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UAM Testing Interview data analysis

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A. Executive summary

The User Acceptance Model (UAM) was put to the test to make sure it works, is accurate, and can be used to figure out how ready small manufacturing businesses are for the two big changes coming up: going digital and being more environmentally friendly. The testing/piloting aimed to reach a number of specific goals:

- To evaluate how businesses, namely manufacturing SMEs, are incorporating and reacting to digital and sustainable practices within their operational structures.
- Assess the present level of integration of digital and green initiatives inside various firms, evidencing the extent to which these technologies and practices are incorporated into their operations.
- Determine the primary obstacles and catalysts that impact the implementation of digital and green technology. This involves investigating obstacles inside the organization, technical challenges, cultural hurdles, and incentives that promote the adoption of such projects.
- Examine how the implementation of these measures impacts several aspects of the business, such as operational effectiveness, staff involvement, customer contentment, and overall business competitiveness.
- Offer practical insights and suggestions derived from survey results to aid firms in enhancing their adoption strategies, overcoming obstacles, and optimizing the advantages of digital and green efforts.
- Show off instances where adoption has been successful and identify efficient techniques that may be used as standards or recommendations for other organizations seeking to improve their digital and sustainability initiatives.

The User Acceptance Model (UAM) is a complete tool that can be used to figure out how ready and mature manufacturing SMEs are to make the switch to digitalization and sustainability. This model is important because it deepens the big problems and chances that manufacturing SMEs face when they try to use digital technologies and greener methods in their operations. The UAM is very important for helping these businesses change because it gives them an organized way to look at their current situation, find gaps, and come up with specific ways to improve their acceptance and twin transition process.

How to Understand the User Acceptance Model (UAM)

The UAM is made up of several main parts that work together to figure out how mature a SME is in the twin shift. Some of these parts are:

a. Adoption of Technology - checking how much manufacturing SMEs have used digital technologies like advanced industrial technologies, the Internet of Things (IoT), artificial intelligence (AI), and blockchain in their daily work.
b. Sustainability Practices - looking at how sustainable practices are being used, like using less energy and waste, following the rules of the circular economy, and managing a supply chain in a way that doesn't harm the environment.
c. Human Element - looking at how owners, managers, employees, and customers think about, feel about, and act with digital and green technologies. This includes looking at people's resistance to change, gaps in their knowledge, and the society as a whole when it comes to innovation and sustainability.
d. Impact on Operations - looking at how digitalization and sustainability change different parts of the manufacturing SMEs business's work, like how they make things, handle their supply chain, find ways to get their products to customers, and deal with complaints.

e. Market Trends and Regulatory Compliance - figuring out how outside factors, like market demands for sustainability and digitalization and regulatory requirements, affect the small business's efforts to make the switch.

There are several reasons why the UAM is important:

- It gives small businesses a structured way to figure out how ready they are for the twin transition, so they can see where they're doing well and where they could do better;
- The UAM helps create personalized support measures, such as training, financial advisory services, technical advisory services, matching and business support services and strategies for implementing technology, by figuring out unique needs, gaps, correlated with their level of understanding and acceptance.
- Focusing on the human element gets everyone involved and on board, improving user acceptance, which is very important for putting digital and sustainable practices into action successfully.
- The UAM helps manufacturing SMEs stay competitive in a market that is becoming more digital and concerned about the environment by leading them through the twin transition.
- Benchmarking - giving small businesses a way to compare their progress in going digital and being environmentally friendly to best practices and standards in the industry.
- Gap Analysis - this section gives a thorough look at the areas that need to be fixed in order for the twin transition to move forward. These areas include technology adoption, sustainability practices, and company culture.
- Giving manufacturing SMEs actionable insights and suggestions based on the test results so they can choose the projects that will have the biggest effect on their change journey.
- Enabling continuous improvement by letting manufacturing SMEs regularly check their level of maturity, make changes to their plans, and see how the changes they've made are working overtime.

The GREENE 4.0 project explored the interplay between digital and green transformations among SMEs across various manufacturing sectors, focusing on identifying the challenges and opportunities these businesses face. Through co-design workshops, co-creation camps, and peer review seminars, the project developed and refined the User Acceptance Model (UAM) to assess SME attitudes toward twin transitions. Four distinct typologies emerged: Digital Believers and Enthusiasts, Conservative Business Realists, Green Strategists, and Cosmopolitan Hi-Tech Transitioners, each representing different levels of digital fascination and ecological responsibility. According to the pilot testing dataset, Conservative Business Realists happened to be the most widespread typologies, with the Digital Believers and Enthusiasts types also being consistently present in the majority of relevant industry clusters.

Key themes identified during the project include "The Curse of Being Small," which highlights the struggles of smaller SMEs to scale digital and green initiatives due to limited resources and an aging workforce. The "Going Digital - Becoming Green?" theme questions the assumption that digitalization automatically leads to ecological benefits. The project found that while digital transformation can contribute to sustainability through efficiency gains and waste reduction, it also risks fostering greenwashing or leading companies to over-digitize marginal processes without achieving meaningful ecological impact.

The "Challenges of Digitization and Datafication" theme revealed that SMEs face significant difficulties in standardizing, integrating, and making systems interoperable. The utility of datafication and metadata, along with the feasibility of remote maintenance, presents further obstacles. These challenges were most prominently observed in the Machinery and Equipment, Building Materials and Furniture clusters, though they also appeared in Metal and Metal Products clusters.

Finally, the "Politicized Resources" theme reflects the challenges SMEs encounter in navigating regulations and resource allocation, often influenced by political agendas, which can further accelerate their efforts to embrace digital and green practices.

The findings emphasize the importance of customized support and strategic planning to help SMEs, particularly smaller ones, engage effectively in the twin transition without overextending their resources. The iterative methodology and feedback loop were essential in refining the UAM, ensuring it accurately represents the diverse realities faced by SMEs as they navigate digital and green transformations.

Overall, the project highlights the complexities of integrating digital and green initiatives, advocating for approaches that consider company size, industry, and market position, while challenging the simplistic notion that digitalization inherently leads to greener outcomes.

B. Introduction

Background

The User Acceptance Model (UAM) is a strategic tool specifically designed to assist manufacturing SMEs, in assessing their preparedness and ability to adopt digital and sustainable transitions, which are collectively known as the twin transition. These transformations entail the incorporation of digital technologies and the implementation of sustainable practices into company operations in order to improve efficiency, competitiveness, and sustainability. Even though its main goal has been to help SMEs, bigger companies can also use it and benefit from its structured system and thorough assessment criteria. Because the model is so flexible, it can be changed to fit the needs and possibilities of different fields, such as manufacturing, services, agriculture, and technology.
What does the UAM want to do?

The main goal of the UAM is to help businesses evaluate, plan, and make the transition to using digital technologies and environmentally friendly (green) methods:

1. Maturity and Readiness assessment - to figure out where a company stands right now in terms of adopting new technologies, being environmentally friendly, and having employees who are ready to make changes. To do this, a business needs to know how it stacks up against industry standards and figure out what it does well and what it could do better.
2. Support strategic planning - to help with strategic planning by showing what steps need to be taken for digital and green changes to go smoothly. The UAM helps make plans for tactics that can be put into action and are in line with business goals and market needs.
3. Enhancement of Stakeholder Engagement - to get all stakeholders—including workers, management, customers, and suppliers—more involved and on board with the changes by pointing out the benefits and addressing any possible resistance from them.
4. User adapted Support Measures - to help make sure that support measures like training programs, investments in technology, and sustainability projects are tailored to the needs that were found in the testing phase.
5. Monitoring and Continuous Improvement - to set up a way to keep an eye on progress and make improvements regularly, so that companies can keep adapting to new challenges and chances in digitalization and sustainability.

The UAM is especially helpful for SMEs because they often have trouble getting the tools, technology, and knowledge they need for the twin transition (digital and green transition). The UAM helps SMEs get past these problems by giving them a personalized evaluation and action plan. They then use digital and green/circular methods to improve their growth, competitiveness and profitability in a sustainable way.
Also, the UAM supports the innovation process and creation of new supply/value chains as it keeps track of critical business processes which are key drivers and need to be addressed through digital and green transition plan. This transition includes engaging in supply chain mapping, circular design and product lifecycle, therefore allowing real-time changes in the supply/value chain, adding new suppliers or new materials and joint participation in production lines design and integration.

The main goal of the UAM is to help companies deal with the challenges of digitalization and sustainability by giving them a comprehensive and usable framework. Companies of all kinds and in many different fields can use its insights to boost innovation, make their businesses more competitive, and help make the future more sustainable. The UAM can be changed to fit the needs and opportunities of each field,

whether it's lowering waste in manufacturing, helping with logistical issues, or encouraging sustainable farming.

Why the UAM?

The value of the UAM comes from the increasing necessity for businesses to adjust to the convergence of two trends:

1. Digitalization, which refers to the incorporation of advanced digital technologies such as artificial intelligence (AI), Internet of Things (IoT), big data, and automation into a company's business operations. Digitalization offers the potential for improved operational efficiency, deeper customer insights, enhanced decision-making capabilities, and the creation of novel business models.
2. Green transition. Businesses are progressively embracing sustainable methods due to environmental concerns, government regulations, and consumer demand. These practices prioritize reducing their impact on the environment, the use of renewable resources, and promoting social responsibility with the principles of equity.

The simultaneous shift presents distinct difficulties and possibilities, especially for SMEs, requiring a framework such as the UAM to evaluate, strategize, and execute essential modifications efficiently.
UAM utility

The UAM has multiple essential purposes: 1) Assessment tool to support SMEs in evaluating their present level of use of digital and green technology. The assessment identifies the strengths, flaws, and deficiencies in their processes and technologies; 2) Guidance tool for SMEs on how to enhance their technology integration and sustainability initiatives, based on the assessment. It provides customized and applicable measures based on their particular circumstances and requirements. (transition plan or customer journey); 3) Acts as a change facilitator for management, providing SMEs management with data and solutions for successful governance of organizational change that occurs when new technologies and processes are adopted. UAM considers the human factor by acknowledging concerns, identifying training requirements, and recognizing the cultural adaptations necessary for a successful implementation. 4) Provides data and steps to enhance SMEs strategic planning processes, guaranteeing seamless integration of digital and sustainability activities into their overall business plans; 5) Can act as a benchmarking tool for individual SMEs as it enables them to compare their activities with industry norms or competitors, offering a comparable assessment of their progress in the dual transition.
Testing aim and methodology

The testing phase of the User Acceptance Model (UAM) aimed to evaluate and refine the framework designed to enhance SMEs' adoption of green and digital technologies in Central Europe. The methodology employed a sequential mixed-method approach, beginning with a comprehensive survey of 422 SMEs across seven countries to assess their current practices and perceptions. This quantitative phase identified key trends and gaps, which informed the development of a detailed UAM questionnaire. In the subsequent qualitative phase, 68 in-depth interviews were conducted with selected SME representatives to gain nuanced insights into their attitudes and barriers toward the twin transition. The interview progress was integrated in a broader co-design and co-creation process, involving workshops and peer review seminars, where SMEs actively participated in testing and providing feedback on the UAM.

The qualitative phase of the User Acceptance Model (UAM) framework research targeted small and medium-sized enterprises (SMEs) in seven Central European countries, adhering to criteria of fewer than 250 employees, annual turnover below EUR 50 million, and a balance sheet total not exceeding EUR 43 million. Industry clusters were defined based on the most common sectors identified in a previous survey,

including Food and Beverages, Rubber and Plastics, Metal and Metal Products, Machinery and Equipment, Building Materials and Furniture, and Electronics and Software. The sampling approach was flexible to address anticipated low response rates, initially focusing on SMEs with established relationships and gradually expanding to include diverse industry types. Targeted business profiles ranged from CEOs to technical and production managers, ensuring comprehensive coverage of digital and green transition practices within SMEs.

The methodology also included thematic analysis of interview data, enabling the identification of contextual factors influencing technology adoption. The iterative testing process ensured the UAM's flexibility and relevance across different industry clusters and SME sizes, ultimately aiming to create a demand-driven, evidence-based framework to support SMEs in their digital and green transitions.
UAM checks how ready manufacturing SMEs are for the two-step process of going digital and becoming more environmentally friendly. It gives a complete picture of their strengths, weaknesses, and chances for growth in this process. It can be used to plan, select, and tailor support measures that will help SMEs accept change more quickly and easily:

1. Analysis and evaluation in great detail
- Evaluating current maturity levels. UAM can find out exactly where a company stands and what areas need help or growth by evaluating the current maturity level of SMEs in adopting green and digital technologies.
- Understanding the human element. UAM stresses how important the human element is, which includes how managers, staff, and customers think and feel. It is important to understand these factors in order to create support measures that are not only technically sound but also widely accepted within the company.

2. Making Support Measures and tools (including GREENE 4.0 innovation platform and WP2 toolkit) fit manufacturing SMEs needs
- With information from the UAM, support services and tools can be tailored to fit the specific needs of each SME. This could include everything from new technologies to better processes, technical advisory, innovation vouchers and staff training.
- The UAM helps SMEs decide which actions to take first based on how they might affect the twin transition. High-impact areas found during the assessment can get instant attention, making sure that resources are used effectively.
- Facilitating Stakeholder Engagement
- Information about how stakeholders feel can help suppliers, customers, and industry partners work together to support the change process by building collaborative networks.

4. Growth and training programs
- The test can show which skills or knowledge employees lack with regard to digitalization and green transition. Then, customized training programs can be made to help workers learn new skills and make sure they are ready to use new technologies and methods.
- Supportive actions can include programs that help leaders learn new skills and change the way an organization works so that it encourages new ideas and environmentally friendly methods.

5. Choice of Technology and Implementation
- The UAM figures out which digital and green technologies an SME is ready to use and where it needs more time before it can do so. Then, support measures like financial assistance, technical training, and pilot projects can be used to facilitate the use of these technologies.

- Knowing more about how customers interact with brands and how the supply chain works can lead to new ideas in product development and operational processes, making them more in line with digital skills and sustainability goals.

6. Benchmarking and Continuous Assessment
- The UAM lets SMEs compare their operations to the standards in their field and keep an eye on their progress over time. This ongoing evaluation is meant to check if the support measures are working properly and change them if needed.
- Using the UAM regularly sets up a feedback loop where the results of the support measures are used to guide future actions. This creates a cycle of constant growth and adaptation.

7. Planning for Regulatory Compliance and market dynamics
- The UAM can help manufacturing SMEs plan for and predict future changes to regulations that will affect digitalization and sustainability. This will help them stay compliant and competitive.
- The UAM can help SMEs make sure that their goods and services are in line with what customers want, giving them a competitive edge. Focusing on the specific needs, barriers, and opportunities found during the exam will help support measures work better, leading to a smoother and more successful twin transition.

The UAM is made up of several important parts that show how complicated the two-way shift to digitalization and sustainability is. These major variables, or components, give us a complete way to analyse a company's readiness and find places where it can improve:

1. Digital and green technology
This test checks the extent to which a business has adopted digital solutions (like AI, IoT, and cloud computing) and green technologies (like waste management systems and renewable energy sources), as well as the barriers to adopting them by listing the things that make it hard for people to use new technologies, such as the cost, a lack of knowledge, or cultural pushback within the company.

2. Supply Chains
Sustainability in the supply chain looks at how sustainability principles are built into the supply chain. These include ethical sources, lowering carbon emissions, and using circular economy methods. UAM testing explores also how digital tools, such as bar- or QR- codes for tracking, digital platforms for working together with suppliers, and analytics for predicting demand, can be used to improve the supply chain.

3. Business models
Innovation in Business Models - checks how much companies have looked into new models such as the Product as a Service (PaaS), circular business models, or services that are made possible by technology. Also, the UAM whether or not business models are in accordance with sustainability goals like saving resources, making products last longer, and having less of an effect on the environment.

4. Methods of production
The UAM analyses how digital technologies are being used in production, like digital twins, additive manufacturing, and other smart factory solutions. In addition, the UAM looks for ways in which the production methods could be altered so as to use less energy, produce less waste, use materials in a way that doesn't harm the environment, and reduce pollution.

5. Distribution channels
Analyses how e-commerce platforms, digital markets, and digital logistics solutions are being used to spread goods through digital channels. Assesses ways in which distribution can be less harmful to the

environment, such as using eco-friendly packaging, reducing emissions through more efficient modes of transportation, and setting up take-back programs.

6. Consumer Relations Engagement on Sustainability
This UAM driver measures how well a business communicates its efforts to be more environmentally friendly to its customers, gets customers to follow sustainable practices, and meets customer requests for eco-friendly products. The digital customer experience checks how digital tools, like personalized services, digital customer support, and data analytics, are used to improve the customer experience.

7. Regulatory Compliance and Market Trends Adaptation to Regulatory Changes:
This driver measures how well a business can adapt to changes in regulations that affect digitalization and sustainability, such as following data protection and environmental laws.

It also measures how well a business adapts to changes in the market, like rising demand for eco-friendly goods, higher standards for digital services, and shifts toward a circular economy.

Adopting new technologies and making the switch to more sustainable practices are not just technical problems; they are strongly connected to how people behave and how organizations work:

1. Thoughts and feelings
- Perceptions - how people think about new tools and efforts to be more environmentally friendly can have a big effect on how well they are accepted. People's views may be affected by what they think about how well these things work, how easy they are to use, and the possible benefits or risks that come with them.
- Emotional reactions are very important. Examples include the fear of losing one’s job, anxiety about learning new skills, or excitement about new ideas that will help the environment. Positive emotions can make people excited about and open to change, while negative emotions can make people unwilling to accept it.

2. How Owners and Management Feel
- How owners and management feel about going digital and green is very important. A company culture that welcomes change, new ideas, and sustainability can grow with supportive leadership. On the other hand, doubt or uncertainty from the top can make it harder to accept.
- How employees feel about new tools and ways of doing things depends on how they think these changes will affect their chances to learn and grow at work and in their personal lives. Attitudes can range from reservations about doing something because they are afraid of the unknown to being eager to start using the new methods.
- How people feel about goods and services can be affected by digitalization and sustainability, which can affect demand and market acceptance. When people feel good about sustainable methods, it can help boost brand loyalty and market share.

3. Why some people aren’t receptive to these changes
- New technologies and sustainability efforts may not be adopted if the culture doesn't want to change or if there isn't a shared goal towards innovation.
- One big problem is that people don't always know how to use new tools and environmentally friendly methods. In the same way, unskilled staff members may not want to use new methods.
- To deal with people effectively, you need to be able to handle change well. If we don't, people's unwillingness to change can be very strong, even if the technological answers and strategies for sustainability are good.

- Giving people the chance to keep learning and receive training can fill in skill gaps and ease worries about new technologies. Bringing up opportunities for job growth and personal benefits can help change people's minds.
- Recognizing and praising people who support new technologies and work to make the world a better place can help spread a positive attitude and reduce resistance even more.

C. Methods

Research design

The basic methodology for the User Acceptance Model (UAM) consisted of a sequential mixed-method research design. The first step involved a quantitative and qualitative survey, completed in November 2023. A total of 422 valid surveys were collected. The highest percentage of responses came from Austria (43.8%, N=185), with other countries more evenly distributed: the Czech Republic at 11.6% (N=49), Germany and Hungary each at 10.2% (N=43), Italy at 9.5% (N=40), Slovenia at 7.8% (N=33), and Poland at 6.9% (N=29). In this analytical phase, we employed frequencies and descriptive statistics, including means, minimum and maximum values, and standard deviations.

This survey was central to the regional mapping analysis, with the primary aim of assessing the current adoption levels of green manufacturing practices and digital technologies among SMEs, and understanding the perceptions, attitudes, and barriers these companies face in transitioning to greener and more digitally integrated business models. All seven GREENE 4.0 countries were included in the study.

For this report and further research exploration, we can summarize the relevant findings as follows: the quantitative data indicates that acceptance of green practices among companies was moderate. On a scale of 1 to 7, the average use of green practices was 3.7, with Slovenia scoring the lowest at 3.2 and Italy the highest at 4.4. However, the perceived benefits of these practices were quite high. Companies agreed that adopting green practices would improve their sustainability (average score of 4.6), reduce waste and improve environmentally friendly processes (4.3), and increase their capacity to green the supply chain (4.3). Fewer companies believed these practices would improve product quality (3.9). Perceived benefits were highest in Slovenia (5.2) and Italy (5.1), but lower in Austria (3.8) and the Czech Republic (4.1). Despite these benefits, regional SMEs struggle on both digital and green fronts. Surveys conducted by GREENE 4.0 project partners in seven Central European countries highlight prevalent gaps. Only 60% of SMEs use basic cloud computing tools, while advanced technologies like sensors and blockchain remain underutilized. Uneven green practices and risk perceptions further hamper the transformation.

This gap between the perceived benefits and actual business practices can be interpreted as another variation of the ‘value-action’ or ‘belief-action’ gap (see, for example, Grandin, Boon-Falleur, and Chevallier, 2021; Blake, 2007). The gap refers to the disconnect that often exists between what individuals or organizations say they believe or value and how they actually behave. The phenomenon is particularly evident in the context of environmental issues and sustainable actions, where people or companies might express strong support for sustainability and green practices, yet their actions do not always align with these beliefs. However, this gap can be more thoroughly studied through face-to-face conversations, where the interviewer can pose additional sub-questions and handle sensitive situations by establishing trust or showing genuine interest in the interviewee's specific circumstances and concerns.

Another element requiring further exploration is the treatment of SME representatives as actors of the general public. Social science research consistently points to other important reasons for public technology resistance, such as basic value conflicts, distributive concerns, and a lack of trust in governing institutions like regulatory authorities and technical advisory bodies (see, for example, Winickoff in OECD, 2017, pp. 277; Vorm and Combs, 2022). When a government endorses a particular technology, whether through subsidies, tax incentives, or public procurement policies, it signals to businesses that the technology is viable and valuable. However, if businesses perceive the government or any supra-national body (like the European Union) as corrupt or inefficient, they may view such endorsements with scepticism, leading to reluctance in adopting the technology. Additionally, in the context of the twin transition, the relationship between authorities and technology adoption is influenced by the consistency

and integrity of the imposed policies. Frequent regulatory changes or a lack of clear direction can erode trust and lead to uncertainty, making businesses hesitant to adopt new technologies that require significant investment and long-term commitment.

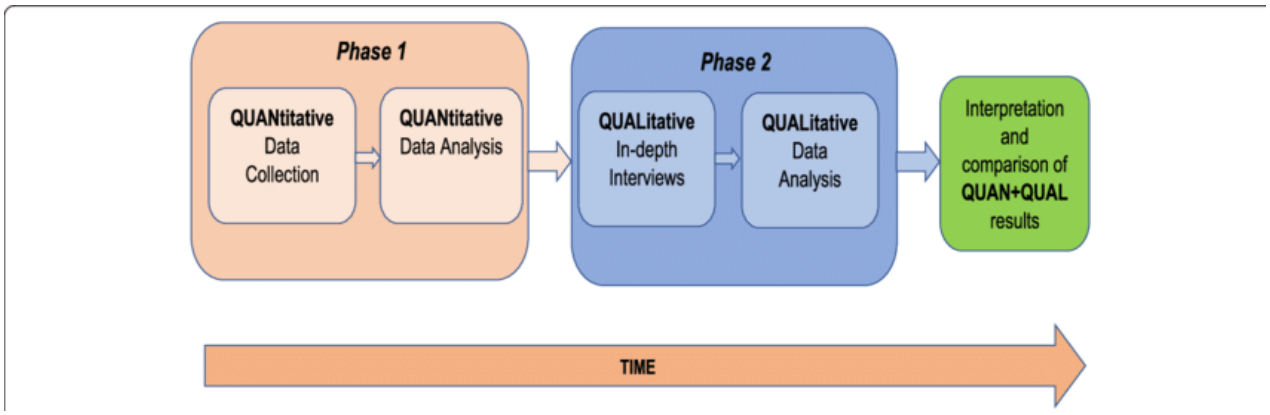
Trust in national or supra-national authorities and their measures is a complex phenomenon, with an additional dimension in the context of SMEs and their technology acceptance: trust in state authorities also involves the belief that the benefits and burdens of new technologies will be distributed fairly. The November 2023 survey already indicated this, revealing a lack of sufficient government support and subsidies in Austria, the Czech Republic, Hungary, Poland, and Slovenia. If businesses or the public believe that the government will ensure a fair distribution of costs and benefits – such as through financing grants or other forms of targeted support for affected industries – they are more likely to support and adopt these technologies. This naturally puts greater pressure on the GREENE 4.0 consortium partners and their interview recruitment activities since potential interviewees might view them as extensions of national or supra-national entities or even as representatives of their policies.

Therefore, a second step in research was needed in the form of in-depth qualitative interviews to obtain richer and more fine-grained data on how regional SMEs rationalize the twin transition, whether the acceptance of green or digital practices is jeopardized by failures of trust in state institutions (or European policies), and to construct a model of prevalent attitudes capable of explaining the quantitative findings and preferably going beyond them. For this second step, **thematic analysis** was chosen for its flexibility and overall usefulness, as it can potentially provide a rich, detailed, but somehow complex account of data (Braun and Clarke, 2006, p. 78). Moreover, it is often used when working with participants whose views on the topic are not known and when the topic is not yet well researched.

This second step in the sequential mixed-methods research design serves a variety of practical functions and tasks for the GREENE 4.0 project, as it is intended as a feedback loop by testing the pilot version of the acceptance model with targeted groups, which will be further explained in the upcoming sections. **The User Acceptance Model (UAM) is the outcome and an innovative method that provides a body of knowledge or a comprehensive framework that combines evidence-based strategies with practical tools to increase SMEs' acceptance and adoption of green and digital technologies.** The November 2023 quantitative and qualitative survey was aimed at gathering broad, generalizable data from a larger sample, which helped identify key trends, patterns, and variables of interest. The findings from the first phase informed the development of an in-depth qualitative instrument, namely the UAM questionnaire. Additionally, the UAM pilot phase seeks to incorporate user validation to ensure that the methods and measures developed by the GREENE 4.0 consortium are effective, relevant, and user-centric. The insights and feedback from the pilot testing phase are intended to be used for further refinement and improvement of the UAM. This key step in the process involves actively engaging SMEs in testing, providing feedback, and co-creating solutions that aim to improve their acceptance and adoption of twin transition technologies. The methodological approach underpinning this process – combining UAM testing, user validation, and co-creation – will be further explained as a form of action research. This approach, common in the social sciences, seeks transformative change through active research engagement. When company representatives engaged with the UAM questionnaire and explored the possibilities of becoming more digitized and environmentally sustainable, their participation went beyond mere research interests. The respondents were given the opportunity to learn new concepts and technological utilities, articulate their everyday challenges, and connect these issues to the broader context of twin transitioning. Needless to say, this was not a one-way transformative process. The GREENE 4.0 partners also had the opportunity to learn from the respondents. This exchange allowed them not only to adjust and refine the UAM instruments but also to gain insights into the shortcomings of digital and green policies. Alas, the UAM pilot phase testing enabled the partners to analyse which aspects

of Industry 4.0 are overhyped and why they may not be practical or relevant for SMEs across the seven different countries and regions involved.

Ultimately, the incorporation of user validation helps create a more demand-driven and evidence-based approach to improving SMEs' acceptance and adoption of green and digital technologies. It ensures that the solutions are not imposed from the top-down (and can therefore at least partially address the problem of official political authorities and trust) but are rather co-created and validated from the bottom-up, leading to more impactful outcomes.



The User Acceptance Model Test Setting

The GREENE 4.0 consortium conducted a series of co-design workshops, co-creation camps, and interregional and transnational peer review seminars to develop, test, and refine the User Acceptance Model (UAM). These events took place during the second half of 2023 and the first half of 2024. The organization of the co-design workshops and co-creation camps involved companies from various manufacturing sectors, yielding valuable insights into the current state, challenges, and opportunities for digital and green transformation. Several co-creation camps, each lasting two days, were planned and organized by three partners to design the user acceptance model.

The online interregional peer review seminars held in the first half of 2024 served as methodology training for interviewers from partner institutions. Discussing common challenges and issues related to interviewee recruitment was crucial to avoid interview fatigue among the invited company representatives. More importantly, it provided interviewers with specific tips for handling sensitive questions and topics, such as regulatory compliance failures, EU skepticism, cyber-attacks, and potential signs of global warming denialism. Additionally, interviewers were instructed on how to prepare for interviews by completing administrative data in advance and adopting a strategic approach to anticipate which business processes or sub-questions the company representatives might find important or irrelevant.

Interviewers were frequently reminded to approach the representatives with honesty, show genuine interest in their business practices, and avoid making promises that the UAM could not fulfill. They were also instructed to emphasize the anonymity of respondents and refrain from sending the entire UAM questionnaire in advance without prior discussion. However, interviewers were encouraged to send a brief list of general questions and discussion points beforehand.

Another aim of the interregional peer review seminars was to discuss proposed changes and suggestions made by the already-interviewed company representatives. Following these discussions, the accepted changes were implemented, and the UAM questionnaire was updated.

However, a problem arose when the majority of partners began uploading only Feedback Templates and not the completed UAM Excel questionnaires with actual notes. In April and May 2024, during a comprehensive review of data quality, it became evident that some partners had taken a different approach, interviewing respondents about their existing digital and green business practices regardless of whether the discussed business processes were identified as value drivers for the company. As a result, the GREENE 4.0 consortium requested a delay in the due date for the Testing Reports Deliverable (D1.4.1) and User Acceptance Model Deliverable (D1.3.1) to standardize the UAM testing phase. Additional (and initially unplanned) one-on-one meetings with several partners were held to ensure better data quality, provide more detailed and individualized methodology training, and clarify testing report instructions.

The transnational peer review online seminars and workshops (May 2024) were used to validate the provisional findings with the help of suitable companies, relevant stakeholders, and feedback from the external advisory board.

