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Scenario #3
DIGITALIZATION FOR THE GREEN TRANSITION

Green Acceleration Methodology for EU Clusters

Introduction

At the core of the rapidly evolving global economy lies an untapped potential that could redefine and reshape the essence of industrial progress. We are currently at the golden age for targeted climate action, since, according to the World Economic Forum, digital solutions could reduce global emissions by 20%[1].

The green and digital transitions hold the potential to be mutually reinforcing, with digital technologies acting as key drivers of the paradigm shift towards greater sustainability.

These technologies, through capabilities such as monitoring, tracking, simulation and forecasting, can increase resource efficiency, enable the customization of products and services and extend their life cycles.

As time progresses and the enabling technologies of the so-called Industry 4.0 diversify, digitalization will play an increasingly pivotal role in increasing the competitiveness of SMEs and startups and boosting sustainable growth in the European industrial landscape**.**

Lastly, it is imperative to understand that digitalization also entails a series of social, ethical and environmental implications and challenges that must be properly addressed.

[1] World Economic Forum, Digital solutions can reduce global emissions by up to 20%. Here's how, 23 May 2022.

>> TWIN TRANSITION

The twin green and digital transition is a model in which industry 4.0 technology and the fight for sustainability go hand in hand to build a more efficient society, as the intersections between these transitions are not just plentiful but also potent.

Rather than treating digital and sustainability in isolation, a twin transition strategy recognizes that there is a huge and largely untapped opportunity for technology and data to drive sustainability goals[2].

>> KETS

The concept of Key Enabling Technologies (KETs) was introduced by the EU in 2009 with the aim of boosting industrial competitiveness and promoting European reindustrialization. These knowledge-intensive technologies are characterized by high R&D input, rapid innovation rates and the creation of highly skilled and specialized workforces. They are multidisciplinary, cover many technological fields and show a trend towards convergence and integration[3].

>> DIGITAL ETHICS

Digital ethics refers to the principles, values and guidelines that drive our behavior in the online world, but also to the impact of digital technologies. It encompasses a wide range of complex and multifaceted issues, such as privacy, security, and accessibility, but also relates to cross-cutting issues of sustainability and environmental protection.

[2] World Economic Forum. What is the 'twin transition' - and why is it key to sustainable growth?, 26 October 2022.
[3] Interreg Europe. Key Enabling Technologies (KETs) – A European Priority for Industrial Modernisation, 3 May 2021

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green accelerator for EU clusters

Part 1

Learn

1. Digital Transformation and Sustainability

Introduction

Integrating digital innovation into the European Green Deal

Digital enabling technologies, which have emerged as the cornerstone of Industry 4.0, are instrumental to the long-term sustainability of EU clusters in all industrial sectors. From Artificial Intelligence and the Internet of Things to Additive Manufacturing and Extended Reality, these technologies are disrupting companies and catapulting them into new competitive arenas by shaping industrial transitions and building resilience.

As these practices have gradually evolved, the definition of sustainability has broadened to encompass broader social and economic considerations. Over the next decade, sustainability is expected to move from being a competitive advantage to a business imperative within clusters. The focus is likely to be on a more integrated approach, embedding sustainability into all aspects of operations and decision-making.

>> INDUSTRY 4.0

Industry 4.0 embodies the next stage of digitization in the manufacturing sector, propelled by four key drivers of disruptive technologies: the surge in computational power and connectivity; data analytics and artificial intelligence; human-machine interaction; and advanced engineering coupled with innovations in robotics. Nevertheless, technology is just one aspect of the Industry 4.0 mix. To thrive in the Fourth Industrial Revolution, companies must make sure their employees are suitably trained through upskilling and re-skilling[4].

>> CIRCULAR ECONOMY

A circular economy is an economic model designed to minimize waste and make the most of resources by keeping products, materials, and resources in use for as long as possible. It's a departure from the traditional linear economy, where goods are produced, used, and then disposed of as waste. In a circular economy, products and materials are reused, refurbished, remanufactured, and recycled to create a closed-loop system that is regenerative and sustainable.

[4] McKinsey & Company. What are Industry 4.0, the Fourth Industrial Revolution, and 4IR?, 17 August 2022.

Why is it important for cluster teams?

Digital transformation and sustainability are fundamental to the evolution and industrial clusters of Europe. Digitalization, exemplified in the so-called Industry 4.0, not only improves productivity but also opens new opportunities for SMEs and startups to grow and compete globally as a primary vehicle of innovation, thus ensuring their viability and development within the cluster ecosystem.

Moreover, combining digitalization with sustainability efforts via a dual transition to achieve a more sustainable, digital, resilient, and globally competitive economy, as reflected in the European Union's industrial strategy, has been drastically affected and accelerated in the post-pandemic context.

Since cooperation and exchange are key elements to ensuring the success of the twin transition, clusters must be adequately equipped to face the challenges it entails, especially to help SMEs and startups in their ecosystem identify, develop, and apply pathways for transition and adaptation both at the systemic and business level.

Additionally, clusters need to be able to co-create transition pathways to identify the actions needed to achieve the twin transition, providing a better understanding of the scale, benefits, and conditions required.

For this, it is necessary for clusters to be capable of implementing an integrated approach, understanding the concept of Industry 4.0 and how digitalization is a key catalyst for the green transition.

Key concepts

#1 Digitalization and Industry 4.0

The industrial revolution of the 21st century has been, is and will be, unquestionably, digital. If steam triggered the first Industrial Revolution in the 18th and 19th centuries; electricity, propelled the second from the mid-19th century; and preliminary automation and machinery, drove the third from 1969 on; no it's cyber-physical systems (or intelligent computers), hyperconnectivity and advanced manufacturing technologies the ones that are shaping the Fourth Industrial Revolution or Industry 4.0, which emerged in the mid-2010s. Industry 4.0 includes a structure that has completely changed the relationship between production and consumption[5].

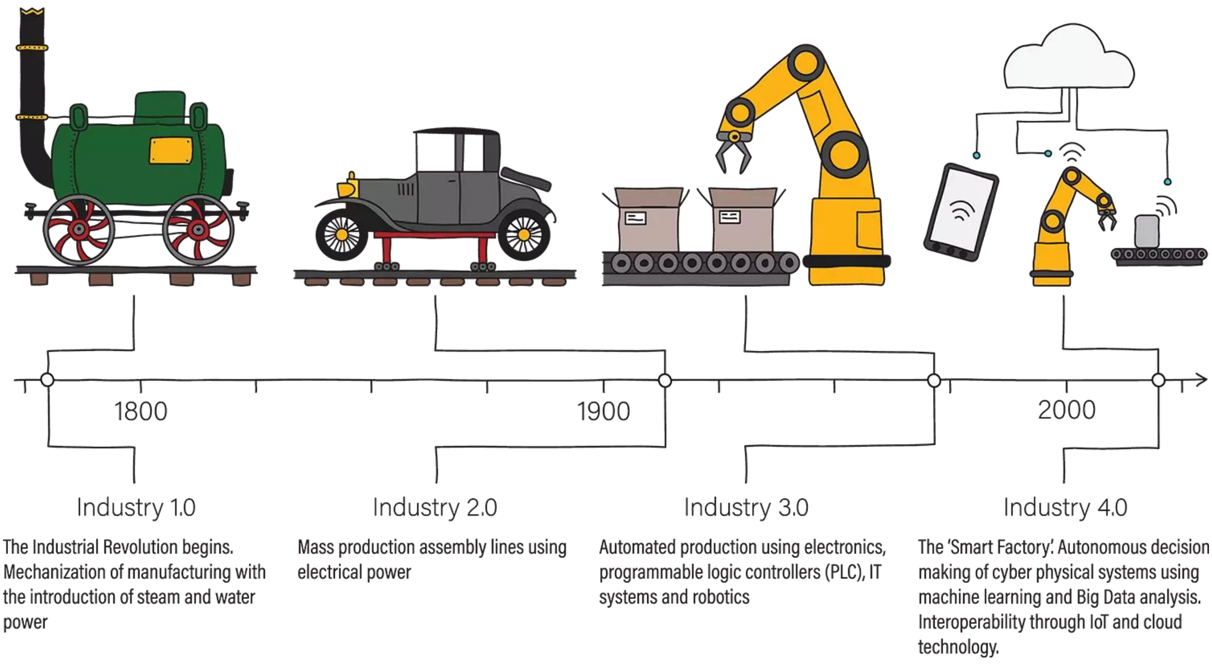


Image 1. Industrial revolutions through the ages. Source: SIMIO.

Prior to 2014, the Google search term "Industry 4.0" was virtually nonexistent, but in 2019, 68% of respondents to a McKinsey global survey[6] considered Industry 4.0 a top strategic priority, and 70% of them claimed that their companies were already either testing or deploying new digital

[5] Skender, F. & Ali, I, & Selim, A. *Digitalization and Industry 4.0*, 13 November 2019.
[6] McKinsey & Company. *Capturing value at scale in discrete manufacturing with Industry 4.0*, 13 September 2019.

technologies.

