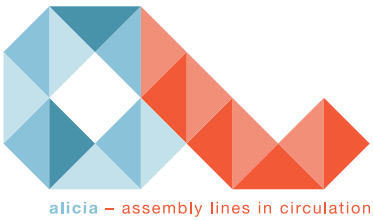

Assembly Lines In CIrculAtion – smart digital tools for the sustainable, human-centric and resilient use of production resources

D7.5

Standardization report (1st) - Revision

version 2.0

Project details

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0.3	01. December 2023	Comments from WP partners and consumers integrated; Reviewers: Nora Reinbold, German Bluvstein	in review
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1.1	07. February 2025	Revision according to the comments from the project reviewers	draft
1.2	15. February 2025	Comments from internal reviewers (YAGHMA)	in review
2.0	17. February 2025	Integration of comments from internal reviewers (YAGHMA) and final adjustments	final

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Revision comments

The present deliverable is a revision of D7.5 submitted in M12 of the project. Table 1 lists the comments submitted by the reviewers of the ALICIA project for D7.5 which led to the rejection of the previous version. Table 1 contains a brief response to these comments and the way in which these comments have been implemented in this version of D7.5. Since some of these review comments refer to results that were not yet available at the time of M12, this report no longer reflects only the results achieved in the standardization task up to M12 of the project, but goes beyond that.

Table 1: Overview of the review comments and the associated revision of this document

Number	Comment	Response and reference in revised D7.5
1	*The IEC 62443 standard has not been considered relevant both in the Industry Area and The Digitization one. Failing to apply effective cybersecurity controls in the design and implementation of critical infrastructures can lead to main Safety, Environmental and Security Issues. The NIS 2 directive moreover should be considered relevant to the project since ALICIA project focuses on bringing solutions to specific critical infrastructures. Moreover, the marketplace when reaching TRL9 will become a critical infrastructure itself.*	The standards of the IEC 62443 standard series are not explicitly used in ALICIA, as they are not directly related to the developed solution. The in-depth explanation can be found in subclause 4.6 - Application of standards in ALICIA and alignment with regulations (new)
2	*The standard IEC 62443 should be considered relevant both in the Industry Area and The Digitization one. Failing to apply effective cybersecurity controls in the design and implementation of critical infrastructures can lead to main Safety, Environmental and Security Issues.*	Cybersecurity measures are applied within ALICIA, even if these do not relate to the IEC 62443 series of standards. The in-depth explanation can be found in subclause 4.6 - Application of standards in ALICIA and alignment with regulations (new)
3	*While the documentation extensively explores the standardization landscape related to ALICIA, it primarily focuses on identifying and listing relevant standards. It fails to delve into the practical implications of these standards for the development and implementation of the CME. We suggest to include a section discussing how the identified standards will be effectively used in the ALICIA project. This could involve*	An overview of the standards used in ALICIA has been added in subclause 4.6 - Application of standards in ALICIA and alignment with regulations (new)

	describing how the standards will inform system design, ensure interoperability among different components, or facilitate data exchange within the CME.	
4	*The documentation presents a comprehensive list of potentially relevant standards but lacks a critical assessment of their suitability and potential limitations in the context of ALICIA. Some standards may be outdated, others may not fully align with the specific requirements of a CME, and some may overlap or even conflict with each other. We suggest to conduct a more in-depth analysis of the identified standards, evaluating their relevance, timeliness, alignment with ALICIA's objectives, and potential interoperability. Discuss any gaps or conflicts within existing standards and how ALICIA plans to address them."*	An overview of the standards used in ALICIA has been added in subclause 4.6 - Application of standards in ALICIA and alignment with regulations (new). In subclause 6.3 - Identification of standardization potentials (new) the standardization potentials identified by the ALICIA consortium are described, which were collected in a standardization potential workshop (clause 5 - Methodology: Standardization potential workshop – the basis for the standardization strategy in ALICIA (new)).
5	*Although the documentation acknowledges the importance of standardization for ALICIA's success, it does not thoroughly address potential challenges and obstacles in achieving widespread standardization within the CME. We suggest to include a section discussing the anticipated challenges in the standardization process, such as resistance to adopting new standards, the complexity of coordinating among different stakeholders, and the need to ensure the evolution and updating of standards over time.*	The first part of this comment is discussed in subclause 6.3 – Identification of standardization potentials. In subclause 2.4 - Challenges in the standardization process (new) the second part of the comment is considered.
6	*The documentation outlines some planned future steps, such as workshops and interactions with standardization committees. However, it lacks a comprehensive and detailed roadmap that outlines the planned standardization activities for the entire project duration.*	The standardization strategy for ALICIA has been included in clause 6 - Standardization strategy (new) providing an overview of the standardization activities already conducted and planned for the remaining project duration. The possible options to get active as a project in standardization are presented in subclause 2.6 - Getting involved in standardization (new).

7	*We suggest to develop a standardization roadmap specifying objectives, milestones, and concrete activities for each project phase. This roadmap should include participation in relevant standardization committees, development of new standards or specifications where necessary, and dissemination of standardization outcomes to a wider audience.*	The standardization strategy for ALICIA has been included in clause 6 - Standardization strategy (new) providing an overview of the standardization activities already conducted and planned for the remaining project duration.

Executive Summary (updated)

The present deliverable D7.5 is a revision of the version submitted at M12 of the ALICIA project which includes additional (sub)clauses based on the comments from the review. The deliverable presents the results achieved by February 2025 within Task 7.5 – Standardization activities, which goes on for the entire duration of the project.
Within this deliverable, the subtask of investigating relevant standards is covered. The knowledge about existing standards is important for the project since it enables the development of solutions which are compliant with the latest standards and further paves the way for upcoming liaison activities with relevant technical committees. This document provides a general summary of the basic knowledge on standardization in order to bring the consortium on a uniform level in this respect. Nevertheless, the focus of this deliverable is on the standardization landscape, which is relevant to the ALICIA project as well as the standardization strategy for the project.

In a first step, the methodology of the standards research conducted is described. With essential keywords provided by the consortium and defined areas, a search for standards with a strong link to ALICIA was conducted. International, European, and national (German) standards were included in the **standards overview** and shared with the project partners in the form of an excel file, a so-called **dashboard**. Besides providing a summary on relevant aspects regarding project related standards, the dashboard allows the consortium members to search for specific standards by using keywords and to identify standardization gaps. It is therefore used as the basis for the following activities in T7.5. Altogether 372 standards were included in this overview.

The dashboard was also used within this deliverable to provide an **overview of the standardization landscape** related to ALICIA. The different technical committees on international and European level, which are responsible for the development of the standards, are described. For particularly relevant topic areas related to ALICIA, possible relevant standards and technical committees (TC's) on European and international level are described. The ISO/TC 184 "Automation systems and integration" is of most interest to ALICIA, as 98 standards developed by the ISO/TC 184 are relevant to ALICIA and have been included in the dashboard.

A separate subsection lists the **standards used in ALICIA** and explains how they are applied in the development of the solutions. The alignment of the project with the applicable **regulations** is also explained.

All this information about standardization, standards, and TC's related to ALICIA is supposed to raise awareness within the consortium for the opportunities that standardization can provide for Research and Innovation (R&I) projects. This is the essential basis to develop a standardization strategy for ALICIA and to implement corresponding standardization activities (see Figure 1).

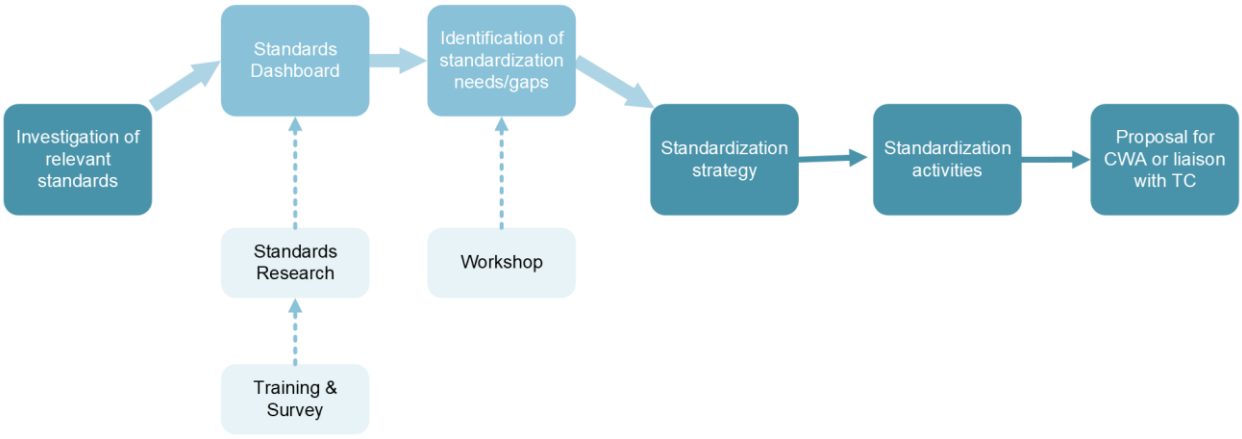


Figure 1: Overview of the subtasks of Task 7.5 – Standardization.

The **standardization strategy** for ALICIA is developed and explained within this deliverable by addressing the main points of this strategy: the interaction with standardization committees, the contribution to ongoing standardization activities and the identification of standardization potentials.

List of acronyms

Acronym	Description
AFNOR	Association française de normalisation (engl: French Standardization Association)
ANSI	American National Standards Institute
BSI	British Standards Institute, Federal Office for Information Security
CD	Committee draft
CEN	Comité Européen de Normalisation (engl: European Committee for Standardization)
CEN-CLC/JTC	CEN-CENELEC Joint Technical Committee
CENELEC	Comité Européen de Normalisation Électrotechnique (engl: European Committee for Electrotechnical Standardization)
CME	Circular manufacturing ecosystem
CWA	CEN Workshop Agreement
DfSS	Design for Six Sigma
DIN	Deutsches Institut für Normung e.V. (engl: German Institute for Standardization)
DIS	Draft international standard
DKE	Deutsche Kommission Elektrotechnik Elektronik Informationstechnik in DIN und VDE (engl: German Commission for Electrotechnical, Electronics, and Information Technologies of DIN and VDE)
EDC	Eclipse data space connector
EFTA	European Free Trade Association
EN standard	European standard
EU	European Union
FDIS	Final draft international standard
FMEA	Failure Mode and Effects Analysis
ICS	International Classification for Standards
IDSA	International Data Space Association
IDTA	Industrial Digital Twin Association e.V.
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IEEE SMC	Institute of Electrical and Electronics Engineers Systems, Man, and Cybernetics Society
ISO	International Organization for Standardization
ITU	International Telecommunication Union
IWA	International Workshop Agreement
JTC	Joint Technical Committee
NSB	National Standardization Body
OEM	Original equipment manufacturer
R&I	Research and Innovation
SC	Subcommittee
TC	Technical Committee
TR	Technical Report
TS	Technical Specification
UNE	Asociación Española de Normalización (engl: Spanish Association for Standardization)
VDA	Verband der Automobilindustrie e.V. (engl: Association of the Automotive Industry e.V.)
VDE	Verband der Elektrotechnik Elektronik Informationstechnik (engl: Association for Electrical, Electronic & Information Technologies)
VDI	Verein Deutscher Ingenieure (engl: Association of German Engineers)
VDMA	Verband Deutscher Maschinen- und Anlagenbau e.V. (engl: Association of German Mechanical and Plant Engineering)
WG	Working Group
WP	Work Package

1. Introduction

Standardization[1] is of great importance both at national and European level. Although European standardization activities are in the foreground of the EU-funded research project ALICIA, which is coordinated by Technische Universität München (TUM), international and relevant national standardization is presented, as a transnational harmonization of standardization documents is considered highly relevant and is the basis for the common economic area in the European Union.