Sampling criteria

Company size

The sampling criteria for the second qualitative phase of the User Acceptance Model (UAM) framework closely mirrored those used in the initial quantitative survey during the regional mapping analysis. The target group for the in-depth interviews was small and medium-sized enterprises (SMEs) across seven Central European countries. Consistent with the SME definition used in the survey, the criteria ensured that the majority of interviewed companies had:

- Fewer than 250 employees
- Annual turnover not exceeding EUR 50 million
- Annual balance sheet total not exceeding EUR 43 million

This approach followed a country-specific methodology, allowing each country to define its own sampling procedures. The primary aim of the initial survey was to include as many SMEs as possible, with limited involvement of larger companies, considered crucial for the project when relevant for future collaboration. These sampling criteria were repeated in the second phase of the research.

The pragmatic decision to maintain a flexible sampling approach was driven by the anticipated low response rate, as SME representatives often face significant time constraints. To address this challenge, methodology trainings held in March, during the partner meetings in the form of interregional seminars, recommended a strategic approach for initiating the interviewing pilot phase. It was advised that partners begin the pilot phase by selecting a handful of suitable companies with which they already had a good relationship or where a certain level of trust had already been established. This approach was intended to ease the process of engagement, ensuring that initial interviews would be conducted with participants more likely to provide meaningful insights and feedback. By starting with these trusted partners, the consortium aimed to refine the UAM framework more effectively and build momentum for broader engagement in the subsequent stages of the research. Furthermore, several partners took a proactive approach by reaching out to companies that had already participated in the November 2023 survey. Many of these companies responded positively, which helped ensure that the GREENE 4.0 project maintained regular feedback loops with SMEs throughout its development. However, these feedback loops also presented a potential downside. Many of the participating SMEs were likely involved in other similar activities, leading to a risk of oversaturation due to the extensive research demands from various partners.

Additionally, testing the UAM questionnaire's flexibility and relevance for SMEs of different sizes and stages of progression was a critical component of the pilot phase. This process revealed some limitations. For instance, a failed interview attempt in the Czech Republic indicated that the UAM questionnaire was not suitable for smaller start-ups in their early years of existence, particularly those in the initial stages of product development. The approach also aimed to include larger companies, which tend to be more advanced in terms of twin transitioning and have greater resources for innovation, technology implementation, and research and development. However, it's important to note that sustainability management tools and frameworks are generally underdeveloped in SMEs, as these tools were primarily designed with larger organizations in mind.

Industry type

Industry clusters for the targeted representatives were based on the most commonly reported sectors from the November 2023 survey. Respondents primarily belonged to the following industries:

- Agriculture, forestry, and fishing
- Manufacture of food products
- Manufacture of beverages
- Manufacture of textiles
- Manufacture of chemicals and chemical products
- Manufacture of rubber and plastics products
- Manufacture of basic metals
- Manufacture of fabricated metal products, except machinery and equipment
- Manufacture of computers, electronic and optical products
- Manufacture of electrical equipment
- Manufacture of machinery and equipment
- Manufacture of furniture
- Other

After some discussions, the GREENE 4.0 partners merged these sectors into the following industry clusters for simpler and more transparent results:

- Food and beverages industry cluster
- Rubber and plastics products industry cluster
- Metal and metal products industry cluster
- Machinery and equipment industry cluster
- Building materials and furniture industry cluster
- Other

As the pilot phase progressed, the consortium decided to add another industry cluster:

- Electronics and software industry cluster

This additional cluster was created to recognize the unique position of companies involved in computer products, electronics, or software development. Unlike the companies from more traditional manufacturing sectors (like food and beverages cluster or building materials and furniture production), the sector of electronics products and software services is a continuously changing sector in need of constant innovations due to market competition and customer demands. These companies naturally tend to be more digitized, potentially biasing results if grouped with other manufacturing sectors. Moreover, the environmental impact of the electronics and software industry is complex and insufficiently researched. While digitization can drive energy efficiency and optimization, the production of digital and ICT devices increases electricity consumption and may contribute to higher greenhouse gas emissions (see, for example, Belkhur and Emeligi, 2018; Wang, Yang, and Yue, 2023; Istrate et al., 2024). This distinctive

character of electronic devices was acknowledged by recent EU legislative developments, leading to the introduction of the Digital Product Passport (DPP)[1] in 2023, reflecting the need for greater transparency and traceability in the lifecycle of these products. The initial implementation efforts have particularly targeted electronic devices and batteries, among others (Rizos and Urban, 2024).

Even in cases when digitization supports renewable energy transitions, concerns about the finite availability of rare minerals and metal resources remain. The production of electronic devices and integrated circuits demands the extraction and processing of raw materials, which cannot be fully mitigated by renewable energy technologies or carbon dioxide removal. Therefore, the electronics and software industry cluster is in need of caution against mindless digitization, where companies might digitize extensively without considering sustainability. Instead, the transition towards the circular economy approach could play a more definite role in reducing the environmental impact of electronic devices and systems. Two of the means to achieve this lie in (1) extending producer responsibility, which may in turn extended the durability of electronic devices and in (2) possible reutilization of electronic devices with second hand markets. However, if reutilization can ever be a viable option is ultimately dependent of consumer preferences and price attractiveness in comparison with a new device (Istrate et al., 2024).

In the light of these uncertainties and in order to avoid any additional erosion of trust in those institutions trying to accelerate the twin transition, electronics and software manufacturing SMEs as well as SMEs from other industry clusters should advance in their digitization roadmaps by applying advanced digital technologies selectively, focusing on business processes that drive value for each individual company or within their specific industry cluster.

Targeted positions and suitable business profiles

The User Acceptance Model (UAM) aims to provide a comprehensive framework or body of knowledge that supports evidence-based strategies for advancing the twin transition (digital and green) of SMEs in the seven countries of the GREENE 4.0 consortium. To achieve this, the initial questionnaire was developed to be extensive, covering a variety of business categories and their subtypes, along with the corresponding business processes. This approach, while thorough, could pose challenges for larger companies with segregated departments. In such cases, a single company representative may not have the holistic and in-depth knowledge required to answer questions about the company's various business processes.

However, in smaller SMEs, this risk is mitigated as business owners or CEOs typically have a comprehensive understanding of the company's past and current business practices, investments in new technologies, and the practical issues of day-to-day operations. Reflecting on the regional mapping survey conducted in November 2023, it was observed that the majority of respondents were CEOs (53%), followed by CTOs (8.6%) and quality managers (7.9%). Approximately one-third (35.9%) of all survey respondents occupied other positions within the company. This suggests that in the targeted SMEs, various other roles or job profiles may also possess the necessary knowledge to describe the value-driving business processes, understand regulation implementation, and, most importantly, provide

[1] The digital product passport (DPP) is a specific digital tool and policy program designed to ‘electronically register, process and share product-related information amongst supply chain businesses’ with the means of ‘easily accessible information by scanning a data carrier, such as watermark or QR code’ (European Commission, 2022, p. 9). In essence, this tool aims to ensure that product-related information aligns with the principles of the circular economy, encompassing details about a product’s composition, origin, and environmental impact, among other key factors.

insights into the state of their manufacturing operations. This is particularly relevant in cases where supply chain management is not as differentiated or segmented.

At the outset of the UAM pilot testing phase, alternative targeted positions ranged from technical experts to production managers. Consequently, the partners conducting the UAM pilot phase did not impose strict limitations on which positions or job profiles were suitable for interview recruitment, provided the interviewee had a good overview of the implemented (or missing) digital technologies and sustainable practices. Ultimately, CEOs were the most commonly invited participants for in-depth qualitative interviews. However, this did not always guarantee a competent or engaged discussion partner. Some CEOs were reluctant to share meaningful insights, while others felt overwhelmed by the new concepts and terminology introduced in the discussions. The November 2023 survey indicated that the majority (almost 60%) of SME respondents were between 45 and 64 years old. In a few cases during the pilot phase, older CEOs of more traditional micro-enterprises (employing just two or three people) struggled to relate to the structured business processes and categories, which did not align with their business practices. They also found it challenging to engage in lengthy discussions about digital optimization systems, IoT sensors, or waste production measurement.

Throughout the pilot testing process, other suitable positions emerged, such as innovation managers, as suggested by the Intellimech partners. A few German interviews were conducted with quality managers and a head of PR, though the latter was less successful. On the other hand, the Krakow Technology Park team successfully tested the UAM pilot questionnaire on an even more diverse sample of company representatives, ranging from senior management staff to sales managers and various production personnel. This diversity in interviewee roles provided valuable insights and highlighted the flexibility of the UAM framework in accommodating different perspectives within SMEs.

Sampling process in GREENE 4.0 partner countries

Slovenia

In the initial phase of the UAM piloting activity (spring 2024), Pomurje Technology Park issued a “call for interest” and utilized online tools that attracted significant number of companies. However, as the project progressed, the search criteria were refined, introducing new limitations and preconditions to better target the intended audience. By late spring 2024, the criteria had been finalized, focusing on attracting companies from the following industry clusters: Building and Furniture, Food and Beverages, Machinery and Equipment, Metal and Metal Products, Plastics and Rubber. The rest of the business activities were categorized as ‘Other’ and the Technology Park did not contribute an example of a company operating in the Electronics and Software industry cluster in its sample. As instructed, the Pomurje Technology Park has first reached out to companies already familiar with its projects and those that had previously expressed at least some interest in digitization or sustainability.
During this period, Pomurje Technology Park organized a workshop where multiple companies participated simultaneously. However, this method proved ineffective for several reasons. Primarily, it was challenging to gather companies in one place at the same time, and the discussions often remained superficial. Many SMEs felt uncomfortable sharing their challenges and particular situations in front of others, which hindered meaningful dialogue. Consequently, Pomurje Technology Park shifted to an online campaign, inviting SMEs to participate through an online application that required the companies to provide crucial information. Assistance was offered in completing the application form, to ensure higher participation. Despite these efforts, the response to direct mailing for project events was even less successful than anticipated. One possible misstep was sending out the questionnaire in advance, which may have discouraged 3-5 SMEs from participating, as its intention to prepare the respondents for the actual in-depth interviews was misinterpreted.

Pomurje Technology Park continued to expand its database of manufacturing companies to ensure the sustainability of the platform beyond this report. Despite the challenges in recruiting respondents, one general observation was clear: companies in the regions of Eastern Slovenia (particularly the Pomurje region) perceive greater benefits from digital solutions and technologies than from green and sustainable business practices. For many SMEs, digital solutions are already contributing to more sustainable practices, such as optimized raw material usage, reduced energy consumption, and shorter production time due to automation.

Germany

Based on various GREENE 4.0 seminars and workshops, the Bautzen Innovation Centre initially decided to contact the companies individually. When targeting the companies involved in relevant manufacturing production (e.g., the respective industry clusters), an additional selection was made based on the level of pre-established trust with specific companies and an informal assessment of their willingness and interest in participating in the pilot phase.

The first stage (March 2024) resulted in the successful completion of 4 interviews. However, after April 2024, securing additional interview partners became considerably more challenging. One of the associated partners was able to connect the Bautzen Innovation Centre with another enterprise from the Electronics sector, and the other 3 interviews conducted by the Bautzen Innovation Centre were the result of fairly intensive mail and telephone campaigns. During this process, Bautzen Innovation Centre employees occasionally got the impression that the company representatives were deliberately avoiding their calls, which was a new and unpleasant experience for the team.

However, from the informal assessment and selection criteria revealed a potential bias in the piloting sample: it is likely to be skewed toward company representatives who have an above-average openness for discussing and considering digital and sustainable topics.

Austria

In the context of GREENE 4.0, selecting 10 SMEs for testing the UAM as a meticulous and strategic process. This selection was crucial to ensuring the robustness and relevance of the findings, particularly concerning the twin transition. FH Kufstein Tirol identified potential candidates for the UAM pilot phase by adhering to specific criteria that would ensure a diverse and committed group of participants, although in the end, due to time and availability restrictions ended up in interviewing company representatives from 3 industry clusters. To enhance the selection process, FH Kufstein Tirol utilized data from the survey and the regional mapping analysis report, which provided valuable insights into the local business landscape, as well as the specific needs and readiness levels of SMEs in the region. This survey data was instrumental in assessing the initial interest and engagement levels of potential candidates, especially in the early spring 2024.

FH Kufstein Tirol reached out to companies that had participated in the initial survey conducted in the summer of 2023. These companies were prime candidates due to their existing involvement in the project. Additionally, one study program at FH Kufstein Tirol is strongly dedicated to Business Management, Entrepreneurship, and Family Businesses, which allowed the institution to tap into the network of students whose families run companies in the manufacturing industry. This direct connection facilitated a trustworthy and motivated group of SMEs eager to participate and contribute to the project's goals.
Furthermore, FH Kufstein Tirol leveraged the career fair held at the institution in March 2024 as an effective strategy to engage a broader spectrum of manufacturing SMEs. This event provided a platform to present the project, attract interest, and identify companies committed to the twin transition.

Nevertheless, the institution managed to conduct 5 interviews before May 2024 and 5 in between summer time (i.e., by the end of July 2024).

CRITERIA FOR SELECTION:

- **WILLINGNESS FOR TWIN TRANSITION:** The primary criterion was the SMEs' readiness to engage in the twin transition. FH Kufstein Tirol sought companies that demonstrated a proactive approach to integrating digital technologies and sustainable practices. This included firms that had already started implementing digital tools or sustainability measures, as well as those eager to begin their journey. Following the development of the UAM, which categorized companies into different stages of maturity, FH Kufstein Tirol ensured that the testing process included companies from all maturity stages.
- **SECTOR DIVERSITY:** To gain a comprehensive understanding of the UAM's applicability across various industries, FH Kufstein Tirol selected SMEs from diverse sectors. The selection focused on the seven predefined sectors for the platform: Electronics Products, Food & Beverage Products, Pharmaceutical & Chemical Products, Metal & Metal Products, Plastics & Rubber Products, Machinery & Equipment, and Building Materials & Furniture. The interviewed companies were evenly divided among the sectors of Metal & Metal Products, Machinery & Equipment, and Building Materials & Furniture. This sector diversity allowed us to observe sector-specific challenges and opportunities, enriching our analysis and recommendations. Furthermore, the results are comparable, as an equal number of companies from these three sectors were surveyed.
- **GEOGRAPHIC FOCUS:** Our efforts were concentrated on the area surrounding FH Kufstein Tirol, leveraging local networks and knowledge. This geographic focus provided a cohesive and manageable group of SMEs, facilitating better collaboration and support. Due to the proximity to Bavaria, several interviewed companies were located in Germany.

Czech Republic

The Innovation Centre of Usti Region aimed to reach the widest possible range of SMEs that might be interested in participating in the UAM pilot phase, which in Usti Region took place in between March and May 2024. The final list included SMEs that had already expressed interest in the twin transition, those that had previously collaborated with the Innovation Centre of Usti, as well as regional startups and even companies that the Centre knew were operating in the region but with which it had no prior collaboration or knowledge of their digitization and sustainability processes. It is safe to say that the recruitment process for pilot phase was indeed pragmatic, as the Innovation Centre of Usti Region adhered to the pre-determined criteria of appropriate industry clusters but faced challenges in securing the willingness of individual companies to dedicate their valuable time. On several occasions, the Centre encountered difficulties in persuading company representatives to complete the UAM questionnaire and in convincing them of the questionnaire's benefits.

The interviewed companies provide a diverse snapshot of SMEs in the Usti region. While some companies are highly advanced in their digital or green practices, making them atypical for the region, others - especially from the Metal and Metal Products, Building Materials and Furniture, Food and Beverages industry clusters - reflect the traditional practices and slower adoption rates more commonly found in the region.

Italy

Considering that Intellimech is an industrial private consortium dedicated to innovation, all of the selected companies were already interested in the twin transition as a key enabling factor. Specifically, the company representatives chosen for the pilot phase had already recognized the value of investing in research and development activities to enhance their sustainability, and digitization efforts. The selected companies had previously participated in events organised by Intellimech and are well positioned within the local, regional, and European business eco-systems. They are generally interested in innovation

trends and share a desire to invest in human and economic resources, driven by the awareness of the need to develop new solutions.

The majority of the interviews were conducted in early spring of 2024, while the final 4 were organized in summer of 2024. However, the pilot phase recruitment was not without challenges, as companies in the Lombardia region, connected through the Intellimech consortium, are often over-saturated with surveys and interviews on similar topics.

Intellimech ensured that the selected 10 SMEs from its ecosystem represented different sectors, thereby collecting valuable insights into the adoption of both digital and green technologies. To be more precise, the selected SMEs operate in the machinery and equipment, electronics production, building materials and furniture, metal and metal products and, last but not least, the food and beverages industry cluster. Only one selected company was categorized under the tag of 'Other', as the consortium could not find a suitable representative company from the Plastics and Rubber industry cluster. Nevertheless, capturing insights from 6 different industry clusters revealed variations in the levels of maturity and readiness for the adoption of digital and green technologies. This process also highlighted their specific needs and challenged, the related regulations, market fluctuations, and existing facilities.

Finally, the interviewed SMEs showed an interest in the GREENE 4.0 activities and could serve as key contact points for further development throughout the project's duration.

Poland

The Krakow Technology Park selected 10 companies from different sectors and industry clusters, including Food and Beverages, Metal and Metal Products, Plastics and Rubber, Machinery and Equipment, Electronics and Software and Building and Furniture industry clusters. The pilot phase was carried out between March 2024 and mid-May 2024.

First, a thorough review of companies operating within the Krakow Technology Park ecosystem was performed; focusing on those already familiar with digital and/or green transformation topics. A significant number of the interviewed companies had previously participated in workshops organized by the Technology Park, which were dedicated to the aforementioned transformation. Their prior involvement served as an indicator of their willingness to share information about their operations, plans, and attitudes towards the ongoing change. The sample of companies reflects the vast economic diversity of the Malpolska region and its dynamism when it comes to developmental disparities. The sample included both young enterprises and long-established firms, present on market for many years or even decades. The mix featured companies that are heavily invested in the latest technologies as well as those that stilly rely on more traditional methods. By incorporating this range of businesses, the pilot phase gathered a broad spectrum of opinions on sustainable urban mobility and future economic transformations.
Hungary

The Hungarian Economic Development Agency meticulously planned the selection of SMEs for the UAM pilot phase to ensure a diverse representation across different industry clusters, reflecting various levels of digital and green maturity. The selection criteria were closely aligned with the unique characteristics and operational contexts of each company, ensuring that the testing would yield comprehensive and actionable insights. Each of the 8 selected SMEs demonstrated a clear interest in exploring or advancing their digital and green transitions. For instance, companies in the Food and Beverages and Building and Furniture industry clusters were chosen due to their proactive approaches in integrating advanced digital systems, such as ERP and CMR, and their ongoing investments in sustainable practices, including

renewable energy and waste management. The first 5 interviews were conducted by the mid-May 2024, while the remaining 3 were held during the summer of 2024, specifically by early August 2024.

Due to several work-force reorganisations within the Agency and due to the unavailability of company representatives', the selected pilot sample was limited to 8 in-depth interviews. Despite these limitations the Agency covered a broad spectrum of industries amidst the Food and Beverages, Plastics and Rubber, Building and Furniture industry clusters, while companies operating in the cosmetics and textile industries were categorized as 'Other'. The selected SMEs ranged from traditional manufacturing, represented by the companies from Plastics and Rubber industry cluster, to custom and artisanal production, exemplified by a portion of companies operating in Food and Beverages cluster and in Cosmetics production. This diversity allowed the UAM to be evaluated in both highly digitized environments and those still in the early stages of technological adoption. Therefore, a key criterion was the varying degree of digital and green maturity among the Hungarian SMEs. For example, a Building and Furniture company, with its advanced energy efficiency initiatives and customized digital solutions, contrasted heavily with other from the Food and Beverages cluster, which are only beginning to explore digital tools and sustainability practices. This mix ensured that the UAM could be tested for its applicability and usefulness across a range of maturity levels, from nascent to advanced.

However, the strategic relevance of SMEs' sectors to broader market trends in digitization and sustainability as also a consideration. Companies that operate in highly competitive markets where digital and green transitions are becoming increasingly critical were prioritized. Consequently, Metal and Metal products and Machinery and Equipment companies were left out. Conversely, a company producing frozen food, with its structured management systems, was considered an ideal candidate due to its capacity to implement and provide feedback on the UAM. In the end, each of the selected SMEs for the testing phase was assessed for its commitment to fully engage in the process. Speaking in more concrete terms, this included their ability to allocate the necessary resources, like time and personnel, to complete the UAM assessment thoroughly.

The UAM Instruments, Procedure and Data Collection

General Overview

The body of data (namely, the data corpus) in this particular case refers to self-assessed numerical scores from the maturity and readiness assessment's questionnaire, data from the Guidelines and Notes UAM Excel sheet and the UAM Feedback Template data. However, the relevant dataset for performing qualitative analysis consists of data from the Guidelines and Notes Excel sheet and the Feedback Template data. The initial plan was to draw the analysis mainly from Guidelines and Notes section, but this proved to be an unviable due to data scarcity, as only a few partners successfully captured the in-depth interview thread along with statements and exact descriptions of the interviewed representatives. The GREENE 4.0 partner consortium interviewed representatives from 68 different companies, mainly operating in the following sectors: 16 companies involved in metal and metal Products, 13 companies producing building materials and furniture, 10 companies manufacturing machinery and equipment, 9 companies producing or processing food and beverages, 6 companies producing and/or developing electronics and software products, 6 companies manufacturing plastics and rubber products, whereas the remaining 8 companies were engaged in other types of manufacturing activity (namely, in textile sector, cosmetics , sports equipment, telecommunications and advertising sector). The interview data was collected in between March and August 2024 across 7 different countries: in all of the cases 10 interviews per partner were conducted with the notable exception of Hungary conducting 8 interviews in total. The quality of the interviews varied depending on the partner involved and the level of effort they invested. In some cases, even within a single partner's set of interviews, there were noticeable differences, particularly

when the company representative was sceptical or reluctant to share details about their business practices. This variability can partly be explained by the challenges of conducting initial interviews, which are typically more difficult and require extensive preparation. The structured and detailed nature of the questionnaire made these early interviews especially demanding for the interviewer. Overall, the transcriptions of the interview excerpts were often sparse and lacked depth.

Industry cluster	LP/SL	PP2/ GER	PP3/ AUS	PP6/ CZH	PP7/ ITA	PP8/ POL	PP9/ HUN	TTL
Metal and metal products	3	5	4	1	2	1		16
Building materials & furniture	2		3	1	2	4	1	13
Machinery and equipment	1	3	3	1	2			10
Food and beverages	1			2	1	2	3	9
Electronics and software		1		1	2	2		6
Plastics and rubber	2			1		1	2	6
Other	1	1		3	1		2	8
Total	10	10	10	10	10	10	8	68

The UAM Instruments and Procedures

In general, the interview process qualifies as **action research**, a common approach in social sciences when seeking transformative change through doing research. Hence, the GREENE 4.0 consortium employed a two-step interviewing process: in the first step, companies engaged in a lengthy discussion about their maturity assessment in terms of the digital and green segments of their business processes. To facilitate this process, an exhaustive in-depth questionnaire was developed, covering essential business process categories with exploratory sub-questions focused on the digital and green aspects of business practices. The questionnaire was structured as an Excel file with two spreadsheets.

The first sheet, titled "Questionnaire," included blank brackets for respondents to insert their self-assessed scores (ranging from 1 to 4) in the digital and green maturity assessment. The second sheet, titled "Guidelines and Notes," provided a comprehensive set of sub-questions designed to help the GREENE 4.0 interviewing partners stimulate discussion. This sheet also contained empty brackets for the digital and green categories, allowing partners to input their notes or transcriptions of the interviews.

For clarity, the initial version of the UAM pilot testing was designed and structured around the following business categories and processes, which were identified as relevant for measuring twin transition maturity:

- Technological Category
    - Manufacturing Operations Process
        - Production Error Checking System
        - Production Planning System
        - Material Consumption Control System
        - Maintenance Prediction System
        - Improve Finished Product Inventory Tracking System
        - Manufacturing Process Optimization with Data Analytics and Automation
        - Packaging Activities

        - Final Product Quality Testing Activities
        - Measuring Energy Efficiency
        - Measuring Waste Production
- Organizational and Managerial Category
    - Infrastructure, Organisation and Management
        - Company WIDE SYSTEM (TQM, ISO, TS, other certificates)
        - Ensure Compliance with Upcoming Regulation
        - Measuring Systems of key company KPIs
        - Finance and Accounting Support Activities
- Training and Skills Development Category
    - Human Resource Management Process
        - Recruiting Process Activities;
        - Employee Efficiency and Reward Measuring System
        - Use of Visual Management or AIDS
        - Training Process for New Workers
        - HRM Management Process
- Financial Category
    - Investment and Financing Process
        - Market Research Process
        - Improving Scouting Process for New Innovations
        - Cost-Benefit Analysis Process
- Market and Business Category
    - Marketing and Sales Process
        - Advertising Activities
        - Sales Force Activities
        - Pricing Activities
        - Distribution Channels
    - Customer Service Process
        - Customer Support Activities
        - Warranty Service Process Activities
        - Maintenance and Repair Activities
    - Inbound and Outbound Logistics Process
        - Material Receiving Process Activities (quality check, performance delivery, etc.)
        - Material Storing Process Activities (physical, document flow, etc.)
        - Material Distribution Process Activities (reducing time, predictability, etc.)
        - Final Product Storing Process Activities
        - Final Product Distribution Process Activities
        - Final Product Delivery Process Activities (tracking etc.)
- Government Category
    - Impact from Government
        - Regulatory Compliance Processes
        - Access to Favourable Funding (grants, etc.)
        - Improving Ethical Business Practices Within a Company
- Informational Category
    - Information Flow
        - Information Flow System with Employees
        - Data Security and Privacy Process (data management, regulatory, cybersecurity)
        - Data Analytics and Insights Processes (advanced analytic tools, etc.)

In the second step, a follow-up session was organized to give companies an opportunity to reflect on their initial discussions and assessments. This session also aimed to enhance the relevancy of the initial questionnaire framework. **During the follow-up, participants were asked to complete a Feedback Template in a form of a Word file. In this template, the interviewed representatives identified the 2-3 most relevant digital and green business categories and evaluated how well these categories aligned with their actual business activities.**

Additionally, for each UAM business category, the representatives were asked to provide feedback on several aspects: whether they wished to add any processes to the category, if they felt accurately represented by the rating scales, what they perceived as the main challenges and enablers in implementing digital and green technologies, and whether they had already observed any cost-benefits from the implementation of these technologies. The data collected from the Feedback Template was used to refine the UAM questionnaire, ensuring that respondents felt more accurately represented. However, since the UAM questionnaire is designed as an action research instrument, its purpose extends beyond mere representation. It also aims to inspire companies to consider how they can evolve toward twin transitioning. Therefore, the questionnaire should not be perfectly aligned with the existing business practices and needs of SMEs, at least not in the UAM's early phases of development. Instead, one of its key roles is to broaden participants' understanding and encourage them to explore new possibilities.

One of the last sections of the Feedback Template contained questions about whether the initial questionnaire was indeed helpful in improving the understanding of digital and green technologies usage and whether the interview in any way encouraged willingness to integrate digital and green technologies. This process doing connected research with providing insights and exploration of various digital and green options in the first step, while in the second step the interviewed representatives were asked to estimate the impact of the interviewing process briefly. This is a key feature of any action research, where the chosen methodological approach is prone to influencing and transforming the participants' existing knowledge and perceptions. Moreover, the two-step interview process offered the representatives a chance to revise their initial answers in addition to serving as a set of control questions, uncovering some 'desired' or 'wishful thinking'[2] answers from the first phase. The final part of the Feedback Template was filled by the GREENE 4.0 partner, describing the overall impressions of each individual interview and any additional specific circumstances that might have influenced the data quality. For a detailed overview of the User Acceptance Model questionnaire and the Feedback template, see Appendix.

Qualitative Approach

Although qualitative methodological approaches are incredibly diverse, many regard **thematic analysis** as a foundational method for qualitative data analysis, i.e. as *"a method for identifying, analysing and reporting patterns (themes) within data"* (Braun and Clarke, 2006, p. 79). Thematic analysis was chosen for its flexibility and overall usefulness, as it can potentially provide a rich, detailed, but somehow complex account of data (Braun and Clarke, 2006, p. 78). Moreover, it is often used when working with participants whose views on the topic are not known and when the topic is not yet well researched. Despite the prevalence of 'digitization' and 'green' buzzwords and tags in mainstream media, empirical research cases with a more thorough and systematic approach are rare. Apart from literature reviews articles (see De Felice and Petrillo, 2021; Rosario and Dias, 2022), ambitious and comprehensive studies on dual

[2] This is a common problem in social sciences' research. Providing desired answers or practicing wishful thinking negatively influences the validity of the results. It is natural to suppose that a portion of representatives wanted to present their companies in best possible light, namely with overstating the importance of the digital and green elements of their business processes.

transition of multiple countries and sectors are seldom seen. The GREENE 4.0 project aims to address this gap.

The questions that guided the coding and the extraction of themes were tied to the construction of meaning in respect to digital and green transitions: *How do the interviewed companies perceive the digitization of business processes? How do companies make sense of incorporating green elements in their own business processes?* **Guided by these general and exploratory questionings, several themes were then extracted after the readings and re-readings of the dataset materials, and discussed among the PP4 University of Ljubljana team members. The extraction of themes was triangulated with the Regional Mapping quantitative survey's findings.**

The following themes can be considered as important aspects of the collected data and represent some level of patterned response or meaning within the data set:

- Techno-optimism vs. Techno-modesty
- The Curse of Being Small
- Employing Digital, Becoming Green?
- Relevant and Outdated Benchmarking criteria
- Diabolical Nature of Government Activities
- Challenges of Digitization and Datafication
- Politicized Resources.