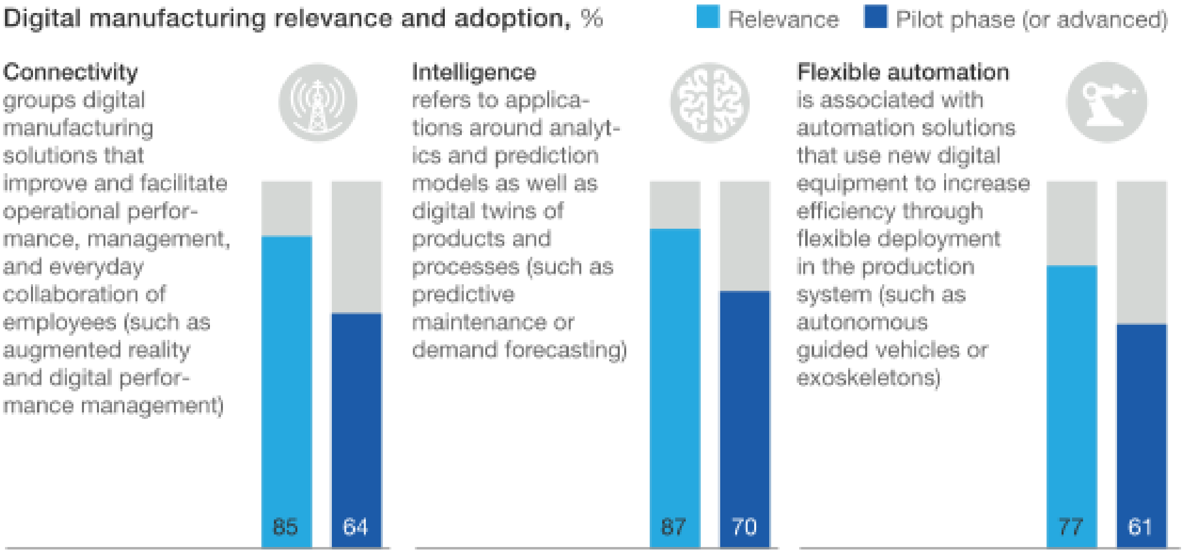


Image 2. Digital manufacturing solutions are adopted consistently across all industry sectors and categories. Source: McKinsey.

If Industry 4.0 is characterized by the seamless and integrated use of technologies that blur the boundaries between the physical, digital and biological realms, digital transformation constitutes the process by which companies and organizations are fundamentally changing the way they operate with the help of technological innovations.

If industrial companies were on the fringes of digitalization and IT in the past, digital transformation is now responsible for shifting the industry and transforming it into a connected industry. It is a process that requires great personal awareness and commitment, as it unifies all parts of a company.

Digital transformation is propelling companies into the Industry 4.0 era by assisting them in better understanding customer needs to deepen their interactions with them, increasing operational efficiency, innovating in their products and services, responding faster and more flexibly to market demands and creating new revenue streams. This ultimately empowers companies to set themselves apart in the global marketplace thus acquiring a competitive advantage.

However, while it is true that Industry 4.0 enabling technologies form the foundation of digital transformation strategies, the process of digital transformation not only entails the adoption of new technologies, but also the progressive transformation of business models, corporate culture and customer experiences.

Industry 4.0 is primarily characterized by the massive expansion of the Internet and its widespread penetration in almost all industries. The environment is digitized, connecting the physical with the digital and providing better access, understanding and manipulation of the business framework.

Within the era of Industry 4.0, intelligent and data-driven decisions can be made by manufacturing systems through real-time communication and collaboration between production units, thus facilitating the development of flexible, high-quality, customized products within mass production.

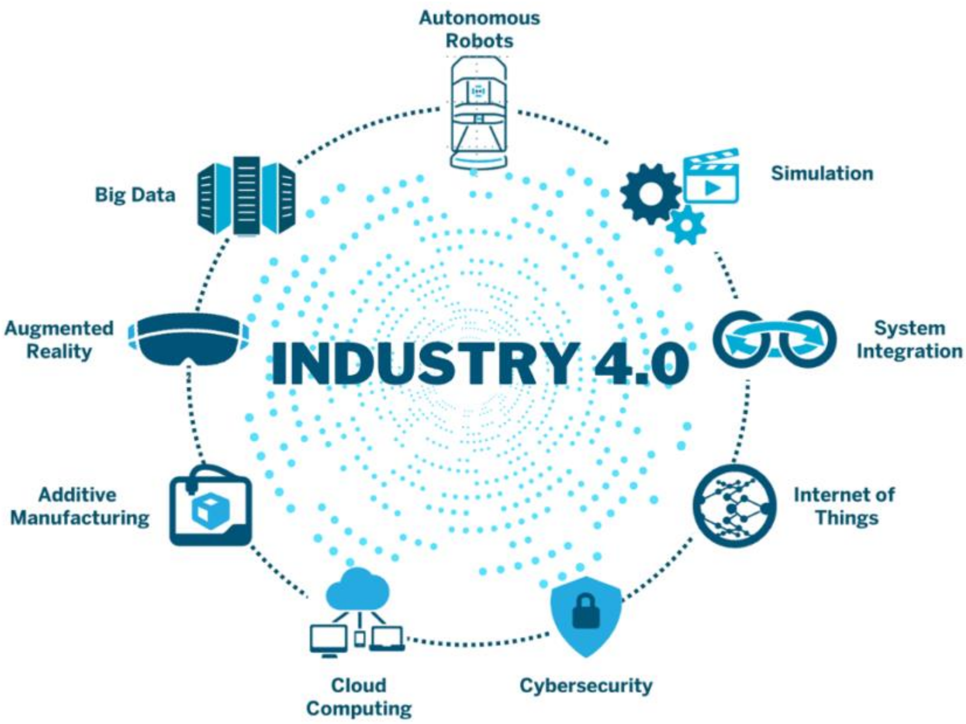


Image 3. The nine key technologies of Industry 4.0. Source: Calsoft .

Technology, however, is only half of the equation in Industry 4.0. While this autonomy in the operation of smart factories means that they will take over most of the work from employees, jobs will not disappear completely. Thanks to the complex deployment and performance of factories under the Industry 4.0 concept, new jobs will also be created for employees with higher qualifications or retraining.

So, in order to thrive in an increasingly globalized, interconnected and rapidly changing business ecosystem, companies must therefore make sure that their employees are adequately empowered, trained and equipped.

This is where organizations can benefit from reskilling and upskilling by giving their employees new skills to satisfy organizational needs. The difference between these two concepts is in the goal of the training:

- **Reskilling**, also known as professional recycling, attempts to train people to adapt to a different post within the firm, which produces workers who are more adaptable.
- **Upskilling**, on the other hand, strives to teach employees new skills to optimize their performance, which produces workers who are more specialized, productive, efficient, and innovative.

Barriers and challenges

With the great promise that it is and brings Industry 4.0, there are, however, great difficulties, especially since the vast majority of companies are small and medium-sized. Here are some of the barriers and challenges the may face:

Table 1. Barriers and challenger of Industry 4.0.

Data Vulnerability	• Increase in concerns over data and internet protocol privacy issues, ownership, and management. • Data required for AI algorithms must be shared for training and testing, but companies are reluctant to share data with third-party developers. • Current data governance policies lack the quality to support cross-organizational data sharing. • Ensuring the security of data, which is a powerful asset for organizations.
Ability of Computer Systems	• Lack of detachment between protocols, components, products, and systems delays innovation. • Interoperability issues prevent easy swapping of vendors or system parts, restricting upgrades.
Security	• Emerging weaknesses in factory systems pose significant concerns. • Interconnected physical and digital systems increase the risk of attacks due to an enlarged attack surface. • Vulnerability of equipment components could expose systems to potential attacks. • Need to predict both enterprise system vulnerability and machine-level vulnerability.

Supply Chain Disruptions	• Increased connectedness exposes supply chains to new risks, including cyberattacks and technological glitches. • Lack of skilled personnel to manage complex Industry 4.0 elements. • Increased online connectivity and data transfer heighten vulnerability to cyber threats. • IT network issues like misconfiguration, erroneous commands, and software failures are constraints.
New Business Models and Digital Transformation	• Digital technology in manufacturing prompts business leaders to rethink strategies. • Task of preparing a hesitant, reluctant, and digitally unskilled staff for digital transformation. • High costs of Industry 4.0 adoption, with big companies having an advantage due to their investment capabilities in research and development of custom digital solutions.

Companies tend to forecast technological development going into the future rather than pinpointing the areas of greatest impact and matching them to the value drivers of Industry 4.0. In addition, governance and organizational alignment are often unclear.

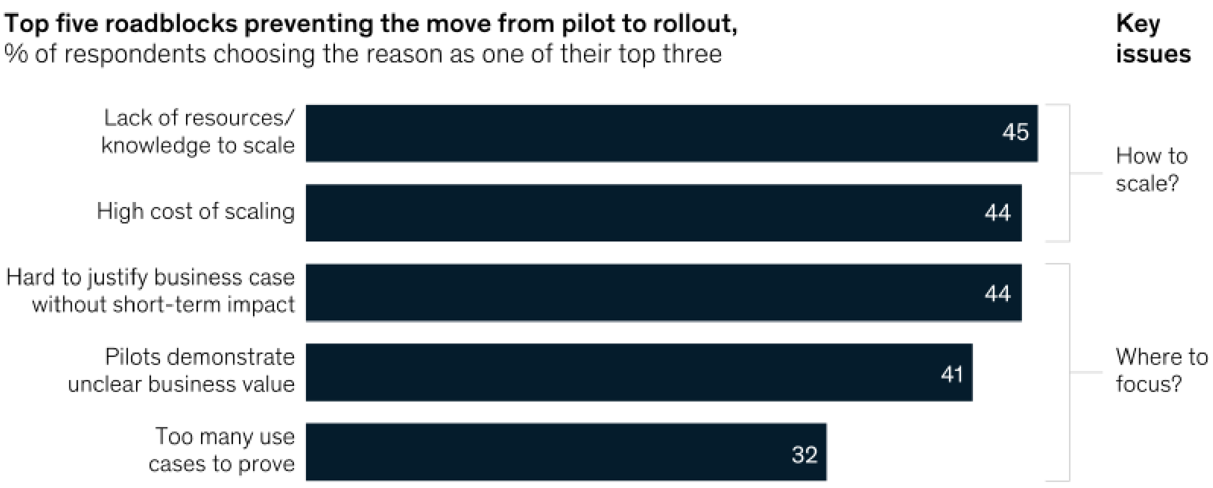


Image 4. Top five roadblocks preventing the move from pilot to rollout. Source: McKinsey.

Smart factories,

Industry 4.0 has brought with it the development of so-called "smart factories", digitized manufacturing facilities that uses connected devices, machinery and production systems to continuously collect and share large amounts of data, which is then used to inform decisions to improve processes, minimize production times and costs and address any potential issue that may arise.

