrial ecosystem. A signal with a score of -4 or lower, or +4 or higher, is categorized as a potential hyperdisruptor, indicating a potential for extreme disruption, whether positive or negative.

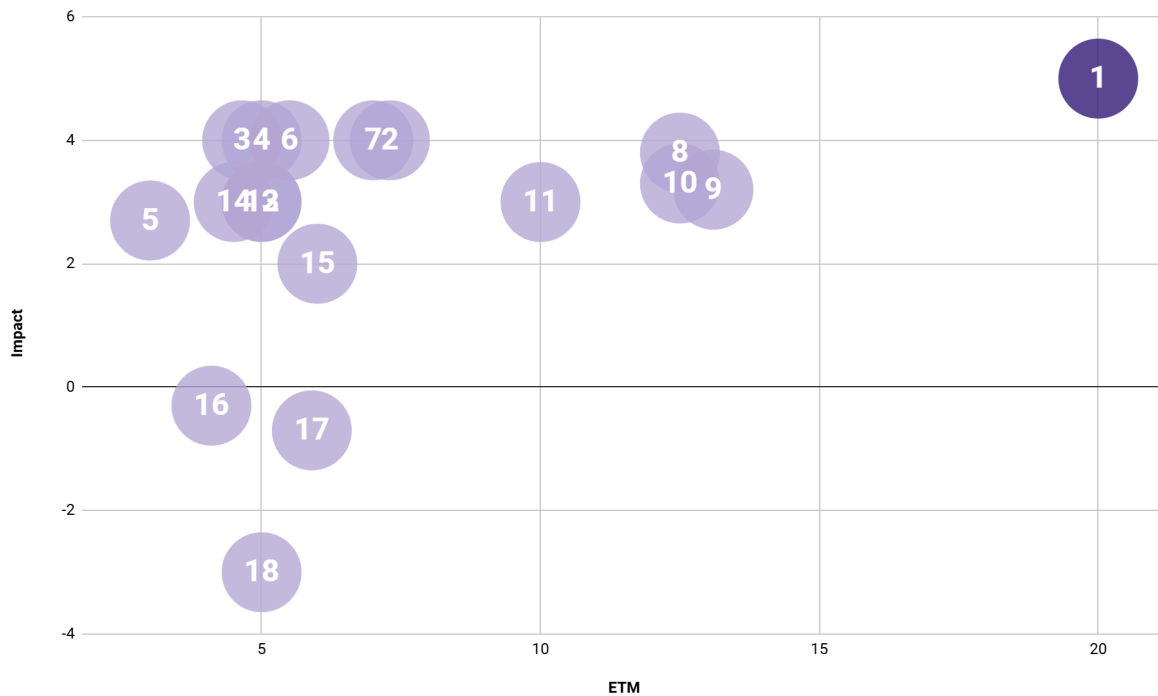
5.2.1. Signal 1: Room-Temperature Superconductors³²

Superconductors are materials that can have loss-free electrical currents and thus pose the possibility of loss-free energy transport over great distances. The Superconducting state for all materials presently known is bound to temperatures far below 0°C in the cryogenic regime. Through research efforts more and more materials exhibiting superconduction at elevated temperatures have been discovered and superconduction at room-temperature does not seem impossible anymore.

5.2.1.1. ETM, IMPACT matrix

³² Source: https://en.wikipedia.org/wiki/Room-temperature_superconductor
<https://www.digitaltrends.com/computing/why-room-temperature-superconductors-are-a-big-deal/>
<https://theconversation.com/room-temperature-superconductors-could-revolutionize-electronics-an-electrical-engineer-explains-the-materials-potential-201849>

Figure 27. Impact and ETM Analysis of Internet of Room-Temperature Superconductors in Energy-Intensive Industries.



The impact of signal 1 (Room-Temperature Superconductors) was estimated at 5. Its score of 5 categorizes it as a hyperdisruptor, which may positively influence the ecosystem's development. The estimated ETM is 20 years, which means that the signal may fully materialize by mid-2044.

5.2.1.2. How can it change our optics?

The discovery of room-temperature superconductors would mark a technological breakthrough, that many technologies of today would be rendered obsolete. Therefore, this possibility holds many implications of unforeseen scope in the energy sector.

5.2.1.3. How can it change the ecosystem?

The significance of room-temperature superconductors lies mainly in the fact of loss-free electrical energy transport. This would be particularly interesting for transporting energy from desert solar parks or offshore windparks to big cities hundreds of kilometres away. Additionally, if fully developed and integrated to a future superconducting electrical grid, this would render many emerging technologies for energy transportation (H2, batteries, ...) potentially obsolete.

5.2.1.4. What opportunities does the signal carry for the ecosystem?

Room-temperature superconductors offer transformative opportunities for EIs by enabling loss-free energy transport. This breakthrough allows for the decoupling of energy creation and consumption locations, facilitating the efficient transmission of renewable energy over long distances. EIs could access remote renewable sources, optimize energy distribution networks, and potentially reduce reliance on localized fossil fuel-based generation. This enhanced flexibility and efficiency in energy transmission could significantly reshape the landscape of energy-intensive industries.

5.2.1.5. What risks does the signal carry for the ecosystem?

While promising, room-temperature superconductors also pose risks to the EIs ecosystem. Their potential to render existing energy transport technologies obsolete could disrupt established business sectors focused on hydrogen, liquid gas, and other energy carriers. This disruption could lead to significant economic losses, job displacement, and stranded assets in industries heavily invested in conventional energy transport infrastructure. EIs heavily reliant on these technologies may face challenges adapting to this rapid shift, requiring strategic planning and investment in new infrastructure and skills.

5.2.1.6. What challenges does the signal carry for the ecosystem?

Room-temperature superconductors present significant challenges for the EIs ecosystem. The discovery and development of these materials require extensive research and investment, with uncertain timelines and potentially high costs. Even if successfully developed, the final material cost and the expenses associated with integrating them into a new energy grid infrastructure could be substantial. EIs will need to carefully assess the economic feasibility and potential return on investment before committing to large-scale adoption of this potentially disruptive technology.

5.2.2. Signal 2: Green Hydrogen³³

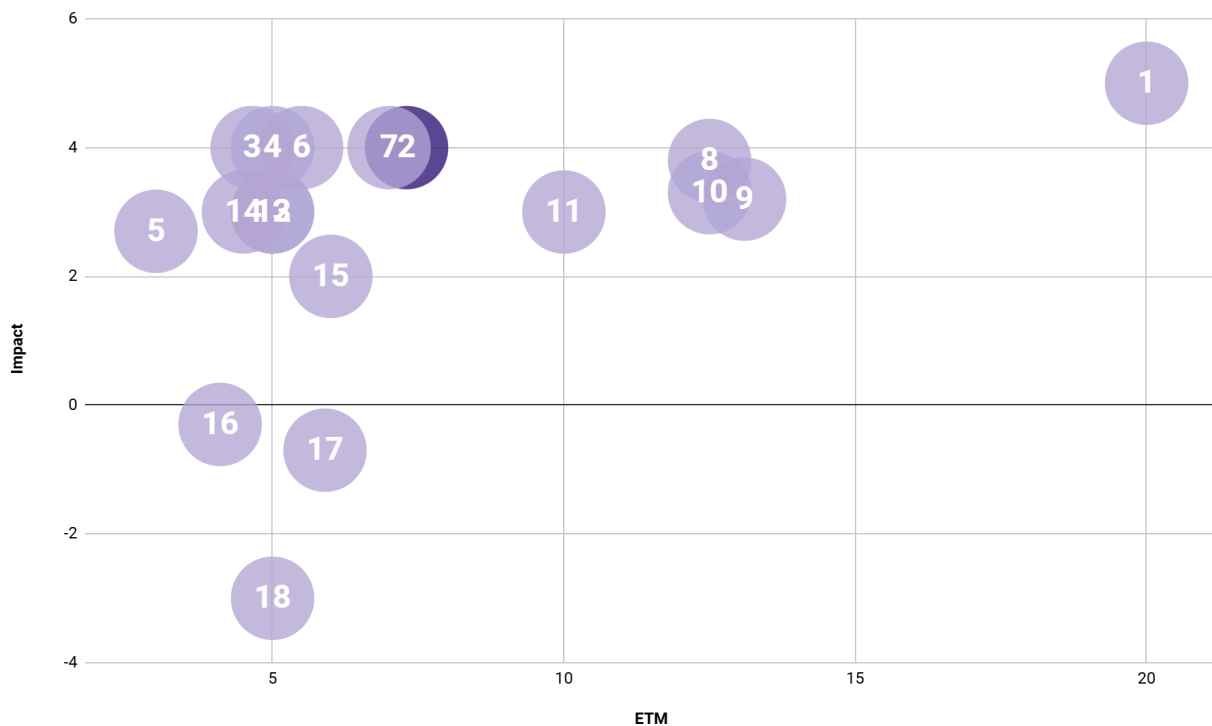
The European Commission's hydrogen strategy defines renewable hydrogen as hydrogen produced through the electrolysis of water powered by electricity from renewable sources or through the reforming of biogas or biochemical conversion of biomass.

³³ Source:

<https://www.forbes.com/sites/sap/2023/10/04/energy-intensive-industries-lead-the-charge-to-green-hydrogen-economy/#:~:text=Energy%2DIntensive%20Industries%20Lead%20The%20Charge%20To%20Green%20Hydrogen%20Economy.-Susan%20Galer&text=Energy%2Dintensive%20industries%20like%20chemicals,creating%20a%20green%20hydrogen%20economy.>

5.2.2.1. Matrix figure (ETM, IMPACT, SOURCE)

Figure 28. Impact and ETM Analysis of Green Hydrogen in Energy-Intensive Industries.



The impact of signal 2 (Green Hydrogen) was estimated at 4. Its score of 4 categorizes it as a hyperdisruptor, which may positively influence the ecosystem's development. The estimated ETM is 7.3 years, which means that the signal may fully materialize by mid-2031.

5.2.2.2. How can it change our optics?

Green hydrogen can transform our perception of the future ecosystem by offering a viable, sustainable solution for decarbonizing hard-to-electrify industries, thus significantly reducing carbon emissions and promoting a cleaner, greener planet.

5.2.2.3. How can it change the ecosystem?

Green hydrogen can support sustainable industrial processes, positively impacting the ecosystem. Its relevance lies in decarbonizing hard-to-electrify sectors and providing energy storage solutions. If scaled up, it could revolutionise energy systems, drive economic growth, and significantly reduce reliance on fossil fuels.

5.2.2.4. What opportunities does the signal carry for the ecosystem?

Green hydrogen offers significant opportunities for EILs, increasing ecosystem resilience and generating positive economic impacts. Its potential as a clean energy carrier and feedstock can decarbonize energy-intensive processes, reduce reliance on fossil fuels, and stimulate growth in new sectors like hydrogen production and storage. This transition can create jobs, attract investment, and enhance the long-term sustainability of energy-intensive industries.

5.2.2.5. What risks does the signal carry for the ecosystem?

Despite its potential, green hydrogen poses risks, particularly regarding high water consumption. Large-scale hydrogen production through electrolysis requires substantial water resources, potentially straining water availability in certain regions and raising concerns about environmental impact. EIs must carefully consider water management strategies and prioritize sustainable sourcing to mitigate these risks.

5.2.2.6. What challenges does the signal carry for the ecosystem?

The widespread adoption of green hydrogen faces challenges related to technical readiness. While promising, the technology for efficient and cost-effective production, storage, and transportation of hydrogen requires further development and scaling up. EIs need to invest in research and innovation, address infrastructure gaps, and overcome cost barriers to fully realize the potential of green hydrogen.

5.2.3. Signal 3: Blockchain in plastics industry³⁴

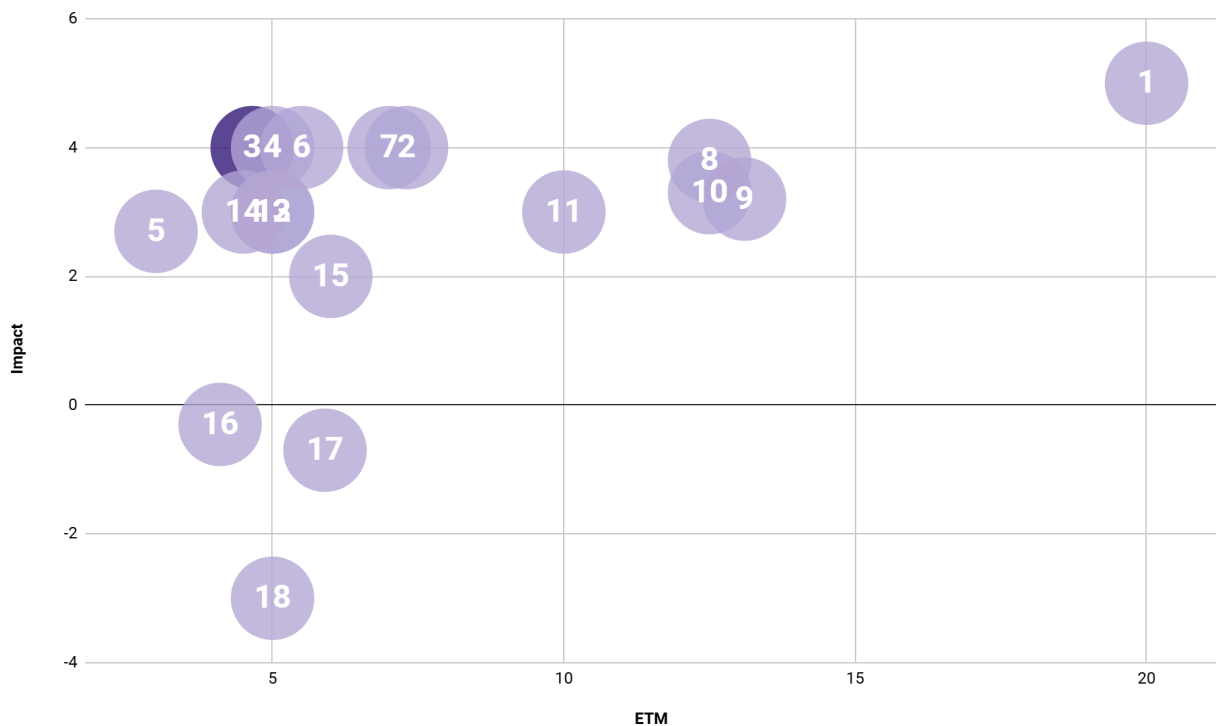
Blockchain technology can be used to create a digital, tamper-proof record of the origin, composition, and processing history of plastic materials. This "watermark" can be used to track plastics throughout their lifecycle, incentivize recycling, and ensure the responsible disposal of plastic waste. By providing transparency and accountability, blockchain can help to promote a circular economy for plastics, reducing waste and environmental pollution.

³⁴ Source:

<https://www.sciencedirect.com/science/article/abs/pii/S0013935122009586#:~:text=Blockchain%20can%20support%20a%20circular,and%20support%20closed%2Dloop%20recycling.>

5.2.3.1. Matrix figure (ETM, IMPACT)

Figure 29. Impact and ETM Analysis of Blockchain in plastics industry in Energy-Intensive Industries.



The impact of signal 3 (Blockchain in plastics industry) was estimated at 4. Its score of 4 categorizes it as a hyperdisruptor, which may positively influence the ecosystem's development. The estimated ETM is 4.65 years, which means that the signal may fully materialize by mid-2029.

5.2.3.2. How can it change our optics?

By providing transparency into the origin and journey of materials, blockchain can empower consumers to make informed choices, fostering trust and accountability within the industry. This increased transparency can also help eliminate fraud and counterfeiting, ensuring the authenticity and quality of plastic products. Furthermore, it supports environmental responsibility by enabling the tracking of recycled content and promoting responsible sourcing practices, ultimately contributing to a more sustainable and circular plastics economy.

5.2.3.3. How can it change the ecosystem?

Integrating blockchain into the plastics industry can transform the ecosystem by improving transparency, traceability and efficiency. It facilitates a circular economy by optimising recycling and reducing plastic waste, while reducing costs and increasing consumer confidence. By revolutionising supply chains and business models, blockchain can encourage more sustainable practices and attract investment, while posing regulatory challenges and disrupting traditional plastics industry models.

5.2.3.4. What opportunities does the signal carry for the ecosystem?

Blockchain technology offers significant opportunities for the plastics industry, particularly in enhancing transparency and traceability within complex supply chains. By providing an immutable record of material flows, blockchain can help verify the origin and composition of plastics, facilitating responsible sourcing and recycling. This increased transparency can boost consumer confidence, reduce disputes among stakeholders, and simplify stock management and regulatory compliance, ultimately contributing to a more sustainable and circular plastics economy.

5.2.3.5. What risks does the signal carry for the ecosystem?

Despite its potential, blockchain implementation in the plastics industry carries certain risks. High implementation costs, technological complexity, and potential confidentiality and security issues are major concerns. Additionally, unclear or inappropriate regulations could hinder the widespread adoption of blockchain technology, potentially stifling innovation and collaboration within the industry. A careful assessment of these risks and proactive mitigation strategies are crucial for successful blockchain integration.

5.2.3.6. What challenges does the signal carry for the ecosystem?

Several challenges need to be addressed for successful blockchain adoption in the plastics industry. Overcoming technical hurdles like scalability, interoperability, and data security is essential to ensure the efficient and reliable functioning of blockchain-based systems. Establishing clear industry standards and guidelines for using blockchain will promote consistency and interoperability across different platforms and stakeholders. Finally, implementing robust data privacy and security measures is crucial to protect sensitive information and maintain trust within the blockchain network.

5.2.4. Signal 4: Reversed Value Chain of CRM (the EU raw materials sourcing strategies)³⁵

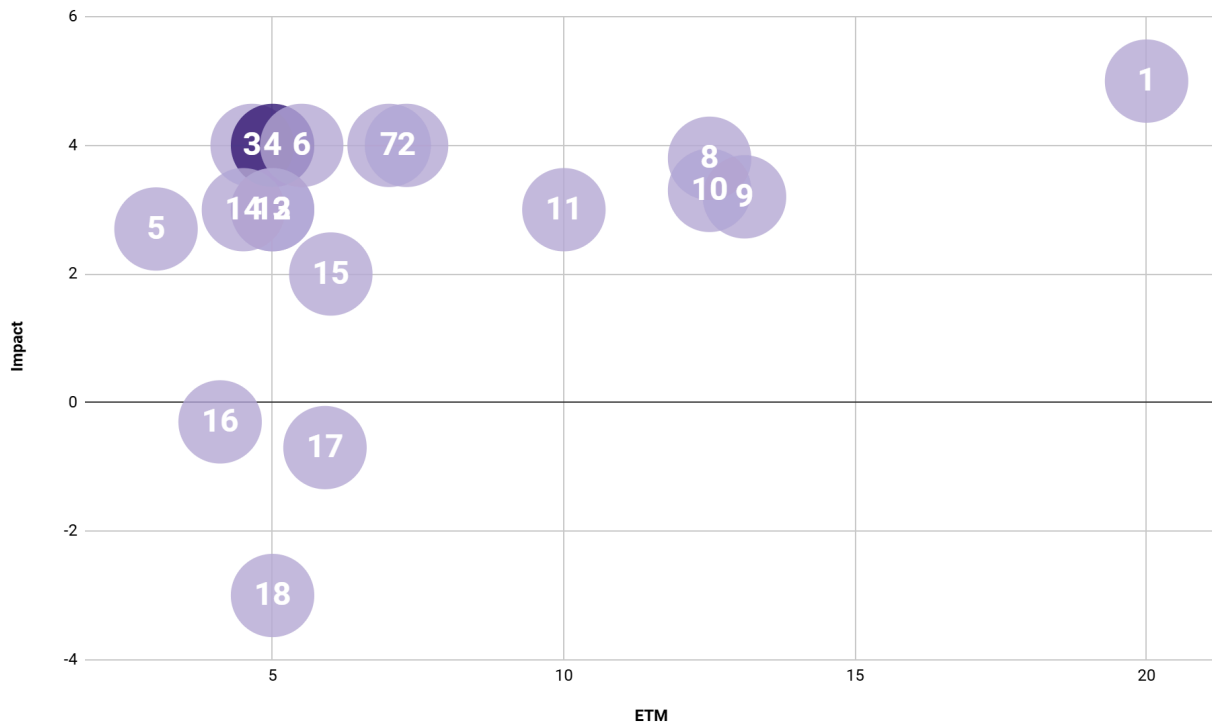
Reversed Value Chain of CRM in the EU focuses on securing access to critical raw materials by prioritising domestic sourcing and processing within the EU. This strategy aims to reduce reliance on imports and promote sustainable practices by emphasising the recovery and recycling of CRMs from waste streams, such as those generated by WEEE (Waste from Electrical and Electronic Equipment). By prioritising the "end-of-life" stage of products and promoting circularity, the EU aims to ensure a more resilient and environmentally responsible supply of critical raw materials.

³⁵ Source:

https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en
https://environment.ec.europa.eu/topics/waste-and-recycling/waste-electrical-and-electronic-equipment-weee_en

5.2.4.1. Matrix figure (ETM, IMPACT)

Figure 30. Impact and ETM Analysis of Reversed Value Chain of CRM (the EU raw materials sourcing strategies) in Energy-Intensive Industries.



The impact of signal 4 (Reversed Value Chain of CRM (the EU raw materials sourcing strategies)) was estimated at 4. Its score of 4 categorizes it as a hyperdisruptor, which may positively influence the ecosystem's development. The estimated ETM is 5 years, which means that the signal may fully materialize by mid-2029.

5.2.4.2. How can it change our optics?

This approach reframes "waste" as a valuable resource for critical raw materials, encouraging energy-intensive industries to prioritize recycling and recovery. By extracting valuable materials from waste streams, such as those from WEEE, these industries can reduce their reliance on energy-intensive primary production and contribute to a more resilient raw materials supply chain. This shift not only lessens environmental impact but also enhances energy security and economic competitiveness by reducing dependence on imports and price volatility.

5.2.4.3. How can it change the ecosystem?

By emphasising the recovery and recycling of critical raw materials from waste streams, this approach can attract investment in new technologies and infrastructure within the raw materials sector, fostering innovation and growth in the EIs ecosystem. Developing the reverse value chain creates opportunities for new stakeholders, such as recycling and refining companies, to play a crucial role in the EIs ecosystem, potentially leading to new business models and partnerships. This shift towards a circular economy can transform the EIs ecosystem by promoting resource efficiency, reducing waste, and enhancing the long-term sustainability of energy-intensive industries.

5.2.4.4. What opportunities does the signal carry for the ecosystem?

The "Reversed Value Chain of CRM" coupled with IoT and blockchain technologies can create a transparent and traceable system for tracking recycled critical raw materials, increasing confidence in their quality and security for EIs manufacturers. This enhanced transparency can justify potentially higher prices for recycled materials, making them a more attractive and competitive option compared to primary raw materials. Ultimately, this can incentivize greater investment in recycling infrastructure and innovation within the EIs ecosystem, driving sustainable practices and reducing reliance on environmentally damaging primary extraction.

5.2.4.5. What risks does the signal carry for the ecosystem?

Focusing on recovering raw materials rather than whole components could lead to a loss of valuable materials and diminish the overall economic value of the recycling process for the EIs ecosystem. If recycled critical raw materials are not processed to the highest standards, the performance of components made from them could be compromised, potentially hindering the efficiency and reliability of EIs systems. Additionally, if the EU's recycling infrastructure and technologies lag behind those in countries like the U.S. and China, it could create a competitive disadvantage for the EIs ecosystem in terms of cost and material quality.

5.2.4.6. What challenges does the signal carry for the ecosystem?

Implementing the "Reversed Value Chain of CRM" requires sophisticated decision-making processes to determine the optimal stage for material recovery, whether it's reuse, recycling, or restoration, posing a challenge for the EIs ecosystem. This necessitates the development of robust assessment systems and infrastructure to effectively categorise and process materials, ensuring efficient resource utilisation and minimising waste. Furthermore, integrating these smart processes within the existing EIs ecosystem may require significant adjustments and investments in new technologies and expertise.

5.2.5. Signal 5: EU Regulations: CSRD, CRMA³⁶

CSRD - Corporate Sustainability Reporting Directive: The CSRD mandates that companies publicly disclose detailed information about their sustainability performance, including environmental, social, and governance (ESG) factors. This directive aims to increase transparency and accountability, enabling stakeholders to assess a company's impact on the environment and society. By requiring standardized reporting, the CSRD helps investors, consumers, and other stakeholders make informed decisions and encourages companies to prioritize sustainability in their operations.

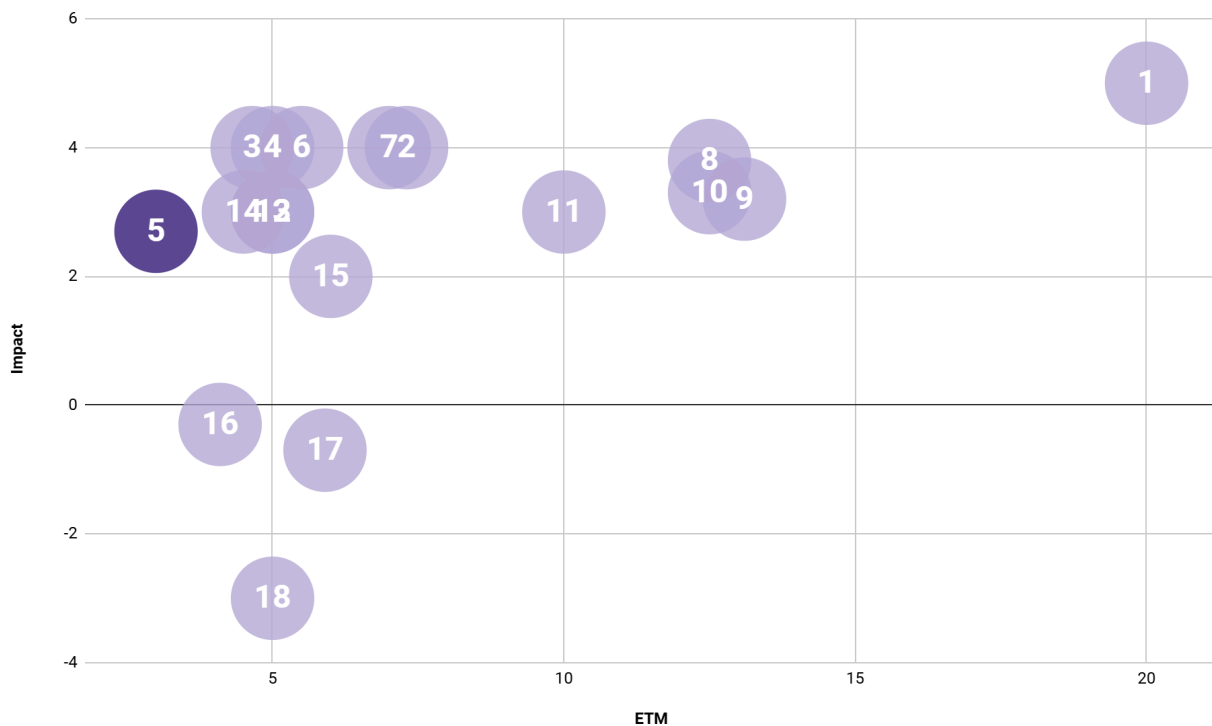
CRMA - Critical Resources Material Act: introduces requirements for recycled content in products containing critical raw materials, incentivizing recycling and reducing reliance on primary raw materials. This act is crucial for ensuring the EU's resilience and competitiveness in strategic sectors while minimizing the environmental and social impacts of raw material extraction and use.

³⁶ Source:

https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials/critical-raw-materials-act_en
https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en

5.2.5.1. Matrix figure (ETM, IMPACT)

Figure 31. Impact and ETM Analysis of EU Regulations: CSRD, CRMA in Energy-Intensive Industries.