ALICIA is about developing a circular manufacturing ecosystem (CME) of industrial production assets such as robotic arms and conveyor belts, which often not reach their maximum service life and become prematurely obsolescent. The machines are prematurely taken out of operation, scrapped, or at best sold for spare parts. The underlaying vision is that production resources will be traded between factories in Europe and reused to their maximum useful life. Thus, it is essential to ensure the applicability, trust, and conformity of ALICIA. Therefore, it is a necessity that ALICIA's solutions are compliant with standards, technical specifications, and procedures. This is a crucial aspect to guarantee that the developed solution is working properly, and the project results are trustworthy. For this reason, ALICIA has integrated standardization as an essential element of the project. Regarding the work structure of ALICIA (Figure 2), standardization is integrated in WP7, in task 7.5.

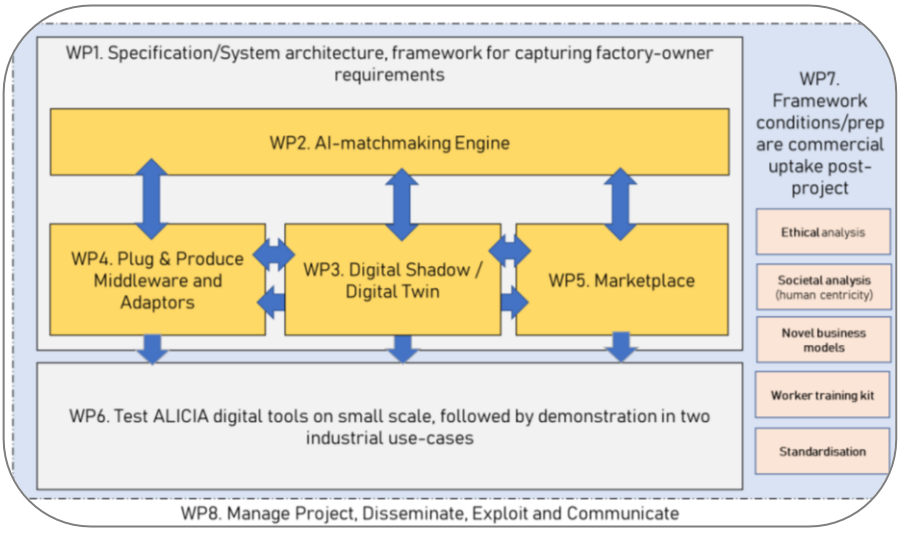


Figure 2: Working structure of the project ALICIA[2]

In WP7 – *Framework conditions/human-centered design for CME/prepare commercial uptake post-project* Task 7.5 – *Standardization* is integrated. One objective of this task is to create a well-grounded overview of the current standards and standardization documents as well as relevant technical committees on national, European, and international level related to ALICIA. This will provide an overview of the state of the art of the standardization landscape that is relevant for the project and thus ensure the compliance of the project's results with what is already on the market. The knowledge about existing standards is of importance for the consortium to align its products, processes, services, and solutions with the current state of the art. The identification of relevant technical committees is the basis for the direct transfer of ALICIA's results into ongoing standardization activities.

The present deliverable 7.5, belonging to Task 7.5, delivers an overview of the standardization landscape and highlights the most relevant standards for ALICIA as well as their impact and implication. Standards used within ALICIA and an explanation on how they are applied is given

[1] Standardization covers all types of standardization documents and is used here in a general manner.

[2] adapted from grant agreement project 101091577 – ALICIA

in this deliverable. Besides the necessity to know about ongoing standardization activities, this knowledge also provides the opportunity to raise awareness for standardization needs in this area. Therefore, this deliverable supports the activities in WP 8 – *Manage project, disseminate, exploit and communicate,* especially Task 8.4 – *Implement dissemination, exploitation and communication activities according to the DEC Plan and IPR management plan*. Within a conducted standardization potential workshop possible standardization needs were collected and further discussed.

In general, knowing about existing standardization documents makes it possible to build on existing knowledge and avoid unnecessary duplication of work. Additionally, existing gaps in standardization can be better identified and impulses for new standardization activities can be developed.

1.1. Document structure

In contrast to patents, knowledge about standardization is less pronounced, especially in the area of research and innovation. For this reason, the basic principles of standardization are presented in this report (see clause 2) as well as the different facets of standardization at national (subclause 2.2.1), European (subclause 2.2.2), and international level (subclause 2.2.3). Subsequently, the various types of standardization documents (subclause 2.3), the process for creating a CEN Workshop Agreement (CWA) (subclause 2.3.3), but also the challenges with regard to standardization (subclause 2.4) are presented. The function of standardization in the context of research projects (subclause 2.5) as well as how to get practical involved in standardization (subclause 2.6) are described. The results of the standardization research for ALICIA are presented by explaining the approach to the standards research (clause 3) and finally by giving an overview of the related standardization landscape (clause 4). Besides a general overview of the standardization landscape of ALICIA (clause 0), the relevant international (subclause 4.2), European (subclause 4.3), and national standardization activities (subclause 4.4) are examined. The standards highlighted as highly relevant for the project are focused on more closely (subclause 4.5). So-called consortial standards also have a strong relation to ALICIA (subclause 4.5.7) and therefore, the relation of selected consortial standards to ALICIA is described. Further, the applied standards within the ALICIA project are described in subclause 4.6. The conduction of the standardization potential workshop is described in clause 5, laying the foundation for clause 6, the standardization strategy.

2. Basics of standardization

The following chapter 2 gives an overview about the basics of standardization including the standard developing organizations, how standardization works, and an explanation of existing standardization documents.

2.1. General

Within ALICIA the standardization part can support the technology development in the context of circular economy also considering social, ethical and environmental aspects. Therefore, it is important to clarify the characteristics of a standard. *In general, a standard is a consensus-based document that is approved by a recognized body or organization, reflecting the state of the art. It should be based on the consolidated results of science, technology, and experience, and aim to promote optimal community benefits*.[3]

Standardization is used to agree on terminologies, methodologies, requirements, characteristics, etc. in specific areas to make a product, process, or service fit for its purpose. Thus, standardization can drive innovative outcomes by agreeing on common product requirements such as interoperability, quality or safety, and provide guidelines for achieving them. Standardization supports the development of a generic language, which is understandable for everyone and thus helps to create a common basis. The result of the standardization process is a document, which provides rules, guidelines or characteristics for activities or their results.

2.2. Standard developing organizations

An essential aspect of standardization is to ensure that standardization documents do not contradict each other, especially since European and international standardization have gained significant importance.This is reflected in DIN's statistics, which show that European and international standards account for 90% of all standardization projects nowadays. The following clauses give a brief description of the framework of formal standardization on international, European, and national level. Figure 3 provides an general overview of the different types and levels of standardization.

[3] ISO/IEC, „ISO/IEC Guide 2:2004: Standardization and related activities - General vocabulary," 2004

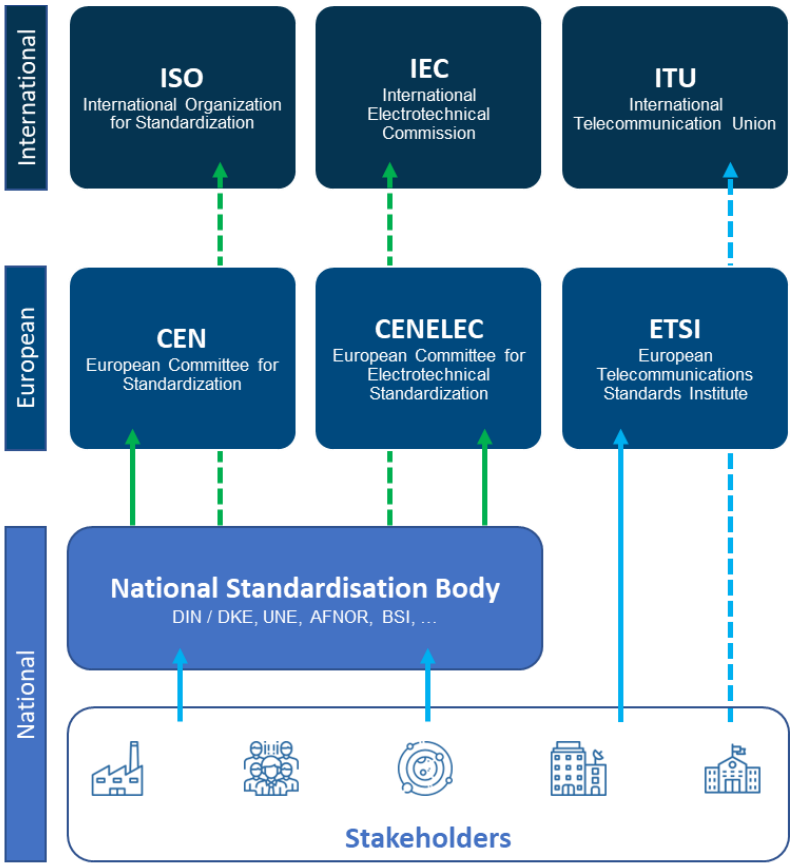


Figure 3: Overview of the organizational structure of the standardization world

2.2.1. National standardization

On national level, there are different structures and standardization bodies in different countries, e.g., German Institute for Standardization (DIN), German Commission for Electrotechnical, Electronic, and Information Technologies (DKE), Spanish standardization body (UNE), the French Standardization Association (AFNOR) and the British Standards Institute (BSI). In general, each country has one or more recognized national standardization bodies (NSB). Within the NSB's experts from different stakeholders, e.g., from organizations belonging to industry, commerce, the public sector, or research, are developing national standards. These NSB's are also responsible for keeping the national standardization repository updated.

