
Futures of Industry 5.0 - a scenario analysis

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Abstract: Industry 5.0 emphasises a shift towards an industrial model grounded in human centricity, resilience, and environmental sustainability, and hence interrelates three distinct policy objectives. In this light we ask how futures of industrial transformation from an industry 5.0 perspective unfold when we consider that there may be trade-offs between the different objectives of Industry 5.0. We present a multi-stakeholder and scenario approach where we start from an industrial policy concept, analyse how this policy concept fits with current developments of industrial transformation in order to identify firm practices and transformation challenges. The crosscutting nature of key trade-offs resulting in transformation challenges let us identify policy areas to address these challenges and strategic directions within these policy areas. The approach taken and presented in this article as well as its conditions for appropriate application together form the contribution of this conference paper.

Keywords: Industry 5.0; scenario analysis; digital technologies; resilience;

sustainability; human centricity.

Introduction

The widespread diffusion of digital technologies is driving profound and often disruptive transformations across industry and society. These technological shifts are unfolding within a context of substantial economic uncertainty, as the pace, direction, and distributional effects of digitalisation remain difficult to predict. At the firm level, the capacity to adopt and effectively integrate advanced digital technologies is uneven. Empirical studies indicate that many organisations face significant constraints related to shortages of managerial capabilities and workforce skills, which may hinder timely and effective technology adoption (Zangiacomi et al. 2020; Cirillo et al. 2023; Delias and Kitsios 2023). As a result, digital transformation may exacerbate productivity gaps and structural asymmetries across firms and sectors.

At the same time, employees are confronted with growing uncertainties regarding the future of work and everyday life. Digitalisation reshapes job tasks, employment relations, and skill requirements, generating concerns about job security, work organisation, and social inclusion (Trzaska et al. 2021; Lima et al. 2023). These dynamics underscore the societal dimension of digital transformation and the need to address its broader social consequences alongside its economic implications.

In response, policy debates increasingly focus on integrated strategic frameworks that seek to align digital transformation with broader societal objectives. Within the European Union, the “twin transition” agenda explicitly links digital leadership with the transition towards climate neutrality, framing both processes as mutually reinforcing pillars of long-term competitiveness and sustainability. Complementing this approach, the concept of Industry 5.0 emphasises a shift towards an industrial model grounded in human centricity, resilience, and environmental sustainability. At the societal level, e.g. the Japanese vision of Society 5.0 extends these principles by promoting economic prosperity while addressing social challenges through the deployment of “supersmart” technologies. Together, these frameworks reflect an emerging policy consensus that digital transformation must be governed in ways that are inclusive, sustainable, and socially responsive.

Background and concepts

Industry 5.0. More recently, the European Commission put forward an industrial strategy coined Industry 5.0 (European Commission et al. 2021) attempting to reconcile the tensions between opportunities stemming from digital transformation and societal risks like inequality and social exclusion, if pursued with shortsightedness. Industry 5.0 is seen as an extension of I4.0, emphasising a human-centric, sustainable, and resilient industrial paradigm while based on similar technologies as I4.0, hence digital automation, particularly AI and cyber-physical systems. Unlike prior industrial transformations that

were centred around transformations of general purpose technologies, I5.0 is based on fostering socially and ecologically relevant values alongside industrial competitiveness. (Müller 2020) In an Industry 5.0 perspective, industrial transformation will rest on three pillars: human centricity, (environmental) sustainability and resilience. In this concept, technological developments particularly around digitalisation, automation and connection normally termed as the fourth industrial revolution (Kagermann et al. 2013; Brynjolfsson and McAfee 2016) are complemented by values to place industry at the service of society (Müller 2020).

Firm practices. Practices can be understood as collective ways of knowing and doing that emerge in everyday working life (Nicolini, 2012; Gherardi, 2012). They are relatively stable and recursively enacted over time, reflecting routines and path dependencies (Brandenberger & Hasu, 2023). Such practices rest on shared knowledge, norms, and habits (Schatzki, 2002; Warde, 2005), and are inherently socio-material, integrating technological elements (Orlikowski, 2010). Importantly, practices do not exist in isolation but rather in interconnected configurations or nexuses (Shove, Pantzar et al., 2012; Hui, 2017).