The listed themes will be described in detail in the 'Results' section of this report. Since thematic analysis is a qualitative method, that the 'keyness' of the extracted themes does not need to strictly depend on quantifiable criteria (e.g., if the extracted theme is prevalent consistently throughout the whole dataset). Instead, their 'keyness' is determined by whether they capture something important in respect to the overall research questions and the research aims, stated in the previous section.

The questions that guide the coding and theme extraction usually differ significantly from the questions that participants have responded to. This example is no exception, as companies' representatives engaged in long conversations and provided descriptions of their business processes and their future orientations, which of course had a distinctive technical side to it. Most often, they were persuaded into agreeing to be interviewed with some hope of future practicality or future benefits. Even so, for UAM and its further utilities are to become accepted, helpful and even serviceable, we need to understand the human factor influencing the technology acceptance and refusal. This includes the previously mentioned thoughts and feelings that might be country-or-sector specific thoughts or feelings, how company managers and owners rationalize and feel, and, even more importantly, which company cohorts will be receptive to digital and green changes with greater pains and efforts or will even simply wait until regulations force them to implement these changes. Hence, the thematic analysis conducted here was primarily mindful of this latent affective meaning, although respondents often believed it might not be significantly important.

This provided the foundation for extracting themes or relevant recurring patterns within the dataset. In the second step, the extracted themes were further employed to construct ideal type-models, which are descriptive abstractions of essential company characteristics and attitudes: 1) Conservative Business Realists; 2.) Digital Believers and Enthusiasts; 3) Green Strategists; and 4.) Cosmopolitan Hi-tech Transitioners. These constructed ideal type-models are universal enough to be applicable across different industry clusters and different countries. To some extent, they reflect the four-point scale the UAM employs it, although the typologies were extracted from latent meaning and attitudes of the interviewed representatives and as an analytical construct therefore surpass the factual nature of different degrees of technological maturity in twin transitioning.

Data Collection GREENE 4.0 Partner Countries

Slovenia

During the pilot testing phase (March 2024 – July 2024), the Pomurje Technology Park did not impose strict limitations on participant involvement, allowing company representatives to include multiple employees from various organizational levels. Hence, in the case of 3 pilot interviews, two company representatives participated, while in one case, the team allowed participation of the three company employees. This approach resulted in a richer and more nuanced dataset. However, in most cases, the interviews were conducted with a single SME representative. The entire process of recruiting suitable representatives - from initial contact to scheduling the interview - generally took between four days to three weeks, depending on the availability of the person and, occasionally, on the Pomurje Technology Park's own scheduling constraints due to other tasks and obligations.

Both online and in-person interviews were conducted, utilizing simplified templates completed during the interview sessions and later transcribed into designated Excel sheets for more efficient data processing. This method enabled interviewers to capture more insights in real-time and revisit the sessions to extract additional details later, including non-verbal cues that provided a fuller understanding of the interviewed respondents' attitudes toward digital, and especially green topics.

The use of the English template posed challenges, as many expressions were not always clear to the interviewees. To address this issue, the team provided on-spot translations and eventually developed a Slovenian version of the UAM questionnaire with accompanying comments in Slovene language. This additional work significantly improved clarity and participant comfort.

Most interviews lasted from 1.5 to 2.5 hours, with an exception of 2 interview sessions extending to 3.5 hours. These longer sessions included very detailed discussions, live tours of the company premises and production halls, and in-depth explorations of bottlenecks in their business processes. Approximately one third of the interviews were held on-line, another third at the companies' locations, and the final third at Pomurje Technology Park's facilities. The highest level of comfort and effectiveness was achieved when interviews were conducted at the companies' locations. This setting allowed interviewees to demonstrate their production processes and openly discuss their concerns, which provided an opportunity to validate issues identified in the UAM questionnaire. This hands-on approach fostered a deeper level of engagement and yielded richer insights into specific challenges faced by the interviewed SMEs.

Germany

During the pilot testing phase (March 2024 to July 2024), two representatives from the Bautzen Innovation Centre were present at each interview – one as the interview leader and one as a notetaker. There were two exceptions due to scheduling conflicts, where only one representative from the Innovation Centre representative could attend.

Scheduling interviews with company representatives proved challenging, as interviewees were often reluctant to commit a significant amount of time. Despite this, most interviewees were quite willing to share information about their companies, although time constraints were an issue at several occasions, pressing the interview leaders to jump quickly through the latter parts of the UAM questionnaire and its Feedback Template – often faster than preferred. All interviews involved only one SME representative, predominantly CEOs, with occasional participation from Quality Managers and Heads of PR.

Two interviews were conducted in person at the Bautzen Innovation Centre, and these were notably longer on average. This suggest that face-to-face interactions may encourage interviewees to take more time to provide comprehensive answers, as opposed to quickly providing numbers and rushing through their feedback. The grave majority of interviews were conducted virtually using MS Teams software.

Austria

The interview sessions conducted from March 2024 to July 2024 typically involved one representative from each SME and a team from FH Kufstein Tirol comprising two to three people, including a lead interviewer, a note-taker, and occasionally an observer to ensure consistency and comprehensiveness. The interviews were not recorded, as participants preferred this arrangement, allowing them to speak more freely and share their thoughts without reservation. Instead, detailed notes were taken during the interviews to capture the essential points and nuances of the discussions.

One major problem during the testing phase was the lack of services that the interview team could offer. The intricate nature of the UAM sometimes made it difficult to explain its functionality and relevance to potential interviewees. Additionally, the lengthy process, UAM complexity, and significant time commitment required were often posed challenges in securing interviews with company representatives. Participants were sometimes sceptical about the development of a platform purported to offer ‘all the solutions’, though they also shared potential ideas and desires.

Interviews were conducted in German language, as the UAM questionnaire was translated into German, which reduced difficulties for the participants. Most interviews were held online using MS Teams software, providing greater flexibility and convenience for both the interviewers and the SMEs. This setup facilitated real-time interaction and ensured that participants could join from their respective locations without logistical challenges. The interview process was carefully scheduled to accommodate the busy schedules of the participating companies. Time slots were coordinated in advance, with ample notice given to ensure maximum participation. The online format and single-session approach streamlined the interview process while still obtaining valuable insights. This method also addressed the common challenge of time commitment, making it easier for companies to participate and contribute to the project. Three out of ten interviews took place in person; however, this did not pose any difficulties, as no notable difference in interview dynamic was observed.

Czech Republic

The pilot phase interviews (March 2024 – May 2024) were organized with the attendance of two representatives from the Usti Region Innovation Centre, namely with one leading the interview and the the other recording the responses and taking notes directly into the questionnaire file. Later, the team supplemented the written answers with excerpts from the recordings’ transcriptions. Most interviews were recorded with the understanding that these recordings were for internal use only and would not be published.

Conducting lengthy interviews in English proved to be too challenging, particularly for SME representatives not active in international markets. To address this, the Innovation Centre translated relevant parts of the UAM questionnaire into Czech and simplified it to conduct all interviews in Czech. The simplification focused on key areas directly related to the UAM’s goals, providing specific insights into technological aspects, environmental business practices, and organisational preparedness of the SMEs. The responses were later on translated back into English.

According to the Innovation Centre’s experience during the pilot phase, innovation-oriented companies such as startups or those in electronics sector were more willing to share their experience and opinions.

Occasionally, the team was concerned that the lengthy interview process might affect the credibility od the Innovation Centre. Additionally, the pilot phase revealed some signs of deeper scepticism and mistrust towards government authorities and climate change in general.

Italy

Intellimech organized one-to-one interview sessions focused on twin transitioning, primarily with research and development managers. In certain cases, production or quality managers and CEOs were also interviewed. Innovation managers were found to be the most proactive and willing participants in these discussions. The interviews were scheduled between April 2024 and the end of July 2024.
A total of of 10 interviews were conducted using a hybrid approach: 3 interviews were held in person at the companies' sites, while the remaining 7 interviews were held online. The in-person interviews were organized with the assistance of an Intellimech reference person through e-mail or telephone. For the online interviews, the Intellimech team first pre-filled the UAM questionnaire with as much information as possible based on prior knowledge of the company. During the interview, the team asked detailed questions to confirm and expand upon the pre-filled information. In one exceptional case, the time allocated for the interview was insufficient, so the Intellimech team requested that the company representative complete the UAM questionnaire independently after the interview. Pre-filling the questionnaire proved to be a very useful exercise, allowing the team to better prepare for the interview and avoid redundant questions.

Some interviews were recorded, with responses reviewed immediately after the session in order to adjust missing or uncertain details. All interviews were conducted in Italian, which necessitated some time for translating the terms and questions. Overall, the mood during the interviews was generally relaxed or focused, even though the length and complexity of the questionnaire occasionally caused frustration among the interviewees.

Poland

The UAM pilot phase was executed from early spring until the mid-May 2024, using a hybrid approach that included both in-person and online interviews to accommodate various logistical needs. The Krakow Technology Park engaged one representative per selected company, with participants ranging from CEOs to senior management and technical experts. This diversity in representatives' profiles and positions provided a wide range of perspectives, allowing the Technology Park to gain a comprehensive understanding of each company's approach to digital and green transitions.

Discussions were tailored to the interviewee's role within the company. For instance, interviews with sales managers focused on sales-related issues, while discussions with production personnel centered on production-related matters. This customization ensured that the interviews were relevant and insightful for each participant.

Interview sessions were meticulously planned and scheduled to last between one to two hours, striking a balance between thorough discussions and respect for the interviewees' time constraints. On average, the actual interviews lasted between 1.5 to 2.5 hours, allowing to collect comprehensive data and ensure clarity in responses. In any case, efforts were made in order to ensure the length and depth of the interviews did not deter companies from participating.

Most interviews were conducted at the Technology Park's offices, with the remainder held online. Although the interviews were not recorded; however, two representatives from Krakow Technology Park's partner organization attended each session. One led the discussion, while the other took detailed notes.

In some cases, representatives from Technology Park's Digital Innovation Hub, responsible for digital transformation in the MaŁopolska region, were also invited.

Challenges in data collection included language barriers and some reluctance to share detailed information. These issues were mitigated by conducting interviews in Polish and by affirming confidentiality to participants. The interviews were later translated into English for further analysis.

Hungary

The interviews conducted by the Hungarian Economic Development Agency during the UAM pilot testing were generally attended by two of its representatives – one leading the discussion and the other taking comprehensive notes. This dual approach ensured that the conversations were both thorough and accurately documented. The testing was carried out across various locations, predominantly at the premises of the selected SMEs. On-site visits typically took place in company meeting rooms or executive offices, providing a comfortable and familiar setting for the respondents.

The testing process was carefully planned to fit into the operational schedules od the company representatives involved. Each SME was contacted in advance to agree on suitable dates and times, ensuring the process was as convenient as possible for the interviewees. The scope of the questionnaire and the expected time commitment were discussed upfront, allowing the SMEs to allocate the necessary resources effectively.

The interviews were conducted in Hungarian, which facilitated clear communication and helped avoid any language barriers that might arose if English had been used, especially since some SME representatives were less comfortable with English. Overall, the Agency prioritized minimizing disruption for participants while maximizing the quality and depth of the information gathered.

Each interviewee participated in a single, comprehensive interview session, usually with a follow-up session scheduled to clarify answers or explore parts of the UAM that appeared interesting but were not fully explored initially. The process began with an introductory meeting where the objectives of the UAM testing and overall project goals were clearly communicated. During this introduction, respondents provided a brief overview of their company, which helped tailor the subsequent discussions to the specific context of each business. Following the introduction, the data collection session delved into detailed questions relevant to the SME's operations. The conversation naturally evolved based on the representatives' responses, allowing the Agency to explore areas that required more in-depth discussions. After the interview, the team focused on completing the UAM questionnaire and transcribing notes to ensure all relevant information was accurately captured.

There was some concern that the lengthy interview process might affect the Agency's credibility, particularly if the interviewees felt the time investment did not yield immediate benefits. However, maintaining open communication about the purpose of the interviews and the potential long-term benefits of the UAM helped mitigate these concerns. Most representatives understood the value of the exercise and were willing to participate fully.

D. Results analysis

The repeated readings and re-readings of the dataset materials resulted in organizing the coded data into meaningful groups, based on which themes were established. The grouping and re-grouping of the coded data pieces made it evident that similarities and pattern extraction from the participants' opinions and thoughts are not as heavily influenced by the companies' region or country. **Instead, the fact that companies belong to a specific industry sector or industry cluster proved to be a more determining factor when it comes to grouping business rationalizations and affectations about employing digital and green technologies.** Naturally, the regional and country-specific factors still influence the business environment from the outset, with laws and regulations, and with enabling (or disabling) the proximity to digital and green innovations. At least up to a point, since the interviewed companies were not bound to be regional actors exclusively— a share of them (57,5%) are actually active in foreign markets or strive to be recognized as global players according to the November 2023 survey. However, the triangulation of the quantitative and qualitative data enabled the extraction of some patterns and region-specific factors, that should be taken into further consideration:

- Pomurje region
  - **Comparative insights:** lower awareness of the twin transition noted, with interviewees rarely articulating how digital technologies connect with sustainable business practices
  - Digital and green aspects were consistently discussed in terms of costs and benefits or ROI calculations
  - **Company size:** small companies dominate - 33% of surveyed Slovenian companies employ fewer than 10 people, and 36.6% employ 10-49 people.
  - interviewed company representatives were repeatedly discussing digitization on the ground of LEAN principles, whether already implemented or as a future plan
- Eastern Saxony region
  - **Comparative insights:** there was a more elaborated emphasis on sustainable business practices, with interviewees expressing a more critical stance towards advanced digital technologies. Notably, they had a clearer perspective on their company's market position or specific niche.
  - Digital and green aspects were often discussed together with other important value drivers, such as product quality and employee wellbeing
  - **Company size:** small companies are prevalent; 25.6% of surveyed German companies employ fewer than 10 people, and 39.6% employ 10-49 people. A significant 72.1% have an international market presence.
  - The majority of interviewed companies had already implemented ERP systems
- Tirol region
  - **Comparative insights:** Interviewees emphasized why certain marginal business activities (e.g., advertising, recruiting) remain undigitized and should stay embedded in a local or regional context.
  - Stronger focus on national or local recruitment and supply chain management, with preferences for local or national materials and ethical considerations (e.g., avoiding Russian energy sources).
  - **Company size**: Small companies dominate; 50.8% of surveyed Austrian companies employ fewer than 10 people, and 37.3% employ 10-49 people. Companies have the strongest presence in local (47%) or regional (57.4%) markets.

- Some interviewees discussed the time-consuming nature of managing funding grants and using digital portals for taxes, banking, and certifications, citing a lack of coordination and data exchange.

- Usti region
  - **Comparative insights:** Czech company representatives showed a strong focus on digitization across various business categories, frequently highlighting the use of basic online tools (e.g., Outlook, Messenger, WhatsApp, MS Teams, Google Analytics). They also highlighted a reduction in paper consumption as a direct consequence of these digital practices.
  - Digital and green aspects were mostly discussed in terms of cost and benefits or ROI calculations
  - **Company size:** Small companies are prevalent; 28.6% of surveyed Czech companies employ fewer than 10 people, and 49% employ 10-49 people. A significant 69.4% have an international market presence.
- Lombardy region
  - **Comparative insights:** Italian interviewees demonstrated a nuanced awareness of twin transition challenges, particularly in areas like Digital Product Passport implementation, data management and analytics, waste production measurement, and the use of advanced sustainable materials.
  - Digital and green aspects were often discussed in relation to other important value drivers, such as innovation scouting and employee well-being (to prevent workforce turnover and ensure knowledge transfer)
  - **Company size** Medium sized companies are prevalent: 37,5% of the surveyed Italian companies employ 50 – 99 people and additional 22,5% employ 100 – 250 people, like in the cases of Czech and Germany, significantly more surveyed Italian companies are present on international markets (72,5%)
- Małopolska region
  - **Comparative insights:** Polish interviewees demonstrated a stronger familiarity and understanding of circular economy concepts, with some companies showcasing advanced levels of green and digital maturity.
  - **Company size:** Medium-sized companies dominate; 17,9% of surveyed Polish companies employ 50-99 people, and 39,3% employ 100-250 people. A significant 82,8% have an international market presence with an additional remark of Polish companies scoring the highest share (36%) of the companies capable of producing more than 100,000 units monthly.
- Hungary
  - **Comparative insights:** Aside from detailed descriptions of production capacities and international supply chains, Hungarian company representatives showed no ethical concerns regarding employee performance tracking.
  - The connection between digital and green aspects was established through descriptions of infrastructure and logistics automation
  - **Company size:** Medium-sized companies are prevalent; 23,3% of surveyed Hungarian companies employ 50-99 people, and 46,5% employ 100-250 people. Notably, 32% of these companies are capable of producing more than 100,000 units monthly.

All of the established themes were more ‘data-driven’ than ‘theory-driven’. Thus, the analysis of the results in this case will not include a comprehensive literature review or be based on an impressive number of scientific articles and monographs. This is a conscious and deliberate choice rather than a coincidental shortcoming since the GREENE 4.0 consortium cannot afford for its research findings to be expressed in an esoteric manner or written in a language saturated with academic theory. This deliberate choice is sensible if we consider the diverse educational backgrounds of GREENE 4.0 partners and their integration

into regional business ecosystems. In the long run, the project seeks to develop a relationship of trust and empathy with regional companies. This necessitates our research findings to be communicated in a clear and sufficiently understandable manner. The generation of codes initially, followed by the sorting, collating, and analyzing of the codes, resulted in the extraction of the following themes:

1.) Techno-optimism vs. Techno-modesty
2.) The Curse of Being Small
3.) Employing Digital, Becoming Green?
4.) Diabolical Nature of Government Activities
5.) Relevant and Outdated Benchmarking criteria
6.) Challenges of Digitization and Datafication
7.) Politicized Resources.

We shall shortly describe each of the listed themes and, in some cases, provide illuminating examples or quotations from the interviewed representatives. The representatives' identities, positions and company names are not relevant for this analysis, so all of the respondents' identifiers shall be anonymized, with the exception of the company's region or country of origin and their general industry cluster.

Techno-optimism vs. Techno-modesty

Positive general attitudes toward technological innovation are usually one of the main factors in determining users' willingness to try out new things or accept new technological bundles. If a company has a strong tradition of innovation, it is far less likely to be reluctant to accept new digital and green solutions. Consequently, determining which industry clusters foster more positive or appreciative stances toward innovation in general, and more importantly, which do not, can enable more systematic targeting with technological solutions.

Across the dataset, the prevailing general attitude towards technology and innovation proved to be a softer or stronger version of technological optimism. The most visible examples of stronger techno-optimistic statements and opinions, even bordering on techno-enthusiasm rooting for the digital revolution, can be found mostly among representatives from the Electronics and Software industry cluster. The peculiarity of these clusters lies in techno-optimistic stances prevailing in many of their business processes, such as in Manufacturing Operations Processes as well as in Infrastructure, Organization and Management, Customer Service Processes, Advertising Processes etc. In other industry clusters, milder versions of techno-optimism were observed in relation to one or two business process categories, not more. Here, we need to bear in mind that the interviewed representatives naturally seized the opportunity to present and promote their company's activities and achievements, which resulted in a variety of positive pitches about technological benefits and modernization impacts.

Very few company representatives were willing to share their negative or failed experiences during the interviews. However, those who did, expressed disappointment with their investments in technological modernization or criticized certain technological advancements. Some examples illustrate ambitious efforts to integrate advanced digital systems into production lines, but these attempts often proved too complex for practical use or suffered from low employee acceptance rates. Other cases were less fatal, since the company was only experimenting with online recruitment or online advertising. These challenges underscore the need for more user-friendly interfaces and patents, tailored to smaller enterprises. Additionally, they highlight the importance of developing comprehensive employee training programs to ensure smoother transitions and higher acceptance of new technologies.

- "Our ERP system performs poorly, especially taking into regard waste minimisation. The industry and the company are caught between two stools because there is no cross-industry solution – to solutions

are made and knitted themselves to be able to initiate optimisation process, but it does not happen continuously… this process has to be started again and again by hand, in a fixed cycle, is checked again and again if we are optimal there and the waste should be reduced by a few percent" (Austrian CR, Building Materials and Furniture)

- "We have undergone through the process of incorporating automated paternoster system, QR code system and E-commerce platform for analytics and informed decision making – 3 years ago, we invested over 100 000 € for these technologies and they are still not in use due to time constraints of our employees who are already 120% overloaded with work and do not have time for proper training or studying all these systems." (Slovenian CR, Plastics and Rubber cluster)

- "Previous attempts at digital production planning were failures: too complex, too much effort, too little acceptance among employees. Whiteboards are currently being used. Existing merchandise management systems do not meet the requirements of a small craft business." (Austrian CR, Machinery and Equipment cluster)

- "I find data collection and measurement systems for employee efficiency as a sensitive issue that shouldn't be approached without criticism" (Hungarian CR, Metal and Metal Products cluster)

- "You see, social media platforms are crowded spaces where businesses compete for attention. The competitive environment means you have to constantly innovate and communicate to stay connected with your audience, which proved out to be a far too time-consuming activity for us" (Czech CR, Plastics and Rubber cluster)

- "Technology usually increases the quality of the products, but a digital analysis of a manufacturing process might no change anything in terms of quality??" (Austrian CR, Metal and Metal Products cluster)

- "We have established an online Moodle platform for training content. To this day it still remains a bit empty due to lack of manpower and nobody feeling responsible for it. In the end of the day, training measures are still passed on from man to man or woman to woman in a traditional manner, a lot is conserved and recorded bot not digitized. Basically, ideas are there, with the implementation still lacking." (Austrian CR, Building Materials and Furniture cluster)

- "CRM isn't integrated into market research – instead, sales staff just talks to customer representatives. And this is what we want, too, not some automated satisfaction survey which was run as an experiment a few years back." (German CR, Metal and Metal Products cluster)

- "Company's design department implemented an ERP system, but it was not successful – work time actually increased, the system was not suited for our company's needs, and it was not widely used in Poland, which made difficult to draw from other companies' experiences." (Polish CR, Building Materials and Furniture – industrial chimneys manufacturer with 50 employees)

Technologically modest or even conservative descriptions were predominantly observed in the Machinery and Equipment industry cluster, the Metal and Metal Products cluster, and in the "Other" category, which includes sectors like the textile industry and cosmetics products. The reasons for these techno-modest stances varied. Some companies reported that they did not feel pressured by external competition, which reduced their motivation to innovate. Others cited a lack of employee support or interest in adopting new technologies. Additionally, some companies were simply not in a position to grow or scale their operations,

making significant technological investments seem unnecessary or impractical. These factors collectively contributed to a more conservative or reserved approach to technological adoption in these sectors.

- "Smaller technological upgrades give concrete and small results." (Slovenian CR, Machinery and Equipment cluster)
- "Every sort of innovation or new technology effectively has to be brought and pushed by myself as a CEO, which is difficult" (Germany CR, Metal and Metal Products cluster)
- "You can digitize yourself to death and too much is not good either" (Austrian CR, Metal and Metal Products cluster)
- "We do not really pay attention to the various new innovation and technologies as we don't have the need or the capacity. Within the company, we monitor industry trends" (Hungarian CR, Other/Cosmetics Products)
- "Our company gets plenty orders for conventional product range, so there is little perceived pressure to innovate" (Slovenian CR, Other/Textile Manufacturing)

As it becomes evident from the case of the respondent sharing its business philosophy, we can acknowledge a sense of identity that influenced his approach to innovation. Similar companies tended to value stability and gradual development over the rapid, risk-laden dynamism seen in larger, more innovative companies. The company representative expressed pride in his steady, stable growth and emphasizing a more cautious, yet a more reliable path.

The Curse of Being Small

In the interviews conducted as part of the UAM framework, various respondents across different countries highlighted the implications of operating on a small scale. For the majority, these implications were seen in a negative light, often citing limitations in resources, time, and capabilities as significant barriers to innovation and twin transitioning efforts (i.e., digital and green transformation). However, there were a few notable exceptions where the small size was perceived in more neutral terms:

- "Since we mainly produce components in small quantities and with a limited mass production, there are no dedicated production error checking systems in place, outside those natively integrated in the machinery. There are no plans nor interest of integrating any kind of AI or machine learning technologies in these systems due to the lack of reliability inherent to these technologies and a simple lack of need. We have had for many years now a comprehensive ERP system which incorporates all resources including labour. No algorithmic production planning is in place or seen as needed due to the small size of the company and large levels of experience and institutional knowledge held by the managing family." (German CR, Metal and Metal Products cluster)
- "As a small company, we rely on digital solutions to significantly improve our material storage efficiency. These technologies provide real-time visibility and automation, which are crucial for our operations. By integrating automated warehousing systems, like automated storage and retrieval systems, we can streamline our storage process. This automation reduced the time and effort needed to locate and manage materials, allowing our small team to focus on more critical tasks. We also use inventory management software to keep track of our stock levels accurately. This software helps us optimize our inventory, ensuring we always have the right amounts of materials on hand without overstocking. This optimization not only reduces storage costs but also minimizes waste. Overall,

these digital solutions are essential for our small business. They help us run more efficiently, save money, and ensure that our operations are smooth and well-coordinate despite our limited workforce." (Czech CR, Building Materials and Furniture cluster)

In this rare instance, the company successfully harnessed advanced digital solutions—such as machine vision and automatic error detection—in their logistics processes, leading to positive business outcomes. These included cost savings, a smoother workflow, and the ability to operate efficiently despite a smaller workforce. The digital transformation also had an environmental impact, introducing initial green effects through waste minimization. This outcome, while noteworthy, aligns with expectations, as the company placed significant emphasis on training processes focused on energy efficiency and waste reduction. In essence, this case exemplifies the twin transition—where digital advancements are implemented alongside appropriate training, ultimately contributing to sustainability. The successful integration of technology in this SME highlights the importance of coupling digital tools with targeted employee training to maximize both operational efficiency and environmental benefits.

For most respondents, small scale was associated with financial limitations, time constraints, and a perceived inferiority to larger companies. This perspective is captured in several recurrent codes:

- "Advancements with SMEs is always difficult, since larger companies are always better" (Austrian CR, Metal and Metal Products cluster)
- "We have the problem of having a strong desire for digitization and sustainable production, but very limited finances" (Czech CR, Building Materials and Furniture production)
- "There is always space for improvement, however the scale of production is small, so there is less need for digitization" (Slovenian CR, Machinery and Equipment cluster)
- "We are currently monitoring tenders as we have done it several times in the past, but we were not able to win. In my view, we are not large enough to win such tenders." (Hungarian CR, Other/Cosmetics)
- "Having a well-developed system to stay on top of upcoming legislation is something that is only realistic for large firms." (German CR, Metal and Metal Products)
- "The main problem includes high initial costs for adopting new technologies, the need to train employees on how to use these systems, and potential complications during the setup phase. Another challenge is figuring out which technologies will provide the best return on investment, especially for small-scale operations" (Czech CR, Building Materials and Furniture cluster)

These remarks reflect a "curse of being small," where limited resources and a smaller workforce are seen as significant hindrances to the twin transition. This sentiment also points to a potential issue in how public communication around twin transitioning is framed. There appears to be a gap between the ambitious goals set for digital and green transformations and the realities faced by smaller SMEs.

To address this, rather than promoting advanced digital tools and ambitious green practices that may seem out of reach for smaller companies, there might be a need to advocate for more gradual and modest technology introductions. For example, promoting Enterprise Resource Planning (ERP) alternatives that can incorporate sustainable metrics or improve energy efficiency could be a more accessible starting point for smaller SMEs, especially those from Slovenia. However, as is indicative from the positive Czech example, technology alone will not be able to produce benefits without additional employee training. This

approach could help bridge the gap between the current capabilities of smaller companies and the expectations set by the twin transition, making the process more inclusive and realistic for businesses of all sizes.

Employing Digital – Becoming Green?

The theme of the twin transition—encompassing both "digital" and "green" codes—has been widely discussed among SMEs. This theme captures the different ways in which companies approach the dual challenge of digitization and sustainability. While the history of digitization policies and initiatives at both the national and European levels has deeper roots than sustainability efforts, this discrepancy was reflected in various discussions among the interviewees.