To represent national positions at European or international level, so-called mirror-committees are set up and coordinated by the NSB's. In these national committees, the work and existing results of corresponding European and international standardization committees are discussed, a national opinion is developed, and the final drafts of standards are agreed upon. When European or international draft standards are published for comment, the mirror committees also vote on whether the standard should be published or not.

Here it is important to mention, that experts working on European or international level need to be members of the national mirror committee and must be delegated by these committees.

2.2.2. European standardization

The main goal of European standardization is the development of European standards, that are valid and accepted within the EU. These European standards are the basis for the European single market. The European standardization organizations CEN[4] (European Committee for Standardization), CENELEC[4] (European Committee for Electrotechnical Standardization), and ETSI (European Telecommunications Standards Institute) are responsible for the organization of European standardization work. CEN is responsible for all non-electronic activities and CENELEC

[4] https://www.cencenelec.eu/, last viewed on 28.11.2023

for electrotechnical standardization activities, while ETSI is responsible for the standardization activities in the field of telecommunication at European level.
There is a particularly close cooperation between CEN and CENELEC, which are made up of national standardization organizations from the EU and EFTA (European Free Trade Association) member states, as well as states seeking membership. In contrast, the members of ETSI are directly European companies, institutes, and organizations.
The so-called delegation principle applies to CEN and CENELEC. This means, that the mirror committees of the national standardization bodies of their member states, send national experts to the technical committees and workings groups at CEN or CENELEC to develop European standards. The European standard (EN) will only be published, when a sufficiently large majority of the national standardization organizations has approved the final draft.
European standards (EN) must automatically be adopted by member states of the EU and opposing national standards must be withdrawn. As a result of this mandatory adoption, the EN standards in Germany then become DIN EN standards (e.g., DIN EN 16575). There are situations in which it is possible to complement EN standards with additional national standards, for instance to set more detailed requirements to meet specific needs of the member state.
European specifications are referred to as CWA as well as CEN TS or CENELEC TS, depending on the type of development and their adoption by the member states is voluntary (e.g., DIN CEN/TS 17045), unlike the adoption of European Standards.

2.2.3. International standardization

The international standardization organization ISO[5] (International Organization for Standardization), IEC[6] (International Electrotechnical Commission), and ITU[7] (International Telecommunication Union) are responsible for the organization of international standardization work. ISO is responsible for all non-electronic and IEC for electrotechnical standardization activities, while the ITU is in charge of standardization activities in the field of telecommunications. ISO and IEC are made up of the national standardization organizations, with e.g., DIN and DKE representing German interests on an international level. The ITU, on the other hand, is a special unit of the United Nations, whose 191 member states develop recommendations together with companies from the private sector and other regional and national organizations. Only when they are adopted by normative organizations such as ISO, ANSI (USA) or ETSI as well as by national regulatory authorities, such as the Federal Network Agency in Germany, they acquire the character of standards.
The so-called delegation principle also applies to ISO and IEC, meaning that the national standardization organizations send their experts to the working groups and technical committees of the international standardization bodies. An international standard (ISO) is only accepted, when a sufficiently large majority of the national standardization organizations has voted for its draft. International specifications are called International Workshop Agreement (IWA) as well as ISO TS or IEC TS, depending on the type of development.
In contrast to European standardization, there is no obligation to adopt international standards in national standards. However, since internationally applicable standards are relevant for international trade or for global stakeholders, conflicting national or European standards should be avoided. There is the possibility of transferring international standards in European and national standards. The resulting documents have the characteristics and names listed in Table 2, depending on the background. There are also parallel processes for developing standards at international and European level. It is possible to directly develop EN ISO or EN IEC standards without first developing the standard on international level and then adopting it at European level.

[5] www.iso.org , last viewed on 28.11.2023
[6] https://www.iec.ch/, last viewed on 28.11.2023
[7] https://www.itu.int, last viewed on 28.11.2023

Table 2: Names of international standards depending on their adoption level

Name	Description
ISO XXXXX	International standard adopted on neither national nor European level
DIN ISO XXXXX	International standard adopted only on national (Germany) level
DIN EN ISO XXXXX	International standard adopted on European and national level

2.3. Standardization documents

2.3.1. General

There are several types of standardization documents that differ in their development process, the degree of consensus to be reached, and the openness to participation (Figure 4). Standardization documents describe products, systems or services by defining their characteristics and requirements and in many cases are publicly available. The fastest way to develop a standard is to develop consortial standards. However, the development process has the lowest degree of openess to participation. For the purpose of achieving a higher degree of consensus through the participation of all interested parties and developing a standardization document relatively quickly, specifications are suiteable. The highest level of consensus, but also the longest development time, is achieved by a standard. The different types of standardization documents are described in more detailed in the following subclauses.

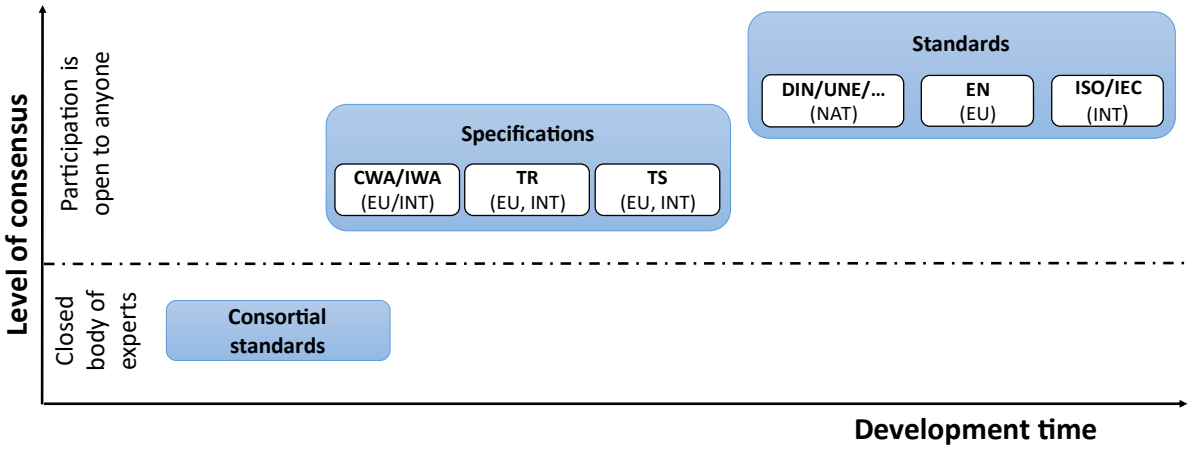


Figure 4: Types of standardization documents

2.3.2. Standard

According to Figure 4, **standards** in the narrower sense are developed within the formal standardization system where all interested parties have to be included in the development process of the document and consensus, meaning the general agreement of all participants and the lack of sustained objection to central content, must be reached. Therefore, a public commenting phase is mandatory in the development of standards. The main objective of the consensus is to take into account the views of all interested parties concerned and to dispel any counter-arguments. The development of a European standard is shown in Figure 5.

Figure 5: Development of a standard

First of all, anyone who has identified a need for a standard can submit a proposal for a new standard. In most cases this has to be done via the national mirror committee. The associated standards committee evaluates the need and whether standardization activities are already taking place or if standards that cover the described need exist. If the need is confirmed, a standard is then developed in a standardization committee. Attention is paid to a balanced composition of these committees with all interested parties concerned (science, consumers, industry, ...) in order to guarantee the neutrality of the documents. A final draft, approved by the standards committee, is then released for public comment. All comments have to be discussed before the final standard is approved by the standardization committee. Due to the high level of transparency and the involvement of the public, the development time increases from national to European and international level. National standards usually require 18 months to develop, while the development of European and international standards normally takes about three years due to the involvement of the national standardization bodies.[8] Due to the high degree of consensus, standards have a high level of acceptance in society.

2.3.3. Specification

To better understand the difference between the various standardization documents, the terms specification and standard are used. However, in many cases both documents will be called standards. In contrast to a standard developed in consensus, the standardization activities in research projects focus mainly on the development of **specifications**. Compared to a standard, consensus is not mandatory in specifications and the involvement of all interested parties is not obligatory. The development of a specification, e. g. CWA on European level, is shown in Figure 6.

[8] https://www.iso.org/developing-standards.html, last viewed on 28.11.2023

Figure 6: Development of a specification

Anyone can submit an application to develop a specification. The scope of the specification will be compared with the existing standardization repository. If no conflicting standards exist, the standardization organization publishes the business plan for public comment and a call for cooperation from interested organizations. In contrast to standards, specifications are created in workshops (temporary committee). A standardization organization acts as a secretary to ensure the procedural requirements and to support the members of the workshops in developing the specification. The workshop also decides whether a draft should be published for comment and once a specification has been successfully adopted by the workshop, the specification will be published.

There are different types of specifications. A Workshop Agreement on European (CEN/CENELEC Workshop Agreement, CWA) or international (International Workshop Agreement, IWA) level is developed in a temporary workshop, which is designed to meet an immediate need and forms the basis for future standardization activities lead by a national standardization body. Even if there are not as strict rules for developing a specification as there are for standards, it is important to ensure the coherence of the standardization regulations to protect the credibility of international, European, and national standardization. The workshop is open to direct participation by anyone who is interested in the development of the agreement but consensus is not required. The development of a Workshop Agreement is fast and flexible, on average between 10 and 12 months and therefore also attractive for research projects. Temporary workshops also develop national specifications, such as DIN SPECs (e.g., DIN SPEC 91392) in Germany.

Specifications can also be developed within standards committees if, for example , no final consensus can be reached. These documents are then referred to as CEN or ISO TS (Technical Specifications). A TS on European level may not conflict with a European standard but conflicting national standards may continue to exist. Technical Reports (TR) are consortial documents that are developed and approved by a technical committee. A TR provides information on technical content and standardization work.

2.3.4. Consortial standard

Regarding the development time, the fastest ones are **consortial standards** (see Figure 4), also called industry, informal or de-facto standards. Among other things, they are characterised by the fact that not all interested parties need to be included in the development process. These closed group of experts can be, e. g., industry-specific consortia that have been formed from different companies. Although these documents have some characteristics of a standardization document, such as defined procedures or documentation rules, consortial standards are often not freely accessible and are developed in private.

