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Standards and Processes in Relation to Cynergy4MIE's Chosen Scenarios

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Acronym Table

ADS	Automated Driving Systems
ADAS	Advanced Driver Assistance Systems
AI	Artificial Intelligence

ASAM	Association for Standardisation of Automation and Measuring Systems
AUTOSAR	Automotive Open System Architecture
CCAM	Connected, Cooperative and Automated Mobility
CEN	European Committee for Standardisation
CYS	Cyprus Organisation for Standardisation
GNSS	Global Navigation Satellite System
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardisation
ITS	Intelligent Transport Systems
SC	Supply Chain
SOTIF	Safety of the Intended Functionality
UNECE	United Nations Economic Commission for Europe
V2X	Vehicle-to-Everything

Executive Summary

The present deliverable provides an updated assessment of the standardisation ecosystem surrounding Cynergy4MIE technologies and demonstrator scenarios during the transition from requirements definition to architecture development. Building upon the baseline established in D7.8 'Standardisation State-of-the-Art and Analysis of Gaps', D7.9 'Standards and Processes in Relation to Cynergy4MIE's Chosen Scenarios' moves beyond standards mapping and focuses on monitoring the practical application of standards, assessing consortium engagement with standardisation ecosystems, and identifying realistic pathways for future standardisation contributions. The assessment is based on four complementary sources of evidence: the findings of D7.8, a dedicated follow-up questionnaire covering all six Supply Chains, bilateral consultations with consortium partners, and targeted engagement with external standardisation experts and stakeholders.

A central finding of D7.9 is the strong validation of the standardisation baseline established in D7.8. Across all six Supply Chains and their associated demonstrators, the previously identified standards, regulatory frameworks and industrial initiatives remain highly relevant and continue to support architectural design, interoperability planning, safety assurance, cybersecurity considerations, AI governance requirements and future certification pathways. Only one additional standardisation gap was identified during the assessment, relating to interoperability and data translation challenges between Building Information Modelling (BIM), Product Parametric Models and fabrication environments within Supply Chain 2. This finding suggests a strong degree of continuity between the original gap analysis and the evolving technical developments of the project, while also indicating that the standardisation strategy defined in D7.8 remains broadly aligned with the needs of the Cynergy4MIE ecosystem.

The follow-up assessment further demonstrated increasing standardisation maturity across the consortium. In addition to reporting several complementary standards, technical reports and industry frameworks, partners documented ongoing participation in standardisation bodies, technical committees and industrial initiatives relevant to their respective domains. These findings were reinforced through external stakeholder engagement activities conducted under Task 7.4, including consultations with experts active in ISO, CEN, CCAM and related standardisation ecosystems. Together, these activities provided valuable insights into current standardisation priorities, emerging developments and realistic mechanisms through which research and innovation projects may contribute to ongoing standardisation work.

Based on the monitoring activities, partner consultations, demonstrator analyses and stakeholder engagements, five preliminary standardisation contribution opportunities were identified: (i) scenario-based validation and testing methodologies; (ii) safety

assumptions and validation approaches for Automated Driving Systems; (iii) trustworthy AI, explainability and human oversight; (iv) cybersecurity of connected cyber-physical systems; and (v) energy interoperability and smart energy systems. The identified opportunities were derived through the combined analysis of demonstrator requirements, partner survey responses, existing consortium participation in standardisation activities and feedback obtained through stakeholder consultations. This approach ensured that the proposed contribution pathways are grounded not only in standards analysis but also in concrete project developments, industrial perspectives and ongoing standardisation discussions. Importantly, these opportunities are directly supported by Cynergy4MIE demonstrators and use cases across multiple Supply Chains, creating a clear connection between project developments, industrial needs and future standardisation pathways.

Collectively, the findings presented in D7.9 demonstrate the evolution of Cynergy4MIE from a standards mapping exercise towards an active standardisation readiness and engagement phase. Having confirmed the strength of its standardisation baseline and established a portfolio of demonstrator-driven contribution opportunities, the consortium is now positioned to focus on validation, prioritisation and evidence generation during the remaining project period. These activities will support the preparation of D7.10 ‘Standardisation proposals to ensure uptake of Cynergy4MIE solutions in different industrial sectors’, where the most mature opportunities will be translated into concrete standardisation proposals, while also creating opportunities for scientific dissemination, industrial collaboration, future research initiatives and the long-term uptake of Cynergy4MIE innovations across multiple industrial sectors.

1. Introduction

1.1 Background and Context

Standardisation is a cornerstone in enabling the deployment, interoperability, safety, trustworthiness, and market uptake of emerging electronic and cyber-physical systems. Within the Cynergy4MIE project, standardisation activities are addressed under Task 7.4, which seeks to maximise the exploitation potential of project outcomes through standardisation, certification, human-in-the-loop approaches, and ethical considerations aligned with Society 5.0 principles.

Cynergy4MIE brings together six technologically distinct but interconnected Supply Chains, addressing domains ranging from automated machinery, mobility and sensing technologies to digital manufacturing, energy systems and cyber-physical infrastructures. As these Supply Chains progress through the architecture development phase, their associated demonstrators and use-case scenarios provide an increasingly concrete basis for assessing how standards, regulatory frameworks and industrial practices are applied in real-world development contexts.

While standardisation requirements may initially emerge within individual Supply Chains, many of the challenges identified across the project relate to common themes such as interoperability, safety assurance, cybersecurity, AI trustworthiness and validation methodologies. Consequently, the present assessment considers not only the standardisation needs of individual scenarios but also the broader opportunities emerging across the Cynergy4MIE ecosystem.

In this context, Deliverable D7.8 *"Standardisation State-of-the-Art and Analysis of Gaps"* (M12), already established a comprehensive baseline by mapping the standardisation landscape across the six Cynergy4MIE Supply Chains (SCs). This mapping encompassed key standards, regulatory frameworks, industrial initiatives, and identified gaps with potential implications for the future deployment of project results. Building upon this foundation, the present deliverable marks a strategic shift: from landscape analysis towards operational engagement. As Cynergy4MIE advances through its architecture and system design phases, project partners are increasingly positioned to assess how standards are being applied in practice, surface emerging standardisation needs, and evaluate concrete pathways for future contributions to relevant standardisation bodies and activities.

1.2 Purpose and Objectives of current document

Current document provides an updated assessment of the standardisation ecosystem surrounding Cynergy4MIE technologies and demonstrator scenarios, while documenting the active engagement of the Cynergy4MIE consortium, including contributions from project partners and CONVERGENCE, with relevant industrial initiatives and standardisation bodies.

More specifically, the deliverable aims to:

- **assess** the practical application of standards within the different Cynergy4MIE Supply Chains during the architecture phase;
- **identify** newly emerging standards, specifications, regulatory developments, and industrial frameworks relevant to project activities;
- **monitor** the evolution of standardisation gaps previously identified in D7.8;
- **map** consortium participation in standardisation bodies and industrial initiatives;
- **identify** opportunities for cross-Supply-Chain collaboration on pre-normative activities;
- **establish** preliminary pathways towards future standardisation contributions and recommendations.

As Cynergy4MIE progresses through its architecture development phase, D7.9 serves as a transitional deliverable between the baseline standardisation analysis presented in D7.8 and the future standardisation proposals to be developed in D7.10. At this stage of the project, technical solutions are still evolving, and large-scale validation activities have not yet been completed. Consequently, the emphasis of this deliverable is placed on monitoring developments within the standardisation landscape, assessing the practical use of standards by project partners, identifying emerging collaboration opportunities both within individual Supply Chains and across the wider Cynergy4MIE ecosystem, and establishing the foundations for future pre-normative and standardisation-related contributions.

Collectively, these objectives position D7.9 as an intermediate yet substantive milestone in the project's standardisation journey. The findings presented herein reflect the consortium's growing standardisation maturity and contribute directly to the preparation of Deliverable D7.10 *"Standardisation Proposals Based on Identified Cynergy4MIE Demonstrators"*.

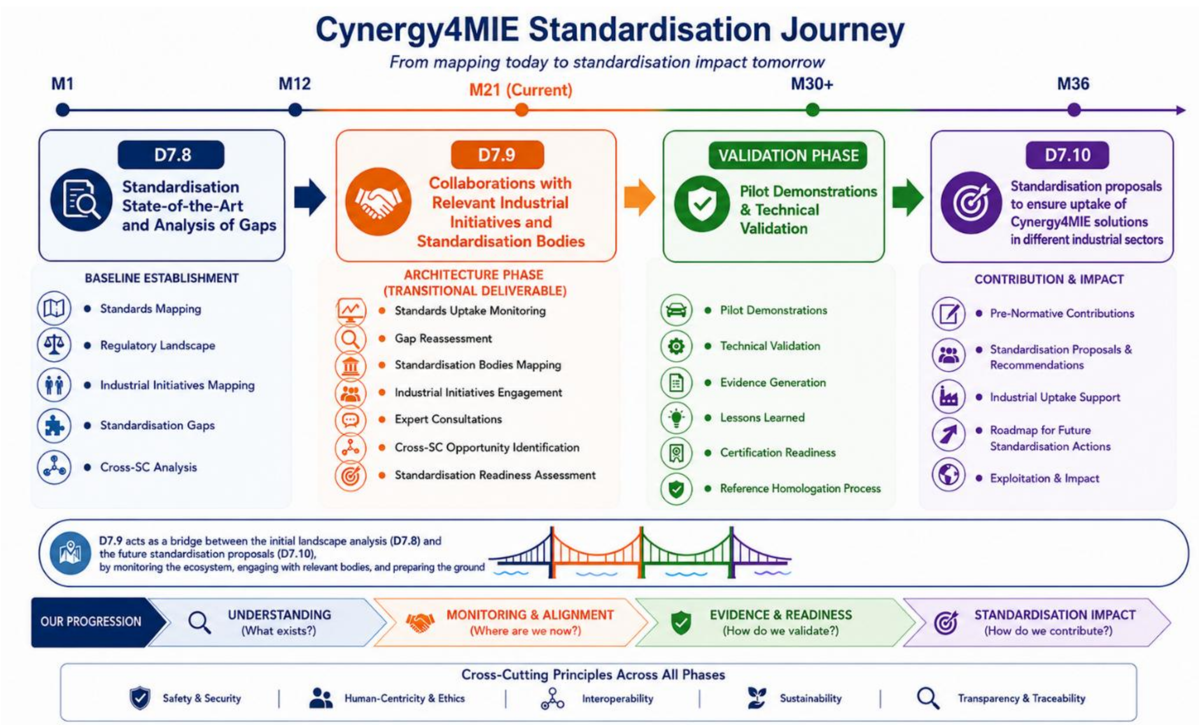

Figure 1. Cynergy4MIE Standardisation Roadmap and Progression Path

1.3 Positioning within the Cynergy4MIE Standardisation Strategy

The three standardisation-oriented deliverables of Task 7.4 form a progressive and complementary framework, each building upon the insights of its predecessor to advance the project's standardisation ambitions.

- D7.8 established the baseline understanding of the relevant standardisation landscape, identifying priority standards, regulatory frameworks, and existing gaps across the six Supply Chains, laying the analytical groundwork for all subsequent standardisation activities.
- D7.9 builds upon this baseline by examining how standards are being applied in practice during the system development phase, assessing partner engagement with standardisation ecosystems, and surfacing emerging opportunities for collaboration and future contributions.
- D7.10 will consolidate the knowledge generated throughout the project and translate it into concrete standardisation proposals, recommendations, and pre-normative contributions, informed by the technical validation activities and lessons learned during the demonstration phase.

Accordingly, D7.9 occupies a pivotal position within this trajectory: serving as the bridge between the descriptive landscape analysis of D7.8 and the forward-looking standardisation recommendations that will be developed in D7.10. In parallel with the standardisation activities described in D7.8 and D7.9, Cynergy4MIE is progressively developing a Reference Homologation Process intended to support the future uptake, validation, certification and standardisation of project outcomes across different industrial sectors. The findings presented in this deliverable contribute to this process by identifying relevant standards, stakeholder expectations, standardisation pathways and areas where future pre-normative contributions may emerge.

While the analysis presented in this document is rooted in the standards and processes associated with the individual Cynergy4MIE Supply Chains and demonstrator scenarios, particular attention is given to identifying common standardisation challenges and opportunities that extend across multiple technological domains. This cross-domain perspective reflects the collaborative and convergent nature of the Cynergy4MIE ecosystem and supports the identification of future standardisation activities with broader industrial relevance.

2. Methodology

2.1 Approach

This deliverable adopts a mixed-method approach, combining evidence gathered from prior project activities, targeted partner consultations, and direct engagement with relevant industrial and standardisation stakeholders. The overarching objective was threefold: to assess the evolution of the standardisation landscape surrounding Cynergy4MIE technologies, to monitor the practical application of standards during the architecture phase, and to identify opportunities for future pre-normative contributions.

The methodology builds directly upon the results of Deliverable D7.8 *"Standardisation State-of-the-Art and Analysis of Gaps"* which established the initial standardisation baseline across the six Cynergy4MIE Supply Chains (SCs). Whereas D7.8 focused on identifying relevant standards, regulations, industrial initiatives, and standardisation gaps, D7.9 shifts the focus towards monitoring their practical uptake and evaluating the project's readiness to engage in future standardisation activities.

