D2.1 Challenges and proposal selection framework and performance KPIs

25/04/2025

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Grant Agreement No.: 101189562
Call: HORIZON-CL4-2024-DIGITAL-EMERGING-01
Topic: HORIZON-CL4-2024-DIGITAL-EMERGING-01-04
Type of action: HORIZON-IA

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Title	Challenges and proposal selection framework and performance KPIs
Document description	Challenges identified, evaluation framework for SME proposal selection, and solution performance KPIs for OC1
Keywords	Challenges, open calls, low-trl playgrounds, high-trl playgrounds
Deliverable type	R — Document, report
Dissemination level	PU - Public
Work package	WP 2
Task	2.1
Lead partner	LEITAT
Partners involved	I2M, UGENT, KUL, JSI, F6S, ARC, ELES, LTH, VKR, ISQ
Due date	30/04/2025
Submission date	25/04/2025
Version	1
Authors	Bastien HUALPA (LEITAT)
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Revision History	Date	Description of change	Author (s)
Version 01	15/04/2025	Creation and redaction	Bastien HUALPA (LEITAT)

Version 02	23/04/2025	Review	Angel J. Lopez (UGENT)
Version 1	24/04/2025	Final version	Bastien HUALPA (LEITAT)

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ABBREVIATIONS & ACRONYMS

AI	ARTIFICIAL INTELLIGENCE
BAU	BUSINESS AS USUAL
COP	COMMUNITY OF PRACTICE
D	DELIVERABLE
DMP	DATA MANAGEMENT PLAN
DOA	DESCRIPTION OF ACTION
DOE	DESIGN OF EXPERIMENTS
DT	DIGITAL TWIN
D&C	DISSEMINATION AND COMMUNICATION
GA	GRANT AGREEMENT
HW	HARDWARE
KER	KEY EXPLOITABLE RESULT
KPI	KEY PERFORMANCE INDICATOR
L	LEAD
LCA	LIFE CYCLE ASSESSMENT
LCC	LIFE CYCLE COSTING
M	MONTH
ML	MACHINE LEARNING
MS	MILESTONE
O	OBJECTIVE
OC	OPEN CALL
P	PARTICIPANT
RP	REPORTING PERIOD
SME	SMALL AND MEDIUM-sized Enterprise
SO	SPECIFIC OUTCOME
SW	SOFTWARE
T	TASK
TRL	TECHNOLOGY READINESS LEVEL

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UC	USE CASE
WP	WORK PACKAGE
W.R.T	WITH RESPECT TO
FSTP	FINANCIAL SUPPORT TO THIRD PARTIES
RGB	RED, GREEN, BLUE
IRT	INFRARED THERMOGRAPHY
QA	QUALITY INSURANCE
EOL	END OF LIFE
NIR	NEAR-INFRARED
VIS	VISIBLE RANGE
O&M	OPERATION AND MAINTENANCE
FAQ	FREQUENTLY ASK QUESTION

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Executive Summary

The AID4SME project aims to advance Artificial Intelligence (AI) and Data-driven solutions tailored for Small and Medium-sized Enterprises (SMEs) and startups, fostering innovation and accelerating digital transformation. The project's approach is structured around four key pillars that encompass the full lifecycle of AI and Data Technologies: (1) data collection, (2) creation of insights, (3) decision support, and (4) automation. These pillars are supported by carefully selected high-TRL playgrounds (industrial sectors) and low-TRL playgrounds (academic and research settings), chosen based on two guiding principles: alignment with Green Deal objectives and strong market potential. The low- and high-TRL playgrounds will provide opportunities for SMEs to test and validate approaches and solutions, together with the AID4SME consortium to address challenges related to the Green Deal.

AID4SME provides a platform for SMEs and startups to demonstrate, validate, and scale their AI-driven solutions. Beyond technical validation, the project actively fosters knowledge exchange and ecosystem building through AI & Data events, networking opportunities, and educational programs through the formation of a Community of Practice (CoP). The CoP will guide SMEs and startups during the development, demonstration, and marketing of the challenge solutions, offering expert knowledge, firsthand market intelligence, and independent testing and validation facilities provided by the academic partners, where the SMEs and startups can safely exchange data and test and validate their low TRL solutions.

This report aims to provide a comprehensive overview of the open challenge concept, the identified challenges, and the evaluation framework for selecting SME proposals and assessing solution performance through Key Performance Indicators (KPIs).

Key highlights include:

- Methodology for defining challenges: the methodology used to define the challenges involves the challenge leaders, contributors, and low-TRL and high-TRL playgrounds. This ensures that the challenges are clearly defined, relevant, and aligned with the project's objectives.
- Key concepts in challenges and open calls: the main concepts used throughout the challenges and upcoming open calls include the technical domains, the playground and contributions.
- Detailed challenges, AID4SME contributions, and sought solutions: The challenges are outlined with specific requirements to evaluate the performance of proposed solutions. AID4SME contributes by providing infrastructure, mentorship, and funding to support SMEs in developing innovative solutions. The sought solutions aim to effectively address the identified challenges, leveraging advanced technologies and collaborative efforts.

1 Introduction

The integration of AI, data analytics, and other related technologies into industrial solutions presents a transformative opportunity to enhance efficiency, sustainability, and innovation. This document serves as a foundational guide for addressing challenges and leveraging the potential of these advanced technologies. By focusing on key technical domains and utilizing both low-TRL and high-TRL playgrounds, we aim to create a dynamic environment for experimentation and development.

Our approach is structured around clearly defined KPIs that measure the success of our initiatives. These KPIs are designed to ensure that our efforts align with broader environmental and societal goals, particularly those outlined in the Green Deal. The collaborative contributions from the AID4SME project, including building blocks, education programs, and mentoring initiatives, are complementary and essential to the success of the challenges.

The challenges posed by combined AI and data solutions for data collection, insight, decision support, and automation require innovative approaches from third parties.

This document outlines the content for future deliverables, including Deliverable D2.3 – Open call documents KIT & third-party financing rules. This forthcoming deliverable will provide comprehensive guidelines and support for applicants, ensuring a transparent and efficient application process.

2 Methodology

As the task leader, LEITAT has taken the lead in refining and detailing the challenges initially integrated into the project. To ensure a comprehensive understanding and effective collaboration, LEITAT organized a series of online meetings involving all key partners. These meetings were meticulously planned to thoroughly review each challenge and gather essential data. During these sessions, LEITAT facilitated in-depth discussions to define the requirements, specific KPIs, and relevant parameters necessary for evaluating the performance of the proposed solutions. The collaborative nature of these meetings allowed for diverse perspectives and expertise to be shared, ensuring that all aspects of the challenges were addressed. By systematically collecting and analyzing data, LEITAT and the partners were able to establish a solid foundation for measuring success and driving the project forward.

3 Main concepts

3.1 Open calls

AID4SME issues open calls (OCs) for funding opportunities aimed at supporting SMEs in developing groundbreaking solutions. These open calls are designed to foster innovation and drive significant advancements in various sectors.

Purpose and Objectives: The primary goal of these open calls is to empower SMEs to create innovative solutions that tackle large-scale resource optimization challenges. By leveraging combined AI and data technologies, these solutions aim to make a substantial impact on industries that are crucial to achieving the objectives of the Green Deal.

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Selection and Support: A minimum of 20 SMEs will be selected through two open calls to receive Financial Support to Third Parties (FSTP). This funding will enable them to develop their proposed solutions with the backing of a Community of Practice (COP). The COP will provide a collaborative environment where SMEs can share knowledge, access expertise, and receive mentorship throughout the project lifecycle.

Focus Areas: The open calls specifically target projects that integrate AI and data solutions to optimize resources on a large scale. These projects should demonstrate the potential for significant impact in areas such as:

- **Impact on Green Deal:** Developing solutions that reduce energy consumption and enhance efficiency in industrial processes; creating solutions that minimize waste and promote sustainable manufacturing practices; as well as innovating ways to reduce carbon footprints and mitigate environmental damage.
- **Impact on social benefits:** Developing solutions that have a profound social impact by fostering inclusive growth and improving quality of life. It aims to create job opportunities, enhance workforce skills, and promote social equity. By addressing key societal challenges, the project contributes to building resilient communities and supports the overall well-being of the population.
- **Impact on resource optimization:** Developing solutions that maximize the efficient use of resources across various industries. This includes optimizing supply chains, reducing material waste, and improving resource allocation.

Application Process: Interested SMEs must submit detailed proposals outlining their project ideas, methodologies, and expected outcomes. The proposals will be evaluated based on criteria such as innovation potential, feasibility, and alignment with the Green Deal objectives. Successful applicants will be selected through a transparent and competitive process.