Within *organisational studies*, practices are typically organised around specific ends or objects. They consist of multiple sub-elements or activities, which individually may not constitute practices in their own right but collectively form coherent practice structures (Nicolini & Monteiro, 2017). In *business management studies*, practices are often associated with core business functions such as production, logistics, human resources, sales, and legal operations. At the same time, certain practices—such as management practices—may operate across or beneath these functional divisions, cutting across organisational boundaries.

Trade offs. Industry 5.0 is structured around three distinct dimensions and objectives, whereby progress in one dimension does not inherently lead to advancements in the others. This implies the presence of trade-offs, understood as situations in which the enhancement of one desirable attribute necessitates a corresponding reduction in another. Such trade-offs reflect inherent tensions between competing objectives (Magalhães et al., 2019; Campbell & Kelly, 1994). They are widely recognised as an integral component of multi-criteria decision-making and priority-setting processes, even at the project level (Nielsen et al., 2016), and become increasingly pronounced at the systemic policy level, where establishing a clear hierarchy among conflicting objectives and constraints is often not feasible (Morrison-Saunders & Pope, 2013).

Trade-offs become apparent in firm practices which evolve in response to technological opportunities, the availability of firm resources, firms' absorptive capacities, and their strategic orientations. Importantly, firm practices involve strategic choices: firms are not merely passive adopters of technology but actively decide how to organise production and work. Consciously or unconsciously they thereby also make choices around human centricity, resilience and sustainability. These choices influence the organisation of work and the nature of jobs within firms, which in turn shape the types of skills that will be required in the future. Consequently, future skill demand depends not only on technological change but also on the strategic pathways firms choose to pursue.

Research question

Industry 5.0 is therefore anchored in and interrelates three distinct dimensions and policy objectives. Progress along one dimension does not necessarily entail proportional advancement in the others, as gains in a specific area may occur independently or even at the expense of alternative objectives. The literature conceptualises this condition as the presence of trade-offs, reflecting the inherent tensions and balancing acts involved in simultaneously pursuing human centricity, environmental sustainability, and systemic resilience. (Magalhães et al. 2019)

In this light we ask how futures of industrial transformation from an industry 5.0 perspective unfold when we consider that there may be trade-offs between the different pillars of Industry 5.0.

Methods

This paper is grounded in scenario analysis, which starts from the premise that the future is not predetermined but unfolds as a widening space of possibilities shaped by current trends, uncertainties, and strategic choices. (Hancock and Bezold, 1994; Gall et al., 2022) Rather than projecting a single outcome, this approach considers multiple plausible futures and their implications. It supports academic, practitioners, and policymakers in developing flexible and robust strategies, identifying early signals of change, and governing developments toward desirable outcomes while preparing for the future under uncertainty.

We construct future scenarios of industrial transformation (time horizon 2035-40), where Industry 5.0 (I5.0) features are present in all scenarios, though with differing intensities and varying degrees of successful implementation. The various dimensions of I5.0 are more appropriately conceptualised as lying along a continuum rather than as clearly delineated or binary conditions. Furthermore, I5.0 exhibits varying levels of exposure to risk and uncertainty and is shaped by inherent trade-offs that manifest differently across the scenarios.

The methodological approach proceeded in several main stages. First, we analysed the key trends and developments within and around industry that are likely to shape firm practices over the next 10–15 years. This included a review of academic literature, an assessment of grey literature (such as reports, blogs, and interviews, etc), and insights generated through an interactive trends workshop with firms and other stakeholders held in October 2024. This step provided a comprehensive evidence base on emerging dynamics affecting industrial transformation. Hence, the analysis first asks what factors have recently shaped industrial development and what is likely to influence firm practices in the near future - at this stage broadly, without explicit reference to Industry 5.0, before focusing more specifically on the key pillars of resilience, human-centricity, and sustainability.

Furthermore, these trends were then synthesised through an Industry 5.0 lens perspective into four framework scenarios, each reflecting different emphases and trade-offs across core Industry 5.0 characteristics. After iterations and synthesising work within the project team and a second expert workshop (=scenario workshop) with firms and stakeholders in June 2025, the decision was to span the scenarios along two dimensions in such a way that the trade-offs between them become apparent. Particularly two dimensions – environmental sustainability and resilience of European industry - were responsible for stretching and challenging the Industry 5.0 concept. Within the four resulting quadrants, we then discussed all four scenarios along the main dimensions of first technology adoption, second, human centricity, third, environmental sustainability and fourth, resilience of European industry.