2.2 Sources of Evidence

The analysis presented in this deliverable draw on four complementary sources of information.

2.2.1 Review of D7.8 Findings.

The standards, regulatory frameworks, industrial initiatives, and gap analyses documented in D7.8 served as the baseline against which developments during the architecture phase were assessed. Particular attention was given to standards identified as highly relevant across multiple Supply Chains, as well as to previously identified cross-cutting standardisation gaps.

The review focused on key standardisation domains previously identified in D7.8, including functional safety, cybersecurity, trustworthy AI, interoperability, certification readiness and human oversight of AI-enabled systems. Examples include standards and frameworks such as ISO 26262, ISO 21448 (SOTIF), ISO/SAE 21434, IEC 62443, IEEE 7000-series standards, ISO/IEC 24028, ISO 15118 and other standards supporting connected mobility, robotics, energy systems and cyber-physical systems. The review also revisited the standardisation gaps identified in D7.8, particularly those related to AI explainability, validation methodologies, interoperability and cross-domain integration, to assess their continued relevance during the architecture development phase

2.2.2 Partner Follow-Up Questionnaire.

A dedicated follow-up standardisation questionnaire was distributed to technical and industrial partners across the six Supply Chains during M19. The instrument was designed to capture:

- the practical application of standards during system architecture and design activities;
- newly identified standards, regulations, or industry specifications;
- emerging standardisation gaps not previously captured in D7.8;
- participation in standardisation bodies and industrial initiatives;
- the maturity of potential pre-normative contributions;
- opportunities for cross-Supply-Chain collaboration.

The questionnaire generated responses from partners representing all six Supply Chains, providing a comprehensive and updated view of standardisation activities across the project.

2.2.3 Bilateral Discussions with Consortium Partners.

Questionnaire findings were complemented by ongoing exchanges with consortium partners during technical meetings, work package activities, and dedicated standardisation discussions. These interactions provided additional context regarding the relevance, applicability, and technical maturity of identified standards within each domain.

2.2.4 External Stakeholder Engagement and Consultations with Standardisation Bodies

Additional insights were gathered through interactions with external experts, industrial stakeholders, and representatives active in relevant standardisation initiatives. These exchanges supported the identification of emerging developments within the broader standardisation ecosystem and helped contextualise Cynergy4MIE activities within ongoing European and international standardisation efforts.

2.3 Analytical Framework

The collected information was analysed across four complementary dimensions. First, a standard uptake assessment was conducted to examine how the standards identified in D7.8 are being applied during the architecture and system design phases, including their role in technical decision-making, system requirements, interoperability planning and future certification considerations. Second, a standardisation ecosystem engagement assessment was performed to evaluate consortium participation in standardisation bodies, technical committees, industrial alliances and other relevant initiatives that may facilitate the dissemination and future uptake of Cynergy4MIE results. Third, the analysis explored emerging gaps and convergence needs, with particular attention to newly identified interoperability challenges, cross-domain standardisation requirements and issues not fully captured during the initial assessment conducted in D7.8. Finally, a future standardisation potential assessment was undertaken to identify areas where Cynergy4MIE technologies, methodologies, demonstrator activities and validation results may provide opportunities for future standardisation contributions, certification-related activities or broader pre-normative engagement.

2.4 Link to the Cynergy4MIE Standardisation Strategy

The methodology adopted in D7.9 reflects the progressive standardisation strategy pursued within Task 7.4. The results presented in this deliverable constitute an intermediate assessment of the project's standardisation readiness and contribute to the ongoing development of the Cynergy4MIE Reference Homologation Process. By systematically documenting current standard adoption, stakeholder engagement, emerging gaps, and convergence opportunities, D7.9 lays the analytical foundation for the concrete standardisation proposals that will be consolidated in Deliverable D7.10 *"Standardisation Proposals to Ensure Uptake of Cynergy4MIE Solutions in Different Industrial Sectors"*.

2.5 Overview of Consultation Results

The follow-up standardisation assessment generated responses from consortium representatives covering all six Cynergy4MIE Supply Chains, ensuring full project-wide representation of the technological domains addressed within the project. The collected responses confirmed the continued relevance of the standardisation baseline established in D7.8, while also providing updated information regarding standards adoption, participation in standardisation activities, and potential contribution opportunities. Several respondents identified additional standards, technical reports, industry specifications and regulatory developments relevant to their respective domains, while only one new standardisation gap was reported.

The assessment also revealed existing engagement of consortium partners with standardisation bodies and industrial initiatives, including participation in ISO working groups, AUTOSAR activities, VDI-related initiatives and other sector-specific standardisation ecosystems. These findings were further complemented through consultations with external standardisation experts and stakeholders active in European and international standardisation activities. Overall, the results indicate that Cynergy4MIE has successfully progressed from an initial standards mapping exercise towards a broader standardisation readiness phase characterised by increasing standards adoption, stakeholder engagement and identification of future contribution pathways.

Table 1. Key Findings of the D7.9 Standardisation Assessment

Indicator	***Result***
Supply Chains covered	*6/6*
New standardisation gaps reported	*1*
Additional standards/frameworks identified	6
Standardisation bodies represented	*ISO, AUTOSAR, VDI and related initiatives*
External expert consultations	*2*
Contribution opportunities identified	5

3. Evolution of the Cynergy4MIE Standardisation Landscape

3.1 From Landscape Mapping to Standardisation Monitoring

Deliverable D7.8 established the initial standardisation baseline for Cynergy4MIE by mapping relevant standards, regulatory frameworks, industrial initiatives, and standardisation gaps across the six Supply Chains. The analysis identified both domain-specific and cross-cutting challenges, including issues related to interoperability, AI assurance, cybersecurity, human oversight, certification, and explainability. Since the completion of D7.8, the project has progressed from requirements definition towards architecture development and system design activities. This transition created an opportunity to move beyond the identification of standards and begin monitoring their practical relevance, uptake, and potential contribution to future standardisation activities.

Consequently, the focus of D7.9 is not to repeat the landscape analysis previously conducted, but to assess how the identified standards are being considered and applied during the architecture phase, how partners engage with relevant standardisation ecosystems, and where opportunities for future standardisation contributions may emerge.

3.2 Confirmation of the D7.8 Standardisation Baseline

One of the most significant outcomes of the follow-up assessment is the overall confirmation of the findings previously reported in D7.8. Across the majority of Supply Chains, partners reported that the standards identified in D7.8 remain relevant and continue to provide an appropriate framework for guiding architectural and design decisions. Only a limited number of additional standards, technical reports and industry frameworks were reported during the assessment, while only one new standardisation gap was identified across all six Supply Chains.

The newly reported gap concerns data translation and interoperability challenges between Building Information Modelling (BIM), Product Parametric Models and fabrication environments within SC2. Aside from this observation, partners largely confirmed that no significant new standardisation gaps have emerged since the completion of D7.8.

These findings suggest that the standardisation landscape identified in D7.8 remains largely valid and continues to provide a robust foundation for the ongoing technical development of Cynergy4MIE solutions. The identification of only one newly identified gap further demonstrates the robustness of the initial standardisation assessment and confirms that the project's standardisation strategy remains aligned with the evolving technical architectures of the different Supply Chains.

3.3 Emerging Developments Since D7.8

Although no major shifts in the overall standardisation landscape were identified, the follow-up assessment revealed a number of domain-specific refinements. Partners reported a limited number of additional standards, industry specifications and technical references that complement the standards previously identified in D7.8. Examples include Mobileye's Responsibility-Sensitive Safety (RSS) framework and ISO/TR 9839 on predictive maintenance in support of functional safety (SC1), EN 1995 (Eurocode 5) and EN 14250 for digital construction and timber manufacturing applications (SC2), ISO 9001, ISO/IEC 27001 and ISO 14001 supporting quality, information security and environmental management processes (SC4), JCGM 100 on measurement uncertainty (SC5), and CNS 15466 related to heat pump performance testing (SC6).

The official titles, scope and relevance of these additional standards and frameworks are further detailed in Table 3 and supported by the corresponding references included in the reference list. While these additions do not substantially alter the conclusions of D7.8, they provide further insight into the evolving technical environments in which Cynergy4MIE solutions are being developed and highlight the importance of continuously monitoring both formal standards and industry-driven initiatives. These developments emerged from the continued evolution of the individual Supply Chains and demonstrator scenarios, while also highlighting several common themes that extend across the broader Cynergy4MIE ecosystem.

3.4 Evolution of Consortium Engagement

In parallel with the technical evolution of the project, the follow-up assessment demonstrates increasing awareness of the importance of engagement with standardisation bodies and industrial initiatives. Several consortium partners reported existing participation in relevant standardisation activities, while others indicated plans to increase their engagement during the validation phase, when project-generated evidence and technical results are expected to reach a higher level of maturity. This finding is particularly relevant for the future development of pre-normative contributions, as it demonstrates the existence of initial pathways through which Cynergy4MIE outcomes may be disseminated and discussed within broader standardisation communities. This evolution was further supported through targeted interactions with external standardisation experts and organisations, helping to connect project activities with ongoing developments in relevant European and international standardisation ecosystems.

3.5 Consortium Participation in Standardisation Bodies and Industrial Initiatives

The follow-up assessment further confirmed that several Cynergy4MIE partners are actively involved in standardisation activities, technical committees and industrial initiatives relevant to the project's technological domains. These existing engagements represent an important asset for the consortium, as they may facilitate future dissemination of project outcomes and provide potential pathways for participation in ongoing standardisation discussions.

Table 2 provides an overview of the standardisation-related activities reported by consortium partners during the D7.9 assessment. Table 2 summarises the standardisation-related activities explicitly reported by consortium partners through the D7.9 assessment. The information reflects publicly shareable contributions and should not be interpreted as a comprehensive overview of all standardisation activities conducted by consortium organisations.

Table 2. Non-confidential overview of Cynergy4MIE partners' engagement with standardisation bodies and industrial initiatives

The following table provides a non-confidential overview of Cynergy4MIE partners' reported engagement with relevant standardisation bodies and industrial initiatives. The information is based on partner input collected under Task 7.4 and is limited to details suitable for inclusion in a public deliverable. Where exact meeting frequency or formal contribution status was not disclosed, this is indicated accordingly.

Partner	SC	Standardisation Body / Initiative	Partner role / relevance in Cynergy4MIE	Type of engagement	Contribution type / relevance for Cynergy4MIE
TTTech Auto	SC4	AUTOSAR, ISO TC22/SC32/WG8	Industrial partner with expertise in automotive software architecture, safety-related E/E systems and software-defined vehicle technologies relevant to automated driving.	Participation and technical monitoring of relevant automotive software and functional safety standardisation activities.	Alignment of SC4 developments with automotive software architecture and functional safety requirements; potential feedback of project insights

					related to software-defined vehicles, safety concepts and automated driving systems.
Murata Electronics Europe	SC1	ISO TC22/SC32/WG8	Industrial electronics and sensor technology partner contributing to automated machinery and transportation-related activities.	Participation and/or technical monitoring of functional safety activities relevant to automotive electronics.	Use of functional safety and automotive electronics standards to inform sensor, electronics and system-level safety considerations within SC1.
GROPYUS	SC2	VDI	Industrial partner active in digital manufacturing, robotics and construction-related innovation for low-emission buildings.	Engagement and monitoring of industrial engineering and construction-related standardisation activities.	Input from modular construction, production-floor integration, digital manufacturing and robotics use cases; relevance to standardisation gaps around BIM, product parametric models and fabrication-oriented workflows.
VTT	SC1	ISO Road Vehicle Activities	Research and technology organisation contributing	Technical monitoring and engagement	Research-based input on automated mobility,

			expertise in automated mobility, transportation systems and validation-oriented research.	with ISO road vehicle-related activities.	system validation and transportation safety; potential transfer of Cynergy4MIE evidence and use-case insights to relevant ISO discussions.

3.6 Towards Standardisation Readiness

Taken together, the findings suggest that Cynergy4MIE is gradually transitioning from standardisation awareness towards standardisation readiness. At the current stage of the project, the primary objective is not yet the submission of formal standardisation proposals, but rather the systematic integration of standards into the development process, the monitoring of emerging needs, the establishment of relevant stakeholder connections, and the identification of areas where future contributions may generate value.

This progression provides an important foundation for the next phase of Task 7.4 activities and for the future development of the Cynergy4MIE Reference Homologation Process and the standardisation proposals that will be consolidated in Deliverable D7.10. Importantly, this readiness has emerged not from a single technological domain but from the combined analysis of the Cynergy4MIE Supply Chains and demonstrator scenarios, enabling the identification of contribution opportunities with relevance across multiple industrial sectors and standardisation ecosystems.

4. Application of Standards Across the Cynergy4MIE Supply Chains

4.1 Overview of Standard Adoption

As Cynergy4MIE progresses from requirements definition towards architecture development and system design, standards increasingly serve as practical reference frameworks supporting technical decision-making across the six Supply Chains (SCs). The follow-up assessment conducted in M19 indicates that the standards identified in D7.8 continue to provide a relevant and robust foundation for the development of Cynergy4MIE technologies.

The practical relevance of these standards is increasingly reflected in the project's demonstrator scenarios, which provide concrete environments for assessing interoperability, safety, cybersecurity, AI governance and system validation requirements. While standards are applied within individual Supply Chains, several recurring themes emerge across the Cynergy4MIE ecosystem, highlighting opportunities for convergence between otherwise distinct technological domains.