The interviews revealed that digitization efforts were more often raised in topics of describing manufacturing processes, logistics, organizational and managerial software, advertising, employee recruitment, and information flow. However, in some instances, the interviewees focused on peripheral business processes or highlighted digitized activities that are now considered standard, such as using Outlook for communication or social media for promotion. In many of these cases, the concept of the twin transition was not really developed, as the concept was often divided to two autonomous realms – that of the digital and that of the green. In such cases, interviewees frequently listed their company's digital activities without making meaningful connections to sustainability, often limiting green efforts to recycling or placing the burden of sustainability on employees:

- “During recruitment, the company highlights its commitment to sustainability, even if it is not integrated.” (Hungarian CR, Other/Cosmetics)

- “The information flow system is utilized to promote sustainability awareness and practices among employees by disseminating relevant information and initiatives while transitioning from paper-based to digital communication has been implemented to reduce environmental impact by minimizing paper usage and promoting eco-friendly practices.” (Czech CR, Electronics and Software cluster)

While these practices may stem from good intentions, employees can quickly recognize them as “greenwashing” and become cynical about their company’s or the broader green transition effort. However, the idea of digital being a distinct domain that can only be linked to sustainability through green practices advertised to customers or employees, was not widespread in the dataset. More commonly, interviewees across the GREENE 4.0 regions viewed sustainability as secondary to the straightforwardness of digitization. Digitization was often seen as easier to understand and already producing economic benefits:

- “It is difficult to see the benefits of introducing green technologies. It is easier to integrate digital ones, in particular for finance and accounting support systems. Furthermore, employees dealing with organizational activities are not aware and trained for the adoption of innovative solutions.” (Italian CR, Food and Beverages cluster)

- “We already see some effects of the digital and we expect to make even more progress in the future. For sustainable parts, this is more difficult… Obviously more can be done, but cost-benefit ratio seems off because of our small company size…” (German CR, Metal and Metal Products cluster)

- "On average, I think we are kind of aware where we stand with the digital… Whether with the green, we are less familiar and this makes it harder to cope with…" (Slovenian CR, Building Materials and Furniture cluster)

- "In particular for green technologies is not easy to see their sustainability when referred to managerial tasks and not technical ones." (Italian CR, Metal and Metal Products cluster)

Another common trend was the prioritization of digitization and the postponement of green practices. This was evident in the advocacy for faster and greater automation of production lines, waiting for customer demand to shift, or waiting for clear economic feasibility before committing to green practices. As one Austrian CR from the machinery and equipment sector noted, SMEs should wait for green to be economically viable before pursuing it:

- "Company representatives recognize the need for digitization and greater automation of processes, noting competition from German firms that can lower prices due to cheaper energy costs and production expenses… […] Management believes that one of the conditions for modernizing the company is the automation of processes wherever possible. We also see potential in using VR goggles for quality control, but believe that such advances solutions should come later, once basic processes are modernized. Automation is seen as an opportunity to "leap forward" and maintain a competitive edge." (Polish CR, Building Materials and Furniture cluster)

- "When there will be users' willingness to pay more for "green products"… Secondly, legislation is not obligatory, while on the other hand, digital gives concrete and quick results…" (Slovenian CR, Plastics and Rubber cluster)

- "We will only become more climate-neutral or greener if it is also economically feasible – basically, we will only manage to become greener through technological leaps. It will not work with coercion, as corporate processes must always be first economically viable…" (Austrian CR, Building Materials and Furniture cluster/Window Production)

Other interviewed representatives favoured digitization and discussed which of its effects can lead to more sustainable business practices. To sum up, digital can to a certain extent be equated with green, or can even be seen as a detour towards sustainability, especially in terms of efficiency of the manufacturing process or minimizing its waste production:

- "But digitalization has more relevance – through the digitization to green… […] Above all, cost-benefit must be presented and to show green and sustainable aspects – then the green idea comes naturally…" (the very same Austrian CR, Building Materials and Furniture cluster)

- "…the differentiation between the green and digital… Well, digitalization improves the effectiveness and efficiency of the processes and leads to savings in the "green area"… […] Digitization promotes optimization and thus scope for the "green"…" (Austrian CR, Machinery and Equipment cluster)

- "Efficiency is a core economic issue, including sustainability goals." (Austrian CR, Machinery and Equipment cluster)

- "Customers increasingly expect digitized products and benefits that come with it in the form of standardized file formats and documentation… Sustainability is not really a big factor here and I'm not sure if it could be, unless the legislator forces the issue… But at least, much of packaging material is recycled, although that is not always possible…" (German CR, Machinery and Equipment cluster)

- "Well, digital enables connectivity between different functions and data flow… we will just follow digital impacts to align with green topics…" (Slovenian CR, Building Materials and Furniture cluster)

A spectrum of similar opinions went one step further and sketched green solutions as a type of non-intentional side effect of other business-driven decisions or "raw technology use." In other words, these opinions depicted green solutions or green effects as something external to economic activity. Accidental green business practices arise not because of their "greenness" but due to other, more relevant business considerations:

- "Green solutions will be implemented if they make business sense – a good example is the use of photovoltaics. Reducing environmental impact is a welcomed additional effect. Green companies can also expect more grants and access to financing." (Polish CR, Building Materials and Furniture cluster)

- "Our company's actions in some aspects undoubtedly contribute to reducing environmental pollution… For instance, through monitoring energy consumption. However, it should be noted that the decisions to implement such solutions are business-driven; the environmental effect is somewhat incidental and represents a side effect" (Polish CR, Metal and Metal Products cluster)

- "We use CRM and a core management system DS4 software […] It is not an environmental consideration to have employees work from home. Due to optimization, we have opted for longer working hours from Monday to Thursday, that is with a 4-day working week." (Hungarian CR, Other/Cosmetics)

- "There is no systematic and digital recordings of any errors that happen, mostly caused by human error and not a defective machine anyway… We only do recordings of produced scrap, which halved over the last decade. We achieved this mainly by using relatively simple measures, like the four eyes principles, or more stringent maintenance protocols… and less so by digital technology aimed at specifically reducing scrap production, although machine commissioned during this period are more efficient in their usage of raw material. The measures undertaken to achieve this were predominantly motivated by persistent rises in material costs, not by sustainability considerations, although improvement in this area are a welcomed side effect." (German CR, Metal and Metal Products cluster)

However, not all interviewed representatives see the green realm as something that needs to be subdued to digitization or automation, nor as something external to conducting business or maintaining financial health. Furthermore, some interviewees view sustainability - although abstract - as a primary goal of their established companies, even though it may face limitations such as product or resource price. Yet, sustainability as a business goal can even encompass digitization, if only to instrumentally achieve reduced carbon footprint:

- "Climate change represents a real threat to society. The company has committed to meeting its goals established in the ESF strategy to effectively address this issue and respond to the demands and expectations of the stakeholders…" (Polish CR, Electronics and Software industry cluster)

- "We maintain a strong focus on financial health and sustainability. […] We actively strive towards implementing energy-efficient and eco-friendly technologies… Usually, these technologies not only increase our production efficiency, but also significantly reduce our environmental footprint…" (Czech CR, Other/Cosmetics)

- "Sooner or later, you have to do this double transformation anyway. Above all, I think the solutions should always come in a double package – sustainability should always be considered and it should not be separated from any digital implementations. […] Sustainability has priority over digitization." (Austrian CR, Metal and Metal Products)

- "Main objective for our company is to measure a recourse use prevention, enabling cleaner technologies. Instead of synthetic chemicals, we are applying mineral ones with low environmental impact. […] Reducing carbon footprint is key. […] Digital transition within our sector is indirect, however, is related to precision agriculture tools which might additionally help reduce the use of chemical input by farmers. We can integrate our technology with digital tools for predictions and precision spraying equipment." (Polish CR, Food and Beverages cluster/Agriculture)

- "We have implemented several measures related to ESG criteria ahead of regulation coming into effect… This serves as well, with our digitized processes giving us major efficiency… […] However, cost-benefits are not the main factor motivating the company in this sense - attracting and keeping valuable employees is…" (German CR, Electronics and Software cluster)

- "Sustainability and ecology is the first priority of our brewery, which is why we will gradually switch from glass bottles to cans…" (Czech CR, Food and Beverages cluster)

- "Sustainability is the strategic goal at our company, but unfortunately the deciding factor for most companies is still the price. […] The importance of this varies, especially from region to region, in the EU it is important, in China it is not worth mentioning…" (Hungarian CR, Building Materials and Furniture)

- "Recycling measures and circular economy are fundamental at our company and have been for 50-60 years. This is deeply embedded in the company's DNA and increasingly demanded by customers like IKEA. Meeting 100% recycling goals is possible with proper adjustment and commitment." (Austrian CR, Building Materials and Furniture/large wood manufacturer)

Diabolical Nature of Governmental Activities

One of the main aims of conducting in-depth interviews and qualitative analysis was to explore whether eroded trust in official authorities—whether regional, governmental, or European—could serve as a significant barrier to the adoption of twin transition technologies. In many countries, trust in political representatives, state organs, and expert institutions has reached an all-time low (Marozzi, 2015). However, this (mis)trust is not uniformly distributed across European countries and regions. While individuals may perceive their national governments as corrupt or ineffective, they might still have confidence in international laws and regulations, such as those from the European Commission. Conversely, some may be sceptical of the EU but driven by nationalistic or local sentiments, might support local sustainability efforts or prefer locally produced goods.

This complexity deepens when considering individuals' beliefs about global warming, which can also correlate with a lack of trust in state institutions. The interplay of these factors suggests that attitudes towards various authorities, expert institutions, and regulatory bodies can significantly influence how businesses perceive and engage with twin transition technologies. Fortunately, no signs of global warming denialism were observed in the data corpus.

Naturally, some negative perceptions of governmental activities, particularly regarding regulatory compliance, were consistently found in the interview dataset. These perceptions ranged from existential fears about future taxation policies to frustrations with the complexity and impracticality of online systems, and the view that green regulatory compliance is an unnecessary burden:

- "Compliance requests are now the rule for orders. In addition to the EU regulations, however, there are many country-specific or sometimes even region-specific ones. Information on content and deadlines is often available in a particular national language only. I think that kind of information should be provided in all national languages." (Austrian CR, Machinery and Equipment)

- "Currently, we have too many different tools for communication with authorities, each has a different access. A kind of (small) business cockpit would be helpful here." (the very same Austrian CR, Machinery and Equipment cluster)

- "We are afraid of government measures and new taxation policies" (Slovenian CR, Plastics and Rubber cluster)

- "Green projects are highlighted, compliance with regulatory requirements set by the government is monitored internally, which takes a lot of time. But in return, these activities do not add anything to the value of the company." (Hungarian CR, Other/Cosmetics)

In the last two cases, where interviewees expressed stronger feelings of fear or viewed green compliance as an alienated activity that doesn't make sense for their business, such negative stances could indeed act as disablers in the further acceptance of twin transition technologies. It's true that SMEs and individuals are often coerced into these activities—whether writing compliance reports, reading regulatory documentation, or incorporating new technologies—but many interviewees acknowledged that regulatory sanctions and impositions are effective in changing business habits. While SMEs are aware of the bureaucratic burdens that regulations can impose, they also recognize that regulation can act as an enabler, especially when coupled with public grants or government subsidies:

- "As for integrating new technology into the manufacturing process, I see state and European subsidies as a great enabler. Legislation forces companies to act." (Polish CR, Plastics and Rubber cluster)

- "Well, public funding are carrots and if not complying… then penalties are sticks, in very concrete figures in my case." (Slovenian CR, Food and Beverages cluster – agriculture)

Some of the interviewees shared their experience with obtaining government grants or subsidies, which bolstered their technology acceptance and accelerated the digital or green maturity of their companies:

- "Government grants and funding dedicated to environmental sustainability projects are leveraged to support initiatives like renewable energy adoption, waste management improvements, and carbon footprint reduction. For instance, we utilized a green grant to install solar panels in our facilities, reducing our reliance on non-renewable energy sources." (Czech CR, Food and Beverages cluster)

- "We won government funding three times. It is a long process to get these funds, also a part of it has to be repaid and only a part of it not repayable, if you meet the conditions. We won funding in IT development, by which we increased, optimized and improved quality of our artisan pizza production capacity. Out of these projects, we enhanced the technological capabilities of the pizza production plant." (Hungarian CR, Food and Beverages cluster)

- "In the past, we have obtained some governmental funding on both levels, state and European, including for some sustainability improvements, such as solar plants…" (German CR, Metal and Metal Products)

However, as the Hungarian representative admitted, the process of applying for funding is an organisationally time-consuming challenge. This ambivalence towards governmental activities was common across the dataset. While there were frequent requests for subsidies to accelerate sustainability efforts and technological innovations, applying for funding often presents similar problems, or poses too great a risk relative to the time and effort required:

- "There are several funding opportunities and the fragmentation of information is the most critical aspect in this respect…" (Italian CR, Electronics and Software cluster)

- "The biggest problems are finances. Subsidized degrees are very time-consuming and built on drawing a higher volume of funds. […] However, we would like to achieve any support from the government." (Czech CR, Building Materials and Furniture cluster)

- "Subsidies are too much extra work and the lengthy process doesn't really pay off for our boss." (Austrian CR, Building Materials and Furniture – small sized joinery manufacturer)

Similar challenges arise when companies face new requirements like the Digital Product Passport or struggle with identifying suitable green KPIs that align with tightening regulations. These examples highlight the need for shifts in business paradigms, requiring types of knowledge or time capacities that SMEs currently lack.

- "We are aware of future issues with digital passports for our products… This will probably be awkward, since we are only producing one unique product in one piece only or small batches… So, calculations of ESG reporting might represent a problem. We would be eager to have some sort of a calculational tool for that…" (Slovenian CR, Metal and Metal Products cluster)

- "An interesting challenge is the identification of proper green KPIs, aligned with the more and more strict regulation, and measured in a proper way. This could require additional skills and competences, currently not present within the company…" (Italian CR, Electronics and Software cluster)

- "I really don't have an idea on how to handle ESG certification… In the future, I might consider hiring an external expert to help me with the product passport." (Slovenian CR, Building Materials and Furniture cluster)

In a few specific instances, interviewees discussed regulatory compliance in more neutral terms, treating it as a given. They even acknowledged the potential for automating compliance reports and, interestingly, established a connection between regulatory aspects of the twin transition and the overall vitality of an average company:

- "The sustainability report is an integral part of our operations and is now a mandatory requirement." (Austrian CR, Building Materials and Furniture – larger wood manufacturer)

- "We use digital tools to track regulatory requirements and generate compliance reports automatically." (Czech CR, Other/Production of printing and advertising materials)

- "Anything that can be reasonably done here makes sense for a healthy, growing company, and much will have to be done anyway because of the upcoming legislative changes" (German CR, Machinery and Equipment cluster)

Rarer, on the other hand, were the situations when the necessitated implemented compliances were given the chance to be incorporated to other business processes, enhancing the product, service or the value of the company:

- "We are monitoring emissions as a part of our quality assurance." (Hungarian CR, Plastics and Rubber cluster)

- "Regarding the Digital Product Passport, the main challenge is the collection and analysis of relevant data avoiding overwhelming information and overcoming information complexity… here, data categorization is fundamental, although it requires time. I see data management as something that is important inside and outside the company… in terms of internal development, but also as an additional service to provide to company customers." (Italian CR, Machinery and Equipment cluster)

The rarest instance in the dataset was that where a representative was almost close to expressing some sort of enthusiasm or support for green policies and regulations, particularly those of the European Union:

- "If you ask me, I see political initiatives for sustainability as something positive, and not as something that can potentially threaten the viability of this company, as many other seem to do. It is more likely for Brussels to do things that are beneficial for SMEs right now than the German Federal Government…" (German CR, Machinery and Equipment cluster)

Regulatory frameworks often aim for legal consistency and coherence. However, European policies are frequently driven by public concerns and based on the "precautionary principles" or "preventive principles" of risk management, particularly with new and emerging technologies. These principles have guided European Union regulations since the mid-90s, particularly in biotechnology, ensuring safe food and preventing unpredictable consequences of genetically modified organisms.
Yet, these precautionary regulations, by focusing intently on the process of production, can pose challenges to agricultural or food manufacturing innovations:

- "Our company encounters challenges in the circular transition primarily related to regulatory aspects. The current EU regulations are not fully aligned with our new products and technologies, posing risks to its seamless integration. Regulatory approval pathways for alternatives to traditional synthetic products in agriculture are not well-established, adding uncertainty to our circular transition efforts." (Polish CR, Food and Beverages cluster)

- "One of the main challenges in food and drinks sector is the introduction of advanced or recycled materials that are more sustainable but also compliant with the food contact and ingestion requirements" (Italian CR, Food and Beverages cluster)

Some Food and Beverages SMEs, therefore, face a common challenge: they prefer preventive forms of regulation that emphasize safety, quality, and efficacy in the manufacturing process. These regulations focus on ensuring that the final products meet stringent standards, regardless of the method of production or the potential risks associated with the materials involved. This cautious regulatory approach, while essential for consumer protection, can sometimes create hurdles for companies trying to innovate with new, sustainable, or recycled materials. Balancing the need for safety with the drive for innovation remains a critical challenge for these SMEs as they navigate the twin transition.

Challenges of Digitization and Datafication

An important theme for detecting the technological (in)practicalities of SMEs revolves around various challenges posed by their manufacturing equipment and universal issues related to digital equipment. These challenges include the possibilities of standardizing, integrating, or making systems interoperable, the utility of datafication and metadata, and the feasibility of remote maintenance. Additionally, some SMEs expressed concerns about the suitability of digitization for certain social activities requiring direct human interaction, although leaving these activities undigitized does not really hinder the twin transition. The difficulties related to digitization and datafication were most prominently found in the Machinery and Equipment, Building Materials and Furniture clusters, with some presence in the Electronics and Software, and Metal and Metal Products clusters, although the list is not complete.

As SMEs have evolved in different historical contexts, cultural settings, political regimes, and resource proximities, their machinery and equipment often reflect these diverse backgrounds. The most extensively reported issue was **the standardization** of different machine components or production process. This problem can arise due to various software issues, such as software that renders machines obsolete or fails to be as efficient, personalized, or user-friendly as SMEs had anticipated. In some cases, the issue isn't with the software itself, but with the production process, where different materials require different temperatures, produce excessive waste, or necessitate significant cleaning before another production process can begin.

Additionally, some SMEs have accumulated equipment over different periods, resulting in a mix of machinery that includes pieces classified as "non-standard configuration" types. This layering of standardization problems—ranging from software issues to hardware difficulties and production line challenges—creates a complex and multifaceted barrier to achieving efficiency and integration in their operations:

- “Most of our machines have CNC control and they report if something is wrong. If something is wrong with the handwritten programme for the machine, the machine cannot know… Or if someone manipulates something, the machine can’t do anything either. […] The control system is the KO criterion for the machines… Many machines were still running on DOS, where you can’t make automated backups, and every few months you went down, removed the PC and made a backup manually. DOS machines have been upgraded to XP… I’m trying to say that machines would me mechanically much more durable… Of course there are companies, that would upgrade the machine with new controls, but this leads to considerable costs… If you upgrade the machine with the operating system, you would have to rebuild the whole machine… But that’s not true, the reverse could be possible…” (Austrian CR, Building Materials and Furniture cluster)

- “Our flagship product is bent glass, which must be customized to meet specific customer needs, making standardization nearly impossible – this complicates creating a closed catalogue that could be used in an e-shop. Each order is individually prices, and the company does not use digital tools for this. […] The production of flat glass is less complicated, made from pre-made sheets and is partially automated, although there is still room for improvement. We monitor the amount of material used at each production station manually through spreadsheets, as there is no software in place for this. The production of bent glass requires significant human involvement and is not automated.” (Polish CR, Building Materials and Furniture cluster)

- "There are currently only two software partners in window production, so we are currently a bit stuck here… The software partners are old and sluggish, so it would be a great saving for our employees, if ideal software were available…" (Austrian CR, Building Materials and Furniture cluster)

- "We currently use a Hungarian software for monitoring inbound and outbound logistics processes with a QR code system and cloud-based software, but we want to customize it according to our needs […] We have atypical manufacturing as we do not manufacture to stock. Rather, we are located between pilot laboratories and manufacturing companies […] We currently have no plans to introduce AI down the production line, mainly because of time and waste of intermediate cleaning, as each material requires different machine temperature." (Hungarian CR, Plastics and Rubber cluster)

- "We are much experience in company-wide ERP, especially due to recent advancements in production planning. Yet, we are still experiencing difficulties in some areas like maintenance planning, as certain parts have different expected lifespans, such as rubber seals. A lot of still depends on unpredictable factors, which means we must rely on internal experience to predict what can be predicted and ensure reasonable levels of material and employee time is available to deal with such disruptions." (German CR, Machinery and Equipment cluster)

- "In some areas, we are working with machinery of different ages and origins… like with two simple grinding machines that date back to the 1970s, some of them also of a non-standard configurations… I find it difficult to apply generalized solutions in certain areas, especially in maintenance prediction… It would be nice to have it for things like grinding wheels, but I think it would be very challenging to build models that are more reliable than the memory and experience of our workers…" (German CR, Metal and Metal Products cluster)

In their business processes, SMEs typically need to integrate employees, resources, machinery, and customers into a cohesive workflow. Although technological systems offer various features and capabilities, their full utility often remains unrealized for several reasons. Even when heterogeneous technologies are successfully integrated into a functioning system, the resulting complexity can ultimately frustrate the customer:

- "Hmmm, interesting question… We have different levels of technology equipment, from very simple or no-brain machines to automated ones… How to connect them into a smart grid?" (Slovenian CR, Building Materials and Furniture cluster)

- "We utilize a VIR system for optimizing production schedules to meet demand and maximize efficiency. The use of VIR is comprehensive, including tasks like offer preparation, material procurement, manufacturing, product delivery, and maintenance, not to mention real-time inventory tracking and predictive maintenance, although we haven't fully utilized the latter." (Hungarian CR, Plastics and Rubber industry cluster)

- "It is hard to integrate different technologies to cover the different steps (e.g., material received from the suppliers, the storing in different locations and the distribution and delivery to different customers or intermediaries) and the obtainment of the final output in a way that is readable and effective for several customers." (Italian CR, Electronics and Software cluster)

Due to the described problems of standardization and integration, quite a few company representatives questioned the value of data analytics, as this would only add another layer of complexity to an already diverse production process. On the other hand, one interviewee does not even see the company's production process as capable of being integrated into a loop, as he considers most of the production to

be linear. Another issue with data analytics and datafication is the question of whether meaningful insights can truly be derived from them. Not all human or machine interactions can be datafied and extracted for business gains, although this is something the AI and Big Data industries are not too keen on admitting. Two other respondents were more open to the potential of data analytics, but with the caveat that effective data management and algorithmic refinement bring a host of additional challenges that the company would need to address if the collected data is to be valuable:

- "We see limited potential in advanced data analytics in general. With our products being mainly conveyor technology and materials handling, the process usually needs to function within a fairly standard set of predictable parameters and has to play well with other, third-party machinery, and almost never just stands for itself." (German CR, Machinery and Equipment cluster)

- "It is difficult to imagine what role advanced data analysis could play considering most of our production processes are relatively linear…" (German CR, Other/Textile industry)

- "Customer support hasn't… and possibly can't be standardized enough for data analytics to play a meaningful role in day-to-day activities, but satisfaction metrics are of course tracked as stated here… We also have an internal and updated dossiers on all core customers…" (German CR, Building Materials and Furniture cluster)

- "Electronics will be one of the first sectors that will adopt the Digital Product Passport (DPP) where data will be essential. However, the type of data to be collected, how to manage it, who will have the access and other information are still unclear. The main challenge is therefore related to management of information flow to allow a green approach of the company." (Italian CR, Electronics and Software cluster)

- "Predictive maintenance predicts equipment failures using sensors and SCADA. Algorithms get smarter with more data. […] Sustainability KPIs like carbon footprint and resource usage are measured and tracked using digital dashboards and reporting tools. Data is collected from various sources and analyzed to monitor progress towards sustainability goals." (Czech CR, Electronics and Software industry cluster)

The challenges SMEs face with digitization are often exacerbated by **the complexity of integrating new technologies with existing processes**. Although AI tools and IoT sensors are promoted as solutions for handling complexity, their effectiveness is limited if the production process hasn't been digitally mapped or if digital production planning systems are too complex for employees to implement. SMEs engaged in craft production or creating unique pieces particularly struggle with the absence of standardisation and datafication, as they often lack precedential digitization. This niche market is less attractive to software developers, who might charge high fees for labour-intensive projects. As a result, many SMEs find complexity to be a costly endeavour, as reflected in the experiences shared by interviewees:

- "Sustainability currently has a priority over digitization. […] If you are a B2B company in the premium sector, personal contact is highly valued. Another challenge I would say is in data analysis and automation – certain processes are not yet digitally mapped. Each process is mapped once until the entire process is set up in production. It takes a lot of resources because it is simply time-consuming and cost-intensive, not to mention the lack of background on what options are available. In some cases, a lot of programming is done in-house, because there are no providers are they are too expensive." (Austrian CR, Metal and Metal Products/Heating Systems Production)

- "Previous attempts at digital production planning were failures: too complex, too much effort, too little acceptance among employees. Whiteboards are currently being used. Existing merchandise management systems do not meet the requirements of a small craft business." (Austrian CR, Machinery and Equipment cluster)

- "Products are labelled with unique barcodes for easier organisation and tracking. This system is costly because it requires ordering a minimum of 40,000 bags per barcode. Each different pasta shape has a separate barcode, increasing the complexity and cost of inventory tracking. Despite the costs, this system allows for precise inventory management." (Another Hungarian CR, Food and Beverages cluster)

- "We are a special machine construction firm, so some of the proposed systems of advanced digital tools are impossible to realise, given the great complexity and variability of our products" (German CR, Machinery and Equipment cluster)

In some cases, digitization through remote machine diagnostics is seen as a value-added service that can enhance a company's competitive edge and client loyalty. However, providing this service is not always straightforward, requiring cooperation with clients and existing digital tools:

- "Customers are always more demanding. Currently, the possibility to have remote connection for the maintenance and the control of equipment is more and more required, but it is not easy to offer this service to the customers. In the end, digitization of product and lines, together with user-friendly interface, is fundamental." (Italian CR, Machinery and Equipment cluster)

- "Remote inspections are done with the help of the customer, and afterwards, service missions are scheduled based on the insights gleaned, if they are necessary… […] Repair part demand is calculated and forecast via ERP. There are no software tools specific to on-site servicing, as technicians use the same tools available when doing remote diagnostics… […] Customers are almost always happy about remote diagnostics and issue analysis as it helps minimize downtime and, if a service mission is necessary after all, ensure that the technicians bring the correct spare parts." (German CR, Building Materials and Furniture cluster)

A consistent preference emerged among many interviewed representatives for real-life, direct interactions over virtual communication and digitization. This sentiment was expressed across various business activities, such as customer engagement, advertising, attending company presentations, and even during recruitment and employee onboarding processes. The representatives valued face-to-face contact and believed it provided more meaningful and effective communication compared to digital alternatives like AI customer systems or virtual presentations at industry events. This stance highlights a scepticism towards fully replacing traditional, personal interactions with digital methods in those more social areas of business.

- "We have an interest in AI customer communication, but are concerned about its unclear benefits and about what will happen if we stop maintaining personal contacts…" (Austrian CR, Machinery and Equipment cluster)

- "Streaming real events is becoming increasingly popular, as it allows customers who are unwilling or unable to travel to our premises to take part. It has to be said, however, that such in-house event is no substitute for a trade fair. At a trade fair, visitors are interested in gathering information, finding out about new products and making contacts, all without obligation. On the other hand, a pure transfer of know-how also works excellently online. In the end, the pandemic showed just how important direct

personal contact is." (Polish CR, Machinery and Equipment cluster – larger manufacturer of high-quality measuring and testing technology)

- "Trend analysis is mainly realized in an analogue way by attending trade fairs and industry conferences, and by talking to customers and suppliers. There is little chance of digitizing this process, and, if anything, Covid-years have demonstrated that people talking to a screen or watching some broadcast is a poor substitute for actually being there and making personal contacts." (German CR, Metal and Metal Products)

- "We primarily utilize traditional methods such as direct contacts, participation in fairs, meet-and-greet days… and other offline channels to promote our products and engage with customers. While we acknowledge the importance of digital platforms in today's marketing landscape, we have not actively incorporated them in our advertising strategies for several reasons… one of the main reasons for not extensively using digital platforms is out target audience's preferences and behaviour… Many of our customers, particularly in out niche market, still prefer personal and face-to-face interactions over digital communication." (Polish CR, Machinery and Equipment cluster)

- "We don't have a digital learning platform and no digital training, as we don't really see any benefits in these aspects – digital platforms cost a lot of money and they would not pay off with the number of apprentices." (Austrian CR, Machinery and Equipment cluster)

- "Recruiting process was carried out online, but didn't yield much… local newspapers turned out to be the most successful…" (Austrian CR, Building Materials and Furniture cluster)

Relevant and Outdated Benchmarking Criteria

The theme of benchmarking mostly emerged in the interviews with predominantly larger SMEs and exclusively in the context of sustainability. The common industry clusters at which the explanations or discussions on benchmarking criteria for highly advanced green maturity were repeated were usually not just concentrated in more innovation-prone sectors (such as Electronics manufacturing or Automotive sector) but also present in the examples of food and wood processing and production. Notably, the wood manufacturer is a larger company, while the frozen food manufacturer employs around 20 people. All companies whose representatives are cited in the next few bullet points are highly advanced in terms of green maturity:

- "We have our own internal rules on what and how to recycle. We even purify used water, which is then after checking to meet water standards released back to the environment. Waste products are reused in a circular manner, with buy-backs under some other agreements" (Hungarian CR, Building Materials and Furniture cluster)

- "We are using some circular economy indicators, namely for the recovery of plastic castings in the injection of new products, waste production index and waste management index." (Polish CR, Electronics and Software cluster/Automotive sector)

- "The company considers green practices very important. We utilize all organic waste, categorizing it into three groups: A-grade quality products to go to major markets, B-grade products, which are misshapen or otherwise do not meet A-grade standards, but are perfectly edible and sold to institutions like prisons. C-grade products, not suitable for human consumption, are given to animals. The system operates on the FIFO principle, supplemented by considering the expiration date. "When

designing packaging, customer requests are taken into account, but products can also come without external boxes. Thanks to these technologies, only 2% of the remaining waste cannot be reused, with the rest being fully recycled." (same Hungarian CR, Food and beverages production)" (Hungarian CR, Food and Beverages sector/Frozen product manufacturer)

Such benchmarking criteria for demonstrating sustainability (e.g., water purification, calculating waste production indexes or utilising all organic waste) can hardly be useful for a central European representative smaller company from some other industry cluster which may produce more waste from plastics, chemicals, wood, glass etc. However, two of the respondents have described a simpler and more intuitive principles by which they benchmark their sustainability efforts in calculating GHG emissions:

- "The company has strong control over Scope 1 emissions and manages Scope 2 effectively. Scope 3 presents a challenge, primarily due to the high CO2 footprint of glue, derived from oil and gas. The company produces 30-40% of its glue needs in-house using green electricity from their power plants." (Austrian CR, Building Materials and Furniture/large wood manufacturer)

- "The company has taken a firm step in environmental accountability by calculating CO2 emissions generated from its operations during the 2022 financial year. We followed the GHG Protocol methodology for managing and reporting CO2 emissions. The emissions identified in the company's business value chain are categorized into three scopes: Scope 1 includes emissions from the company's vehicle fleet, and fuel consumption is carefully monitored. Next, Scope 2 are emissions linked to electricity use and measured using market-based and location-based methodologies. Whereas Scope 3 encompasses emissions from purchased goods and services, purchased capital goods, fuel and energy-related activities, upstream transport and distribution, waste generation, business travel, employee commuting, downstream transportation and distribution, and use of traded products." (same Polish CR, Electronics and Software cluster/Automotive sector)

In certain cases, the most intuitive benchmarking tool for demonstrating sustainability efforts was comparing digitised advertising business processes with the issue of paper consumption:

- "We use various digital platforms such as social media, email marketing and online advertising to promote our products. […] Digital advertising helps to reduce our environmental footprint by cutting down on paper usage, energy consumption, and reaching a wide audience." (Czech CR, Food and Beverages cluster)

- "The company is making strides toward eco-friendly advertising, with efforts to reduce paper and promote sustainable products. Digital ads are preferred to minimise physical waste." (Hungarian CR, Other/Cosmetics)

Comparisons between digital and paper impacts can be made either globally for the paper and IT sectors or by examining the marginal impacts of the specific products being compared. A common mistake, however, is failing to consider other impacts, such as the volume of material inputs, toxicity, energy and water use, air and water emissions, solid waste, and recyclability. Although digital solutions might appear inherently cleaner because they are not material in the same way as paper, digital advertising infrastructure—including high-processing hardware, complex machine learning models used in programmatic advertising, and numerous data centres—consumes vast amounts of energy, uses significant water resources for cooling systems, generates electronic waste, and suffers from inadequate recycling options. Such simplistic digital vs. paper comparisons can be misleading, especially in the context of the lavish digital advertising industry.