Evaluation and Monitoring: Selected projects will be closely monitored and evaluated against predefined KPIs. These KPIs will measure the effectiveness of the solutions in terms of resource optimization, environmental impact, and social benefits. Regular progress reviews will ensure that the projects stay on track and achieve their intended goals.

3.2 Technical domains

AID4SME focuses on four technical domains that combine AI and data technologies: **Automation**, **Data Collection**, **Decision Support**, and **Insights (**Figure 1**)**. These domains are represented by concrete use cases from industrial partners and are accessible through the CoP's low- and high-TRL playgrounds.

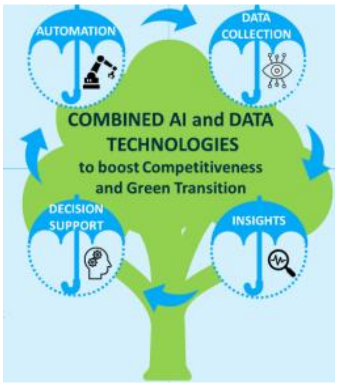

FIGURE 1 OVERVIEW OF THE COMBINED AI AND DATA TECHNOLOGIES OFFERED BY THE AID4SME CONSORTIUM

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3.3 Low-TRL playgrounds

The scientific, low-TRL playgrounds provide a safe and flexible environment for **early-stage experimentation and prototyping** of AI and data solutions. Hosted by research partners within the CoP, these playgrounds offer access to advanced testing infrastructure, simulation tools, and expert mentoring to assist SMEs in exploring innovative ideas before deployment. These include, for example, a platform for data analytics (UGENT), a Digital Twin Experience Center (KUL), robotic testbeds (JSI), and labs for EV battery disassembly and photonics-based 2D/3D image analysis (LEITAT).

Additional information is available in the AID4SME public deliverable titled "COP Targets Report," which contains comprehensive presentations of the playgrounds. This document outlines how the CoP is designed to support SMEs, the structure and members of the CoP as well as its technical domains, the contributions of partners, and the expected outputs. The report presents an extensive overview of the low- and high-TRL Playgrounds available to the CoP and highlights future recommendations to ensure the CoP's sustainability beyond the project's duration.

3.4 High-TRL playgrounds

The high-TRL playgrounds in AID4SME serve as real-world testing and validation environments where SMEs can implement and demonstrate their AI and data-driven solutions at TRL 6 to 7. These playgrounds are built around large-scale industrial challenges provided by the consortium's industry partners from the whitegoods, automotive, energy, and battery recycling sectors. These high-TRL playgrounds include pilot and full-scale production lines and are essential for validating the practical impact of the developed AI solutions.

Additional information is available in the AID4SME public deliverable titled "CoP Targets Report," which contains comprehensive presentations of the playgrounds. This document outlines how the CoP is designed to support SMEs, the structure and members of the CoP as well as its technical domains, the contributions of partners, and the expected outputs. The report presents an extensive overview of the low- and high-TRL Playgrounds available to the CoP and highlights future recommendations to ensure the CoP's sustainability beyond the project's duration.

3.5 Key Performance Indicators

In this section, we outline examples of Key Performance Indicators that will be used to measure the success of the solutions proposed for the challenges. These KPIs are oriented and tailored to address the defined challenges related to the use of AI, data analytics, and other related technologies for industrial solutions. By focusing on **three key domains -resource optimization, impact on Green Deal targets, and social impact-** the project aims to provide a comprehensive framework for evaluating the effectiveness and sustainability of the challenges. Each domain includes specific metrics that will help track progress, identify areas for improvement, and ensure our efforts align with broader environmental and societal goals.

1. Resource Optimization

- Energy Efficiency: Measure the reduction in energy consumption resulting from optimizations driven by AI, data analytics, and other related technologies. Examples include: Percentage decrease in energy usage per unit of production, reduction in peak energy demand during operational hours, or improvement in energy efficiency ratings of equipment and machinery.

- Material Usage: Track the decrease in raw material waste through predictive analytics and AI-driven insights. Examples include: Reduction in material waste percentage in manufacturing processes, Decrease in scrap rates due to improved quality control, or optimization of inventory levels to minimize excess material storage.

- Operational Efficiency: Assess improvements in production cycle times and machine utilization rates driven by AI and data technologies. Example include: Increase in machine uptime and reduction in production delays. Reduction in downtime due to predictive maintenance, for example, improvement in throughput rates of production lines.

2. Impact on Green Deal

- Carbon Emissions: Monitor the reduction of CO2 emissions resulting from AI-enhanced processes and related technologies. Examples: Annual decrease in carbon footprint measured in metric tons, reduction in emissions per unit of product manufactured, or a decrease in transportation-related emissions through optimized logistics.

- Renewable Energy Integration: Evaluate the increase in the use of renewable energy sources facilitated by AI, data analytics, and related technologies. Examples: Percentage of total energy consumption sourced from renewables, increase in the capacity of renewable energy installations, improvement in the efficiency of renewable energy utilization.

- Waste Management: Measure the effectiveness of AI and data technologies in improving recycling rates and reducing landfill waste. Examples: Increase in recycling rate and reduction in waste sent to landfills, reduction in hazardous waste generation, improvement in waste sorting and segregation processes.

3. Social Impact

- Job Creation: Track the number of new jobs created in fields related to AI, data analytics, and other emerging technologies. Examples: Number of new positions in AI and data sectors, increase in employment opportunities in tech-driven industries, growth in startups and small businesses focused on AI and data solutions.

- Skill Development: Assess the increase in workforce skills and training programs related to AI, data analytics, and other technologies. Examples: Number of employees trained in AI and data-related skills, increase in certifications and qualifications in AI and data fields,

- Community Engagement: Measure the level of community involvement and awareness in AI-driven projects and other technological initiatives. Examples: Number of community outreach programs and participant engagement levels, increase in public awareness campaigns about AI and data technologies, growth in community-led initiatives and collaborations with tech companies.

It is important to note that the list of KPIs provided in this section is not exhaustive. Each challenge will be carefully analyzed to identify the most relevant and impactful KPIs tailored to its specific context. This approach ensures that the selected KPIs accurately reflect the unique aspects and requirements of each challenge, allowing for a more precise and meaningful assessment of progress and outcomes. By adapting the KPIs, we can better address the dynamic nature of industrial solutions involving AI, data analytics, and other related technologies.

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3.6 Community of Practice

A Community of Practice is a collaborative structure that brings together individuals who share a common interest or profession, with the goal of learning from each other, solving shared challenges, and advancing knowledge and practice within a specific domain.

The structure of the AID4SME CoP is designed to enable synergies between research, industry, and innovation support actors. Members include:

- **Academic and research institutions**: (KUL, JSI, UGENT and LEITAT) offering mentoring and low-TRL playgrounds for early-stage technology development.
- **Industrial partners** (ARC, LTH, ELES and VKR) operate high-TRL environments for real-world validation.
- **Digital Innovation Hubs and support entities** (I2M, LOGI, EWF, F6S, GreeneDIH, LTC, ISQ) providing technical support, training, and OC coordination.
- **SMEs and startups** engaged through the challenges defined in the open calls, receiving access to technical support and infrastructure.

These contributors provide the following support:

3.6.1 Technical support, training, and OC coordination

SMEs are encouraged to utilize technical support, training, and OC coordination available to them from the support entities. While these are not mandatory, they offer valuable support by providing additional technologies made available through the consortium. This approach enables SMEs to enhance their projects with cutting-edge tools and resources, facilitating innovation and optimizing their solutions.

3.6.2 Education programs

The training programs and workshops under Task 1.2 will encompass a diverse range of topics to support SMEs in AI-driven digital transformation and green skills development. Key topics include:

- AI & Data Technologies: Fundamentals of AI, data analytics, decision support, automation, and data-driven insights.
- Green Skills: Sustainable digital transformation, energy-efficient AI applications, circular-economy considerations in manufacturing.
- Modular Education Framework: Adaptable training modules designed for different levels of expertise (aligned with the European Qualifications Framework - EQF).
- Sector-Specific Applications: Practical implementations of AI & Data technologies tailored for SMEs in various industries.
- Regulatory and Ethical Considerations: Understanding the ethical and legal frameworks surrounding AI deployment in SMEs.