Smart factories manage to operate without too much human intervention, learning and adapting to changes in real time, which makes them more flexible and versatile than former factories[7].

The main characteristics of smart factories are:

- Production processes are streamlined and optimized throughout the entire economic and value chain thanks to vertically and horizontally integrated IT systems.
- Single production cells are replaced by fully automated and interconnected production lines.
- Physical prototypes are replaced by virtual designs of products, production resources and production processes, which are then implemented as part of an embedded process involving both the manufacturer itself and its suppliers.
- Flexible production processes make it possible to efficiently manufacture even small batches of products tailored to each customer's needs.
- Robots, production equipment and products, which communicate with each other, make autonomous real-time decisions to a certain extent, which increases the flexibility and efficiency of the production process.
- Production equipment is optimized and configured according to the parameters of the product.
- Automated logical floor plans through automated trolleys and robots.
- Adaptation to changing production needs that enables the logical chain to also coordinate transport connections between production entities.

Industry 5.0

According to the European Commission, Industry 5.0 "will be defined by a re-found and widened purposefulness, going beyond producing goods and services for profit. This wider purpose constitutes three core elements: human-centricity, sustainability and resilience. (…) In a globalized world, a

[7] IDEA. *What Is a Smart Factory? Features and Technologies*.

narrow focus on profit fails to account correctly for environmental and societal costs and benefits. For industry to become the provider of true prosperity, the definition of its true purpose must include social, environmental and societal considerations”[8].

Som experts talk about Industry 5.0 as a bridge between capitalism and sustainability[9], as companies are challenged nowadays with the need of creating ever more inclusive and environmentally friendly workplaces, building more resilient and efficient supply chains, and doing it all in a sustainable way.

The fifth industrial revolution will be focused on sustainable decision-making throughout the value chain. If Industry 4.0 focused on technology, Industry 5.0 will focus on people and the environment.

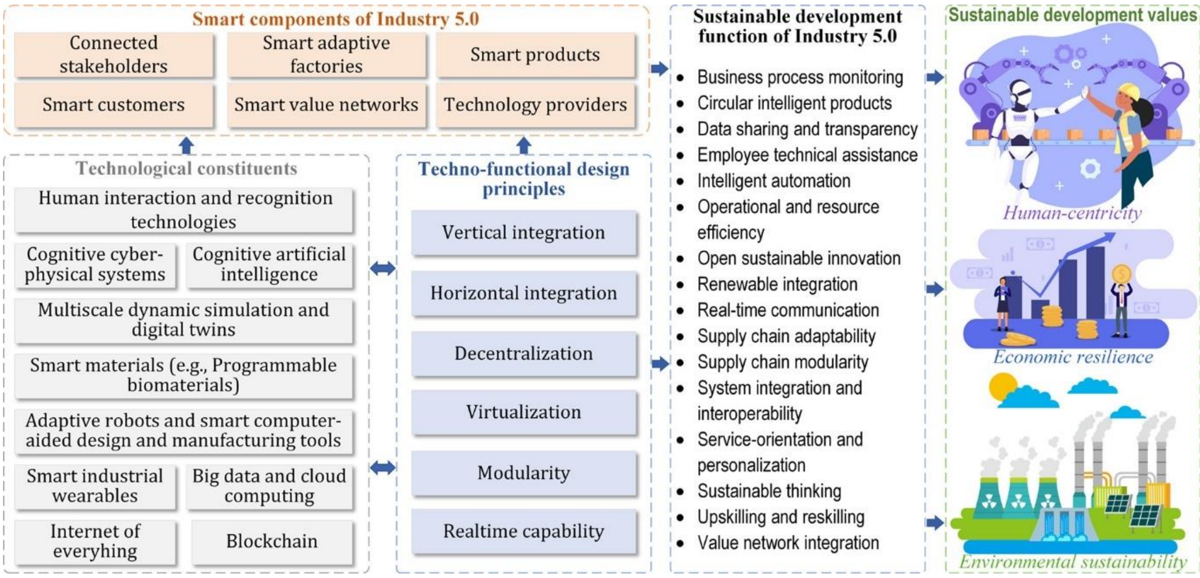


Image 5. Identifying industry 5.0 contributions to sustainable development: A strategy roadmap for delivering sustainability values.

This approach to industry contributes to three of the Commission’s priorities: "An economy that works for people", "European Green Deal" and "Europe fit for the digital age", and elements related to the future of industry are already part of major Commission policy initiatives[10]:

[8] European Commission, Directorate-General for Research and Innovation. *Industry 5.0. Towards a sustainable, human-centric and resilient European industry* ,5 January 2021.
[9] Heartland. *Industry 5.0 – Why Sustainability Will Be The Next Revolution*.
[10] European Commission. *Industry 5.0. What this approach is focused on, how it will be achieved and how it is already being implemented*.

- Adopting a human-centric approach for digital technologies including artificial intelligence (Proposal for AI regulation).
- Up-skilling and re-skilling European workers, particularly digital skills (Skills Agenda and Digital Education Action plan).
- Modern, resource-efficient and sustainable industries and transition to a circular economy (Green Deal).
- A globally competitive and world-leading industry, speeding up investment in research and innovation (Industrial Strategy).

#2 The Twin Transition

The European Green Deal[11], the European Commission's plan for a climate-neutral society, aims to transform the EU into a competitive and resource-efficient economy. To achieve this goal, the Green Deal Industrial Plan[12] was launched in 2023 to address the green transition as a pathway to boost EU competitiveness and resilience.

However, despite the pressing need to take specific steps in the field of digitization to encourage green innovation, the digital transition should occupy a central, rather than a peripheral, place in this plan, as is the case in the current draft.

On the other hand, the New Industrial Strategy for a green and digital Europe aims to make Europe the best place to start a business and grow, and the digital strategy "Shaping Europe's Digital Future" shows how digital solutions are also key to fighting climate change and facilitating an effective green transition of EU's industrial fabric.

Both underline too the need to deploy technologies to match the new global landscape, positioning digital transformation as a key enabler of innovation to support the decarbonization and reshaping of European industries.

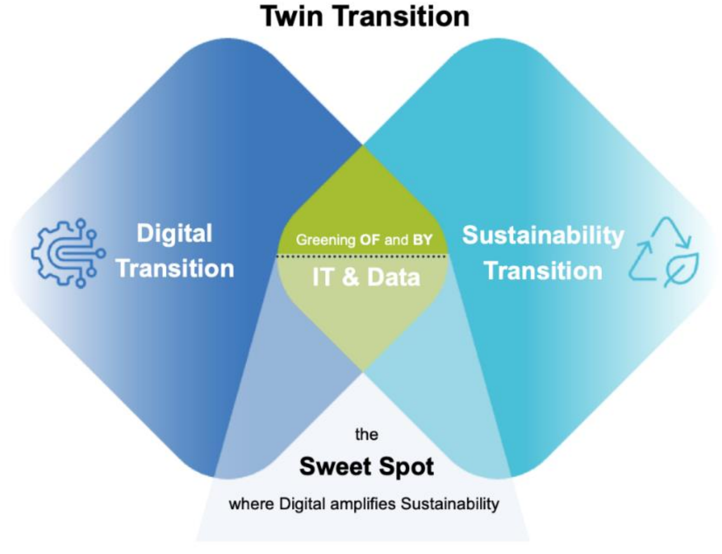


Figure 6. Greening by digital and greening of digital. Source: Royal Schiphol Group & PA Consulting.

[11] European Commission. The European Green Deal: Striving to be the first climate-neutral continent.
[12] European Commission. The Green Deal Industrial Plan: Putting Europe's net-zero industry in the lead.

The digital and green transitions are widely recognised to be the key drivers of current and future industrial change, as reflected in their identification as the two key levers of an industrial strategy for Europe.

So, the question is to know if there is a way for the two most important trends to work together? Yes, there is, and it's called the twin green and digital transition, a model in which industry 4.0 technology and the fight for sustainability go hand in hand to build a more efficient society.

The so-called "twin transition" paradigm, which blends digital innovation with the pursuit of environmental sustainability, is at the forefront of this new frontier. It is no longer a purely academic or theoretical concept, or even a fleeting trend. It is a blueprint for our collective future as a society that seeks to balance technological progress and the environmental sustainability to achieve unprecedented prosperity and greater ecological harmony.

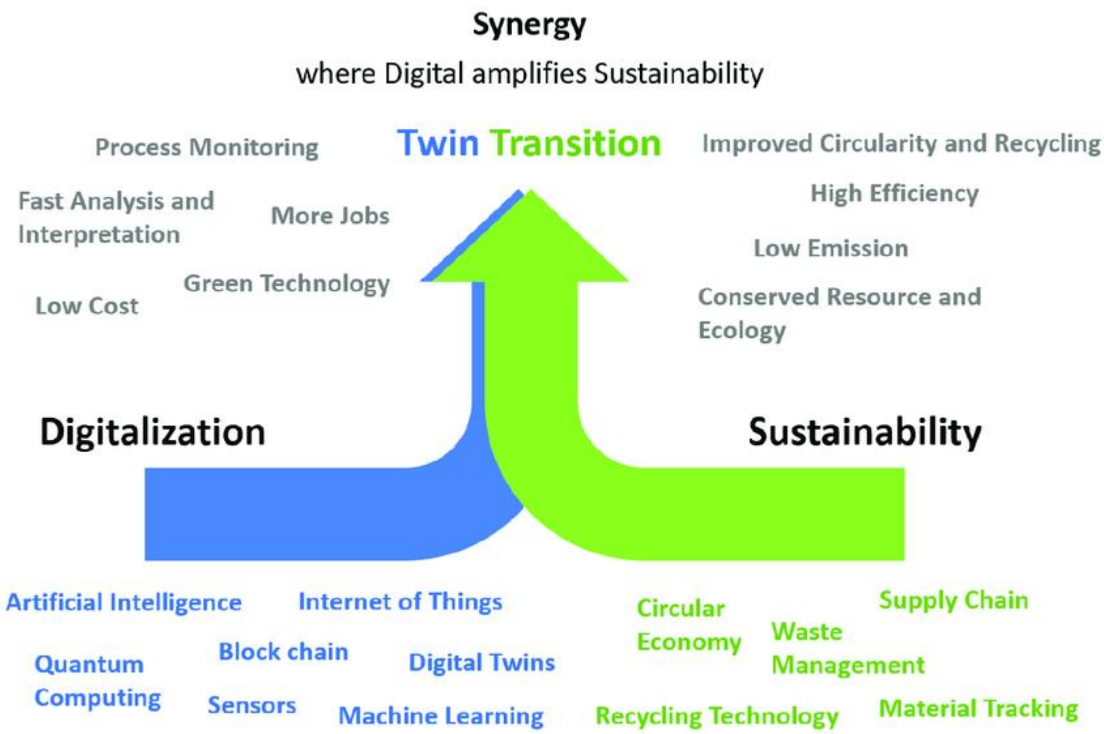


Image 6. Twin transition toward a sustainable digitalized future. Source.