The current green benchmarking criteria landscape is hectic, including various certificates intended for energy management systems, quality management systems, social accountability or sustainable goals reporting. Some larger companies set environmental objectives for specific year and for an individual production sites, while others struggle with self-comparisons or have at least some basic ideas on how to set a target regarding the share of recycled materials and benchmarking themselves against Northern European examples:

- "We lack a common database of what targets we should meet – we just cannot benchmark our own numbers of waste and recycling against others, there isn't really any external target set." (Hungarian CR, Building Materials and Furniture cluster)

- "We are aiming to fast-track a project to process at least 30% of tyres, fitting into the circular economy. This initiative targets the lower tyre usage rates in Hungary compared to Northern Europe, presenting an opportunity for improvement." (Hungarian CR, Plastics and Rubber cluster)

- "The Poland plant has set its environmental objectives for 2022, which include obtaining and maintaining ISO 14001 certification, raising environmental awareness among employees, reducing waste production, and ensuring gas and dust emission levels remain within established limits." (Polish CR, Electronics and Software cluster/Automotive sector)

However, although interview respondents did not explicitly use the term "benchmarking" when discussing digital technologies, a latent notion of benchmarking digital maturity emerged, based on the criteria of (1) usability (i.e., how effectively it is being used across the company) and (2) the number of key business processes a company carries out with automated machinery, software systems, or advanced digital tools. Many interviewed companies have already implemented ERP systems, while some more advanced companies with larger production capacities have equipped their products with barcodes and cloud-based software for organisation and tracking. Another level can be spotted in a lesser share of companies which perform systematic analyses of production errors and scrap. A small number of interviewees described their manufacturing processes and organisational and managerial processes as being more fully automated and integrated with other software systems or sensors in such a manner that their industrial operations can be more extensively controlled or improved for efficiency with data analytics.

Politicized Resources

The final extracted theme emerged only in a few interviews, revealing limited engagement with political discussions or current events. Criticism of regulatory and policy landscapes, particularly their fragmentation across local, national, and European levels, was rare. Contrary to expectations, there were no extensive critiques of green political programs. Instead, only subtle political sentiments appeared occasionally, particularly when Austrian and Hungarian interviewees discussed their sources of raw materials, compliance checks, or long-term supply management plans:

- "We need to manage the sourcing of raw materials within the EU in the long term, as we currently have them around EU and across Asia… " (Hungarian CR, Building Materials and Furniture cluster)

- "Individual or country-specific compliance cannot be digitized or made more sustainable… With partners in challenging countries such as Russia, China or North Korea, compliance checks are very important and very bureaucratic." (Austrian CR, Machinery and Equipment cluster)

- "Individual or country-specific compliance cannot be digitized or made more sustainable… With partners in challenging countries such as Russia, China or North Korea, compliance checks are very important and very bureaucratic." (Austrian CR, Machinery and Equipment cluster)

- "We need to further boycott business connections with Russia." (another Austrian CR, Machinery and Equipment cluster)

Interestingly, the perspectives on supply chains between Hungary and Austria highlight distinct approaches shaped by their geographical sourcing strategies and market focus. According to a November 2023 survey, Hungary exhibits a significant reliance on both EU and non-EU suppliers, with 26.8% of its key suppliers located outside the European Union. This diverse sourcing strategy might reflect Hungary's broader international trade connections and perhaps a necessity to secure competitive pricing or specialised materials from a global network.
In stark contrast, only 5.8% of Austrian companies reported having key suppliers both within and outside the EU. This figure underscores a more localized and EU-centric sourcing approach. Austrian SMEs, in particular, emphasized local sourcing, compliance with FCC guidance, and adherence to Advantage Austria network activities, reflecting a commitment to sustainability and local community support:

- "We source industrial wood from sawmills and collect and reprocess old wood. We follow certification systems like FCC to ensure wood is sourced from sustainable forestry. The supply chain law is also relevant, requiring regular FCC audits by certification bodies. Countries are assessed by risk, and stakeholder surveys are necessary. Processes must be transparently documented in the system to ensure certification. Group certification is completed for Austria and Western locations, ensuring supplier sustainability." (Austrian CR, Building Materials and Furniture – wood supply manufacturer)

- "We operate only in Salzburg, where there are also regular sales and our materials are stored… […] We only produce through orders […] A point I would like to make, is that our company bets on the quality and durability of our products, since our main customers are the communities – different hoteliers, restaurants, residential buildings, kinder gardens…" (Austrian CR, Building Materials and Furniture cluster – joinery manufacturer)

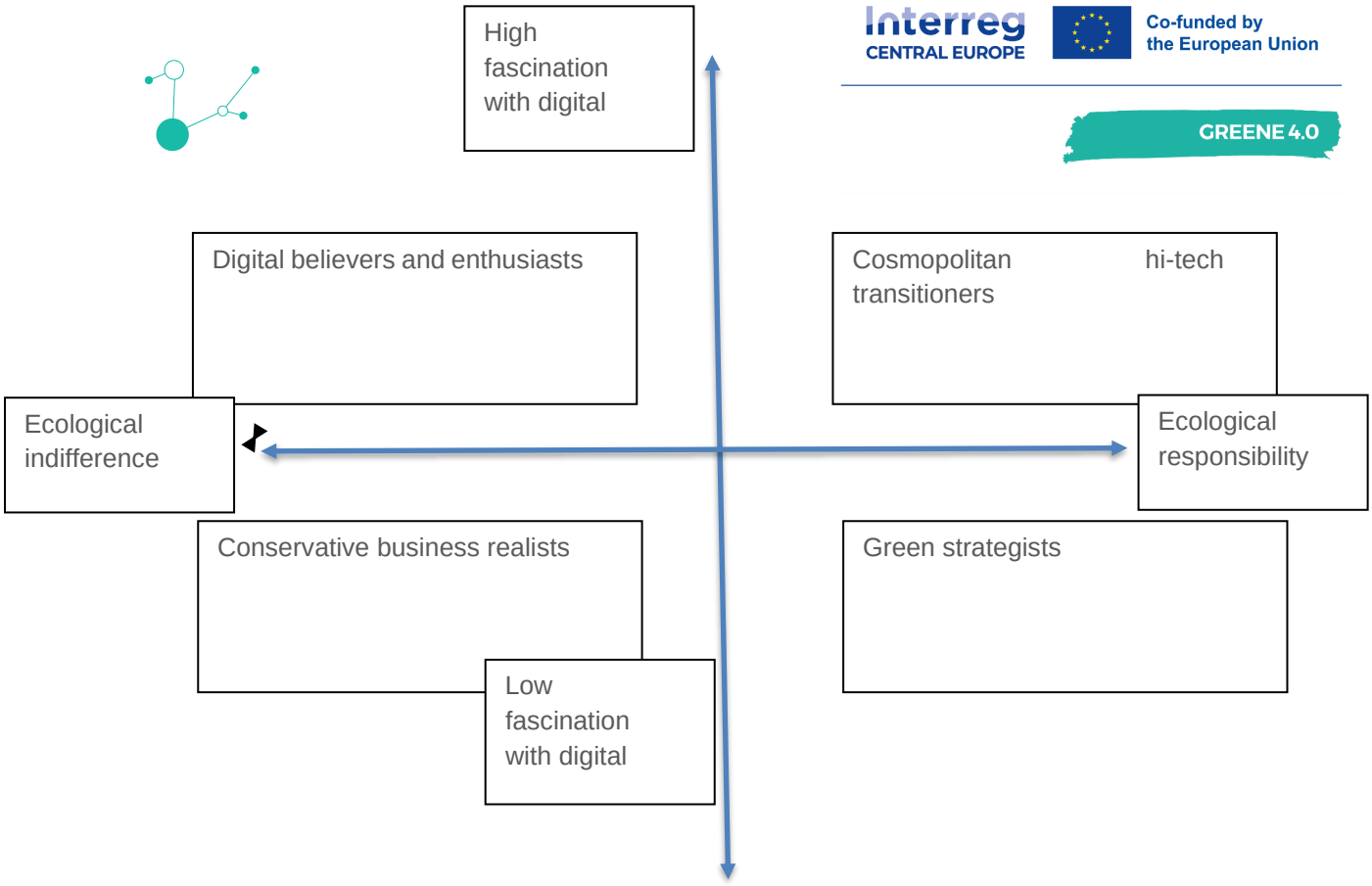
- "Mmmm, our supply chains lack visibility on sustainability aspects…" (Austrian CR, Metal and Metal Products cluster)

This theme of politicized resources highlights a potential enabler for the twin transition in Austrian SMEs: the importance of supply chain visibility and the adherence to democratic values.

Model Building

The proposed model categorizes SMEs into four ideal types based on two primary axes: the level of fascination with digital technologies and the degree of ecological responsibility. This model is built to capture and represent the attitudes, values, and behaviors of SMEs in relation to the twin transitions of digitalization and ecological sustainability from the pilot dataset.

- **Digital Fascination:** represents the degree to which a company is intrigued by and committed to adopting digital technologies.
- **Ecological Responsibility:** Reflects the extent of a company's commitment to ecological sustainability, ranging from ecological indifference to ecological responsibility.



In the second step, the described axes can be used to equip the model with 4 ideal types:

1. An ecologically indifferent type with high digital fascination, i.e., **Digital Believers and Enthusiasts**
2. An ecologically indifferent type with low digital fascination, i.e., **Conservative Business Realists**
3. An ecologically responsible type with low digital fascination, i.e., **Green Strategists**
4. An ecologically responsible type with high digital fascination, i.e., **Cosmopolitan Hi-tech Transitioners**

This four-typology model is flexible enough to accommodate the UAM maturity assessment scores, though it does not align perfectly with them, as the model was primarily built to capture and represent attitudes and value orientations. The acceptance of digital technologies can, to some extent, influence the acceptance of the twin transition. However, when paired with ecological indifference, SMEs may end up overemphasising digital solutions and perpetuating the misconception that green business practices are merely a byproduct of digital adoption. This can lead to an approach of "the more digitized, the better," which is not aligned with sustainable principles, let alone with the principles of a circular economy. We believe that companies in the Electronics and Software industry cluster are more prone to this scenario. Moreover, companies with high levels of digital fascination may end up digitizing not only their core value-driving business processes but also spending excessive time and resources digitizing marginal processes, such as advertising, onboarding, or recruitment. Another issue worth mentioning is the digitization of customer contact and communication, which may not always be well-received by customers who are averse to endless chatbots and automated messages.

However, depending on the industry cluster, company size, and production capacities, digitizing production lines can at least trigger some green effects, even if the company is ecologically indifferent. This can be achieved through cost reduction and process optimization, leading to increased energy efficiency and waste reduction. On the other hand, poorly planned or rushed digitization of manufacturing processes carries the risk of adopting digital solutions too early or without adequate employee competencies, resulting in underutilized technological systems.

Even so, the acceptance of twin transitioning may be harder to achieve if fascination with digital technologies remains low. This might be true only at first glance, as companies with low digital fascination

may carefully automate certain parts of their production or implement partial automation in a way that yields significant business benefits. Of course, this depends on various factors, including the company's market position or niche, the choice of software partners for successful implementation, workforce digital competencies, and whether the company intends to scale up in the near future.

The smaller SMEs are in the most challenging position, especially those engaged in craft production, as they may neglect opportunities for digital planning and automation in manufacturing. These companies often suffer from an aging workforce and a lack of digital skills. The future burden of complying with green transition regulations may overwhelm them, particularly if paired with insufficient digital competencies. Regions with younger SMEs of this type are in a worse position than countries with older family businesses that can rely on extensive knowledge and long-term expertise. Industry clusters at risk include Metal and Metal Products, and Building Materials and Furniture, with the Machinery and Equipment cluster being somewhat less vulnerable.

The majority of interviewed representatives were classified as Conservative Business Realists or Digital Believers and Enthusiasts, though the UAM pilot sample did include a few examples of Green Strategists and Cosmopolitan Hi-Tech Transitioners. Since the GREENE 4.0 project aims to assist companies with the combinations of attitudes described above (i.e., high digital fascination and ecological indifference, and low digital fascination and ecological indifference), we will not discuss possible scenarios for SME cohorts that are ecologically responsible but vary in their level of digital fascination. However, it is worth noting that we found examples of Green Strategists among companies in the Building Materials and Furniture, and Food and Beverages clusters, and a few Cosmopolitan Hi-Tech Transitioners among predominantly larger companies in the Machinery and Equipment (specifically in the automotive sector), Building Materials and Furniture, and Food and Beverages clusters.

However, we will shortly describe the constructed typologies:

1. Digital Believers and Enthusiasts (High Digital Fascination, Low Ecological Responsibility)
   - Over-value digital transition, often equating it with being 'greener' or inherently sustainable
   - Lack focused strategies that align digitization with circular economy principles, especially regarding product life cycles
   - View green business practices and regulations as external burdens with limited economic feasibility, except in energy efficiency
   - Have the potential to further integrate or automate business operations but are prone to green-washing rhetoric and digitizing marginal business processes

2. Conservative Business Realists (Low Digital Fascination, Low Ecological Responsibility)
   - Do not perceive themselves as active participants in the twin transition, viewing it as the domain of larger companies
   - Their small scale may act as a barrier to digitization, leading to a disenchanted attitude or a more critical approach towards digital technologies
   - their approach to sustainable business practices is sporadic or coincidental, with varying degrees of commitment to sustainability
   - they are cautious about incorporating digital technologies or automation into manufacturing process, preferring steady development and workflow changes over ambitious investments
   - may have a better understanding of their market position (when compared to digital enthusiasts and techno-believers)

3. Green Strategists (Low Digital Fascination, High Ecological Responsibility)
   - Proactively engage in the twin transition, regardless of the company size

- aim to position themselves with green products or by designing production lines in accordance with circular economy principles, potentially obtaining a certificate or adopting a green standard
- take a selective approach towards digital technologies and automation, favouring indirect digital transition
- push for the integration of sustainability metrics in their KPIs
- actively seek grants and funding to support their green initiatives

4. Cosmopolitan Hi-Tech Transitioners (High Digital Fascination, High Ecological Responsibility):
   - Twin-transitioning for them represents the terrain of competition
   - The distinction between digital and green initiatives becomes blurred or less irrelevant in their operations
   - Predominantly larger companies with industrial operations managed and optimized through data analytics to achieve sustainability goals
   - Industrial operations are controlled or improved for efficiency with data analytics and reaching the sustainable goals
   - Implement Life Cycle Assessment for their products and sustainable use of water resources
   - Already follows a specific sustainable methodology or framework
   - Do not neglect employee well-being and sustainable means of transportation

PARTNER ANALYTICAL REPORTS

Slovenia

In Slovenia, PTP interviewed 10 companies: 3 from the metal and metal products industry cluster, 1 from the machinery and equipment, 1 from the food and beverages sector, 2 from the plastics and rubber, 2 from the building materials and furniture, and 1 additional company, categorized as 'Other' (namely, from the textile sector).
For the Slovenian companies in **metal and metal products**, the assessment revealed the following:

- Medium digital and low to medium green maturity on average
- Identified key business processes: manufacturing operations; planning and monitoring the quality; infrastructure, organization and management (tools for calculations); inbound/outbound logistics (due to the problem of traceability)
- As significant barriers, time constraints, lack of technology scouting, technology-implementation challenges and the lack of required expertise were highlighted.
- The most notable issues can be summarized as the need for better tools for production planning (e.g., bar/QR tagging), real-time data access or datafication (MES; ERP) and a suitable ROI calculator for the technological novelties

For the Slovenian company producing **machinery and equipment**, the assessment revealed the following:

- Medium digital and low to medium maturity on average
- Identified key business processes: Manufacturing category
- As significant barriers, time constraints, lack of in-house expertise, training challenges and large investment requirements were highlighted.
- The most notable issues can be summarized as the need for a sustainable strategy development and ESG reporting, improving quality control, the lack of real-time data and AI integration

For the Slovenian company in **food and beverages**, the assessment revealed the following:

- Medium digital and low to medium green maturity
- As significant barriers, skills and knowledge gaps, time constraints, funding issues and finding an suitable technological solution were stated
- The most notable issues can be summarized as the need for production planning, CRM and ERP systems, energy efficiency and waste management

For the Slovenian companies in **building materials and furniture**, the assessment revealed the following:

- Low digital and low green maturity on average (one company with minimal scores and another with a CRM system and a complete digitization of paperwork)
- Identified key business processes: most of the manufacturing operations (planning, stocking, calculations, outbound logistics), finances and sales
- As significant barriers, lack of developmental vision, lack of skills and knowledge (in one company) and a general lack of resources were brought to the attention.
- The most notable issues lie in planning the manufacturing operations and stock control, energy management, waste control and even in compliance with the potential future regulations

For the Slovenian companies in **plastics and rubber**, the assessment revealed the following:

- Lower digital and lower green maturity
- Identified key business processes: Manufacturing (planning and control of production, support for employees through MES), traceability and outbound logistics, energy consumption
- As significant barriers, lack of knowledge, connectivity issues, time constraints and step-by-step transition challenges were raised
- The most notable issues lie in CRM integration, material flow control, MES and in robotized production, not neglecting the energy consumption reduction, waste management and quality control

Digital Readiness: Most SMEs show a higher readiness in digital technologies compared to green practices. Companies in sectors with high technology integration and those facing competitive pressures exhibit higher scores in digital readiness. Most SMEs expressed a strong interest in ERP systems and connections to MESs for automated lines. Digital twin technologies are less commonly envisioned at present, indicating a focus on immediate, practical improvements rather than advanced future technologies. The emphasis on categories like manufacturing processes, bookkeeping, and sales is notable, with less focus on HRM/CRM systems.

Green Readiness: Green practices are often viewed as secondary to digital advancements, with varying levels of engagement depending on regulatory pressures and market demands. SMEs generally seek public co-funding for green transition activities and external expert consultations. There is a noticeable lack of internal expertise and capacity to manage the transition independently, highlighting the need for affordable training and knowledge-building resources.

Key Issues and Other Business Processes

In addition to the business processes and key drivers already discussed, several companies mentioned other critical issues and business processes that were not covered by the UAM (User Assessment Methodology) business processes/value drivers. These include:

1. Introduction of AI Across Domains

Key Insights:

- **Cross-Functional AI Applications**: While AI is commonly applied in manufacturing for process optimization and automation, companies are increasingly exploring its use in other domains such as HRM (Human Resource Management) and CRM (Customer Relationship Management). AI can enhance these areas by providing advanced analytics, predictive modeling, and automated decision-making.
- **AI in HRM**: Companies are looking at AI to improve recruitment processes, employee engagement, and performance management. AI tools can assist in screening resumes, predicting employee turnover, and personalizing employee development plans.
- **AI in CRM**: AI can transform CRM by enabling personalized customer interactions, automating customer support, and providing deeper insights into customer behavior and preferences.

Recommendations:

- **Expand AI Integration**: Encourage the integration of AI technologies not only in manufacturing but also in HRM, CRM, and other business areas to improve overall efficiency and decision-making.
- **Explore AI Opportunities**: Evaluate the potential benefits of AI applications across different functions and develop strategies to implement them effectively.

Key outcomes and perceptions

Throughout the implementation of the User Acceptance Model (UAM) tool, we encountered a wide range of reactions from participants, with emotions and responses often varying based on several factors. The day of the week played a notable role, with interviews conducted at the beginning of the week generally being less favorable, potentially due to the start-of-week workload pressures.

The dynamics of the interview also shifted depending on whether one or more persons participated. Interviews involving multiple participants tended to be more concise, substantial, and comprehensive. We observed slight differences in the feedback depending on the participants' roles—technical experts offered more detail-oriented responses, while those from communication or marketing backgrounds provided broader, often more strategic insights.

The personality type of the interviewee also significantly influenced the process. When we engaged with extroverted individuals, the conversation flowed more naturally with fewer direct questions needed, allowing us to focus more on listening and capturing nuanced insights. In contrast, with more introverted participants, a more structured approach with guided questions was necessary to elicit detailed responses. This variability highlighted the importance of adapting our interview technique to the specific context and individuals involved, ensuring we gathered the most relevant and comprehensive data possible.

The User Assessment Methodology (UAM) has demonstrated its value as a robust tool for SMEs seeking to identify their current digital and green transition statuses and pinpoint areas requiring intervention. Here's a concise summary of the observations and suggestions based on the findings:

1. Value of the UAM Tool

Strengths:

- **Comprehensive Assessment**: The UAM effectively captures current levels of digital and green maturity across various business processes, providing a detailed snapshot of where SMEs stand.
- **Guidance for Improvement**: It highlights potential areas for development, helping SMEs prioritize actions and identify where support or interventions are needed.
- **Usability**: SMEs generally find the UAM tool useful for understanding their digital and green transitions, with insights that guide next steps.

Feedback and Areas for Improvement:

- **Length and Detail**: Some SMEs found the tool's length and detail challenging. Streamlining the process and focusing on the most critical elements could enhance user experience.
- **Complexity**: Simplifying complex sections and providing clearer explanations or examples might help in reducing the perceived complexity and improve engagement.

2. Insights Gleaned from SMEs
Positive Reactions:

- **Useful Insights**: SMEs appreciate the insights gained from the UAM interviews, which offer valuable guidance for their digital and green transitions.
- **Identification of Needs**: The UAM has successfully pointed out the specific areas where SMEs need help, whether it's in adopting new technologies, improving sustainability practices, or enhancing overall operational efficiency.

Challenges Identified:

- **No One-Size-Fits-All Strategy**: There is no single strategy that fits all SMEs. Each company's unique context requires tailored approaches to digital and green transitions.
- **Complexity of Implementation**: SMEs often face difficulties in translating UAM insights into actionable steps, particularly due to resource constraints and the need for specialized knowledge.

Key Testing Metrics or Indicators

Based on the provided data, here is a summary of the adoption rates, preparedness levels, and key issues related to digital and green technologies across various industries. This analysis is categorized by industry sector and addresses digital and green technology adoption, barriers, influencing factors, and impacts on business operations.

1. Metal & Metal Products

a) Digital Technologies

- **Current State**: Limited automation and digital integration; some islands of digital equipment without backbone integration.
- **Focus Areas**: Production planning, monitoring/traceability of materials, resource effectiveness, automation of quality control, and logistics.
- **Solutions Needed**: Better tools for production planning, traceability (e.g., bar/QR tagging), real-time data access (MES, ERP), ROI calculators.

b) Green Technologies

- **Current State**: Varies by company size; larger companies adopting solar panels and ISO 14001 standards, smaller companies with minimal green practices.
- **Focus Areas**: Energy efficiency, waste management, and eco-friendly practices.
- **Measures**: Low energy rating machinery, waste recycling, solar panels.

c) Barriers

- Time constraints, lack of technology scouting, implementation challenges, and required expertise.

d) Factors Influencing Adoption

- Awareness, competition, customer expectations, costs, labor issues, and regulation.

e) Impact on Business Operations
- Awareness of long-term benefits, difficulties in short-term financial calculations and ROI assessments.

2. Machinery & Equipment

a) Digital Technologies
- **Current State**: Strong focus on development and control with integration of AI and digital twins. Advanced data readings and servitization.
- **Focus Areas**: Real-time data, AI integration, digital twin, improved quality control.

b) Green Technologies
- **Current State**: Monitoring of energy consumption, modern machinery, and waste control.
- **Focus Areas**: Sustainable strategy development, ESG reporting.

c) Barriers
- Time constraints, lack of in-house expertise, training challenges, and large investment requirements.

d) Factors Influencing Adoption
- Competition, expert availability, real-time data benefits, cost savings, improved quality, and legislation.

e) Impact on Business Operations
- Effective communication between management and accounting, extensive data utilization, need for improved ROI and HR tools.

3. Food & Beverage

a) Digital Technologies Current State: Fragmented technology with plans for ERP integration. Focus on traceability and quality control.
- **Focus Areas**: Centralized data dashboard, ERP for traceability, production planning, CRM.

b) Green Technologies
- **Current State**: Circular processes with biomass for energy, fertilizer production, and solar panels.
- **Focus Areas**: Energy efficiency, waste management, and optimization of distribution.

c) Barriers
- Skills and knowledge gaps, time constraints, funding issues, and finding suitable technology.

d) Factors Influencing Adoption
- Improved efficiency, cost savings, customer relations, new product development, and regulatory requirements.

e) Impact on Business Operations
- Enhanced decision-making with real-time data, better risk management, and improved financial planning.

4. Building Materials & Furniture

a) Digital Technologies

- **Current State**: Mixed digital adoption; one company with minimal changes and another with complete digitization of paperwork and CRM.
- **Focus Areas**: Manufacturing operations, stock control, planning, sales, and logistics.

b) Green Technologies

- **Current State**: Low adoption; one company in concrete with outdated practices, another in furniture with basic energy efficiency measures.
- **Focus Areas**: Energy management, waste control, and compliance with potential future regulations.

c) Barriers

- Lack of vision, skills, and knowledge in one company; time and human capacity issues in the other.

d) Factors Influencing Adoption

- Profit margins, labor force challenges, and financial stability.

e) Impact on Business Operations

- Significant potential impact for the brick producer if digital and green technologies are adopted, but currently limited calculations or debates on investments. For the furniture producer, improved organization and efficiency are achievable.

5. Plastics & Rubber

a) Digital Technologies

- **Current State**: Efforts toward integrating digital systems; challenges with combining various functions into a cohesive backbone.
- **Focus Areas**: MES, cobots, CRM integration, and material flow control.

b) Green Technologies

- **Current State**: Significant focus on energy efficiency with solar panels and waste reduction. Smaller company working on waste management.
- **Focus Areas**: Energy consumption reduction, waste management, and quality control.

c) Barriers

- Time constraints, lack of knowledge, connectivity issues, and step-by-step transition challenges.

d) Factors Influencing Adoption

- Competition, customer demands, energy costs, labor force, and availability of expert partners.

e) Impact on Business Operations

- Positive impacts from energy efficiency measures; need for better ROI calculations and effective data utilization.

6. Textile

a) Digital Technologies

- **Current State**: Advanced real-time control and digitalization of processes, but ongoing need for improved production planning and quality control.
- **Focus Areas**: Real-time quality control, production planning, and process optimization.

b) Green Technologies
- **Current State**: Circular processes with wastewater management and energy efficiency measures.
- **Focus Areas**: Wastewater management, energy efficiency, and cost control.

c) Barriers
- Technological challenges, lack of integration, and time constraints. Also, public funding restrictions for larger companies.

d) Factors Influencing Adoption
- Costs, competition, efficiency improvements, management readiness, and availability of experts.

e) Impact on Business Operations
- Improved production planning, quality control, and financial planning; enhanced awareness of regulation compliance and green funding opportunities.

Overall Summary:
- **Adoption Rates**: Digital technology adoption generally shows higher ratings compared to green technologies across most sectors.
- **Barriers**: Common barriers include time constraints, lack of knowledge, and integration challenges.
- **Influencing Factors**: Competition, customer demands, and costs are significant factors driving adoption.
- **Impact**: Positive impacts are seen in efficiency, cost savings, and regulatory compliance, although financial calculations and ROI assessments are often challenging.

Testing Phase Problems and Challenges

1. Understanding the Methodology:
- Issue: Companies faced difficulty grasping the methodology, especially due to the absence of pre-set criteria and the subsequent shift to a minimum number of employees.
- Solution: Provide a clear methodology guide and criteria before starting the interviews. Consider a pilot phase to refine the approach based on initial feedback.

2. Response Rate:
- Issue: A low response rate (around 4%) despite various outreach methods.
- Solution: Enhance outreach strategies by leveraging more targeted and personalized communication. Use incentives for participation or collaborate with industry associations to increase engagement.

3. Language Barriers:
Issue: English posed a challenge for companies when filling out the questionnaire alone, though it was less problematic during personal visits.

Solution: Offer multilingual questionnaires and provide options for interviews in the preferred language of the company. Ensure that survey tools are available in local languages.

4. Green Strategy Development:
   - Issue: Companies acknowledge the green transition but struggle to develop concrete green strategies. Many views green initiatives as a byproduct of technological improvements rather than a deliberate strategy.
   - Solution: Offer guidance or workshops on creating green strategies and sustainability roadmaps. Share best practices and success stories to illustrate the benefits and feasibility of comprehensive green strategies.