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3.6.3 Mentoring

Each SME will be paired with a mentor from the CoP to ensure they receive comprehensive support throughout the project. This mentorship plan is designed to provide SMEs with regular guidance and access to a wealth of resources. Mentors will hold scheduled meetings with their assigned SMEs to discuss progress, address any challenges, and offer strategic advice. Additionally, mentors will facilitate access to technical tools, research materials, and networking opportunities, ensuring SMEs have everything they need to succeed.

4 Challenges

The challenges addressed by this project are crucial for tackling climate change, enhancing resource efficiency, and promoting social cohesion. These efforts are vital for spreading innovation across Europe's regions and are central to the EU's twin transitions towards a sustainable and digital economy, which are essential for maintaining EU competitiveness.

SMEs play a pivotal role in bringing innovative solutions to these challenges. AID4SME provides the necessary infrastructure and learning environment to empower SMEs to tackle these challenges, develop, and demonstrate Key Exploitable Results (KER), see Table 1. The project offers both low- and high-TRL playgrounds, providing SMEs opportunities to test and validate their approaches and solutions. This collaborative effort with the AID4SME consortium aims to address challenges related to the Green Deal.

TABLE 1 AID4SME KEY EXPLOITABLE RESULTS LINKED TO THE AMBITIONS

Ambition	Innovations and Technologies (KER)
A1. DATA COLLECTION	**KER1**: Augmented sensing solution for polyurethane mould adjustment
	KER2: Image analysis for energy infra predictive maintenance
A2. Creation of INSIGHTS	**KER3**: Product-production Digital Twins for extruder processes
	KER4: Digital Twin based lifespan analysis tool
	KER5: Energy system Digital Twin decision support tool
A3. DECISION SUPPORT	**KER6**: Automated machine selection for parts production
	KER7: Battery production digital work instructions & skill capturing
	KER8: Digital Twin enabled smart production process planning tool
	KER9: Automated warehouse and internal logistics management
A4. AUTOMATION	**KER10**: Automated energy management for parts production
	KER11: Automated energy management for battery production
	KER12: Semi-automated EV battery disassembly for recycling
	KER13: Co-bot refrigerator door assembly solutions
Impact related KERs	**KER14:** Occupational safety solutions for Human-in-the-loop
	KER15: Methodology to evaluate Green Deal alignment
	KER16: Standardization as a route to exploitation

To be taken into consideration, the challenges may be subject to minor modifications to effectively address the project needs, as well as to be compliant with the requirements of the open calls.

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4.1.1 Combined AI and Data solutions for DATA COLLECTION

4.1.1.1 Augmented sensing solution for polyurethane mold adjustment

Leader and contributors: The challenge is led by KUL. Contributors include KUL and I2M for methodology development, ARC as the validation playground provider, and LOGI as the technology provider. KUL will provide a fully instrumented dynamic lab, virtual sensing demonstrators, industrial dynamic systems, and Digital Twin Experience Centre (DTEC) facilities. Principal Investigators (PIs) and researchers involved in the project will be available, with efforts concentrated within WP3.

Playgrounds: ARC will serve as the industrial playground. The project aims to address challenges related to data collection (A1) and develop KER 1: Augmented sensing solution for polyurethane mold adjustment.

Challenge and Context: In engineering, forces, stresses, torques, and power are direct indicators of a system's well-being. However, these quantities are typically expensive, difficult, and intrusive to measure. Augmented sensing approaches within AID4SME can help alleviate these hurdles for use case owners inside and outside the consortium. ARC requires an augmented sensing solution for their refrigerator production facility, which undergoes approximately 120 plastic mold changes per month. Each change necessitates manual, iterative adjustments, causing 60 tons of polyurethane waste and 60 minutes of facility downtime per mold change, resulting in approximately 100 million euros in annual costs due to a 5% production capacity loss.

Use Case and Expected Solution: Digital twins offer a paradigm shift where computational models of various complexities are merged in a coherent framework and linked to online measurement data available on a physical system. This paradigm allows for a hyper-realistic representation of process behavior, enabling novel engineering applications and process improvements, such as Virtual or Augmented Sensors. KUL has technology blocks available at TRL 4 and a playground for augmented sensing of dynamic quantities in mechanical/mechatronic systems and model-based augmented sensing in electro/thermos-mechanical applications in the manufacturing industry.

Specifications for Use Case: Augmented Sensing uses cheap, readily available, non-intrusive, and robust physical sensors to collect data from the real asset component in a digital twin. These measurements are combined intelligently via specific dynamic estimators with heterogeneous, reduced-order models of the system. The desired, yet unknown, quantities are estimated, resulting in a real-time/online virtual sensor fed with real measurement data enriched with physical insights. KUL, I2M, and LOGI will support SMEs in developing an augmented sensing solution for ARC to optimize the mold adjustment phase (KER1), targeting difficult-to-measure quantities and ensuring a comprehensive understanding of the manufacturing process. The data will be fed to an AI-based digital twin decision support tool, enabling first-time-right adjustment of the mold by the operator. The solution, demonstrated at TRL 7, will reduce facility downtime by 15% and decrease annual waste by 30 tons. For use cases outside the consortium, the results will be applications of virtual sensors in mechanical and mechatronic systems for first-time-right manufacturing, demonstrated at TRL 6/7.

Key Performance Indicators:

- First-time-right adjustment of the mold
- Reduce facility downtime by 15%
- Decrease annual waste by 30 tons.

To be noted, the list of KPIs provided in this section is not exhaustive but rather indicative. Additional KPIs will be studied in accordance with section 3.5 and integrated into the open calls to ensure equal treatment of third parties for the open calls.

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4.1.1.2 2D/3D image analysis for large Energy Infrastructure predictive maintenance

Leader and contributors: the challenge is led by LEITAT. LOGI will provide guidance and mentorship. LEITAT will offer facilities, resources, and staff, including photonics facilities equipped with hyperspectral cameras in the NIR and VIS range (2026), and thermal cameras for identification. A design of experiments will be conducted using samples with defects from O&M activities, such as corrosion, color changes, and fouling. These samples will be evaluated using hyperspectral, RGB, and thermal cameras. LEITAT will also provide short courses on using these cameras and their applications in the field.

Playgrounds: ELES will serve as the industrial playground. The challenge focuses on energy-related challenges (A1b) and aims to develop KER2: 2D/3D image analysis for large energy infrastructure predictive maintenance.

Challenge and Context: Timely scheduling of maintenance or decommissioning of large energy infrastructures is challenging. Incorrect End-of-Life (EoL) predictions can lead to unexpected failures, unwanted downtime, and high costs. Grid operators aim to avoid these risks, but often maintenance and decommissioning occur too early, causing high waste and unnecessary costs. AI-supported 2D/3D vision analysis technologies can better predict the maintenance needs and EoL of energy infrastructures. ELES seeks solutions to collect information for predictive maintenance of power lines and transformers and to improve decommissioning planning.

Use Case and Expected Solution: Red, Green, and Blue (RGB), thermographic, and multispectral vision can be used for early identification of weaknesses and failures in energy assets. Different types of failures, such as defects, poor contact, insulation deterioration, or magnetic circuit faults, often manifest as temperature rises. Infrared thermography (IRT) is particularly suitable for fault diagnosis, while RGB is used to quantify surface integrity and detect external discontinuities. Studies have shown the effectiveness of photogrammetric inspection, presented as 3D profiles reconstructed from UAV-captured images. Multispectral images provide more information than RGB alone, identifying issues like material degradation and biofouling. LEITAT has technology bricks available for fusing these images with installed sensor data and historical O&M data at TRL 4.

Specifications for Use Case: LEITAT, supported by LOGI, will guide and mentor SMEs to develop a combined AI and data-based predictive model using image analysis. A dedicated combination of photonic and sensor technologies will be used to determine the asset's health conditions. LEITAT and LOGI will assist SMEs in selecting the appropriate cameras and collecting the necessary 2D and 3D image data for AI-supported vision-based diagnosis. They will also support the AI-supported analysis of images, looking for early indicators of malfunctioning assets, corrosion, etc. The analysis information, combined with data from installed sensors, O&M activities, and historical images, will be used to develop an AI-supported predictive model. LEITAT will support SMEs during the development, evaluation, and validation of the model. Based on the collected data, a set of assets will be identified for model validation, with at least one asset monitored during O&M actions to decide on continuity or decommissioning.

The TRL 7 image analysis solution for ELES will enable predictive planning for the maintenance and decommissioning of part of their infrastructures (KER2), leading to better predictions of asset useful life and resulting in environmental and cost benefits. Once demonstrated, the technology can be further developed and deployed for other ELES infrastructures beyond the project lifetime. For use cases outside the consortium, the results will lead to the development of predictive maintenance and decommissioning planning support tools, based on AI-supported 2D/3D image analysis and data fusion, demonstrated at TRL 7 for large energy infrastructure.