A twin transition mindset acknowledges that there is a vast, but largely unexploited, opportunity for technology and data to drive sustainability goals. Rather than addressing digitalization and sustainability in isolation, a twin-transition approach blends these critical features to potentially unlock significant benefits in terms of efficiency and productivity. A twin transition can have a positive impact by "greening" technology, data assets and infrastructure, while accelerating sustainability across the organization.

According to the European Commission, the key requirements for the twin transition with regards to technology are the following[13]:

- Implement innovation infrastructure: Research ecosystems are needed for the development and improvement of green-digital technologies. Furthermore, enabling technologies require an adequate infrastructure for their roll out.

- Build a coherent and reliable technology ecosystem: Technology interoperability and the reliability of technologies will be crucial in an increasingly complex and interconnected system.

- Ensure data availability and security: Data governance regulations must ensure clarity about who owns data and who has access to it. It must protect stakeholders and make sure that data is secure.

To ease the twin transition and to boost the adoption of sustainable digitalization, Royal Schiphol Group and PA Consulting have joined forces to launch a handbook that provides business leaders with the necessary guidance and tools to build a successful twin transition strategy: the Twin Transition Playbook. Broken down into three main phases and seven small steps, the playbook is a living document that will be iteratively refined based on feedback from adopters.

Image 7. The key phases outlined in the Twin Transition Playbook. Source: Royal Schiphol Group & PA Consulting.

[13] European Commission, Joint Research Centre. *Towards a Green & Digital Future: Key requirements for successful twin transitions in the European Union*, 2022.

#3 Digitalization as a lever for Circular Economy

According to the Ellen MacArthur Foundation[14], "the circular economy is a system where materials never become waste and nature is regenerated. In a circular economy, products and materials are kept in circulation through processes like maintenance, reuse, refurbishment, remanufacture, recycling, and composting. The circular economy tackles climate change and other global challenges, like biodiversity loss, waste, and pollution, by decoupling economic activity from the consumption of finite resources".

Image 8. The Circular Economy an ecosystem collaboration model. Source: [DXC Technology](#).

Digital transformation undeniably poses a great opportunity for companies to rethink their future, their strategy, their value chain, their value creation, their operations and pricing base, as well as their sales and customer acquisition channels. Each of these changes is also possible from a circular economy perspective.

To successfully build and deploy a fully circular business model, digital business ecosystems must be designed to make informed critical decisions

[14] Ellen MacArthur Foundation. *What is a circular economy?*

and act with flexibility. Just as companies advance their digital processes, they must also roll out circular business models, and it is precisely digitalization which is increasingly empowering them to create resilient and interoperable ecosystems. These ecosystems must not only support circular goals, but also foster new opportunities for innovation, differentiation, synergy and job creation.

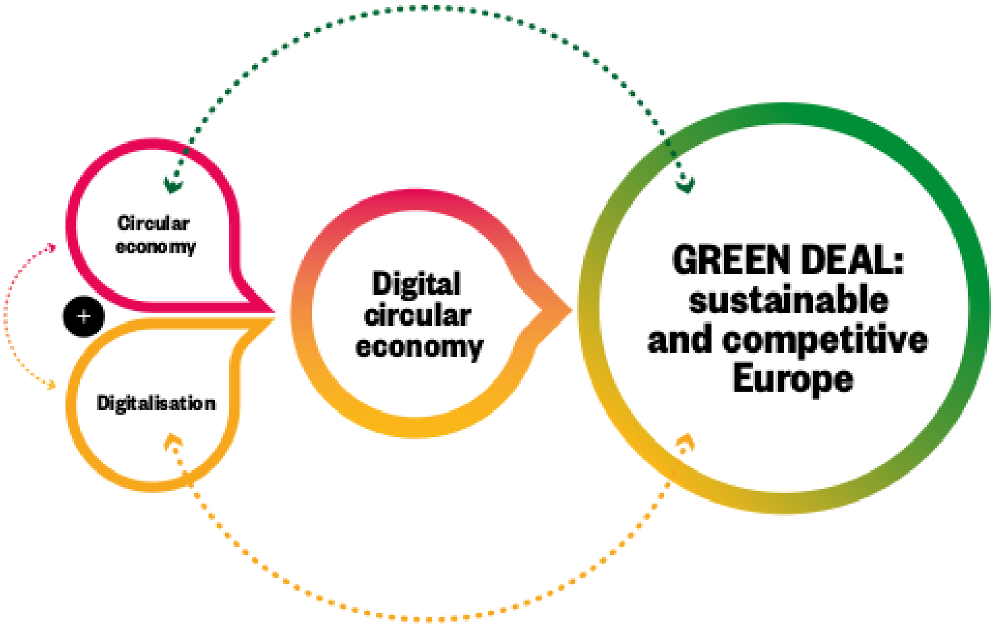


Image 9. How a digital circular economy will enable the European Green Deal.
Source: Hedberg, A. & Šipka, S.

Currently, there is a key innovation opening for the circular economy, especially in a global context of cooperation and exchange, since the idea of the circular business model is that is not a single company which closes the loop, but the ecosystem as a whole, thus requiring a systematic approach that goes beyond the actions of individual companies. Therefore, it is essential to establish networks and to collaborate with stakeholders, but also with new business partners and with customers and consumers in order to make circular business models a reality.

Two key examples of digital technologies enabling circular economy are big data analytics and virtual reality. It is beyond dispute that there cannot be a circular economy without data. Although not sufficient on its own, one of the main preconditions for operating in the circular economy is to have access to upstream information and a thorough understanding of the impact of one's own business actions downstream in the value chain. Connecting physical material flows with digital data flows is thereby a key element of many approaches and strategies used to pursue a circular economy.

By adopting a circular business model based on slowing down, closing and/or reducing the loop, virtualization has also proven to be an effective and valuable technological tool to assist in reducing costs, saving resources and providing accurate and reliable data, as well as in the design of modular and repairable products that can be upgraded.

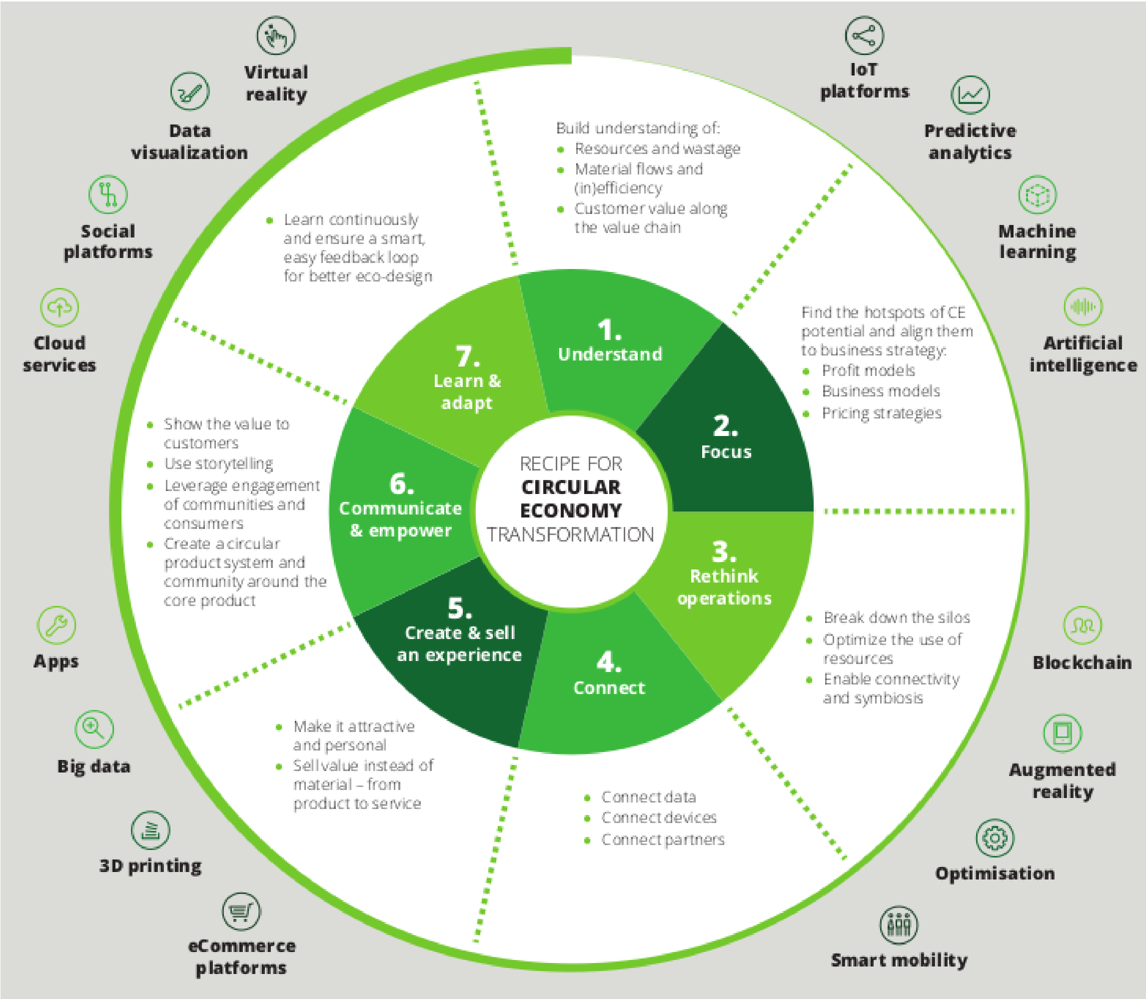


Image 10. How digitalization sparks circular solutions. Source: Deloitte.