5. Time Constraints:
   - Issue: Interviews exceeding 50 minutes led to decreased focus and engagement. In some cases, informal discussions replaced structured interviews.
   - Solution: Structure interviews to be concise and focused. Prepare an agenda to keep discussions on track and ensure all key points are covered efficiently. Consider follow-up interviews or written responses for detailed topics.

6. Differentiation in Digital and Green Transition Awareness:
   - Issue: SMEs are aware of digital and green transitions but often conflate the two, seeing green improvements as secondary to technological advancements.
   - Solution: Distinguish clearly between digital and green transitions in communications and assessments. Provide separate resources and support for each transition area to help companies develop distinct strategies.

Results Analysis and UAM's Practical Application
Due to the number of variables, it is proving difficult to summarize all of the results, but the following is an attempt to do so:

1. Clustering for More Relevant Results
Challenge: Due to the small market size, clustering SMEs by industry, size, and market is difficult.

Approach:
Segment by Industry: While Slovenia's market may be too small for large sample sizes within each industry, you can still categorize findings by industry sectors to identify common trends and pain points.
Size and Market: Within each industry, try to segment SMEs by size and market orientation. Even if the sample sizes are small, comparing similar-sized companies or those in similar markets can yield meaningful insights.
Matrix Analysis: Use a matrix approach to analyze data across different dimensions (industry, size, market). This will help pinpoint the most critical issues and opportunities.

2. Handling Questionnaire Complexity
Challenge: Lengthy or complex questionnaires can discourage participation and lead to incomplete data.

Approach:
   - Simplify and Focus: Streamline the questionnaire to focus on the most critical questions. Use a modular approach where SMEs can select sections relevant to them.
   - Pilot Testing: Conduct a pilot test with a small group to identify sections that may be too complex or lengthy. Refine based on feedback.
   - Support Materials: Provide a summary or guide to help SMEs understand the purpose and relevance of each section, making the questionnaire less intimidating.

3. Addressing Awareness vs. Practice in Green Readiness

Challenge: There is a growing awareness of green practices, but actual implementation often lags behind.

Approach:

- Educational Resources: Provide SMEs with actionable guidelines and case studies on successful green practices. Highlight practical steps and benefits.
- Showcase Success Stories: Use examples from other SMEs who have successfully integrated green practices to illustrate the potential benefits and practical approaches.
- Regulatory Alignment: Emphasize the importance of aligning with upcoming regulations and standards to encourage proactive adoption.

4. Leveraging Data for Development

Challenge: SMEs appreciate the data and guidelines but may struggle to translate them into actionable strategies.

Approach:

- Actionable Insights: Focus on translating collected data into actionable insights. Offer recommendations that are easy to understand and implement.
- Workshops and Consultations: Organize workshops or one-on-one consultations to help SMEs interpret the data and develop tailored strategies based on the findings.
- Continuous Support: Provide ongoing support and resources to help SMEs implement changes and track progress.

5. Ensuring Effective Communication

Challenge: SMEs might feel overwhelmed by the data collection process or unsure about the relevance of their responses.

Approach:

- Clear Communication: Clearly communicate the purpose and benefits of the questionnaire. Explain how the data will be used and how it can benefit their business.
- Feedback Loop: Offer a feedback loop where SMEs can see how their input contributes to broader insights or improvements. This can increase engagement and willingness to participate.

Summary

1. **Segment and Cluster:** Focus on clustering SMEs by industry, size, and market where possible. Use matrix analysis to identify key pain points.
2. **Simplify Questionnaires:** Streamline the questionnaire and provide support materials to ease the process.
3. **Bridge Awareness and Practice:** Offer practical resources and success stories to help SMEs move from awareness to implementation in green practices.
4. **Translate Data into Action:** Provide actionable insights and support to help SMEs develop and implement strategies.
5. **Enhance Communication:** Clearly communicate the benefits and relevance of the data collection process to SMEs.

By adopting these strategies, you can enhance the relevance and impact of your data collection efforts and better support SMEs in their digital and green transitions, again, green readiness seems to be more on paper than in practice, although awareness is slightly growing (TV announcements and news).

Comparing Actual Outcomes with Expected Results
Digital readiness showed fewer surprises, although there were significant disparities between Slovenian SMEs operating in transnational markets and those focusing on local markets. These differences are related to their positions within semi-product and vertical supply chains, where top-down standardization plays a role. Interestingly, Slovenian SMEs producing high-value end products are notably proactive in enhancing their competitiveness and meeting customer demands, including adopting green practices even before they are mandated.

Actionable Steps:
- Benchmarking and Best Practices: Identify and document best practices from SMEs operating in transnational markets. Use these examples to guide local SMEs, particularly those in less digitalized sectors.
- Tailored Digital Strategies: Develop digital transformation strategies that are customized based on the market scope and supply chain position of the SME. For local market SMEs, focus on practical steps that can improve efficiency and competitiveness without requiring extensive resources.
- Training and Resources: Provide targeted training and resources for SMEs to enhance their digital skills and integrate digital technologies effectively. Consider offering workshops or online courses that address common digital challenges and solutions.

In terms of green readiness, the Slovenian level remains relatively low. This is partly because legislation has so far primarily targeted larger companies, leaving Slovenian SMEs with less immediate pressure. However, this will soon change. The objective of this project is to analyze the current state, increase awareness, and identify experts who can help elevate green readiness among SMEs to a higher level.
Actionable Steps:
- Legislative Awareness: Educate SMEs about upcoming legislation and its implications. Highlight how early adoption of green practices can be beneficial not just for compliance but also for improving operational efficiency and market appeal.
- Green Certification and Standards: Promote the benefits of green certifications and standards. Provide guidance on how SMEs can achieve certifications and leverage them for competitive advantage.
- Success Stories: Showcase case studies of SMEs that have successfully implemented green practices. Demonstrating tangible benefits and practical steps can motivate other SMEs to follow suit.

Suggestions for Future Deployment of the UAM

The questionnaire could benefit from simplification and the inclusion of tips and tricks for initiating a step-by-step process for developing either a digital or green strategy. While a one-size-fits-all solution isn't feasible, foundational principles can be adapted with minor adjustments to fit specific contexts. Collecting feedback from additional interviews will provide valuable insights, which can be used to refine future versions of the UAM for various sectors and viewpoints.

In Slovenia, the current lack of public funding for SMEs' twin transition (with no voucher scheme available for two years) means that future financial or regulatory support could significantly drive progress. Regulatory requirements, such as mandatory actions and reports, may also play a role. A proposed two-step template—one focusing on core interests and pain points and the other tailored to specific topics of

interest for SMEs—has both advantages (e.g., willingness to cooperate and quick data collection) and disadvantages (e.g., self-assessment may not accurately identify true challenges and opportunities).
The openness and honesty of SMEs in providing information largely depend on trust, which remains a critical issue to address. We have consistently emphasized and assured anonymity, with data presented in an aggregated manner to prevent identification of individual companies by third parties.

Germany

In Germany, Bautzen Innovation Centre interviewed 10 companies: 1 from the electronics and software industry cluster, 5 from the metal and metal products sector, 3 from the machinery and equipment cluster, and lastly, 1 categorized as 'other' (namely, from the textile industry).

For the German company in **electronics and software** production sector, the assessment revealed the following:

- Identified key business categories: organizational and managerial business processes, training and skills development, governmental impact
- The lack of customer interest in sustainability products or topics was recognized as a significant barrier
- The company highlighted several notable issues regarding the twin transition: the lack of a concrete, unified commercial solution (an organisational system); the absence of dedicated digital learning tools beyond standard technical documentation; and the lack of a digitized compliance tool that is sufficiently useful and flexible to justify the time and effort required for its implementation

For German companies in the **metal and metal products**, the assessment revealed the following:

- Identified key business categories: manufacturing business processes, market and business processes, impact from government on average, while investment and financing, government and customer service categories were also occasionally ticked as important
- Commonly cited barriers included time constraints and limited staff resources
- The most significant issues involve digitizing non-standard configurations, such as difficulties in applying generalized solutions for maintenance prediction due to a wide variation in equipment, ranging from 1970s-era machinery to automated grinders and setters. Other issues include a lack of reliability in AI systems, high rate of redundancy in machines, challenges in digitizing manufacturing operations for smaller companies with a clear ROI, the absence of carbon footprint assessments in distribution networks and a lack of statistics on greenhouse gas emissions from remote diagnostics

For the German companies producing **machinery and equipment**, the assessment revealed the following:

- Identified key business categories: market and business, manufacturing process operations on average, while financial processes and training and skills were also presented as crucial
- Time constraints and limited staff resources were commonly listed as significant barriers
- the most notable issues include digitizing complexity and variability of products, which is especially relevant for special machine construction; difficulties in maintenance planning, where certain parts like rubber have expected lifespans, but are also influenced by unpredictable factors; reducing production downtime; challenges in digitizing and sustaining customer service (often requiring direct physical intervention); and limited potential for advanced data analytics, as some producers, such as those of conveyor technology, typically operate within a set of fairly predictable parameters and must integrate well with third-party machinery.

Regarding **the machinery and equipment** industry cluster in Germany, our impression is that companies in this sector are generally more advanced in terms of digitization. The relatively higher complexity of their products, and the demands of their clients often in the automotive industry, place them in a “sink-or-swim” scenario, requiring them to adapt to remain competitive. The German metalworking SMEs have all fewer than 50 employees; two are less than a decade old, and all three have expressed ambitions for improvements in terms of twin transitioning. However, their resources are relatively limited, often leaving it to the CEOs alone to initiate the change.

Digitization is clearly the more popular focus, as its practical benefits are often more immediately apparent – for example, the ability to instantly check inventors across multiple storage locations. In contrast, sustainability measures are usually viewed through the lens of fiscal prudence and legal compliance. It was rare for interviewees to state that they implemented sustainability measures primarily out of idealism. **Among the SMEs we interviewed, digital technologies have a significantly higher adoption rate compared to sustainability initiatives. Sustainability is often seen as a welcome side effect, typically associated with reduced production costs, rather than as a primary objective.** While come companies show a relatively high awareness of the importance of anticipating future regulations and proactively implementing measures, this is not common. We contend that a larger, more representative sample of SMEs were surveyed, awareness levels in this regard would likely be very low. There was no meaningful awareness of the dual transition concept among the SMEs we interviewed, and it is unclear whether any have considered their challenges from this perspective. Depending on the sector and specific business model, sustainability gains can significantly enhance competitiveness; however, overall, these are still less prioritized compared to digitization, which has become not only a norm but a necessity in many areas of business activity.

In terms of sustainability, both sectors are, on average, similarly underdeveloped. The only area where some progress has been made almost universally is in packaging, with efforts to reduce plastic use and increase recycling.

Similar issues:
They all, to some degree, feel underfinanced and understaffed.

Particular issues per sector:
One notable issue, particularly relevant to the machinery and equipment sector, is the rapidly evolving and increasingly complex customer demands. Large automotive customers, in particular, frequently require strict compliance with their internal systems and standards, especially regarding data security.

Key Business Processes and Drivers for Twin Transition

For nearly all interviewed companies, the manufacturing processes and market and business category were by far the most extensively discussed, and the processes within these categories were consistently viewed as having the greatest potential for improvement. In this context, companies were universally further ahead in implementing digital innovations compared to sustainable ones. Regarding sustainability, only packaging received an average rating higher than 2. Companies also acknowledged am increasing need to address not only compliance challenges but also to engage with state aid programs that could help mitigate their impact. However, they frequently cited a lack of personnel capacity and previous negative experience as reasons for not pursuing the latter.
Key Issues and Other Business Processes
No significant additions were proposed in this context.

Key outcomes and perceptions

Regarding the urgency of making their companies more sustainable in the face of upcoming legislation, there was a wide range of attitudes among the interviewed SMEs. Generally, they tended to view the severity of this challenge as a relatively low and manageable. We believe this is primarily because the interviewed SMEs are predominantly in the metalworking and machinery sectors, where sustainability has traditionally not been a major focus, and where potential ways to improve sustainability may be less apparent than in other sectors. Even if some interviewees might be underestimating the challenge ahead, attitudes and emotions were generally positive, with many expressing enthusiasm about the initiatives they have already implemented. However, this also opens the possibility for bias in interviewee selection, as company representatives who are negatively predisposed to enhancing sustainability in their SMEs, or who feel they have little to share, are unlikely to make themselves available for such interviews.
Both the larger and the younger SMEs in our sample appeared to be better informed and more proactive in addressing these issues. The most at-risk group in this regard seems to be small family firms founded soon after the fall of the iron curtain; these firms often suffer from aging workforces, which further inhibits dynamism.

Testing Phase Problems and Challenges

There were no issues more serious than slight misunderstandings during the interviews themselves, but getting the companies to agree to participate in the first place was very challenging and required persistence. It seemed that most of the contacts were simply not interested, but at the same time, they did not want to explicitly decline the invitation. This increased the effort needed to schedule interviews, as it was nearly impossible to distinguish between companies that were genuinely interested but short on time and those that were not interested but did not communicate this directly. We can only speculate on the motivations of those in the latter group, but it could be a desire to avoid appearing impolite or unprofessional (“better just wait out of it, they’ll go away soon enough”) or a fear of being internally marked as “not interested” and subsequently not being contacted for future initiatives or invited to future events, which they might find more appealing.

Results Analysis and UAM’s Practical Application

Based on the way the interviews were conducted and the feedback provided by the interviewees, it has become apparent that at this stage, the most immediate value of the UAM to those interviewed, is the question compendium. This tool allows participating SMEs to develop an understanding of the potential of digital and sustainable technologies in business areas where they had not previously considered implementing such measures, and it can be used to communicate concrete, new ideas. A few instances of this occurring are documented in our feedback templates. Therefore, we believe that a refined version of this compendium – which is currently quire unwieldy – could be even more valuable if it were further expanded and its questions categorized in a way that allows for automatic assignment to specific sectors. Such a version could serve as the basis for an online knowledge and technology transfer tool.
Given that three quarters of our interviews were held with companies from the metalworking and machinery and equipment industry clusters, both of which are traditionally strong in Eastern Saxony, we believe we can most assess the UAM’s usefulness and reliability for these two sectors. In our opinion, the UAM has demonstrated no systemic issues or shortcomings that would need to be addressed for SMEs in these sectors to find it valuable. Moving forward, we are eager to see how the UAM will continue to evolve, particularly regarding its presentation, a process we are happy to support.
Summary of the findings:

1. The UAM is an adequate tool for mapping the current state of German SMEs in terms of their digital and sustainable readiness, with only minor adjustments suggested.

2. The question compendium is a valuable resource which has the potential to serve as the foundation for a knowledge and technology transfer platform.
3. Among the SMEs we interviewed, digital technologies enjoy a considerably higher adoption rate than those specifically focused on sustainability. Sustainability is often seen as a beneficial synergy effect, usually associated with a decrease in production costs, rather than something that is pursued for its own merits. We believe this is fundamentally due to two major factors: 1) the benefits of digital technology are more readily apparent and easily measurable, and 2) there is considerably more pressure from customers driving its adoption.
4. Some companies do demonstrate a remarkable awareness of the importance of staying ahead of future legislation, and actively pursue measures long before they become mandatory, but this is far from the norm. We believe that if a larger, more representative sample of SMEs were surveyed, awareness levels in this area would be very low.

Comparing Actual Outcomes with Expected Results

In some ways, despite the generally low average scores, our expectations were actually exceeded. For example, we did not anticipate that some small SMEs, with few or no standardized production lines, would already have or be in the process of deploying fully featured ERP systems. On the other hand, we were generally heartened that not a single interviewee expressed a fundamental unwillingness to pursue sustainability initiatives, even if many have not yet begun implementing them.

Austria

In Austria, FH Kufstein Tirol interviewed 10 companies: 4 from the metal and metal products sector, 3 from the machinery and equipment sector and 3 from the building materials and furniture industry cluster. For the regional Tirol companies producing **machinery and equipment**, the assessment revealed the following:

- Identified key business categories: manufacturing operations process, marketing and sales processes and Impact from government

For the regional Tirol companies in **building materials and furniture**, the assessment revealed the following:

- Identified key business categories: manufacturing operations process, human resource management processes, marketing and sales processes

For the regional Tirol companies in **metal and metal products**, the assessment revealed the following:

- Identified key business categories: manufacturing operations process, human resource management processes, marketing and sales processes

The assessment regarding maturity levels did not reveal any peculiarities, neither between the companies within one sector nor between the sectors. Overall, the maturity levels varied across the companies. While some showed significant progress and strategic planning in adopting digital tools and sustainable practices, others were still in the early stages of implementation. **In general companies are more mature in the green dimension comparing to the digital dimension.** Hence also their focus on digital transformation. Digitizing processes are seen as more important, and companies are prioritizing digitization over sustainability.
Companies particularly struggled with assessing their maturity in relation to the external environment, including governmental and informational categories. These dimensions are heavily influenced by external factors beyond the companies' direct control, making self-assessment challenging. The

regulatory landscape, availability of relevant information, and external support systems significantly impact these areas, leading to uncertainty and variability in self-evaluation. They however declared that especially the external environment has a strong influence on the overall business activity.

Key Business Processes and Drivers for Twin Transition

The dimensions perceived as most critical within the UAM, garnering the highest interest from companies, include the technological, market and business, training and skills development, and governmental categories. Especially within the financial category, SMEs were reluctant to answer questions and engage in a discussion. This could be because it includes critical aspects, such as funding mechanisms, cost projections, and revenue models and their desire to keep financial information private, or perhaps they found the processes and questions about finances within the UAM too complex.
For the interviewed companies within the three sectors, the dominating critical business processes are within the manufacturing operations and the human resource management. Furthermore, marketing and sales processes are seen as critical within the metal and metal products and building materials and furniture sector. For the machinery and equipment sector processes regarding governance and the impact of the government are seen as predominantly critical.

Key Issues and Other Business Processes

Companies particularly struggled with assessing their maturity in relation to the external environment, including governmental and informational categories. These dimensions are heavily influenced by external factors beyond the companies' direct control, making self-assessment challenging. The regulatory landscape, availability of relevant information, and external support systems significantly impact these areas, leading to uncertainty and variability in self-evaluation. They however declared that especially the external environment has a strong influence on the overall business activity.

Key outcomes and perceptions

The outcomes of the interviews revealed a mixed landscape of digital and sustainable practice adoption among the companies. While some companies showcased advanced levels of digitization and integration of sustainable practices, others were still in the early stages, facing significant challenges. Many participants recognized the importance of digitization and sustainability but struggled with the practical implementation due to limited resources, knowledge, and time. Perceptions varied significantly, with larger companies generally more optimistic about the benefits of digital transformation, while smaller firms were more cautious and sceptical. The need for practical, easily understandable solutions was a recurring theme, emphasizing the importance of user-friendly interfaces and clear demonstrations of economic benefits to increase acceptance. Overall, there was a strong recognition of the potential benefits, but a clear need for more supportive measures to facilitate the transition.

Key Testing Metrics or Indicators

The interviews aimed to capture a comprehensive set of metrics and indicators across various business processes. Key areas of focus included inbound and outbound logistics, marketing strategies, customer service practices, production processes, and human resource management (HRM). Specific indicators measured included the extent of digitization in marketing and sales tools, the level of automation in production and quality control, the efficiency of document and data management systems, and the effectiveness of digital learning platforms for employee training. Additionally, the interviews evaluated energy efficiency measures, waste production metrics, the presence of sustainability initiatives, and the company's approach to compliance with regulatory standards. These metrics provided a detailed view of

how companies integrate digital and sustainable practices into their operations and highlighted areas for potential improvement.

Testing Phase Problems and Challenges

The first interviews, conducted, before the re-evaluation and changes to the interview process, were generally not as successful as the later ones. While the more recent interviews have been easier, companies have noted missing services and opportunities through GREENE 4.0. Problems within the process included a lack of time, insufficient instructions for interview partners, and a shortage of available services at the moment, all of which impacted the efficiency and overall success of the interviews.

Results Analysis and UAM's Practical Application

The results from the interviews indicate several important directions for the future development and deployment of the UAM. First, there is a clear need for these models to include more supportive measures, such as educational resources and hands-on training, to bridge the knowledge gap and make the transition smoother for companies. Simplifying the implementation process and providing clear, practical demonstrations of the economic benefits can help increase acceptance, especially among smaller firms. The UAM should also be highly adaptable, capable of being tailored to the specific needs of different industries and company sizes, as well as business models (B2B, B2C, …). Developing a modular approach, where companies can start with basic digital and sustainable practices and gradually build up to more advanced levels, could be particularly effective. Furthermore, ongoing support and consultation can help companies overcome initial resistance and ensure that they continue to advance along their digitization and sustainability journeys. By addressing these areas, future deployments of the UAM can be more effective in driving widespread adoption and achieving the desired outcomes.

Comparing Actual Outcomes with Expected Results

Comparing the actual outcomes with the expected results revealed some significant gaps. While the expectation was that most companies would have at least a foundational understanding of digitization and sustainability, the reality showed a much more varied landscape. Many companies, especially smaller ones, were still heavily reliant on manual processes and had only a basic understanding of digital marketing and sales tools. **This gap suggests that the theoretical frameworks used in developing the UAM may overestimate the current readiness and capacity of many companies, particularly SMEs.** The resistance to digitization efforts, often due to perceived complexity and resource constraints, was more pronounced than anticipated. This highlights the need for more accessible, step-by-step approaches that can gradually build the necessary foundation for more advanced digital and sustainable practices.

Czech Republic

In the Czech Republic, the Innovation Centre of Usti interviewed 10 companies as follows: 1 from the metal and metal products sector, 1 from the machinery and equipment sector, 2 from the food and beverages sector, 1 from the building materials and furniture sector, 1 from the plastics and rubber sector, 1 from the electronics and software sector, and 3 companies categorized as other (namely, a printing and advertising materials producer, a cosmetics manufacturer, and a sports equipment producer).

For the company producing **metal and metal products**, the assessment revealed the following:

- Medium digital and low green maturity
- Identified key business categories: manufacturing operations processes; infrastructure, organization and management; investment and financing

- The most notable issues were recognized in financial constraints to invest in technological equipment (high initial costs), technological complexity and lack of time

For the company producing **machinery and equipment**, the assessment revealed the following:

- Medium digital and medium green maturity
- Identified key business categories: information flow; infrastructure, organization and management; training and skills development; marketing and sales
- The most notable issues for the aforementioned company were to be found in creating a new position focused on innovation and digitization (capable of effectively implementing new technologies) and in applying for existing (yet complex) grant schemes

For the companies producing **food and beverages**, the assessment revealed the following:

- Medium digital and medium green maturity on average
- Identified key business categories: marketing and sales; training and skills development; organization and management, manufacturing operations
- The most notable issues in terms of twin transition were explained as requiring more strategic planning and technology-implementation support, meeting regulatory demands and involving new technologies, lack of sustainability metrics, a half-way digitized manufacturing process, lack of resources for a SAP system (as it is designed for larger companies), finding a business model with cost savings through sustainability measures

For the company producing **building materials and furniture**, the assessment revealed the following:

- Medium digital and low green maturity
- Identified key business categories: manufacturing operations processes; organization and management; investment and financing
- The most notable issues were explained as applying for government grants and obtaining a technological system, with the capabilities of producing more units and lowering the overall costs (due to infrastructural limitations)

For the company producing **plastics and rubber**, the assessment revealed the following:

- high digital and medium green maturity
- Identified key business categories: information flow; infrastructure, organization and management; marketing and sales
- The most notable issues was expressed as having a strong desire for further digitization and sustainable production, but very limited financial resources, and secondly, the ordering system software being too opaque (instead of simple and clear)

For the company producing **electronics and software**, the assessment revealed the following:

- High digital and high green maturity
- Identified key business categories: information flow; infrastructure, organization and management; marketing and sales
- The most notable issues were found in not having enough financial means for further innovation

Common Barriers: Financial constraints were a frequent issue, as many companies had limited funds for new technology investments. There were also gaps in skills and training, with cultural resistance to change evident in some firms.

Technical Challenges: Companies often struggled with integrating new technologies into existing systems, highlighting the need for better support and resources.

Most SME representatives view digital transformation positively, seeing it as essential for increasing efficiency, productivity, and competitiveness. They appreciate the benefits of technologies such as artificial intelligence and big data, but are concerned about the costs and complexity of implementation. Attitudes towards the green transition are generally positive, but more cautious than towards digital transformation. Companies understand the importance of sustainability for regulatory compliance and company image, but are worried about costs and the lack of expertise needed for implementation.

Many small and medium-sized enterprises (SMEs) found the high initial costs and technical complexity of new technologies daunting. They were worried about the financial burden and whether the investment

would pay off. There was occasionally noticeable resistance to change, especially in companies with older management teams or deeply entrenched traditional practices.

Similar issues:

- High initial costs for implementing digital and green technologies.
- Resistance to change, particularly in companies with entrenched traditional practices.
- Lack of expertise and need for comprehensive training programs.
- Financial constraints and difficulty in accessing funding and subsidies.

Particular issues per sector:

- **Metal production**: High financial demands and time constraints.
- **Building materials and furniture production**: Need for automation and robotics, hindered by high costs and competitive infrastructure; challenges with in-house software and integration of new systems.
- **Perfumes and toilet preparations**: Emphasis on lean management and digital supply chain management.
- **Food and beverage production**: Focus on cost savings and need for digital marketing strategies.
- **Electronics and software production**: Heavy investment in digital technologies as a core business focus.
- **Technical Equipment**: Need for dedicated innovation positions and funding.
- **Printing and advertising**: Utilization of government subsidies and need for continuous technological modernization.
- **Sports Equipment**: Twin transition is currently not of any priority, focus on product development.

Key Business Processes and Drivers for Twin Transition

- **Automation of Production Processes**: Seen as crucial across all sectors to improve efficiency and reduce costs.
- **Digital Supply Chain Management**: Important for maintaining competitiveness and streamlining operations.
- **Customer Relationship Management (CRM)**: Essential for market expansion and enhancing customer satisfaction.
- **Energy-Efficient Technologies**: Key for long-term cost savings and sustainability.
- **Training and Skills Development**: Ongoing staff training to keep up with technological advancements.

Key Issues and Other Business Processes

- Integration of tailor-made software solutions.
- Resistance to change and lack of expertise.
- Need for more detailed case studies and practical examples in UAM.
- Financial planning tools specific to green investments.

Key outcomes and perceptions

Emotions: Overall, the mood among the company representatives was positive and open. Many expressed interest and enthusiasm about participating in a project that could bring significant benefits to their business. Some representatives hoped that the UAM would help them better understand their current situation and provide a pathway for digital and green transitions.

Attitudes: Company representatives exhibited varying degrees of readiness and willingness to adopt digital and green technologies. Some companies, especially those in more innovative sectors, were very proactive and saw the UAM as an opportunity for further growth and improvement. On the other hand,

there were firms that approached these changes with a degree of caution and skepticism, often due to concerns about the costs and complexities of implementing new technologies.

Collaboration and Openness: Most representatives were very cooperative and willing to share their experiences and opinions. They appreciated the opportunity to discuss their challenges and find ways to improve. This open approach significantly contributed to in-depth discussions and valuable insights.

Concerns and Skepticism: Some representatives expressed concerns about the administrative and financial burden associated with implementing new technologies and regulations. It was important to acknowledge these concerns and explain how the UAM could help overcome these challenges and what specific benefits they could expect.

Testing Phase Problems and Challenges

Some of the interviewed representatives were not willing to share details about their business practices and incorporated technologies. A large majority of the respondents got even more frustrated with the Feedback template, as they were often under the impression some of the questions in the UAM questionnaire are duplicated, while the Feedback template triplicated some of the topics discussed.

Results Analysis and UAM's Practical Application

1. Enhanced Financial Support
Suggestion: Incorporate detailed information on accessing funding and subsidies to help SMEs overcome financial barriers.
Description: Many SMEs identified financial constraints as a major barrier to adopting digital and green technologies. The UAM should provide comprehensive guides on available financial resources, including grants, loans, and subsidies, and detailed instructions on how to apply for them. This will help SMEs secure the necessary funds to invest in new technologies.

2. Tailored Training Programs
Suggestion: Develop sector-specific training modules to address skill gaps and reduce resistance to change.
Description: The testing revealed a significant need for tailored training programs that cater to the unique requirements of different sectors. The UAM should include customized training modules focusing on the specific digital and green technologies relevant to each sector. These programs should be available both online and in-person to maximize accessibility and effectiveness.

3. Simplified Integration Processes
Suggestion: Offer practical, step-by-step guides for integrating digital and green technologies.
Description: To facilitate the adoption of new technologies, the UAM should provide clear, practical guides that detail the integration process. These guides should include best practices, common pitfalls to avoid, and video tutorials to demonstrate the steps involved. Simplifying the integration process will make it easier for SMEs to implement new technologies without overwhelming their resources.

4. Sector-Specific Case Studies
Suggestion: Include detailed case studies and best practices tailored to various sectors.
Description: Providing real-world examples of successful digital and green transitions within specific sectors will help SMEs understand the practical benefits and potential challenges. The UAM should gather and present success stories from different industries, highlighting the strategies and technologies that led to positive outcomes. This will offer SMEs relatable and actionable insights.

5. Continuous Feedback Mechanism
Suggestion: Establish a robust feedback loop to continually refine the UAM based on user experiences and challenges.
Description: To ensure the UAM remains relevant and effective, it is crucial to implement a continuous feedback mechanism. Regular surveys and feedback sessions with participating SMEs will help gather insights on their experiences, identify any issues, and make necessary adjustments. This iterative approach will enhance the UAM's responsiveness to the evolving needs of SMEs.

6. Improved User Interface
Suggestion: Enhance the user interface to be more intuitive and user-friendly.
Description: A more intuitive and user-friendly interface will encourage wider adoption and better user engagement. The UAM should focus on improving navigation, reducing complexity, and providing clear instructions and support. An enhanced user experience will make it easier for SMEs to interact with the UAM and utilize its features effectively.