2.4. Challenges in the standardization process (new)

The standardization process is essential for ensuring compatibility, efficiency, and innovation across industries. However, while standards provide significant benefits, their development and implementation present several challenges that must be navigated effectively.

One of the key challenges in standardization is achieving widespread adoption. Since applying standards is generally voluntary, organizations must see a clear advantage in their implementation. While standards can enhance credibility and streamline operations, they may also require significant investments in new technologies or modifications to existing workflows. Balancing these costs with the long-term benefits can be a complex decision for many stakeholders.

The development of standards itself is another challenge. As described in subclause 2.3.2, the process is thorough and time-consuming, often taking around three years to ensure that the final document incorporates the latest validated knowledge. While this meticulous approach ensures high-quality outcomes, it can sometimes lag behind rapidly evolving innovations. In such cases, the development of specifications (see subclause 2.3.3) can provide a more flexible, interim solution that allows industries to keep pace with emerging technologies.

Maintaining the relevance of standards over time is also a crucial yet difficult task. While formal revisions typically occur every three years, technological advancements and shifting industry needs may demand more frequent updates. The process of reviewing and updating standards can be slow, leading to potential gaps between innovation and standard. Ensuring a dynamic, adaptable standardization framework is essential to mitigate this challenge.

Another fundamental difficulty lies in the consensus-driven nature of standardization. The process involves multiple stakeholders all of whom may have differing priorities and interests. Reaching agreements on technical specifications, implementation timelines, and compliance requirements can be time-consuming and, at times, contentious. Additionally, achieving consensus may sometimes lead to compromises, resulting in standards that provide broad guidance but lack detailed specificity.

Despite these challenges, standardization remains a important tool for fostering interoperability and technological progress.

2.5. Standardization in research projects

It is crucial for an R&I project to know the state of the art in the areas relevant for or connected to the project. Since standards reflect this state of the art in a specific area it is essential for R&I projects to have an overview of the standardization landscape related to the project. This knowledge enables the project to tailor its results or findings to current market requirements and helps ensure that they are interoperable with existing solutions. R&I projects need to consider the developments within other relevant activities. Irrespective of the technical merits of the R&I project developments, these efforts will be inconsequential if developed in isolation and the market decides to follow another path.
Furthermore, the knowledge about related standards also enables the R&I project to overcome additional challenges and go beyond the current state of the art. On the one hand, an overview of the related standardization landscape offers an R&I project the advantages described above. On the other hand, awareness is raised on where standardization is still needed. This opportunity can be used by the R&I project to implement project results in already ongoing standardization activities or by developing new standards/specifications from project results.
For ALICIA in particular, aspects of standardization play an important role. The European research framework program Horizon Europe addresses the topic of standardization in a series of calls for proposals.

2.6. Getting involved in standardization (new)

2.6.1. General

In the previous subclauses the different types of standardization documents as well as the standardization process on international, European and national level was described. This chapter describes the many ways to get involved in standardization especially for R&I projects like ALICIA.
To better understand the further descriptions, it is important to know how a standardization body is structured in general. The standardization work takes place in Technical Committees (TC's) which are technical decision-making bodies with a title, a scope, and a work program. It manages the preparation of standardization documents in accordance with the agreed business plan. To ensure a high value of standards, the TCs are composed of experts belonging to different interested groups, so called working groups (WG's) (Figure 7).[9]

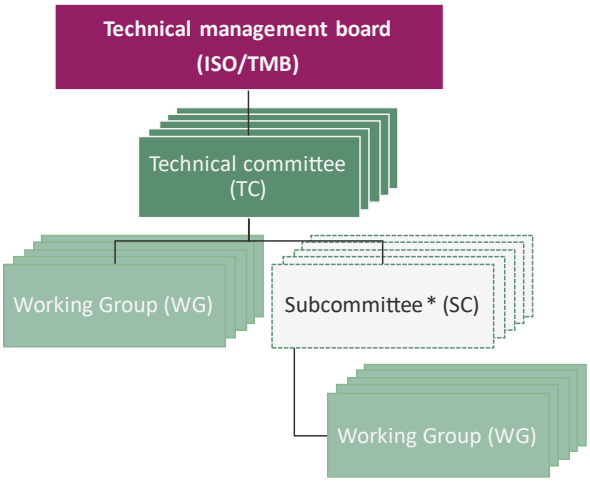


*Figure 7: Structure of a standardization body (example within ISO). *Subcommittees are not always part of the structure.*

The structure of a TC on national or European level is similar to that on international level. Any expert is welcome to apply for a seat in a national TC. The applications will be examined, depending on the composition, the number of experts already present in the relevant TC, and the regulations of the national standards body.
Experts, who are members of national TC's, have the chance to participate in European and international standardization. They are sent as national delegates to European or international TC's to represent the national interests within a standardization project.
The different options to participate in the standardization process are illustrated in Figure 8.

Usually, the general way to participate in standardization starts at the national level, where everyone can join the national standardization committee to participate as an expert directly in the work.[10]
People from outside those TCs have the opportunity to propose new standardization topics to the national standards body or comment on public draft standards. This is a quite powerful possibility, as the responsible committee has to discuss every comment. Every person who made a comment also can join the meeting to discuss the comment in person.

[9] https://boss.cen.eu/technicalstructures/pages/tcwg/
[10] https://www.din.de/en/getting-involved

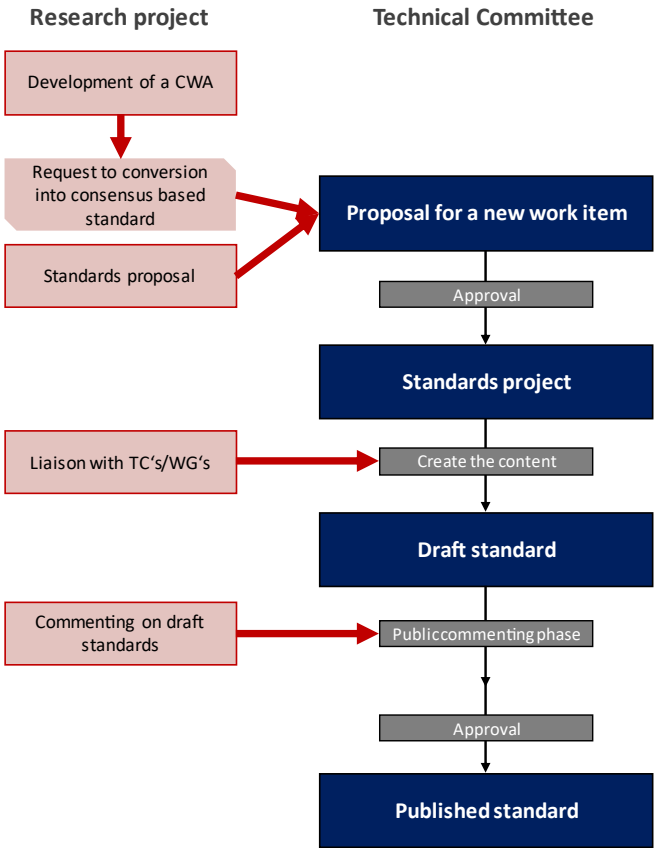


Figure 8: Options to participate in the standardization process.

European associations and research projects have the option to participate directly at the European and international level through liaisons with TC's. Besides proposing new work items, the initiation of CEN/CENELEC Workshop Agreements (CWA's) is suitable to address quick standardization needs.[11] The choice of how to participate in standardization and which instrument to use depends strongly on the individual case. The different options which are suitable for R&I projects are presented in the following focusing on those at European level.

2.6.2. Proposing a New Work Item

General procedure

On European level new standardization documents like European Standards (EN), CEN Technical Specifications (CEN/TS) or CEN Technical Reports (CEN/TR) that are developed within CEN Technical Committees (CEN/TC) are usually initiated by a New Work Item Proposal (NWIP),[12] which is commonly proposed by a TC or a corresponding WG. The experts within the WG recommend the NWIP to the TC for balloting, and the TC then decides on how to proceed.
The Committee Internal Balloting (CIB) is subsequently started; it constitutes an enquiry with all CEN member states. Each member state has one vote on whether to proceed with the NWIP or not, and they vote according to the outcome of their respective national enquiry. The national experts can leave comments and information about deviating national regulations that should be taken into account and they can volunteer to participate in the work on the European Level if the NWIP is accepted. The TC then determines the outcome of the CIB. Other entities that can propose a NWI are the EC or EFTA Secretariat, international organizations or European trade, professional, technical or scientific organizations or national standardization bodies of CEN member states. A common misinterpretation is that any person or organization can propose a NWI at European level. The usual way is to propose the work envisaged at national level to the

[11] https://boss.cen.eu/developingdeliverables/cwa/pages/
[12] https://boss.cen.eu/startingnewwork/pages/propnewwork/pages/

national standardization body which then considers whether this work should possibly be carried out at the European level.
When proposing a new work item, it is highly advisable to deliver a first draft of the envisaged document in order to convince fellow members of a working group to actively collaborate on the topic as well. Once the NWIP is accepted, there is a rather strict time frame to be followed, and the time to the next steps, such as the enquiry, is limited. Within European research projects, a NWIP could be a potential deliverable to start new standardization work that uses the results of the project.
The technical committee evaluates the need and checks whether standardization activities are already taking place or if standards already exist. If there is an interest within the committee and no standards are established yet, the committee can then initiate the development of the new standard. If the committee decides to develop the document, the drafting phase starts within the relevant WG of the responsible TC. If there is not yet a WG where the topic thematically fits, a new WG could be established within the TC.
On international level the process is similar.

International harmonized stage codes for standards

All standards are labelled with stage codes indicating their progress of work. The different stage codes can be seen in Figure 9 and in more detail in Annex 4.[13]

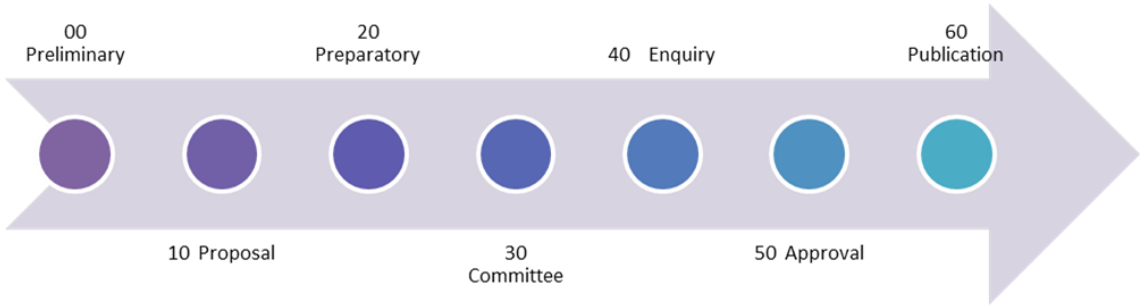


Figure 9: International harmonized stage codes for standards.