The impact of signal 5 (EU Regulations: CSRD, CRMA) was estimated at 2.7. Its score of 2.7 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 3 years, which means that the signal may fully materialize by mid-2027.

5.2.5.2. How can it change our optics?

The EU regulations CSRD and CRMA can significantly shift perspectives by emphasizing corporate sustainability and responsible sourcing. This increased focus can drive investments in sustainable technologies and practices, enhancing transparency and accountability within value chains. Stakeholders will likely place greater importance on environmental and social performance, leading to a more holistic evaluation of companies and their impact.

5.2.5.3. How can it change the ecosystem?

These regulations can reshape the ecosystem by promoting the development of novel technologies and circular economy systems to reduce reliance on critical raw materials. However, they could also lead to unintended consequences, such as shifting raw material supply to regions with lower environmental and social standards. Supply chains will require thorough verification and due diligence to ensure compliance and mitigate potential risks.

5.2.5.4. What opportunities does the signal carry for the ecosystem?

The regulations offer opportunities for improved sustainability performance and increased transparency across industries. They can drive innovation in sustainable technologies, processes, and business models, fostering a more competitive and resilient ecosystem. By promoting

responsible sourcing and circularity, these regulations can contribute to a more sustainable and equitable economy.

5.2.5.5. What risks does the signal carry for the ecosystem?

The regulations also carry risks, such as increased compliance costs for businesses, particularly SMEs. There's a potential for greenwashing, where companies may exaggerate their sustainability efforts to comply with regulations without genuine commitment. Additionally, stringent regulations could create a competitive disadvantage for European businesses compared to those operating in regions with less stringent standards.

5.2.5.6. What challenges does the signal carry for the ecosystem?

Implementing these regulations presents challenges, including developing standardized reporting frameworks and ensuring data accuracy and reliability. Balancing the regulatory burden with flexibility for businesses to innovate and adapt is crucial. Providing adequate support to SMEs in meeting compliance requirements is essential to avoid disproportionate impacts on smaller businesses.

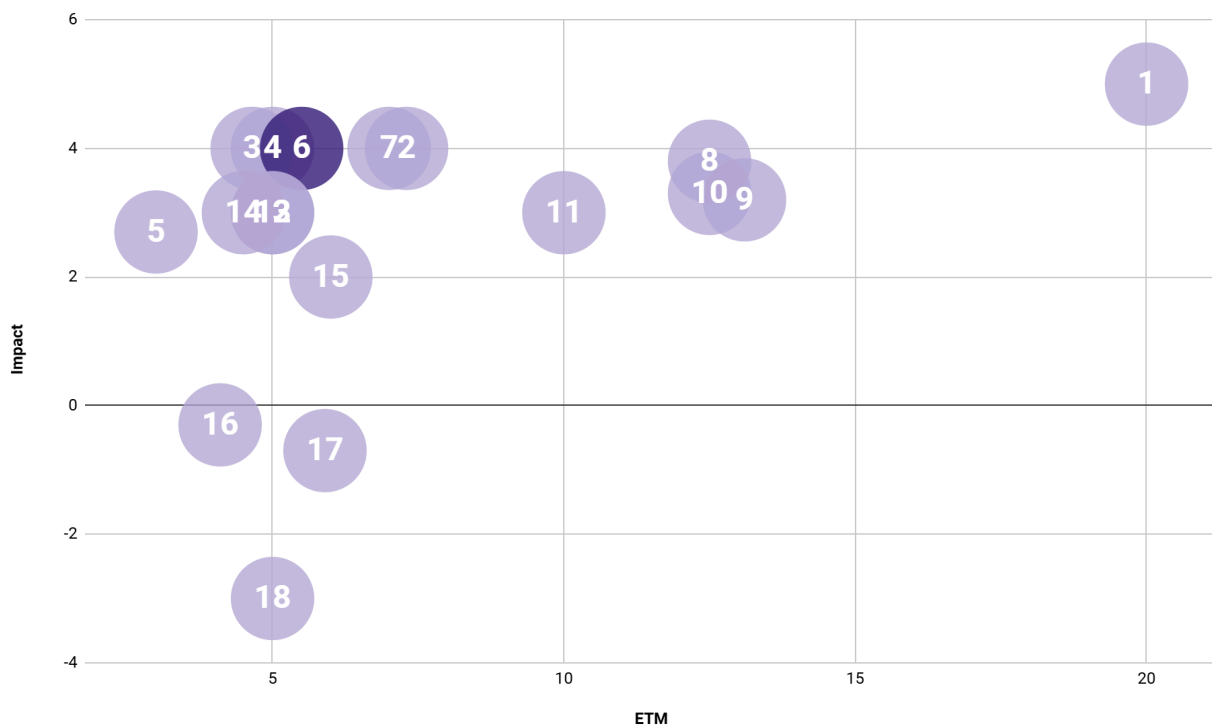
5.2.6. Signal 6: Federative industrial ecosystems orchestrated through Data Space³⁷

Federative industrial ecosystems orchestrated through Data Spaces refer to a collaborative model where different companies and organisations within an industry share data and resources in a secure and controlled manner. This approach leverages data spaces, which are virtual environments that facilitate data sharing and collaboration while ensuring data sovereignty, security, and trust. In the context of energy-intensive industries, this could involve sharing data on energy consumption, production processes, and emissions to optimise resource utilisation, improve efficiency, and drive innovation in clean technologies.

³⁷ Source: https://www.researchgate.net/publication/382889196_Industrial_data_ecosystems_and_data_spaces

5.2.6.1. Matrix figure (ETM, IMPACT)

Figure 32. Impact and ETM Analysis of Federative industrial ecosystems orchestrated through Data Space in Energy-Intensive Industries.



The impact of signal 6 (Federative industrial ecosystems orchestrated through Data Space) was estimated at 4. Its score of 4 categorizes it as a hyperdisruptor, which may positively influence the ecosystem's development. The estimated ETM is 5.5 years, which means that the signal may fully materialize by mid-2030.

5.2.6.2. How can it change our optics?

- It shifts attention towards collaborative innovation and data-driven optimization in energy-intensive industries
- It underlines the importance of data sovereignty and security in industrial collaboration.
- It brings a new element to the discussion about the role of digital technologies in the decarbonizing industry.
- It facilitates the understanding of a potential change in industry collaboration and competition.

5.2.6.3. How can it change the ecosystem?

- The development of secure data sharing platforms, data analytics tools, and AI applications for optimising energy consumption and emissions in industrial processes.
- Federative ecosystems can lead to increased efficiency, cost savings, and improved competitiveness for companies by enabling data-driven optimization and collaborative innovation.
- Federative ecosystems can accelerate the development and adoption of clean technologies.

- Federative ecosystems can contribute to decarbonizing energy-intensive industries by facilitating the sharing of best practices, promoting the adoption of energy-efficient technologies, and enabling data-driven optimization of industrial processes.

5.2.6.4. What opportunities does the signal carry for the ecosystem?

- Accelerated innovation and adoption of clean technologies, leading to faster progress in decarbonizing energy-intensive industries.
- Improved efficiency and cost savings, reduce waste, and optimise resource utilisation, leading to cost savings and improved competitiveness.
- Enhanced sustainability facilitating the sharing of best practices and enabling collective action on climate change.
- Increased resilience to supply chain disruptions, energy price volatility, and other external shocks.

5.2.6.5. What risks does the signal carry for the ecosystem?

- Data security and privacy concerns
- Competition and antitrust issues
- Complexity and cost

5.2.6.6. What challenges does the signal carry for the ecosystem?

- Building trust and establishing data governance frameworks
- Ensuring data interoperability and standardisation
- Addressing cybersecurity threats
- Balancing collaboration and competition

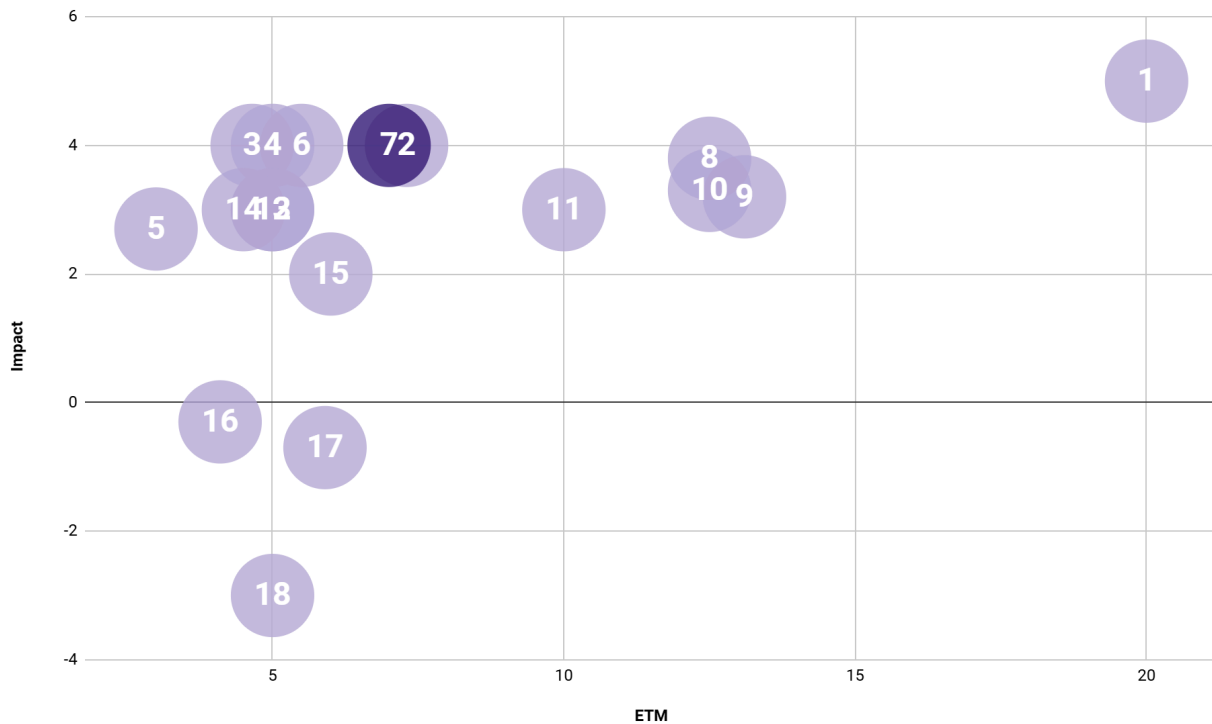
5.2.7. Signal 7: Waste Stream Valorization & Environmental mitigation³⁸

Waste stream valorization and environmental mitigation through innovative approaches like DIY mycelium experiments represent a growing trend towards utilising waste materials for valuable purposes and reducing environmental impact. Mycelium, the root-like structure of fungi, has shown promising potential in various applications, including bioremediation, biofabrication, and creating sustainable materials. DIY mycelium experiments, often originating from grassroots initiatives and citizen science projects, explore the diverse applications of mycelium in addressing environmental challenges and creating valuable products from waste streams.

³⁸ e.g. DIY Mycelium experiments since the 80s Source: https://www.researchgate.net/publication/334750398_Waste-Derived_Low-Cost_Mycelium_Nanopapers_with_Tunable_Mechanical_and_Surface_Properties

5.2.7.1. Matrix figure (ETM, IMPACT)

Figure 33. Impact and ETM Analysis of Waste Stream Valorization & Environmental mitigation in Energy-Intensive Industries.



The impact of signal 7 (Waste Stream Valorization & Environmental mitigation) was estimated at 4. Its score of 4 categorizes it as a hyperdisruptor, which may positively influence the ecosystem's development. The estimated ETM is 7 years, which means that the signal may fully materialize by mid-2031.

5.2.7.2. How can it change our optics?

- It shifts attention towards the potential of bio-based solutions and circular economy models.
- It underlines the importance of grassroots innovation and citizen science in driving environmental solutions.
- It brings a new element to the discussion about waste management and resource utilisation.
- It facilitates the understanding of a potential change in material science and manufacturing practices.

5.2.7.3. How can it change the ecosystem?

- DIY mycelium experiments can drive innovation in biofabrication, bioremediation, and material science, leading to the development of new technologies and applications for mycelium-based materials and processes.
- Waste stream valorization through mycelium can create new economic opportunities by transforming waste into valuable products and generating revenue from previously discarded materials.

- DIY mycelium initiatives can empower communities to take action on environmental issues and contribute to local solutions for waste management and resource utilisation.
- Mycelium-based solutions offer a more sustainable alternative to conventional materials and processes, reducing waste, conserving resources, and minimising environmental impact.

5.2.7.4. What opportunities does the signal carry for the ecosystem?

- Waste reduction and resource recovery
- Sustainable materials and biofabrication
- Bioremediation and environmental cleanup
- Community engagement and citizen science

5.2.7.5. What risks does the signal carry for the ecosystem?

- Scalability and commercialization
- Quality control and standardisation
- Safety and regulatory considerations

5.2.7.6. What challenges does the signal carry for the ecosystem?

- Further research and development are needed to optimise mycelium cultivation techniques, develop new applications, and improve the performance and scalability of mycelium-based solutions.
- Public awareness and acceptance
- Infrastructure and investment

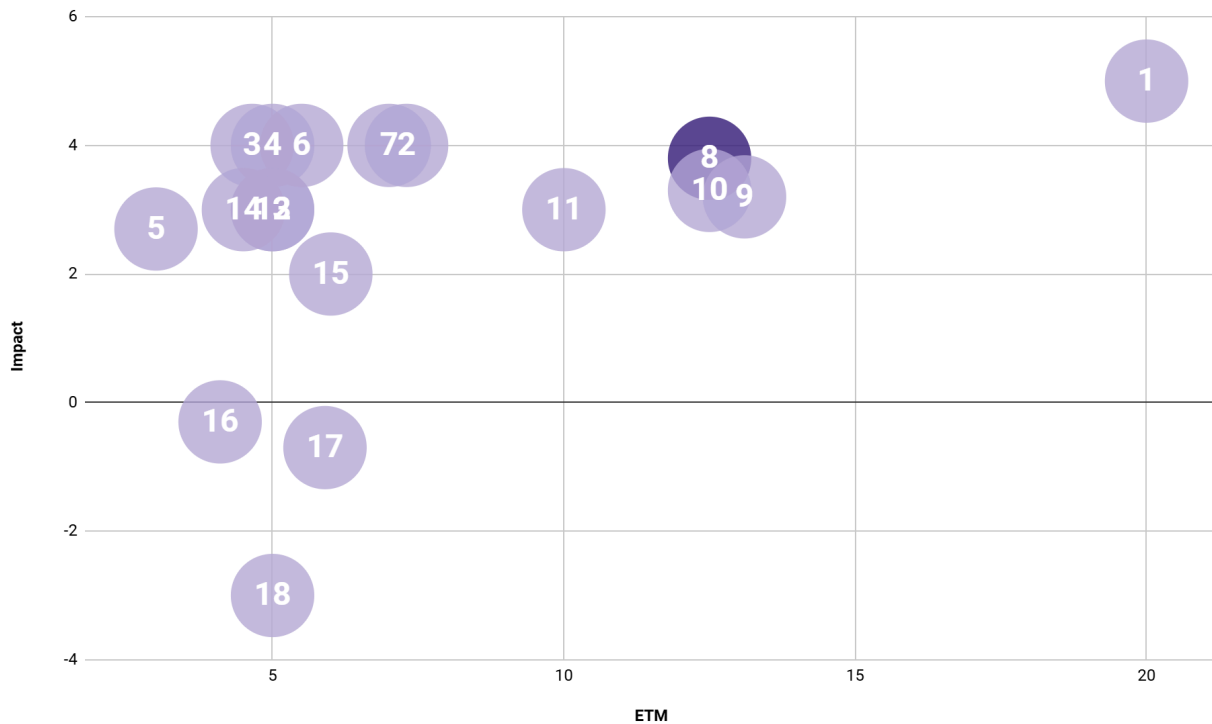
5.2.8. Signal 8: (Re-)Discovery of Direct current (DC) grids³⁹

Alternating current (AC) grids currently make up about 99% of electric grids. AC exhibits lots of technical drawbacks like idle/reactive power, but became the dominant choice in the past due to technical limitations of the time. DC (Direct current) exhibits lesser efficiency losses and many modern technologies (e.g. electric cars) require, additionally, renewable energy sources often produce DC. If it were not for the dominating past of AC over DC, DC electric grids would be the choice to go.

³⁹ Source: <https://www.encn.de/en/research/energy-management-technologies/direct-current-grids>
<https://www.reinhausen.com/impulses/standard-compliant-grid-integration-of-wind-and-solar-power/direct-current-at-all-grid-levels> <https://www.phoenixcontact.com/en-au/industries/dc-grid>

5.2.8.1. Matrix figure (ETM, IMPACT)

Figure 34. Impact and ETM Analysis of (Re-)Discovery of Direct current (DC) grids in Energy-Intensive Industries.



The impact of signal 8 ((Re-)Discovery of Direct current (DC) grids) was estimated at 3.8. Its score of 3.8 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 12.5 years, which means that the signal may fully materialize by mid-2037.

5.2.8.2. How can it change our optics?

DC grids are enabled by modern technical advances and are superior to AC grids in many aspects (e.g. lesser energy losses), needed for certain modern technologies (e.g. electric cars) and are the "natural" choice for many renewable energy sources (e.g. photo voltaics). This underlines the emerging importance of DC grids, which are held back by the current dominance of AC grids due to technical limitations in the past. In essence the challenge here can be summarised to:

- How much is industry willing to spend on adapting a new technology standard in electric grids (to accommodate for the benefits of DC grids).

5.2.8.3. How can it change the ecosystem?

DC grids are important for renewable energy sources and modern technologies. Electric cars need to be charged by a steady DC (non-alternating), as switching polarities would simply yield no net charging of the car. Photo voltaics produce their electrical output in the form of DC and right now this DC needs to be transformed into AC to be usable in our current AC electric grids which in itself exhibits energy losses and also poses an unnecessary step regarding the potential use of DC grids.

5.2.8.4. What opportunities does the signal carry for the ecosystem?

The (re-)discovery of DC grids offers EILs the opportunity to reduce energy losses during transmission. This could enable new technologies related to DC grids and encourage investment in updated infrastructure. These changes could support the ongoing transition to renewable energy sources.

5.2.8.5. What risks does the signal carry for the ecosystem?

The primary risk associated with the widespread adoption of DC grids is the high cost of adaptation. Currently, AC grids dominate the energy landscape, making up about 99% of existing infrastructure. Transitioning to DC grids would require substantial investments in new equipment, grid upgrades, and potentially the replacement of existing infrastructure, posing a significant financial burden for the EILs ecosystem.

5.2.8.6. What challenges does the signal carry for the ecosystem?

The investment costs associated with transitioning from well-established AC grids can be substantial. This shift requires careful planning, coordination among stakeholders, and potentially overcoming regulatory hurdles. Ensuring compatibility and interoperability between existing AC and new DC infrastructure is crucial for a smooth transition and to avoid disruptions in energy supply.

5.2.9. Signal 9: Self-healing technologies for new materials⁴⁰

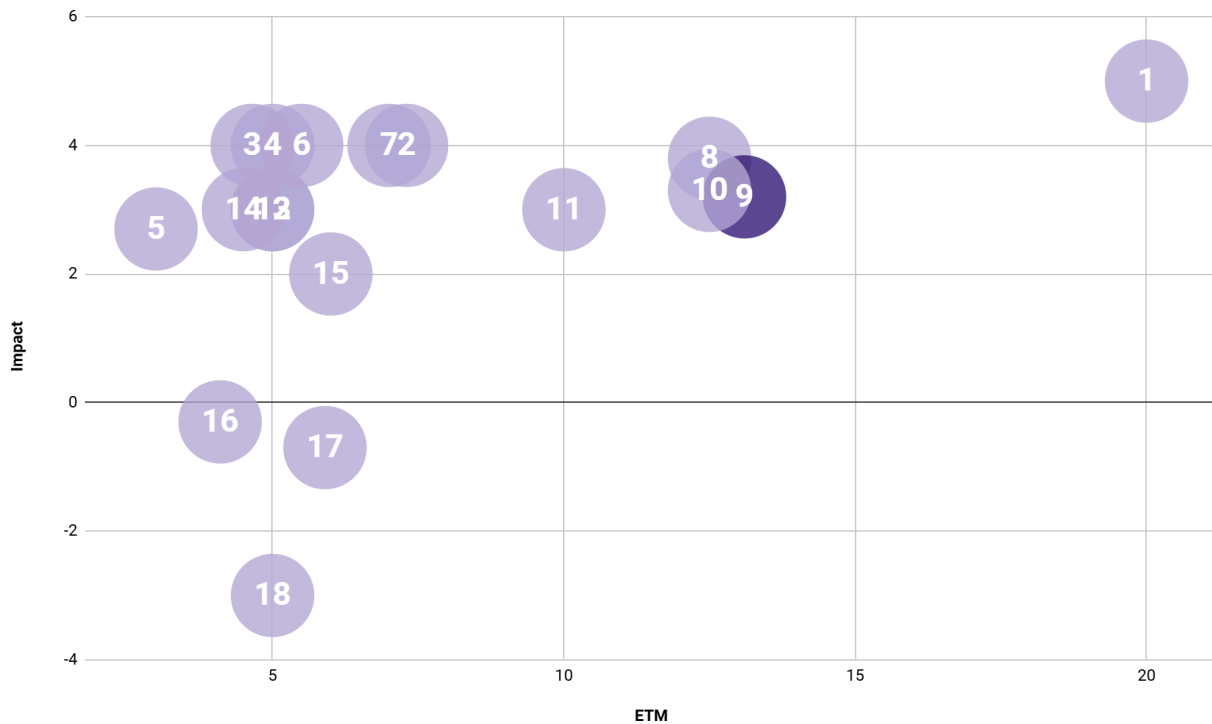
Polymeric composites are prone to undergo damage, such as microcracks, during their operation, that can ultimately lead to catastrophic failure. To contradict such a problem, effort has been put, by the scientific community, towards developing self-healing composites that, by mimicking biological systems, can autonomously and prematurely repair flaws, extending durability and improving security of materials. The present review explores the progress being made in such an area, focusing on extrinsic self-healing methods, considering that they can be employed to a variety of materials. Reservoir-based techniques, that resort to capsules, hollow fibres or microvascular networks, and thermoplastic-based ones are overviewed, prioritising innovative approaches made in recent years. At last, promising practical applications for self-healing composites are highlighted and future challenges and opportunities are pointed out.

⁴⁰ Source:

file:///C:/Users/Maxime%20Nourtier/Downloads/Self-Healing_Composites_A_Path_to_Redefining_Mater.pdf
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7077370/>
<https://meddocsonline.org/annals-of-biotechnology/the-future-of-self-Healing-technologies.html>
<https://www.linkedin.com/pulse/rise-self-healing-materials-what-we-know-weve-learned-bis-research-560oc/>
<https://www.sciencedirect.com/topics/materials-science/self-healing-material>

5.2.9.1. Matrix figure (ETM, IMPACT)

Figure 35. Impact and ETM Analysis of Self-healing technologies for new materials in Energy-Intensive Industries.



The impact of signal 9 (Self-healing technologies for new materials) was estimated at 3.2. Its score of 3.2 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 13.1 years, which means that the signal may fully materialize by mid-2037.

5.2.9.2. How can it change our optics?

Self-healing composites can be implemented in varied areas, especially standing out in applications with difficult access and high inspection and maintenance costs, such as wind turbine blades. Some examples include aerospace and aeronautic industry, particularly structural parts, for example wings, which must withstand high temperatures and pressures and resist impact, fatigue, corrosion and environmental factors. In fact, the European Space Agency has considered self healing materials as “one of the most futuristic concepts” for space crafts, due to the extreme fluctuations of the environmental conditions and the high velocity impacts that these can undergo. As a matter of fact, it is estimated by his agency that the materialisation of this principle could double the lifetime of an earth-orbiting spacecraft, therefore halving the overall cost of the mission. Also, in the automotive industry, these composites might find application in vehicle body parts, bumpers, tires and even batteries that can recover from damage, such as dents, puncture damage and wear, thus maintaining appearance, functionality and performance. In such a way, the materials in question contribute to improving the safety, efficiency, lifespan and even the environmental impact of vehicles, minimising the need for replacements of repairs.

5.2.9.3. How can it change the ecosystem?

With continued development and seamless integration of 'self-healing' materials into modern-day applications, it is set to open up a new era of enhanced consumer experience, infrastructure maintenance, environmental management, as well as countless unprecedented and unique applications resembling those in science fiction. To achieve these futuristic technological outcomes, one should allow much room for visualising new opportunities/possibilities by 'self-healing' technologies, in order to bring about many more useful and innovative applications to benefit the society as a whole. In this regard, it is anticipated that biotechnology and AI will play increasingly prominent roles in driving further advancements and adoptions of 'self-healing' technologies, mainly through introducing novel/enhanced bio-features, data-driven customised healing strategies, as well as through bestowing performance or production advantages such as mechanical robustness, ease of scaling up, cost-effectiveness, enhanced biocompatibility, eco-friendliness, etc.

- It could redefine the way to build a production of appliances
- Reduced material waste
- New Safety Protocols needed for such materials
- Creation of novel business models

5.2.9.4. What opportunities does the signal carry for the ecosystem?

The potential applications of self-healing materials span numerous industries, offering substantial benefits:

- **Construction:** Self-healing concrete is a groundbreaking development in the construction industry. Concrete structures are prone to cracking, leading to costly repairs and maintenance. Self-healing concrete incorporates capsules containing healing agents, such as bacteria or chemical compounds, that activate upon cracking to fill the gaps and restore structural integrity. This innovation can significantly extend the lifespan of buildings, bridges, and other infrastructures, reducing maintenance costs and improving safety.
- **Automotive:** The automotive sector stands to gain immensely from self-healing materials. Self-healing paints and coatings can repair scratches and minor damages, maintaining vehicles' aesthetic appeal and durability. Additionally, self-healing polymers used in car components can enhance safety and longevity by preventing the propagation of cracks and wear.
- **Electronics:** Self-healing materials can address issues like micro-cracks in circuits and batteries, leading to device failure in the electronics industry. Incorporating self-healing polymers in electronic components can improve the reliability and lifespan of devices, reducing the need for frequent replacements and repairs.
- **Healthcare:** Self-healing materials have promising applications in the medical field. They can be used to develop self-healing medical implants and devices, such as stents and prosthetics, that maintain functionality and reduce the risk of failure. This can lead to improved patient outcomes and reduced healthcare costs.
- **Aerospace:** The aerospace industry can benefit from self-healing materials regarding safety and maintenance. Aircraft components made from self-healing composites can repair minor damages autonomously, enhancing the safety and longevity of the aircraft.

5.2.9.5. What risks does the signal carry for the ecosystem?

The entire economic system will have to adapt, particularly if products last longer and are more resilient. This will have an impact on the way we consume, forcing companies to adapt in order to continue their activities.

5.2.9.6. What challenges does the signal carry for the ecosystem?

While the potential of self-healing materials is immense, several challenges need to be addressed:

- **Cost and Scalability:** Producing self-healing materials is expensive, and scaling manufacturing processes to meet industrial demands is a significant challenge. Researchers are exploring cost-effective methods and materials to make self-healing technologies more accessible.
- **Performance and Reliability:** Ensuring that self-healing materials perform reliably under various conditions is crucial. The healing process must be efficient, consistent, and repeatable to be practical for real-world applications. Ongoing research aims to optimise these materials' performance and durability.
- **Environmental Impact:** The environmental impact of self-healing materials, especially those using chemical healing agents, must be carefully considered. Developing eco-friendly and sustainable self-healing materials is a priority to minimise adverse environmental effects.
- **Integration with Existing Technologies:** Integrating self-healing materials with existing manufacturing and design processes can be complex. This requires interdisciplinary collaboration and innovation to incorporate self-healing capabilities into conventional materials and products seamlessly.