These recommendations aim to address the key challenges identified during testing and enhance the overall effectiveness and usability of the UAM for SMEs. By implementing these improvements, the UAM can better support SMEs in their digital and green transitions.
Comparing Actual Outcomes with Expected Results
Overall, the testing showed that companies are open to change but need more support, clear guidelines, and financial assistance to successfully transition to digital and green technologies. To the larger extent, the initial expectations of the twin transition not being a coherent concept have been confirmed

Italy

In Italy, Intellimech interviewed 10 companies as follows: 2 from the metal and metal products sector, 2 from the machinery and equipment sector, 1 from the food and beverages sector, 2 from the building materials and furniture sector, 2 from the electronics and software sector, and 1 company categorized as other (namely, from the electrocommunications sector).
For the companies producing **metal and metal products**, the assessment revealed the following:

- Medium digital and low green maturity
- Identified key business categories: manufacturing operations processes; infrastructure, organization and management; government impact
- The most notable issues identified were difficulties in measuring waste production at different stages of the manufacturing process, integrating digital solutions with workers' activities (while providing real support for their tasks), a lack of knowledge on implementing sustainability in managerial tasks (as opposed to technical ones), and the fragmentation of information about funding opportunities.

For the companies producing **machinery and equipment**, the assessment revealed the following:

- Medium digital and medium green maturity
- Identified key business categories: manufacturing processes; infrastructure, organization and management; investment and financing processes
- The most notable issues for the aforementioned company were the lack of flexibility in digital solutions to easily adapt to different products (without a strong dependence on external expertise), the challenge of connecting organizational and managerial tools to eco-sustainability, limited awareness of available alternatives, the absence of clear cost-benefit analyses for green and digital solutions, difficulty distinguishing groundbreaking initiatives from greenwashing and low-impact use cases, overcoming the complexity of information related to the Digital Product

Passport concept, waste production during the manufacturing process, ensuring a fast and effective training process for new workers, and providing remote connectivity for equipment maintenance at the customer's request (a service that is not easy to offer).

Digital maturity is significant in the machinery and equipment sector, particularly concerning the products, as customers are increasingly demanding machine digitalization. From a digital perspective, the human-robot interface is essential for automating production lines that rely on human employees. Additionally, the ability to provide remote connectivity for equipment maintenance and control is becoming more frequently requested. In general, the digitalization of products and production lines with user-friendly interfaces is crucial. From a manufacturing standpoint, companies implement automation to optimize processes, reduce material consumption, and analyze data during production. The mapping of information flow and extraction of valuable data is generally used for KPI measurement and cost-benefit analysis. Finally, machinery and equipment companies utilize digital technologies to scout for new innovations, enabling them to increase market competitiveness in line with new digital and green trends.

Green maturity in the machinery and equipment sector is currently limited, mainly focused on integrating product tracking systems and enhancing quality testing activities to minimize waste in manufacturing processes. However, there is growing emphasis on green maturity in marketing and sales processes due to customer demand. Data analysis is particularly important to comply with KPIs set at the European level. Looking ahead, this will become increasingly relevant, especially for the traceability of products and processes (e.g., Digital Product Passports, eco-labels) and measuring environmental impact. A challenge in this area is that the machinery and equipment sector is broad and intersects with other sectors depending on the specific product, which may include electronics or other components with distinct requirements and regulations. It is challenging to maintain a clear understanding of regulations and their evolution over time, particularly from a long-term perspective. Therefore, access to funding for testing innovative green solutions is needed to help companies understand how to proceed effectively.

For the company producing **food and beverages**, the assessment revealed the following:

- Medium digital and medium green maturity on average
- Identified key business categories: manufacturing operations, investment and financing processes
- The most notable issues related to the twin transition include the introduction of advanced or recycled materials that are more sustainable but still compliant with food contact and ingestion requirements, establishing a system to support the transfer of knowledge and experience from individuals to the company, the time-consuming training of new technical employees, detecting and analyzing statistical data from products and transforming it into warranties, certifications, or additional services for customers, and identifying available funding opportunities for innovation (along with the necessary competencies to secure such funding).

Digital maturity is significant. The company has invested heavily in digital technologies to assist operators with clear instructions during the assembly process, reducing errors and quickly reporting nonconformities. The company is particularly interested in measurement systems for KPIs and has integrated digital technologies that can analyze production data to enable accurate production planning. Customers increasingly demand reliable data about products, such as details on working processes and consumption. The main challenge is to detect and analyze statistical data from the products and transform this information into a warranty, certification, or additional service available to the customer.

Green maturity is limited in the food and beverage sector. From a green perspective, one of the main challenges is introducing advanced or recycled materials that are more sustainable but also compliant with food contact and ingestion requirements. Regulatory compliance is crucial, and companies invest

heavily in this area, as well as in scouting for new innovations. The company has implemented lean production, assisted by digital technologies, to reduce waste.

For the company producing **building materials and furniture**, the assessment revealed the following:

- Medium digital and low green maturity
- Identified key business categories: manufacturing operations processes; infrastructure, organization and management; inbound and outbound logistics, information flow
- The most notable issues were explained as problems with materials sorting at end-of-life, the maintenance activities and workers' safety on construction sites

Digital maturity is higher than green maturity. A key aspect of implementing digital technologies in industrial environments is human centricity, where technologies are designed to support humans rather than replace them. Digital technologies are primarily used to support maintenance activities, enhance worker safety on construction sites, and enable customization of solutions based on customer requirements. The main business processes involved in digitalization include managing information flow, ensuring regulatory compliance, and optimizing infrastructure, organization, and management processes. In technological areas, digital tools assist in monitoring material consumption and manufacturing quality.

Green maturity in the building sector is very limited and is primarily in the research stage. Companies mainly focus on integrating and substituting materials with more sustainable alternatives, as well as managing end-of-life products and materials through sorting, waste reduction, and recycling. The challenge is to find materials that offer similar performance and cost-effectiveness. Quality testing, certification, and regulatory compliance are also key aspects for this sector. The most advanced activities are related to scouting for innovation and enhancing marketing and sales processes.

For the companies producing **electronics and software**, the assessment revealed the following:

- High digital and high green maturity
- Identified key business categories: manufacturing operations; information flow; infrastructure, organization and management; investment and financing processes
- The most notable issues were found in not having enough financial means for further innovation

Digital maturity is crucial in manufacturing electronics. As previously mentioned, the miniaturization of products requires increased accuracy to prevent production errors. Implementing a reliable and efficient production planning system is essential to minimize production costs. This need for precision also impacts the training process for new workers, as the process demands high accuracy with minimal errors, which is supported by digital technologies. Additionally, protecting information from leakage to competitors is critical in this sector. Companies pay close attention to data security because a significant amount of data is stored and collected in electronic devices and must be analyzed and protected throughout all stages of the process.

Green maturity is relatively advanced in the electronics sector, particularly regarding manufacturing operations and compliance with regulations, especially for handling WEEE (Waste Electrical and Electronic Equipment). However, one of the main challenges in this sector is the miniaturization of products, which complicates the handling of components. From a circular economy perspective, the primary challenge lies in multi-material products, where the integration of plastics and metals complicates recycling efforts.
On the positive side, implementing recycling and green technologies can reduce costs and lessen dependency on foreign resources by applying circular economy principles (such as using recycled materials and minimizing waste). Measuring KPIs is also crucial to align with increasingly strict regulations. In this context, staying informed about regulatory changes (certifications, compliance, etc.) is vital to ensure timely adaptation.

Electronics is integrated into various sectors, each with distinct requirements and barriers. Regulations vary by country and may include long-term considerations, particularly for waste management and classification. Electronics is expected to be among the first sectors to adopt the Digital Product Passport (DPP), where data will be essential. However, details about the type of data to be collected, its management, and access are still unclear. Therefore, a key challenge is managing information flow to support the company's green approach. To effectively test and implement green technologies in established processes within this competitive market, access to funding is essential.
Similar issues:
The most promising area for adopting digital and green technologies is the manufacturing process, considered the core of a company. When these technologies optimize processes and products or reduce waste, the economic benefits are significant, encouraging investment and unlocking new business opportunities. In other areas, digitization is viewed as an added value, especially for training activities. A common trend across various sectors is the increasing introduction of regulations related to sustainability and digitalization. These regulations can sometimes pose barriers or concerns for businesses, particularly SMEs. Navigating the current and evolving regulatory framework is challenging for products that intersect multiple sectors. Aligning with these regulations requires time and expertise to adapt to KPIs and implement new procedures effectively.

Particular issues per sector:
As explained in the previous paragraphs, some issues could be generalized for the different sectors in terms of high investment costs, lack of competencies, cutting-edge technologies and needs, and lack of best practices. However, sector-specific challenges are present and need to be addressed in a peculiar way. For Machinery and Equipment sectors, the main challenges are the remotization of services, traceability, and the introduction of user-friendly interfaces. For Electronics and Software production sectors, the main challenges are miniaturization, which requires higher process accuracy, and the WEEE regulation for end-of-life product management. For Building and Furniture sectors, the main challenges are the sorting of materials at end-of-life, maintenance activities, and the safety of workers on construction sites. For the Metals sector, the main challenges are energy consumption, the management of logistic processes, and the norms and regulations. Finally, for Food and Beverage sectors, the main challenges are the management of product data to monitor consumption and the introduction of non-toxic, sustainable/recycled materials compliant with food contact regulations.

Key Business Processes and Drivers for Twin Transition

Green solutions have not been largely adopted so far: on the one hand, companies are struggling with continuously evolving directives that impose increasingly strict KPIs with no standardized measurement systems, and on the other hand, there is a lack of best practices demonstrating the benefits of green technology adoption at both technological and economic levels. The development, adoption, and implementation of recycling technologies, for example, could represent a considerable investment with limited short-term business return. In this context, key drivers could include the sharing of best practices, cost-benefit analysis, "test before invest" activities, access to funding, and awareness of current norms and regulations. Digital technologies, on the other hand, are mainly applied to production processes. They have already demonstrated a positive impact, although some issues related to legal and ethical aspects are emerging, particularly concerning AI. In this case, the main drivers for their widespread adoption are interoperability, flexibility of the solution if conditions change, and, similarly, monitoring of regulations.

Key Issues and Other Business Processes

An additional process suggested by interviewed companies was product/process design: in some cases, the company is asked to manufacture a new machine or system to treat materials and products. For this reason, support for designing the new line and adjusting process steps according to specific requirements is needed, and digital tools could be useful in this regard. Furthermore, in the customer service process, both warranty and certification should be addressed as they represent different aspects. Warranty has a long-term perspective, whereas certification simply assesses the main features of the product. Another process that could be added is handling the product during different manufacturing phases, which can be critical with large pieces and could potentially be digitized and automated. Finally, related to the training of new workers, the handover process with employees changing jobs or retiring is also important. A system that supports the transfer of knowledge and experience from individuals to the company is crucial for continuity.

Testing Phase Problems and Challenges

Some companies consider certain UAM categories irrelevant for their specific business, and the assessment was constrained by the proposed scale. Integrating a "Not Applicable" option could be beneficial, as it would allow companies to provide additional information about areas outside their scope or interest.
Another problem is that the UAM is a time-consuming tool, and companies have a limited amount of time to dedicate to it. During the interviews (approximately 1 hour), open questions were challenging for the companies and could also generate vague or unfocused responses, making it difficult to extract actionable insights. Guidance for completing the UAM is always needed to obtain meaningful contributions.
Finally, the request for feedback with open questions has not been well received, especially questions addressing general topics (e.g., main challenges in implementing digital and green technologies), as these require additional effort from the company. Quick and specific questions are preferred because they provide concrete insights on the tool (e.g., whether the time required is appropriate, if the scale assessment was effective, if the respondent is knowledgeable about all areas of the company, etc.).

Results Analysis and UAM's Practical Application

In general, the results obtained from the interviews were positive and highlighted SMEs' interest in moving towards the adoption of digital and green technologies. In this direction, partnering with local intermediaries, such as Digital Innovation Hubs (DIHs), is a strategic approach to support the use of tools in industrial environments. Intermediaries could also improve execution and identify areas for further testing. These intermediaries are well-positioned to support targeted campaigns by leveraging their local knowledge and networks.
For the practical application of UAM, it is important to have a relatively easy and reliable tool. Companies are likely to devote time to filling out questionnaires only if they believe the effort will yield effective or interesting results. When companies see the value in the feedback process, they are more motivated to participate. In the case of UAM, the tool helps identify strengths and weaknesses in different areas of the company.

Comparing Actual Outcomes with Expected Results

The actual outcomes are quite in line with the expected results. Companies demonstrated their interest in moving towards the adoption of digital and green technologies. The path towards digital technologies is more advanced than the one towards green technologies.
The rationale behind this evidence is that digital investments have been driven by long-term fiscal incentives and a higher maturity level of available technologies. Green technologies are still in their initial stages of development.

Poland

In Poland, Krakow Technology Park interviewed 10 companies as follows: 1 from the metal and metal products sector, 2 from electronics and software production, 2 from food and beverages, 4 from the building materials and furniture sector, and 1 from the plastics and rubber industry cluster.
For the company in **the metal production** the assessment revealed the following:

- High digital and medium green maturity
- Identified key business categories: manufacturing operations processes; infrastructure, organisation and management; investment and financing processes; marketing and business processes and informational flow
- The most notable issues are represented in the company's perception of the technological utilities (intended to increase efficiency, while reducing environmental pressure is a welcomed side effect) and in environmental issues not having an impact yet on customer decisions

Digital maturity: The surveyed company from this sector demonstrated a high level of digitization; it uses production management programs, has modern logistics based on a barcode system, and collects a lot of data. At the same time, it does not pay much attention to marketing issues; sales activities are conducted during personal meetings.

Green maturity: The company is not directly interested in the ecological dimension of production—at least for now. It undertakes ecological initiatives, such as very precise energy measurements and waste management, but these primarily serve cost-saving purposes.

For the companies from **electronics and software production** the assessment revealed the following:

- High digital and medium to high green maturity on average
- Identified key business categories: manufacturing operations processes; infrastructure, organisation and management; training and skills development; marketing and business processes, information flow
- The most notable issues were explained as pursuing the implementation of a 'Life Cycle Assessment' (when following the GHG Protocol methodology and UN's Sustainable Development Goals) and in increasing the quantity of recyclable packaging or in reusing the resources concentrated in the plant's activities

Digital maturity: Companies within the sector represent different levels of digital maturity. In general, however, they show a high willingness to implement modern solutions that optimise production processes and work organisation.

Green maturity: Discussions were held with companies at various levels of green maturity. One company places significant importance on this aspect of its operations, demonstrating a commitment to ecological production ideas and implementing circular economy solutions. It has adopted a strategic document on sustainability, knows its carbon footprint, and strives to reduce it. Additionally, the company has a policy for assessing materials used for potential environmental hazards, recovers raw materials from waste for further production, and monitors energy consumption in its facilities.

For the companies from **food and beverages production** the assessment revealed the following:

- medium digital and medium green maturity on average

- Identified key business categories: manufacturing operations processes; infrastructure, organisation and management; training and skills development; financial category; marketing and business processes, information flow
- The most notable issues were found in complying with legal regulations concerning the chemical parameters of products and in struggles with implementing water-saving technologies (such as recuperation and recirculation water systems in order to reduce water consumption); basically, in deepening the involvement through activities with circular economy (by means of PV installations, energy storage, closer water circulations, creation of a program for monitoring and forecasting production integrated with warehouse inventories etc.)

Digital maturity: Differences exist within this sector. One company shows a fairly high level of digital maturity across various processes—from production (IoT) to warehousing (real-time inventory tracking system) to marketing activities (various digital channels, gathering customer feedback, monitoring tools, etc.).

Green maturity: Depending on the company, the level of green maturity varies. Generally, however, this issue is considered important at various levels and within different processes. In one case, it is mainly about compliance with legal regulations concerning the chemical parameters of products; in the other case, involvement in green initiatives is part of the brand's image as a producer of natural food. This also entails, for example, paying close attention to the quality and origin of raw materials, using environmentally-friendly packaging, and taking action to reduce their carbon footprint, such as optimizing fleet routes.

For the companies from the **building materials and furniture production sector,** the assessment revealed the following:

- low digital and low green maturity on average
- Identified key business categories: manufacturing operations processes (as the most important); training and skills development; marketing and business processes, information flow, while to a lesser extent financial category and infrastructure, organisation and management were ticked as well
- The most notable issues were found in some inherent barriers to automation, such as automating some processes is simply impossible due to the unique nature of products (created by special orders and produced in single copies) and in automation and modernization not being always possible or cost-efficient for furniture production on smaller scales

Digital maturity: Companies in this sector make little use of digital tools to modernize production. They generally associate this with potentially high costs, uncertainty about the direction of changes, and the specific nature of their industry—automating some processes is simply impossible due to the unique nature of products, which are custom-made and produced in single copies. One of the surveyed companies places a relatively strong emphasis on digitizing sales processes and using modern marketing tools, while the others rely on personal contact with customers and expect to be contacted by them.

Green maturity: The level of ecological maturity among companies in this sector is low in the areas studied. At the same time, high energy prices are noted, which attract more interest from the surveyed entities. For these companies, the primary and most important process is production.

Furniture manufacturing (1 company):
Digital maturity: The company produces furniture on a relatively small scale; with such operations, automating and modernizing processes is not always possible or cost-effective. The area where more

advanced tools are used is marketing and sales policy—achieving a higher level of digitization here is easier due to the relatively low costs of such investments.
Green maturity: The company representing this sector shows a relatively low level of ecological maturity. It does not pay much attention to this dimension of activity within business processes.

For the company in **plastics and rubber production**, the assessment revealed the following:

- low to medium digital and low green maturity
- Identified key business categories: manufacturing operations processes; training and skills development; marketing and business operations
- The most notable issue was found in the financial viability of implementing both digital and green technologies due to the small scale of operations, as it can hardly justify the costs

Digital maturity: In terms of production processes, the company shows a rather low level of digital maturity; it tries to use modern technologies in departments such as production planning and material consumption control. Its marketing and customer acquisition activities, as well as warehouse processes, demonstrate a higher level of digital maturity.

Green maturity: The company representing this sector shows a rather low level of ecological maturity; ecology and green technologies are not currently a significant priority.

Similar issues:
Companies always pay close attention to their finances and funding opportunities—without access to funds, further progress in digital and green transformation may be significantly hindered. Only large companies with sufficient capital will be able to afford it; for smaller entities, adopting new technologies may simply be too costly. Additionally, companies need access to knowledge, as they are not always aware of how their efficiency could be improved.

Particular issues per sector:
All sectors face similar challenges in terms of green and digital transformation. Some issues, such as rising energy prices, will impact companies with larger production volumes more—this is the case for the surveyed company in the metal components production sector and companies in the construction sector. One of the companies in the food and agriculture sector emphasized the exceptionally important role of regulations.

Key Business Processes and Drivers for Twin Transition

The critical business processes and key drivers for engaging in digital and green transitions included:

- **Regulatory compliance and reporting** (ensuring compliance with environmental regulations and reporting sustainability metrics, using digital solutions for transparent and accurate sustainability reporting, avoiding penalties, and gaining certifications that can open up new markets.)
- efficiency improvements,
- **cost savings** (lowering operational costs through energy efficiency, waste reduction, and resource optimization, reducing costs associated with non-compliance and waste disposal)
- **market competitiveness, investors and stake-holders pressure and customer demand for sustainable practices** (responding to the growing emphasis on Environmental, Social, and Governance (ESG) criteria from investors, meeting stakeholder expectations for corporate responsibility and transparency)
- **human resources and training** (providing training and programs focused on digital skills and sustainability practices, soft skills training for managers/workers who are pessimistic about green

and digital transformation, and who are generally afraid of the transformation and stop it in the company)

- **supply chain management** (implementing digital tools for real-time tracking, demand forecasting, and inventory management, adopting sustainable sourcing practices and optimizing logistics to reduce carbon footprints)

These drivers varied by sector but generally focused on leveraging technology to enhance operational efficiency and meet sustainability goals.

Key Issues and Other Business Processes

The UAM testing phase uncovered several critical needs and challenges that were not fully captured in the initial business processes or mapping analysis. One significant issue was the intricate nature of regulatory compliance, particularly in sectors like agriculture and manufacturing. Companies frequently cited the difficulty of navigating complex regulatory environments, which often lack clarity and flexibility, thereby impeding the implementation of innovative technologies and sustainable practices. Financial constraints emerged as another prominent barrier across all sectors. Many SMEs highlighted the high upfront costs associated with adopting digital and green technologies, such as purchasing new equipment, training staff, and upgrading existing infrastructure. For smaller firms with limited access to funding, these financial burdens are particularly daunting and often slow down their transition processes. Additionally, the need for enhanced internal communication and data integration was highlighted. Many companies lack advanced analytical tools that could provide a comprehensive overview of their operations, leading to inefficiencies and missed opportunities for optimization. Improved data integration could help bridge this gap, enabling more informed decision-making and streamlined processes. Overall, the testing phase revealed that while there is a broad recognition of the importance of digital and green transitions, companies require more targeted regulatory support, financial assistance, and sector-specific strategies to overcome the challenges they face. These findings underscore the importance of a nuanced and adaptable approach to supporting SMEs in their transition journeys.

Key outcomes and perceptions

The key outcomes and perceptions from the testing phase included a generally positive reception of the UAM tool, with actionable feedback for improvement. Companies recognized the need for a balanced approach combining digital and green transitions. The importance of tailored strategies and continuous support was evident, with many companies appreciating the structured guidance provided by the UAM tool.

Key Testing Metrics or Indicators

Building Materials (3 companies)

Use of Digital Technologies: Companies in the construction sector currently do not utilize modern technologies on a large scale or have started to explore digital technologies like BIM. They are in the early stages of understanding the potential benefits and cost savings associated with these technologies, although their management expresses a strong desire to change this situation. Despite the nature of the company excluding the automation of all processes, the management aims to implement modern solutions wherever possible. The implementation of an ERP system unfortunately failed due to a lack of in-depth knowledge during its selection. One of the companies uses digital technologies to a very limited extent, partly due to the nature of the production (each order is made according to individual parameters). They try to monitor material consumption using spreadsheets manually filled out by production workers.

Use of Green Technologies: The company uses energy generated by photovoltaic panels. Another company is beginning to implement green technologies, focusing on state and European subsidies to overcome financial barriers. They aim to adopt practices that enhance sustainability and reduce environmental impact. The third company does not currently use green technologies in its processes.

Barriers to Adopting Digital and Green Technologies: Representatives of the companies note that the primary obstacle is a lack of sufficient knowledge in the area of new technologies—they are unsure of what and to what extent could be automated. From the perspective of others, the financial viability of these technologies is a significant barrier, along with the need for a better understanding and knowledge of effective implementation strategies.

Factors Influencing the Desire to Adopt New Technologies: The desire to strengthen their position in the Polish market and to gain the ability to compete with companies operating in the pan-European market is evident. Feedback from another company was that staying competitive, achieving cost savings, and meeting regulatory requirements are key drivers. The desire to improve sustainability and customer satisfaction also influences their adoption of new technologies.

Impact on Business Operations: The company is just at the beginning of its journey and is trying to understand the situation—learning about financing options, current trends, and conducting a technological audit. Adopting digital and green technologies is expected to improve the operational efficiency of another company interviewed by KPT, reduce costs, and enhance sustainability, making their business more competitive and environmentally responsible.

Furniture (1 company)

Use of Digital Technologies: the company operating in the furniture manufacturing sector encounters difficulties in adopting digital technologies primarily due to the small scale of its operations. They acknowledge the benefits of digitalization and are exploring various digital tools that can enhance their operations, but full-scale implementation is financially challenging at this point.

Use of Green Technologies: the company has shown interest in green technologies but finds financial justification difficult. They view state and European subsidies as potential enablers for adopting green technologies. Currently, their use of green technologies is minimal.

Barriers to Adopting Digital and Green Technologies: The company's primary barrier is financial as well. They find the implementation of these technologies not financially viable due to their operational scale. There is also a knowledge gap in understanding how to best utilize these technologies.

Factors Influencing the Desire to Adopt New Technologies: The company’s desire to adopt new technologies is influenced by the need to stay competitive, reduce costs, and increase productivity. The potential for innovation and growth, along with regulatory compliance and sustainability concerns, also motivates their interest.

Impact on Business Operations: The company believes that integrating these technologies will enhance their operational efficiency, sustainability practices, and overall competitiveness. They foresee benefits in terms of better resource management and reduced environmental footprint.

Sector: Metal (1 company)

Use of Digital Technologies: The production process of components is automated and based on data entered into the system by technologists; warehouse management is automated and uses barcodes. The company is in the process of implementing a program that measures working time at individual stations, which will allow for better planning of activities; production data is collected by a company-wide system and analyzed. The most digitized departments are production and logistics; digital technologies are also used in enterprise management. The company's management system is also somewhat digitized.

Use of Green Technologies: Workstations are equipped with a program that measures energy and material consumption; the company is considering acquiring a program to measure the carbon footprint. Barriers to Adopting Digital and Green Technologies: The company is capable of implementing new digital and green solutions.

Factors Influencing the Desire to Adopt New Technologies: Business reasons—decisions to introduce new technology are always driven by the desire to increase efficiency; reducing environmental pressure is a welcome side effect. Currently, the company does not see environmental issues as having a decisive impact on customer decisions. If this situation changes, they will respond accordingly.

Impact on Business Operations: The introduced solutions have a positive impact on efficiency.

Sector: Electronics and software (2 companies)

Use of Digital Technologies: Both companies in the equipment production sector confirmed that the use of digital technologies in their production facilities is very important, with a high level of priority. This is because they are large companies with branches located in several cities across Europe, focused on serial and repetitive production, and required to adhere to environmental regulations. One of the companies highlighted that the digital revolution is already present in their sector, with technologies such as artificial intelligence and digital twins being predominant. The company confirmed that these technologies are useful, as they use them to deliver products that meet the demands of sustainable, energy-oriented businesses and individual clients. They focus on technologies supporting low-emission cars (special filters) and electric cars. The production process for components is automated.

The second company emphasized that they have invested heavily in digitalization. They successfully switched to an integrated ERP system 18 months before the crisis struck. The company has embraced digital tools and technologies, including Microsoft Dynamics CRM, to optimize and streamline their sales processes. The integration of digital technology into their sales force's daily operations has significantly enhanced their efficiency, customer relationships, and overall business performance. They leverage Microsoft Dynamics CRM to centralize customer data, track interactions, and manage sales pipelines more effectively. Digital tools like Dynamics CRM automate routine tasks such as lead nurturing, follow-ups, and proposal generation, freeing up valuable time for sales representatives to focus on building meaningful relationships with clients. The company can analyze sales trends, forecast demand, and make data-driven decisions to optimize sales strategies and resource allocation. Among the tools and technologies supporting sales and customer service activities, the company mentioned several innovative digital advertising strategies to enhance outreach and engagement with clients. These strategies include leveraging newsletters for clients, establishing a YouTube channel, maintaining a presence on LinkedIn and Twitter, and exploring the use of AI (artificial intelligence) in their marketing efforts. The company is also exploring the integration of AI technologies, such as chatbots or personalized recommendation engines, to enhance their digital advertising efforts. AI enables them to automate customer interactions, deliver personalized experiences, and optimize ad targeting based on data-driven insights.

Use of Green Technologies: Both companies in this sector demonstrated actions confirming the use of green technologies in their facilities. These actions include the installation of photovoltaic systems. Another company is actively pursuing the implementation of a Life Cycle Assessment. It has taken a significant step in environmental accountability by calculating the CO2 emissions generated from its operations. The company followed the GHG Protocol methodology for managing and reporting CO2 emissions. As a global entity, it must also play an active and positive role in achieving the United Nations' Sustainable Development Goals (SDGs). To measure its progress in ESG matters, the company has established specific indicators and actions for each pillar of the ESG strategy. Each indicator is reported quarterly, semi-annually, or annually, depending on the defined frequency, with different target dates for completion. The Sustainability team is responsible for meeting each indicator and action area and for managing staff to achieve the targets. The actions and KPIs are reviewed periodically, taking into account additional context analysis, new trends in the automotive industry, stakeholder interests, and evolving legislation. The company's most significant source of waste is packaging. Therefore, one of the objectives is to increase the amount of recyclable packaging. Additionally, the company's actions are directed toward reusing resources concentrated in the plant's activities. Among these activities are new measures linked to the circular economy:

Sustainable Use of Resources:

Water: Regarding measures to optimize water use, the company continued its commitment to purely sanitary water and launched a Water Consumption Awareness Campaign to achieve its EHS objective.

Raw Materials: The production of the company's components involves the use of raw materials such as steel and nonferrous metals, as well as auxiliary materials such as threads, welding gases, oils, and more. The company has implemented a system to recover plastic waste from new products to optimize raw material consumption. They are continuously improving in this direction by introducing new shredding models and increasing the use of recyclable packaging. Moreover, the company has invested in machines that unify three polyacetal materials and recover 20% of the original castings. If these tests with the polyacetal materials are successful, they will lead to annual savings and other benefits.

Energy Efficiency: At the company, it is essential to monitor the energy consumption of its four sites, which includes grid electricity and natural gas. In addition, energy efficiency criteria are included in the purchase of new machinery, such as compressed air molders and dryers.

Barriers to Adopting Digital and Green Technologies:
One of the companies commented that if certain tools or technologies have not been fully integrated, it may be due to factors such as resource constraints, ongoing training needs, or the necessity for customizations to meet specific business requirements. Nevertheless, the company recognizes the importance of digital transformation in sales and is committed to pursuing initiatives that deliver tangible value and a competitive advantage for the organization.