The responses collected from consortium partners suggest that standardisation considerations are progressively being integrated into architectural design activities, safety and cybersecurity assessments, interoperability planning, AI governance considerations, and future validation and certification pathways. Rather than being treated solely as compliance references, standards are increasingly informing system requirements, interface specifications, operational constraints, and design choices across multiple technological domains.

At the current stage of the project, standards are primarily supporting:

- architectural and system design activities;
- safety, reliability, and cybersecurity considerations;
- interoperability between components and subsystems;
- AI governance, transparency, and trustworthiness requirements;
- future validation, certification, and deployment pathways.

The analysis further indicates that while the level of standardisation maturity varies across Supply Chains, the overall standardisation baseline established in D7.8 remains valid and continues to guide technical development activities throughout the project.

The assessment further indicates that the demonstrator scenarios are increasingly serving as practical validation environments through which the relevance, applicability and limitations of existing standards can be assessed. As technical development progresses, the project is gradually moving from the identification of relevant standards towards the generation of evidence that may support future standardisation, certification and pre-normative activities.

4.2 Standards Driving Architectural Decisions

The analysis of the six Supply Chains demonstrates that standards are not only supporting compliance-related activities but are increasingly shaping architectural choices, validation approaches and system requirements. Although the technological domains addressed by Cynergy4MIE are diverse, several recurring standardisation themes emerge across multiple demonstrators, highlighting opportunities for cross-domain convergence and future standardisation collaboration.

Although each Supply Chain operates within a distinct technological environment, several recurring standardisation domains can be observed across the project.

4.2.1 Safety, Reliability and Functional Assurance

Safety-related standards continue to play a central role across several Cynergy4MIE Supply Chains,, namely SC1, SC2, SC3, SC4, SC5 and SC6, although their relevance differs depending on the technological context. In particular, SC1 and SC4 are concerned through autonomous machinery, transportation, ADAS/ADS and mobility-related applications; SC2 through collaborative robotics and construction-related automation; SC3 through safety-critical electric powertrain components and control systems; SC5 through multi-agent sensing, control and emergency-response applications; and SC6 through energy-efficiency systems and distributed intelligent control. Standards such as ISO 26262, ISO 21448 (SOTIF), IEC 61508, ISO 13849, and IEC 62061 provide essential frameworks for the development of safe and reliable systems operating in dynamic and potentially safety-critical environments.

The continued relevance of these standards demonstrates the importance of structured safety assurance methodologies within Cynergy4MIE, particularly as solutions become increasingly autonomous, interconnected and AI-enabled.

4.2.2 Cybersecurity and Software Assurance

Cybersecurity remains a cross-cutting priority across Cynergy4MIE Supply Chains. particularly SC1, SC2, SC3, SC4, SC5 and SC6, where connected, software-enabled and data-driven systems are being developed or validated. More specifically, cybersecurity is relevant to SC1 in relation to automated machinery and transportation systems; SC2 through collaborative robotics, digital manufacturing and construction-related automation; SC3 through electric powertrain components, embedded systems and software-controlled architectures; SC4 through ADAS/ADS, V2X communication, software-defined vehicles and over-the-air update processes; SC5 through multi-agent sensing, control and emergency-response coordination; and SC6 through distributed intelligent control, energy-efficiency systems and connected energy infrastructure.

Standards and regulatory frameworks including ISO/SAE 21434, IEC 62443, UNECE R155, and UNECE R156 are being considered to support secure system architectures, software lifecycle management, risk assessment processes, cybersecurity governance, and secure software update management. While ISO/SAE 21434 and UNECE R155/R156 are particularly relevant to mobility and automotive-related activities, especially SC3 and SC4, IEC 62443 is especially relevant for industrial automation, distributed control and connected infrastructure aspects across SC2, SC5 and SC6.

The responses suggest that cybersecurity is increasingly viewed as an integral component of system design rather than a standalone compliance requirement, reflecting broader developments within European industrial and mobility ecosystems.

4.2.3 Artificial Intelligence, Transparency, Trustworthiness and Ethical Governance

The growing integration of AI-enabled functionalities across Cynergy4MIE is reflected in the consideration of standards and frameworks addressing transparency, trustworthiness, accountability and ethical AI governance. These considerations are particularly relevant to SC1, SC2, SC4, SC5 and SC6, and are also relevant to SC3 where AI/ML-enabled control, diagnostics, optimisation or safety-analysis functions are considered.

More specifically, AI transparency, trustworthiness and ethical governance are relevant to SC1 in relation to automated machinery, AI-supported perception, motion planning and human–machine interaction; to SC2 through collaborative robotics, AI-enabled human–robot interaction, worker safety and privacy-sensitive perception functions; to SC4 through ADAS/ADS, V2X-enabled mobility, autonomous decision-making, HMI, logging and explainability; to SC5 through multi-agent sensing, coordination and emergency-response decision-support; and to SC6 through AI-assisted energy optimisation, distributed intelligent control and traceable human oversight. For SC3, these frameworks are relevant where machine-learning or AI-supported methods are used in control, diagnostics, predictive maintenance or safety-related analysis of electric powertrain components and embedded systems.

Relevant references include the EU AI Act, the IEEE 7000-series standards, IEEE 7001 and ISO/IEC 24028. Beyond technical performance considerations, these frameworks support broader ethical requirements related to human oversight, accountability, transparency, explainability, bias mitigation and the responsible deployment of AI-enabled systems.

Such considerations are particularly relevant within Cynergy4MIE given the project's focus on autonomous decision-making, cyber-physical systems and human interaction with intelligent technologies. The adoption of these frameworks highlights the importance of trustworthy and human-centric AI principles in supporting the future acceptance, validation and deployment of Cynergy4MIE solutions across different industrial sectors.

4.2.4 Energy Systems and Interoperability

Within the energy- and mobility-related Supply Chains, particularly SC6 and SC3, standards such as ISO 15118, IEC 61851, IEEE 1547, ISO 50001 and ETSI SAREF provide important reference points for interoperability, distributed energy resources, Vehicle-to-Grid communication, smart energy management and intelligent control systems.

More specifically, SC6 is directly concerned through its focus on ECS for energy efficiency, distributed intelligent control, hydrogen-related energy systems, smart heat-pump control and connected energy infrastructures. In this context, standards such as IEEE 1547, ISO 50001 and ETSI SAREF are relevant for grid integration, energy management, semantic interoperability and intelligent control of distributed energy systems.

SC3 is also relevant where electric powertrain components, intelligent batteries, WBG-based converters and vehicle-battery interfaces interact with energy infrastructure. In this context, ISO 15118 and IEC 61851 are particularly relevant to EV charging communication, Vehicle-to-Grid interfaces and the interoperability between vehicle-side components and off-vehicle energy systems. The relevance of SC3 is therefore mainly linked to the interface between electric mobility, powertrain components, batteries and energy infrastructure, rather than to broader building or grid management.

The continued application of these standards reflects the increasing convergence between electric mobility, energy efficiency and digital infrastructure domains, while also highlighting the need for stronger interoperability between SC3 and SC6 developments.

4.2.5 Robotics and Human–System Interaction

Robotics and human–system interaction standards are primarily relevant to SC2, and to a more limited extent to SC1 and SC5 where robotic, autonomous or semi-autonomous systems interact with human operators or operate in shared environments. In particular, SC2 is directly concerned through its focus on collaborative robotics, fenceless human–robot collaboration, AI-enabled human–robot interaction, digital manufacturing and construction-related automation. Standards including ISO 10218-1, ISO 10218-2 and ISO/TS 15066 provide important guidance for the safe deployment and integration of collaborative robotic systems, including safe contact limits, speed and separation monitoring, and risk reduction in shared human–robot workspaces.

SC5 is also relevant where multi-agent sensing and emergency-response systems involve robotic or semi-autonomous agents operating under human supervision or in coordination with human responders. In this case, robotics and human–system interaction standards may provide useful reference points, although additional domain-specific guidance for search-and-rescue, unmanned systems and emergency-response operations may also be required.

SC1 has a more indirect relevance, mainly where automated machinery and transportation systems include robotic characteristics or require direct interaction with human operators in dynamic environments. In such cases, robotics terminology and safety principles, including ISO 8373 and, where appropriate, ISO 13482, may provide complementary guidance, while machinery safety and functional safety standards remain the primary reference framework.

Their relevance is therefore particularly evident in SC2, and partially in SC1 and SC5, where human operators interact directly with automated, robotic or semi-autonomous technologies. This distinction avoids overextending robotics-specific standards to Supply Chains where other standardisation frameworks are more appropriate.

4.3 Additional Standards, Specifications and Frameworks Identified During the Follow-Up Assessment

In addition to confirming the continued relevance of the standards landscape mapped in D7.8, the follow-up assessment identified a limited number of additional standards, technical reports and industry frameworks that were not explicitly captured during the initial mapping exercise. These additions reflect the increasing maturity of the project architecture and provide further insights into domain-specific standardisation developments relevant to individual Supply Chains.

The mapping presented in Table 3 should therefore be understood as a focused, non-exhaustive overview of additional standards, technical reports and frameworks reported by partners during the D7.9 follow-up assessment. Each entry has been reviewed against official or reliable source descriptions, where available, in order to clarify the official title, scope and relevance of the reported reference. Where a reference constitutes an industry framework rather than a formal standard, or where its relevance to a demonstrator is indirect or conditional, this is explicitly indicated to avoid overstatement. The table also distinguishes between standards that directly support demonstrator design, validation or performance assessment and references that provide broader contextual support for future standardisation monitoring.

To strengthen the connection between standardisation monitoring and the project's chosen scenarios, the additional standards reported by partners were mapped against the demonstrators and use cases to which they are most directly related.

Table 3. Additional Standards, Framework and Relevance to Cynergy4MIE Demonstrators

Supply Chain	Demonstrator / Use Case & Chosen Scenarios	Additional Standard / Framework	Official title / description	Verified relevance for Cynergy4MIE	Source traceability
SC1	Demo 1.1 – Visibility Assessment under	Mobileye RSS	Responsibility-Sensitive Safety (RSS) – safety model	Provides a supplementary reference for formalising	Mobileye official RSS documentation

	Adverse Weather Conditions		/ framework for automated vehicle behaviour	safety-aware decision-making and responsibility-sensitive behaviour in automated mobility contexts. Its relevance to SC1 should be understood as complementary, particularly where automated machinery or transportation functions require safe behavioural decision rules under complex operating conditions. RSS should not be presented as a formal standard (Mobileye, n.d.).	
SC1	Demo 1.3–1.5 – Localisation and Mapping in GNSS-Denied Environments	ISO/TR 9839	Road vehicles; Application of predictive maintenance to hardware with ISO 26262-5	Supports the consideration of predictive maintenance, degrading faults and hardware reliability in safety-related E/E systems. Its relevance to localisation and mapping demonstrators is indirect and	ISO catalogue / ISO/TR 9839:2023

				should be linked to the reliability and functional safety of the underlying electronic hardware, sensors or embedded components, rather than to localisation or mapping methods themselves (ISO, 2023).	
SC2	Demo 2.1 – Digital Design-to-Fabrication Workflow	EN 1995 (Eurocode 5)	Eurocode 5: Design of timber structures	Provides design principles and structural reference rules for timber buildings and civil engineering works. It is relevant to SC2 where digital design-to-fabrication workflows involve timber construction, structural design assumptions and alignment between digital models and construction requirements (European Commission, JRC, 2004).	European Commission / JRC Eurocodes

SC2	Demo 2.1 – Automated Timber Fabrication	EN 14250:2010	Timber structures; Product requirements for prefabricated structural members assembled with punched metal plate fasteners	Relevant to prefabricated timber structural members, including trusses and other factory-produced elements. It supports the link between automated timber fabrication, product requirements, documentation and conformity-related considerations for prefabricated structural components (CEN, 2010).	BSI / CEN standard catalogue
SC4	Demo 4.1 – Traffic Flow Optimisation	ISO 9001:2015	Quality management systems; Requirements	Provides a general quality management framework supporting structured development, documentation, process control, validation planning and continuous improvement. Its relevance to SC4 is organisational and process-related, rather	ISO catalogue

				than specific to traffic flow optimisation algorithms (ISO, 2015a).	
SC4	Demo 4.1 – Traffic Flow Optimisation / V2X Services	ISO/IEC 27001:2022	Information security, cybersecurity and privacy protection; Information security management systems	Relevant to information security management for connected mobility services, V2X-related data environments and digital service operation. It supports risk management, governance and protection of information assets associated with SC4 activities (ISO, 2022).	ISO catalogue
SC4	Demo 4.1 – Mobility Services and Infrastructure Interaction	ISO 14001:2015	Environmental management systems; Requirements with guidance for use	Provides an environmental management framework relevant to the organisational and deployment context of mobility services and infrastructure interaction. Its relevance is linked to environmental management, sustainability considerations	ISO catalogue

				and systematic handling of environmental responsibilities, rather than to the technical performance of SC4 systems (ISO, 2015b).	
SC5	Multi-Agent Emergency Response Demonstrators	JCGM 100:2008	Evaluation of measurement data; Guide to the expression of uncertainty in measurement	Provides general rules for evaluating and expressing measurement uncertainty. It is relevant to SC5 where sensing, monitoring, localisation or measurement-based decision-support outputs need to be assessed for uncertainty, reliability and traceability. It should not be presented as an emergency-response-specific standard (BIPM & JCGM, 2008).	BIPM / JCGM
SC6	Portable Heat Pump	CNS 15466	Testing method of	Provides a reference for	CNS / Bureau of Standards,

	Demonstrator		performance for air source heat pump water heaters	performance testing of air-source heat pump water heaters. Its relevance to SC6 is appropriate where the demonstrator involves comparable air-source heat pump performance evaluation, heating performance or water-heating use cases. If the portable heat pump demonstrator is not a water-heating system, the relevance should be described as conditional or complementary (BSMI, n.d.).	Metrology and Inspection-related documentation

The above standards and frameworks were reviewed against official or reliable source descriptions. Where a reference is a framework rather than a formal standard, or where its relevance is indirect or conditional, this has been explicitly clarified to avoid overclaiming in the public deliverable.