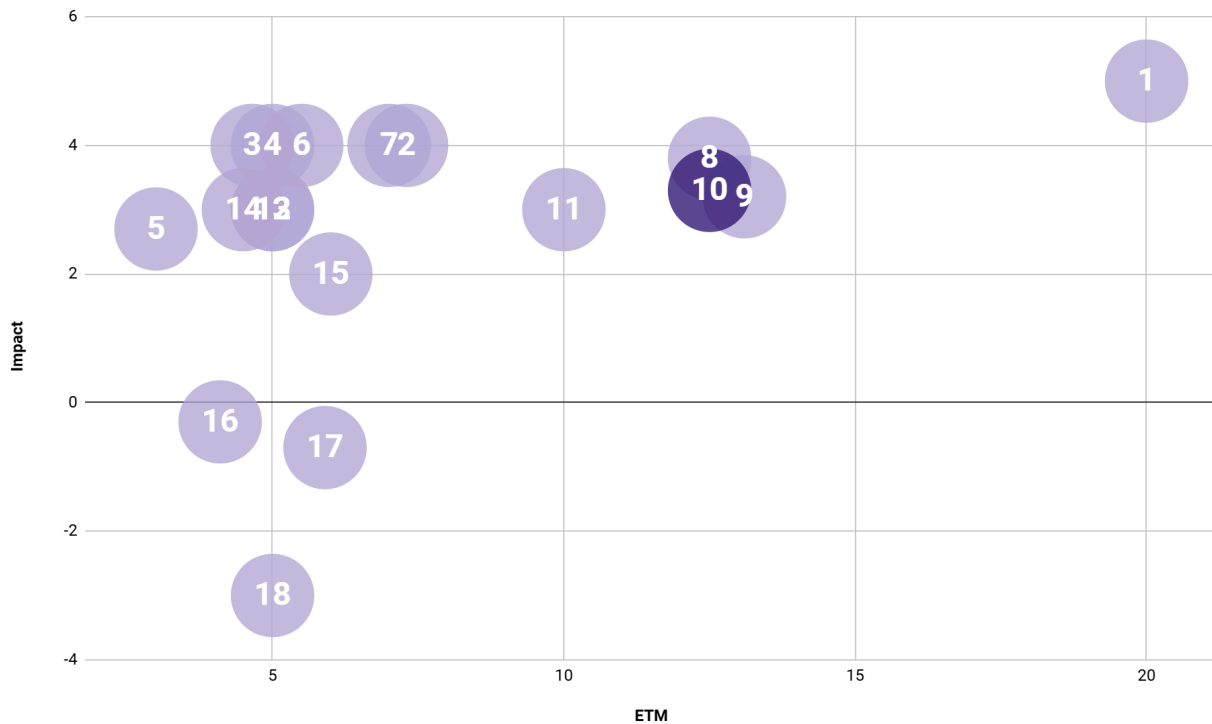
5.2.10. Signal 10: 4D printing for advanced manufacturing⁴¹

The introduction of the fourth dimension to 3D printing technology is termed as "4D Printing". With this new dimension, 3D printed objects possess the capability to change its shape by itself over the influence of external stimuli, such as light, heat, electricity, magnetic field, etc. By integrating the dimension of time, printed objects change their shape dynamically based on the needs and demands of the situation, without any electromechanical parts or moving parts. This shape-changing phenomenon of 3D printed objects is based on the material's ability to transform over time in response to specific stimuli, and it does not require human intervention to aid the process.

⁴¹ Source: <https://www.linkedin.com/pulse/shaping-future-unraveling-potential-4d-printing-market-parkhe/>
<https://www.sculpteo.com/en/3d-learning-hub/best-articles-about-3d-printing/4d-printing-technology/>
<https://www.futurebridge.com/industry/perspectives-mobility/4d-printing-the-technology-of-the-future/>
<https://research.vit.ac.in/publication/4d-printing-of-materials-for-the-future/pdf/preprint-4d-printing-of-materials-for-the-future.pdf> <https://www.sciencedirect.com/science/article/pii/S0264127521007486>
<https://www.sciencedirect.com/science/article/abs/pii/S2214860422002925>

5.2.10.1. Matrix figure (ETM, IMPACT)

Figure 36. Impact and ETM Analysis of 4D printing for advanced manufacturing in Energy-Intensive Industries.



The impact of signal 10 (4D printing for advanced manufacturing) was estimated at 3.3. Its score of 3.3 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 12.5 years, which means that the signal may fully materialize by mid-2037.

5.2.10.2. How can it change our optics?

The future with 4D printed materials is bright and highly optimistic. 4D printing has the potential to eradicate the inherent weakness of mechanical systems. 4D printed smart materials can possibly be used to design novel systems that are not limited to any particular degree of freedom. Such novel systems are achieved by replacing traditional mechanical components like motors and gears with suitable smart materials. New and more efficient methods of incorporating electronics into smart structures can lead to the improvements of novel smart devices. The growth of biocompatible smart material systems can revolutionise the medical sector and can boost the efficiency of the healing process. It is very difficult to imagine a future where 4D printing has an inadequate and significant impact on the industrial sector.

5.2.10.3. How can it change the ecosystem?

As a whole, opportunities and challenges have been highlighted and developed in a way to increase this emerging technology to an industrial threshold. In its actual shape, 4D printing exhibits useful capabilities to play a crucial role in the era of Industry 4.0 but also introduces new usage scenarios that deserve to be investigated in terms of human factors and experience for the adoption of stimulus-responsive structures in society.

5.2.10.4. What opportunities does the signal carry for the ecosystem?

The various advances in 4D printing offer an exciting future wherein the technique would be used across all the different industrial and manufacturing sectors. In order to bring about a successful future with regard to 4D printing, there is a need to develop new and highly customizable material which could respond to a range of external stimuli to undergo their respective shape transformation. There is a need to develop new 4D printing software for the different types of 4D printing techniques.

5.2.10.5. What risks does the signal carry for the ecosystem?

Like any new production method, 4d printing will pose problems for the employment market, forcing the ecosystem to adapt to limit job losses. The same applies to the need for new training to nurture tomorrow's talent and maintain a balanced employment market.

5.2.10.6. What challenges does the signal carry for the ecosystem?

Despite the promising potential, 4D printing still faces challenges, such as high production costs, limited material options, and the need for precise control over the activation triggers. Additionally, the technology is relatively nascent, requiring further research and standardisation before widespread adoption.

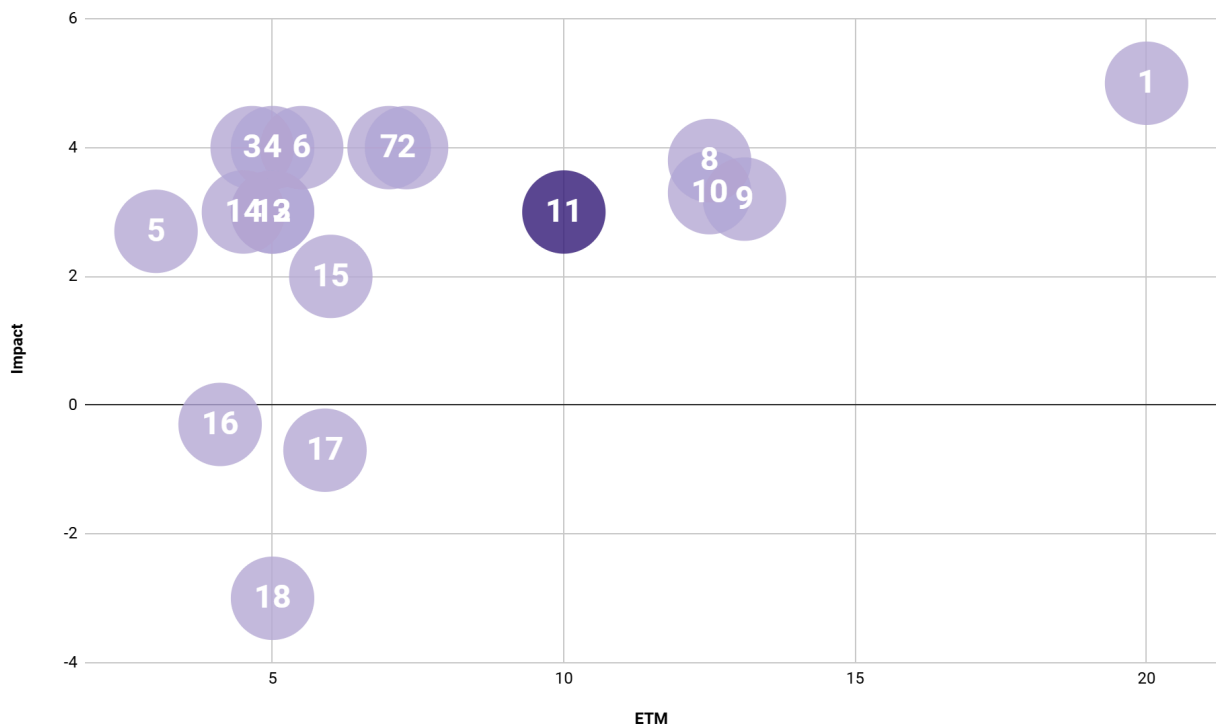
5.2.11. Signal 11: Quantum computing⁴²

Quantum technology, a class of technology that harnesses the principles of quantum mechanics, promises to revolutionise various fields, including navigation, communication, healthcare, and computing. Unlike traditional computers that rely on binary "bits" (1s and 0s), quantum computing utilises "qubits," which are subatomic particles capable of existing in a superposition of states—simultaneously both 1 and 0, analogous to a spinning coin before it lands. This unique property, along with quantum entanglement, allows quantum computers to tackle problems that are intractable for classical computers, paving the way for more reliable navigation and timing systems, secure communications, accurate healthcare imaging through quantum sensing, and ultimately, more powerful computing.

⁴² Source: <https://time.com/6249784/quantum-computing-revolution/>
<https://www.paconsulting.com/insights/what-is-quantum-technology>

5.2.11.1. Matrix figure (ETM, IMPACT)

Figure 37. Impact and ETM Analysis of Quantum Computing in Energy-Intensive Industries.



The impact of signal 11 (Quantum computing) was estimated at 3. Its score of 3 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 10 years, which means that the signal may fully materialize by mid-2034.

5.2.11.2. How can it change our optics?

Quantum technology is poised to revolutionise the plastics industry, among other fields, by offering a fundamentally different approach to processing information and solving complex problems. For instance, quantum computers could simulate complex molecules and chemical reactions with unprecedented precision, facilitating the discovery of new plastic materials with improved properties. This capability surpasses classical computers in solving certain problems, particularly those involving complex simulations and optimizations, which will also impact fields like cryptography, drug discovery, and artificial intelligence by enabling faster and more efficient computations.

5.2.11.3. How can it change the ecosystem?

Quantum computing is a disruptive technology poised to revolutionise numerous fields, including chemistry and materials science, medicine and biology, artificial intelligence, economics and finance, climate science, environmental research, and fundamental physics. Its impact on the IT industry will be particularly transformative, potentially reshaping the landscape of manufacturers as existing players exit and new ones emerge. This shift will further strengthen the position of AI and its associated data ecosystems. Furthermore, quantum computing's inherent energy efficiency promises to significantly reduce the energy consumption of data centres, contributing to a more sustainable future.

5.2.11.4. What opportunities does the signal carry for the ecosystem?

- Materials optimisation and manufacturing process efficiency, waste management and recycling.
- Many opportunities in transport, finance, logistics, aerospace, new materials, militech etc.⁴³

5.2.11.5. What risks does the signal carry for the ecosystem?

- Data protection
- Environmental impact
- Research costs

5.2.11.6. What challenges does the signal carry for the ecosystem?⁴⁴

- Modern encryption methods will be rendered useless
- Web interactions will be at risk
- DNNs will be more difficult to evaluate
- Some nation-states could be more vulnerable in warfare
- Encrypted data can be harvested now for exploitation later
- There may be HR-related impacts
- The digital divide could grow exponentially
- Organisations may struggle to find needed helium
- Blockchain technology's algorithms could be cracked
- The costs may be prohibitive for most organisations
- Businesses may have to upgrade or be left behind
- There are security vulnerabilities that haven't even been discovered yet
- Finding relevant use cases may be difficult

5.2.12. Signal 12: Biomimicry for advanced materials⁴⁵

Biomimicry is a concept and a methodology that will enable the development of new means of production, an invaluable tool for the eco-design of tomorrow's products, and the emergence of new technologies that consume much less energy, taking their example from what nature does on a daily basis.

⁴³ <https://spectra.mhi.com/how-quantum-technology-could-change-heavy-industry>

⁴⁴

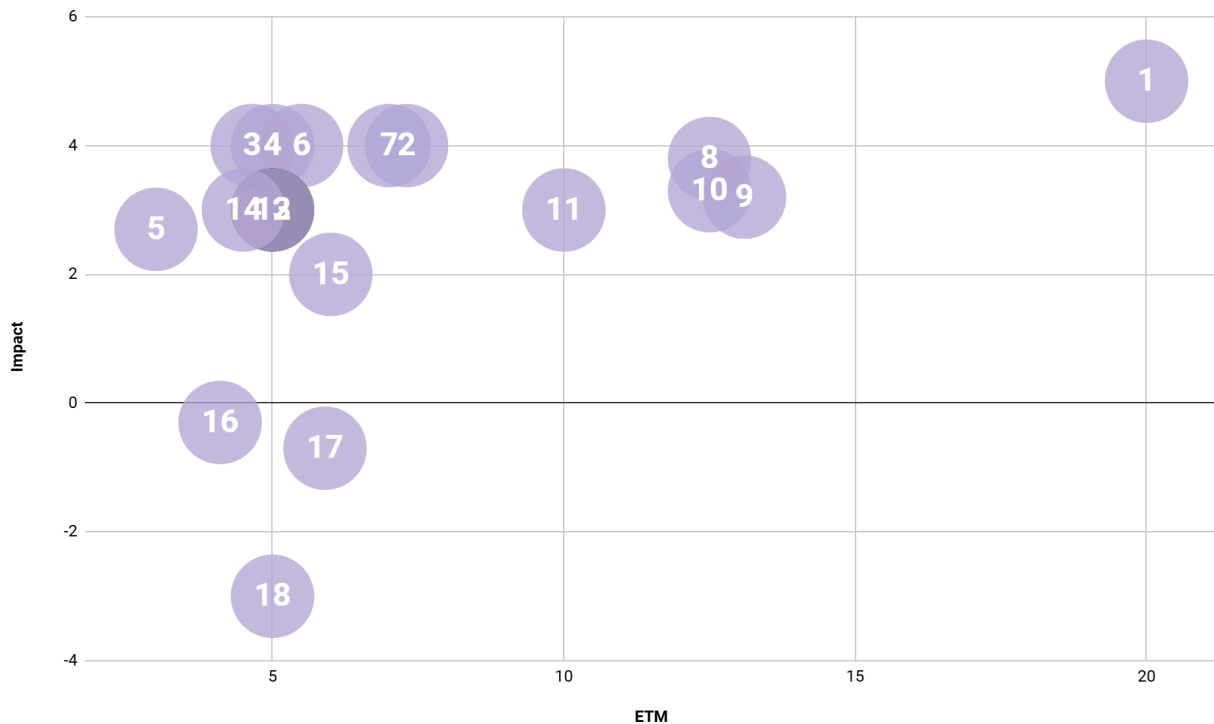
<https://www.forbes.com/sites/forbestechcouncil/2022/11/08/13-risks-that-come-with-the-growing-power-of-quantum-computing/>

⁴⁵ Source:

<https://medium.com/@rakshit.aryadesign/biomimicry-an-approach-towards-future-of-design-and-sustainability-ffbb07fa9cd8> <https://www.linkedin.com/pulse/biomimicry-future-industrialization-40-shreeram-joglekar-p6fof/>

5.2.12.1. Matrix figure (ETM, IMPACT)

Figure 38. Impact and ETM Analysis of Biomimicry for advanced materials in Energy-Intensive Industries.



The impact of signal 12 (Biomimicry for advanced materials) was estimated at 3. Its score of 3 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 5 years, which means that the signal may fully materialize by mid-2029.

5.2.12.2. How can it change our optics?

As biomimicry progresses, ethical considerations become important. It is crucial to ensure that the imitations of nature's designs and processes do not harm ecosystems or exploit natural resources. Responsible biomimicry practices should prioritise sustainability and environmental stewardship.

5.2.12.3. How can it change the ecosystem?

Biomimicry has the potential to revolutionise Industrialization 4.0 by providing sustainable, efficient, and resilient solutions. By imitating nature's designs and processes, industries can create technologies that are in harmony with the environment. From energy solutions to manufacturing processes, biomimicry offers a wide range of applications. However, overcoming technological limitations, fostering collaboration, and addressing ethical considerations are essential for the successful implementation of biomimicry in the future. As we continue to explore and learn from nature, biomimicry will undoubtedly play a significant role in shaping the future of Industrialization 4.0.

5.2.12.4. What opportunities does the signal carry for the ecosystem?

The creation of new multi-skill professions and greater synergy between a company's different professions (biology, mechanical engineering, chemistry, etc.). Biomimicry requires interdisciplinary collaboration and knowledge sharing. Scientists, engineers, and designers need to work together to understand and apply nature's principles effectively. Collaborative platforms and networks dedicated to biomimicry can facilitate the exchange of ideas and accelerate the development of innovative solutions.

5.2.12.5. What risks does the signal carry for the ecosystem?

While biomimicry for advanced materials promises innovation, it could lead to job displacement in traditional manufacturing sectors as new, bio-inspired production methods emerge. This shift may require significant workforce retraining and could potentially result in job losses for those unable to adapt to the new skillsets required.

In addition to this, biomimicry raises ethical considerations related to the sourcing and utilization of biological resources. Replicating nature's designs may require extracting materials from living organisms or ecosystems, raising concerns about environmental impact and potential harm to biodiversity.

Finally, biomimicry often involves replicating complex biological structures and processes, which can lead to materials with unpredictable or inconsistent properties. This could pose challenges in ensuring quality control and standardization, potentially hindering widespread adoption in industrial applications.

5.2.12.6. What challenges does the signal carry for the ecosystem?

Biomimicry presents a challenge to established processes, potentially disrupting existing industries and revolutionizing manufacturing. However, before realizing its full potential, the ecosystem must overcome technological limitations in replicating nature's complex designs and functionalities at scale. This requires significant investment in research and development and overcoming hurdles in translating biological principles into practical manufacturing processes.

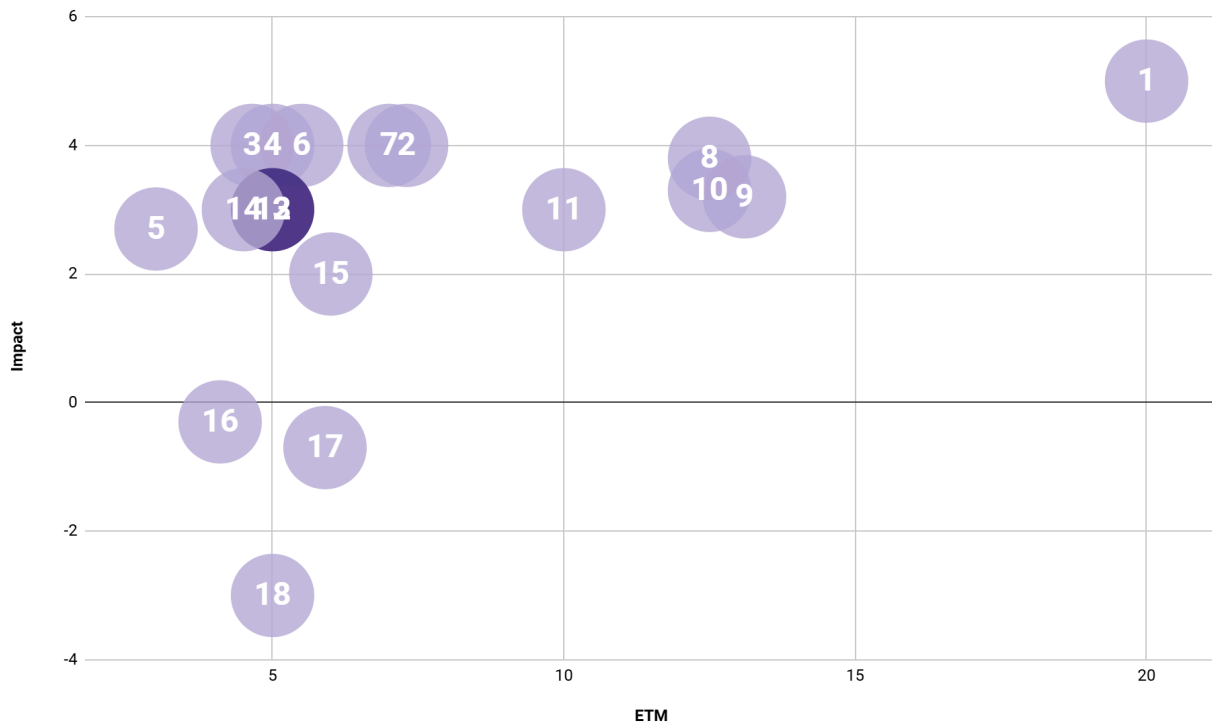
5.2.13. Signal 13: Scoring a product (or its packaging) based on its sustainability⁴⁶

The idea is to develop something similar to nutritional score but based on the sustainability/carbon footprint of a product or its packaging to inform the consumers about its choice. This could prevent greenwashing and allow a better visibility to real efforts towards sustainability while also justifying the difference of cost for the consumers.

⁴⁶ Source: conversation at the FIP trade fair in Lyon in March 2024

5.2.13.1. Matrix figure (ETM, IMPACT)

Figure 39. Impact and ETM Analysis of Scoring a product (or its packaging) based on its sustainability in Energy-Intensive Industries.



The impact of signal 13 (Scoring a product (or its packaging) based on its sustainability) was estimated at 3. Its score of 3 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 5 years, which means that the signal may fully materialize by mid-2029.

5.2.13.2. How can it change our optics?

It shifts attention towards sustainable consumption. This practice encourages consumers and businesses to prioritize products with lower environmental impacts, prompting EIs to adopt more sustainable production processes and materials. By highlighting the environmental footprint of products, this scoring system can drive greater transparency and accountability within the sector, ultimately promoting a shift towards a more circular and sustainable economy.

5.2.13.3. How can it change the ecosystem?

This is particularly relevant for the plastic industry and the packaging industry as today recycled materials used for packaging cost way more than virgin raw material, this could enhance the visibility of sustainable practices in the industry while offering concrete understanding of what is sustainable and what is not to prevent greenwashing (if the scoring is properly recognised by the authorities).

5.2.13.4. What opportunities does the signal carry for the ecosystem?

Scoring a product's sustainability within the EIs ecosystem presents a valuable opportunity to drive the industry towards greater environmental responsibility. By providing clear and transparent metrics, it incentivizes companies to adopt more sustainable practices, fostering innovation and competition in the development of eco-friendly products and processes. This increased visibility can also empower consumers to make informed choices, further driving demand for sustainable alternatives. Moreover, it can stimulate research and development in areas like recycling technologies, the use of recycled materials, and eco-design principles, ultimately accelerating the transition towards a circular economy within the EIs ecosystem.

5.2.13.5. What risks does the signal carry for the ecosystem?

Sustainability scoring in the EIs ecosystem poses a significant challenge for certain sectors, particularly packaging industries. These industries often face stricter regulations and requirements, especially when dealing with food contact materials, which can limit their ability to quickly adopt more sustainable practices. As a result, a rigid scoring system could disproportionately penalise these companies, potentially leading to financial difficulties and hindering their ability to invest in necessary innovations for a greener transition. This highlights the need for flexible and adaptable scoring systems that consider industry-specific constraints and provide support for companies facing unique challenges in their pursuit of sustainability.

5.2.13.6. What challenges does the signal carry for the ecosystem?

Scoring a product's sustainability within the EIs ecosystem presents the challenge of ensuring the scoring system itself doesn't contribute to greenwashing, where companies exaggerate or misrepresent their environmental performance to gain a marketing advantage.

In addition to that, it presents the challenge of establishing standardised and transparent metrics that accurately reflect the complex environmental impacts across the entire lifecycle. This requires comprehensive data collection and analysis, considering factors like energy consumption, emissions, waste generation, and resource depletion, which can be resource-intensive and technically challenging. Furthermore, ensuring consistent and comparable scoring across diverse industries and products within the EIs ecosystem necessitates collaboration and agreement on methodologies, which can be hindered by competing interests and varying levels of commitment to sustainability.

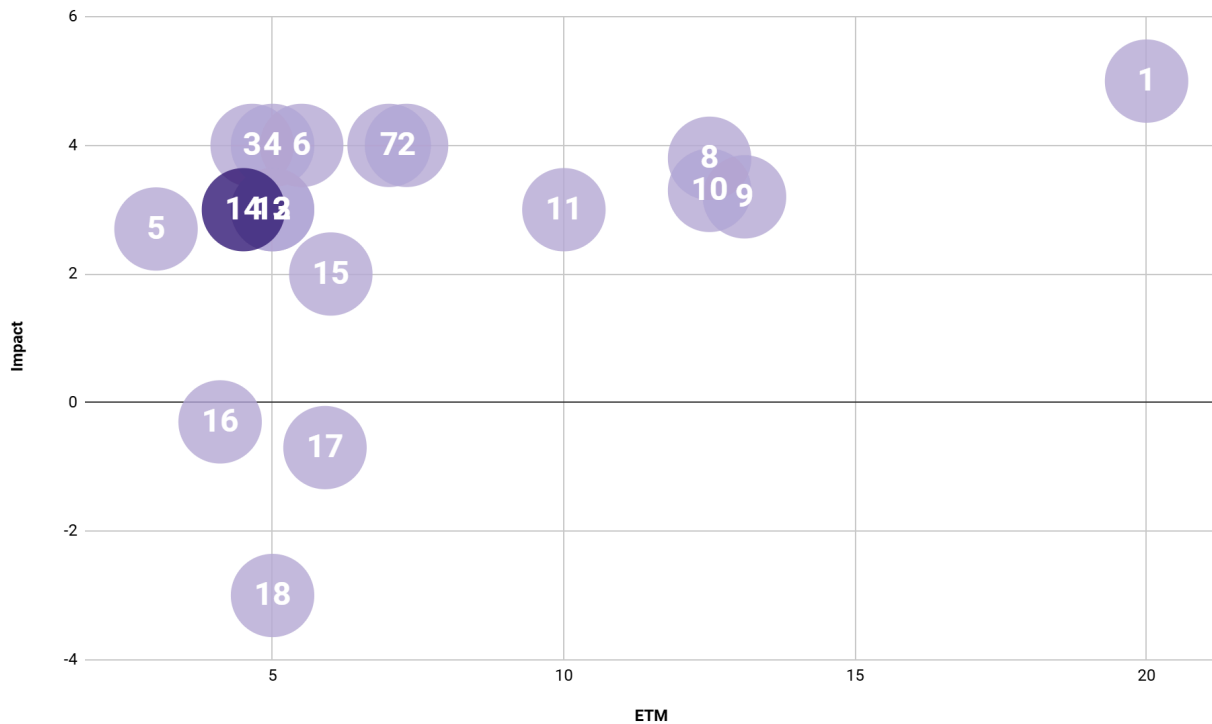
5.2.14. Signal 14: Return of old concepts: Kinetic energy storage (e.g. Fly wheels)⁴⁷

Faced with multiple challenges such as energy security & efficiency or recyclability & reuse of materials concepts from early industrialization or older emerge as potential opportunities: for example fly wheels as kinetic batteries or modular design for full disassembly of products.

⁴⁷ Source: <https://eepower.com/tech-insights/could-flywheels-be-the-future-of-energy-storage/#https://www.enel.com/company/stories/articles/2024/03/gravity-storage>

5.2.14.1. Matrix figure (ETM, IMPACT)

Figure 40. Impact and ETM Analysis of Return of old concepts: Kinetic energy storage (e.g. Fly wheels) in Energy-Intensive Industries.