The series of codes starts with the code 00.00 *Preliminary*, which means that the proposal of the new project has been received. When the project is registered, it is given the code 10.00 *Proposal*. If the committee decides to follow up the project, the *Preparatory phase* starts (20.00) and the document (called working draft – WD) is developed.
A WD is established and commented on within the WG only. When the WG approves the WD, the next phase starts. In this stage (30.00 *Committee*) the TC is involved, and the document is called *committee draft* - CD. If the CD is approved by the members of the TC, the next phase (40.00 *Enquiry*) starts. At the end of this phase the international document is registered as DIS (draft International Standard) and the European document as prEN (draft European Standard).
The DIS / prEN is released for a commenting period, which involves the public. All received comments need to be discussed in the working group. The finished standard is then either published by consensus (stage 60.00 *Publication*) or, if technical changes need to be considered, reaches stage 50.00 *Approval* and is registered as FDIS (international) or FprEN (European). After the approval, the document will then be published by consensus (stage 60.00 *Publication*).

2.6.3. Development of CEN/CENELEC Workshop Agreements

A CEN (or CENELEC for electrotechnical topics) Workshop Agreement (CWA)[11] is a standardization document that is developed and approved outside the TC structure in a temporary CEN or CENELEC Workshop to meet an immediate need. The development of Workshop Agreements can be used as a quick standardization tool on the European level for EU-funded

[13] https://www.iso.org/stage-codes.html

research projects. These Workshop Agreements can be initiated out of an R&I project and can be created and published within the timeframe of the project.
The nature and the procedure of a CWA development is described in the CEN-CENELEC Guide 29. In general, the process can be divided into different phases starting from the *proposal phase*, followed by a *drafting phase* in which the manuscript will be written; a *development phase* in which the workshop members further discuss and improve the manuscript; an optional *commenting phase* (mandatory if the CWA deals with safety aspects) allowing the public to give comments on the script and finally the *publication phase*. An overview of the main steps of the process can be seen in Figure 10.

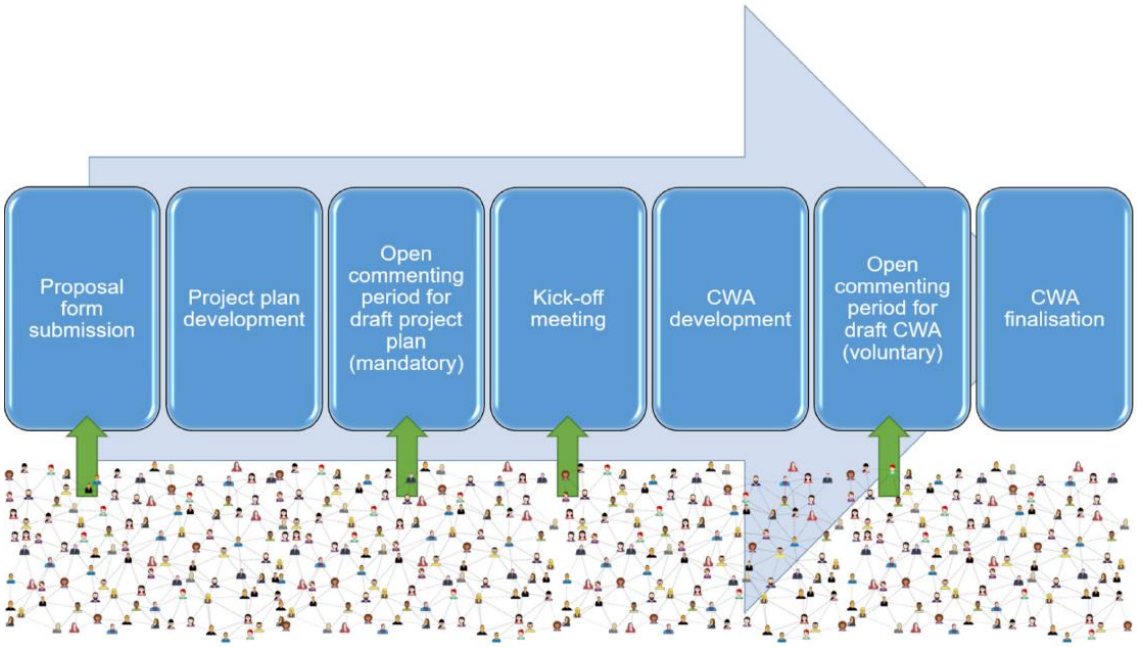


Figure 10: CWA development process.[14]

The development of a CWA starts with the *proposal phase*. Anyone can submit a proposal for a new CWA to either CEN, CENELEC or the national standardization body. During this phase, the initiator of a proposed idea and the standardization body work together on the formal initiation of the standardization project. The initiator provides information on the idea allowing the standardization body to check if there are existing standards or standardization activities on this topic that would permit the development of a CWA. A CWA is not allowed to conflict with standards. If there is a standardization gap that can be filled with the proposed idea, the next step can be initiated.
A project plan needs to be set up by the proposers with the help of a standardization body. The project plan aims to inform the public about the idea, thus the project plan is published for 30 days. The project plan includes the background to the proposed workshop, the motivation for the creation of the workshop, and information on the market and legal environment, including a list of existing standards and standard-related activities and documents. Information regarding the workshop proposers and workshop participants with a short description of their background is also included. The scope shall be set and should be very clear, providing an overview of what is within the scope of the document and what is excluded. Furthermore, the target group of the CWA should be mentioned. The working plan and schedule should be presented, also including the work that has already been delivered. Other sections refer to the workshop structure, resource requirements, related activities and liaisons, usually filled in by the proposed secretary of the workshop. Furthermore, it is important to set up a date and venue where the kick-off meeting is about to take place to ensure the possibility of direct participation of anyone with an interest.
The project plan is sent to CCMC together with the agenda of the kick-off meeting and is published by CEN or CENELEC for comments. All the inputs received will be addressed during the kick-off meeting. If the proposed topic touches a scope of a European standardization committee, the technical body shall be consulted on the CWA proposal.

[14] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.cencenelec.eu/media/Guides/CEN-CLC/cenclcguide29.pdf

The kick-off meeting shall take place after the end of the first commenting phase. During the kick-off meeting, the workshop chair is appointed and the project plan is approved by the workshop participants. With the approval of the project plan, each participant of the kick-off meeting, who voted in favour of the project plan, becomes a member of the workshop and the *drafting phase* starts. The workshop committee is then responsible for the development of the document. If, during the initiation phase, the workshop has decided that a *public consultation* should be done, the draft version of the CWA is published for 30 days. A commenting phase for 60 days is mandatory if the CWA includes safety matters. In case of a public commenting phase, each of the comments received must then be discussed in the workshop. The consortium does not have to take into account the feedback of the general public, but they can, if they want to. When agreement on the technical content of the CWA is reached, the document is published and all organizations that approve the CWA will be listed in the European foreword.
The CWA is a specification and therefore does not have the same character as a European or international standard. Thus, this standardization document brings no obligation to be adopted at national level contrary to European standards. A CWA can be used to support the market and is ideal for R&I projects because of its short development time which allows the creation and publication of the document within the project duration. The timeframe for the creation of a CWA is about 6 to 12 month and the lifetime is restricted to six years. After three years the participants of the workshop have to decide if the document is reconfirmed for another three years, revised, proposed for an upgrade into a EN or ISO standard or withdrawn. After six years the document has to be withdrawn or transformed into another standardization deliverable. Since a CWA can be used as the basis for the preparation of a full standard, it may be a first step to an ISO or EN standard. That is why it has the character of a "pre-standard".

2.6.4. Liaisons

Without being delegated from the national standardization committee to European or international technical committees, there is the possibility for organizations, forums and consortia to establish a liaison with TC's and WG's.
On European level according to CEN/CENELEC Guide 25[15] a liaison can be established for interested groups which are committed to provide input to the work of a technical body. Therefore, the liaison organization is expected to provide high quality, added-value expertise in a defined technical field. For a R&I project such a fee-based liaison can be established on European level to a TC and its corresponding WG's for the project duration. The liaison enables to access all committee documents that have been circulated via a document exchange system and the attendance of meetings of the TC including its WG's. A liaison provides insight into the work programme of the TC and its WG's. This can help to get an impression of the future standardization landscape of a specific topic and can also support identify standardization gaps. A liaison further provides the possibility to get into contact with the experts working in this field and expanding the network.

In the framework of a liaison with a CEN/TC accompanying rights are:

- Access of the working documents associated with the TC including its WG's
- Possibility to propose technical documents
- Possibility to introduce preparatory work as a support to ongoing standardization activities
- Possibility to submit technical contributions to the body's meetings
- Possibility to formulate advice on current and future standards programmes
- Participation in TC's as observers
- Participation in WG's as experts
- No voting rights

On international level a liaison can also be established if the organization meets the following eligibility criteria:

- not-for-profit;
- legal entity (for category A / B liaisons);

[15] https://www.cencenelec.eu/media/Guides/CEN-CLC/cenclcguide25.pdf

- membership-based and open to members worldwide or over a broad region (for category A / B liaisons);
- having competence and expertise to contribute to the development of international standards or the authority to promote their implementation;
- having a process for stakeholder engagement and consensus decision-making to develop the input it provides.

A liaison on international level[16] is free of charge and there are different categories of liaisons: A, B and C. The liaison categories including purpose, participation as well as rights and obligations are summarized in Figure 11.[17]

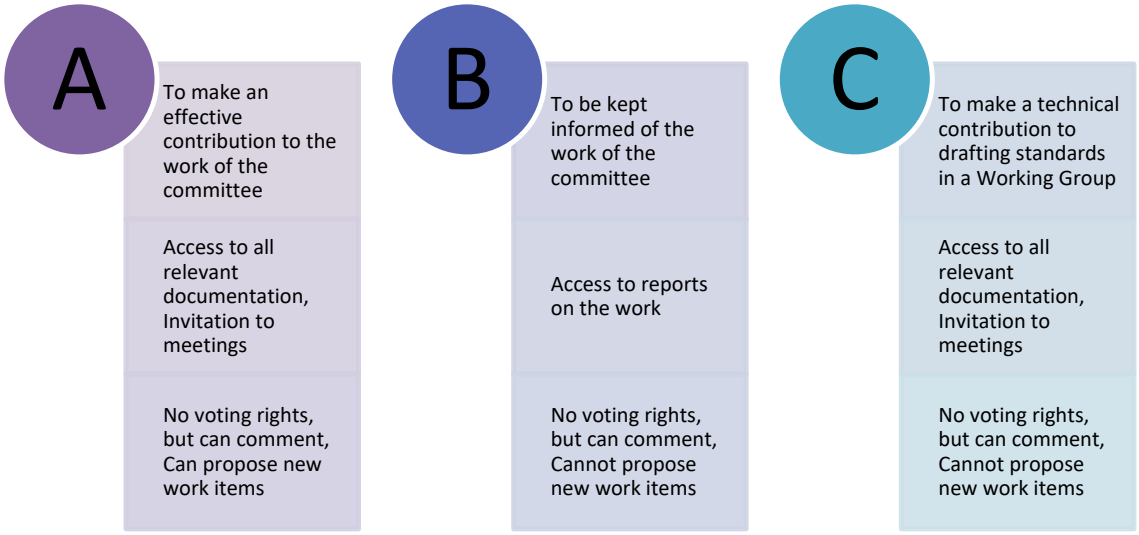


Figure 11: ISO/IEC liaison categories.