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The use cases can include:

1. **Vegetation Recognition in Transmission Line Corridors**: Utilizing multispectral cameras, it is possible to recognize vegetation types from imagery. This is important because different types of vegetation grow at different rates, making it easier to predict when intervention will be necessary.
2. **Assessing Vegetation Health**: With multispectral cameras, it is possible to assess the health of vegetation from imagery. This is crucial because healthy vegetation poses significantly less risk to infrastructure compared to diseased or damaged specimens.
3. **Assessing Infrastructure Condition**: Using hyperspectral imagery, it is possible to determine the condition of infrastructure. Discussions indicate that it is possible to detect the amount of biofilm and dirt on insulation, identify corrosion, detect overheating, and more.
4. **Other Use Cases**: Additional applications may also be considered.

Key Performance Indicators:

- Resources optimization: Prediction accuracy of AI models in identifying maintenance needs and failure risks, Reduction in false positives and false negatives in anomaly detection, Improvement in defect detection and classification compared to traditional methods, reduction in manual intervention required for maintenance planning, improvement in decision-making speed for decommissioning strategies.
- Impact on green deal: -reduction in infrastructure failures leading to environmental hazards, compliance with safety regulations and decommissioning best practices, decrease in CO_2 emissions by reducing unnecessary maintenance trips.
- Social impact: number of prevented accidents due to early failure detection, number of workers trained in AI, data fusion, and predictive maintenance tools.

To be noted, the list of KPIs provided in this section is not exhaustive but rather indicative. Additional KPIs will be studied in accordance with section 3.5 and integrated into the open calls to ensure equal treatment of third parties for the open calls.

4.1.2 Combined AI and Data solutions for creation of INSIGHTS

4.1.2.1 Product-production Digital Twins for extruder processes

Leader and contributors: The challenge is led by KUL. Contributors include KUL for methodology development, ARC as the validation playground provider. KUL will provide industrial dynamic systems and a digital polymer processing pilot plant. PIs and researchers involved in the project will be available, with efforts concentrated within WP3.

Playgrounds: ARC will serve as the industrial playground. The challenge focuses on the creation of insights (A2) and aims to develop KER 3: Product-production Digital Twins for extruder processes.

Challenge and Context: Manufacturers are striving to reduce their ecological footprints by minimizing energy consumption, material use, and waste. Traditional design cycle paradigms have been optimized to their limits, and further gains are expected from cross-stage optimization through combined AI and Data solutions. AID4SME is flexible in overcoming these challenges for use case owners both inside and outside the consortium. Inside the consortium, ARC operates extruder processes to blend virgin plastic material with plastic scrap. Quality operators examine both plastic sources in separate labs without a structured integrated inspection process. Flaws in the mixing rate can lead to discoloration and cracking, generally caused by high ratios of recycled material, resulting in scrap of produced parts. ARC seeks a product-

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production Digital Twin solution to optimize material mixing ratios based on real-time measurement of visual and mechanical properties of the different plastic source materials. This aims to increase the ratio of recycled plastic, enhancing sustainability while maintaining quality and reducing scrap. Additionally, ARC's consumer electronics refurbishing factory, which refurbishes over 50,000 products annually, seeks a solution combining augmented sensing (technology A1a) and a product-production Digital Twin to optimize End-of-Life Product Refurbishment processes by assessing the health and predicting the remaining lifespan of components.

Use Case and Expected Solution: Leveraging the concept of Digital Twins supported by combined AI and Data technologies, the manufacturing industry is on the verge of fully exploiting Industry 4.0's digitalization potential. Digital information is becoming available in large amounts during different stages of product design, manufacturing, useful life, and recycling. Digital Twins enable the collection and comprehensive management of all digital information linked to a unique product asset, exploiting it for added value creation within the same stage the data was collected. Within the low-TRL playground, the Digital Twin Experience Centre (DTEC) of KUL demonstrates basic technology blocks for developing such twins on a polymer processing pilot lab (injection molding) at TRL 4, which can be used as a starting point for ARC's solutions. More product-production Digital Twin technology blocks are available at TRL 4 within the DTEC of KUL for other challenges, inviting SMEs to bring their own industrial challenge providers and high-TRL playgrounds.

The expected solution enables ARC to optimize the blending of virgin and recycled plastic materials and increase quality.

Specifications for Use Case: Digital Twins add value by digitally connecting the product design, manufacturing, useful life, and recycling stages in a closed loop. This increases the amount of available information and knowledge, enabling optimized and effective decisions. Such a straight-through digitalization (STD) approach promotes sustainability beyond zero manufacturing towards truly closing the loop. KUL, supported by LOGI, will guide and mentor SMEs to deploy STD in the challenges. For this ARC challenge, a product-production digital twin for their extruder processes for blending virgin and recycled plastic materials will be developed and demonstrated at TRL 6 at the high-TRL playground of ARC (KER3). This will result in a 5% increase (1200 tons) in recycled plastic content in ARC refrigerator products, while resolving 95% of quality control issues and optimizing energy efficiency.

Key Performance Indicators:

- 5% increase (1200 tons) in recycled plastic content in ARC refrigerator products
- Resolving 95% of quality control issues

To be noted, the list of KPIs provided in this section is not exhaustive but rather indicative. Additional KPIs will be studied in accordance with section 3.5 and integrated into the open calls to ensure equal treatment of third parties during the selection process.

4.1.2.2 Digital Twin based lifespan analysis tool

Leader and contributors: The challenge is led by KUL. Contributors include KUL for methodology development and ARC as the validation playground provider. KUL will provide industrial dynamic systems, virtual sensing demonstrators, and DTEC facilities. PIs and researchers involved in the project will be available, with efforts concentrated within WP3.

Playgrounds: ARC will serve as the industrial playground. The challenge focuses on insights (A2) and aims to develop KER4: Digital Twin-based lifespan analysis tool.

Challenge and Context: Manufacturers are striving to reduce their ecological footprints by minimizing energy consumption, material use, and waste. Traditional design cycle paradigms have been optimized to their limits, and further gains are expected from cross-stage optimization through combined AI and Data solutions. AID4SME is flexible in overcoming these challenges for use case owners both inside and outside

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the consortium. Inside the consortium, ARC operates extruder processes to blend virgin plastic material with plastic scrap. Quality operators examine both plastic sources in separate labs without a structured integrated inspection process. Flaws in the mixing rate can lead to discoloration and cracking, generally caused by high ratios of recycled material, resulting in scrap of produced parts. ARC seeks a product-production Digital Twin solution to optimize material mixing ratios based on real-time measurement of visual and mechanical properties of the different plastic source materials. This aims to increase the ratio of recycled plastic, enhancing sustainability while maintaining quality and reducing scrap. Additionally, ARC's consumer electronics refurbishing factory, which refurbishes over 50,000 products annually, seeks a solution combining augmented sensing (technology A1a) and a product-production Digital Twin to optimize End-of-Life Product Refurbishment processes by assessing the health and predicting the remaining lifespan of components.

Use Case and Expected Solution: Leveraging the concept of Digital Twins supported by combined AI and Data technologies, the manufacturing industry is on the verge of fully exploiting Industry 4.0’s digitalization potential. Digital information is becoming available in large amounts during different stages of product design, manufacturing, useful life, and recycling. Digital Twins enable the collection and comprehensive management of all digital information linked to a unique product asset, exploiting it for added value creation within the same stage the data was collected. Within the low-TRL playground, the Digital Twin Experience Centre (DTEC) of KUL demonstrates basic technology blocks for developing such twins on a polymer processing pilot lab (injection molding) at TRL 4, which can be used as a starting point for ARC's solutions. More product-production Digital Twin technology blocks are available at TRL 4 within the DTEC of KUL for other challenges, inviting SMEs to bring their own industrial challenge providers and high-TRL playgrounds.

The tool enables ARC to determine the remaining life of parts and optimize their refurbishment processes. This will increase the repurposing of parts from discarded products as spare parts, adjust warranty periods and pricing for resold products and parts, and enhance overall sustainability of the refurbishment process by minimizing waste and facilitating responsible and resourceful management of end-of-life products.