Factors Influencing the Desire to Adopt New Technologies: Business Reason
Companies are continuously evaluating new digital and green technologies and advertising strategies to stay ahead in a competitive market. Among the factors that influence the desire to adopt new technologies, they mention competitive advantages, cost reduction, increased productivity, improved customer experience, innovation and growth, regulatory compliance, sustainability and environmental impact, market demand, clients' specific requirements, and policies that greatly influence the components' recycling potential.

While companies have made significant strides with the aforementioned approaches, they remain open to adopting innovative techniques that align with their business objectives and client needs. Looking ahead, both companies aim to continually enhance their use of digital tools and technologies to further empower their sales force and drive business growth.

Impact on Business Operations:

Digital and green technologies significantly impact business operations, leading to improved:

- Automation and efficiency, mainly energy efficiency, and reduced energy consumption: adopting energy-efficient technologies to lower energy usage and costs and integrating renewable energy sources to power operations, reducing reliance on fossil fuels.
- Data analytics and decision making
- Enhanced customer experience
- Supply chain management
- Sustainable practices, waste reduction: implementing processes to minimize waste, such as recycling and using biodegradable materials.
- Resource Optimization: Using sustainable resources and optimizing resource use to reduce environmental impact.
- Lifecycle Assessment: Conducting lifecycle assessments to ensure products are sustainable from production to disposal.
- Brand Image: Enhancing brand image and reputation by adopting green practices and demonstrating a commitment to sustainability.
- Cost Savings
- Employee engagement: creating a modern, sustainable workplace that attracts and retains top talent.
- Training and Development: providing ongoing training in digital skills and sustainability practices to enhance employee capabilities and engagement.
- By integrating digital and green technologies, businesses can achieve operational excellence, enhance sustainability, and drive long-term growth and success.

Sector: Food and beverage (2 companies)

Use of Digital Technologies:
The companies indicated that when it comes to implementing digital technologies in their plants, they are at an exploratory level. One of the companies uses Jira and Excel for production planning and resource management. For inventory management, it employs real-time tracking software but desires RFID or barcode technology for better accuracy and visibility. Cloud-based systems and predictive analytics are considered beneficial for maintaining optimal inventory levels. Integrated sensors and IoT technologies monitor equipment for predictive maintenance, enhancing reliability and reducing costs. Through data analysis, the company identifies areas for energy consumption optimization, leading to equipment upgrades and investments in renewable energy for better efficiency. Digital cash registers improve the efficiency of financial and accounting systems, while financial reporting is conducted using Excel, Jira, and cash systems. However, the company acknowledges the significant manual effort required due to a lack of integration. The company uses digital platforms and social media for recruitment and promoting itself as an employer. It tracks employee performance and facilitates training with internal systems but sees potential for more interactive digital tools. For digital advertising and customer engagement, the company uses Google Ads, Facebook, and Instagram, tracking effectiveness with Google Analytics and employing innovative strategies like geolocation. Customer data analytics are integrated to tailor advertising efforts and enhance engagement. In sales and customer service, the company uses tools for sales tracking and customer relationship management, enabling personalized interactions and improving

processes. Digital platforms are utilized to identify and apply for government grants and project funding, with data analysis enhancing the quality and alignment of applications. For internal communication, the company uses platforms like Slack for efficient information flow and employee feedback collection.
The company from the agriculture sector recognizes the immense potential of digital and technological solutions for circular transition. In the context of its products, digital technologies could streamline data collection on crop performance, environmental impact, and regulatory compliance, contributing to sustainable agriculture. Awareness of digital solutions is high, and they acknowledge their utility. Technologies such as precision agriculture tools, data analytics, and IoT sensors could optimize resource utilization, monitor crop health, and ensure compliance with sustainable practices. Despite recognizing their benefits, implementation is still in the early stages, and the company is actively exploring opportunities to integrate digital solutions into their circular transition strategy.

Use of Green Technologies:
Both companies have implemented a number of initiatives to reduce the energy consumption and environmental footprint of their production equipment. The company from the food sector prioritizes the use of energy-efficient and low-emission machines through preferential purchasing and regular monitoring and optimization of energy consumption. Both companies also aim to use water-saving technologies, such as recuperation and recirculating water systems, to reduce water consumption. In equipment management, the companies measure to ensure proper disposal or recycling, such as identifying and segregating used equipment and working with certified recycling companies. One of the companies has implemented sustainable packaging strategies by selecting packaging materials that are recyclable, biodegradable, or made from renewable resources. The decision-making process behind the choice of packaging materials includes an analysis of their environmental impact, market availability, recyclability or biodegradability, and their ability to meet product protection and customer satisfaction requirements. When selecting sustainable packaging materials, the company follows the principle of "reduce, reuse, recycle" to minimize its impact on the environment. The approach of one of the companies is to design packaging to minimize environmental impact and support recycling and reuse. They employ strategies to minimize packaging waste at the design stage by reducing packaging layers and optimizing sizes. For example, based on the LCA assessment, the company has reduced the amount of plastic packaging used in their products by 60%, replacing it with more sustainable alternatives such as paper, metal, or biodegradable packaging. They also place great emphasis on sorting and recycling their packaging, thus supporting the circular nature of materials and the reduction of waste.

At the same time, the company would like to deepen its involvement in circular economy activities through initiatives such as PV installations, energy storage, closed water circulation (cooling tower), replacement of equipment with energy-saving alternatives, and the creation of a program for monitoring and forecasting production integrated with warehouse inventories. The company continuously monitors energy consumption and uses technology to identify areas for improvement. It employs various strategies to minimize the environmental impact of energy and resource consumption. The company measures and tracks the carbon footprint of its manufacturing operations and implements circular economy principles, such as reusing production waste as secondary raw materials and minimizing waste by optimizing processes. They are planning initiatives to use renewable energy sources, including the installation of photovoltaic panels at their facility, the installation of a closed-circuit water-cooling tower for cooling the chillers, and collaborating with suppliers that offer sustainable raw materials. The company also employs sustainable storage practices by optimizing space and using eco-friendly, reusable packaging materials. Additionally, they have introduced initiatives to reduce energy consumption, such as LED lighting and partial replacement of appliances with energy-efficient ones. In the future, they aim to partially power their storage devices with electricity from PV installations.

Barriers to Adopting Digital and Green Technologies:

The company from the agriculture sector highlighted that it encounters challenges in the circular transition, primarily related to regulatory aspects. The current EU regulations are not fully aligned with new products and technologies like theirs, posing risks to seamless integration. Regulatory approval pathways for alternatives to traditional synthetic products in agriculture are not well-established, adding uncertainty to their circular transition efforts. Besides funding, there is a lack of knowledge on how the digitization of processes could be achieved.

Factors Influencing the Desire to Adopt New Technologies: Business reasons—fear of competition that can produce faster and cheaper, both through improved production processes and reduced energy costs.

Sector: Plastic and rubber (1 company)

Use of Digital Technologies: The company is engaged in the manufacturing sector, specifically in plastic products. The company has expressed an interest in incorporating digital technologies; however, they currently face significant challenges due to the scale of their operations being too small to justify the financial investment. While digital technologies are recognized for their potential benefits, their integration remains limited.

Use of Green Technologies: The company utilizes photovoltaic panels to generate energy, marking their commitment to green technologies. However, similar to digital technologies, the scale of operations poses a significant barrier to the broader implementation of green technologies.

Barriers to Adopting Digital and Green Technologies: The main barrier for the company is the financial viability of implementing both digital and green technologies. They find it challenging to justify the costs given their small scale of operations. Additionally, there is a need for more knowledge and expertise in selecting and implementing these technologies.

Factors Influencing the Desire to Adopt New Technologies: The company is driven by the potential for gaining competitive advantages, cost reduction, increased productivity, and improved customer experience. Legislative pressures and available subsidies also play a crucial role in influencing their desire to adopt new technologies.

Impact on Business Operations: The company anticipates that adopting digital and green technologies will lead to improved efficiency and sustainability. They expect better resource optimization, reduced environmental impact, and potential cost savings.

Testing Phase Problems and Challenges

The challenges encountered during the testing process included reluctance to share detailed data, language barriers, and varying levels of digital literacy among company representatives. These issues were mitigated through careful planning, use of local languages, and ensuring confidentiality to encourage open and honest feedback. Additionally, the User Acceptance Model itself is a tool that, if approached comprehensively, requires the involvement of several people from a given company representing different departments and a significant investment of time. Unfortunately, companies are unable to dedicate more than 2-3 hours to discussions on this topic.

Results Analysis and UAM's Practical Application

The analysis of the results indicated that while the UAM tool is practical and useful, it requires simplification to be more user-friendly. Tailored support and sector-specific strategies are crucial for its

effective implementation. Feedback from the testing phase highlighted the importance of continuous refinement and improvement based on user experiences and emerging challenges.

Comparing Actual Outcomes with Expected Results
The actual outcomes were generally in line with the expected results, although some challenges, such as regulatory hurdles, were more pronounced than anticipated. The positive reception of the UAM tool and the actionable feedback provided valuable insights for its refinement and future application.

Hungary

In Hungary, the Hungarian Economic Agency for Development interviewed 8 companies as follows: 3 from the food and beverages production sector, 2 from the plastics and rubber sector, 1 from the building materials and furniture sector, and 2 categorized as "other" (involved in cosmetics production).
For the companies **in the food and beverages sector** the assessment revealed the following:

- Low and high digital and low green maturity
- Identified key business categories: manufacturing operations processes; training and skills development and information flow
- The most notable issue recognized as the need for energy efficient technologies and in improving the waste management systems

For the company in **the plastics and rubber** sector the assessment revealed the following:

- High digital and high green maturity
- Identified key business categories: manufacturing operations processes and governmental impact
- The most notable issues were found in applying AI systems in manufacturing processes and speeding up data evaluation. Additionally, managing different materials that require varying heating processes was a challenge, with heating representing the largest cost. In this context, the company would like to have enough work to justify more shifts

For the company in **building materials and furniture production** the assessment revealed the following:

- High digital and high green maturity
- Identified key business categories: manufacturing operations processes; training and skills development and information flow
- The most notable issues recognized were the importance of sustainability and varying prices across different international markets, the lack of benchmarking criteria (due to the absence of common databases for target setting), and an insufficient production planning system that does not account for energy consumption (leading to overproduction of energy with solar panels). Additionally, there is a need for AI solutions and adequate human resources capable of implementing and monitoring these systems. The company also faces challenges with owning diverse machinery, each requiring different maintenance systems and staff.

The general attitude towards digital transformation is overwhelmingly positive. Company representatives recognize it as a crucial factor for enhancing efficiency, productivity, and overall competitiveness. They appreciate the potential of technologies such as artificial intelligence, data analytics, and automation to streamline operations and drive growth. However, there are concerns about the costs and complexities associated with implementing these digital tools, particularly for smaller businesses that may lack the necessary resources and technical expertise.

When it comes to the green transition, attitudes are also positive but tend to be more cautious compared to digital transformation. While SMEs understand the importance of sustainability for meeting regulatory requirements and improving their corporate image, there is significant apprehension about the financial burden and the expertise needed to implement green practices effectively. Many companies are aware of the long-term benefits of sustainability but are wary of the immediate costs and challenges involved.

Common challenges included high initial costs for adopting new technologies, resistance to change, especially in companies with entrenched traditional practices, and a lack of expertise and comprehensive training programs. Financial constraints were a significant barrier for many, impacting their ability to invest in both digital and green technologies.

Key Issues and Other Business Processes

During the UAM testing phase by MGFÜ, several key challenges emerged that were not fully captured in the initial analysis. A significant issue was the lack of expertise and skills in digital and green technologies, which hampers SMEs' ability to adopt and integrate new solutions effectively. Additionally, many businesses face financial constraints that limit their capacity to invest in necessary technologies and sustainable practices.

The testing also highlighted a lack of adequate support and consultancy, leaving SMEs without the guidance needed to navigate digital and green transitions. Furthermore, some companies lack a clear vision or strategy for these transitions, making it difficult to plan and implement changes effectively. Addressing these challenges is crucial for SMEs to successfully undertake digital and sustainable transformations.

In terms of areas requiring additional testing, it is important to explore Sector-Specific Integration Challenges further, particularly in sectors like custom manufacturing, to better understand how these industries handle the integration of digital and green technologies. Additionally, evaluating the Effectiveness of Training Programs will be crucial in determining how well these programs reduce resistance to change and improve the adoption rates of new technologies among SMEs.

Key outcomes and perceptions

During the UAM testing phase conducted by MGFÜ, the team observed a range of emotions and attitudes among the representatives of the interviewed companies. Overall, the mood was predominantly positive, with many participants expressing genuine interest and enthusiasm about the potential benefits the UAM could bring to their businesses. There was a shared sense of optimism, particularly among those who viewed the UAM as a valuable tool to help them better understand their current operational state and to chart a clear path forward in their digital and green transitions.

However, the attitudes toward adopting new technologies varied significantly across the companies. Some, especially those in more innovative sectors (e.g., plastics and rubber), were highly proactive. They saw the UAM as an opportunity for growth and were eager to embrace the changes needed to stay competitive. These companies were generally more open and collaborative, readily sharing their experiences and insights, which contributed to rich and meaningful discussions.

In contrast, other firms, particularly those rooted in more traditional practices like the interviewed companies from food and beverages industry cluster, approached the UAM with a degree of caution and skepticism. Their concerns were primarily centered around the financial and administrative burdens

associated with implementing new technologies and meeting regulatory requirements. For these companies, the complexities of the digital and green transitions seemed daunting, leading to a more guarded approach during the discussions. It was crucial to acknowledge their concerns and to clearly explain how the UAM could help them navigate these challenges while highlighting the specific benefits they could gain.

One consistent observation across all companies was the impact of daily workload pressures on their capacity to focus on innovation. Due to personnel savings and the demands of day-to-day operations, many representatives indicated that their teams had limited time to dedicate to exploring new digital and green initiatives. While there was a clear desire to learn and implement processes that could save time, reduce errors, and improve efficiency, the reality of their daily responsibilities often left little room for such exploration.

Key Testing Metrics or Indicators

1. Adoption Rates of Digital and Green Technologies
   - Digital Technology Adoption: Varying levels across sectors, with the building material and furniture company showing advanced integration, while others, mostly from food and beverages industry cluster are just beginning.
   - Green Technology Adoption: Implementation of green practices was generally lower, with most companies at early stages of adopting sustainable practices.
2. Levels of Preparedness and Development
   - Digital Maturity Scores: Ranged from Basic to Advanced, with larger and more advanced building materials and furniture producer scoring high due to their significant investments in digital technologies.
   - Green Maturity Scores: Similarly varied, with some companies showing basic levels of green integration, while others from plastics and rubber innovations are more advanced.
3. Obstacles to Implementation
   - Common barriers included financial constraints, gaps in skills and training, and technical challenges related to integrating new technologies.

Results Analysis and UAM's Practical Application

The UAM highlighted several areas for improvement that should inform future developments of the tool. Enhanced Financial Support emerged as a critical need, particularly for smaller companies from food and beverages manufacturing., which face significant financial barriers to adopting new technologies. Future UAM versions should offer more detailed guidance on accessing funding sources tailored to support digital and green transitions.

Additionally, the Need for Tailored Training Programs was evident, especially in companies lacking expertise in digital and green technologies. The UAM should include targeted training to help businesses build the necessary skills, with content customised to the specific challenges of each sector.
To address the technical challenges of implementation, the UAM should provide Simplified Integration Processes with practical guides and sector-specific examples, assisting even medium developed companies in navigating digital transformations.

Lastly, establishing a Continuous Feedback Mechanism will be crucial for refining the UAM based on real-world experiences, ensuring it remains relevant and effective for SMEs across different industries.

For the efficient execution of the UAM among SMEs, several tactics are recommended. Firstly, engaging key stakeholders early is essential. Involving SME leadership from the start, as was done with the

company producing packaging products, through initial meetings and regular updates, will ensure their buy-in and ongoing engagement. Secondly, it is important to customise the questionnaire to be sector-specific. Developing and piloting sector-specific questions will make the questionnaire more relevant and easier for SMEs to complete. Thirdly, Providing Comprehensive Support throughout the UAM process is vital. Setting up a support team to assist more developed food and beverages companies with guides and video tutorials can address common challenges during completion. Lastly, Building Trust and Encouraging Participation is key. This can be achieved by clearly communicating the UAM's purpose, guaranteeing confidentiality, and offering incentives such as exclusive reports or benchmarking data, as successfully done with the example from the advanced building materials and furniture company.

In terms of areas requiring additional testing, it is important to explore Sector-Specific Integration Challenges further, particularly in sectors like custom manufacturing, to better understand how these industries handle the integration of digital and green technologies. Additionally, evaluating the Effectiveness of Training Programs will be crucial in determining how well these programs reduce resistance to change and improve the adoption rates of new technologies among SMEs.

E. Recommendations

Based on the extensive qualitative analysis and results of the User Acceptance Model (UAM) testing across 68 manufacturing SMEs in seven Central European countries, we have identified several key recommendations to help manufacturing companies navigate their digital and green transformation journeys more effectively. These recommendations are grounded in real-world experiences and challenges faced by actual companies, and are designed to provide practical, actionable guidance for improving your digital and green maturity.

Adopt a Modular and Flexible Approach to Transformation

One of the most significant findings from our UAM testing was the wide variation in digital and green maturity levels across different companies and sectors. We found that a one-size-fits-all approach to digital and green transformation is ineffective. Therefore, we strongly recommend adopting a modular and flexible approach to your transformation journey. What does this mean for your company? Instead of trying to implement a comprehensive transformation all at once, break down your journey into smaller, manageable modules. The UAM can help you identify which areas of your business are most critical for improvement and which are likely to yield the quickest returns on investment.

For example, if the company was assessed low in digital maturity for production planning but high in energy efficiency, the company might want to prioritise implementing a digital production planning system before tackling more advanced green initiatives. This approach allows SMEs to focus their resources where they're needed most and see tangible results more quickly, which can help build momentum and support for further transformation efforts.

Invest in Workforce Skills and Culture Change

Our UAM testing revealed that one of the biggest barriers to digital and green transformation is the lack of necessary skills within the workforce and resistance to change in a variety of attitudes, captured in the ‘conservative business realists’ ideal type. To address this, we recommend making significant investments in workforce development and fostering a culture of continuous learning and innovation. This doesn't just mean sending the employees to training courses (although that can be part of it). It means embedding learning and innovation into SMEs’ daily operations. Here are some specific steps:

- Develop a comprehensive skills assessment and training program, using the UAM to identify key skill gaps in organisation.
- Implement mentoring and knowledge-sharing programs to spread digital and green expertise throughout a variety of companies
- Create cross-functional teams to work on digital and green initiatives, fostering collaboration and breaking down silos.
- Establish an innovation space within SMEs where employees can experiment with new technologies and sustainable practices.
- Recognize and reward employees who contribute to SMEs digital and green transformation efforts.

Alas, successful transformation is as much about people as it is about technology.

Use Data for Decision-Making

Our UAM testing showed that companies that effectively leverage data for decision-making are more successful in their digital and green transformations. We strongly recommend implementing robust data collection and analysis practices across SMEs’ organisation. It would be sensible to start by identifying

the key metrics that matter most for the SMEs' respective business operations and sustainability goals. The UAM can help to determine which metrics are most relevant for a specific industry cluster and the company's maturity level. In the second step, implementing systems to consistently collect and analyse this data shall be needed.

Participating in Collaborative Ecosystems

One of the key insights from our UAM testing was the importance of collaboration in driving successful transformations. Many SMEs, particularly those in traditional manufacturing sectors, tend to operate in isolation. However, we found that companies that actively engage with external partners and ecosystems are more successful in their digital and green transformations. We recommend actively seeking out and participating in collaborative ecosystems:

- Joining industry associations or clusters focused on digital and green transformation.
- Partnering with technology providers or sustainability experts to access specialised knowledge and capabilities.
- Collaborating with research institutions or universities on innovation projects.
- Engaging with supply chain partners to implement end-to-end digital and green solutions.

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Integrate digital and green Initiatives

Our UAM testing revealed that companies often treat digital transformation and sustainability as separate initiatives. However, we found that the most successful companies integrate their digital and green efforts, leveraging technology to drive sustainability and vice versa. We recommend looking for opportunities to integrate digital and green initiatives, such as:

- Use IoT sensors and data analytics to optimise energy consumption in SMEs production processes.
- Implement digital twin technology to simulate and optimise any product designs for sustainability.
- Use QR codes, barcodes or other digital technologies to improve traceability and transparency in various supply chain, supporting sustainable sourcing efforts.
- Leverage AI and machine learning to predict and prevent waste in your production processes.

Develop a clear roadmap with measurable milestones

Our UAM testing showed that companies with clear, well-defined transformation roadmaps are more likely to succeed in their digital and green efforts. We recommend using the insights from your UAM assessment to develop a detailed roadmap for different transformation journey. This roadmap should include:

- Clear, measurable goals for both digital maturity and sustainability.
- Specific initiatives and projects to achieve these goals.
- Timelines and milestones for each initiative.
- Assigned responsibilities for each project or initiative.
- Key performance indicators (KPIs) to track progress.

For example, if your UAM assessment revealed low maturity in waste management, this roadmap might include a goal to reduce waste by 30% within two years. The company might then outline specific projects to achieve this, such as implementing a digital waste tracking system, redesigning products for recyclability, and partnering with recycling companies.

Prioritise cybersecurity and data privacy

As companies become more digitised, the risks associated with cybersecurity and data privacy increase. Our UAM testing revealed that many manufacturing SMEs are not adequately prepared for these risks.

We strongly recommend prioritising cybersecurity and data privacy as part of your digital transformation efforts. This includes:

- Conducting regular cybersecurity risk assessments.
- Implementing robust data protection measures.
- Training employees on cybersecurity best practices.
- Developing and regularly updating an incident response plan.
- Ensuring compliance with relevant data protection regulations (e.g., the GDPR in the EU).

Use government support and funding

Our UAM testing revealed that many SMEs are not fully utilising available government support and funding for digital and green initiatives. We recommend actively seeking out and leveraging these resources. Many governments offer grants, tax incentives, and other support programs for companies investing in digital technologies and sustainable practices. For example, the European Union's Recovery and Resilience Facility provides significant funding for digital and green transitions.

Implement continuous improvement processes

Digital and green transformation is not a one-time effort, but an ongoing journey. Our UAM testing showed that companies that implement continuous improvement processes are more successful in the long term. We recommend implementing a structured continuous improvement process, such as the Plan-Do-

Check-Act (PDCA) cycle. This involves:

- Plan - Use the UAM assessment to identify areas for improvement and develop action plans.
- Do - Implement the planned improvements.
- Check - Use data and metrics to assess the effectiveness of the improvements.
- Act - Based on the assessment, adjust the plans and start the cycle again.

Through this kind of structured improvement process, companies can ensure that digital and green transformation efforts continue to evolve and improve over time.

Foster leadership commitment and vision

Finally, our UAM testing consistently showed that leadership commitment is crucial for successful digital and green transformation. We recommend that company leaders not only support these efforts but actively champion them. This comprises:

- Developing and communicating a clear vision for the company's digital and green future.
- Aligning the company's strategy and investments with this vision.
- Regularly communicating about the importance of digital and green initiatives to all employees.
- Leading by example in adopting new technologies and sustainable practices.

These recommendations, derived from our extensive UAM testing and analysis, provide a roadmap for manufacturing SMEs to successfully navigate their digital and green transformation journeys.

F. Conclusions

The User Acceptance Model (UAM) testing process collected some key info that have significant implications for manufacturing companies embarking on their digital and green transformation journeys. Through our extensive qualitative analysis of 68 manufacturing SMEs across 7 Central European countries, we've gained valuable insights into the challenges, opportunities, and best practices in adopting digital and sustainable technologies. We will summarize some of its key discoveries below.

KEY FINDINGS

Varied maturity levels across sectors

One of the most striking discoveries from our analysis is the significant variation in digital and green maturity levels across different manufacturing sectors. We assessed that companies in the electronics and software sector or machinery and equipment generally scored quite high in digital maturity but were not necessarily leaders in green transition. In contrast, traditional sectors like metal and metal products or food and beverages scored lower on average. Therefore, regardless of the sector, there's room for improvement in both digital and green practices. If a company is in a traditionally less digitized sector, such SMEs have an opportunity to gain a competitive edge by accelerating their digital transformation. For those in more advanced sectors, the challenge is to maintain the lead and continue pushing the boundaries of innovation.

Curse of Being Small

Many smaller SMEs reported feeling disadvantaged in their ability to adopt new technologies and sustainable practices due to limited resources, both financial and human. This "curse of being small" was a recurring theme across various sectors and countries.

However, collecting various SMEs experiences and business models also revealed that size isn't destiny. We found some examples of smaller companies (10-49 employees) achieving high levels of digital maturity, often outperforming larger counterparts.

Synergies Between Digital and Green Transitions

Our analysis revealed a notable correlation between digital and green maturity assessment. Companies scoring high in digital maturity were more likely to also score high in green maturity, and while the companies assessing their green maturity as advanced, necessarily scored high in some aspects of digital maturity. This suggests a synergistic relationship between digital and green transitions.

This discovery implies that SMEs shouldn't view digital and green initiatives as separate efforts. Instead, the companies should look for opportunities where digital technologies can drive sustainability improvements, and where sustainability goals can be a catalyst for digital innovation. This integrated approach can lead to more efficient use of resources and more effective overall transformation.

Challenge of Skills and Expertise

A recurring code present in various themes across our interviews, was the lack of necessary skills and expertise to effectively implement digital and green technologies. Many companies, particularly in

traditional manufacturing sectors, reported difficulties in attracting and retaining employees with the right mix of technical and sustainability skills.

This skills gap was often cited as a major barrier to digital and green transitions. For instance, a metal products company in Slovenia, despite having the financial resources for advanced digital systems, struggled to implement them due to a lack of time resources and digital skills in their workforce.

Measurable goals and continuous improvement

Our analysis revealed that companies that set clear, measurable goals for their digital and green initiatives, and implemented systems for continuous monitoring and improvement, generally made more progress in their transformation efforts.

For instance, companies that used data analytics to track key performance indicators (KPIs) related to energy efficiency, waste reduction, or process optimization were better able to identify areas for improvement and demonstrate the value of their initiatives.

The implication for the SMEs is to establish clear metrics and KPIs for your digital and green initiatives, implement systems for regular data collection and analysis, and use this information to drive continuous improvement. This data-driven approach can help SMEs prioritize their efforts, justify investments, and demonstrate progress to stakeholders.

However, the benefits and impacts of the UAM framework extend far beyond the individual SMEs that use it. By providing a common language, framework, and platform for digital and green transformation, the UAM has the potential to catalyze wider changes and collaborations across the manufacturing industry and the broader ecosystem of stakeholders. This is particularly important in the context of the twin transition, which requires a systemic and coordinated approach to address the complex and interconnected challenges of digitalization and sustainability, such as skills development, infrastructure investment, regulatory alignment, and societal acceptance.

One of the key ways in which the UAM can catalyze wider digital and sustainable changes is by fostering a culture of continuous learning, experimentation, and collaboration among manufacturing SMEs. Through the UAM testing and recommendation process, SMEs are encouraged to reflect on their current practices and performance, identify areas for improvement, and explore new technologies and business models. This process of self-reflection and exploration can help SMEs to break out of their traditional silos and mindsets, and to embrace a more open and innovative approach to digital and green transformation.

For example, policymakers can use the UAM data to identify the skills and infrastructure gaps that need to be addressed to support the twin transition, and to design and implement more effective education, training, and investment policies. Technology providers can use the UAM insights to develop and market more relevant and user-friendly digital and sustainable solutions for manufacturing SMEs, and to co-create and test these solutions with the end-users. Industry associations and clusters can use the UAM framework to benchmark and support their members in the twin transition, and to facilitate more collaboration and knowledge-sharing across the value chain.

The wider importance of the UAM framework in catalysing digital and sustainable changes cannot be overstated. By providing a common language, framework, and platform for assessment, recommendation, and collaboration, the UAM has the potential to drive systemic and transformative changes across the manufacturing industry and the broader ecosystem of stakeholders involved in the twin transition. It can

help to foster a culture of continuous learning, experimentation, and collaboration among manufacturing SMEs, to inform and support the development of targeted policies, programs, and solutions, and to raise awareness and understanding of the importance and benefits of digital and sustainable transformation among a wider audience.

To fully realise the wider importance and potential of the UAM framework, it is essential for manufacturing companies, policymakers, technology providers, and other stakeholders to work together and align their efforts and resources towards a common vision and roadmap for the twin transition. This could involve:

- Scaling up the adoption and use of the UAM framework across the manufacturing industry, by raising awareness, providing incentives, and supporting the implementation of the UAM assessment and recommendation process.
- Strengthening the collaboration and knowledge-sharing among manufacturing SMEs, experts, and stakeholders involved in the UAM framework, by creating more opportunities for peer learning, networking, and co-creation.
- Aligning the policies, programs, and investments in support of the twin transition with the insights and recommendations generated through the UAM framework, by using the UAM data and evidence to inform and guide the decision-making process.
- Communicating and disseminating the progress and impact of manufacturing SMEs in the twin transition, by using the UAM framework to track and report on the key performance indicators and success stories, and to engage and inspire a wider audience.
- Adapting and replicating the UAM framework to other industries and sectors, by sharing the lessons learned and best practices, and by co-designing and piloting similar approaches and tools for digital and sustainable transformation.

In conclusion, these key findings from our UAM testing and qualitative analysis provide valuable insights for manufacturing companies embarking on their digital and green transformation journeys. They highlight the complexities of these transitions, but also point to significant opportunities for companies that can effectively navigate these challenges. By understanding these insights and their implications, you can develop more effective strategies for your own digital and green initiatives, positioning your company for success in an increasingly digital and sustainable future.

G. Annexes

1. UAM surveys – 68 surveys
2. Feedback Templates