Following the development of these framework scenarios, together with experts we elaborated how firm practices would unfold within the framework scenarios and what trade-offs in particular would become apparent through firm practices in the scenarios. These scenarios offer a structured, system-level mapping of key uncertainties and drivers, focusing on how evolving firm practices may impact work in the 2035–2040 timeframe. Scenario development as well as policy debates were accompanied by stakeholder workshops in June 2025 and January 2026 respectively. In general, the process was iterative, involving repeated cycles of literature analysis, synthesis and refinement within the project team, and validation through workshops with a broader expert group, ensuring both analytical depth and stakeholder relevance.

Four framework scenarios – futures of Industry 5.0

Across all four framework scenarios, Industry 5.0 principles are present to different degrees. Rather than binary outcomes, resilience, sustainability, human-centricity and technological development form continua along which Europe’s industrial future may evolve. Each scenario reflects a distinct configuration of these dimensions and exposes specific trade-offs and risks that shape the feasibility and pace of Industry 5.0 implementation. The dimensions specifically addressed in each of the scenarios are resilience, sustainability, human centricity and technology adoption, defined in line with European Commission et al. 2021 and Oeij et al., 2024.

Resilience is understood as a higher degree of robustness in industrial production, “arming it better against disruptions and making sure it can provide and support critical infrastructure in times of crisis”. (European Commission et al. 2021) This encompasses, first, the reorganisation of supply chains, including efforts to enhance their stability and adaptability. Second, it involves considerations of technological sovereignty, particularly with regard to the production of critical goods within Europe.

Sustainability, in line with European Commission et al. 2021, is interpreted here specifically as environmental sustainability. This includes challenges related to energy systems, as well as the management and protection of natural resources. Furthermore, it incorporates issues associated with natural hazards and the broader impacts of climate change.

A *human-centric* approach places fundamental human needs and interests at the core of the production process. The perspective on the human role is that of a creative, reflective and responsible agent, as well as a decision-maker. (Heikkilä, 2026) In this context, digital advancements are aligned with human capabilities, fostering work environments that support continuous learning, skills development, and employee well-being.

Technology adoption, in turn, encompasses the diffusion, development, and utilisation of critical technologies. This includes, but is not limited to, artificial intelligence, robotics, and cloud-based solutions, with attention to both their integration into industrial processes and their broader systemic uptake. Although some technologies (like AI and quantum technologies) develop fast and are more debated currently, the distinction between Industry 5.0 and earlier industrial transformation is not done along technologies, but along the dimensions of human centricity, sustainability and resilience. (Müller, 2020)

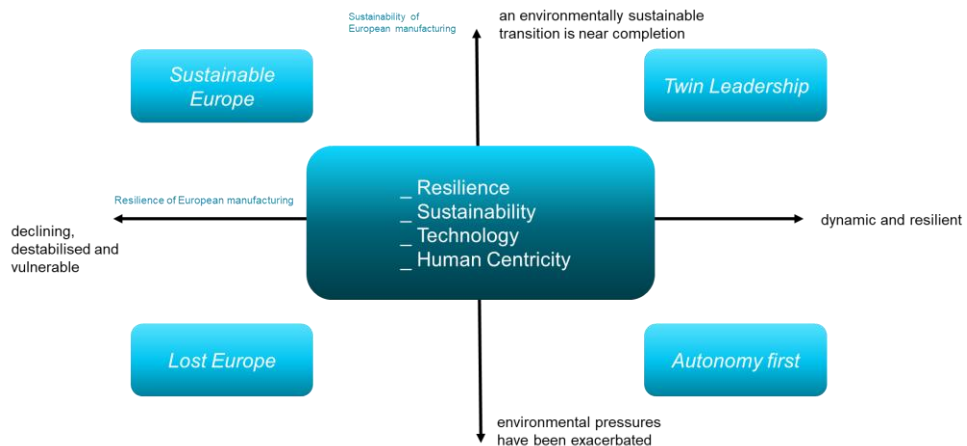


Figure 1 Four framework scenarios.

Twin Leadership

From an Industry 5.0 perspective, Twin Leadership represents the most desirable of the four scenarios, characterised by the alignment of technological leadership, sustainability, resilience, and human centricity within European industrial transformation. *Technology adoption* has been successful and positions Europe as a global frontrunner in artificial intelligence, robotics, IoT, and advanced manufacturing, enhancing productivity, transparency, and supply chain coordination while supporting industrial renewal.