To go further

Do you want to learn more about the digital transformation and the twin transition?

- European Cluster Collaboration Platform. *Clusters Driving the Green and Digital transitions*, 22-23 November 2021.
- European Cluster Collaboration Platform. *Cluster business models fit for accelerating the twin transitions. Key actions for clusters to implement transition pathways*, 2021.
- Royal Schiphol Group & PA Consulting. *The Twin transition Playbook 2.0*, 2023.
- European Commission, Joint Research Centre. *Towards a Green & Digital Future: Key requirements for successful twin transitions in the European Union*, 2022.
- European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs & European Expert Group on Clusters. *Recommendation Report*, December 2020.
- Hedberg, A. & Šipka, S. *The circular economy: Going digital*, 2020.

2. Technologies enabling Circular Economy

Introduction

Key Enabling Technologies

Industry 4.0 technologies, also known as Key Enabling Technologies (KETs), offer a new perspective on automated and more efficient production systems. I4.0 technologies are closely linked to sustainability concerns, as they should contribute to solve the environmental and societal challenges of today's society. Thus, they are considered a driving force of the circular economy transition[15] [16], with a clear effect on the reduction of the environmental impact of manufacturing industries[17] [18].

As Industry 4.0 technologies are the 'technology building blocks' behind a wide range of innovations (such as 3D printers, LED lighting, advanced robotics, bio-based products, smart phones, nanodrugs, smart textiles and many more), they have the potential for application in virtually all sectors and industries.

In this context, I4.0 technologies have the potential to modernize manufacturing processes while having a direct impact on the adoption of sustainability practices, related with the circular economy model, and enabling the twin green and digital transition.

[15] R. Rocca, P. Costa, C. Sassanelli, L. Fumagalli and S. Terzi. Industry 4.0 solutions supporting circular economy. 2020 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC), vol. June, pp. 1-8, 2020.
[16] D. Tronchoni and G. Brennan, Industry 4.0: A Key Enabler of the Circular Economy," Climate Innovation Insights, Series 2, No. 7.
[17] Berg, H et al. Unlocking the Potential of Industry 4.0 to Reduce the Environmental Impact of Production, European Environment Agency, European Topic Centre on Waste and Materials in a Green Economy: Mol, Belgium, 2021.
[18] Blunck, E.; Werthmann, H. Industry 4.0—An Opportunity to Realize Sustainable Manufacturing and its Potential for a Circular Economy, Proceedings of the 3rd Dubrovnik International Economic Meeting (DIEM), Dubrovnik, Croatia, 12–14 October 2017; pp. 644–666.

Why is it important for cluster teams?

The enabling technologies coming from Industry 4.0 are already increasingly being used to support a more sustainable global future, as the digital transformation impacts sustainability in two main ways. For one, sustainable design enables product engineers to consider more carefully materials, processes and logistics, thereby reducing material and energy consumption, emissions and waste.

In addition, as companies are facing growing demands to cut down emissions across their entire operations, technology can provide them with the data they need to understand inefficiencies, allowing them to make data-driven decisions that optimize operations and improve resource utilization.

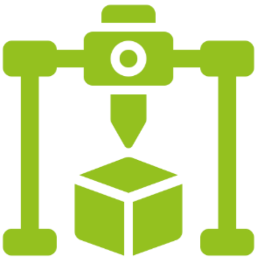
Clusters, as knowledge pools and drivers of specialized innovation at regional level, and due to their operational mechanisms based on trust and cooperation among actors, are natural facilitators of the digital transition.

However, not all clusters are able to play such a prominent role if they do not have an adequate know-how foundation that allows them to identify the most appropriate technological solutions for each case and process, which is particularly relevant when it comes to enabling sustainability in companies.

Key concepts

Which are the Key Enabling Technologies driving the twin transition and how are they doing it?

#1 Additive Manufacturing



What is it?

Additive manufacturing, also called 3D printing, is a process of creating three dimensional objects by layering successive layers of raw materials (mainly polymer plastics) from a computer-aided design model. It also makes it possible to produce complex shapes using less material than traditional manufacturing methods.

How can it be applied with sustainable purposes?

- Circular design: by opening up new possibilities for designing products that can be easily repaired, reused or recycled, thus extending product life and ensuring total material recovery.

- Use of environmentally friendly materials: by optimizing material flows, integrating waste from other industrial processes and improving recyclability, thus fostering industrial symbiosis.

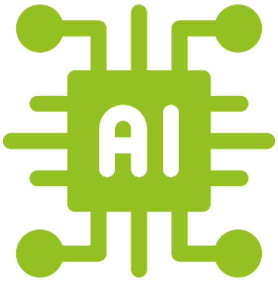
- Resource conservation: by producing the products layer by layer, it uses only the necessary amount of raw materials, which reduces waste.

- Waste minimization: by accurately allocating raw materials and recycling waste, it minimizes material consumption and scraps, which is especially beneficial for industries such as automotive and aerospace, which require sustainable production methods.

- Product fixation: by enabling mass customization, creating unique and affordable products that build a deeper connection between customers and products, thus addressing both technical and psychological factors to extend the product's useful life.

- On-demand manufacturing and repairability: it enables local production and the production of spare parts on demand, facilitating repairs and reducing the need for transportation and storage of large inventories, thereby reducing CO2 emissions and shortening supply chains.

#2 Artificial Intelligence



What is it?

Artificial intelligence (AI) is a subset of technologies designed to enable computers and machines to mimic human intelligence and problem-solving capabilities. On its own or combined with other technologies (e.g., sensors, geolocation, robotics), AI can perform tasks that would otherwise require human intervention.

How can it be applied with sustainable purposes?

- Design support: by helping designers to create initial designs or suggest modifications to improve disassembly, recycling and reuse.

- Rapid prototyping and testing: by assisting in rapid prototyping and testing iterations, thus accelerating the design of products, components and materials.

- Improved resource traceability and real-time monitoring: by providing a clear view of product and resource flows, enhancing transparency and facilitating improved future design and reuse.

- Assessment and reprocessing: by assessing quality for returned products, determining their reprocessing needs and identifying optimal disposal methods, thus improving sustainability and resource efficiency.

- Efficient and optimized sorting, disassembly and remanufacturing: by using algorithms that identify and classify objects with cameras and sensors, which enables precise techniques and the extraction of valuable components.

- New business models: by enabling real-time analysis of product data, it fosters new business models, supporting circular practices.

#3 Augmented, Virtual, Mixed & Extended Reality

What are they?

Augmented and virtual reality technologies create immersive experiences by integrating virtual elements into the physical world using sensors to understand the surroundings (AR) or by simulating entire environments isolating users from the real world, usually with the help of a headset and headphones to help (VR).

In the case of mixed reality (MR), it blends the real and virtual worlds, allowing physical and digital objects to coexist and interact in real time. Lastly, extended reality (XR) is an umbrella term that encompasses all immersive technologies (VR, AR and MR), as well as any future innovations that may emerge in this field.

How can they be applied with sustainable purposes?

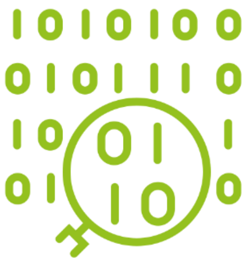
- <u>Enhanced factory floor planning:</u> by boosting spatial decision making through immersive technologies, they can improve the layout of buildings, the floor planning of production plants and logistical strategies and systems.

- <u>Efficiency in production processes:</u> they ease the optimization of machine tool programming by being able to solve complex spatial issues, such as the verification of shapes without molding defects or the physical properties of the machined workpiece in forming, among others, assisting as well in precision assembly.

- <u>Improved assembly and servicing:</u> they facilitate virtual assembly and disassembly to verify assembly processes and plan ergonomic workstations, supporting real-time assembly with precise tool and component placement instructions. In the case of services, they provide virtual training, remote expert assistance and digital documentation, thus reducing the need for the allocation of physical resources.

- <u>Reduction of the global environmental impact:</u> by minimizing waste, improving performance throughout the entire supply chain and cutting down on process interruptions, ultimately resulting in a reduction of energy and material consumption.

#4 Big Data Analytics



What is it?

Big data refers to the huge amounts of data, often complex and fast, generated in production environments and collected at all stages, either through equipment and devices using machine sensors, for example, or even from operators. The goal of analyzing this data is to transform it into practical and useful intelligence that assists in decision making to improve efficiency and productivity, fostering innovation in product development and service delivery.

How can it be applied with sustainable purposes?

- <u>Improved supply chain efficiency and optimization:</u> by helping to improve the management of supply demand, it accelerates the development of new products, optimizes supplier management and helps in designing efficient and resilient supply chain structures.

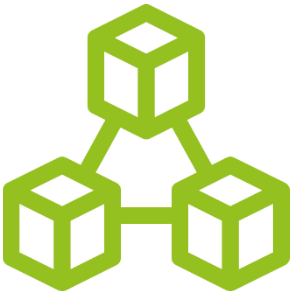
- <u>Improved risk management and predictive management:</u> by identifying potential disruptions in real time, it facilitates de identification and elimination of sources of error in the production process before they lead to major problems, thus enabling proactive mitigation measures to be adopted. At the same time, by analyzing data from IoT-enabled machines, potential problems can be identified before they occur.