The impact of signal 14 (Return of old concepts: Kinetic energy storage (e.g. Fly wheels)) was estimated at 3. Its score of 3 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 4.5 years, which means that the signal may fully materialize by mid-2029.

5.2.14.2. How can it change our optics?

Kinetic energy storage, exemplified by flywheels, prompts a shift in perspective within the energy sector. It encourages exploration of potentials across multiple dimensions, fostering a broader understanding of "energy" itself. This necessitates continuous research and an open-minded, critical approach that looks "beyond the obvious." Furthermore, it revives "outdated" concepts like flywheels, decoupling them from their historical limitations and reimagining their role in modern energy systems.

5.2.14.3. How can it change the ecosystem?

Kinetic energy storage, like flywheels, offers a multi-faceted opportunity for the EII ecosystem. It drives technological innovation in materials and power electronics, leading to more efficient energy storage. Economically, it allows for the utilisation of existing infrastructure and decentralisation, reducing costs and improving access. Societally, it enhances energy reliability and independence. Environmentally, it provides a clean alternative to traditional batteries, increasing efficiency and reducing reliance on fossil fuels.

5.2.14.4. What opportunities does the signal carry for the ecosystem?

Kinetic energy storage offers potential for the EII ecosystem. It enables the development of advanced, high-efficiency systems for grid stabilisation and renewable energy integration, improving reliability and reducing reliance on fossil fuels. This technology can revitalise existing infrastructure, such as repurposing mines for energy storage, leading to cost-effective and decentralised energy solutions. By fostering innovation in materials science and power electronics, kinetic energy storage drives economic growth and creates new opportunities within the EII ecosystem.

5.2.14.5. What risks does the signal carry for the ecosystem?

Kinetic energy storage carries inherent risks for the EII ecosystem. High-speed rotating components raise safety concerns, requiring robust containment and safety protocols to prevent accidents and potential damage to surrounding infrastructure. Limited energy density compared to other storage technologies may restrict their application in certain contexts, particularly where space constraints are a major factor. Self-discharge, or energy loss over time due to friction, can reduce efficiency and necessitate regular energy input to maintain operational readiness, potentially impacting overall cost-effectiveness. Finally, the relative complexity of these systems compared to traditional solutions may require specialised expertise for installation and maintenance, increasing operational costs.

5.2.14.6. What challenges does the signal carry for the ecosystem?

Kinetic energy storage presents several challenges for widespread adoption in the EII ecosystem. Continued technological development is crucial to improve energy density and reduce self-discharge rates, making the technology more competitive with existing solutions. Cost reduction remains a key hurdle, requiring innovative manufacturing processes and economies of scale to achieve price parity with alternative storage technologies. Scalability presents another challenge, as deploying large-scale kinetic energy storage systems may require significant infrastructure investment and grid integration upgrades. Finally, ensuring seamless integration with existing grid infrastructure and control systems will require sophisticated power electronics and communication protocols to maintain grid stability and optimise performance.

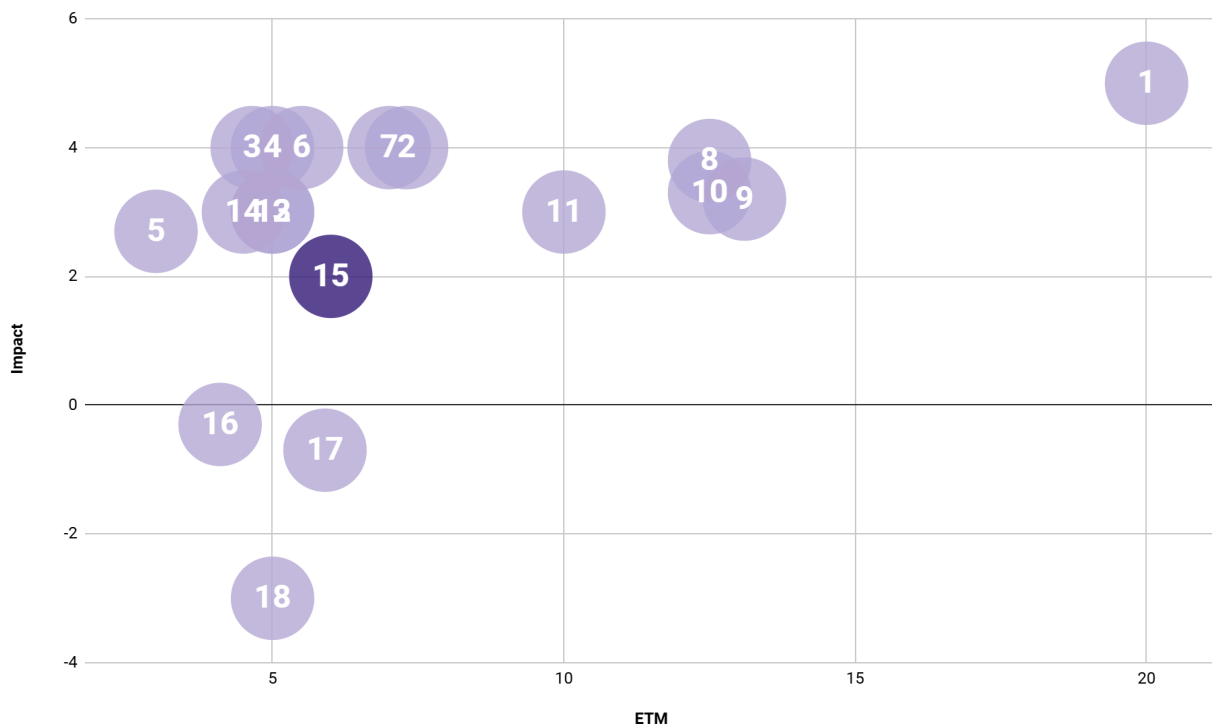
5.2.15. Signal 15: Increasing vertical integration⁴⁸

In energy-intensive industries, increasing vertical integration means companies are expanding their control over different stages of the energy supply chain. This could involve an oil company acquiring renewable energy assets like wind farms to generate its own electricity, or a steel manufacturer investing in mining operations to secure raw material supply. By bringing more processes in-house, companies aim to increase efficiency, reduce reliance on external suppliers, and potentially gain greater control over costs and energy sources. This trend can lead to greater self-sufficiency and potentially more sustainable operations by streamlining processes and reducing reliance on volatile energy markets.

⁴⁸ Source: <https://fordauthority.com/2023/11/ford-ceo-farley-says-vertical-integration-will-increase/>

5.2.15.1. Matrix figure (ETM, IMPACT)

Figure 41. Impact and ETM Analysis of Increasing Vertical Integration in Energy-Intensive Industries.



The impact of signal 15 (Increasing vertical integration) was estimated at 2. Its score of 2 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 6 years, which means that the signal may fully materialize by mid-2030.

5.2.15.2. How can it change our optics?

Increased vertical integration in energy-intensive industries signals a shift towards greater self-reliance and potentially localised supply chains, changing the perception of these sectors as solely dependent on global markets. This move can enhance energy security by reducing vulnerabilities to geopolitical disruptions and price volatility, portraying these industries as more resilient and strategically positioned. Furthermore, by integrating sustainable energy sources and potentially streamlining processes, vertical integration can improve the environmental image of energy-intensive industries, showcasing a commitment to reducing their carbon footprint and contributing to a cleaner energy future.

5.2.15.3. How can it change the ecosystem?

Vertical integration provides resilience against market volatility, insulating against both downstream and upstream impacts through greater control and lower production costs. This business model also allows a mining company to take advantage of improved margins in adjacent sectors of the value chain, and boost upstream channels to market and generate incremental demand for commodities. In addition, a vertical integration strategy can provide a pathway for a company to ensure a sustainable and responsible supply chain — from extraction and processing to sale and distribution, and potentially even product development.

5.2.15.4. What opportunities does the signal carry for the ecosystem?

Vertical integration in the energy-intensive industry offers a range of benefits. For exploration and mining companies, it provides greater price stability by reducing exposure to market fluctuations. Manufacturers, by controlling more of their supply chain, can mitigate risks associated with resource availability and transportation disruptions. This increased control also has the potential to improve transparency and traceability of raw materials, enabling manufacturers to better understand the origin and environmental impact of the resources they use. Furthermore, by having greater oversight of their supply chain, manufacturers can communicate these insights to end-users, raising awareness about the importance of responsible sourcing and the complexities of energy production.

5.2.15.5. What risks does the signal carry for the ecosystem?

This signal also carries risks for the EIs ecosystem. By consolidating control over the supply chain, energy companies may inadvertently alienate existing customers of their upstream assets, such as independent mining companies who previously relied on them for mineral sales. This perceived channel conflict could push these customers towards alternative suppliers, potentially disrupting established market relationships and creating new competition. This shift could lead to a loss of revenue for the vertically integrated company and potentially destabilise the broader market for raw materials. Moreover, this consolidation could stifle innovation and competition in the long term by reducing the diversity of suppliers and potentially limiting access to specialised expertise or emerging technologies.

5.2.15.6. What challenges does the signal carry for the ecosystem?

- Integrating different stages of the production process and managing a more complex organisational structure.
- Balancing the benefits of vertical integration with the need for agility and responsiveness to market changes.
- Avoiding anti-competitive behaviour and ensuring fair competition in the market.
- Addressing potential job losses.

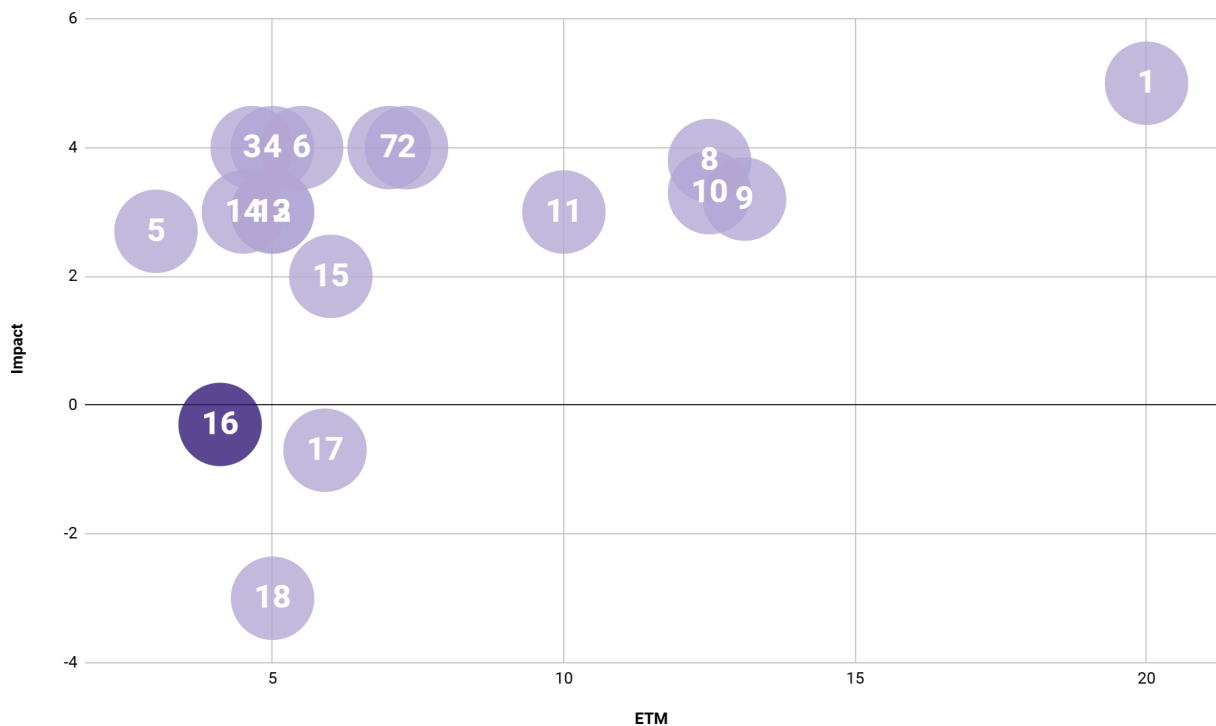
5.2.16. Signal 16: Climate / sustainability fatigue⁴⁹

Climate/sustainability fatigue describes a psychological state where individuals acknowledge the threat of climate change but feel overwhelmed by its scale and complexity. This sense of powerlessness stems from the perception that individual actions are insignificant in the face of such a monumental global challenge. The constant bombardment of information and seemingly endless debates surrounding climate change, without clear and accessible pathways for meaningful individual contribution, can lead to apathy, disengagement, and a sense of hopelessness.

⁴⁹ Source: <https://www.theguardian.com/commentisfree/2023/nov/08/climate-fatigue-europe-voters-green-costs>
<https://nonprofitquarterly.org/how-does-climate-fatigue-hurt-our-efforts/#:~:text=Another%20name%20for%20climate%20fatigue,we%20are%20destined%20to%20fail>.

5.2.16.1. Matrix figure (ETM, IMPACT)

Figure 42. Impact and ETM Analysis of Climate / sustainability fatigue in Energy-Intensive Industries.



The impact of signal 16 (Climate / sustainability fatigue) was estimated at -0.3. This score, being below -1.0, means it was not categorized as a disruptor, and its influence on the ecosystem's development is expected to be rather marginal. The estimated ETM is 4.1 years, which means that the signal may fully materialize by mid-2028.

5.2.16.2. How can it change our optics?

This sense of powerlessness in the face of climate change can significantly alter our perspective and hinder effective action. It can lead to a sense of apathy and disengagement, where individuals feel their actions are inconsequential and systemic change is beyond reach. This can manifest as a focus on individual lifestyle choices rather than demanding systemic change, diverting attention from holding corporations and governments accountable for their role in the climate crisis. Furthermore, this feeling of helplessness can breed cynicism and distrust towards proposed solutions, hindering collective action and delaying crucial progress in addressing climate change.

5.2.16.3. How can it change the ecosystem?

Climate change fatigue can hinder the transition to a sustainable EII ecosystem in several ways. Firstly, voter apathy and disillusionment can translate into electoral outcomes that favour less environmentally-focused policies, potentially slowing down the adoption of renewable energy and sustainable practices. Secondly, reduced consumer awareness regarding sustainable products and industrial practices can lead to a decline in demand for eco-friendly alternatives, undermining the economic incentives for companies to invest in green technologies and processes. This combination of political inaction and consumer disengagement can ultimately slow down the

green transition within the EIs ecosystem, prolonging reliance on fossil fuels and delaying the shift towards a more sustainable energy future.

5.2.16.4. What opportunities does the signal carry for the ecosystem?

- Focus on developing local and regional supply chains, potentially reducing reliance on global trade and enhancing resilience to external shocks.
- Re-evaluation of existing trade partnerships and a focus on building stronger relationships with countries that share similar values and interests.
- Shield domestic industries from foreign competition, potentially allowing them to grow and become more competitive.

5.2.16.5. What risks does the signal carry for the ecosystem?

- Disruption of global supply chains.
- Reduced innovation and competitiveness by limiting access to new technologies, ideas, and markets.
- Increased trade tensions and conflicts.
- Weakened international cooperation on climate change and other global challenges, making it more difficult to achieve shared goals and address common threats.

5.2.16.6. What challenges does the signal carry for the ecosystem?

- Balancing national interests with global cooperation
- Maintaining a competitive edge in the global market.
- Ensuring access to critical resources and raw materials needed for energy-intensive industries.

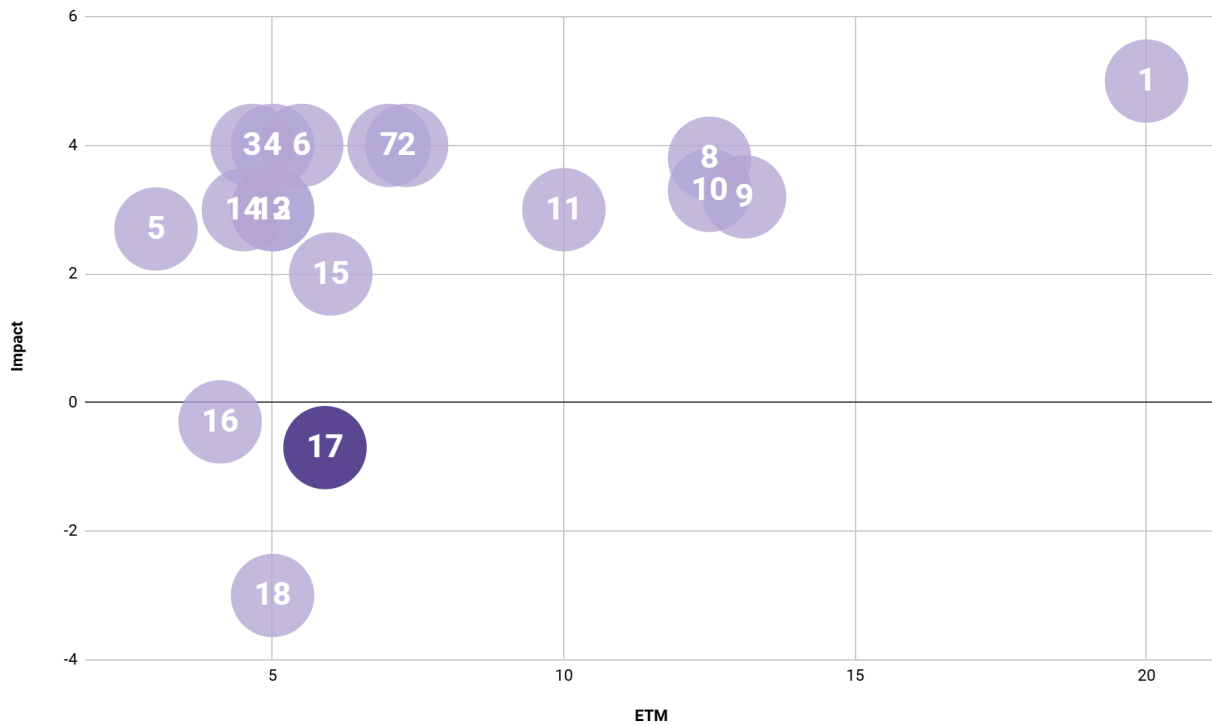
5.2.17. Signal 17: Rising isolationism (in EU) due to right-wing politics shift⁵⁰

Rising isolationism in the EU, fueled by a political shift, signifies a growing trend towards prioritising national interests over regional cooperation and integration. This often (but not always) involves scepticism towards the EU's supranational institutions and a preference for unilateral decision-making on issues like border control, trade, and immigration. This shift can lead to reduced collaboration on key challenges like climate change and energy security, potentially hindering the EU's ability to act cohesively and effectively on the global stage. However, it could also potentially lead to a re-evaluation and strengthening of national identities and a renewed focus on domestic issues and concerns.

⁵⁰ Source: Hooghe, L., & Marks, G. (2018). Cleavage theory meets Europe's crisis: Lipset, Rokkan, and the transnational cleavage. *Journal of European Public Policy*, 25(1), 109-135. The Economist. (2023, September 21). The new nationalism. How Europe's right is turning against the EU.

5.2.17.1. Matrix figure (ETM, IMPACT)

Figure 43. Impact and ETM Analysis of Rising isolationism (in EU) due to right-wing politics shift in Energy-Intensive Industries.



The impact of signal 17 (Rising isolationism (in EU) due to right-wing politics shift) was estimated at -0.7. This score, being below -1.0, means it was not categorized as a disruptor, and its influence on the ecosystem's development is expected to be rather marginal. The estimated ETM is 5.9 years, which means that the signal may fully materialize by mid-2030.

5.2.17.2. How can it change our optics?

It may lead to a prioritization of national interests over pan-European collaboration on issues like energy security and climate change. This could hinder the development of integrated energy markets and cross-border initiatives for renewable energy infrastructure.

5.2.17.3. How can it change the ecosystem?

- Weaker cooperation
- Disruption of common efforts on fighting climate change.
- Reduce advantages of European internal market increasing costs for resources and products
- Diminishing European role on a global/geopolitical scale

5.2.17.4. What opportunities does the signal carry for the ecosystem?

- Focus on developing local and regional supply chains, potentially reducing reliance on global trade and enhancing resilience to external shocks.

- Re-evaluation of existing trade partnerships and a focus on building stronger relationships with countries that share similar values and interests.
- Shield domestic industries from foreign competition, potentially allowing them to grow and become more competitive.

5.2.17.5. What risks does the signal carry for the ecosystem?

- Disruption of global supply chains
- Reduced innovation and competitiveness by limiting access to new technologies, ideas, and markets
- Increased trade tensions and conflicts
- Weakened international cooperation on climate change and other global challenges, making it more difficult to achieve shared goals and address common threats.
- This shift could create a more fragmented and less cooperative landscape within the EII sector, potentially slowing progress towards a sustainable energy transition.

5.2.17.6. What challenges does the signal carry for the ecosystem?

- Balancing national interests with global cooperation.
- Maintaining a competitive edge in the global market.
- Ensuring access to critical resources and raw materials needed for energy-intensive industries.

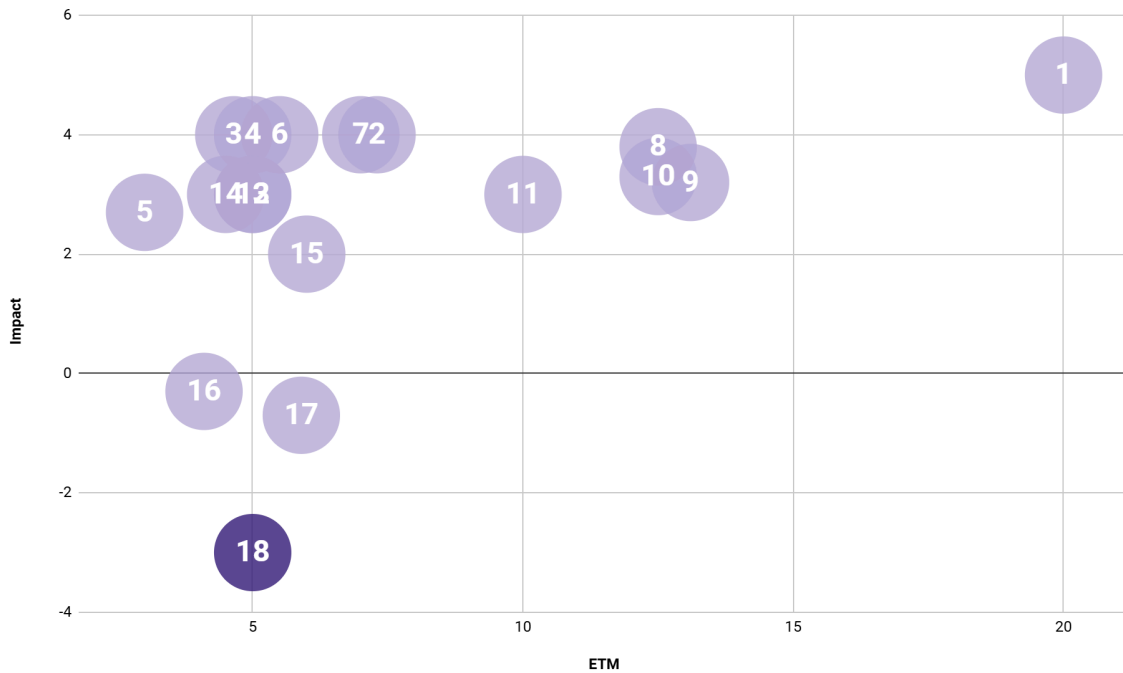
5.2.18. Signal 18: Increasing (critical) raw materials export restrictions⁵¹

The global incidence of export restrictions on critical raw materials increased more than five-fold in the last decade, with several countries significantly intensifying use of these measures. In recent years, about 10% of global value of exports of critical raw materials faced at least one export restriction measure.

5.2.18.1. Matrix figure (ETM, IMPACT)

Figure 44. Impact and ETM Analysis of Increasing (critical) raw materials export restrictions in Energy-Intensive Industries.

⁵¹ Source: OECD Raw materials critical for the green transition Production, international trade and export restrictions, https://www.oecd-ilibrary.org/trade/raw-materials-critical-for-the-green-transition_c6bb598b-en



The impact of signal 18 (Increasing (critical) raw materials export restrictions) was estimated at -3. Its score of -3 categorizes it as a disruptor, which may negatively influence the ecosystem's development. The estimated ETM is 5 years, which means that the signal may fully materialize by mid-2029.

5.2.18.2. How can it change our optics?

Increasing export restrictions on critical raw materials significantly raises awareness of the vulnerabilities and dependencies within global supply chains. It highlights the geopolitical risks associated with relying on specific countries for essential resources, forcing industries and governments to re-evaluate their sourcing strategies and prioritize diversification. This shift in perspective emphasizes the need for greater resilience and self-sufficiency in critical raw material supply.

5.2.18.3. How can it change the ecosystem?

To mitigate supply disruptions, various actions will likely be initiated, such as seeking alternative suppliers, exploring substitute materials, increasing stockpiles, and intensifying recycling efforts. However, despite these efforts, export restrictions will likely cause price volatility and uncertainty in the raw materials market, potentially impacting production costs and hindering innovation in industries reliant on these resources.

5.2.18.4. What opportunities does the signal carry for the ecosystem?

This presents an opportunity to revitalize the raw materials sector in Europe by promoting domestic extraction, processing, and recycling of critical raw materials. It also encourages investment in research and innovation to develop alternative materials and more resource-efficient technologies, potentially leading to a more sustainable and resilient industrial base.

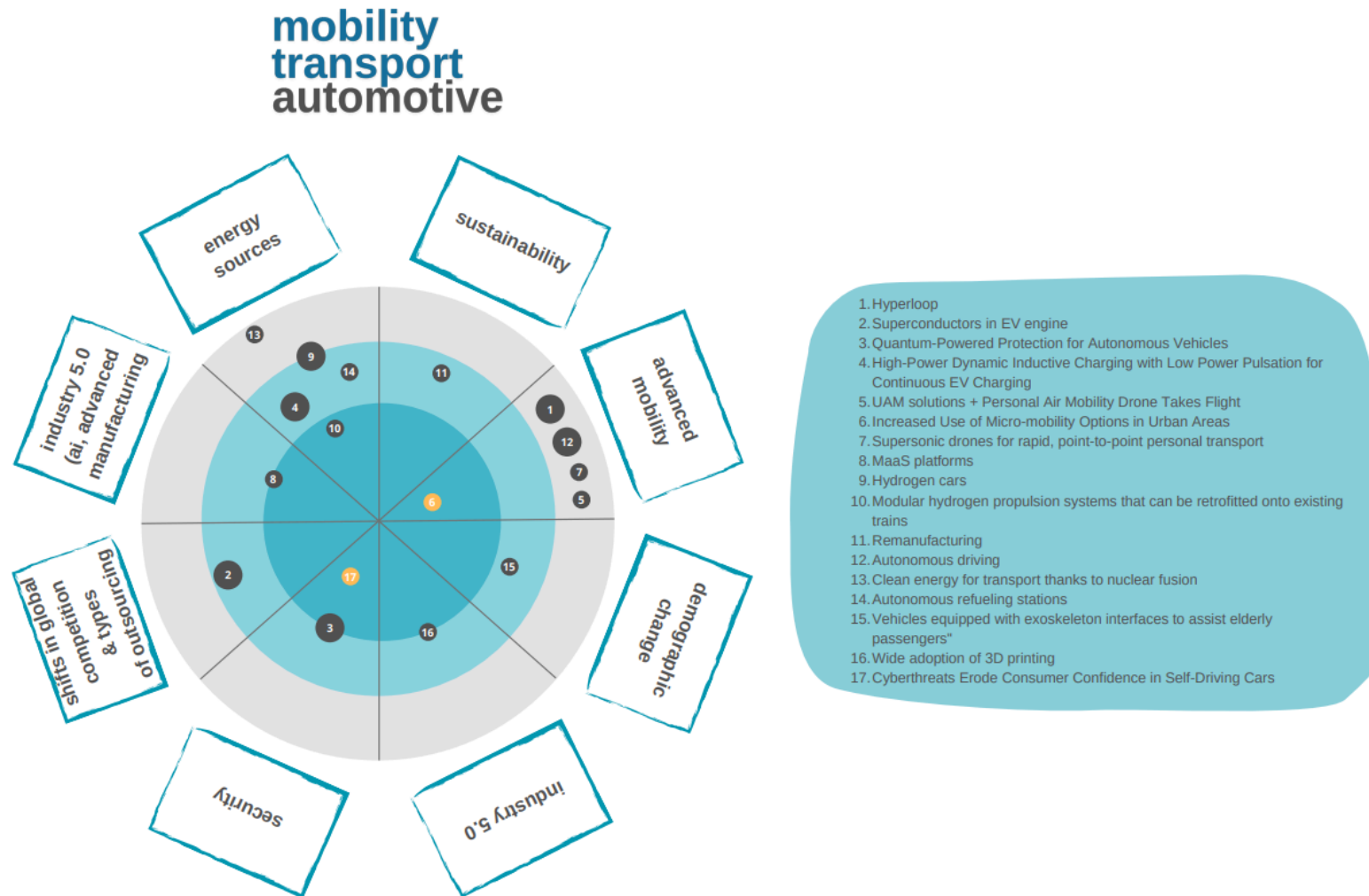
5.2.18.5. What risks does the signal carry for the ecosystem?