Specifications for Use Case: Digital Twins add value by digitally connecting the product design, manufacturing, useful life, and recycling stages in a closed loop. This increases the amount of available information and knowledge, enabling optimized and effective decisions. Such a straight-through digitalization (STD) approach promotes sustainability beyond zero manufacturing towards truly closing the loop. KUL, supported by LOGI, will guide and mentor SMEs to deploy STD in the challenges. For this challenge, a Digital Twin-based lifespan analysis tool (KER4) for ARC will be demonstrated at TRL 6. This tool will determine the remaining life of products and parts, enabling ARC to increase the repurposing of parts from discarded products as spare parts, adjust warranty periods and pricing for resold products and parts, and enhance the overall sustainability of the refurbishment process by minimizing waste and facilitating responsible and resourceful management of end-of-life products.

Key Performance Indicators:

- Reduction in waste generated during refurbishment due to optimized part reuse
- Reduction in warranty-related costs due to data-driven lifespan predictions
- Improved sustainability metrics for refurbished products

To be noted, the list of KPIs provided in this section is not exhaustive but rather indicative. Additional KPIs will be studied in accordance with section 3.5 and integrated into the open calls to ensure equal treatment of third parties during the selection process.

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4.1.2.3 Energy system Digital Twin decision support tool

Leader and contributors: The challenge is led by JSI. Contributors include JSI and UGENT for methodology development, ELES for real-life data and validation playground, I2M as the technology provider, and LOGI providing the Omnipower motherboard for data acquisition, processing, and control algorithms. JSI will provide a low-TRL playground for energy component scaling and energy management, including a Digital Twin of the energy system environment and prototype optimization algorithms for scaling energy system components. JSI researchers will be available to support mentoring and development throughout the project. ELES will provide data from its electric car charging stations, which includes time series data of energy consumption, peak power draw and number of connected vehicles from its Electric Vehicle (EV) charging network. It will provide time series data of power consumption in its commercial buildings and technical data of installed battery storage systems. This data will provide a digital playground to test and validate the results obtained from the digital twin.

Playgrounds: ELES will serve as the industrial playground. The challenge focuses on decision support (A3) and aims to develop KER5: Energy system Digital Twin decision support tool.

Challenge and Context: Grid operators for transmission and distribution increasingly face grid balancing challenges due to growing energy demand and decentralized renewable energy production. To balance power generation and demand, various energy storage technologies can be used. However, energy conversion and storage equipment incur capital and operational expenditures that affect the final price of electric energy. Optimal sizing of local renewable sources and energy storage is crucial for achieving an economically optimized energy system. Due to numerous variables, such as time profiles of energy consumption, energy generation, and dynamic pricing, and their nonlinear relationships, optimal solutions cannot be obtained analytically. AID4SME is flexible in overcoming these challenges for use case owners both inside and outside the consortium. Inside the consortium, ELES seeks AI and Data solutions for a Digital Twin-based decision support tool to optimally size and control smaller parts (microgrids) of the energy system.

Use Case and Expected Solution: A Digital Twin (simulation model) structure for local energy systems is available at JSI. Various prototype tools for manual and automated optimization have been developed and tested at TRL 4. The Digital Twin structure will serve as the low-TRL playground for SMEs. This includes modules for energy consumption, generation (including local renewable sources), prices of electric energy from the grid, and energy storage systems (battery, electrolyser, fuel cell, hydrogen, pumped hydro). The Digital Twin enables simulation of the energy balance over a desired time period (typically an entire year) and observing economic results as a function of equipment sizes and prices. ELES, the Slovenian grid operator, will provide a challenge and high-TRL playground for this technology. The solution enables ELES to cost-optimize microgrid sizing and operation. This will result in reduced costs for energy production, optimized sizing of energy storage systems, and minimized wastage of renewable energy, contributing to a more efficient and sustainable energy system.

Specifications for Use Case: The TRL 4 Digital Twin environment and low-TRL playground of JSI will be used by an SME to develop a Digital Twin-based decision support tool for a production plant and electric energy system of ELES using the corresponding model-based automatic optimization algorithm. JSI, I2M, KUL, and UGENT will support the SME during development. The solutions will be demonstrated at the high-TRL playground of ELES, which will enable testing and demonstration of the tool on real-world data. This support tool will enable ELES to determine the most optimal local energy system (microgrids) sizing and its mode of operation (KER5), achieving reduced costs for energy production, energy storage system CAPEX, and wastage of renewable energy. For use cases outside the consortium, the results will also be a tailored Digital Twin-based decision support tool for energy system/grid sizing and operation.

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Key Performance Indicators:

Improved scaling of the energy storage components for the selected microgrid setup is envisioned to:

- Decrease CAPEX of energy storage systems,
- Improve local consumption of renewable energy,
- Increase number of integrated EV charging stations while not affecting grid stability.

To be noted, the list of KPIs provided in this section is not exhaustive but rather indicative. Additional KPIs will be studied in accordance with section 3.5 and integrated into the open calls to ensure equal treatment of third parties during the selection process.

4.1.3 Combined AI and Data solutions for DECISION SUPPORT

4.1.3.1 Automated machine selection for parts production

Leader and contributors: The challenge is led by UGENT. Contributors include UGENT and JSI for methodology development. UGENT will provide a data analytics platform that can be used to test general aspects of data analytics and AI. UGENT's researchers will be available to support mentoring and development, with efforts concentrated within WP3.

Playgrounds: LTH will serve as the industrial playground. The challenge focuses on decision support (A3a) and aims to develop KER6: Automated machine selection for parts production.

Challenge and Context: Many complex production processes are still partially controlled by operators with highly specialized knowledge and skills, which are difficult to formalize and document as they exist only in the operators' minds. If this knowledge is lost, the product quality or even the entire production process is at risk. Digitalizing this knowledge is crucial for the long-term strategic growth of industries. Additionally, real-time adaptation of digital work instructions (DWI) to the operational context (e.g., operator experience level, needs, assembly line conditions, QA/QC) can facilitate complex manual safety-critical manipulations, increasing production speed, quality, and compliance, boosting overall equipment efficiency, and reducing production costs. AID4SME is flexible in overcoming these challenges for use case owners both inside and outside the consortium. For example, operators at LTH choose the best machine to cast or process a certain part from many identical machines that behave differently.

Use Case and Expected Solution: The challenge underscores the critical need to formalize and digitalize the valuable knowledge held by experienced operators. The inherent difficulties in capturing and representing this knowledge require a more complex approach that combines effective knowledge capture methodologies with advanced technological solutions. The potential of machine learning and artificial intelligence to analyze historical production data and operator decisions offers a promising avenue for developing intelligent systems capable of predicting optimal machine selection. Integrating real-time production data from machines and production processes further enhances the adaptability and responsiveness of such systems to dynamic operational conditions. UGENT has IP blocks (MOVE platform) at TRL 4, including knowledge graphs for DWI, learning models for assembly operators, automated operator experience level classification, data fusion and analytics, including AI needed to handle expert knowledge and IoT data, with proper attention to differences in representation, accuracy, and error margins. In the scope of the Slovenian national research project DIGITOP, JSI has developed basic concepts at TRL 4 to capture, formalize, and digitize operator knowledge and skills. Machine learning methods are applied to extract the relationship between operator actions and process conditions through digital observation of operator actions and collecting sufficient relevant digital information from the process.

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The solution will enable LTH to increase productivity and reduce downtime, scrap, and risk. This will result in more efficient production processes, better utilization of machinery, and enhanced overall operational efficiency.

Specifications for Use Case: UGENT and JSI will support SMEs in further developing solutions for challenges related to operator skill capturing and DWI technology, adapting them to the environment and relevant processes. Various machine learning approaches will be tested for operator skill capturing and formalization. UGENT will support SMEs in using their data analytics platform, which can integrate basic DWI knowledge and Internet of Things data streams. This is linked to the UGENT MOVE, Flexible Assembly Living Lab (low-TRL playground), and can be used to explore with SMEs the potential added value of adaptive work instructions, mimicking the challenge context. Additionally, a simulated pilot process will be developed to test and demonstrate the technology on the low-TRL playground. A solution for LTH will be integrated and demonstrated with their smart planning tool and shop floor (high-TRL playground) at TRL 7 (KER6). This solution will enable LTH to increase productivity, reduce downtime, and mitigate risk by automating the selection of the right machines for producing certain parts.

Key Performance Indicators:

- Machine utilization rate: Improved machine selection should lead to higher utilization rates.
- Peak energy demand: Optimal machine selection could lead to a reduction in peak energy consumption.
- Scrap rate: Optimized machine selection should contribute to a reduction in scrap rates due to improved quality.
- Production Throughput: Automated machine selection aims to increase the overall production rate.
- Cycle time per part: Optimizing machine selection could lead to reduced cycle times.
- Reduction in Time spent on machine selection due to a more automated process.
- Waste reduction rate: Percentage decrease in the total amount of waste generated during the production process.