- <u>Analysis of consumption pattern and market trends:</u> by identifying consumption patterns they help in designing eco-friendly and circular products. Also, by analyzing unstructured data such as customer reviews and cultural trends, product developers can quickly respond to changes and adapt their products.

- <u>Application of smart factory concepts:</u> by gathering smart data along the supply chain, from raw materials to end-of-life products, they enable an efficient use of resources and supports waste reduction.

- <u>Real-time decision making:</u> by sharing the analyzed results in real time, fast and accurate decision making is made possible, which leads to sustainable practices in production planning and raw material procurement.

#5 Blockchain



What is it?

Blockchain is a secure and distributed database consisting of an organized list of immutable blocks in continuous growth. Each block contains a cryptographic hash of the previous block, a timestamp and the transaction data, and each transaction is authorized by the digital signature of the owner.

This makes it almost impossible to alter, hack or manipulate by third parties, thus guaranteeing the authenticity and security of the transaction.

How can it be applied with sustainable purposes?

- Decentralized decision-making and governance: by improving transparency and accountability in decision-making processes, it ensures the integrity and reliability of environmental data, thus fostering trust and openness in sustainable initiatives.

- Support for renewable energy monitoring and carbon footprinting: by enabling the monitoring and deployment of renewable energies, it helps to reduce greenhouse gas emissions and promotes a sustainable energy market. In addition, it empowers companies to measure, manage and reduce their environmental impact, encouraging proactive sustainability approaches.

- Retrieval and traceability of materials: by tracking the flow of materials through supply chains and consumption stages, it assists refurbishment and recycling through the identification and procurement of recycled and/or remanufactured components. It also enables the decentralized creation and circulation of value through the connection of shared databases, fostering cooperation and competitiveness in the global context of Circular Economy.

- Materials recovery for the long term: by collecting and storing information about materials, it preserves valuable datasets that facilitate their potential reuse or recycling in an efficient manner as new methods of reuse emerge in the future.

- Real-time data tracking and end-user empowerment: by being integrated or combined with GPS or IoT sensors, it allows the creation of real-time data trails to support data-driven decisions on the management of materials throughout the life cycle of a product. In addition, through QR coding or RFID tagging, it can help end users to make informed choices about product repair or disposal, thus encouraging collaborative responsibility for material flows.

- Smart contracts and supply chain transparency: by automating and streamlining sustainable supply chain practices, such as renewable energy trading and the management of carbon credits, it increases efficiency and reduces waste disposal, as well as enables the monitoring of ethical sourcing.

#6 Internet of Things

What is it?

The Internet of Things (IoT) currently stands out as the flagship digital technology of Circular Economy, as it is the most integrated technology in circularity strategies due to its ability to facilitate the extensive collection of information throughout the product life cycle.

IoT enables the exchange of information between different smart devices that can communicate with each other and with other devices connected to the Internet, thus forming an expansive network capable of seamless data exchange and autonomous task execution.

How can it be applied with sustainable purposes?

- Data monitoring for sustainable manufacturing: by monitoring data in manufacturing operations, waste rates are reduced, equipment wear and tear is minimized and energy consumption is lessened. At the same time, it enables maintenance and fault detection, extending product life, improving serviceability and optimizing asset utilization.

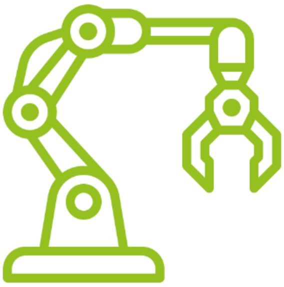
- Support for circular supply chains: it facilitates the tracking of materials and of product flows from design to end of use, as well as facilitates decentralized production, reverse logistics and remanufacturing in circular supply chains.

- Real-time stock visibility and warehouse optimization: it allows for a real-time visibility of product stock, which ultimately reduces waste, improves inventory management and increases efficiency. Advanced tools such as robotic pickers, handheld devices and RFID tags in smart warehouses optimize the flow of goods, reduce overproduction and encourage the resale or recycling of products.

- Efficient waste sorting and processing: sensor-equipped garbage cans and containers enable efficient sorting and processing of discarded materials and, coupled with blockchain technology, improve material identification.

- Innovative business models: such as product-as-a-service, shared use or pay-per-use, improve operational efficiency and meet changing market demands.

#7 Robotics



What is it?

Robotics is the design, construction and use of machines (robots) to undertake tasks normally performed by humans. Traditional robotics needs to have physical barriers for safe use and requires more space, but is built for power and speed.

Collaborative robotics (cobots) work in collaboration with the human operator without the need for physical barriers and are more suitable for slower, more specialized work. Adaptive robotics is an evolution of both types and can react to the environment and adapt its movements to the specific task at hand.

How can it be applied with sustainable purposes?

- Improved manufacturing efficiency: by ensuring stable processes, higher production yields and fewer rejects, they lead to improved cost management, increased performance and enhanced sustainability in the manufacture of high quality products by offering adaptability, versatility and compliance with safety standards. Robotic solutions such as service compactor vehicles and line markers further reduce material waste and promote sustainable production.

- Green logistics and transportation: autonomous vehicles and drones can optimize delivery routes, reducing fuel consumption and minimizing emissions, while warehouse robots can streamline order fulfillment processes, reducing the need for excessive packaging and unnecessary transportation.

- Revolutionizing waste sorting and recycling: by streamlining waste sorting tasks through the use of methods such as object recognition and artificial intelligence, they make recycling more convenient and efficient. Cobots also facilitate accurate product dismantling and sustainable resource utilization.

#8 Simulation & Digital Twins

What is it?

A simulation is a model that mimics the performance of an existing or proposed system through the creation of a visual mock-up, providing evidence for decision making by being able to test different scenarios or process modifications. It can be coupled with virtual reality technologies for a more immersive experience. Simulations can be used to fine-tune performance, optimize a process, improve safety, test theories and even train staff.

A digital twin is a virtual representation of an object or system designed to accurately depict a physical object. It spans the lifecycle of the object, is updated from real-time data and uses simulation, machine learning and reasoning to guide decision making.

While it is true that both simulations and digital twins use digital models to reproduce the various processes of a system, a digital twin is actually a virtual environment, which makes it considerably richer for conducting tests and research studies. The main difference between a digital twin and a simulation is mostly a matter of scale: while a simulation usually studies a single process, a digital twin can run any number of simulations useful for studying multiple processes.

How can it be applied with sustainable purposes?

- Optimized energy consumption: by using simulation tools to model different scenarios and pinpoint areas of energy waste, it is possible to reduce energy consumption and carbon footprint while saving costs, thus reducing the environmental impact.

- Improved production processes: by helping companies to optimize the layout of their production facilities, whether it is space, manufacturing or process flows by creating virtual models of production processes to simplify the detection of inefficiencies and bottlenecks, leading to data-driven decisions that improve efficiency across the entire production chain.

- Sustainable product design: by using digital twins to streamline the design of products, it is possible to optimize their use and improve recycling processes, ensuring that products are sustainable throughout their entire lifecycle. In addition, both the product and its packaging can be modeled, using a variety of simulation environments to find new ways to optimize the packaging.

- Innovation for sustainability: by using simulation to engineer sustainable products and services through the identification of improvement potentials, it contributes to driving innovation, reducing environmental impact, improving competitive advantage, creating new revenue streams, and attracting sustainability-minded customers.

- Resilient supply chain management: by helping to simulate elements of the wider supply chain to enable the development of a resilient supply chain and to ensure that more transparent processes are applied in the real environment. This further ensures more sustainable operations by optimizing transportation planning, spare parts management and decision making for returned products.

#9 System Integration

What is it?

System integration involves merging individual processes into a cohesive system, connecting multiple software applications, hardware systems, networks and technologies to enable a seamless flow of data and communication.

Systems integration aims to synchronize important data, streamline processes and improve efficiency, allowing tasks to be automated and eliminating the need for manual data transfers, which ultimately brings greater interoperability and scalability of systems and increased competitiveness by being able to react more dynamically to changes (thanks to the concept of modularity, which allows for the construction of complex systems based on different individual components).

How can it be applied with sustainable purposes?

- Improved resource management: by facilitating real-time data sharing, resulting in efficient resource management, increased energy efficiency, reduction of waste and emissions, and optimization of supply chains.

- Enabling data-driven decision making: by identifying inefficiencies, leakages or wastes in industrial operations, prompting that corrective actions to be taken and operational efficiency can be improved globally.

- Optimized efficiency in the supply chain: by ensuring better coordination and collaboration between all stakeholders, which leads to a more robust, resilient and transparent supply chain while lowering operational costs.

- Increased flexibility and adaptability: by enabling new machines or production lines to be smoothly integrated into already established systems, allowing for faster response to market demands and changes.

- Enhanced testing and quality assurance: by facilitating the creation of a safe and reliable test environment where changes can be pre-tested in isolated environments prior to full implementation, minimizing risks and malfunctions and identifying and rectifying faults at an early stage.

To go further

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3. Ethical considerations in Digital Transformation

Introduction

In a global arena where environmental concerns are more acute than ever and companies are called upon to adopt clear, effective and meaningful steps to curb their environmental impact, the intersection between technology and sustainability has now become a central issue. Yet, as society as a whole grapples with the implications of this rapid technological advance, ethical considerations often take a back seat.

As we have already explained in previous sections, at the core of Industry 5.0 lies its potential to align technological innovation with the fundamental values of sustainability and ethics, envisioning a future in which industries operate in a manner that is efficient and innovative, but also humane and morally responsible.

For, while the digital transformation offers immense opportunities, it also raises ethical and social issues that must be brought to light and dealt with, as reconciling technological advancement with ethical responsibility is paramount to ensure that these innovations can benefit the planet and society as a whole.

Why is it important for cluster teams?