The most significant risk is the potential for unpredictable supply disruptions and price fluctuations in the raw materials market. This can disrupt production, increase costs for manufacturers, and hinder investment in new technologies, particularly in sectors heavily reliant on these materials.

5.2.18.6. What challenges does the signal carry for the ecosystem?

The key challenge lies in minimizing the impacts of raw material export restrictions. This requires a multi-faceted approach, including diversifying supply sources, promoting circular economy principles, fostering international collaboration, and investing in research and innovation to reduce reliance on critical raw materials.

6. Map of drivers and disruptions in the Mobility – Transport – Automotive ecosystem (MTA)



7. Zooming in to examine key drivers and disruptions in MTA

The Mobility – Transport – Automotive ecosystem covers automotive, rail and waterborne. It is characterised by a long and complex supply chain. The ecosystem is dominated by a few players that became global players.

The Mobility, Transport, and Automotive sector is a major driving force in the European economy, providing employment for at least 16 million people, including indirect jobs, with 14.6 million in direct employment. This sector contributes significantly to the EU's overall value added, representing 7.5% (€906 billion). Composed of 1.8 million companies, the vast majority (99.7%) are SMEs, highlighting the key role these businesses play in this dynamic and evolving sector.⁵²

7.1. List of key drivers of MTA sector

Drivers are influential forces of changes that are currently shaping or have the capacity to shape or transform a given system. They can take on different states and thus affect a system in many ways, therefore are often called uncertainties.

MTA Focus group experts involved in the IDEALIST's Horizon Scanning identified the following key drivers of the sector: Sustainability, Advanced Mobility, Demographic Change, Industry 5.0 (Automation of Production & Reskilling), Security, Shifts in Global Competition & Types of Outsourcing, Evolution of Ownership Models, Energy Sources.

7.1.1. Sustainability

Sustainability has emerged as a powerful force reshaping the Mobility, Transport & Automotive sector. Growing environmental awareness, stricter regulations, and increasing consumer demand for eco-friendly solutions are pushing the industry towards a greener future. This driver encompasses a wide range of initiatives and innovations aimed at minimising the environmental impact of transportation while ensuring economic viability and social equity.

- Reducing carbon emissions through the development and adoption of electric vehicles (EVs), hydrogen fuel cell vehicles, and alternative fuels. This includes improving battery technology, expanding charging infrastructure, and promoting renewable energy sources.
- Increasing fuel efficiency and reducing energy consumption through vehicle design, lightweight materials, and optimised powertrains. This also involves promoting shared mobility, optimising logistics, and adopting intelligent transportation systems.
- Moving towards a circular economy model by promoting vehicle reuse, remanufacturing, and recycling. This includes designing vehicles for disassembly, developing sustainable materials, and optimising end-of-life processes.
- Encouraging the use of sustainable transportation modes such as walking, cycling, and public transport. This involves integrating different modes of transport through Mobility-as-a-Service (MaaS) platforms and promoting micro-mobility solutions like e-scooters and e-bikes.
- Ensuring that sustainable transportation solutions are accessible and affordable for all, including low-income communities and those with disabilities. This involves promoting equitable access to public transport, developing inclusive infrastructure, and addressing transportation poverty.

⁵² https://commission.europa.eu/system/files/2021-05/swd-annual-single-market-report-2021_en.pdf

Sustainability is not merely a trend but a fundamental shift in how the Mobility, Transport & Automotive sector operates. This driver is transforming every aspect of the industry, from vehicle design and manufacturing to consumer behaviour and urban planning. By embracing sustainability, the sector can contribute to a cleaner, healthier, and more equitable future for all.

7.1.2. Advanced Mobility

Advanced Mobility is a powerful force driving transformation within the Mobility, Transport & Automotive sector. It encompasses a wide range of technological advancements and innovative approaches that are reshaping how people and goods move. This driver is characterised by a focus on efficiency, connectivity, automation, and personalization, leading to new possibilities for transportation systems and vehicle technology.

- Self-driving cars, trucks, and delivery robots are being developed and tested, with the potential to improve safety, efficiency, and accessibility in transportation.
- Vehicles are becoming increasingly connected to each other and to infrastructure through vehicle-to-everything (V2X) communication, enabling advanced traffic management, improved safety, and optimised traffic flow.
- Electric vehicles (EVs), hydrogen fuel cell vehicles, and other alternative propulsion systems are gaining traction, offering reduced emissions and improved environmental performance.
- Drones, air taxis, and other aerial vehicles are being developed for urban transportation, potentially offering new ways to navigate congested cities and improve connectivity.
- Mobility-as-a-Service (MaaS) platforms are integrating various modes of transportation into a single, user-friendly interface, offering seamless and personalised travel experiences.
- Advanced transportation systems like Hyperloop and high-speed rail are being explored to reduce travel times and improve long-distance connectivity.
- Roads, traffic signals, and other infrastructure are becoming increasingly intelligent, using sensors and data analysis to optimise traffic flow and improve safety.
- Vehicles and transportation services are being tailored to individual needs and preferences, offering greater flexibility and convenience.

Advanced Mobility is driving rapid innovation and transformation within the Mobility, Transport & Automotive sector. These advancements have the potential to significantly improve efficiency, safety, and sustainability in transportation while offering new levels of connectivity and personalization. However, challenges such as infrastructure development, regulatory frameworks, and public acceptance need to be addressed to fully realise the potential of Advanced Mobility.

7.1.3. Demographic Change

Demographic change, encompassing shifts in population size, age structure, urbanisation patterns, and income distribution, is a significant force reshaping the Mobility, Transport & Automotive sector. These demographic trends are altering transportation needs, preferences, and behaviours, prompting the industry to adapt and innovate to meet evolving demands.

- Increasing life expectancy and declining birth rates in many developed countries are leading to an ageing population. This trend creates a need for transportation solutions that cater to the specific needs of older adults, such as accessible vehicles, age-friendly infrastructure, and specialised mobility services.
- The continued growth of cities and urban areas is increasing demand for efficient and sustainable urban transportation systems. This includes investments in public transport,

micro-mobility solutions, and smart infrastructure to manage traffic congestion and reduce emissions.

- Global migration patterns and increasing cultural diversity are influencing transportation needs and preferences. This requires the development of inclusive transportation solutions that cater to diverse languages, cultural backgrounds, and accessibility needs.
- In some regions, rising incomes and changing lifestyles are leading to increased car ownership and demand for personalised transportation options. This necessitates the development of innovative mobility services, such as ride-sharing, car subscription models, and on-demand transportation.
- Different generations have varying transportation habits and preferences. Younger generations are more likely to embrace shared mobility, micro-mobility, and public transport, while older generations may prefer private car ownership. Understanding these generational differences is crucial for developing effective transportation solutions.

Demographic change is a complex and multifaceted driver of change in the Mobility, Transport & Automotive sector. Adapting to these demographic trends requires a deep understanding of evolving transportation needs, preferences, and behaviours. By proactively addressing these changes, the industry can develop innovative and sustainable solutions that promote accessibility, efficiency, and inclusivity in transportation.

7.1.4. Industry 5.0 (Automation of Production & Reskilling)

Industry 5.0, with its focus on human-centric automation and advanced technologies, is a significant driver of change in the Mobility, Transport & Automotive sector. It represents a shift towards a more collaborative and sustainable approach to manufacturing, where human skills and creativity are combined with the power of automation and data-driven insights. This driver is characterised by increased efficiency, flexibility, and personalization in production processes, leading to new possibilities for vehicle design, manufacturing, and supply chain management.

- Increased use of collaborative robots (cobots), artificial intelligence (AI), and machine learning in manufacturing processes to improve efficiency, precision, and flexibility. This includes automating tasks such as assembly, painting, and quality control, allowing human workers to focus on more complex and creative tasks.
- Fostering collaboration between humans and machines by integrating human expertise and decision-making with the speed and precision of automated systems. This includes developing intuitive interfaces and user-friendly technologies that empower workers to effectively interact with and control machines.
- Utilising Industry 5.0 technologies to enable mass customization and personalization of vehicles, catering to individual customer preferences and needs. This includes flexible manufacturing systems and advanced production techniques that allow for efficient production of highly customised products.
- As automation increases, there is a growing need for reskilling and upskilling the workforce to adapt to new roles and technologies. Industry 5.0 emphasises the importance of human capital and invests in training programs to equip workers with the skills needed for the future of work.
- Leveraging Industry 5.0 technologies to enhance sustainability and resilience in the automotive sector. This includes optimising resource utilisation, reducing waste, and improving energy efficiency in production processes. Wide adoption of 3D printing, with its potential to reduce material waste and enable on-demand manufacturing, is also a key aspect of this trend.

Industry 5.0 is transforming the Mobility, Transport & Automotive sector by promoting a more human-centric, sustainable, and technologically advanced approach to manufacturing. This driver is leading to increased efficiency, flexibility, and personalization in production processes, while also emphasising the importance of human skills and creativity. By embracing Industry 5.0 principles, the sector can enhance its competitiveness, resilience, and ability to meet the evolving demands of the market.

7.1.5. Security

Security concerns, encompassing both physical and cybersecurity, are increasingly critical drivers of change in the Mobility, Transport & Automotive sector. As vehicles become more complex and interconnected, ensuring the safety of passengers, goods, and data is paramount. This driver necessitates the development and implementation of robust security measures across all aspects of the industry, from vehicle design and manufacturing to infrastructure and data management.

- Advanced safety features, such as collision avoidance systems, lane departure warnings, and adaptive cruise control, are becoming increasingly common in vehicles, enhancing passenger safety and reducing accidents.
- Connected and autonomous vehicles are vulnerable to cyberattacks, requiring robust cybersecurity measures to protect against data breaches, unauthorised access, and malicious control. This includes securing vehicle software and communication networks, implementing strong authentication protocols, and developing intrusion detection systems.
- The increasing amount of data generated and collected by vehicles raises concerns about data privacy and security. Regulations and industry standards are being developed to ensure responsible data handling and protect personal information.
- Transportation infrastructure, such as roads, bridges, and traffic management systems, is also vulnerable to physical and cyber threats. Investing in resilient infrastructure and implementing security measures are crucial to prevent disruptions and ensure public safety.
- Ensuring the integrity and security of the automotive supply chain is essential to prevent counterfeiting, tampering, and other risks. This involves implementing traceability systems, secure logistics processes, and robust quality control measures.

Security is a critical driver of change in the Mobility, Transport & Automotive sector, influencing vehicle design, manufacturing processes, infrastructure development, and data management practices. As technology advances and transportation systems become more complex and interconnected, the importance of security will only continue to grow. The industry must proactively address these challenges to ensure the safety, reliability, and trustworthiness of transportation systems for the future.

7.1.6. Shifts in Global Competition & Types of Outsourcing

The Mobility, Transport & Automotive sector is experiencing significant **shifts in global competition and outsourcing practices**. These changes are driven by factors such as the rise of new players, evolving technologies, and changing economic conditions. This driver is reshaping the industry landscape, impacting manufacturing locations, supply chain dynamics, and the types of services being outsourced.

- Emerging economies and new companies are entering the automotive market, challenging established players and intensifying competition. This includes the rise of Chinese

automakers, as well as new entrants in the electric vehicle (EV) and autonomous driving sectors.

- Manufacturing is shifting to regions with lower labour costs, favourable regulations, and proximity to growing markets. This trend is leading to the relocation of production facilities and the emergence of new automotive hubs in Asia and other regions.
- Outsourcing is evolving beyond traditional manufacturing to encompass a wider range of services, including research and development (R&D), software development, and data analytics. This trend is driven by the increasing complexity of vehicle technology and the need for specialised expertise.
- Companies are increasingly focusing on their core competencies and outsourcing non-core activities to specialised suppliers. This allows them to leverage external expertise, reduce costs, and improve efficiency.
- Recent events, such as the COVID-19 pandemic and geopolitical tensions, have highlighted the vulnerabilities of global supply chains. Companies are seeking to diversify their supply sources, build resilience, and reduce reliance on single suppliers.
- The industry is witnessing the emergence of new collaborative models, such as joint ventures and strategic alliances, to share resources, expertise, and risks. This trend is driven by the need for innovation and the increasing complexity of vehicle technology.

Shifts in global competition and outsourcing are reshaping the Mobility, Transport & Automotive sector, leading to a more dynamic and interconnected industry landscape. Companies need to adapt to these changes by developing flexible strategies, building strong partnerships, and focusing on their core competencies. These shifts also present opportunities for new players and emerging markets to gain a foothold in the industry. The future of the sector will be shaped by how effectively companies can navigate these evolving competitive and collaborative dynamics.

7.1.7. Evolution of Ownership Models

The Mobility, Transport & Automotive sector is undergoing a significant **shift in vehicle ownership models**. Traditional individual car ownership is being challenged by a variety of new models, driven by factors such as changing consumer preferences, technological advancements, and economic considerations. This driver is altering the way people access and use vehicles, impacting vehicle design, business models, and the overall transportation landscape.

- Car subscription services are gaining popularity, offering consumers flexible access to vehicles without the long-term commitment of traditional ownership. These models often include maintenance, insurance, and roadside assistance, providing a hassle-free experience.
- Ride-hailing services, car-sharing platforms, and micro-mobility options are becoming increasingly prevalent, providing alternatives to individual car ownership, particularly in urban areas.
- Fractional ownership models allow individuals to share ownership of a vehicle, reducing the financial burden and environmental impact associated with individual ownership.
- Leasing and financing options are becoming more flexible and tailored to individual needs, providing alternative pathways to vehicle access without outright purchase.
- Pay-per-use models and dynamic pricing structures are emerging, allowing consumers to pay only for the actual usage of a vehicle or service.
- The development of autonomous vehicles is expected to lead to the growth of shared, on-demand autonomous vehicle fleets, potentially disrupting traditional car ownership models.

The evolution of ownership models is transforming the Mobility, Transport & Automotive sector, offering consumers greater flexibility, convenience, and affordability in accessing and using vehicles. This driver is impacting vehicle design, manufacturing strategies, and business models across the industry. As these new ownership models continue to evolve, they will likely play a significant role in shaping the future of transportation and mobility.

7.1.8. Energy Sources

The shift towards sustainable and diversified **energy sources** is a major driver of change in the Mobility, Transport & Automotive sector. The transition away from fossil fuels is prompting the industry to explore and adopt a variety of alternative energy sources to power vehicles and support transportation infrastructure. This driver is influencing vehicle design, manufacturing processes, and the overall energy landscape of the transportation sector.

- Battery electric vehicles (BEVs) are becoming increasingly prevalent, driven by advancements in battery technology, declining costs, and government incentives. This trend is leading to the expansion of charging infrastructure and the development of smart grids to manage electricity demand.
- Hydrogen fuel cell vehicles (FCVs) are emerging as a promising alternative, offering long ranges, fast refuelling times, and zero tailpipe emissions. This technology requires the development of hydrogen production and distribution infrastructure.
- Biofuels, derived from renewable biomass sources, are being used as a sustainable alternative to fossil fuels in some transportation applications. This includes biodiesel and ethanol blends for conventional vehicles, as well as sustainable aviation fuels (SAFs) for aircraft.
- Transportation infrastructure is increasingly integrating renewable energy sources, such as solar and wind power, to reduce reliance on fossil fuels and lower carbon emissions. This includes solar-powered charging stations, wind-powered ferries, and renewable energy-powered microgrids.
- Advanced energy storage technologies, such as solid-state batteries and hydrogen storage systems, are being developed to improve the performance and range of electric and hydrogen vehicles.
- Improving energy efficiency in vehicles and transportation systems is a key focus, driven by the need to reduce fuel consumption and emissions. This involves optimising vehicle design, powertrains, and logistics processes.

The diversification of energy sources is transforming the Mobility, Transport & Automotive sector, leading to the development of new vehicle technologies and infrastructure solutions. This driver is accelerating the transition towards a more sustainable and decarbonized transportation system. However, challenges such as cost, infrastructure development, and technological advancements need to be addressed to fully realise the potential of alternative energy sources in transportation.

7.2. List of key disruptions in MTA

MTA Focus group experts involved in the IDEALISTss Horizon Scanning identified key signals that will shape the future of the sector. **Signals** are early indications that disruptive change could be underway.

Experts assessed each signal using two metrics:

- **Earliest Time to Mainstream (ETM):** this measures the minimum time needed for a signal to become mainstream defined as the point of peak impact on the ecosystem. Assessments ranged from 2 to 20 years in the future.
- **Impact** describes the nature (positive or negative) and the level of the signal's estimated impact on the ecosystem, using a scale of -5 to +5.

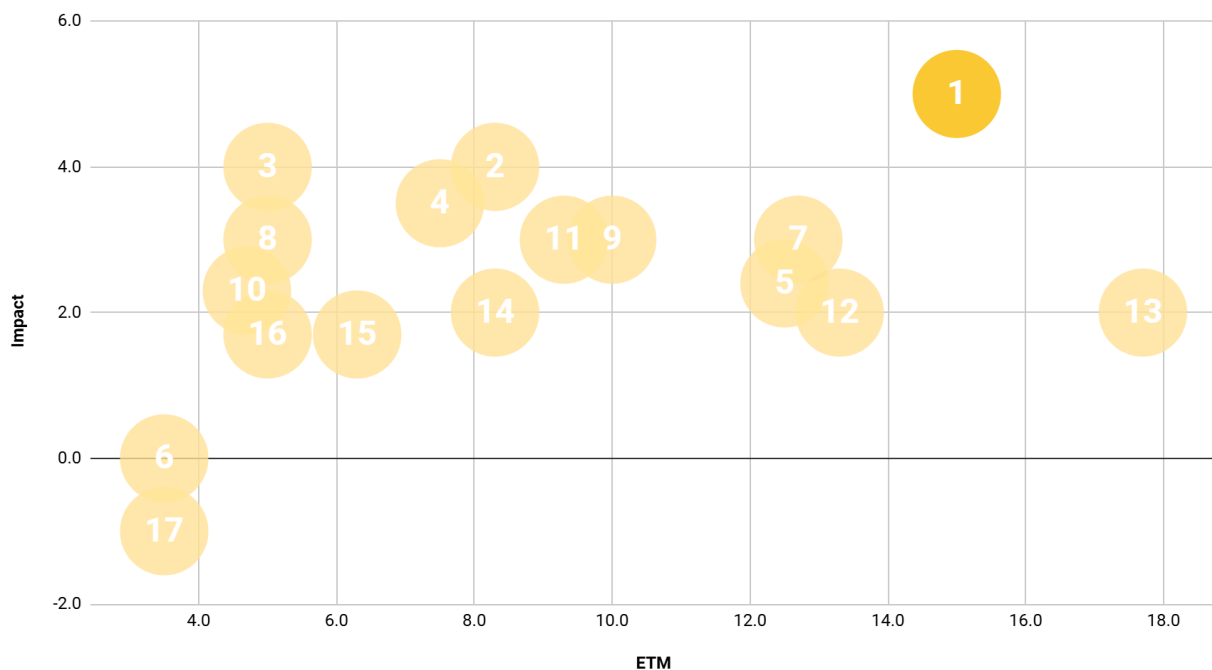
These assessments made it possible to identify signals of change as potential **disruptors**, indicating substantial shifts within the study area. A signal is classified as a potential disruptor if its impact receives a score below -1 or above +1. This scoring system uses negative values to represent adverse effects and positive values for beneficial effects on the industrial ecosystem. A signal with a score of -4 or lower, or +4 or higher, is categorized as a potential hyperdisruptor, indicating a potential for extreme disruption, whether positive or negative.

7.2.1. Signal 1: Hyperloop (super fast land mobility)⁵³

Hyperloop, a new transportation technology that uses vacuum tubes to move people and cargo at very high speeds, could change the way we travel and transport goods over long distances.

7.2.1.1. Matrix figure (ETM, IMPACT)

Figure 45. Impact and ETM Analysis of Hyperloop (super fast land mobility) in Mobility, Transport & Automotive.



The impact of signal 1 (Hyperloop) was estimated at 5. Its score of 5 categorizes it as a hyperdisruptor, which may positively influence the ecosystem's development. The estimated ETM is 15 years, which means that the signal may fully materialize by mid-2039.

7.2.1.2. How can it change our optics?

- It shifts attention towards high-speed and futuristic transportation solutions.

⁵³ Source: <https://www.ferrovial.com/en/innovation/technologies/hyperloop/>

- It underlines the importance of investing in next-generation infrastructure for rapid travel.
- It brings a new element to the discussion about reducing travel time and enhancing connectivity between major urban centers.
- Important focus will be on safety issues

7.2.1.3. How can it change the ecosystem?

- Particularly relevant for transportation planners, infrastructure developers, and policymakers.
- Significance of this can be seen in its potential to drastically cut travel times and improve the efficiency of freight transport.
- Ecosystem dynamics are expected to change as traditional modes of long-distance travel (e.g., trains, planes) may face competition from hyperloop systems

7.2.1.4. What opportunities does the signal carry for the ecosystem?

- Creation of new high-speed transport corridors.
- Economic growth through improved connectivity and reduced travel times.
- Potential for innovative infrastructure and engineering solutions.

7.2.1.5. What risks does the signal carry for the ecosystem?

- High costs and technical challenges in developing and implementing hyperloop systems.
- Regulatory and safety concerns related to high-speed travel.
- Potential environmental impacts during construction and operation.

7.2.1.6. What challenges does the signal carry for the ecosystem?

- Funding and investment for large-scale projects.
- Developing safe and reliable hyperloop technology.
- Overcoming regulatory and public acceptance hurdles.

7.2.2. Signal 2: Superconductors in EV engine⁵⁴

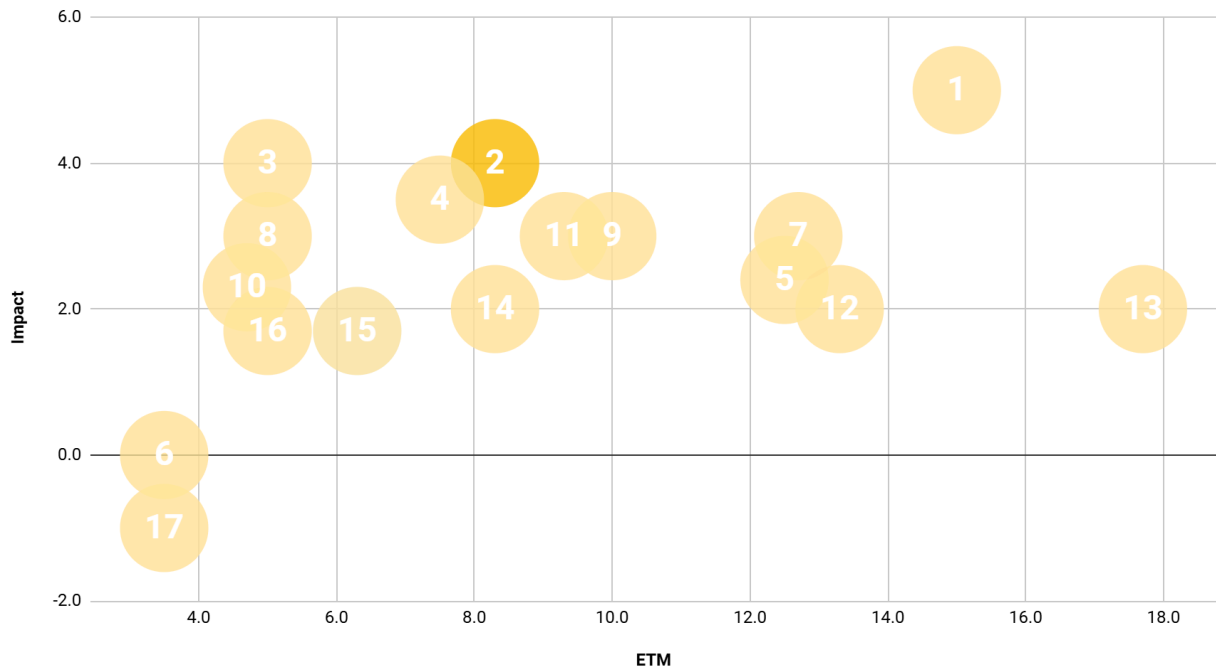
A new superconducting technology could revolutionise transportation by enabling lighter vehicles with high power and low energy consumption. However, the technology would need additional devices to control the torque and to keep the characteristics of the superconductor highly dependent on temperature.

⁵⁴ Source:

https://www.researchgate.net/publication/351919326_Superconductors_in_electric_vehicles-analysis_and_feasibility

7.2.2.1. Matrix figure (ETM, IMPACT)

Figure 46. Impact and ETM Analysis of Superconductors in EV engines in Mobility, Transport & Automotive.



The impact of signal 2 (Superconductors in EV engine) was estimated at 4. Its score of 4 categorizes it as a hyperdisruptor, which may positively influence the ecosystem's development. The estimated ETM is 8.3 years, which means that the signal may fully materialize by mid-2033.

7.2.2.2. How can it change our optics?

Will change the structure of the vehicles. EV will be applicable for trucks, and the materials used as now as rare earth elements.

7.2.2.3. How can it change the ecosystem?

This will allow it to be thought of as a solution for EV in higher scope (decarbonization of the transport by road). It will have a change in the dependency of the current materials as rare earth elements, swifiting to other new materials (conductors).

7.2.2.4. What opportunities does the signal carry for the ecosystem?

- Being more effective and green.
- New players on the market.
- New possibilities are new industries becoming relevant for the necessity of new devices (specific gearbox or cooling systems).

7.2.2.5. What risks does the signal carry for the ecosystem?

The research to develop this technology could be extremely high.