4.4 Supply-Chain-Specific Observations

SC1 – All-Weather Automated Machinery and Transportation

SC1 addresses automated machinery and transportation systems operating under adverse environmental conditions, including reduced visibility, snow-covered environments, GNSS-denied operation and remote-control scenarios. The demonstrators developed within SC1 focus on AI-enabled visibility assessment, localisation and mapping, remote operation, and privacy-preserving occupant monitoring systems.

The continued relevance of the safety and functional assurance standards identified in D7.8 was confirmed during the architecture phase, particularly through the reported use of ISO 21448 (SOTIF) and ISO 26262 by SC1 partners. According to the partner input collected under Task 7.4, ISO 21448 is currently referenced in the design process, while ISO 26262 is used to drive safety-related design decisions. This confirms that functional safety and safety-of-the-intended-functionality considerations are not treated only as background references, but are actively informing the development logic of SC1 demonstrators.

Within SC1, ISO 26262 supports the structuring of safety-related design decisions for road-vehicle-related E/E systems, embedded control functions and safety-critical components. It provides a reference framework for analysing hazards, defining safety requirements and ensuring that safety considerations are integrated into the system architecture and development process.

ISO 21448 (SOTIF) is particularly relevant to SC1 because several demonstrators operate in complex environmental conditions where unsafe behaviour may arise not only from component failure, but also from performance limitations of perception, localisation or decision-support functions. This is especially important for visibility assessment under adverse weather, snow-covered environments, GNSS-denied operation and remote-control scenarios, where sensor performance, environmental uncertainty and operational design domain limitations must be considered during design and validation.

Other standards identified in D7.8, including machinery safety, cybersecurity, AI trustworthiness and environmental robustness references, remain relevant as broader contextual frameworks for SC1. However, based on the current partner feedback, ISO 26262 and ISO 21448 represent the most directly applied standards during the present phase of SC1 development.

In addition, partners reported the use of Mobileye's Responsibility-Sensitive Safety (RSS) framework and ISO/TR 9839. RSS is considered as a complementary safety framework for formalising safety-aware behaviour and decision-making in automated mobility contexts, while ISO/TR 9839 is relevant more indirectly by supporting predictive maintenance and hardware reliability considerations for safety-related E/E components. ISO/TR 9839 should therefore not be interpreted as a localisation or mapping standard, but as a reference for the reliability of the underlying hardware used in safety-related functions.

The demonstrator requirements also highlight several areas where standardisation activities continue to evolve. These include validation methodologies for AI-enabled visibility assessment under adverse weather conditions, performance metrics for GNSS-independent localisation systems, safety requirements for remote operation of automated machinery, and privacy-preserving occupant monitoring technologies. While no significant new standardisation gaps were formally reported, the SC1 demonstrators provide valuable validation environments capable of generating evidence relevant to ongoing discussions on automated mobility safety, SOTIF-oriented validation, functional safety, AI trustworthiness, scenario-based validation and human oversight.

SC2 – Digital Manufacturing, Robotics, and AI for Low-Emission Buildings

SC2 focuses on highly automated construction and manufacturing environments, combining digital building design, robotic fabrication, AI-assisted scheduling and human–robot collaboration technologies. The demonstrators address challenges associated with digital continuity across the construction value chain, ranging from Building Information Modelling (BIM) and Product Parametric Models to robotic production and assembly processes.

The continued relevance of the robotics, human–robot collaboration, functional safety, human-centred design and construction-related standards identified in D7.8 was confirmed during the follow-up assessment. Based on the partner input collected under Task 7.4, SC2 partners specifically reported that ISO 8373, ISO 13482, ISO 10218-1 and ISO/TS 15066 are currently referenced in the design process. One SC2 response indicated that no additional applicable standards were identified at this stage. This suggests that the standards are primarily being used as design and alignment references during the current architecture and demonstrator development phase, rather than as formal certification targets.

Within SC2, ISO 10218-1 and, where relevant, the broader ISO 10218 framework provide a reference for the safe design and integration of industrial robotic systems. These standards support the definition of safety requirements for robot manufacturers, robot systems and integration activities, particularly in relation to hazardous movements, protective measures, safety functions, emergency stopping and the interaction between robotic systems and their operating environment.

ISO/TS 15066 is particularly relevant to the human–robot collaboration aspects of SC2. It supports the design of collaborative robotic applications by providing guidance on safe human–robot interaction, including power and force limitation, speed and separation monitoring, safe contact thresholds and risk reduction in shared workspaces. In SC2, this is relevant to fenceless or semi-fenceless collaborative environments, where workers may operate near robots, robotic tools or automated fabrication equipment.

ISO 8373 is used as a terminology reference for robotics. Its relevance is mainly to ensure common understanding and consistent use of robotics-related terminology across technical partners, demonstrator descriptions and standardisation discussions. This is useful in SC2 because the Supply Chain combines industrial robotics, collaborative operation, automated fabrication and human–system interaction.

ISO 13482 is more indirectly relevant, as it concerns safety requirements for personal care robots and service-type robotic systems rather than industrial construction robotics. However, it can provide complementary design inspiration where SC2 technologies involve robots operating in close proximity to humans, shared environments, human-aware movement, or service-like interaction patterns. Its relevance should therefore be described as complementary rather than primary.

In addition to the robotics-related standards, SC2 remains linked to functional safety and machinery safety standards identified in D7.8,, including ISO 13849, IEC 62061 and IEC 61508, where safety-related control systems, collision avoidance functions, emergency stops, protective sensing or fail-safe behaviours are involved. These references support the design logic for safe machinery operation and human protection in automated manufacturing and construction settings.

Human-centred design and trustworthy AI considerations also remain relevant. Standards and frameworks such as ISO 9241-210 and ISO/IEC TR 24028 provide useful reference points for designing usable interfaces, reducing operator cognitive load, supporting human oversight and improving transparency in AI-enabled robotic decision-support functions. These considerations are particularly important where SC2 demonstrators involve AI-assisted scheduling, process recognition, worker monitoring or adaptive robot behaviour.

In relation to construction and fabrication, partners reported the relevance of EN 1995 (Eurocode 5) and EN 14250. EN 1995 provides a structural design reference for timber structures and is relevant where digital design-to-fabrication workflows involve timber construction elements. EN 14250 is relevant to prefabricated timber structural members and supports the link between automated fabrication, product requirements and construction-related conformity considerations.

The architecture analysis also revealed one of the most notable findings of the follow-up assessment: interoperability and data translation challenges between BIM environments, Product Parametric Models and fabrication systems. This represents the only new standardisation gap identified across all six Supply Chains and highlights the growing need for standardised approaches supporting seamless information exchange between design, manufacturing and construction environments.

Overall, the SC2 demonstrators show that existing robotics and construction standards provide useful references for design, safety and fabrication alignment. However, they do not fully address the combined challenges of AI-enabled production optimisation, dynamic human–robot collaboration, worker safety, privacy-preserving monitoring and BIM-to-fabrication interoperability. SC2 therefore offers a valuable validation environment for generating evidence relevant to future standardisation discussions on safe human–robot collaboration, trustworthy AI in industrial settings and digital continuity across the construction value chain.

SC2 focuses on highly automated construction and manufacturing environments, combining digital building design, robotic fabrication, AI-assisted scheduling and human-robot collaboration technologies. The demonstrators address challenges associated with digital continuity across the construction value chain, ranging from Building Information Modelling (BIM) and Product Parametric Models to robotic production and assembly processes.

SC3 – Precise Measurements for Efficient, Reliable and Safe Electric Powertrains in Transportation

SC3 focuses on advanced sensing, measurement and control technologies supporting efficient and reliable electric powertrains and charging systems. The demonstrators address challenges related to precision measurements, battery systems, charging infrastructure, power electronics and functional safety within next-generation transportation environments.

Based on the standardisation landscape established in D7.8 remain, SC3 remains associated with standards and regulatory references related to electric powertrains, charging systems, functional safety, cybersecurity, power electronics reliability, battery systems and measurement accuracy. These references provide a useful background for understanding the standardisation context in which SC3 developments may be positioned.

However, during the follow-up assessment, no additional SC3-specific standards, frameworks or standardisation gaps were reported by partners through the Task 7.4 questionnaire. Therefore, the relevance of the standards identified in D7.8 should be understood at this stage as a reference framework for the domain, rather than as evidence of newly reported or actively applied standards within the current assessment period.

In this context, functional safety and system assurance standards remain relevant to SC3 where safety-related electric powertrain components, embedded control systems, battery interfaces or charging-related functions are considered. Cybersecurity and software assurance references are also relevant where SC3 technologies interface with connected charging infrastructure, vehicle-to-grid communication, software-controlled components or data exchange processes.

SC3 also has an important interface with SC6, particularly in areas where electric mobility, charging systems, distributed energy resources, intelligent energy management and grid interaction overlap. Standards related to EV charging communication, interoperability and energy-system integration may therefore be relevant to future cross-SC discussions. Nevertheless, no new SC3-specific standardisation gaps were identified during this follow-up assessment.

Overall, the absence of additional partner input suggests that the standardisation landscape for SC3 should be treated cautiously in this deliverable. While D7.8 provides a solid baseline for the relevant standards environment, further validation with SC3 technical partners would be needed before drawing stronger conclusions on active standard use, implementation maturity or concrete contribution opportunities.

SC4 – Emergent Automated Driving Systems for Extrinsic Efficiency in Mobility

SC4 represents one of the most standardisation-intensive domains within Cynergy4MIE and includes demonstrators addressing Traffic Flow Optimisation and Road Condition Monitoring. These demonstrators combine V2X communication, sensor fusion, AI-assisted decision-making, federated learning and cooperative mobility concepts within connected transportation environments.

The relevance of the automated-driving, functional safety, SOTIF, cybersecurity and software-update standards identified in D7.8 was further supported by the partner input collected under Task 7.4. For the SC4 activities where specific standards were considered applicable, partners reported the use of ISO 26262, ISO 21448, UNECE R155, UNECE R156, IEEE 2846 and ISO 34502. In other SC4-related responses, specific standards were marked as not applicable to the respective activity or contribution at this stage.

Based on the received responses, ISO 26262 is one of the most directly applied standards in SC4 and was reported as driving design decisions. Its relevance lies in supporting functional safety considerations for road-vehicle-related E/E systems, safety-critical control logic, system architecture, hazard analysis and the definition of safety requirements for automated and connected mobility functions.

ISO 21448 (SOTIF) was also reported as driving design decisions. It is particularly relevant to SC4 because Traffic Flow Optimisation, Road Condition Monitoring and cooperative mobility scenarios may involve unsafe behaviour arising not only from component failures, but also from performance limitations, incomplete situational awareness, perception uncertainty, operational design domain limitations or complex environmental conditions.

Cybersecurity and software assurance are addressed through UNECE R155 and UNECE R156, both of which were reported as driving design decisions. UNECE R155 is relevant to cybersecurity management, threat analysis and risk mitigation for connected and automated mobility systems, while UNECE R156 supports software update management considerations, including the governance of software changes and update-related safety and security impacts. These references are particularly important for SC4 due to the involvement of connected services, V2X-related data exchange, software-defined vehicle concepts and cooperative mobility functions.

In addition, IEEE 2846 and ISO 34502 were reported as referenced in design. IEEE 2846 is relevant to safety-related assumptions for automated driving systems, particularly where assumptions about the behaviour of other road users, infrastructure, communication environments or system boundaries need to be made explicit. ISO 34502 is relevant to scenario-based safety evaluation and provides a useful reference for structuring validation scenarios, test conditions and safety evaluation logic for automated driving functions.

Other standards and frameworks identified in D7.8, including ISO/SAE 21434, UL 4600 and ASAM OpenSCENARIO-related approaches, remain relevant as part of the broader SC4 standardisation landscape. However, based on the current partner feedback, they should be presented as contextual or potential future reference points unless direct application is further confirmed by technical partners.

The Traffic Flow Optimisation and Road Condition Monitoring scenarios are particularly relevant to ongoing developments in scenario-based validation, operational design domain definition, SOTIF-oriented assessment, safety assumptions for automated driving systems, cybersecurity management, software update governance and cooperative mobility testing methodologies. Although no major new standardisation gaps were reported by the responding partners, SC4 provides one of the strongest opportunities for future Cynergy4MIE contributions, particularly in relation to scenario-based validation, IEEE 2846, ISO 34502 and ASAM OpenSCENARIO/OpenX-related approaches for connected and automated mobility systems.