It is becoming increasingly clear that industrial performance must be reconciled with consideration for the values and interests of citizens while addressing environmental challenges in alignment with certain ethical principles and regulatory standards.

Yes, technologies such as artificial intelligence or the internet of things are providing vast opportunities for growth, innovation and efficiency, but digital transformation cannot come at the expense of citizens' rights or environmental sustainability.

Clusters must therefore equip themselves and be clear about their role in navigating and ensuring an ethical, fair, sustainable and responsible digital transformation, thus anticipating the needs of the companies that are part of their ecosystems.

Key concepts

#1 Digital ethics

That technology is reshaping the world (and will continue to do so) at an unprecedented pace is a real fact, and that is why it is essential to bear in mind that, although we often talk about users and potential customers, what lies behind the digital world are people. In today's interconnected world, where digital technologies such as artificial intelligence, big data analytics and the Internet of Things are ubiquitous, digital ethics play a critical role in determining how we interact with technology and each other.

Digital ethics is a somewhat new applied ethical approach, arising with the explosion of ICTs, the Internet and social media, and is positioning itself more strongly with the emergence of human dilemmas in the face of the use of artificial intelligence.

Digital ethics refers to the moral principles and standards that govern the ethical behavior and responsibility of individuals and organizations in the digital environment. It goes beyond the question of what is within the legal boundaries, encompassing considerations of fairness, transparency, privacy, security, and the impact of technology on individuals and society as a whole, but also on the environment.

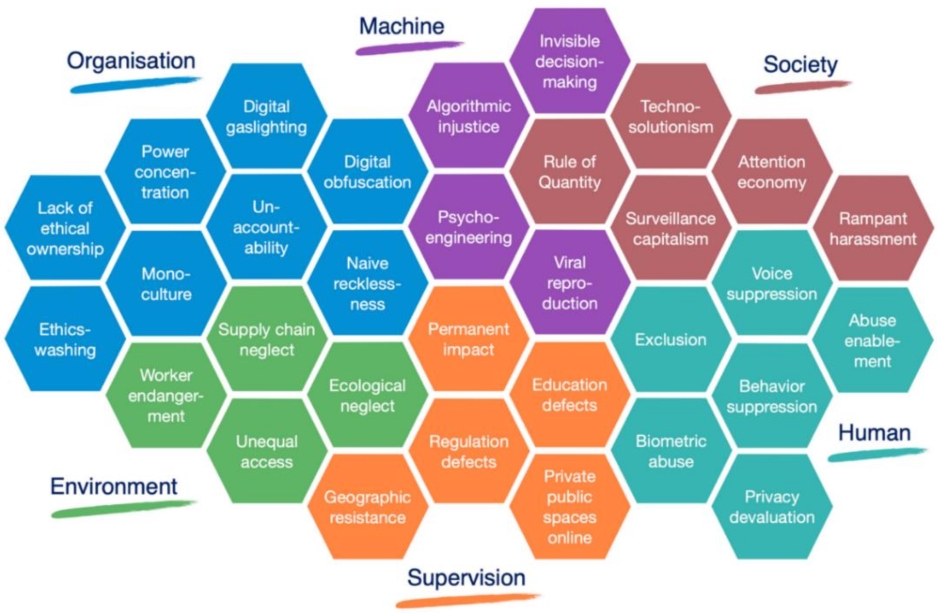

Image 11. The elements of digital ethics. Source.

The key to a successful digital ethics strategy in companies relies on three basic foundational elements : committed and value-conscious employees, an effective organization and responsible process design. The more systematically digital ethics are taken into account at these three levels of the company, the more credible the company will be to its customers, business partners and other stakeholders.

Digital ethics must run as an integral part of business operations, and to this end, companies should develop and apply ethical frameworks and impact assessment tools to evaluate the potential social implications of digital innovations, taking into account factors such as equity, diversity, inclusion, privacy and cultural sensitivity.

A robust ethical framework, established and communicated throughout the company's value chain, provides a clear statement of what an organization believes in and what standards it applies. It is a roadmap for making good decisions and, if lived throughout the organization, it is also a guide to making that organization the best version of itself.

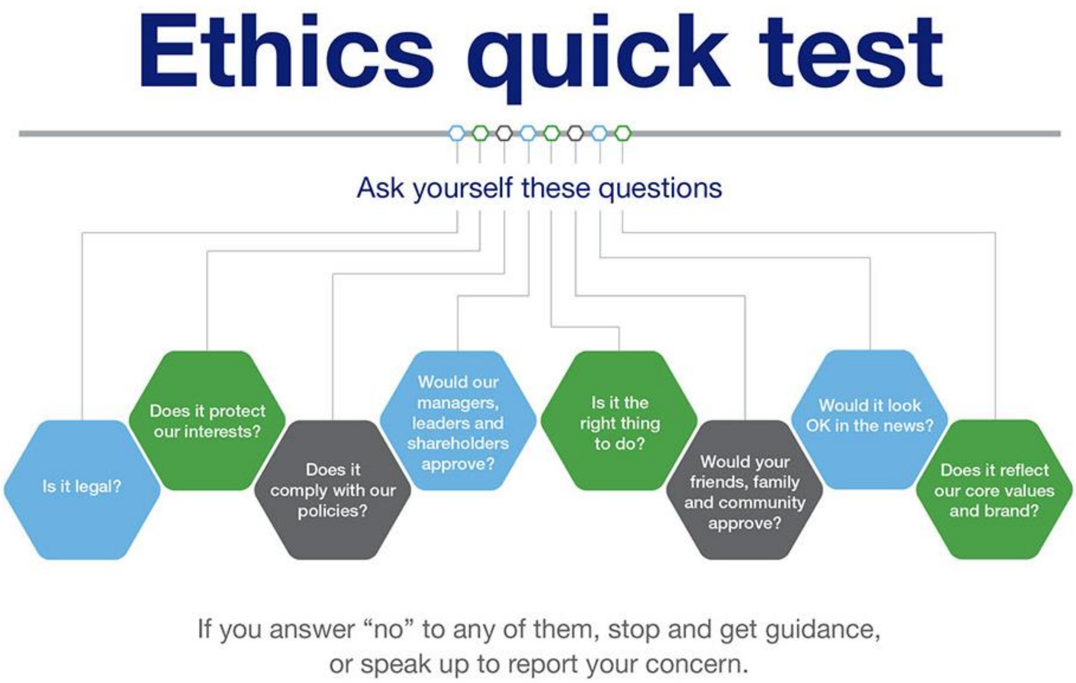

Image 12. Ethics quick test. Source.

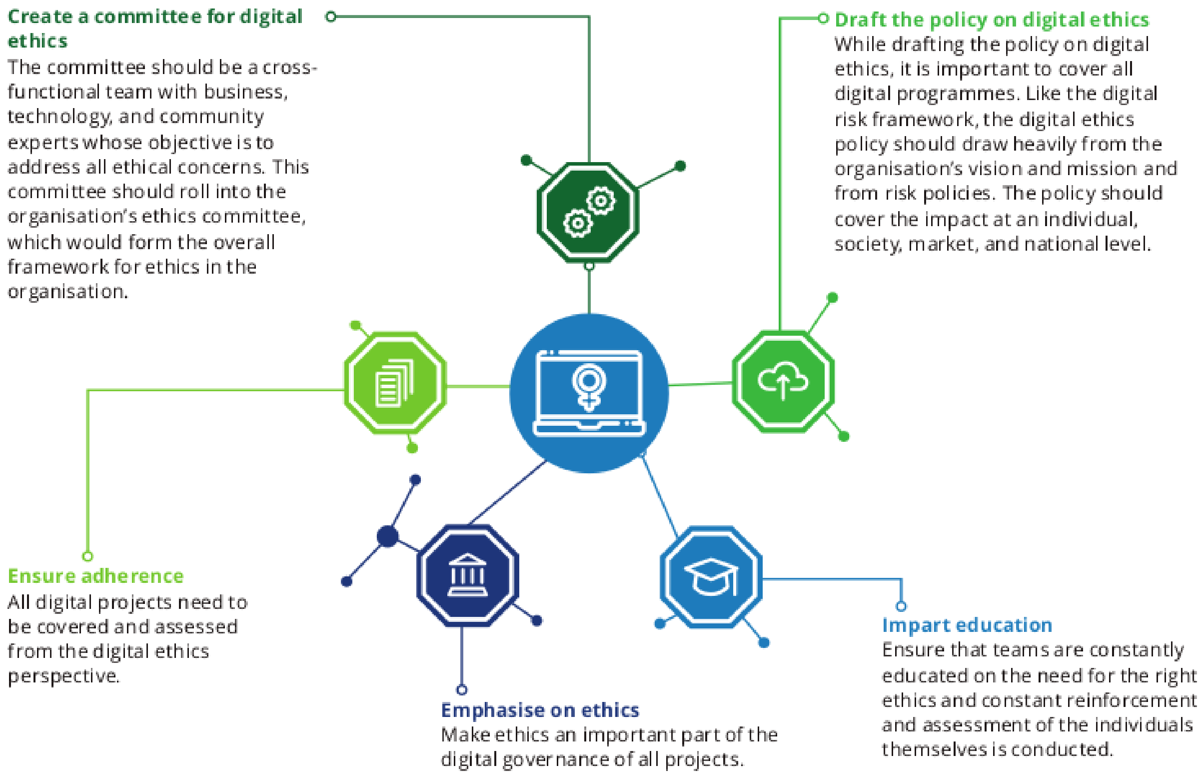

Image 13. Key recommendations for introducing digital ethics. Source: [Deloitte](#).

#2 Digital pollution and e-waste

Digital pollution is an umbrella term that encapsulates the environmental impact of the digital world. It manifests in various ways, such as electronic waste (e-waste), excess data storage, the energy consumption of digital platforms, and the carbon footprint of the entire digital industry.