7.2.2.6. What challenges does the signal carry for the ecosystem?

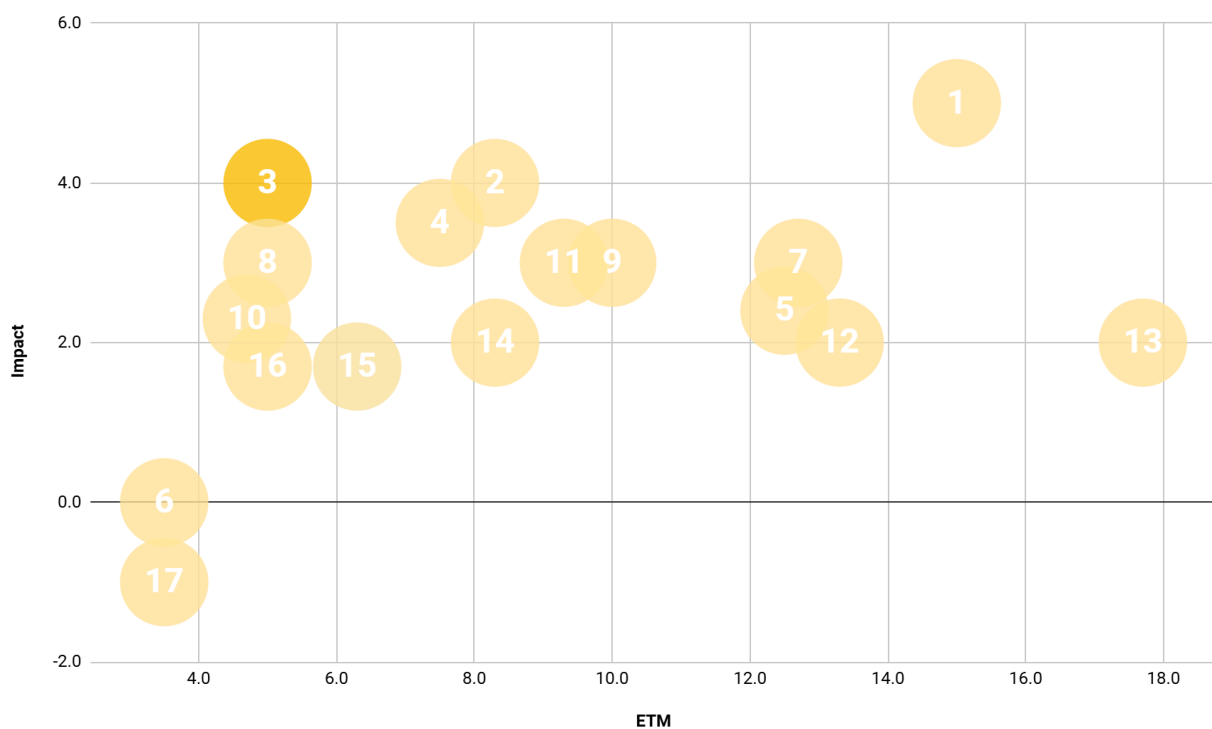
This option becomes unfeasible or expensive.

7.2.3. Signal 3: Quantum-Powered Protection for Autonomous Vehicles⁵⁵

Quantum technologies could significantly improve the safety and reliability of self-driving cars. This could involve using quantum computers for better navigation and decision-making, and quantum cryptography to protect against hacking.

7.2.3.1. Matrix figure (ETM, IMPACT)

Figure 47. Impact and ETM Analysis of Quantum-Powered Protection for Autonomous Vehicles in Mobility, Transport & Automotive.



The impact of signal 3 (Quantum-Powered Protection for Autonomous Vehicles) was estimated at 4. Its score of 4 categorizes it as a hyperdisruptor, which may positively influence the ecosystem's development. The estimated ETM is 5 years, which means that the signal may fully materialize by mid-2029.

7.2.3.2. How can it change our optics?

- It shifts attention towards the potential of quantum technologies to revolutionise transportation showcasing their applicability in ensuring the safety and security of autonomous vehicles.
- It underlines the importance of cybersecurity in the era of autonomous vehicles as autonomous vehicles become increasingly reliant on complex software and interconnected systems.

⁵⁵ Source: <https://vicone.com/blog/quantum-computing-forging-new-frontiers-for-autonomous-vehicles>

- Quantum-powered protection could accelerate the adoption of autonomous vehicles and pave the way for a future where transportation is safer and more efficient.

7.2.3.3. How can it change the ecosystem?

- Quantum-powered protection could drive innovation in autonomous vehicle technology, cybersecurity, and quantum communication systems.
- Potential for new jobs, investments, and economic growth associated with these emerging technologies.

7.2.3.4. What opportunities does the signal carry for the ecosystem?

- Quantum-powered protection can significantly improve the safety and security of autonomous vehicles by providing robust defence against cyberattacks and enhancing the reliability of autonomous navigation systems.
- Quantum-powered protection could accelerate the adoption of autonomous vehicles.
- The development and implementation of quantum-powered protection could drive further innovation in quantum computing, cryptography, and communication technologies.

7.2.3.5. What risks does the signal carry for the ecosystem?

- Quantum technologies could be misused for malicious purposes, raising concerns about the potential for new types of cyberattacks.
- The use of quantum technologies in autonomous vehicles raises ethical questions about data privacy, algorithmic bias, and the potential impact on human autonomy.

7.2.3.6. What challenges does the signal carry for the ecosystem?

- Establishing standards and ensuring interoperability between different quantum-powered protection systems.

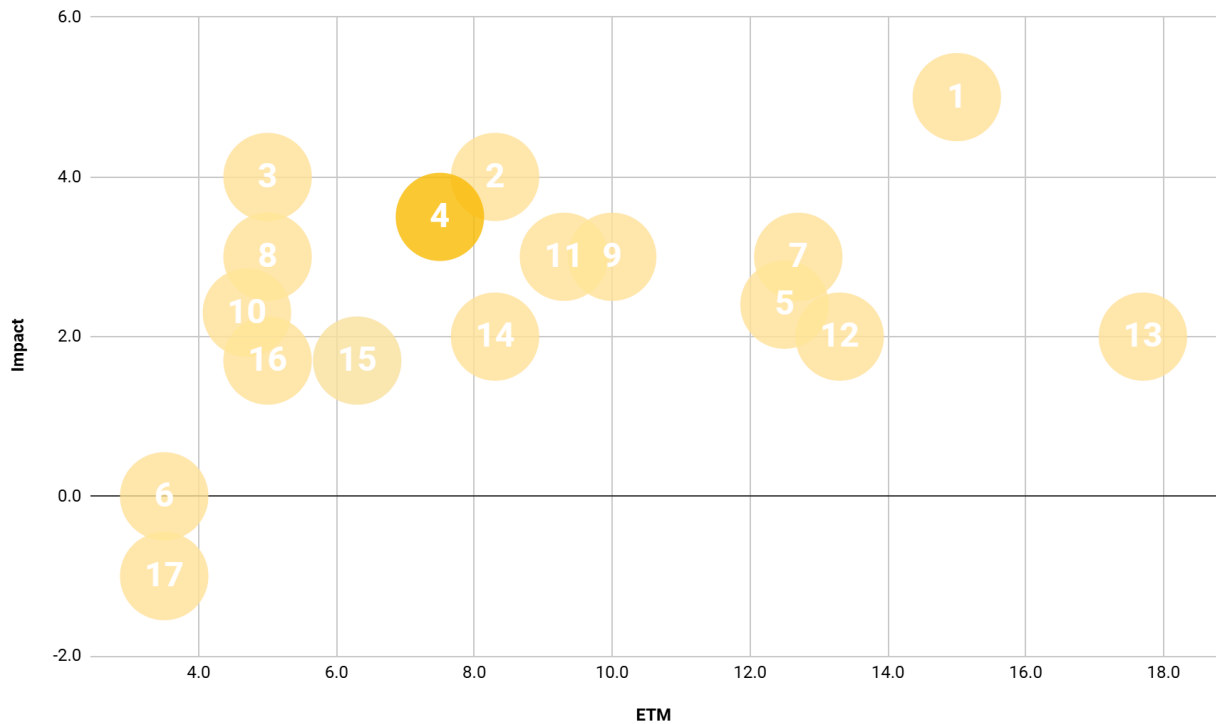
7.2.4. Signal 4: High-Power Dynamic Inductive Charging with Low Power Pulsation for Continuous EV Charging⁵⁶

Electric vehicles (EVs) may soon be able to charge wirelessly while driving, using a new technology called high-power dynamic inductive charging. This system allows for continuous charging with minimal power fluctuations, making it efficient and convenient for long journeys.

⁵⁶ Source: <https://www.nature.com/articles/s41598-023-44949-z>

7.2.4.1. Matrix figure (ETM, IMPACT)

Figure 48. Impact and ETM Analysis of High-Power Dynamic Inductive Charging with Low Power Pulsation for Continuous EV Charging in Mobility, Transport & Automotive.



The impact of signal 4 (High-Power Dynamic Inductive Charging with Low Power Pulsation for Continuous EV Charging) was estimated at 3.5. Its score of 3.5 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 7.5 years, which means that the signal may fully materialize by mid-2032.

7.2.4.2. How can it change our optics?

- Neverending autonomy. Self-charging on the go. Comfort during charging or refuelling. Stress-free EV ownership. Drivers can focus on more creative pursuits instead of worrying about charging.
- Infrastructure Transformation: HPDIC-LPP could lead to a shift away from traditional charging stations and towards a network of charging lanes embedded in roadways, transforming the way we think about EV infrastructure.

7.2.4.3. How can it change the ecosystem?

- Decreased dependency on batteries leads to less technological reliance on China (for critical raw materials and batteries themselves).
 - Price reduction for consumers, but high initial investment in infrastructure by governments.
 - Charging with induction requires a redesign of city architecture, impacting pedestrians and other vehicles (which necessitates new regulations and standards for compatibility).
- Environmental ++: Reduced Greenhouse Gas Emissions, Lower Noise Pollution, Increased Energy Efficiency: HPDIC-LPP systems with low power pulsation can transfer energy more

efficiently than traditional charging methods, leading to reduced energy losses and a more sustainable transportation system.

- Environmental ---: Increased Electricity Demand; Resource Extraction: The production of EVs and HPDIC-LPP infrastructure requires the extraction and processing of raw materials, such as lithium, cobalt, and rare earth elements, which can have negative environmental and social impacts; Battery Disposal: Lithium-ion batteries used in EVs have a limited lifespan and their disposal poses environmental challenges due to the presence of hazardous materials.

7.2.4.4. What opportunities does the signal carry for the ecosystem?

- Dynamic inductive charging could significantly accelerate the adoption of electric vehicles (EVs) by eliminating range anxiety and reducing the need for frequent stops to recharge.
- Dynamic inductive charging could improve traffic flow and reduce congestion on highways and in urban areas.

7.2.4.5. What risks does the signal carry for the ecosystem?

- Electromagnetic Fields (EMF): There are concerns about potential health effects from exposure to the electromagnetic fields generated by wireless charging systems. However, research on this topic is ongoing and current evidence suggests that exposure levels from HPDIC-LPP are within safe limits.

7.2.4.6. What challenges does the signal carry for the ecosystem?

- Implementing dynamic inductive charging infrastructure could be complex and expensive, requiring significant investments in research, development, and deployment.
- Ensuring the safety and electromagnetic compatibility of dynamic inductive charging systems.

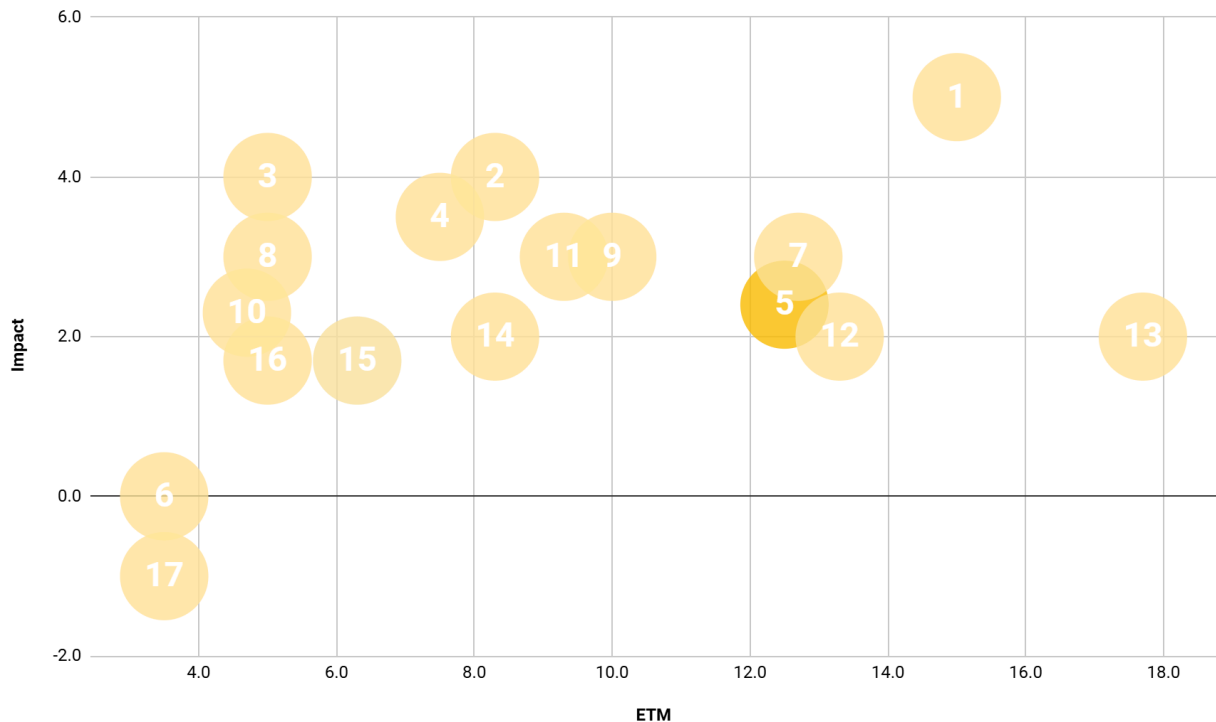
7.2.5. Signal 5: UAM solutions + Personal Air Mobility Drone Takes Flight⁵⁷

Autonomous flying vehicles, like drone taxis, are being tested in some cities as a new form of urban transportation. This development in Urban Air Mobility could revolutionise how we travel within cities, offering faster, more efficient, and potentially more sustainable ways to navigate urban environments.

⁵⁷ Source: "<https://link.springer.com/article/10.1007/s13272-024-00733-x>
https://www.easa.europa.eu/sites/default/files/dfu/uam_-_faq.pdf"

7.2.5.1. Matrix figure (ETM, IMPACT)

Figure 49. Impact and ETM Analysis of UAM solutions + Personal Air Mobility Drone Takes Flight in Mobility, Transport & Automotive.



The impact of signal 5 (UAM solutions + Personal Air Mobility Drone Takes Flight) was estimated at 2.4. Its score of 2.4 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 12.5 years, which means that the signal may fully materialize by mid-2037.

7.2.5.2. How can it change our optics?

- It shifts attention towards the feasibility and practical applications of autonomous aerial transport within urban environments.
- It underlines the importance of airspace management, urban planning, and regulatory frameworks for UAM.
- It brings a new element to the discussion about the future of urban mobility and the reduction of ground traffic congestion.
- It facilitates the understanding of how advanced aerial technology can integrate with existing transportation systems

7.2.5.3. How can it change the ecosystem?

- This is particularly relevant for urban transportation planners, policymakers, and technology developers.
- The significance of this can be seen in its potential to reduce urban road congestion and provide faster, more efficient transport options.
- Ecosystem dynamics are expected to change as traditional ground-based transport solutions may need to adapt to the introduction of aerial alternatives, impacting everything from infrastructure development to regulatory policies.

7.2.5.4. What opportunities does the signal carry for the ecosystem?

- Creation of new business models around UAM services.
- Reduction in urban traffic congestion.
- Potential for new infrastructure developments and urban planning innovations

7.2.5.5. What risks does the signal carry for the ecosystem?

- Safety and security concerns regarding autonomous flying vehicles.
- Regulatory and airspace management challenges.
- Potential job displacement in traditional transport sectors

7.2.5.6. What challenges does the signal carry for the ecosystem?

- Developing robust and reliable technology for autonomous flight.
- Ensuring public acceptance and trust in autonomous UAM solutions.
- Creating comprehensive regulatory frameworks to manage UAM operations.

7.2.6. Signal 6: Increased Use of Micro-mobility Options in Urban Areas⁵⁸

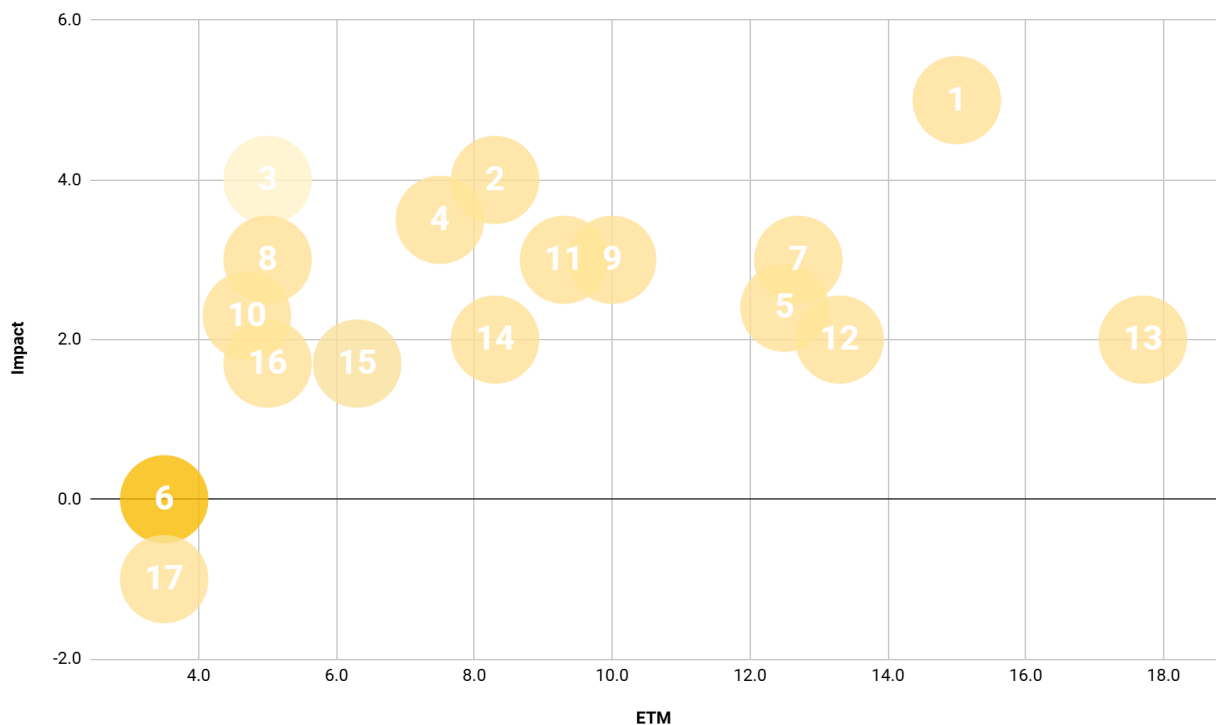
People in cities are increasingly using small, electric vehicles like e-scooters and e-bikes for short trips. These "micro-mobility" options offer a convenient and eco-friendly alternative to cars, especially for navigating crowded streets and connecting to public transport.

⁵⁸ Source:

https://single-market-economy.ec.europa.eu/sectors/automotive-industry/environmental-protection/emissions-automotive-sector_en

7.2.6.1. Matrix figure (ETM, IMPACT)

Figure 50. Impact and ETM Analysis of Increased Use of Micro-mobility Options in Urban Areas in Mobility, Transport & Automotive.



The impact of signal 6 (Increased Use of Micro-mobility Options in Urban Areas) was estimated at 0. This score means it was not categorized as a disruptor, and its influence on the ecosystem's development is expected to be rather marginal, if any. The estimated ETM is 3.5 years, which means that the signal may fully materialize by mid-2028.

7.2.6.2. How can it change our optics?

- It shifts attention towards more sustainable and people-centred urban design.
- It facilitates the understanding of a potential change in urban lifestyle and commuting habits.
- It underlines the importance of multi-modal transportation systems.

7.2.6.3. How can it change the ecosystem?

- The growth of micro-mobility drives innovation in battery technology, lightweight materials, and smart mobility solutions, such as apps for booking and managing shared vehicles.
- Micro-mobility can create new economic opportunities for shared mobility providers, maintenance and repair services, and supporting industries.

7.2.6.4. What opportunities does the signal carry for the ecosystem?

- Reduced congestion and emissions.

- Provide efficient last-mile connectivity to public transportation hubs, making it easier for people to navigate cities without relying on cars.

7.2.6.5. What risks does the signal carry for the ecosystem?

- Accidents involving micro-mobility vehicles raise safety concerns, particularly in cities with inadequate infrastructure for cyclists and pedestrians.
- The rapid growth of micro-mobility has outpaced regulations in many cities, leading to uncertainty about usage rules, parking restrictions, and safety standards.

7.2.6.6. What challenges does the signal carry for the ecosystem?

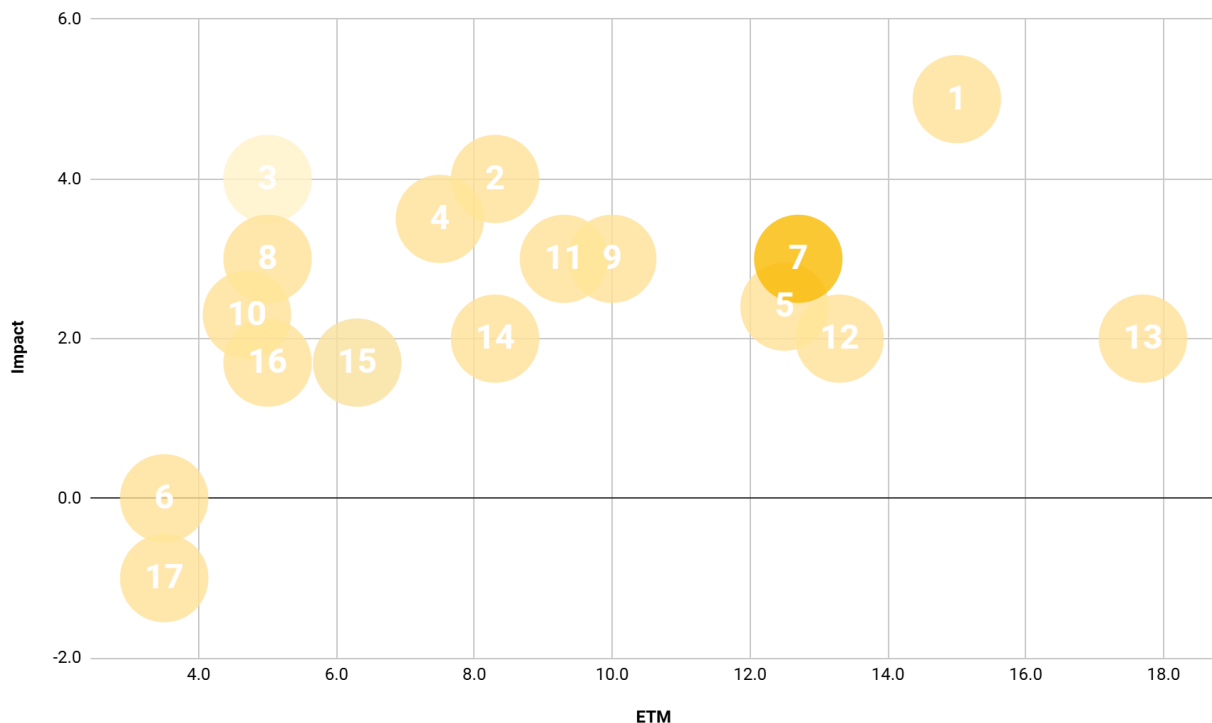
- Integrating micro-mobility into existing urban infrastructure can be challenging.
- Developing comprehensive safety regulations and infrastructure to protect micro-mobility users and pedestrians.

7.2.7. Signal 7: Supersonic drones for rapid, point-to-point personal transport⁵⁹

This technology proposes utilising supersonic drones to revolutionise personal travel, enabling rapid commutes between distant locations.

7.2.7.1. Matrix figure (ETM, IMPACT)

Figure 51. Impact and ETM Analysis of Supersonic drones for rapid, point-to-point personal transport in Mobility, Transport & Automotive.



The impact of signal 7 (Supersonic drones for rapid, point-to-point personal transport) was estimated at 3. Its score of 3 categorizes it as a disruptor, which may positively influence the

⁵⁹ Source: <https://www.rid.it/shownews/5319/china-unveils-its-hypersonic-uav>

ecosystem's development. The estimated ETM is 12.7 years, which means that the signal may fully materialize by mid-2037.

7.2.7.2. How can it change our optics?

- It shifts attention towards the potential for personalised aviation and on-demand air travel.
- Supersonic drones could revolutionise personal transportation, making long-distance travel more accessible and convenient.
- It underlines the importance of technological advancements in propulsion and flight control systems.

7.2.7.3. How can it change the ecosystem?

- Supersonic drones will drive innovation in aerospace engineering, materials science, and autonomous navigation systems.
- Air travel becomes more personalised and on-demand, potentially impacting urban planning, infrastructure development, and transportation regulations.

7.2.7.4. What opportunities does the signal carry for the ecosystem?

- Supersonic drones could significantly reduce travel times
- This technology could make air travel more accessible to a wider population, potentially connecting remote areas.

7.2.7.5. What risks does the signal carry for the ecosystem?

- Supersonic flight can generate significant noise pollution, potentially impacting communities and ecosystems.
- The cost of developing and operating supersonic drones could initially be high.

7.2.7.6. What challenges does the signal carry for the ecosystem?

- Building the necessary infrastructure to support supersonic drone operations, including vertiports and charging or refuelling stations.
- Developing a comprehensive regulatory framework to ensure safety, manage air traffic, and address environmental concerns.
- Gaining public acceptance and addressing concerns about safety, noise.

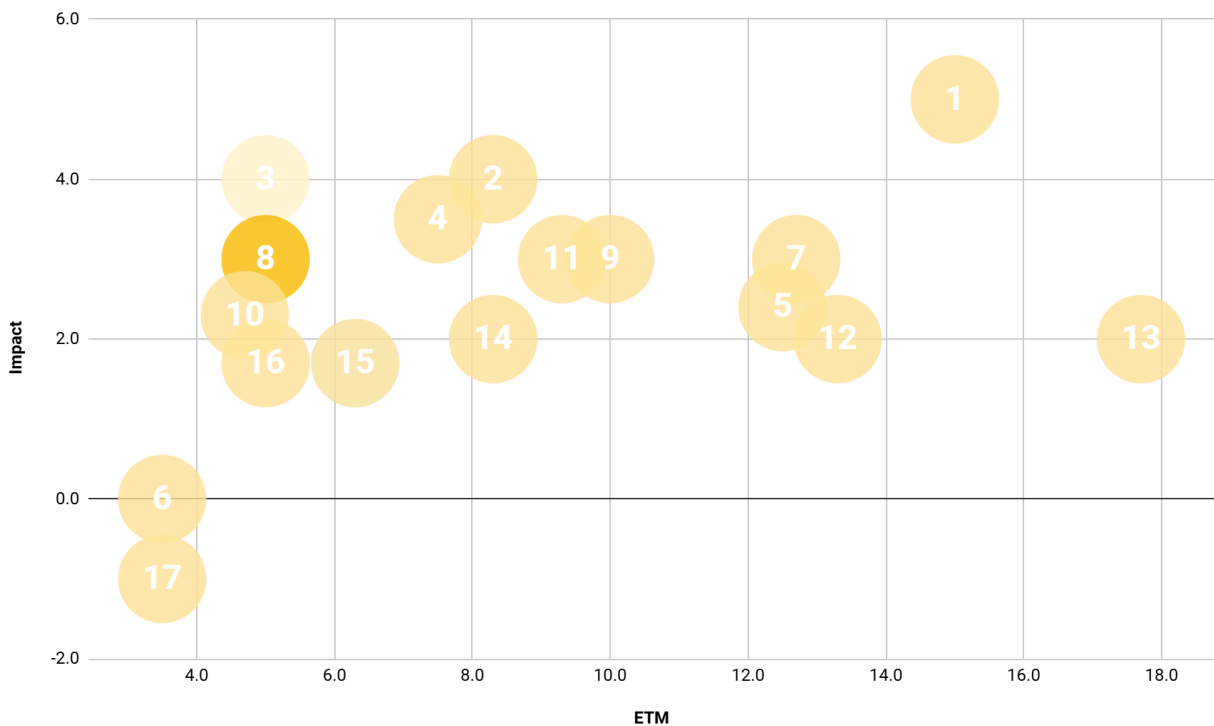
7.2.8. Signal 8: MaaS platforms⁶⁰

Mobility-as-a-Service (MaaS) platforms are becoming increasingly popular. These platforms combine different transportation options like buses, trains, ride-sharing, and bike rentals into a single, easy-to-use app, making it simpler for people to plan and pay for their journeys.