SC5 – Multi-Agent and Cooperative Sensing & Control in Emergency Response Applications

SC5 focuses on multi-agent coordination, collaborative sensing, autonomous aerial and ground systems, and emergency response operations. The demonstrators investigate swarm intelligence, collaborative perception, C-SLAM techniques and human–machine cooperation within dynamic and highly uncertain operational environments.

The follow-up assessment confirmed the continued relevance of standards and standardisation references related to emergency management, resilience, AI trustworthiness, communication interoperability and system reliability. Based on the partner input collected under Task 7.4, the most relevant references currently used in SC5 are ISO/IEC TR 24028, ISO 22320, ISO/TC 292 and ETSI ITS-related specifications for emergency services. These references were reported as referenced in design, meaning that they are used to inform design choices, architecture considerations and validation planning, rather than as direct certification targets at this stage.

ISO/IEC TR 24028 is relevant to SC5 as a reference for AI trustworthiness. It supports the consideration of robustness, reliability, transparency, explainability, safety, security and human oversight in AI-enabled systems. Within SC5, this is particularly relevant to collaborative perception, target detection, swarm coordination, autonomous decision-support and AI-enabled prioritisation in emergency-response contexts. Since SC5 operates in safety-critical and uncertain environments, trustworthy AI considerations are important for ensuring that AI-supported outputs can be interpreted, audited and supervised by human operators.

ISO 22320 is relevant to SC5 through its focus on emergency management and incident response. Although it does not specifically address autonomous robotic agents or multi-agent systems, it provides a useful reference for structuring information flows, operational coordination, roles, responsibilities and incident-management processes. In SC5, this is relevant to how outputs from drones, ground robots and sensing systems could be organised and presented to emergency-response actors, including maps, alerts, victim-location information, cleared-area information and mission status updates.

ISO/TC 292 – Security and resilience is not a single standard, but a relevant standardisation committee and family of work addressing security, resilience, emergency management, continuity and related societal safety topics. Its relevance to SC5 lies in the broader alignment of multi-agent emergency-response technologies with resilience-oriented standardisation discussions. This is particularly important because SC5 demonstrators sit at the interface between autonomous systems, emergency operations and public safety procedures.

ETSI ITS-related specifications for emergency services are relevant to SC5 where communication, cooperative awareness, message exchange and interoperability between agents or with external systems are considered. While ETSI ITS standards were primarily developed for intelligent transport and cooperative mobility contexts, they provide useful reference points for communication reliability, low-latency information exchange and cooperative system behaviour. In SC5, these references are used as design inputs for thinking about how heterogeneous autonomous agents could exchange information in degraded, dynamic or mission-critical environments.

In addition, measurement and reliability considerations remain relevant for SC5, particularly where sensing, localisation, monitoring or measurement-based decision-support outputs are used. In this context, references such as JCGM 100 may provide complementary guidance for evaluating measurement uncertainty and supporting traceability of sensor-derived information.

While no new formal standardisation gaps were reported during the follow-up assessment, SC5 continues to highlight several areas where existing standards provide only partial coverage. These include interoperability between heterogeneous autonomous systems, validation of cooperative multi-agent behaviours, integration of autonomous-agent data into incident-command workflows, trustworthy AI deployment in safety-critical emergency environments, and the absence of standard performance metrics for multi-agent SAR missions.

These findings suggest potential opportunities for future cross-domain standardisation activities involving validation methodologies, collaborative autonomous systems, resilience-oriented cyber-physical systems and emergency-response data exchange. SC5 therefore remains an important area for pre-normative evidence generation, particularly because it combines AI, robotics, communications, human supervision and emergency-management requirements in a domain where dedicated standards are still limited.

SC6 – ECS for Energy Efficiency and Distributed Intelligent Control

SC6 addresses intelligent energy systems, distributed control architectures, power electronics and energy-efficient technologies, including demonstrators related to heat pumps, distributed energy resources and advanced control systems. The Supply Chain is particularly relevant to the convergence of energy efficiency, digital control, power electronics, smart buildings and cyber-physical energy infrastructures.

Based on the partner input collected under Task 7.4, EN 14511 was specifically reported as referenced in design for SC6 activities. EN 14511 is relevant because it provides a reference framework for testing and rating the performance of air conditioners, liquid chilling packages and heat pumps. Within SC6, it can support the assessment of heat pump performance, including heating/cooling capacity, coefficient of performance, energy efficiency under defined operating conditions and comparison of performance improvements introduced by intelligent control strategies.

In practical terms, EN 14511 is relevant to the heat pump demonstrator where smart control, sensor-based monitoring, variable-speed operation or coordinated component control may affect overall system performance. It provides a recognised baseline against which improvements in heat pump operation can be evaluated, even if the project does not aim at formal certification during the current phase.

In addition to EN 14511, CNS 15466 has been identified as a complementary regional reference associated with air-source heat pump performance testing. Its relevance should be presented carefully, as it is not a European or international standard. It is most relevant where the SC6 heat pump demonstrator or partner activities require comparison with Taiwanese testing approaches or support future harmonisation discussions between regional and international heat pump performance assessment methods.

Other standards identified in D7.8 remain relevant as broader domain-level references for SC6. For example, IEC 60335-2-40 is relevant to safety aspects of heat pumps, air conditioners and dehumidifiers, particularly where equipment modification, operation or testing may raise product safety considerations. IEC 62477-1 is relevant to power electronic converter systems, especially where SC6 activities involve WBG-based converters, hydrogen-related power conversion or high-efficiency electrical conversion systems.

SC6 also has a clear connection to distributed energy resources and grid interaction. In this context, IEEE 1547 is relevant as a reference for interconnection and interoperability of distributed energy resources with electric power systems. It may inform future considerations around grid-support functions, reactive power control, voltage/frequency response or safe integration of converter-based resources.

Cybersecurity and software assurance are relevant where SC6 demonstrators involve connected energy devices, distributed controllers, data exchange or remote monitoring. In this context, IEC 62443 provides a relevant reference for industrial automation and control system cybersecurity, including secure system architecture, network segmentation, authentication and risk-based cybersecurity management. These considerations are important because distributed intelligent control creates additional interfaces between energy devices, controllers and external systems.

Significant overlap can also be observed with SC3, particularly where electric mobility, charging systems, batteries, power electronics and energy infrastructure interact. Standards such as ISO 15118 and IEC 61851 may therefore be relevant to future cross-SC discussions on EV charging communication, Vehicle-to-Grid interfaces and interoperability between vehicle-side systems and energy infrastructure. However, these should be presented as cross-domain reference points rather than as standards directly reported by SC6 partners during the follow-up assessment.

Overall, the follow-up assessment did not identify major new SC6-specific standardisation gaps. However, the demonstrators illustrate concrete areas where existing standards may need to evolve or be complemented, including performance evaluation of smart heat pump control, harmonisation of regional and international heat pump testing methods, cybersecurity of distributed energy controllers, interoperability of DER interfaces and integration of intelligent control functions into energy-efficiency assessment. SC6 therefore remains strongly connected to future standardisation discussions concerning smart energy interoperability, distributed control architectures and energy-efficient cyber-physical systems.

5. Evolution of Standardisation Gaps and Emerging Developments

5.1 Reassessment of the D7.8 Gap Analysis

One of the primary objectives of the follow-up assessment was to evaluate whether the standardisation gaps identified in D7.8 remained relevant as Cynergy4MIE progressed from requirements definition towards architecture development and system design activities. The responses collected across the six Supply Chains indicate that the vast majority of previously identified gaps continue to remain applicable. Most respondents reported that no significant new standardisation gaps have emerged since the completion of D7.8, suggesting that the original gap analysis continues to provide an accurate representation of the challenges associated with the development and future deployment of Cynergy4MIE technologies. This finding is particularly important as it demonstrates the robustness of the initial standardisation assessment and confirms that the project's standardisation strategy remains aligned with the evolving technical architecture of the different Supply Chains.

Several respondents explicitly confirmed the continued validity of the existing analysis:

> *"No new gaps identified."* (SC1)
>
> *"No new critical gaps have emerged since the start of the architecture phase."* (SC4)
>
> *"None."* (SC6)

Rather than revealing substantial shifts in the standardisation landscape, the follow-up assessment indicates a phase of consolidation, during which previously identified challenges continue to shape technical development activities and architectural decisions.

Only one additional standardisation gap was reported during the present assessment. This gap concerns data translation and interoperability challenges across the digital construction value chain, specifically between Building Information Modelling (BIM), Product Parametric Models and fabrication processes. The issue was identified within Supply Chain 2 and is directly linked to demonstrators addressing digital design-to-fabrication workflows and automated timber production environments. The finding highlights the continuing need for standardised approaches supporting seamless information exchange between design, engineering and manufacturing systems.

5.2 Emerging Refinements to the Standardisation Landscape

Although the overall conclusions of D7.8 remain valid, several respondents identified additional standards, industry specifications, technical reports, and domain-specific references that complement the original mapping exercise.

Examples include Mobileye's Responsibility-Sensitive Safety (RSS) framework, ISO/TR 9839 addressing predictive maintenance concepts in support of functional safety, Eurocode 5 and EN 14250 within digital construction environments, as well as regional standards related to energy efficiency and heat pump performance testing.

These additions should not be interpreted as indications of major shifts within the standardisation ecosystem. Instead, they represent refinements that reflect the increasing technical maturity of the project and the growing understanding of domain-specific requirements as architectural development progresses.

The findings also demonstrate that innovation ecosystems increasingly rely not only on formal standards but also on industrial frameworks, technical reports, implementation guidance, and emerging best practices that may eventually influence future standardisation activities.

Several of these additions emerged directly from the evolution of specific demonstrators and use cases. For example, safety assurance frameworks were reported in relation to automated mobility scenarios, construction-sector standards were linked to digital manufacturing and building automation demonstrators, while energy-performance testing standards were associated with heat pump and energy-efficiency applications. This observation further illustrates how demonstrator development can reveal additional standards and industry frameworks that complement the baseline standardisation landscape.

Consequently, continuous monitoring of both formal and informal standardisation developments remains essential throughout the remainder of the project.

6. Preliminary Standardisation Contribution Opportunities

6.1 Overview

Building upon the standards mapping activities conducted in D7.8, the partner survey results, and consultations with industrial stakeholders and standardisation experts, a number of preliminary contribution opportunities have been identified for Cynergy4MIE.

The objective of this analysis is not to propose the development of entirely new standards, but rather to identify realistic pathways through which project partners may contribute to ongoing standardisation activities within relevant technical committees, working groups, and industry-led initiatives.

At M22, the project is still progressing through architecture developments and system design, while large-scale validation activities have not yet been completed. So, the contribution opportunities presented in this section should be understood as preliminary pathways to be further explored, validated and refined during the remaining project period and consolidated at the end of the project (M36) with the final deliverable.

The identified opportunities were selected based on:

- their relevance to the technological developments pursued within Cynergy4MIE;
- their alignment with the standardisation gaps identified across the six Supply Chains;
- existing participation of consortium partners in standardisation organisations and technical committees;
- the maturity level of the project's technical developments;
- their potential contribution to the long-term exploitation and market uptake of project results.

The following sections present a set of preliminary contribution pathways that could be further explored during the remaining project period and refined within D7.10. These preliminary proposals are intended to support the prioritisation of future standardisation activities and provide an initial basis for identifying realistic contribution targets aligned with both consortium expertise and ongoing standardisation developments.

6.1.1 Engagement with Standardisation Stakeholders

Beyond the standards mapping and gap analysis activities, Cynergy4MIE has initiated direct engagement with standardisation stakeholders and experts active in European and international standardisation ecosystems.

As part of these activities, consultations were conducted with representatives involved in ISO, CEN, ITS, AI, cybersecurity and Connected, Cooperative and Automated Mobility (CCAM) standardisation initiatives. These exchanges provided valuable insights regarding current standardisation priorities, emerging developments and realistic pathways through which research projects can contribute to ongoing standardisation work.

In addition to the standardisation activities and industry connections already maintained by several consortium partners, CONVERGENCE, as leader of Task 7.4, conducted targeted outreach activities with external standardisation stakeholders in order to complement the consortium-wide assessment.

These activities included an expert consultation with András Csepinszky, an industrial and standardisation expert actively involved in ISO, CEN and CCAM-related initiatives, as well as exchanges with representatives of national standardisation organisations, including the Cyprus Organisation for Standardisation (CYS).

These engagements have helped validate the relevance of the gaps identified through the standards mapping exercise and have informed the preliminary contribution opportunities presented in the following sections.

The consultation with CYS provided practical insights into the mechanisms through which research and innovation projects may engage with formal standardisation processes and contribute to ongoing standardisation activities. The organisation demonstrated a strong willingness to exchange knowledge and discuss potential pathways for connecting research outcomes with standardisation ecosystems. These discussions complemented the expert perspectives gathered through the consultation activities and contributed to the identification of realistic contribution pathways presented in this deliverable.