For categories A and B there is a critical need to assess the above-mentioned eligibility as these liaisons take place on TC level. Therefore, R&I projects mostly appear at WG level as category C liaisons. Category C enables the R&I project to be informed about ongoing standardization activities by getting access to all relevant documents and to be invited to working group meetings. Further, the project can make technical contributions to the draft standards established within the working group.
For R&I projects the possibility to comment on draft standards offers the opportunity to include project results and content into standards and therefore supports the long-term dissemination of the project results.

Contribution to existing Standards

Everyone can comment on standards when their draft version is published. A draft version of a standard is published when either a new standard is developed, or an old standard is revised. This is an essential part of the standardization process since it provides the opportunity to collect comments by every interested party.
At the latest every five years, each standard needs to be reviewed regarding its current relevance and actuality. If the standardization committee decides to revise a standard its draft gets published for commenting – for national (German) standards it is two months, for a European standard and an international standard it is three months. Within this framework, the European standard is understood as an EN standard developed by technical committees from CEN or CENELEC and the international standard is understood as an ISO or IEC standard developed by the technical committees of ISO and IEC.
Comments are always provided to the national standardization committee, which mirrors the European or international committee in the corresponding country. The corresponding national

[16] https://www.iso.org/files/live/sites/isoorg/files/archive/pdf/en/guidance_liaison-organizations.pdf
[17] https://www.iso.org/files/live/sites/isoorg/files/store/en/PUB100447.pdf

committee decides which comments they see as relevant for the standard, and in case of European or international standards, they pass those comments to the European or international committee, where they get discussed again.
A contribution to existing activities and standards should especially be made, if:

- an existing standard or draft standard is inaccurate,
- a standard is hindering innovation, and/or
- standards contradict each other.

The responsible CEN/TC has to be contacted immediately, if a standard hinders innovation or if standards contradict each other. In case of an inaccurate standard, a research project or organization could improve the standard by taking part in the public commenting phase of the draft document. The CEN and ISO search websites can be used to identify such draft documents in the public commenting phase. An organization or research project then has to fill out the commenting form and send it to a national standardization body that can forward it to the respective CEN/TC before the end of deadline. The standardization committee must discuss each comment. Nevertheless, the standardization committee decides whether they accept or reject received comments.

3. Methodology: How the ALICIA standardization landscape was developed

This clause describes how the standardization landscape relevant for ALICIA was developed. A standardization landscape for a specific topic provides an overview of the existing standards relevant and related to the defined topic(s). Such an overview of the standardization landscape should raise awareness among the project partners on what already exists on the market and prevents them from re-inventing the wheel. Further, the standardization landscape provides the basis for further standardization activities of the project. The approach to developing a standardization landscape is shown in Figure 12.

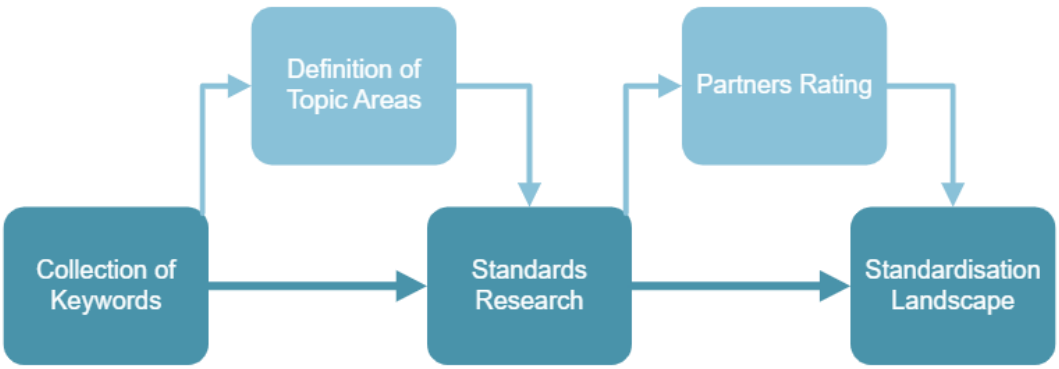


Figure 12: Steps for the development of a standardization landscape within ALICIA

As a first step Keywords with relation to the different tasks within ALICIA are collected from the partners. They were grouped into broader topic areas and used in a second step for the standards research. The standards which came up during this research were rated by the project partners with regard to their relevance for their work within ALICIA. Those relevant standards constitute the standardization landscape for ALICIA. Those steps are described in more detail in the following subclauses.

3.1. Training “Basics on Standardization”

In order to gain a sufficient basis for the upcoming standardization tasks within the consortium, a training “basics in standardization” was performed at the beginning of the project. Within this training the following points were addressed:

- *Why are standards important for Research and Innovation projects?*
- *What are the results of standardization?*
- *How are standards and specifications developed?*
- *How can ALICIA participate in standardization and how can the results of the project/project results be disseminated?*

13 people from six different organizations participated in the training “basics on standardization”. The presentation was made available to the entire consortium on the online project platform and can be found in annex 1.

3.2. Survey on partners’ expertise regarding standardization and keyword collection

The basis for providing a standardization landscape for the consortium is the standards research where all standards relevant to the project are collected. The first step to performing this standards research was to get an overview of the partners' knowledge, activities, and expectations regarding standardization within ALICIA. In this context, a survey was conducted, where the partners were asked to answer questions about their expertise on standardization. 13 people from 7 different partner organizations participated in the survey. The questions and the corresponding answers are listed in annex 2.
A small part of the project consortium is already familiar with standardization. Three people from three different organizations have been or are currently active in standardization, and one person has already participated in the development of a pre-standardization document such as a CWA. Within the ALICIA project, nine people are applying or planning to apply standards as part of their activities within ALICIA, including digitalization, industrial interoperability, and manufacturing systems, etc. In particular, quality management standards, such as ISO 14040 or ISO 9001, as well as standards related to the design of manufacturing systems and safety of machinery are of interest for ALICIA and are already known or used within ALICIA.
The survey showed that some partners already are aware of areas with standardization gaps. This involves circular manufacturing, the connectivity of machines and the exchange of data between machines, the architecture of manufacturing systems and digitalization of production systems, as well as standards for the re-use of equipment, among other things to increase trust and acceptance for the sector of buying and selling used machinery.

In order to provide the consortium with an overview of already existing standards and standards under development in the areas relevant for ALICIA, a standards research was conducted. For this reason, keywords were collected from the project partners as part of the survey described above. The partners were asked for which specific areas/topics they would like to get an overview of the existing standards, which led to the identification of five relevant topics: *Circular Economy, Digitalization/IT, Industry, Automation, and Other*. The keywords were matched to the identified topics and are listed in Table 3. The keywords were used to identify standardization documents and other TC’s related to ALICIA. They were also used to search for existing standards (standards research), using the standards data base Nautos[18]. To identify further standards of interest, the standards research was extended to modifications and alternatives to the keywords provided by the partners.

Table 3: Supplied keywords by ALICIA partners and added keywords by DIN (*).

Topic: Circular Economy	
Circularity	Environmental Product Declaration
Circular Economy	Environmental management
Circular manufacturing	LCA / LCA assessments
Circular manufacturing ecosystems	Social LCA

[18] https://nautos.de/, last viewed on 27.11.2023

Sustainability for manufacturing/sustainable manufacturing	Second use*
Sustainable business models	Used goods / used machines*
Product Environmental Footprint	
Topic: Digitalization/IT	
Digital tools for manufacturing	Digitalization of production systems
Digital tools in automation	Industrial digital twin
Digital tools	digital product passport
Digitalisation / digitalization	Digital platform activities
Industrial IoT	Digital platform*
Architecture	IT security
Machine connectivity	
Topic: Industry	
Machine communication	GS1 standards: (RAMI 4.0)
Industry 4.0	Standardized ways to specify worker skills
industrial data spaces	Operator safety standards
Industrial Interoperability	Mechanical Design
Manufacturing systems architecture(s)	Equipment health assessment*
Middleware(s)	Controls Design
Assembly process(es)	Retrofit/retrofitting*
Assembly resources	
Topic: Automation	
Automation	
Topic: Quality management	
Quality management	
Topic: Others	
Ethical (assessment)	Artificial intelligence

3.3. Standards research

For the standards research, mainly the search engine Nautos was used to find formal standards. The database includes national standards as well as standards from the European organizations CEN, CENELEC, ETSI, and international organizations such as ISO, IEC, and ITU. Technical documents and reports on these levels have been considered for the analysis. In case of national standards, it should be noted that due to language barriers mostly those providing at least one English title have been considered. Since one third of the project partners comes from German organizations and Germany is a pioneer in the automotive industry, the standards research focused on German standards in the context of national standards. If required, other national standards can also be searched for. All the hits from the Nautos search, using the different keywords, resulted in a list of 2304 standards.

Besides the keywords used for the Nautos research, the project partners also mentioned organizations that are not standardization bodies or developing consortial standards. These are listed in the subclause 4.5.7.

An analysis and assessment of the standards relevant and important to ALICIA was conducted by the consortium. The identification of these standards was done by filtering the list of standards by keywords relevant for the specific areas and an individual evaluation based on the title as well as the abstract of the standards. Based on their expertise, at least two partners were chosen to evaluate the preliminary list of standards relevant to their topic of expertise. The standards were rated according to their relevance and partners could choose between the following criteria:

relevant, not relevant, already used within ALICIA. This way 373 formal standards were highlighted as relevant for ALICIA. The following table shows the number of relevant standards per topic.