Human centricity is essential ensuring that these developments augment human labour, fostering high-quality jobs, inclusive workplaces, and continuous skills development. *Sustainability* is advanced through a rapid energy transition, circular economy practices, and industrial symbiosis, aligning environmental objectives with

long-term competitiveness. *Resilience* is strengthened through diversified and digitally enabled supply chains, selective reshoring, and strategic international partnerships. Supported by coherent public policies and investment, these dimensions reinforce one another, enabling Europe to maintain competitiveness while embedding industrial transformation within broader social and environmental goals.

Sustainable Europe

Sustainable Europe represents a scenario characterised by high levels of sustainability and human centricity, but comparatively lower levels of resilience. *Sustainability* constitutes the primary driver, deeply embedded in societal values, individual behaviours, and policy priorities following a series of environmental crises. The European Union emerges as a leader in net-zero manufacturing and sustainable technologies; however, broader industrial capacity, along with skilled labour and associated research and development, has shifted abroad. As a result, resilience is weakened, with increased dependence on external partners for critical raw materials and technologies.

Human centricity is central to economic, social, and political systems. Emphasis on job quality, ethical organisational practices, and worker representation is even higher than in Twin Leadership, enhancing well-being, productivity, and inclusion. At the same time, reduced consumption patterns offset lower income levels. Sustainability has been given priority over speed in technology adoption, which is now less domestically anchored, reflected in limited control over key technological infrastructures.

Autonomy first

This scenario is characterised by a strong emphasis on resilience and technology adoption, while sustainability and human centricity play a more limited role. *Resilience* is pursued through substantial investments in strategic autonomy, including the reshoring of critical sectors such as pharmaceuticals, defence, and digital infrastructure. This reduces dependence on external actors but also reflects a more inward-oriented economic model. *Technology adoption* is central to productivity growth and global positioning, supported by proactive industrial policies promoting automation, robotisation, and the expansion of smart factories. However, limited international cooperation constrains the pace of technological advancement.

Sustainability is not a primary objective – neither on the policy nor on the industrial level - and is mainly addressed insofar as it contributes to resilience, particularly in reducing dependence on external energy sources. *Human centricity* is partially integrated, as technological development creates opportunities for improved work organisation, but is constrained by prioritisation of security over individual responsibility, privacy and transparency.

Lost Europe

Lost Europe represents a scenario characterised by high levels of technology adoption, but low levels of resilience, sustainability, and human centricity. European industry is largely foreign-owned, with significant control exercised by investors from China and India, while the United States dominate digital services. Open trade regimes and minimal regulatory constraints facilitate rapid technological diffusion, leading to

widespread automation, advanced AI deployment, and highly efficient production systems. Europe exhibits a structurally negative trade balance and strong external dependencies.

Resilience is weak, as strategic autonomy has been largely abandoned and reliance on global partners is high, increasing vulnerability to external shocks. *Sustainability* is marginal, with environmental considerations subordinated to economic objectives and regulatory frameworks significantly weakened. *Human centricity* is similarly limited, as labour is displaced by automation, resulting in increased inequality and reduced job quality.

Scenario assessment: Firm practices and trade-offs associated with different Industry 5.0 futures

Trade-offs in Twin Leadership

Firm practices in Twin Leadership: In this scenario, technology adoption is characterised by the use of digital tools as supportive instruments that enhance human work rather than replace it. Human centricity is strongly embedded, with artificial intelligence and robotics optimising human-machine collaboration in ways that prioritise worker needs and capabilities. Governance models reflect this orientation, as organisational designs explicitly incorporate worker well-being and participation. Management and leadership practices further reinforce these principles by fostering inclusive participation, close cooperation with labour representatives, and a focus on engagement, productivity, and retention. At the level of values, firms integrate economic objectives with broader social and environmental responsibilities, thereby aligning business performance with societal goals.

The relationships between key Industry 5.0 dimensions can be conceptualised through a set of firm-level practices and associated trade-offs or dilemmas. For Twin Leadership, the main trade-offs are as follows.

Sustainability vs. Resilience: Firms increasingly invest in green technologies and circular production processes. However, to ensure operational stability, they often rely on transitional energy sources, such as natural gas. This reflects a trade-off between sustainability objectives and operational continuity, as firms require reliable and affordable energy inputs to remain competitive during periods of transformation.