Key Outcome

Through the activities conducted under Task 7.4, Cynergy4MIE has moved beyond a traditional standards review exercise by combining consortium expertise, partner participation in standardisation activities, and targeted engagement with external experts and national standardisation organisations. These interactions provide an important basis for identifying realistic contribution opportunities and increasing the long-term standardisation impact of project results.

6.2 Scenario-Based Validation and Testing

Scenario-based validation is increasingly recognised as one of the most important approaches for the verification and validation of automated and autonomous systems. Within the mobility domain, standardisation activities led by ASAM have established a comprehensive ecosystem of standards, including OpenSCENARIO, OpenDRIVE and other OpenX specifications, which support the development, testing and validation of Advanced Driver Assistance Systems (ADAS), Automated Driving Systems (ADS) and autonomous mobility solutions. ASAM OpenSCENARIO is widely used for the virtual development, testing and validation of automated driving functions and enables the structured representation of traffic situations, environmental conditions and interactions among road users.

The relevance of this standardisation area to Cynergy4MIE is particularly evident within SC4, where project activities focus on traffic flow optimisation, road condition monitoring, V2X-enabled mobility services, sensor fusion and AI-assisted decision-making. These activities generate valuable knowledge regarding complex operational environments, degraded driving conditions and cooperative mobility scenarios that are directly relevant to scenario-based testing and validation approaches.

Based on partner feedback and the standardisation activities already pursued by consortium members, ASAM OpenSCENARIO and the broader OpenX ecosystem emerge as a promising area for potential Cynergy4MIE contributions. In particular, project results could provide valuable insights regarding the representation and validation of road-condition-aware automated driving scenarios, cooperative mobility situations and AI-enabled decision-making processes under challenging operating conditions. In addition, scenario-based validation activities are increasingly linked to the implementation of safety assurance frameworks such as ISO 21448 (Safety of the Intended Functionality – SOTIF), which addresses performance limitations and foreseeable misuse scenarios in advanced driving systems.

Rather than contributing directly to the development of new standards, a realistic contribution pathway would involve the provision of technical feedback, validation requirements and use-case-driven knowledge derived from Cynergy4MIE demonstrators. Such contributions could support ongoing discussions related to scenario definition, scenario libraries, edge-case identification and the validation of automated driving functions under adverse environmental and traffic conditions.

A preliminary contribution opportunity therefore relates to the development and refinement of scenario-based validation methodologies for cooperative and connected mobility systems, particularly in relation to road-condition monitoring, traffic optimisation and V2X-enabled interactions. These activities align closely with the objectives of existing ASAM OpenX initiatives and may provide a practical pathway for translating Cynergy4MIE research results into future standardisation discussions.

6.2.1 Preliminary Contribution Proposal

- **Standardisation Body:** ASAM
- **Relevant Standards:** OpenSCENARIO, OpenDRIVE, OpenX Ecosystem
- **Contribution Area:** Scenario-based validation of cooperative mobility systems and road-condition-aware automated driving functions
- **Potential Evidence Source:**
  - Demo 4.1 Traffic Flow Optimisation
  - Demo 4.2 Road Condition Monitoring
  - V2X communication scenarios

  - Cooperative mobility use cases
- **Potential Contribution Type:** Technical feedback, validation requirements, scenario definition recommendations, edge-case identification and testing methodologies

Consortium Perspective

An SC4 automotive and automated-driving technology partner with active involvement in relevant standardisation activities highlighted additional opportunities for future engagement in this area. In particular, the partner identified potential collaboration opportunities related to IEEE 2846 safety assumptions for automated driving systems, including possible interaction with established automotive stakeholders such as Mercedes-Benz AG and AVL, as well as potential alignment activities with Virtual Vehicle Research GmbH concerning ISO 34502 and scenario-based validation methodologies.

These observations further reinforce the relevance of scenario-based validation, safety assurance and automated driving verification activities as promising standardisation pathways for Cynergy4MIE. Moreover, they demonstrate that relevant consortium partners already maintain links with ongoing standardisation initiatives and industrial networks, creating favourable conditions for future contribution activities during the remaining project period.

6.3 Safety Assumptions for Automated Driving Systems

The increasing deployment of Automated Driving Systems (ADS) has generated significant standardisation activity related to safety assurance, operational design domains, and the validation of automated driving behaviour. Within this context, IEEE 2846 provides a framework for defining and evaluating safety assumptions associated with automated driving systems and serves as an important reference for the assessment of ADS safety performance. Complementary standards such as ISO 21448 (SOTIF) and ISO 26262 further contribute to the broader safety assurance ecosystem for automated driving systems and remain highly relevant for the validation of AI-enabled driving functions operating under complex environmental conditions.

The relevance of this topic to Cynergy4MIE is closely linked to the activities developed within SC4, particularly those involving automated decision-making, cooperative mobility services, intelligent sensing, traffic optimisation and connected vehicle environments. As automated systems become increasingly dependent on AI-enabled decision processes and interactions with complex operational environments, the identification, documentation and validation of safety assumptions become critical elements of system design and verification.

A preliminary contribution opportunity was identified through feedback provided by consortium partners active in automotive standardisation activities. In particular, the possibility of contributing to ongoing discussions related to IEEE 2846 was highlighted as a promising pathway for future engagement, especially in relation to safety assumptions, operational design domain considerations and the validation of automated driving functionalities.

Potential Cynergy4MIE contributions may emerge from demonstrator activities addressing cooperative mobility scenarios, road condition monitoring, V2X-enabled interactions and AI-assisted decision-making under varying environmental conditions. Such activities may provide valuable evidence regarding the behaviour of automated systems operating in complex and dynamic environments, supporting future discussions on safety assumptions and validation approaches.

Although the maturity of project results will ultimately determine the scope of any future contribution, IEEE 2846 represents a relevant and realistic standardisation pathway that aligns with both the technological focus of SC4 and the expertise already present within the consortium.

The relevance of this topic is further reinforced by demonstrator activities addressing complex operational environments, degraded road conditions, cooperative mobility services and AI-assisted decision-making. In particular, the Traffic Flow Optimisation and Road Condition Monitoring demonstrators provide practical environments for examining how safety assumptions evolve when automated systems interact with changing infrastructure conditions, connected vehicles and dynamically varying traffic situations. These activities may generate valuable evidence supporting future discussions on operational design domains, safety assumptions and validation approaches for automated driving systems.

6.3.1 Preliminary Contribution Proposal

- **Standardisation Body:** IEEE
- **Relevant Standard:** IEEE 2846
- **Contribution Area:** Safety assumptions and validation approaches for Automated Driving Systems
- **Potential Evidence Source:**
    - SC4 Traffic Flow Optimisation demonstrator
    - SC4 Road Condition Monitoring demonstrator
    - V2X-enabled cooperative mobility scenarios
    - AI-assisted decision-making functions operating under varying environmental and traffic conditions
    - Visibility-aware driving and degraded-condition operation concepts developed within SC1

- **Potential Contribution Type:** Technical feedback, safety-related observations, validation evidence and operational design domain considerations

Beyond SC4, several SC1 demonstrators address challenging operational conditions including adverse weather, reduced visibility and localisation constraints. These environments are highly relevant to ongoing discussions concerning Safety of the Intended Functionality (SOTIF), performance limitations and the validation of automated systems operating under degraded conditions.

Consortium Perspective

An SC4 automotive and automated-driving technology partner with relevant experience in automated driving safety assurance and standardisation activities indicated interest in exploring joint standardisation input related to IEEE 2846 safety assumptions for Automated Driving Systems. This may include potential collaboration with established automotive and research stakeholders, including Mercedes-Benz AG and AVL, where appropriate and subject to further confirmation during the next phase of Task 7.4.

This observation suggests that existing industrial networks and ongoing standardisation activities may provide favourable opportunities for future Cynergy4MIE engagement in ADS safety assurance discussions. It also reinforces the relevance of combining evidence from SC4 automated-driving and cooperative mobility demonstrators with selected SC1 degraded-condition scenarios, particularly where adverse weather, reduced visibility, localisation constraints and SOTIF-related performance limitations are concerned.

6.4 AI Trustworthiness, Explainability and Human Oversight

A recurring theme across the follow-up assessment concerns the need for trustworthy, explainable and human-centred AI-enabled systems. This topic is relevant across several Cynergy4MIE Supply Chains, particularly SC1, SC2, SC4 and SC5, where AI-enabled perception, decision-making, robotics, mobility services and multi-agent coordination are central to the project's technical developments.

Existing and emerging standardisation frameworks, including the IEEE 7000 series, IEEE 7001, ISO/IEC 24028, ISO/IEC 42001 and ISO/IEC 23894, provide important reference points for AI governance, transparency, risk management, accountability and human oversight. These frameworks are highly relevant to Cynergy4MIE because the project addresses cyber-physical systems that must operate in complex environments while remaining safe, understandable, auditable and acceptable to human users.

The partner responses confirm that AI trustworthiness and explainability are not isolated concerns limited to one Supply Chain. Instead, they represent a cross-cutting standardisation challenge affecting automated machinery, robotics, automated driving systems and emergency response applications. In this context, Cynergy4MIE may be able to contribute practical evidence on how explainability, human oversight and auditability requirements can be implemented across different industrial domains.

A realistic contribution pathway would not involve proposing a new AI standard, but rather providing implementation-oriented insights, lessons learned and validation evidence demonstrating how trustworthy AI principles can be operationalised within cyber-physical systems.

6.4.1 Preliminary Contribution Proposal

- **Standardisation Body / Initiative**: IEEE, ISO/IEC JTC 1/SC 42
- **Relevant Standards / Frameworks:** IEEE 7000 series, IEEE 7001, ISO/IEC 24028, ISO/IEC 42001, ISO/IEC 23894
- **Relevant Supply Chain(s):** SC1, SC2, SC4, SC5
- **Contribution Area:** Trustworthy AI, explainability, auditability and human oversight in AI-enabled cyber-physical systems
- **Potential Evidence Source:**
    - SC1 Visibility Assessment
    - SC1 GNSS-independent localisation
    - SC2 Human-Robot Collaboration
    - SC2 AI-based Scheduling
    - SC5 Multi-Agent Coordination
- **Potential Contribution Type:** Implementation feedback, human oversight considerations, explainability requirements, audit-ready logging recommendations and cross-domain lessons learned

6.5 Cybersecurity of Connected Cyber-Physical Systems

Cybersecurity remains one of the most important cross-cutting standardisation areas for Cynergy4MIE. The project involves connected and software-enabled systems operating across mobility, powertrains, energy systems, distributed control, automated driving and industrial environments. These systems require secure architectures, resilient communication, trusted software updates, and risk management processes that address both safety and security implications.

The partner survey confirmed the continued relevance of cybersecurity-related standards and regulatory frameworks, including ISO/SAE 21434, IEC 62443, UNECE R155 and UNECE R156. These standards are particularly relevant for SC3, SC4 and SC6, while also having broader implications for other Supply Chains involving connected devices, data exchange and software-defined functions.

A preliminary contribution opportunity may therefore emerge around the identification of cross-domain cybersecurity patterns for connected cyber-physical systems. Cynergy4MIE is well positioned to generate evidence on how cybersecurity requirements are interpreted and applied across different industrial contexts, including automotive systems, electric powertrains, distributed energy resources and smart control environments.

Rather than focusing on one domain-specific cybersecurity framework, Cynergy4MIE could contribute to broader discussions on how cybersecurity practices can be aligned across heterogeneous cyber-physical systems and how security requirements interact with safety, interoperability and certification readiness.

6.5.1 Preliminary Contribution Proposal

- **Standardisation Body / Initiative**: ISO, SAE, IEC, UNECE
- **Relevant Standards / Regulations**: ISO/SAE 21434, IEC 62443, UNECE R155, UNECE R156
- **Relevant Supply Chain(s)**: SC3, SC4, SC6
- **Contribution Area**: Cybersecurity patterns for connected and software-defined cyber-physical systems
- **Potential Evidence Source:**
    - SC3 Electric Powertrain demonstrators
    - SC4 Connected mobility services
    - SC6 Distributed intelligent control systems
- **Potential Contribution Type:** Cross-domain cybersecurity observations, implementation challenges, risk management feedback, secure software lifecycle insights and alignment recommendations

6.6 Energy Interoperability and Smart Energy Systems

Energy interoperability represents another promising contribution pathway for Cynergy4MIE, particularly in relation to SC3 and SC6. These Supply Chains address electric powertrains, charging-related technologies, energy efficiency, distributed intelligent control and smart infrastructure applications.

Standards such as ISO 15118, IEC 61851, IEEE 1547, ISO 50001 and ETSI SAREF provide important foundations for interoperability, smart energy management, Vehicle-to-Grid communication, distributed energy resources and semantic data exchange. However, as mobility, infrastructure and energy systems become increasingly interconnected, further practical experience is needed regarding how these standards can be applied in integrated cyber-physical environments.

Cynergy4MIE may contribute implementation-oriented insights from demonstrators addressing powertrain efficiency, distributed control, heat pump performance, energy optimisation and smart energy interactions. These results may help identify interoperability challenges, data exchange needs and certification-related considerations relevant to future standardisation discussions.

This opportunity is particularly aligned with the broader Cynergy4MIE objective of supporting convergence across mobility, infrastructure and energy ecosystems.