⁶⁰ Source: <https://www.sciencedirect.com/science/article/pii/S2667091722000164>

7.2.8.1. Matrix figure (ETM, IMPACT)

Figure 52. Impact and ETM Analysis of MaaS platforms in Mobility, Transport & Automotive.



The impact of signal 8 (MaaS platforms) was estimated at 3. Its score of 3 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 5 years, which means that the signal may fully materialize by mid-2029.

7.2.8.2. How can it change our optics?

- It shifts attention towards the integration and digitization of transportation services., underlining the importance of user-centric and flexible mobility solutions.
- MaaS expansion above all brings a new element to the discussion about optimising urban mobility and reducing reliance on private car ownership.

7.2.8.3. How can it change the ecosystem?

- Particularly relevant for urban planners and public transport authorities but also technology providers.
- The significance of this can be seen in its potential to improve access to various transport modes and reduce traffic congestion.
- Ecosystem dynamics are thus expected to change as MaaS platforms encourage more sustainable and efficient transportation behaviours.

7.2.8.4. What opportunities does the signal carry for the ecosystem?

- Increased convenience and accessibility of transportation options.
- Potential for data-driven optimization of transport networks.
- Reduction in traffic congestion and environmental impact.

7.2.8.5. What risks does the signal carry for the ecosystem?

- Security concerns and Data privacy
- Potential monopolisation of mobility services by large platforms.
- Challenges in integrating diverse transportation services

7.2.8.6. What challenges does the signal carry for the ecosystem?

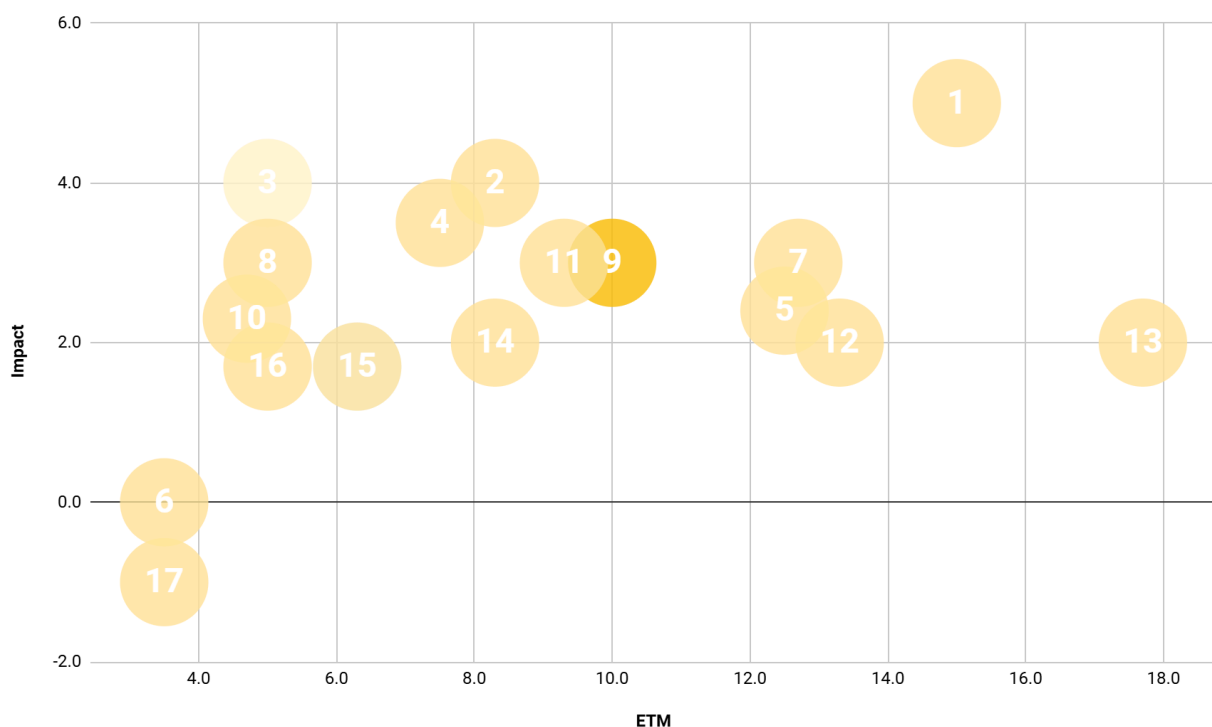
- Gaining user trust and widespread adoption.
- Addressing regulatory and compliance issues across different Countries (=jurisdictions)
- Ensuring interoperability between different transport providers.

7.2.9. Signal 9: Hydrogen cars⁶¹

Hydrogen cars are emerging as a potential alternative to battery-electric vehicles, offering faster refuelling times and longer ranges. This could simplify the infrastructure needed for widespread adoption of electric vehicles, making them a more attractive option for consumers and businesses.

7.2.9.1. Matrix figure (ETM, IMPACT)

Figure 53. Impact and ETM Analysis of Hydrogen cars in Mobility, Transport & Automotive.



The impact of signal 9 (Hydrogen cars) was estimated at 3. Its score of 3 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 10 years, which means that the signal may fully materialize by mid-2034.

⁶¹ Source: <https://seshydrogen.com/en/hydrogen-cars-what-should-you-know-about-them/>

7.2.9.2. How can it change our optics?

It brings a new element to the discussion about alternative fuels, continuing with fuels instead of moving to electricity: quick refuelling, long autonomy.

7.2.9.3. How can it change the ecosystem?

Ecosystem dynamics are expected to change as hydrogen infrastructure expands.

7.2.9.4. What opportunities does the signal carry for the ecosystem?

- Hydrogen cars can reduce greenhouse gas emissions and contribute to cleaner air quality, especially in urban areas.
- Hydrogen can be produced from various sources, including renewable energy like solar and wind power, enabling a shift away from fossil fuel dependence and enhancing energy security.
- Hydrogen cars can offer longer driving ranges compared to many battery electric vehicles, making them suitable for long-distance travel.

7.2.9.5. What risks does the signal carry for the ecosystem?

- Producing hydrogen in an environmentally sustainable way.
- The lack of widespread hydrogen refuelling infrastructure.
- Hydrogen is a flammable gas, raising safety concerns about storage, transportation, and handling.

7.2.9.6. What challenges does the signal carry for the ecosystem?

- Reducing the cost of hydrogen production, storage, and distribution.
- Increasing public awareness and addressing concerns about the safety and reliability of hydrogen cars.

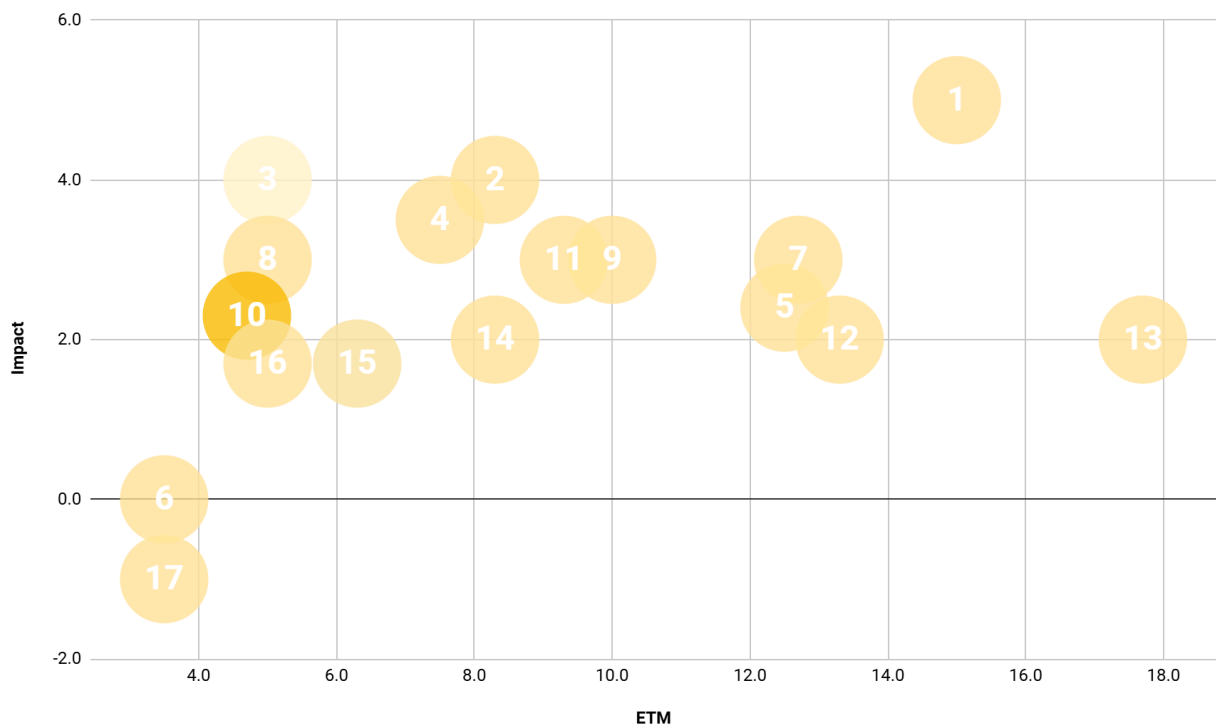
7.2.10. Signal 10: Modular hydrogen propulsion systems that can be retrofitted onto existing trains⁶²

This technology allows existing diesel trains to be converted to run on clean hydrogen fuel by installing pre-built hydrogen engine modules.

⁶² Source: <https://www.sciencedirect.com/science/article/pii/S2210970622000385>

7.2.10.1. Matrix figure (ETM, IMPACT)

Figure 54. Impact and ETM Analysis of Modular hydrogen propulsion systems that can be retrofitted onto existing trains in Mobility, Transport & Automotive.



The impact of signal 10 (Modular hydrogen propulsion systems that can be retrofitted onto existing trains) was estimated at 2.3. Its score of 2.3 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 4.7 years, which means that the signal may fully materialize by mid-2029.

7.2.10.2. How can it change our optics?

It brings a new element to the discussion about decarbonizing transportation and achieving climate goals.

7.2.10.3. How can it change the ecosystem?

Reducing emissions and noise pollution from trains.

7.2.10.4. What opportunities does the signal carry for the ecosystem?

- Hydrogen fuel cell technology can offer higher energy efficiency compared to diesel engines.
- Reduced emissions
- Reduced noise pollution

7.2.10.5. What risks does the signal carry for the ecosystem?

- Producing hydrogen in an environmentally sustainable way.

- Hydrogen is a flammable gas, raising safety concerns about storage, transportation, and handling.

7.2.10.6. What challenges does the signal carry for the ecosystem?

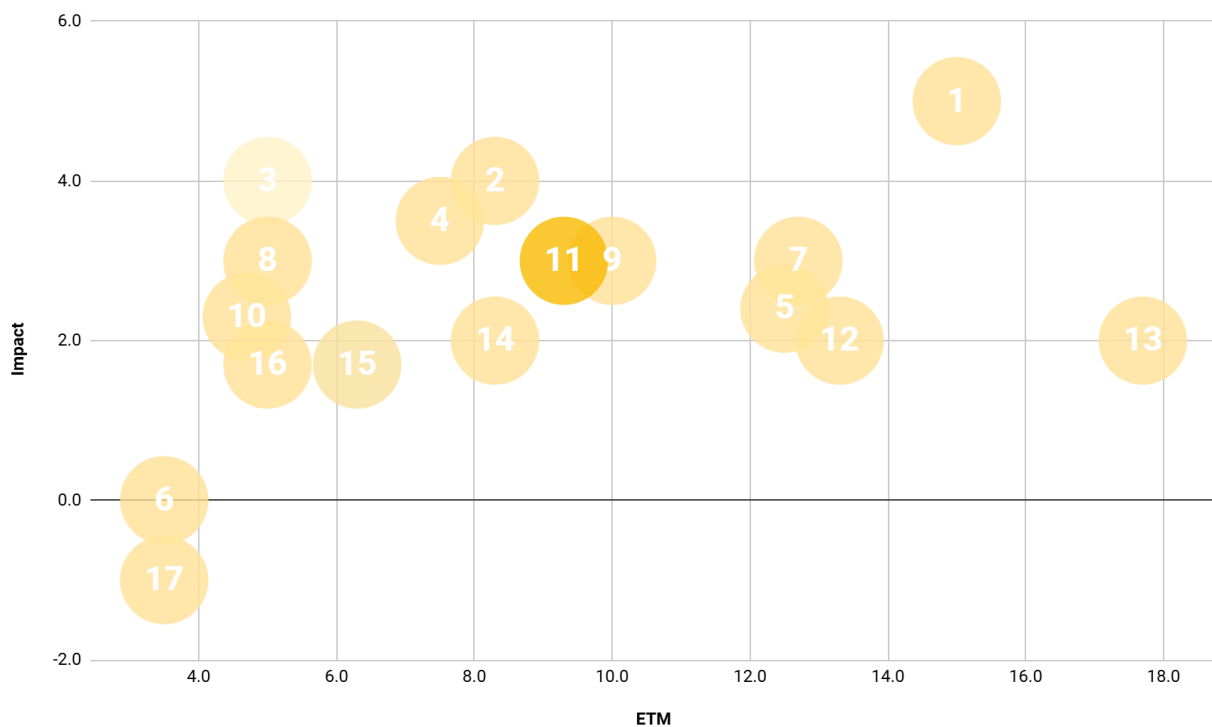
- Improvement of the efficiency, durability, and cost-effectiveness of hydrogen fuel cell systems for trains.
- Building out a hydrogen refuelling infrastructure for trains.
- Reducing the cost of hydrogen production, storage.

7.2.11. Signal 11: Remanufacturing⁶³

Remanufacturing is gaining traction as a sustainable way to give old products a second life. By restoring used items to like-new condition through disassembly, cleaning, and replacement of worn parts, it reduces waste, conserves resources, and offers a cost-effective alternative to buying new. This process also often comes with warranties, providing consumers with confidence in the quality and longevity of remanufactured products.

7.2.11.1. Matrix figure (ETM, IMPACT)

Figure 55. Impact and ETM Analysis of Remanufacturing in Mobility, Transport & Automotive.



The impact of signal 11 (Remanufacturing) was estimated at 3. Its score of 3 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 9.3 years, which means that the signal may fully materialize by mid-2034.

⁶³ Source: <https://borgautomotive-reman.com/what-we-do/remanufacturing-explained>

7.2.11.2. How can it change our optics?

Remanufacturing encourages a holistic view of sustainability and resource management within mobility since it fosters a forward-thinking mindset, where the emphasis is placed not only on innovation but also on responsible consumption and waste reduction. This change in optics can lead to a more resilient and sustainable future for the entire ecosystem.

7.2.11.3. How can it change the ecosystem?

Remanufacturing can lead to strong advancements in manufacturing technologies first of all. A focus on product design for remanufacturing can enhance efficiency and drive innovation, while this shift can also create new jobs AND reshape consumer attitudes, thus significantly reducing landfill waste.

7.2.11.4. What opportunities does the signal carry for the ecosystem?

- Remanufacturing reduces waste, conserves resources, and lowers greenhouse gas emissions compared to manufacturing new products.
- Remanufactured products can be offered at lower prices than new products, making them more accessible to consumers and businesses.
- Remanufacturing extends the lifespan of products.

7.2.11.5. What risks does the signal carry for the ecosystem?

- Remanufacturing can add complexity to the supply chain, requiring efficient collection, sorting, and processing of used products.
- Some consumers may have negative perceptions about remanufactured products, associating them with lower quality or reliability.

7.2.11.6. What challenges does the signal carry for the ecosystem?

- Designing products for disassembly and remanufacturing can be challenging, requiring careful consideration of materials, components, and assembly processes.
- Ensuring the quality and reliability of remanufactured products.
- Efficiently collecting and sorting used products for remanufacturing can be logistically challenging.

7.2.12. Signal 12: Autonomous driving⁶⁴

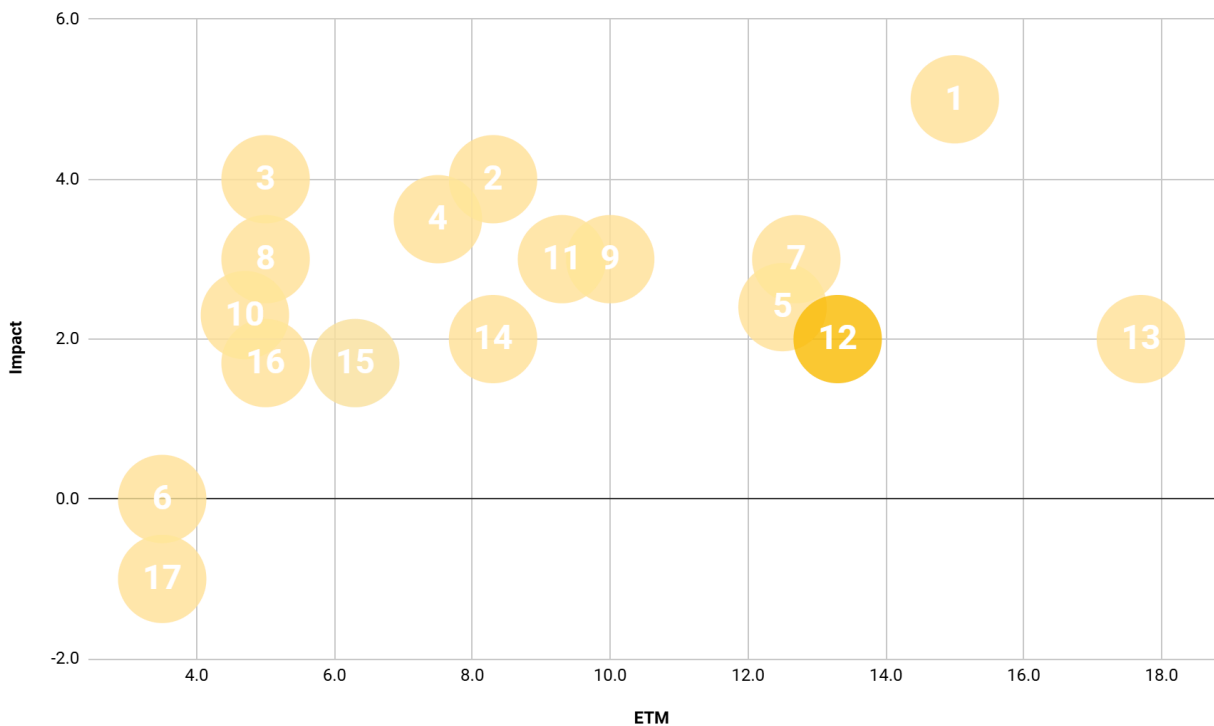
Self-driving cars are being developed using advanced technologies like sensors, cameras, and artificial intelligence. These vehicles can navigate and make driving decisions without human input, potentially changing the future of transportation.

⁶⁴ Source:

<https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/autonomous-drivings-future-convenient-and-connected>

7.2.12.1. Matrix figure (ETM, IMPACT)

Figure 56. Impact and ETM Analysis of Autonomous driving in Mobility, Transport & Automotive.



The impact of signal 12 (Autonomous driving) was estimated at 2. Its score of 2 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 13.3 years, which means that the signal may fully materialize by mid-2038.

7.2.12.2. How can it change our optics?

Autonomous driving encourages discussions about the role of technology in enhancing road safety and underlines the importance of urban planning and infrastructure(=need to rethink urban environments and transportation infrastructure).

7.2.12.3. How can it change the ecosystem?

Several potential implications:

- technological, i.e. development of autonomous vehicles can drive innovation in AI and sensor technologies, leading to improvements in data processing, navigation and safety systems.
- economic, i.e. new business models like MaaS, job creation.
- societal, i.e. accessibility for individuals who cannot drive.

7.2.12.4. What opportunities does the signal carry for the ecosystem?

- Autonomous systems have the potential to reduce traffic accidents.
- Autonomous driving can optimise traffic flow, leading to less congestion and lower transportation costs.

- This technology opens the door for new mobility business models, such as robotaxis and autonomous freight transport.

7.2.12.5. What risks does the signal carry for the ecosystem?

- Concerns remain about the safety of autonomous vehicles and their ability to handle unforeseen situations.
- Autonomous driving could lead to job losses for professional drivers.
- The liability for accidents involving autonomous vehicles and the ethical decision making of AI systems are questions that need to be addressed.

7.2.12.6. What challenges does the signal carry for the ecosystem?

- Further technological development (sensors, AI algorithms, and real-time data processing) would be necessary to achieve full autonomy and ensure safety.
- Investments in road infrastructure and communication systems will be needed to support autonomous driving.
- New legislation on autonomous driving will be needed to ensure safety and clearly define liability.

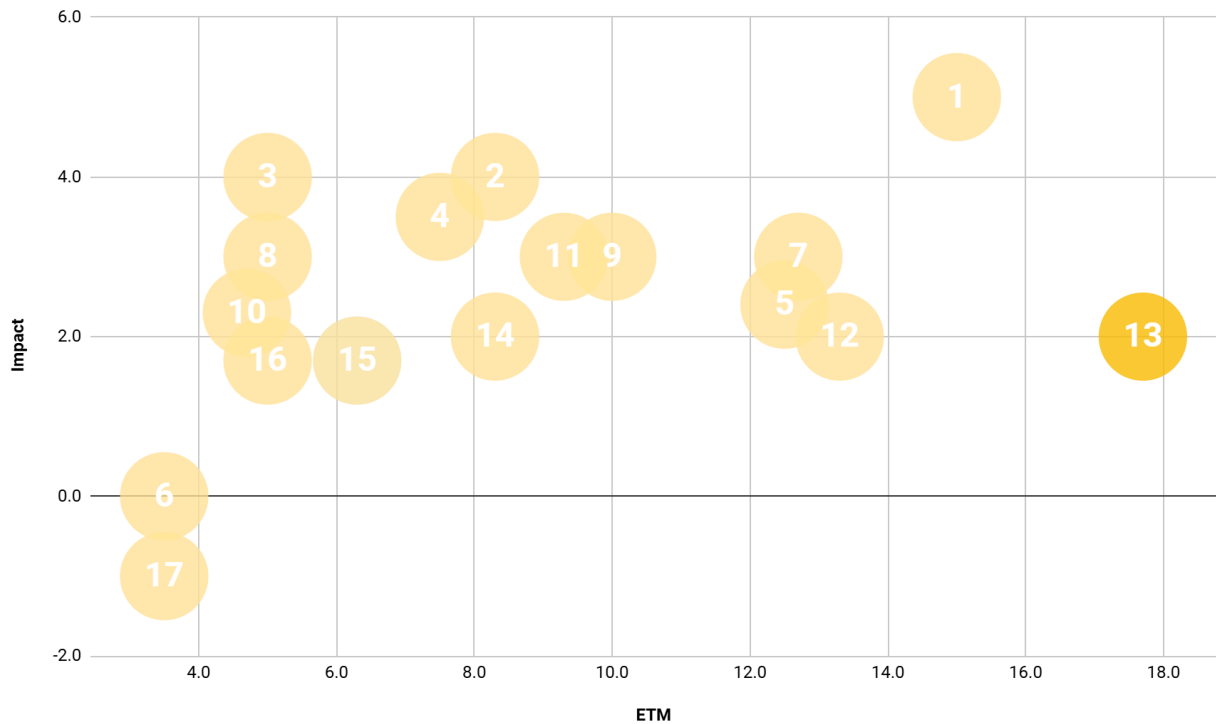
7.2.13. Signal 13: Clean energy for transport thanks to nuclear fusion⁶⁵

Nuclear fusion, a technology that produces clean energy by fusing atoms, could become a viable power source for energy-intensive industries and electric vehicles. This could revolutionise energy production and reduce reliance on fossil fuels.

⁶⁵ Source: <https://www.independent.co.uk/tech/nuclear-fusion-energy-clean-sun-b2162498.html>

7.2.13.1. Matrix figure (ETM, IMPACT)

Figure 57. Impact and ETM Analysis of Clean energy for transport thanks to nuclear fusion in Mobility, Transport & Automotive.



The impact of signal 13 (Clean energy for transport thanks to nuclear fusion) was estimated at 2. Its score of 2 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 17.7 years, which means that the signal may fully materialize by mid-2042.

7.2.13.2. How can it change our optics?

- It shifts attention towards nuclear energy.
- It underlines the importance of green energy and also the importance of finding a way to reduce supply chain and production costs in order to not transfer them on to customers.

7.2.13.3. How can it change the ecosystem?

- This is particularly relevant for industries, families and for the environment. It will be interesting if in the future a way can be found to commercialise it and to keep the process stable.
- It will also be interesting how big energy players will react to this way of producing energy.

7.2.13.4. What opportunities does the signal carry for the ecosystem?

- Increased safety: produces no waste.

7.2.13.5. What risks does the signal carry for the ecosystem?

- Lack of raw materials (e.g. for nuclear batteries).
- Environmental impact of accidents.

7.2.13.6. What challenges does the signal carry for the ecosystem?

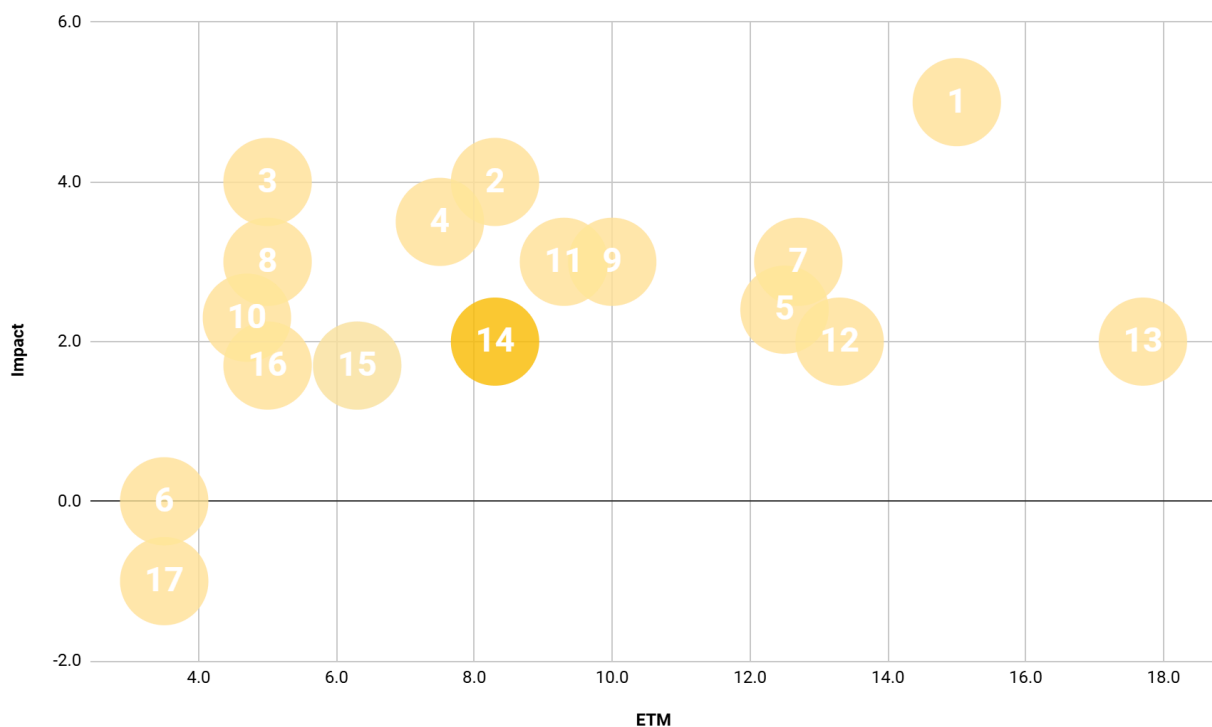
- Decommissioning question (e.g. batteries).