Note that the KPIs provided in this section are not exhaustive but indicative. Additional KPIs will be studied in accordance with Section 3.5 and integrated into the open calls to ensure equal treatment of third parties during the selection process.

4.1.3.2 Battery production digital work instructions & skill capturing

Leader and contributors: The challenge is led by UGENT. Contributors include UGENT and JSI for methodology development. UGENT will provide a data analytics platform that can be used to test general aspects of data analytics and AI. UGENT's researchers will be available to support mentoring and development, with efforts concentrated within WP3.

Playground: VERKOR will serve as the industrial playground. The project focuses on decision support (A3a) and aims to develop KER 7: Battery production digital work instructions and skill capturing.

Challenge and Context: Many complex production processes are still partially controlled by operators with highly specialized knowledge and skills, which are difficult to formalize and document as they exist only in the operators' minds. If this knowledge is lost, the product quality or even the entire production process is at risk. Digitalizing this knowledge is crucial for the long-term strategic growth of industries. Additionally, real-time adaptation of digital work instructions (DWI) to the operational context (e.g., operator experience level, needs, assembly line conditions, QA/QC) can facilitate complex manual safety-critical manipulations, increasing production speed, quality, and compliance, boosting overall equipment efficiency, and reducing production costs. AID4SME is flexible in overcoming these challenges for use case owners both inside and outside the consortium. For example, VERKOR seeks a solution to digitally capture operator production line adjustment skills to dynamic production conditions.

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Use Case and Expected Solution: Battery manufacturing is a complex, highly sensitive process in which small variations can greatly affect product quality, safety, and reliability. DWIs and skill-capturing technologies can effectively address aspects such as production ramp-up, quality control, process optimization, and managing variability in battery design. UGENT has IP blocks (MOVE platform) at TRL 4, including knowledge graphs for DWI, learning models for assembly operators, automated operator experience level classification, and data fusion and analytics, including AI needed to handle expert knowledge and IoT data, with proper attention to differences in representation, accuracy, and error margins. In the scope of the Slovenian national research project DIGITOP, JSI has developed basic concepts at TRL 4 to capture, formalize, and digitize operator knowledge and skills. Machine learning methods are applied to extract the relationship between operator actions and process conditions through digital observation of operator actions and collection of sufficient relevant digital information from the process.

The solution enables VERKOR to upscale production capacity and automate new battery production lines. This will result in more efficient production processes, better utilization of machinery, and enhanced overall operational efficiency.

Specifications for Use Case: UGENT and JSI will support SMEs in further developing solutions for challenges related to operator skill capturing and DWI technology, adapting them to the environment and relevant processes. Various machine learning approaches will be tested for operator skill capturing and formalization. UGENT will support SMEs in using their data analytics platform, which can integrate basic DWI knowledge and Internet of Things data streams. This is linked to the UGENT MOVE, Flexible Assembly Living Lab (low-TRL playground), and can be used to explore with SMEs the potential added value of adaptive work instructions, mimicking the challenge context. The solution for VERKOR (KER7) will be integrated into their pilot production line at TRL 7, enabling them to upscale their production capacity and automate new battery production lines. For use cases outside the consortium, solutions will be tested and demonstrated at TRL 7.

Key Performance Indicators:

- Energy Consumption per Unit: Improved efficiency through optimized processes guided by DWIs and operator knowledge should lead to a decrease.
- Scrap rate: Effective DWIs and operator skill application should reduce errors and thus scrap.
- Production Throughput: Higher throughput indicates more efficient use of production resources (workers).
- Cycle Time per Unit: Reducing the time to produce each battery unit implies improved operational efficiency.
- Changeover Time: Reducing the time when switching between different product types by increasing the flexibility and efficiency of production resources.
- Waste reduction rate: Percentage decrease in the total amount of waste generated during the production process

Note that the KPIs provided in this section are not exhaustive but indicative. Additional KPIs will be studied in accordance with Section 3.5 and integrated into the open calls to ensure equal treatment of third parties during the selection process.

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4.1.3.3 Digital Twin enabled smart production process planning tool

Leader and contributors: The challenge is led by UGENT. Contributors include UGENT and KUL for methodology development. UGENT will provide a data analytics platform that can be used to test general aspects of data analytics and AI. UGENT's researchers will be available to support mentoring and methodology development, with efforts concentrated within WP3.

Playgrounds: LTH will serve as the industrial playground. The challenge focuses on decision support (A3b) and aims to develop KER8: Digital Twin-enabled smart production process planning tool.

Challenge and Context: Digital Twin-based processes and control frameworks in metal part production have the potential to improve production process resilience with respect to the raw materials used (e.g., recycled materials), reduce process operator effort, and minimize scrap due to out-of-specification parts. These frameworks can leverage state-of-the-art technologies in system-level management of decision processes. However, several challenges need to be addressed, including appropriate Digital Twin decision process architecture setup and smooth decision process integration. AID4SME is flexible in overcoming these challenges for use case owners both inside and outside the consortium. Inside the consortium, LTH aims to implement a Digital Twin of the production process within their aluminium casting plant to develop an AI-enabled smart production process planning tool.

Use Case and Expected Solution: The implementation of a Digital Twin in aluminium casting enhances efficiency by reducing operator effort, minimizing scrap, optimizing energy use, and improving machine utilization. It provides real-time recommendations for process parameters, decreasing manual adjustments, while predictive analytics help detect deviations early. The system also analyzes energy consumption, predicts equipment issues, and streamlines scheduling, leading to lower energy costs and improved sustainability. By identifying bottlenecks and maximizing machine uptime, the Digital Twin supports faster, more reliable, and cost-effective production. UGENT has IP blocks at TRL 4 related to their MOVE platform, where advanced IoT-driven architectures have been successfully implemented, along with associated decision recommender systems built on sampled machine learning surrogate models of decision processes. These systems are integrated into decision support recommender-based systems. UGENT and KUL will support SMEs in defining the Digital Twin for metal part production and digitized toolchains system-level management of decision processes. This will advance Digital Twin decision support developments. Building on existing results from the Metafacturing project, where a decision recommender is shaped on top of sampled machine learning surrogate models of decision processes, the solution will address the complexity of integrating multiple decision processes into one model.

The solution enables LTH to reduce operator effort, scrap from production, and increase overall energy efficiency. This will result in more efficient production processes, better utilization of machinery, and enhanced overall operational efficiency

Specifications for Use Case: One solution developed will be a Digital Twin-enabled smart production process planning tool for LTH (KER8), demonstrated at TRL 6. This tool will enable LTH to reduce operator effort, minimize scrap from production, and increase overall energy efficiency. For use cases outside the consortium, the results will be tested and demonstrated at TRL 7.

Key Performance Indicators:

- Reduction in the overall production cycle time for casting a part or batch.
- Increase in machine uptime and reduction in production delays.
- Reduction in emissions per unit of product manufactured (through reduced energy consumption and material waste).
- Increase in the effective recycling rate of internal scrap by optimizing the process to minimize contamination or make recycling more feasible.
- Number of new positions created related to the development, deployment, maintenance, and data analysis of the Digital Twin system.

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Note that the KPIs provided in this section are not exhaustive but indicative. Additional KPIs will be studied in accordance with Section 3.5 and integrated into the open calls to ensure equal treatment of third parties during the selection process.

4.1.3.4 Automated warehouse and internal logistics management

Leader and contributors: The challenge is led by UGENT. Contributors include UGENT and KUL for methodology development. UGENT will provide a data analytics platform that can be used to test general aspects of data analytics and AI. UGENT's researchers will be available to support mentoring and methodology development, with efforts concentrated within WP3.

Playgrounds: LTH will serve as the industrial playground. The challenge focuses on decision support (A3b) and aims to develop KER9: Automated warehouse and internal logistics management.

Challenge and Context: Digital Twin-based processes and control frameworks in metal part production have the potential to improve production process resilience with respect to the raw materials used (e.g., recycled materials), reduce process operator effort, and minimize scrap due to out-of-specification parts. These frameworks can leverage state-of-the-art technologies in system-level management of decision processes. However, several challenges need to be addressed, including the appropriate Digital Twin decision process architecture setup and smooth decision process integration. AID4SME is flexible in overcoming these challenges for use case owners both inside and outside the consortium. Inside the consortium, LTH seeks to develop a smart planning tool for their automated buffer warehouse and internal logistics system to optimize internal workflows for transporting around 200 pallets on the shop floor.