6.6.1 Preliminary Contribution Proposal

- **Standardisation Body / Initiative:** ISO, IEC, IEEE, ETSI
- **Relevant Standards / Frameworks:** ISO 15118, IEC 61851, IEEE 1547, ISO 50001, ETSI SAREF
- **Relevant Supply Chain(s):** SC3, SC6
- **Contribution Area:** Interoperability and smart energy integration across mobility and energy systems
- **Potential Evidence Source:**
  - SC3 charging and powertrain environments
  - SC6 Portable Heat Pump demonstrator
  - SC6 distributed energy management use cases
- **Potential Contribution Type:** Interoperability observations, data exchange requirements, implementation feedback, energy efficiency testing insights and recommendations for integrated mobility-energy systems

6.7 Summary of Preliminary Contribution Opportunities

The preliminary contribution opportunities identified in this section demonstrate that Cynergy4MIE has the potential to engage with standardisation activities across both domain-specific and cross-cutting areas. While some opportunities are strongly linked to specific Supply Chains, such as scenario-based validation and ADS safety assurance in SC4, others cut across multiple technological domains and reflect broader convergence challenges.

Table 4. Preliminary Standardisation Contribution Opportunities and Supporting Cynergy4MIE Demonstrators

Contribution Opportunity	Relevant Standards / Initiatives	Supporting Demonstrators / Use Cases	Relevant Supply Chains
Scenario-Based Validation and Testing	ASAM OpenSCENARIO, OpenDRIVE, OpenX Ecosystem	Traffic Flow Optimisation, Road Condition Monitoring, V2X-enabled Mobility Services	SC4
Safety Assumptions for Automated Driving Systems	IEEE 2846, ISO 21448 (SOTIF), ISO 26262	Traffic Flow Optimisation, Road Condition Monitoring, Cooperative Mobility Scenarios, Adverse Weather and Visibility-Aware Driving Functions	SC4

AI Trustworthiness, Explainability and Human Oversight	IEEE 7000 Series, IEEE 7001, ISO/IEC 24028, ISO/IEC 42001, ISO/IEC 23894	Visibility Assessment, GNSS-Independent Localisation, Human-Robot Collaboration, AI-based Scheduling, Multi-Agent Coordination and Decision-Making	SC1, SC2, SC4, SC5
Cybersecurity of Connected Cyber-Physical Systems	ISO/SAE 21434, IEC 62443, UNECE R155, UNECE R156	Electric Powertrain Demonstrators, Connected Mobility Services, Distributed Intelligent Control Systems	SC3, SC4, SC6
Energy Interoperability and Smart Energy Systems	ISO 15118, IEC 61851, IEEE 1547, ISO 50001, ETSI SAREF	Electric Powertrain and Charging Technologies, Portable Heat Pump Demonstrator, Distributed Energy Management and Intelligent Control Applications	SC3, SC6

The preliminary contribution opportunities identified in this section demonstrate that Cynergy4MIE has the potential to engage with standardisation activities across both domain-specific and cross-cutting areas. Importantly, the identified opportunities are not derived solely from theoretical standards mapping activities but are also supported by concrete demonstrators and use cases developed across the six Supply Chains. This creates a direct link between the project's chosen scenarios, its technical developments and the future standardisation pathways explored in this deliverable.

The opportunities presented here therefore constitute a structured basis for the future work to be consolidated in D7.10, where standardisation proposals will be further refined and linked to the Reference Homologation Process, exploitation pathways and industrial uptake of Cynergy4MIE solutions.

While some contribution opportunities are closely associated with specific technological domains, a key objective of Cynergy4MIE is to maximise cross-Supply-Chain relevance and facilitate knowledge transfer across different industrial sectors. For this reason, the contribution opportunities identified in this deliverable were selected not only on the basis of their relevance to individual Supply Chains, but also according to their potential to address common challenges related to safety, trustworthiness, cybersecurity, interoperability, validation and certification readiness.

As illustrated in Figure 2, several opportunities extend beyond a single technological domain and create natural points of convergence between mobility, robotics, energy systems, emergency response applications and cyber-physical systems. This cross-domain perspective is expected to strengthen the long-term standardisation impact of Cynergy4MIE and support the development of future standardisation proposals with broader applicability across industrial sectors.

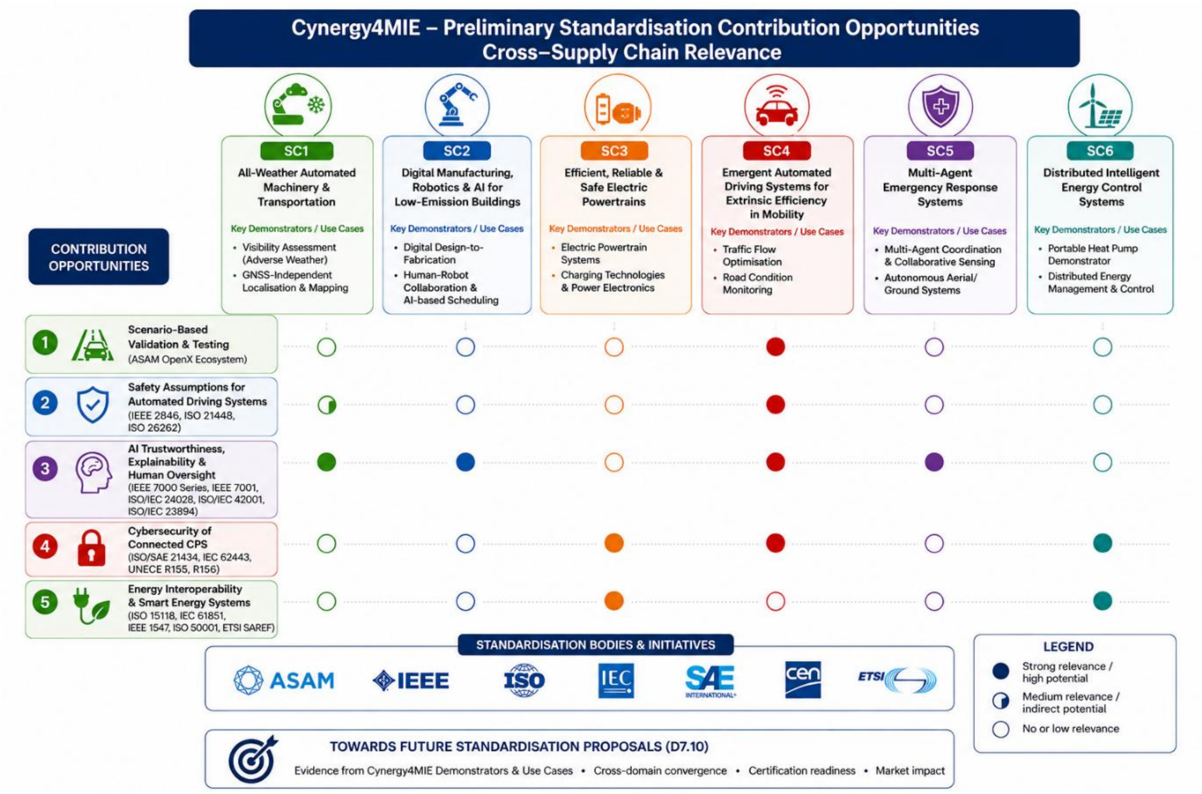

Figure 2. Cross-Supply-Chain alignment of preliminary standardisation contribution opportunities within Cynergy4MIE.

The figure demonstrates how several identified contribution opportunities are shared across multiple Supply Chains, indicating areas where collaborative and cross-sector standardisation efforts may be pursued.

The analysis highlights that while some contribution opportunities remain strongly linked to specific application domains, particularly automated driving and cooperative mobility systems, others demonstrate significant cross-Supply-Chain relevance. In particular, AI trustworthiness, explainability, human oversight and cybersecurity emerge as recurring themes across multiple technological domains, suggesting that these areas may provide the strongest basis for future consortium-wide standardisation activities.

This finding is consistent with both the partner survey results and the consultations conducted with external experts and standardisation stakeholders, which repeatedly emphasised the growing importance of trustworthy AI, cybersecurity, validation methodologies and interoperability as common challenges across modern cyber-physical systems.

7. Conclusions and Next Steps Towards D7.10

7.1 Main Findings

Building upon the standardisation baseline established in D7.8, the activities conducted under Task 7.4 have provided an updated view of the standardisation landscape relevant to Cynergy4MIE and its six Supply Chains.

The follow-up assessment confirmed the continued relevance of the majority of standards, technical specifications and regulatory frameworks previously identified, while also highlighting several emerging developments related to trustworthy AI, cybersecurity, validation methodologies, interoperability and safety assurance. At the same time, the analysis demonstrated that many of the standardisation challenges identified in D7.8 remain highly relevant and continue to affect multiple technological domains addressed within the project.

The partner survey results further revealed that standardisation activities are already embedded within several consortium organisations, with partners actively participating in technical committees, standardisation working groups and industrial initiatives. These activities provide valuable opportunities for future engagement and facilitate the identification of realistic pathways for translating project outcomes into future standardisation discussions.

Finally, the consultation activities conducted with external experts and standardisation stakeholders confirmed the growing importance of cross-cutting topics such as functional safety, cybersecurity engineering, AI trustworthiness, explainability, interoperability and scenario-based validation. These themes emerged consistently across both the internal assessment and the stakeholder engagement activities conducted during the reporting period.

7.2 Towards D7.10: From Readiness to Contribution

D7.9 represents a transitional milestone within the overall standardisation strategy of Cynergy4MIE. While D7.8 focused on establishing the initial standards landscape and identifying existing gaps, the present deliverable concentrates on monitoring developments, engaging with stakeholders and assessing the consortium's readiness for future standardisation contributions.

At the current stage of the project, the technological developments remain under refinement and large-scale validation activities have not yet been completed. Consequently, the opportunities identified in Section 6 should be understood as preliminary contribution pathways rather than formal standardisation proposals.

Furthermore, the preliminary opportunities identified in D7.9 will be discussed with the relevant technical partners and demonstrator owners during the remaining project period in order to verify their technical relevance, maturity and alignment with ongoing standardisation activities. This validation process will support the selection of a smaller set of priority contribution areas that can be further developed within D7.10.

The next phase of work will focus on transforming demonstrator results, validation evidence, stakeholder feedback and lessons learned into more concrete contribution proposals. Particular attention will be given to opportunities demonstrating strong cross-Supply-Chain relevance, as these areas offer the greatest potential for generating broader industrial impact and supporting future standardisation activities across multiple technological domains.

In this respect, the opportunities identified in D7.9 represent a first portfolio of candidate contribution areas. Their purpose is to guide the consortium's standardisation efforts during the validation phase and support the identification of those activities that demonstrate sufficient maturity, industrial relevance and standardisation value to be further developed into concrete proposals within D7.10.

7.3 Future Standardisation Activities

During the remaining project period, standardisation-related activities will focus on four complementary directions:

7.3.1 Validation and prioritisation of contribution opportunities.

Particular attention will be given to opportunities linked to demonstrator validation activities and to those addressing cross-cutting topics such as AI trustworthiness, cybersecurity, interoperability, safety assurance and scenario-based validation, which were identified as recurring priorities across multiple Supply Chains. As a next step, the consortium will validate the preliminary contribution opportunities identified in this deliverable through targeted consultations with technical partners and demonstrator owners. The objective of this process will be to assess the availability of supporting evidence, identify interested contributors, evaluate the maturity of each opportunity and prioritise those pathways that demonstrate the strongest potential for future standardisation impact. The outcomes of this validation process will directly support the preparation of D7.10.

7.3.2 Reference Homologation Process.

The Reference Homologation Process developed within Cynergy4MIE will support the assessment of certification, compliance and market uptake considerations, helping to bridge the gap between technological innovation and industrial deployment.

7.3.3 Stakeholder and standardisation engagement.

The consortium will continue monitoring relevant standardisation developments and, where appropriate, maintain engagement with standardisation experts, industrial initiatives and standardisation organisations in order to validate and refine future contribution opportunities.

7.3.4 Preparation for the next steps.

The opportunities identified in this deliverable will be further assessed, prioritised and refined based on demonstrator results, validation outcomes and stakeholder feedback. This process will ultimately support the preparation of D7.10, where concrete standardisation proposals and recommendations for the uptake of Cynergy4MIE solutions will be consolidated. Where appropriate, the consortium will also explore opportunities for interaction with relevant technical committees, industry associations and standardisation initiatives identified through the stakeholder consultations conducted under Task 7.4.

7.4 Standardisation-Driven Exploitation Opportunities

Beyond their relevance for future standardisation activities, the findings presented in D7.9 also create opportunities for scientific dissemination, industrial collaboration and future research initiatives. Several consortium partners highlighted topics that could benefit from further investigation and knowledge exchange, particularly in areas related to trustworthy AI, safety assurance for automated systems, cybersecurity of connected cyber-physical systems, interoperability of digital engineering environments, predictive maintenance, and energy-efficient intelligent control systems.

The identified standardisation gaps and contribution opportunities may therefore provide a valuable basis for future scientific publications, technical position papers, workshops and collaborative research activities. In particular, the cross-domain nature of Cynergy4MIE creates opportunities to explore common challenges related to safety, interoperability, explainability, validation and certification across multiple industrial sectors.