7.2.14. Signal 14: Autonomous refuelling stations⁶⁶

Autonomous refuelling stations are being developed to refuel vehicles without human intervention. This technology could involve self-driving cars navigating to a charging station or a mobile refuelling unit that comes to the vehicle. This could make refuelling more efficient and convenient.

7.2.14.1. Matrix figure (ETM, IMPACT)

Figure 58. Impact and ETM Analysis of Autonomous refuelling stations in Mobility, Transport & Automotive.



The impact of signal 14 (Autonomous refueling stations) was estimated at 2. Its score of 2 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 8.3 years, which means that the signal may fully materialize by mid-2033.

7.2.14.2. How can it change our optics?

- Changing human role: humans deal with complex and creative tasks, while a self-driving vehicle/charger performs tedious work.

⁶⁶ Source: <https://scottautomation.com/en/insights/autonomous-truck-refueling>

- One stops thinking about choosing a charging station/fuel station.

7.2.14.3. How can it change the ecosystem?

- This will have an impact on the regulatory sphere and traffic jams.
- People will lose their jobs at gas stations (and in the value chain of logistics).
- Trade unions answer: social guarantees for former workers (e.g. reskilling).
- A push towards innovations in spheres of: sensors, measuring devices and batteries.

7.2.14.4. What opportunities does the signal carry for the ecosystem?

- Security opportunities: robots are more efficient than humans in terms of security (e.g. they are not tired).
- Optimise the energy consumption (e.g. autonomous decision on energy consumption; predictive maintenance).

7.2.14.5. What risks does the signal carry for the ecosystem?

- Security issues (transparency; explainability; human oversight).

7.2.14.6. What challenges does the signal carry for the ecosystem?

- Finding space for these stations in densely populated cities, especially those with older infrastructure, may be difficult.
- Ensuring convenient and equitable access to these stations across a city will be important.
- The design and placement of these stations need to be compatible with existing urban landscapes and infrastructure.
- Effective communication and coordination between autonomous vehicles and refuelling stations will be crucial for smooth operation.

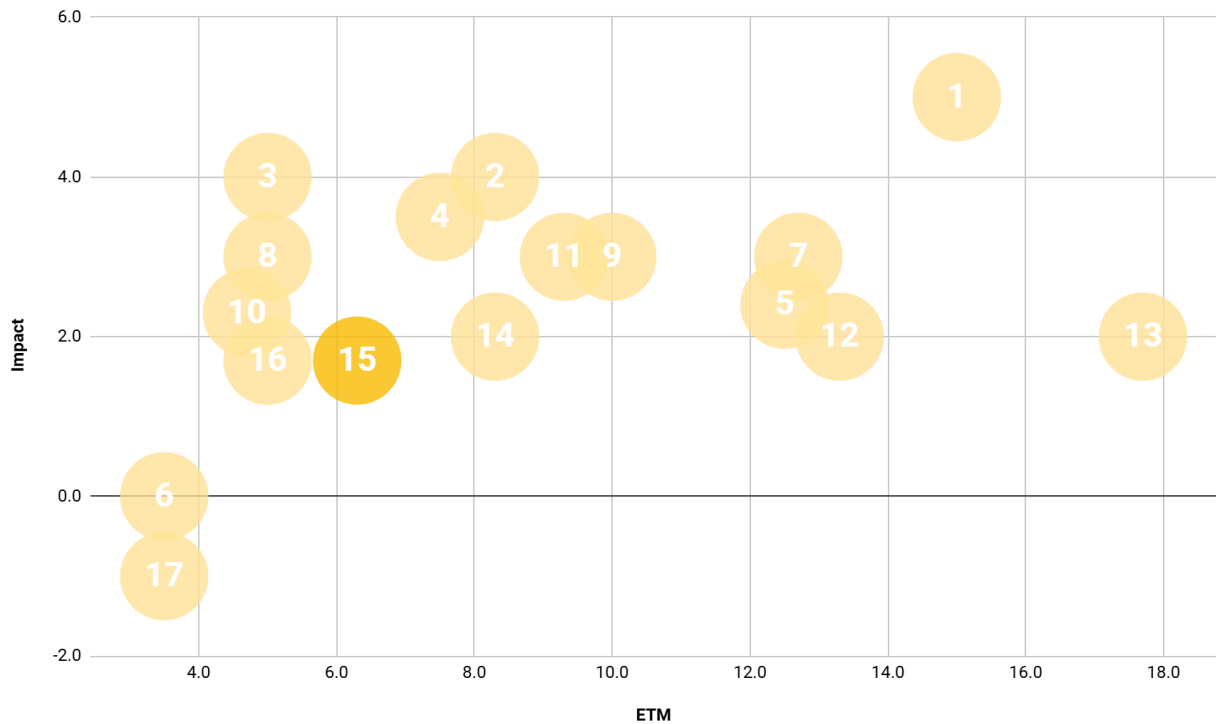
7.2.15. Signal 15: Vehicles equipped with exoskeleton interfaces to assist elderly passengers⁶⁷

These vehicle-integrated exoskeleton interfaces provide physical assistance for entering, exiting, and manoeuvring within the vehicle, promoting independent mobility and a dignified travel experience.

⁶⁷ Source: <https://rail-research.europa.eu/>

7.2.15.1. Matrix figure (ETM, IMPACT)

Figure 59. Impact and ETM Analysis of Vehicles equipped with exoskeleton interfaces to assist elderly passengers in Mobility, Transport & Automotive.



The impact of signal 15 (Vehicles equipped with exoskeleton interfaces to assist elderly passengers) was estimated at 1.7. Its score of 1.7 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 6.3 years, which means that the signal may fully materialize by mid-2031.

7.2.15.2. How can it change our optics?

Exoskeletons have the potential to revolutionise mobility for seniors by overcoming physical limitations that make traditional transportation difficult. This technology could provide seniors with increased independence and dignity, allowing them to travel with greater ease. The improved mobility could also lead to economic benefits, as seniors could more easily participate in activities like shopping, visiting, and accessing healthcare.

7.2.15.3. How can it change the ecosystem?

- This innovation could push for more inclusive design principles in vehicles, considering the needs of a wider range of passengers --> a new standard for transport.
- Upgrade (/update) and obligatory standard for producers of means of transport (like a mandatory belt).
- These systems would involve complex mechanics and require regular maintenance to ensure functionality. Any downtime could disrupt passenger reliance on this vital assistance.

7.2.15.4. What opportunities does the signal carry for the ecosystem?

- Exoskeletons could trigger new applications for the comfort & health of truck drivers.
- Increased social engagement: good impact on health (physical and mental) among the elderly.
- New companies & jobs: design, manufacturing, maintenance and post.

7.2.15.5. What risks does the signal carry for the ecosystem?

- Negative impact on health: older people will have physical problems moving around without support.
- Environmental impact of raw materials (extraction & utilisation).
- Technology dependencies & geopolitical impact of raw materials.
- Privacy issues/legal problems: Data collected by the exoskeletons regarding user movement or health metrics would need to be handled responsibly with clear privacy measures in place.

7.2.15.6. What challenges does the signal carry for the ecosystem?

- Creating exoskeletons that fit diverse body types and adapt to various modes of transport, such as cars, buses, and trains, presents a significant design challenge.
- Ensuring comfortable and safe integration with different vehicles will be crucial for widespread adoption.

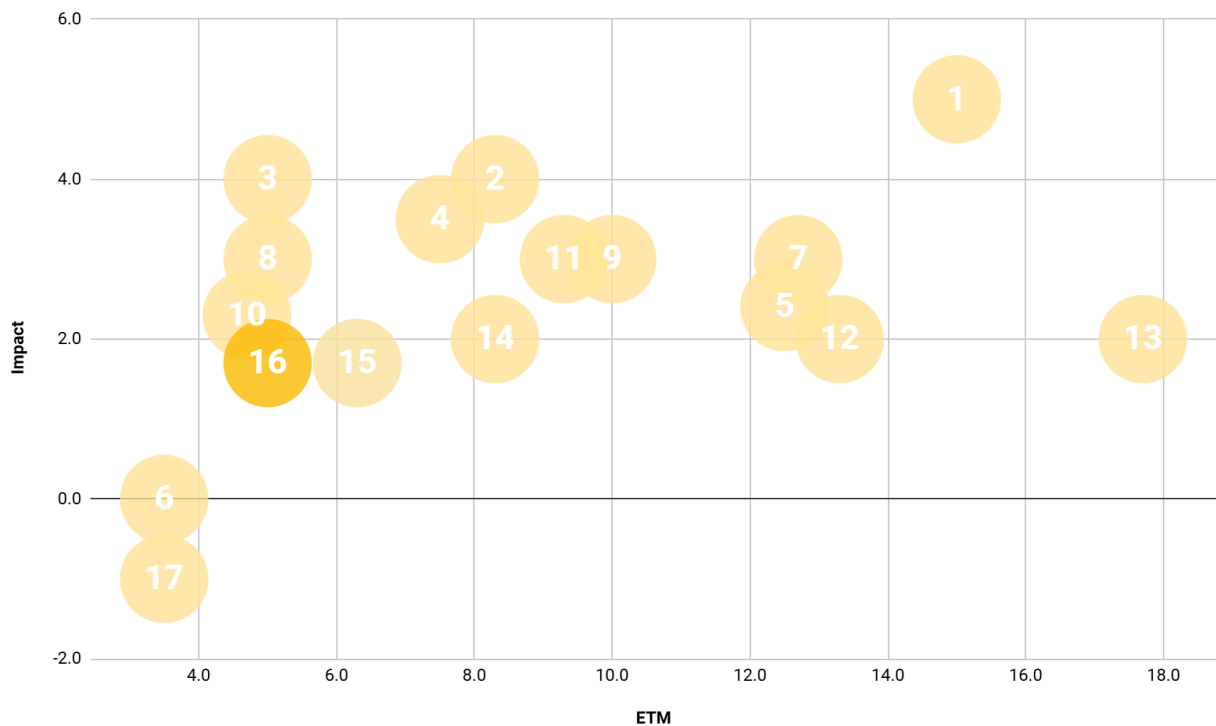
7.2.16. Signal 16: Wide adoption of 3D printing⁶⁸

3D printing allows for the creation of vehicles with complex designs and potentially lighter weight structures using specialized materials.

⁶⁸ Source: <https://builtin.com/articles/3d-printed-car>

7.2.16.1. Matrix figure (ETM, IMPACT)

Figure 60. Impact and ETM Analysis of Wide adoption of 3D printing in Mobility, Transport & Automotive.



The impact of signal 16 (Wide adoption of 3D printing) was estimated at 1.7. Its score of 1.7 categorizes it as a disruptor, which may positively influence the ecosystem's development. The estimated ETM is 5 years, which means that the signal may fully materialize by mid-2029.

7.2.16.2. How can it change our optics?

- 3D printing allows for rapid iteration and prototyping of vehicle designs, accelerating innovation and development cycles.
- Sustainable manufacturing: 3D printing has the potential to reduce waste and energy consumption compared to traditional vehicle manufacturing processes.
- New instruments: printers & software.

7.2.16.3. How can it change the ecosystem?

- Having lighter materials will help to reduce energy consumption.
- Local manufacturing: 3D printing could enable localised production of vehicles, potentially reducing reliance on large factories and global supply chains. This could empower local communities and create new job opportunities.
- Additive manufacturing: waste is certainly less compared to traditional ways of producing. Also, 3D is really interesting in prototyping.
- Jobs: it will replace a lot of production schemes.
- Speed.
- Economic impact: reduced cost of vehicle and fast & wide supply.

7.2.16.4. What opportunities does the signal carry for the ecosystem?

- 3D printing could allow for on-demand customization, fostering a sense of individuality and self-expression.

7.2.16.5. What risks does the signal carry for the ecosystem?

- Ensuring consistent quality and standardisation in 3D-printed parts, , especially as production becomes more decentralised and distributed.
- The ease of replicating designs using 3D printing raises concerns about intellectual property theft and counterfeiting.
- Material limitations.

7.2.16.6. What challenges does the signal carry for the ecosystem?

- Scaling up 3D printing for mass production while maintaining cost-effectiveness.
- Expanding the range of materials compatible with 3D printing, including high-performance materials and sustainable alternatives.

7.2.17. Signal 17: Cyberthreats Erode Consumer Confidence in Self-Driving Cars⁶⁹

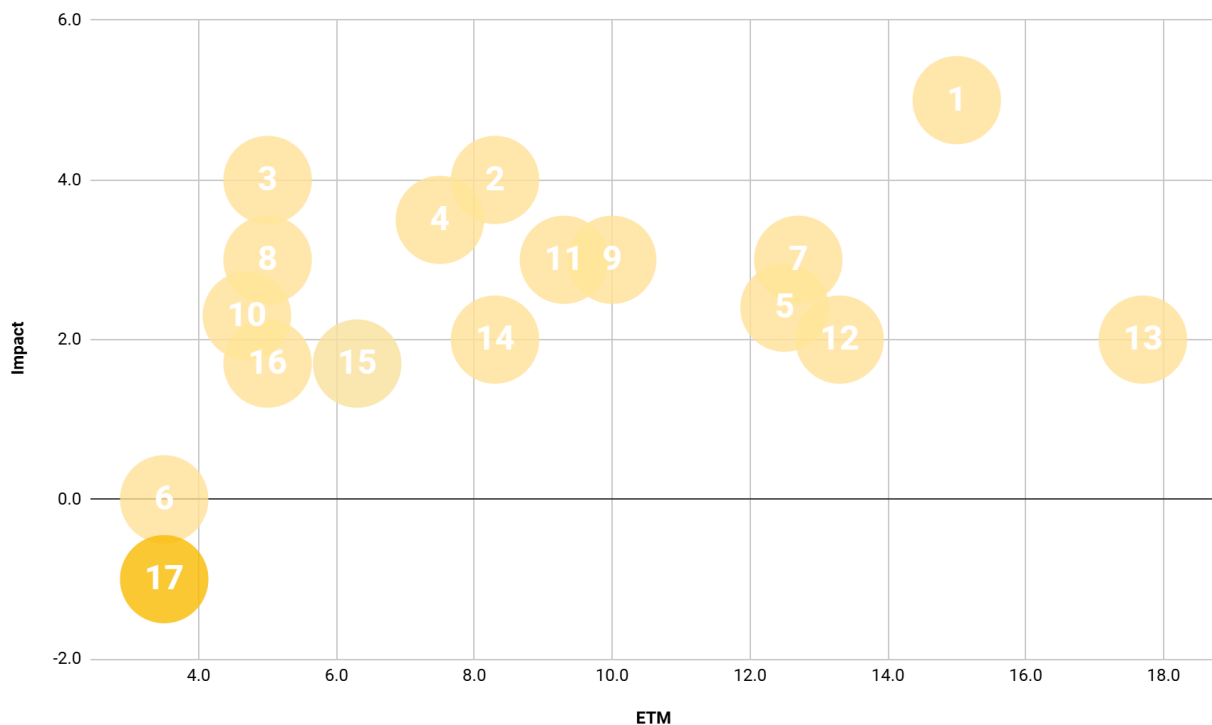
As autonomous vehicles become increasingly reliant on complex software, sensors, and connectivity, they become vulnerable to hacking, data breaches, and other cyber threats. These incidents can erode consumer confidence in the safety and reliability of self-driving technology, potentially delaying its adoption and impacting the future of transportation.

⁶⁹ Source:

https://futuretodayinstitute.com/wp-content/uploads/2024/03/TR2024_Mobility-Robotics-Drones_FINAL_LINKED.pdf

7.2.17.1. Matrix figure (ETM, IMPACT)

Figure 61. Impact and ETM Analysis of Cyberthreats Erode Consumer Confidence in Self-Driving Cars in Mobility, Transport & Automotive.



The impact of signal 17 (Cyberthreats Erode Consumer Confidence in Self-Driving Cars) was estimated at -1. Its score of -1 categorizes it as a disruptor, which may negatively influence the ecosystem's development. The estimated ETM is 3.5 years, which means that the signal may fully materialize by mid-2028.

7.2.17.2. How can it change our optics?

- It underlines the need for robust security measures and regulations to protect autonomous vehicles from cyberattacks.
- It brings a new element to the discussion about the ethical and societal implications of autonomous vehicles.

7.2.17.3. How can it change the ecosystem?

- Drive innovation in cybersecurity solutions specifically designed for autonomous vehicles, such as quantum-resistant cryptography, intrusion detection systems, and secure software development practices.
- Erosion of consumer trust due to cyber threats could delay the widespread adoption of self-driving cars.

7.2.17.4. What opportunities does the signal carry for the ecosystem?

- Increased investment in cybersecurity.
- Development of more robust security standards and regulations for autonomous vehicles.

7.2.17.5. What risks does the signal carry for the ecosystem?

- Cybersecurity breaches and accidents caused by hacking could damage the reputation of autonomous vehicle manufacturers and the industry as a whole.

7.2.17.6. What challenges does the signal carry for the ecosystem?

- The rapid evolution of technology and the increasing sophistication of cyberattacks pose a constant challenge for securing autonomous vehicles.
- Establishing a clear and comprehensive regulatory framework for cybersecurity in autonomous vehicles.

8. Cross-ecosystem analysis & sense-making

In the final, sense-making phase of the Horizon Scanning activity, the representatives of three industrial ecosystems: Aerospace and Defense, Energy-Intensive Industries, and Mobility, Transport, and Automotive were asked to answer the following questions:

- What would be your (cluster's/SMEs') first decision/action to adapt if the implications of emerging signals of change and disruptions, which you had identified in the horizon scanning activities, would arrive not at some point in the future but today?
- What do your company/cluster already have that could be optimised to meet the implications of the signal?
- What do you wish your company/cluster already had in place that it doesn't have today?

The summary of the responses and discussions is presented below.

8.1. What would be your (cluster's/SMEs') first decision/action to adapt?

The responses from the three industrial ecosystems highlight a shared sense of urgency and a focus on practical steps to adapt to the identified disruptions. Here's a synthesis of their key priorities:

- **Leadership, R&D, and Strategic Planning:**
 - Mobility, Transport & Automotive: Emphasizes strong leadership, dedicated R&D efforts, and securing funding to drive adaptation. This includes revisiting business plans, considering ROI, and collaborating with infrastructure managers.
 - Energy-Intensive Industries: Focuses on strategic decision-making in response to disruptions, including potentially relocating operations if necessary. They also highlight the need for a clear strategy for adopting new technologies and diversifying supply chains.
 - Aerospace & Defense: Stresses the importance of diversification into new markets like renewable energy and developing green technologies. This involves strategic communication to address public concerns and convince stakeholders of the continued relevance of air travel.
- **Technology and Skills:**
 - Mobility, Transport & Automotive: Prioritizes digital competencies, knowledge of new materials, and collaboration with research centers.

- Energy-Intensive Industries: Highlights the need for IT personnel skilled in blockchain technology for managing information flows. They also emphasize embracing and utilizing modern technologies.
- Aerospace & Defense: Investing in composite technology and training a workforce skilled in its manufacturing processes is crucial. They also see the need for a change in mindset to adapt to new business models like XaaS (Anything as a Service).
- **Supply Chain and Sustainability:**
 - Mobility, Transport & Automotive: Focuses on securing the bill of materials, addressing legal and standardization aspects, and managing waste effectively.
 - Energy-Intensive Industries: Aims to ensure the quality of secondary materials for reuse and recycling, secure smelter capacities in Europe, and develop business models that support a reversed value chain.
 - Aerospace & Defense: Securing raw materials for composite aircraft production is critical. They also plan to adapt their know-how and products to meet the demands of hydrogen and new fuels, investing in testing equipment and collaborative projects.

Overall, the responses reveal a shared focus on:

- **Strategic adaptation:** Diversification, new business models, and proactive responses to emerging challenges.
- **Technological advancement:** Investing in new technologies, R&D, and upskilling the workforce.
- **Sustainability:** Circular economy principles, waste management, and the use of green technologies and alternative fuels.

These immediate actions reflect the need for agility, innovation, and collaboration across these ecosystems to navigate the disruptions and ensure their long-term viability.

8.2. What do your company/cluster already have that could be optimised to meet the implications of the signal?

The responses from the three industrial ecosystems reveal existing strengths that can be optimized to address the implications of emerging signals of change. Here's a synthesis of their key assets:

- **Human Capital and Knowledge:**
 - Mobility, Transport & Automotive: Possesses valuable human resources and technical skills that can be further developed and leveraged to adapt to new technologies and market demands.
 - Energy-Intensive Industries: Has a skilled IT personnel capable of applying blockchain technology for optimizing supply chain management and information flow.
 - Aerospace & Defense: Benefits from an "open innovation mindset" and existing digital tools that can be adapted for commercial projects and collaborative R&D.

- **Technology and Infrastructure:**

- Mobility, Transport & Automotive: Has access to energy production capabilities, which can be optimized to meet the demands of a changing energy landscape.
- Energy-Intensive Industries: Owns existing energy infrastructure that can be adapted for increased efficiency and to accommodate new energy sources like hydrogen. They also highlight the potential to repurpose old gas pipelines for hydrogen transport.
- Aerospace & Defense: Possesses proven experience with composite materials in aircraft manufacturing, which can be scaled up and further developed to meet the growing demand for lightweight and sustainable solutions.

- **Processes and Networks:**

- Mobility, Transport & Automotive: Benefits from established mechanisms for sharing information, data, and threat intelligence, which can be crucial for responding to disruptions and coordinating adaptation efforts.
- Energy-Intensive Industries: Has established product life cycles that can be optimized for a circular economy model. They also possess a strong information network for local and international sourcing.
- Aerospace & Defense: Has existing diversification strategies and ongoing technological development initiatives that can be accelerated to address sustainability concerns. They also have experience with collaborative projects and supply chain management in the context of hydrogen and new fuels.

Overall, the responses reveal a shared focus on:

- **Leveraging Existing Strengths:** All three ecosystems possess valuable assets, including skilled personnel, technology, and infrastructure, that can be optimized to address emerging challenges.
- **Collaboration and Knowledge Sharing:** Sharing information, best practices, and resources within and across ecosystems can accelerate adaptation and innovation.
- **Sustainability:** Optimizing existing processes for circularity, adopting new technologies for energy efficiency, and developing sustainable solutions are key priorities.

By strategically leveraging their existing strengths, these industrial ecosystems can enhance their resilience, accelerate their transition towards a sustainable future, and maintain their competitiveness in a rapidly changing landscape.

8.3. What do you wish your company/cluster already had in place that it doesn't have today?

The responses highlight a desire for enhanced capabilities and resources to effectively navigate the future landscape. Here's a synthesis of their key insights:

- **Knowledge and Skills:**

- Mobility, Transport & Automotive: Expresses a need for greater SME knowledge and enhanced digital competencies across the ecosystem.

- Energy-Intensive Industries: Desires access to digital product information (like a digital product passport) from customers to improve transparency and traceability in the supply chain.
 - Aerospace & Defense: Wishes for a skilled workforce readily available to support the transition to new technologies like composite materials and hydrogen. They also express a need for greater knowledge sharing and collaboration across the industry.
- **Infrastructure and Technology:**
 - Mobility, Transport & Automotive: Identifies a need for new industrialization processes, improved logistics, and dedicated infrastructure to support emerging technologies and business models.
 - Energy-Intensive Industries: Wishes for readily available infrastructure to support the production, storage, and distribution of hydrogen and other alternative fuels. They also express a need for a reliable network supporting circular economy activities (reduce, reuse, recycle, recover).
 - Aerospace & Defense: Desires access to production equipment and testing facilities for composite materials and hydrogen technologies. They also highlight the need for robust cybersecurity solutions and "plug and play" workshops to facilitate knowledge transfer and collaboration with clients.
- **Investment and Partnerships:**
 - Mobility, Transport & Automotive: Seeks new partnerships, both geographically and with companies developing new technologies.
 - Energy-Intensive Industries: Wishes for reliable trade partners to stabilize the supply chain and the widespread adoption of modern technologies for improved performance.
 - Aerospace & Defense: Seeks investors who understand and support the transition to new technologies, as well as banks willing to provide loans for these ventures. They also express a need for stronger connections and trust within the industry to facilitate collaboration and knowledge sharing.

Overall, the responses reveal a shared focus on:

- **Bridging the Gap:** The responses reveal a gap between current capabilities and the desired future state across all three ecosystems.
- **Investment in Innovation:** There's a clear need for investment in new technologies, infrastructure, and skills development to adapt to the changing landscape.
- **Collaboration and Trust:** Stronger partnerships, knowledge sharing, and trust within and across ecosystems are essential for navigating the challenges and seizing the opportunities of the future.

These wishes reflect a proactive mindset and a recognition of the need for continuous improvement and collaboration to ensure the long-term resilience and competitiveness of these vital industrial ecosystems.

9. Conclusions

The Horizon Scanning activity across the Aerospace and Defense, Energy-Intensive Industries, and Mobility, Transport, and Automotive sectors reveals several common challenges and crucial takeaways for ensuring their future resilience.

Shared Challenges:

- **Supply Chain Vulnerabilities:** All three ecosystems face the pressing need for robust and diversified supply chains, particularly regarding access to critical raw materials. This requires reducing dependence on single suppliers, exploring alternative sourcing options, and potentially investing in regional production capabilities.
- **Energy Transition:** Preparing for potential energy shortages and transitioning to new fuels and energy sources is crucial across these sectors. This necessitates investment in research and development of alternative energy solutions, adapting infrastructure, and supporting the development of a skilled workforce for the changing energy landscape.
- **Circular Economy Imperative:** Establishing circular economy principles is vital to minimize waste, optimize resource utilization, and ensure the long-term sustainability of these industries. This involves implementing life-cycle assessments, eco-design principles, and training workers to adapt to a circular economy model.
- **SME Resilience:** Small and medium-sized enterprises (SMEs) play a vital role in these ecosystems but often lack the financial resources to invest in long-term adaptation and innovation. Supporting SMEs through public funding, access to finance, and incentives for sustainable practices is crucial for their resilience and competitiveness.

Key Takeaways:

- **Proactive adaptation is key.** Across all three ecosystems, there's a clear recognition of the need for proactive adaptation to emerging disruptions. This involves:
 - **Strategic foresight:** actively scanning the horizon for signals of change and anticipating their potential impact,
 - **Agility and flexibility:** developing the capacity to respond quickly and effectively to unexpected challenges and opportunities;
 - **Embracing innovation:** investing in research and development, adopting new technologies, and fostering a culture of innovation.
- **Collaboration is essential.** This includes:
 - **Intra-ecosystem collaboration:** Strengthening partnerships and knowledge sharing within each ecosystem, particularly between large companies and SMEs.
 - **Inter-ecosystem collaboration:** Exploring synergies and opportunities for collaboration across different sectors, for example, in areas like energy transition and circular economy initiatives.
 - **Public-private partnerships:** Fostering closer collaboration between policymakers, industry leaders, and investors is crucial to address these challenges effectively. This includes aligning public funding priorities with industry needs, encouraging private investment in sustainable technologies, and fostering an environment that supports innovation and long-term resilience.
- **Strategic investment is crucial:**
 - **Human capital:** Developing a skilled workforce capable of adapting to new technologies and driving innovation. This includes upskilling existing

employees and attracting new talent with expertise in areas like digital technologies, cybersecurity, and sustainability.

- **Technology and infrastructure:** Investing in research and development, upgrading infrastructure, and adopting new technologies to enhance efficiency, resilience, and sustainability. This includes areas like automation, digitalization, and the development of new materials and energy sources.
- **Long-term Vision:** A clear, long-term vision (10-30 years) is essential to guide policy decisions and private investment towards sustainable solutions. This requires overcoming short-term political cycles and aligning public and private interests with long-term sustainability goals.

By addressing these shared challenges and embracing a long-term, collaborative approach, these industrial ecosystems can navigate the complexities of the future and ensure their continued contribution to a sustainable and prosperous European economy.