Use Case and Expected Solution: The increasing complexity of manufacturing processes, particularly in specialized sectors like die casting and battery production, requires highly efficient, resilient, and adaptable internal logistics and warehouse management. Traditional automation systems often lack the intelligence and flexibility to dynamically respond to variations. Implementing a Digital Twin that integrates real-time data from internal logistics and production equipment will accurately model system behavior and enable intelligent decision-making. UGENT has IP blocks at TRL 4 related to their MOVE platform, where advanced IoT-driven architectures have been successfully implemented, along with associated decision recommender systems built on sampled machine learning surrogate models of decision processes. These systems are integrated into decision support recommender-based systems. UGENT and KUL will support SMEs in defining the Digital Twin for metal part production and digitized toolchains system-level management of decision processes. This will advance Digital Twin decision support developments. Building on existing results from the Metafacturing project, where a decision recommender is shaped on top of sampled machine learning surrogate models of decision processes, the solution will address the complexity of integrating multiple decision processes into one model.

The solution enables LTH to reduce logistics energy consumption, production stops, and optimize efficiency. This will result in more efficient production processes, better utilization of machinery, and enhanced overall operational efficiency.

Specifications for Use Case: The smart planning tool for LTH's automated buffer warehouse and internal logistics management (KER9) will be demonstrated at TRL 6. This tool will reduce energy consumption in internal logistics by optimizing the driven distances of automated forklifts and improving production efficiency by reducing stops. For use cases outside the consortium, the results will be tested and demonstrated at TRL 7.

Key Performance Indicators:

- Reduction of operators' efforts: The number of manual interventions (automation level) and time saved due to automation and decision support.
- Reduction in the energy consumption of internal logistics.
- Decrease in production stops caused by logistics delays.

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- Reduction in emissions per unit of product manufactured (through reduced energy consumption due to optimal internal logistics).
- Warehouse space utilization efficiency.

Note that the KPIs provided in this section are not exhaustive but indicative. Additional KPIs will be studied in accordance with Section 3.5 and integrated into the open calls to ensure equal treatment of third parties during the selection process.

4.1.4 Combined AI and Data solutions for AUTOMATION

4.1.4.1 Automated energy management for parts production

Leader and contributors: The challenge is led by JSI. Contributors include JSI and Ugent for methodology development, I2M and LOGI as technology providers, and LTH for problem definition and validation playground. JSI will provide a playground for Production Energy Consumption Prediction, including an energy simulation model of discrete and batch production processes and prototype algorithms for automated identification of energy prediction models from historical process data. JSI researchers will be available to support mentoring and development throughout the project.

Playgrounds: LTH will serve as the industrial playground. The challenge focuses on automation (A4a) and aims to develop KER10: Automated energy management for parts production.

Challenge and Context: Automated prediction and optimization of electric energy consumption in energy-intensive production processes can have a significant positive impact. On the one hand, based on factory daily production plans, the electric energy consumption time profile can be predicted. Subsequently, the time distribution of production steps can be optimized to keep the electric energy time profile within limits determined by the electric grid operator. This helps industries and grid operators balance their grids and maximally exploit the potential of renewable energy sources. On the other hand, energy predictability can help to better monitor and manage production machines and operations. LTH is currently enabling energy monitoring of all key infrastructure equipment for aluminium casting and automotive parts production. As a next step, LTH aims to implement an automated energy management tool for the plant's infrastructure.

Use Case and Expected Solution: Energy consumption prediction models for production processes exist and are used in practice, but they are manually developed and tailored for specific production processes, considering particular energy consumers. Manual design of such models requires expert knowledge of process and energy modeling, is time-consuming and expensive, and limits transferability between different processes and reusability. JSI has technology blocks available at TRL 4 and a low-TRL playground for automatic determination of the relationship between energy consumption time profile and production plans, based on AI and machine learning methods using historical data about production plans and related energy consumption profiles. This automatic learning capability enables wide usage of the method across different production processes. The data-based approach also allows modeling the effects of external conditions (temperature, weather, season, etc.). At LTH Currently, there is no centralized monitoring and management over the machines and consequently it happens that particular machines stay switched-on and consume electric energy in periods when production is not running, which can be during night periods or pause periods. This leads to electric energy waste, increased costs and increased pollution due to excess electric energy consumption. The idea is to automatically monitor and manage machines states according to the central production time plan. This includes automatic startup and automatic shutdown or entering various standby modes.

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The solution will enable LTH to automate control over energy intensive operation machines. Optimized control over operation states of the machines (e.g., pre-heat, standby, off-mode) should be in accordance with the actual production plan, while minimizing the overall energy consumption.

Specifications for Use Case: JSI, supported by UGENT, I2M and LOGI, will guide and mentor SMEs to use existing building blocks for automated energy management of production processes and further develop and implement these technologies in real production environments of use-case owners. For the LTH use case, automated energy management of their production plant (KER10) demonstrated at TRL 7 will enable LTH to automate control over high energy consumption assets according to the production, leading to minimization of energy related costs, while not affecting the execution of the planned production activities.

Key Performance Indicators:

- Accuracy of predicted energy consumption for the observed production operation.
- Reduction of daily energy consumption per produced part, for the controlled machine/operation.
- Production schedule adherence, indicating how closely production adheres to the planned schedule for the controlled production operation (operation delay time).

Note that the KPIs provided in this section are not exhaustive but indicative. Additional KPIs will be studied in accordance with Section 3.5 and integrated into the open calls to ensure equal treatment of third parties during the selection process.

4.1.4.2 Management for parts production

Leader and contributors: The challenge is led by JSI. Contributors include JSI, providing an energy simulation model of discrete and batch production processes and algorithms for automated identification of energy prediction models from historical process data; LOGI, providing the Omnipower motherboard for data acquisition, processing, and control algorithms, with real-time data sharing over USB, BLE, WiFi for OTA (Over The Air) and cloud processing; I2M; and UGENT supporting methodology development.

Playgrounds: JSI will provide a playground for production energy consumption prediction (see D1.1). VERKOR will serve as the industrial playground, with contributions from outside the consortium. The project focuses on automation (A4a) and aims to develop KER 11: Automated energy management for parts production.

Challenge and Context: Automated prediction and optimization of electric energy consumption in energy-intensive production processes can have a significant positive impact. Based on factory daily production plans, the electric energy consumption time profile can be predicted. Subsequently, the time distribution of production steps can be optimized to keep the electric energy time profile within limits determined by the electric grid operator. This helps industries and grid operators balance their grids and maximally exploit the potential of renewable energy sources. AID4SME is flexible in implementing such automated energy management for different industrial use case owners both inside and outside the consortium. VKR is monitoring their energy-intensive battery production processes and attempts to model the consumption. Optimization remains a challenge, and VKR seeks an automated energy management solution on top of their energy and production models.

Use Case and Expected Solution: Energy consumption prediction models for production processes exist and are used in practice, but they are manually developed and tailored for specific production processes, considering particular energy consumers. Manual design of such models requires expert knowledge of process and energy modeling, is time-consuming and expensive, and limits transferability between different processes and reusability. JSI has technology blocks available at TRL 4 and a low-TRL playground for automatic determination of the relationship between energy consumption time profile and production plans, based on AI and machine learning methods using historical data about production plans and related energy consumption profiles. This automatic learning capability enables wide usage of the method across different

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production processes. The data-based approach also allows modeling the effects of external conditions (temperature, weather, season, etc.).

The solution enables VKR to balance energy consumption and optimize renewable energy consumption. This will result in more efficient energy management, reduced operational costs, and enhanced overall sustainability.

Specifications for Use Case: JSI, supported by UGENT and LOGI, will guide and mentor SMEs to use existing building blocks for automated energy management of production processes and further develop and implement these technologies in real production environments of use-case owners. The VKR use case and use cases outside the consortium, automated energy management and optimization demonstrated at TRL 7 (KER11) will enable VKR and other use-case owners to balance their energy consumption.

Key Performance Indicators: KPIs will be provided further on in accordance with Section 3.5 and integrated into the open calls to ensure equal treatment of third parties during the selection process.

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4.1.4.3 Semi-automated EV battery disassembly for recycling

Leader and contributors: The challenge is led by LEITAT. Contributors include KUL, JSI, and LOGI, providing hardware and firmware such as the Omnipower motherboard for grading and testing, and battery's-9R (refuse, rethink, reduce, reuse, repair, refurbish, remanufacturing, repurpose, recycling, and recover). Real-time data sharing over USB, BLE, WiFi for OTA (Over The Air) and cloud processing is available, with 5G included when needed. Omnipower data can be further exploited for AI models, fully trained and validated, integrating chemistry, data-driven, physical, and hybrid models. Additionally, Omnipower supports Digital Twin technology, adaptable to cells, modules, and systems, enabling easy scalability for battery recycling.