Table 4: List of number of relevant standards per topic before and after partners rating

Topic	Number of standards after standards research	Number of standards after partner's rating
Circular Economy	340	57
Digitalization	559	56
Industry	479	111
Automation	860	89
Quality Management	56	24
Others	10	4

These standards represent the first overview of the standardization landscape for ALICIA and were therefore shared with the partners of the consortium in the form of a dashboard (Figure 13). All standards are listed in a complete list in annex 3.
An initial version of the dashboard with all relevant standards was provided in September 2023. The dashboard is an Excel template, which was developed specifically for the research of standards and provides an overview of the main information regarding the relevant standards. It can be used to search for specific standards by keywords or to get an overview of the standards within a specific ICS (International Classification for Standards) field or developed by a specific technical committee. The ICS is intended to serve as a structure for catalogues of international, regional, and national standards and other normative documents, and as a basis for standing-order systems for international, regional, and national standards.[19] This dashboard was shared within the whole ALICIA consortium. An explanation of how standards of interest can be identified using this dashboard was given in a virtual standardization session at the end of September 2023. Nine partners from seven different organizations participated in this meeting. Furthermore, for each topic identified using the keywords, a list of standards was provided. These lists were sorted from highest to lowest, counting the number of keywords found in the standards.

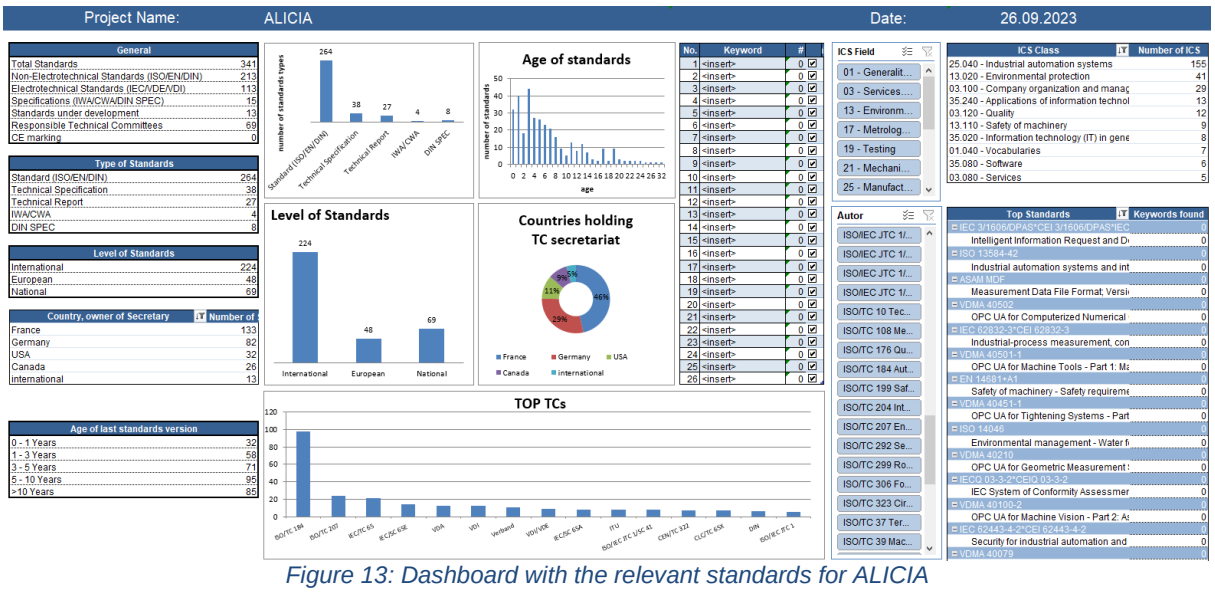


Figure 13: Dashboard with the relevant standards for ALICIA

Since the development of standards does not stand still, the dashboard will be updated annually.

19 International Classification for Standards, 2015; Available at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.iso.org/files/live/sites/isoorg/files/archive/pdf/en/international_classification_for_standards.pdf, last viewed on 24.11.2023

4. Overview of the ALICIA standardization landscape

This section gives an overview of the standardization landscape related to ALICIA. Besides providing a general overview of standards which could be relevant for ALICIA, relevant standardization committees that are active in the fields interesting for ALICIA are also given. As a basis for this analysis the dashboard described in subclause 3.3 was used.

4.1. General

The dashboard is used to provide some general information on standards that might be relevant to ALICIA. The origin of the documents included in the ALICIA dashboard is visualized in Figure 14. The majority (66%) of standards were developed on international level, whereas around 14% originated on European level, and 20% on national level. ALICIA is a European research project and therefore individual national standards are of secondary importance for the first overview of the standardization landscape. Figure 15 breaks down the types of the standardization documents listed. 77% of the documents included in the dashboard are standards in the narrower sense (see subclause 2.3.2) like ISO- / EN- or national standards, whereas the rest are specifications. Nearly 47% of the documents were published within the last 5 years.

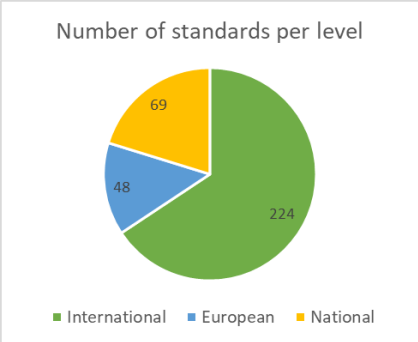


Figure 14: Level of standards.

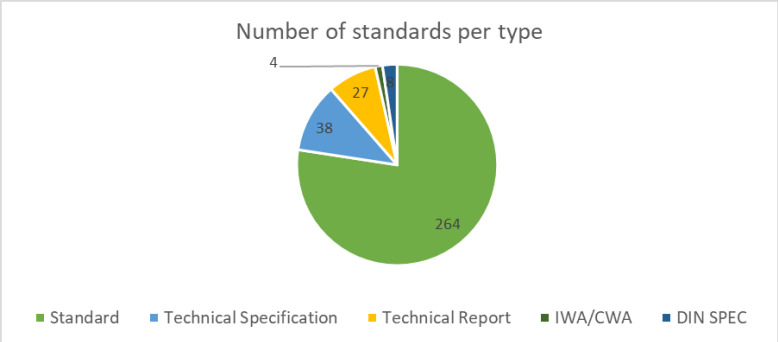


Figure 15: Type of standardization documents.

The standards related to ALICIA cover a wide range of different areas. Based on the International Classification for Standards (ICS) fields, an overview of the different areas can be given (Table 5). For this overview only ICS fields which are assigned to at least 50 standards are listed in Table 5.

Table 5: Overview of the number of standards in the different ICS fields.

	ICS field	Number of standards
25 - Manufacturing Engineering	*25.040 – Industrial automation systems*	162
	25.120 – Chipless working equipment	6
	25.060 – Machine tool systems	3
	25.080 – Machine tools	3
	25.030 – Additive manufacturing	2
	25.020 – Manufacturing forming processes	2
	25.140 – Hand-held tools	1
	25.160 – Welding, brazing and soldering	1
	25.180 – Industrial furnaces	1
35 – Information technology	*35.240 – Applications of information technology*	109
	35.020 – Information technology (IT) in general	13
	35.030 – IT Security	9
	35.200 – Interface and interconnection equipment	8

	ICS field	Number of standards
	35.080 – Software	7
	35.100 – Open systems interconnection (OSI)	6
	35.040 – Information coding	2
	35.160 – Microprocessor systems	2
	35.060 – Languages used in information technology	2
	35.210 – Cloud computing	1
	35.180 – IT-terminal and other peripheral equipment	1
13 – Environment. Health protection. Safety	*13.020 – Environmental protection*	66
	13.110 – Safety of machinery	11
	13.180 – Ergonomics	6
	13.030 – Wastes	4
	13.220 – Protection against fire	1

The standards are part of 19 different ICS fields, with ICS field 25, ICS field 35, ICS field 13, and ICS field 03 being the most present ones. It is important to keep in mind that one standard can be part of several different ICS fields. 53% of the standards included in the ALICIA dashboard are classified within ICS field 25 – *Manufacturing Engineering*. Nearly the same amount (47%) of standards is included in ICS field 35 – *Information technology*. The third largest amount of standards are part of ICS field 13 – *Environment. Health protection. Safety* (26%).

4.2. Standardization activities on international level

Of the standards that could be relevant for ALICIA, 224 documents at international level were included in the ALICIA dashboard. The main technical committees, which are responsible for these standards, are listed in Table 6 and are described in the following. Only TC's that published more than five standards of the ones included in the dashboard are listed and described below. In addition, relevant standards under development are listed below.

Table 6: Relevant standard setting organizations and TC's on international level.

TC	Title
ISO/TC 184	Automation systems and integration
ISO/TC 207	Environmental management
IEC/TC 65	Industrial-process measurement, control and automation
IEC/TC/SC 65A	System aspects
IEC/TC/SC 65E	Devices and integration in enterprise systems
ISO/IEC JTC 1	Information technology
ITU	International Telecommunication Union (ITU)

4.2.1. ISO/TC 184

The scope of this TC is standardization in the field of automation systems and their integration for design sources, manufacturing, production and delivery, support, maintenance and disposal of products and their associated services. Areas include information systems, automation and control systems, and integration technologies. The ISO/TC 184 will actively collaborate with the relevant technical committees responsible for areas such as machines, manufacturing resources and facilities, robotics, electrical and electronic equipment, PLC for general application, quality

management, industrial safety, information technologies, multi-media capabilities, and multi-modal communication networks.[20] The secretariat of this TC is held by AFNOR, the French standardization body.
The TC 184 is divided into three subcommittees (SC) and seven working groups (WG). The most relevant SC for ALICIA are listed in the following:

- *ISO/TC 184/SC 1: Industrial cyber and physical device control*
- *ISO/TC 184/SC 4: Industrial Data*
- *ISO/TC 184/SC 5: Interoperability, integration, and architectures for enterprise systems and automation applications*
- *ISO/TC 184/AG 2: Digital Twin*
- *ISO/TC 184/AHG 2: Environmental criteria*
- *ISO/TC 184/JWG 21: Smart Manufacturing Reference Model(s) linked to ISO/TC 184*
- *ISO/TC 184/WG 6: Asset intensive industry interoperability*

This TC has published 891 ISO standards so far and is currently working on 99 ISO standards. In the following, the most relevant standards on which the TC and relevant SC are currently working on are listed with their respective stage code below. The stage codes describe the working status of a standardization document. The meaning of each stage code can be found in annex 4. Table 7 shows standards under development from the ISO/TC 184.

Table 7: Standards under development from the ISO/TC 184.