High Upfront Investments: Companies undertake substantial initial investments in sustainability, digitalisation, and supply chain restructuring. These expenditures typically reduce short-term profitability, highlighting a tension between immediate financial performance and long-term strategic benefits, as returns on such investments materialise only over extended time horizons.

Digital vs. Green Transition: The adoption of digital technologies can generate rebound effects, increased energy consumption, and electronic waste, even as firms aim

to meet environmental standards. This creates a dilemma between digital innovation and environmental performance, where efficiency gains may inadvertently intensify resource use.

Human-Centricity vs. Speed: While firms invest in workforce training and well-being, rapid technological change can lead to increased stress and mental health challenges. This underscores a trade-off between the pace of innovation and worker well-being, as accelerated transformation may exceed the adaptive capacity of employees.

Trade-offs in Autonomy First

Firm practices in Autonomy first: In the AF scenario, technology adoption is shaped by a hybrid model in which collaboration between humans and machines leverages their respective strengths. Human centricity is more instrumental, as human-machine interaction is primarily optimised for productivity gains. Governance models prioritise automation and control over digital assets, with firms investing in internal technological capabilities rather than outsourcing, while also addressing cybersecurity concerns. Management and leadership face challenges related to resistance to change, which need constant attention and moderation to facilitate technological integration and appease employees. In terms of values, firms promote diversity within European supply chains and emphasise technological sovereignty.

For Autonomy First, key Industry 5.0 relationships can be articulated through corresponding firm practices and the tensions or dilemmas they entail in the following way.

Independence vs. External Technologies: Firms pursue strategies aimed at reducing dependence on external actors outside the European Union, particularly in relation to strategic products and services such as artificial intelligence, pharmaceuticals, and military equipment, which are increasingly produced within the EU. This orientation, however, generates a tension insofar as Europe may forego access to high-quality or more cost-efficient technologies developed externally, potentially limiting overall technological advancement.

Tariff Measures and Economic Growth: Firms increasingly prioritise value chains located within the EU, influenced by both traditional tariffs and non-tariff regulatory measures. While this supports internal market integration and strategic autonomy, it introduces a dilemma as higher costs associated with cross-border trade may constrain import and export activities, thereby negatively affecting overall economic growth.

Trade-offs in Sustainable Europe

Firm practices in Sustainable Europe: Here, technology adoption is more cautious and selective, with digital tools primarily supporting human workers and often constrained by stricter regulatory frameworks. Human centricity is strongly emphasised, particularly in sectors such as healthcare, social services, and green industries, where technological implementation is aligned with societal needs. Governance models prioritise worker well-

being, with flexible workplaces and hybrid work arrangements becoming integral to organisational design. Management and leadership promote inclusion, sustainability, and employee well-being as central objectives. At the level of values, firms are guided by the principle of a just transition, focusing on purpose-driven business models that integrate social, environmental, and economic considerations.

The relationships between key Industry 5.0 dimensions can be articulated through firm-level practices and the associated trade-offs or dilemmas, as follows.

Primacy of Sustainability: Firms are required to adapt to evolving consumer preferences and governmental demands for significantly higher levels of sustainability in goods and services. This necessitates a transition towards access-based and circular business models. However, this shift entails a tension between sustainability and resilience, as meeting ambitious environmental targets requires profound structural changes resulting in higher prices, that may challenge short-term stability.

Technology: European firms assume a leading role in the development of sustainability- and net-zero-related technologies. In contrast, other technological domains are predominantly developed and implemented outside Europe, partly due to stricter regulatory environments. This creates a trade-off between digital and green innovation, positioning Europe more as a consumer than a producer of non-green technologies.

Human Centricity: While some high-skilled jobs, particularly in non-green technologies and manufacturing, are relocated outside Europe, firms increasingly promote 'good work' practices that enhance productivity, health, and well-being. This reflects a tension between economic and social resilience, as improvements in job quality coexist with employment losses in key sectors.

Resilience: Economic restructuring leads to short-term shocks, including reduced employment and wage levels, as well as smaller firm sizes and supply chains. Firms increasingly compete on quality and sustainability rather than cost and scale. This highlights a trade-off between sustainability and resilience, as the transition from linear to circular economic models may constrain growth, employment, and income in the short term.