Playgrounds: LEITAT will provide robot facilities and senior experts. The technical capacities and facilities available for SMEs include a disassembly battery lab equipped with an ABB IRB6620 with a force control sensor, a 3D camera, and a tool changer system. The lab currently has a deburring tool, automatic screwdriver, and power cable cutter. A new lab is being built with added safety measures such as an emergency water immersion table and automatic fire extinguishing storage areas. Additionally, LEITAT has cobots (UR10, Doosan M1013, Kuka IIWA), cameras, and VR/AR goggles. VERKOR will serve as the industrial playground in their production pilot line. As the pilot line is able to produce around 800 cells per day, automation of not good battery recycling would help upscaling process and reduce the risks associated with this activity.. The project focuses on battery recycling (A4b) and aims to develop KER12: Semi-automated EV battery disassembly for recycling.

Challenge and Context: EV batteries across manufacturers and cars vary significantly, with each battery type having its own cables, bus bars, modules, and different types of cells inside. This variability makes the automation of battery dismantling for recycling purposes challenging. Additionally, current EV batteries subject to recycling are mainly Li-ion based, posing hazard risks for recycling processes. Automating each process for each battery type is time-consuming and costly. Battery recycling companies face these challenges, which AID4SME can overcome for use-case owners both inside and outside the consortium. Inside the consortium, VKR aims to implement semi-automatic dismantling of batteries cells and modules. As the dismantling would be implemented on not-good batteries coming out of the production line, automation could be envisioned since battery cells and modules design would be known and controlled. This would enable the creation of an in-house circular input stream for the resources needed for their battery production.

Use Case and Expected Solution: Currently, different battery recycling developments are ongoing, using collaborative robots. However, these activities mainly focus on automating the dismantling of one type of battery, with limited applicability to other types of batteries with different geometries and internal distributions. LEITAT has a laboratory for battery dismantling with an industrial robot at TRL 4, specifically focusing on developing a flexible battery dismantling process. LEITAT has several technology blocks at TRL 4, using computer vision and AI technologies from other areas, supporting the development of dismantling operations on different batteries without specific robot programming for each.

The solution enables VKR to upscale the circular input stream for battery production and reduce hazard risks. This will result in more efficient battery recycling processes, better utilization of resources, and enhanced overall sustainability.

Specifications for Use Case: LEITAT, supported by KUL, JSI, and LOGI, will guide and mentor SMEs to develop a robot cell for semi-automatic battery dismantling of various EV battery types, extending to overall mechatronic system demanufacturing approaches. In this solution, a human operator manually performs tasks the robot cannot, while the robot handles repetitive and dangerous operations such as opening the battery pack while charged or picking up heavy components. For operations that cannot be automated, the user can control the robot using teleoperation, moving the robot and indicating the position using a VR

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device. Solutions will be demonstrated for the VKR use case at TRL 6 (KER12). This will enable VKR to implement an EV battery type-agnostic, semi-automated dismantling process, upscaling the circular input stream of resources needed for their battery production while maintaining low hazard and safety risks for operators.

Key Performance Indicators:

- Resources optimization: Percentage of dismantling operations performed autonomously by the robot, reduction in manual intervention compared to traditional dismantling methods, value of battery dismantled in a week, percentage of weight battery recovery, accuracy of robotic operations, scalability potential.
- Impact on green deal: demonstrate flexible and green process, increase in the number of reusable/recyclable materials recovered, reduction in waste and environmental impact from battery dismantling
- Social impact: demonstrate progress in labour conditions, improvement in ergonomic conditions for workers, adoption rate of teleoperation, gender diversity.

To be noted, the list of KPIs provided in this section is not exhaustive but rather indicative. Additional KPIs will be studied in accordance with section 3.5 and integrated into the open calls to ensure equal treatment of third parties for the open calls.

4.1.4.4 Co-bot refrigerator door assembly solutions

Leader and contributors: The challenge is led by JSI. Contributors include JSI and LEITAT. JSI will provide a low-TRL playground and a catalogue of collaborative robot technologies, initial solutions, and challenges. The collaborative modular robotic cell at JSI includes two Franka Emika FR3 collaborative robots and several modular tables, which can be arranged around the robot modules as required by the process. The robots are equipped with grippers and internal joint-torque sensors, which estimate the forces at the end-effector. Additional external sensors, such as cameras and depth cameras, can be added to the cell. The cell is readily available and operational, providing mock-ups of workplaces for human-robot collaboration.

Playgrounds: ARC-BEKO will serve as the industrial playground. The project focuses on manufacturing (A4c) and aims to develop KER13: Co-bot refrigerator door assembly solutions.

Challenge and Context: The development of new automation technologies for the manufacturing industry directly contributes to efficiency, safety, and human factors. Modular, reconfigurable, energy-efficient, and collaborative robots can enable industries to optimize their operations, reduce waste, lower their environmental impact, and improve human operator job attractiveness. The whitegoods factory of ARC is one area where collaborative robots can make a significant difference. ARC will provide a use case for their refrigerator production line, where refrigerator gaskets of different shapes and sizes are installed on refrigerator doors. Manual installation of the refrigerator gaskets poses ergonomic challenges, resulting in inefficiencies and potential product rejections. Partial (co-bot) automation of gasket installation, particularly flexible elastomer gaskets, presents unique challenges that require the integration of collaborative robotics and AI to optimize the installation process. This ensures precision, safety, and adaptability to the deformable nature of elastomers, as the co-bot must apply the right force on the flexible material without causing deformation. ARC seeks a co-bot solution to overcome these challenges while aligning with the Green Deal's focus on promoting worker well-being and safety.

Use Case and Expected Solution: JSI has a catalogue of developed technologies validated in the lab (TRL 4), building on results from previously funded EU projects like ReconCell, CoLLaborate, and ReconCycle, related to collaborative assembly and riveting for automotive assembly. These technologies will be combined

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with 2D/3D video analysis technology blocks from A1b. JSI has several low-TRL playgrounds based on these technologies.

The solution enables ARC to improve efficiency, operator ergonomics, and inclusiveness, and reduce waste. This will result in more efficient production processes, better utilization of machinery, and enhanced overall operational efficiency.

Specifications for Use Case: JSI, supported by LEITAT, will guide and mentor SMEs to further develop the technology bricks of JSI and A1b using their low-TRL playground and adapt these technologies for deployment in other industry sectors. For the “bring your own use-case” challenges, co-bot solutions will be demonstrated at TRL 7. The AID4SME solutions will foster a sustainable and inclusive digital transition that benefits both manufacturing companies and society at large. Specifically for the ARC use case, a co-bot refrigerator door assembly solution (KER13) will be demonstrated in the factory of ARC at TRL 7. This will enable ARC to improve efficiency, operator ergonomics, and inclusiveness, decrease waste, and increase the longevity of refrigerator doors through enhanced stability of gasket installation quality.

Key Performance Indicators:

- Demonstrate effective and flexible autonomous processes.
- Ensure safety of workers in the vicinity.
- Improved efficiency: reduce the number of workers required at the production line.
- Operator ergonomics: reduce operator/worker effort, as they will be able to focus on other tasks.
- Increase quality: robotized processes can more easily detect errors in production during the process itself.

To be noted, the list of KPIs provided in this section is not exhaustive but rather indicative. Additional KPIs will be studied in accordance with section 3.5 and integrated into the open calls to ensure equal treatment of third parties for the open calls

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5 Conclusions

In conclusion, this document outlines a comprehensive framework for addressing the challenges associated with the integration of AI, data analytics, and other related technologies in industrial solutions. By exploring various technical domains and leveraging both low-TRL and high-TRL playgrounds, we have established a robust foundation for innovation and development. The identification of key performance indicators (KPIs) provides a clear roadmap for measuring success and ensuring our efforts align with broader environmental and societal goals. Additionally, contributions from various stakeholders, including building blocks, education programs, and mentoring initiatives, underscore the collaborative nature of this endeavor.

The next steps will focus on Deliverable D2.3 – Open call documents KIT & third-party financing rules. This deliverable will include a comprehensive document set for applicants to submit, encompassing application guidelines, FAQs, and templates for the declaration of honour and sub-grantee agreement for OC1 (D2.3). These documents will provide clear instructions and support for potential applicants, ensuring a smooth and transparent application process.

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