Digital pollution is an all-encompassing term for the environmental impact of the digital world. It can take many forms, such as e-waste, excess data storage, energy consumption of digital platforms and the carbon footprint of the entire digital industry.

Digital pollution has staggering impacts. For example, it is estimated that 80% of digital pollution is related to the manufacturing of the equipment. For example, a 2 kg computer requires 22 kg of chemicals, 240 kg of fuel and 1.5 tons of clean water.

In addition, data centers alone consume an estimated 1,000 kWh per square meter, which is equivalent to almost ten times the electricity consumption of a typical European household. The production of digital technology also puts pressure on the environment, as it often involves the mining of rare metals, draining the Earth's limited resources.

New technologies consume about 10% of the world's electricity, making them the world's third largest consumer, behind China and the United States. The use of these new technologies contributes to CO2 emissions. Approximately 4% of greenhouse gas emissions are due to digital technology. That is 1.5 times more than air transport.

A persistent issue when analyzing the environmental footprint of digital devices is the pressing problem of e-waste. E-waste refers to electronic products that are unwanted, non-functional, and near or at the end of their useful life. E-waste is the fastest growing solid waste stream in the world.

Existing market patterns in the global digitization landscape are quickly fueling the generation of e-waste, due to an increase in production and consumption rates of digital devices, short life cycles due to product obsolescence (often programmed by the manufacturers themselves) and few repair options, even when customers don't want to buy a new device, but rather to be able to get it fixed.

In 2019, the world generated 53.6 million metric tons of e-waste, with only 17.4% of this amount officially documented as collected and properly recycled, and a record 62 million tons of e-waste were reported in 2022, 82% more than in 2010[19].

Also, e-waste contains precious materials and hazardous substances, so it can be toxic, as it is non-biodegradable and accumulates in the environment, soil, air, water and living things. For example, open burning and acid baths used to recover valuable materials from electronic components and release toxic materials that permeate into the environment.

Most of the discarded devices end up as waste, which is subsequently incinerated or illegally exported to countries in the global South, mainly Africa, and Asia. This has already led to serious contamination of water and air, soil and the health of workers and the local population.

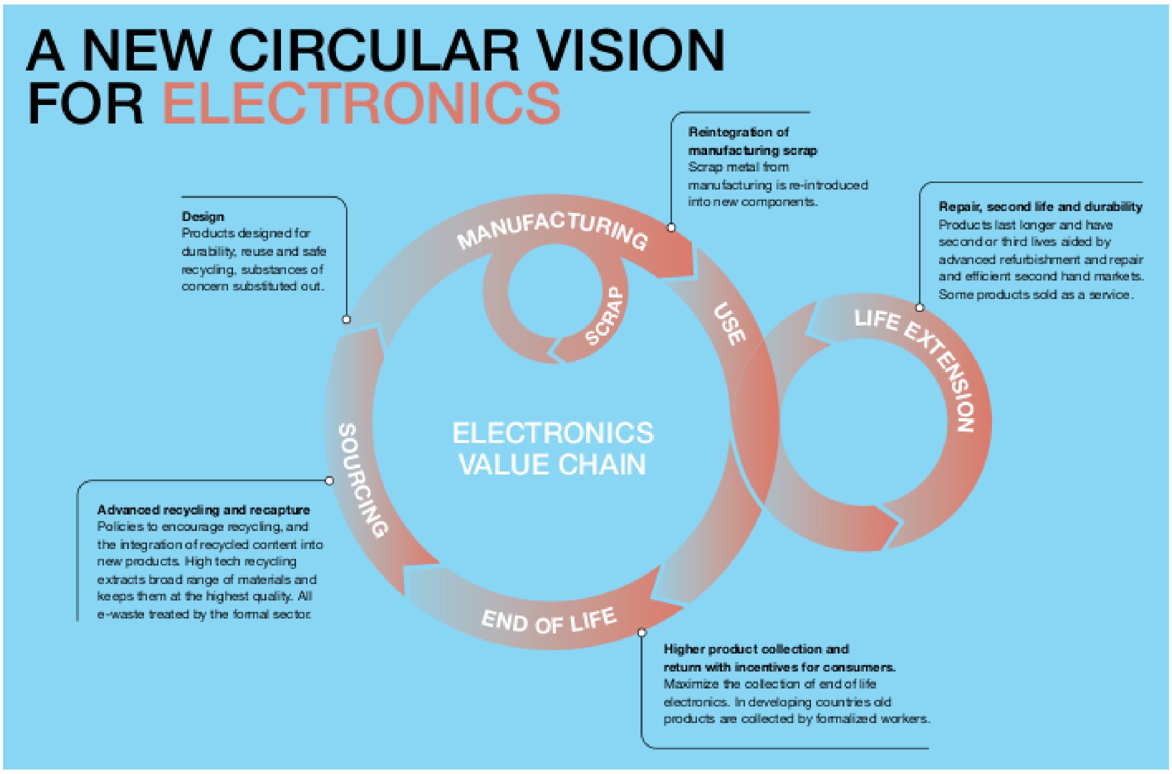

Image 14. A circular new vision for electronics. Source: PACE & WEF.

[19] United Nations Institute for Training and Research. *Global E-Waste Monitor 2024: Electronic Waste Rising Five Times Faster Than Documented E-Waste Recycling*.

#3 Cybersecurity and privacy

Digital transformation has triggered a dramatic shift in the way companies handle data. As companies digitize their operations, data becomes their lifeblood. Cloud computing, the internet of things, artificial intelligence and other digital technologies have enabled them to collect, store and analyze massive amounts of data from a wide range of sources, making it difficult to manage and safeguard. From sensitive customer information to proprietary business strategies, protecting data is imperative.

The protection of personal data, confidentiality and security are fundamental rights of individuals when it comes to the use of technology, so companies must guarantee that users' rights are respected, protecting their personal information from cybercrime or unauthorized use at all times. As a result, companies must ensure that their IT systems are equipped with the necessary safeguards to protect the integrity and security of data, as well as to prevent unwanted access or potential data breaches.

This protection has evolved as new technologies have entered the realm of the so-called information society. Compliance with data protection regulations such as GDPR has become a challenge as data flows across diverse systems and geographic boundaries.

Image 15. Critical issues in cybersecurity and privacy. Source: PwC.

The adoption of digital technologies and the rise of global data flows has exponentially increased the potential areas of attack, making organizations more vulnerable to cyberthreats. As more devices, systems and networks become interconnected, the risk of successful cyberattacks grows.

Cybercriminals are constantly looking for vulnerabilities to exploit, and digital transformation provides them with new openings. Data breaches, intellectual property theft, ransomware attacks and insider threats are some of the top cybersecurity risks organizations face during digital transformation.

A 2021 report[20] showed that The majority of SMEs use some basic security controls such as endpoint antivirus protection, backups, firewalls and perform systematic software updates. At the same time fewer SMEs perform security awareness trainings of staff and utilize logging and alerting systems.

SMEs appear to implement some of the basic cybersecurity measures only as part of their overall IT implementation. However, it appears that unless cybersecurity controls are included as part of an IT solution, many SMEs do not realize the potential resultant risks posed to their business.

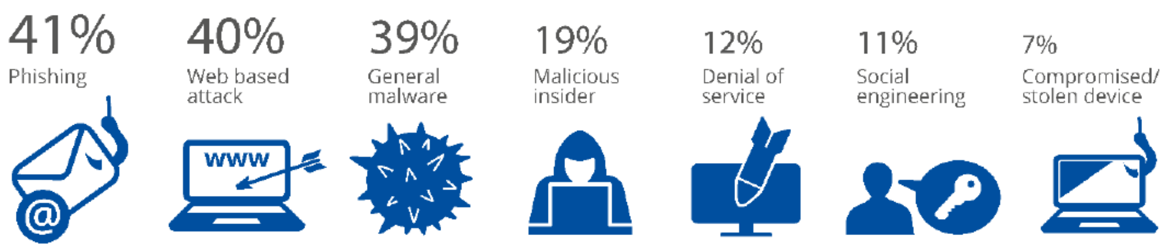

Image 16. Distribution of Cybersecurity Incidents based on their origin. Source: ENISA.

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To go further

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Part 2

In practice

Learn from others

How is digitalization for the green transition applied in practice? Have a look at the following stories compiled under the ENDURANCE project, which provide concrete examples of SMES and cluster practitioners who have already incorporated digitalization into their sustainability strategies.

endurance-accelerator.eu/video-toolkit

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Part 3

Get equipped

Get equipped

In this section, we introduce you to specific tools and frameworks that can support you in taking a strategic approach to digital transformation and sustainability.

These tools can be used individually or in combination to enhance your organization's capacity for innovation and sustainable growth.

They are categorized to identify three possible uses: specifically to promote the development of skills within the cluster, as a support resource aimed at the development of green innovation in SMEs and startups, or in both cases.

Tool 1: Digital Transformation Assessment

Tool 2: Twin Transition Roadmap Canvas

Tool 3: Net-Carbon Impact Assessment

Tool 4: Digital Ethics Compass

Tool 5: Digital Ethics Canvas

CLUSTERS

SMES & STARTUPS

BOTH

Take aways

There is no doubt that European clusters can play a key role in addressing the climate emergency, but to do so, they must be adequately equipped. As cooperation is crucial to the success of the green transition, it is critical that the business support programmes of clusters are designed to help SMEs and startups identify, develop and implement sustainable digital transition pathways.

By developing approaches that will empower them to support SMEs and startups to embrace the twin transition, clusters can unify the digital and sustainability agendas, improve the uptake of digital solutions, drive sustainability goals and prepare their members to be future proof.

As stakeholders become more demanding and regulations more stringent, clusters who excel in approaches to sustainability will set the standard. They will be leaders not only in environmental responsibility, but also in achieving operational success in a fast-changing global arena.

Thanks to their privileged position as building blocks of regional competitiveness, clusters must act as catalysts for the green and digital transition, contributing to environmental challenges by creating high quality shared value in the context of the progressive digitization of production ecosystems in Europe.

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