Trade-offs in Lost Europe

Firm practices in Lost Europe: The Lost Europe scenario is characterised by a dominant emphasis on automation, with technology adoption leading towards near-complete machine takeover of production processes. Human centricity is significantly diminished, as human roles lose meaning and autonomy within highly automated systems. Governance models reflect a focus on efficiency and cost reduction, often through outsourcing technological development, thereby limiting firms' ability to shape technological solutions. Management and leadership practices prioritise automation-driven restructuring, including workforce reductions. Correspondingly, firm values centre on cost awareness, efficiency, and resource optimisation, with organisational structures

streamlined to enhance competitiveness, often at the expense of broader social considerations.

The relationships between key Industry 5.0 dimensions in the “Lost Europe” scenario and the trade-offs they generate can be conceptualised in the following way.

Resilience vs. Open Strategic Autonomy: Firms adopt an open approach to foreign capital and technology, resulting in significant foreign ownership of critical assets. Corporate structures become increasingly centralised, with market power concentrated among a limited number of large firms. This gives rise to a tension between openness and sovereignty, whereby rapid infrastructure development and short-term competitiveness are achieved at the expense of control over critical systems. In addition, efficiency gains for dominant firms contrast with increased dependency and fragility among smaller firms and supply networks.

Security and Data Governance: Firms exhibit a preference for commercially available foreign technology stacks, with limited local control over AI and robotic systems. Data is predominantly stored and managed on external platforms. This creates a dilemma between operational efficiency and control, as reliance on externally governed systems introduces risks related to system disruptions, manipulation, and cybersecurity vulnerabilities.

Technology (Digitalisation and R&D): Firms rapidly adopt externally developed digital platforms, cloud infrastructures, and AI systems, while research and development activities are increasingly driven by investor priorities and short-term market returns. This results in a trade-off between technological adoption and independence: although productivity gains are realised, internal R&D capacities and sovereign technological capabilities are eroded. Furthermore, the prioritisation of short-term returns constrains strategic and long-term innovation trajectories, aligning them with external rather than domestic interests.

Discussion and conclusion

The approach followed in this research was to start from an industrial policy concept (Industry 5.0), analyse how this policy concept fits with current developments in industrial transformation in order to identify firm practices and transformation challenges. The crosscutting nature of key trade-offs and firm-level challenges let us identify policy areas to address these challenges and strategic directions within these policy areas.

Figure 2 outlines the approach taken from developing framework scenarios and using them as an entry point to structure policy implications around industrial transformation from an Industry 5.0 perspective. It begins by eliciting key trade-offs in parallel scenarios of industrial transformation by 2035/40, which frame the range of possible system dynamics and constraints. These trade-offs are then translated into the identification of firm-level and transformation challenges, ensuring analytical grounding in implementation realities. Building on this, the approach synthesises insights to define

priority policy areas and surface core tensions requiring coordination. The process ultimately supports the formulation of strategic directions, linking scenario analysis to actionable and forward-looking policy choices.



Figure 2 From framework scenarios to policy.

Conceptually we suggest this is an appropriate approach for future-oriented and scenario analysis under certain conditions. These conditions are:

1. Point of departure is a strategy or policy document that has been formulated by a (public) actor with powerful implications for the future. This is the case with the industry 5.0 concept that strongly postulates that industry be seen as part of society and not juxtapose economy and society as different arenas.
2. The public actor has devised the strategy as part of their agenda-setting and discursive roles. (Cantner et al., 2026) This is a role of state particularly in transformative settings, where innovation processes and their spreading in the economy should not only underly state intervention in cases of market failures or systemic failures, but more generally also in a directional type of policy (e.g. mission orientation) (Polt and Weber, 2026)
3. The strategy or policy document is characterised by trade-offs as it refers to several goals or dimensions that do not necessarily follow the same directions.
4. The transformation process is characterised by complexity and multi-level governance, here including the public actors, firms, supply chains, etc. Hereby, the community where the strategy or policy document origins from only partly overlaps with the community or set of actors addressed by its agenda.

The approach taken and presented in this article as well as its conditions for appropriate application together form the contribution of this conference paper.

Acknowledgements

This research was funded by the European Union under the BRIDGES 5.0 project (Bridging Risks to an Inclusive Digital and Green future by Enhancing workforce Skills for industry 5.0, grant agreement No 101069651).

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