In addition, the standardisation pathways identified in this deliverable may support the preparation of future European and national research proposals addressing AI governance, automated mobility, industrial digitalisation, cybersecurity, smart energy systems and cyber-physical systems engineering. The knowledge generated through Cynergy4MIE can contribute not only to future standardisation discussions but also to broader research and innovation activities aimed at accelerating the adoption of trustworthy, interoperable and human-centric technologies.

These exploitation opportunities further reinforce the strategic value of the standardisation activities conducted under Task 7.4 and demonstrate how standardisation-related knowledge can support both the uptake of project results and the development of future collaborative initiatives.

To support the preparation of D7.10, the identified opportunities will be assessed against a set of practical criteria including technological maturity, availability of validation evidence, relevance to project outcomes, stakeholder interest, existing standardisation activities and expected industrial impact. This prioritisation process will support the selection of the most promising contribution pathways for further development.

7.5 Conclusion

The work presented in D7.9 demonstrates that Cynergy4MIE has successfully evolved from a standards mapping exercise towards an active standardisation readiness and engagement phase. Through standards monitoring, stakeholder consultations, partner engagement and the identification of preliminary contribution opportunities, the project has established a structured basis for future standardisation activities. The next phase will focus on validating and prioritising these opportunities, strengthening the supporting evidence base through demonstrator activities and transforming the most mature pathways into concrete standardisation recommendations within D7.10. In doing so, Cynergy4MIE aims to maximise the long-term industrial relevance, interoperability and market uptake potential of its technological developments.

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Annex A – Follow-up Questionnaire (as administered via EU-Survey)

Cynergy4MIE | Follow-up Standardisation Questionnaire

About this Questionnaire

Objective:

Gather structured input from all partners contributing across all six Supply Chain areas (SC1–SC6) to support Cynergy4MIE's ongoing standardisation activities, the monitoring of pre-normative contributions, and the project's engagement with industrial initiatives and standardisation bodies.

To be completed by:

All technical and industrial partners of Cynergy4MIE.

This questionnaire is part of T7.4 'Maximizing the Cynergy4MIE exploitation potential via Standardisation, certification, human-in-the-loop approaches, and ethical aspects' considerations towards Society 5.0' and contributes directly to the project's contractual obligations as described in the Cynergy4MIE Grant Agreement. Its primary purpose is to collect targeted input from technical and industrial partners that will support the development of Deliverable D7.9 'Standards and Processes in Relation to Cynergy4MIE's Choosen Scenarions'. The information gathered may also inform additional or future outputs of T7.4, where relevant and appropriate, including D7.10.

This activity follows on from the questionnaire administered in support of D7.8 'Standardisation State-of-the-Art and Analysis of Gaps' (M12, approved). Whereas the first instrument focused on mapping the standardisation landscape and identifying gaps across SC1–SC6, the present questionnaire focuses on the operational follow-up: how partners are applying standards in the architecture phase, the maturity of pre-normative artefacts that can be submitted to standardisation bodies, and the engagement status of consortium partners with the relevant bodies and industrial initiatives.

Any personally identifiable information (e.g. your email) will be used solely for internal communication and coordination purposes (e.g. to request clarification on submitted responses). It will not appear in any public deliverables. All data will be handled in full compliance with the General Data Protection Regulation (GDPR) and securely stored for the duration of the project. In line with EU audit requirements, the data may be retained for up to five years following the final payment of the project.

Project Duration: Start date: 1 September 2024 – End date: 31 August 2027

For any questions or concerns, please contact:

Research coordinator for this activity:
Panagiota Kokoliou ***(p.kokoliou@convergence.gr)***

Cynergy4MIE Project Coordinator: Katrin Al Jezany ***(katrin.aljezany@avl.com)***

Thank you for your time and contribution. Your input is invaluable to the success of Cynergy4MIE and to shaping impactful, forward-looking outcomes.

Please select the Supply Chain (SC) you are currently working on.

If you are involved in more than one, please complete the questionnaire separately for each SC.

SC1

SC2

SC3

SC4

SC5

SC6

SC1 Standards in practice

For each standard below, tick the column that best reflects how it is currently applied in your SC1 work. Tick one column per row.

Not aware, Acknowledged only, Referenced in design, Driving design decisions, Certification planned

ISO 26262 – Functional safety (road vehicles)

ISO 13849 – Machinery control systems safety

IEC 61508 – Functional safety of E/E/PE systems

IEC 62061 – Safety of machinery

IEC 60204-1 – Electrical safety in machinery

ISO/PAS 8800 – Road vehicle safety and AI

ISO 13228 (LiDAR test methods, draft)

ISO/IEC 24029 – AI robustness

ISO 21448 – SOTIF

5GAA / AUTOSAR / ASAM frameworks

CEN/TC 114 guidance (Safety of machinery)

--> Have you identified any additional standards, regulations or industry specifications relevant to your SC1 work that were NOT listed in D7.8?

If yes, please list and briefly state how they apply.

--> Since the architecture phase started, have NEW gaps emerged that were not captured in D7.8?

Please describe the most critical new gap(s).

--> Is your organisation currently a member of, or active in, a standardisation body or industrial initiative relevant to SC1?

If yes, please list the body, committee / working group, your role, and meeting frequency

--> Since M1 of Cynergy4MIE, have you made any contribution to a standardisation body or industrial initiative in the context of the project?

- Yes, please describe below
- No, but planned after M24
- No, and no plans yet

If yes: what, when, to whom, and reference (meeting minutes, document ID, etc.)

SC2 Standards in practice

For each standard below, tick the column that best reflects how it is currently applied in your SC2 work. Tick one column per row.

Not aware, Acknowledged only, Referenced in design, Driving design decisions, Certification planned

ISO/TS 15066 – Collaborative robot safety

ISO 10218-1 – Robot manufacturer safety

ISO 10218-2 – Robot system integration safety

ISO 13482 – Personal care/service robot safety

ISO 8373 – Robotics terminology

ISO/TR 20218-1/-2 – End-effector / load stations

CEN/TC 310 – Advanced automation in manufacturing

CEN-CENELEC JTC 21 – AI

IEEE 7000-series (ethical design)

EU AI Act (Reg. 2024/1689)

--> Have you identified any additional standards, regulations or industry specifications relevant to your SC2 work that were NOT listed in D7.8?

If yes, please list and briefly state how they apply.

--> Since the architecture phase started, have NEW gaps emerged that were not captured in D7.8?

Please describe the most critical new gap(s).

--> Is your organisation currently a member of, or active in, a standardisation body or industrial initiative relevant to SC2?

If yes, please list the body, committee / working group, your role, and meeting frequency

--> Since M1 of Cynergy4MIE, have you made any contribution to a standardisation body or industrial initiative in the context of the project?

- Yes, please describe below
- No, but planned after M24

- No, and no plans yet

If yes: what, when, to whom, and reference (meeting minutes, document ID, etc.)

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SC3 Standards in practice

For each standard below, tick the column that best reflects how it is currently applied in your SC3 work. Tick one column per row.

Not aware, Acknowledged only, Referenced in design, Driving design decisions, Certification planned

ISO 26262 – Functional safety (powertrain E/E)

ISO 21498 – Electrified powertrain architecture

ISO 15118 – V2G communication

ISO 12405 – Li-ion battery testing

IEC 61851 – EV conductive charging

SAE J1772 / CCS – Charging interoperability

IEEE 2030.1.1 – EV interconnection

AEC-Q100 / AEC-Q101 – Component qualification

JEDEC WBG reliability series (SiC / GaN)

--> Have you identified any additional standards, regulations or industry specifications relevant to your SC3 work that were NOT listed in D7.8?

If yes, please list and briefly state how they apply.

--> Since the architecture phase started, have NEW gaps emerged that were not captured in D7.8?

Please describe the most critical new gap(s).

--> Is your organisation currently a member of, or active in, a standardisation body or industrial initiative relevant to SC3?

If yes, please list the body, committee / working group, your role, and meeting frequency

--> Since M1 of Cynergy4MIE, have you made any contribution to a standardisation body or industrial initiative in the context of the project?

- Yes, please describe below
- No, but planned after M24
- No, and no plans yet

If yes: what, when, to whom, and reference (meeting minutes, document ID, etc.)

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SC4 Standards in practice

For each standard below, tick the column that best reflects how it is currently applied in your SC4 work. Tick one column per row.

Not aware, Acknowledged only, Referenced in design, Driving design decisions, Certification planned

ISO 26262 – Functional safety

ISO 21448 – SOTIF

ISO/SAE 21434 – Road vehicle cybersecurity

UNECE R155 – Cybersecurity management

UNECE R156 – Software update management

UNECE R157 – ALKS

ISO 34502 – Scenario-based safety evaluation

ISO 34503 – ODD taxonomy

UL 4600 – Autonomous product safety case

ETSI ITS-G5 / IEEE 1609.x – V2X

IEEE 2846 – ADS safety-related assumptions

IEEE 7001 – Transparency of autonomous systems

ISO 39003 – Ethics in road vehicles

--> Have you identified any additional standards, regulations or industry specifications relevant to your SC4 work that were NOT listed in D7.8?

If yes, please list and briefly state how they apply.

--> Since the architecture phase started, have NEW gaps emerged that were not captured in D7.8?

Please describe the most critical new gap(s).

--> Is your organisation currently a member of, or active in, a standardisation body or industrial initiative relevant to SC4?

If yes, please list the body, committee / working group, your role, and meeting frequency

--> Since M1 of Cynergy4MIE, have you made any contribution to a standardisation body or industrial initiative in the context of the project?

- Yes, please describe below
- No, but planned after M24
- No, and no plans yet

If yes: what, when, to whom, and reference (meeting minutes, document ID, etc.)

SC5 Standards in practice

For each standard below, tick the column that best reflects how it is currently applied in your SC5 work. Tick one column per row.

Not aware, Acknowledged only, Referenced in design, Driving design decisions, Certification planned

ISO/TC 292 – Security and resilience

IEEE RAS benchmarks (multi-robot)

ETSI ITS for emergency services

ISO 22320 – Emergency management

ISO/IEC 24028 – AI trustworthiness (TR)

IEEE 7001 / 7003 – Transparency / bias

IEC 60068 – Environmental testing

ISO 21384-3 – UAS operational procedures

--> Have you identified any additional standards, regulations or industry specifications relevant to your SC5 work that were NOT listed in D7.8?

If yes, please list and briefly state how they apply.

--> Since the architecture phase started, have NEW gaps emerged that were not captured in D7.8?

Please describe the most critical new gap(s).

--> Is your organisation currently a member of, or active in, a standardisation body or industrial initiative relevant to SC5?

If yes, please list the body, committee / working group, your role, and meeting frequency

--> Since M1 of Cynergy4MIE, have you made any contribution to a standardisation body or industrial initiative in the context of the project?

- Yes, please describe below
- No, but planned after M24
- No, and no plans yet

If yes: what, when, to whom, and reference (meeting minutes, document ID, etc.)

SC6 Standards in practice

For each standard below, tick the column that best reflects how it is currently applied in your SC6 work. Tick one column per row.

Not aware, Acknowledged only, Referenced in design, Driving design decisions, Certification planned

EN 14511 – Heat pump performance

IEC 62477-1 – Power electronic converters safety

IEEE 1547 – Distributed energy resource interconnection

ISO 15118 – V2G communication

ISO 50001 – Energy management

IEC 62443 – Industrial automation & control security

IEC TC 47 / JEDEC – WBG device reliability

ETSI SAREF – Smart appliances data model

--> Have you identified any additional standards, regulations or industry specifications relevant to your SC6 work that were NOT listed in D7.8?

If yes, please list and briefly state how they apply.

--> Since the architecture phase started, have NEW gaps emerged that were not captured in D7.8?

Please describe the most critical new gap(s).

--> Is your organisation currently a member of, or active in, a standardisation body or industrial initiative relevant to SC6?

If yes, please list the body, committee / working group, your role, and meeting frequency

--> Since M1 of Cynergy4MIE, have you made any contribution to a standardisation body or industrial initiative in the context of the project?

- Yes, please describe below
- No, but planned after M24
- No, and no plans yet

If yes: what, when, to whom, and reference (meeting minutes, document ID, etc.)

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Cross-SC collaboration and convergence

D7.8 identified four cross-cutting convergence issues (coverage gaps, HRC outside the factory, communication-stack divergence, fragmented component reliability). Joint contributions from partners across SCs are the strongest way to turn these into pre-normative outputs.

--> On which cross-cutting themes would you be interested in jointly contributing with partners from another SC? (tick all that apply)

- Vehicle-to-Grid (SC3 × SC4 × SC6)

- Human–Robot Collaboration outside the factory (SC1 × SC2 × SC5)

- AI / ML validation methods (all SCs, anchor SC4)
- Adverse-weather perception (SC1 × SC4)
- Simulation-based homologation (SC4 × SC5)
- Cross-domain cybersecurity patterns (SC3 × SC4 × SC6)
- Ethics, DEI and HITL accountability frameworks (all SCs)
- Explainability and audit-ready logging (SC2 × SC4 × SC6)
- Wide-bandgap semiconductor reliability (SC3 × SC6)

Would you be willing to co-author a joint position paper, dataset or draft clause on one of the themes of the above question?

If yes, please specify below

Are there specific Cynergy4MIE partners with whom you have already discussed, or would like to explore, a joint standards input?

Partner names and topic. WP7 will facilitate the pairing.