Document number	Title	Stage code
IEC/CD TR 63319	A meta-modelling analysis approach to smart manufacturing reference models	30.99
IEC/FDIS 63339	Unified reference model for smart manufacturing	50.20

In the SC 1 one document is currently under development (see Table 8).

Table 8: Standards under development from the ISO/TC 184/SC1 - Industrial cyber and physical device control.

Document number	Title	Stage code
ISO/AWI 23704-4	Reference Model for Cyber-Physically Controlled Smart Machine Tool Systems (CPSMT) — Part 4: Part 4: Requirements and guidelines for implementing reference architecture of CPSMT for subtractive manufacturing	20.20

Table 9 shows the documents under development from the ISO/TC 184/SC 4.

Table 9: Standards under development from the ISO/TC 184/SC 4 - Industrial Data.

Document number	Title	Stage code
ISO/AWI 8000-1	Data quality – Part 1: Overview	20.00
ISO/AWI 8000-114	Data quality – Part 114: Master data: Application of ISO/IEC 21778 and ISO 8000-115 to portable data	40.60
ISO/AWI 8000-118	Data quality — Part 118: Application of ISO 8000-115 to natural location identifiers	30.99
ISO/AWI 8000-200	Data quality — Part 200: Transaction data: Quality of transaction data	20.00
ISO/AWI 8000-210	Data quality — Part 210: Part 210: Sensor data: Data quality characteristics	30.60
ISO/AWI 8000-220	Data quality — Part 220: Sensor data: Quality measurement	20.00
ISO/DPAS 8329	xMCF — Description and data standard for connection and joining data in structural systems	50.00

[20] https://www.iso.org/committee/54110.html, last viewed on 09.10.2023

Document number	Title	Stage code
ISO/PRF 10303-1	Industrial automation systems and integration — Product data representation and exchange — Part 1: Overview and fundamental principles	50.00
ISO/FDIS 10303-2	Industrial automation systems and integration — Product data representation and exchange — Part 2: Vocabulary	50.00
ISO/CD TS 10303-15	Industrial automation systems and integration — Product data representation and exchange — Part 15: Description methods: SysML XMI to XSD transformation	30.99
ISO/DIS 10303-239	Industrial automation systems and integration — Product data representation and exchange — Part 239: Application protocol: Product life cycle support (PLCS)	40.20
ISO/CD TS 10303-439	Industrial automation systems and integration — Product data representation and exchange — Part 439: Application module: AP239 product life cycle support	30.99
ISO/CD TS 10303-1251	Industrial automation systems and integration — Product data representation and exchange — Part 1251: Application module: Interface	30.99
ISO/CD TS 10303-1253	Industrial automation systems and integration — Product data representation and exchange — Part 1253: Application module: Condition	30.99
ISO/CD TS 10303-1254	Industrial automation systems and integration — Product data representation and exchange — Part 1254: Application module: Condition evaluation	30.99
ISO/CD TS 10303-1348	Industrial automation systems and integration — Product data representation and exchange — Part 1348: Application module: Requirement management	30.99
ISO/CD TR 17999	Reference model for industrial data	30.92
ISO/AWI 23247-5	Automation systems and integration — Digital twin framework for manufacturing — Part 5: Part 5: Digital thread for digital twin	20.00
ISO/AWI 23247-6	Automation systems and integration — Digital twin framework for manufacturing — Part 6: Part 6: Digital twin composition	20.00

Table 10 shows the standards under development from ISO/TC 184/SC 5.

Table 10: Standards under development from the ISO/TC 184/SC 5: Interoperability, integration, and architectures for enterprise systems and automation applications.

Document number	Title	Stage code
ISO/PRF 16400-2	Automation systems and integration - Equipment behavior catalogues for virtual production system - Part 2: Formal description of catalogue template	50.20
ISO/DIS 16400-3	Automation systems and integration - Equipment behavior catalogues for virtual production system - Part 3: Guideline for construction of equipment instance model	40.99
ISO/PRF 19450	Automation systems and integration - Object-Process Methodology	50.20
ISO/DIS 20140-5	Automation systems and integration — Evaluating energy efficiency and other factors of manufacturing systems that influence the environment — Part 5: Environmental performance evaluation data	40.60
ISO/AWI 20850	Supply chain interoperability and integration — Part 210: Strategic sourcing concepts, principles, and data requirements	20.00
ISO/AWI 21175-1	Automation systems and integration --Collaboration Environment Requirements of Simulation on Different Manufacturing Platforms — Part 1: Part 1: Reference Model and Process	20.00

Document number	Title	Stage code
ISO/AWI 22400-1	Automation systems and integration — Key performance indicators (KPIs) for manufacturing operations management — Part 1: Overview, concepts and terminology	10.99
ISO/AWI 22400-2	Automation systems and integration — Key performance indicators (KPIs) for manufacturing operations management — Part 2: Definitions and descriptions	30.00

4.2.2. ISO/TC 207

The scope of the ISO/TC 207 is to address environmental and climate impacts, including related social and economic aspects, in support of sustainable development. TC 207 is focused on environmental management systems, auditing, verification/validation and related investigations, environmental labelling, environmental performance evaluation, life cycle assessment, climate change and its mitigation and adaptation, ecodesign, material efficiency, environmental economics and environmental and climate finance. Where appropriate, the ISO/TC 207 works in cooperation with existing committees on subjects that may support environmental management.[21] The secretariat is held by the Standards Council of Canada. The ISO/TC 207 is divided into six sub committees and seven working groups. The sub committees most relevant for ALICIA are listed below:

- *ISO/TC 207/SC 1: Environmental management systems*
- *ISO/TC 207/SC 5: Life cycle assessment*
- *ISO/TC 207/SC 7: Greenhouse gas and climate change management and related activities*

The ISO/TC 207 has published 67 ISO standards so far and currently works on 19 ISO standards. The following standards are currently under development and could be of interest for the project. Table 11 shows the standards under development from ISO/TC 207/SC 1.

Table 11: Standards under development from the ISO/TC 207/SC 1 – Environmental management systems

Document number	Title	Stage code
ISO 14002-4	Environmental management systems — Guidelines for using ISO 14001 to address environmental aspects and conditions within an environmental topic area — Part 4: Part 4: Resources and waste	20.20

The following standards in
Table 12 are currently under development from ISO/TC 207/SC5.

Table 12: Standards under development from the ISO/TC 207/SC 5 – Life cycle assessment

Document number	Title	Stage code
ISO/DIS 14071	Environmental management — Life cycle assessment — Critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006	40.00
ISO/DIS 14072	Environmental management — Life cycle assessment — Requirements and guidelines for organizational life cycle assessment	40.00
ISO/DIS 14075	Environmental management — Principles and framework for social life cycle assessment	40.00
ISO/WD TS 14076	Eco-Technoeconomic Analyses: Principles, requirements and guidelines	20.60

[21] https://www.iso.org/committee/54808.html, last viewed on 09.10.2023

Table 13 shows the standards under development from ISO/TC 207/SC 7.

Table 13: Standards under development from the ISO/TC 207/SC 7 - Greenhouse gas and climate change management and related activities

Document number	Title	Stage code
ISO 14002-4	Environmental management systems — Guidelines for using ISO 14001 to address environmental aspects and conditions within an environmental topic area — Part 4: Part 4: Resources and waste	20.20
ISO/DIS 59014	Environmental management and circular economy — Sustainability and traceability of secondary materials recovery — Principles and requirements	40.00

4.2.3. IEC/TC 65

IEC/TC 65 deals with the preparation of international standards for systems and elements used for industrial process measurement, control and automation in order to coordinate standardization activities which affect integration of components and functions into such systems including safety and security aspects.[22]I The secretariat is held by AFNOR. The technical committee is divided into four subcommittees and eleven working groups as well as four joint working groups with other technical committees. The following committees could be relevant for ALICIA:

- *IEC/SC 65A: System aspects*
- *IEC/SC 65E: Devices and integration in enterprise systems*
- *IEC/TC 65/WG 16: Digital factory*
- *IEC/TC 65/WG 19: Life-cycle management for systems and products used in industrial-process measurement, control and automation*
- *IEC/TC 65/WG 23: Smart Manufacturing Framework and Concepts for industrial-process measurement, control and automation*
- *IEC/TC 65/WG 24: Asset Administration Shell for Industrial Applications*

The IEC/TC 65 has published 49 IEC standards so far and currently works on 20 IEC standards.

The Subcommittee 65A is part of IEC/TC 65 and deals with System aspects, especially generic aspects of systems used in industrial process measurement, control and manufacturing automation. The committee is led by the United Kingdom and is divided into seven working groups.[23]
The following working groups could be of interest:

- *IEC/TC 65/SC 65A/WG 16: Evaluation of systems properties for the purpose of system assessment*
- *IEC/TC 65/SC 65A/WG 19: Human Machine Interfaces for Process Automation Systems*
- *IEC/TC 65/SC 65A/WG 21: Artificial intelligence – Functional Safety and AI systems – Requirements*

The following standards in Table 14 are currently under development and could be of interest for the project:

Table 14: Standards under development from the IEC/TC 65/SC 65A – systems aspects

Document number	Title	Subcommittee
IEC 63303 ED1	Human-Machine Interfaced for Process Automation Systems	SC 65A/WG 19

[22] https://www.iec.ch/dyn/www/f?p=103:7:0::::FSP_ORG_ID,FSP_LANG_ID:1250,25, last viewed on 09.10.2023
[23] https://www.iec.ch/dyn/www/f?p=103:7:0::::FSP_ORG_ID,FSP_LANG_ID:1369,25, last viewed on 09.10.2023

ISO/IEC TS 63521 ED1	Artificial intelligence – Functional Safety and AI systems - Requirements	SC 65A/WG 21

Another Subcommittee of IEC/TC 65 of interest is the SC 65E. It deals with devices and integration in enterprise systems and is led by the United Stated of America.[24] There are ten working groups within this subcommittees. The following are the interesting ones:

- *IEC/TC 65/SC 65E/WG 4: Field device tool interface specification*
- *IEC/TC 65/SC 65A/WG 7: FB for process control, EDDL and FDI*
- *IEC/TC 65/SC 65A/WG 8: OPC*
- *IEC/TC 65/SC 65A/WG 9: AutomationML – Engineering Data Exchange Format*
- *IEC/TC 65/SC 65A/WG 12: Predictive Maintenance*

The following standards in Table 15 are currently under development and could be of interest for the project:

Table 15: Standards under development from the IEC/TC 65/SC 65E – devices and integration in enterprise systems

Document number	Title	Subcommittee
IEC 62453 series (part 2, 42, 43, 51-20, 52-31, 52-90, 53-31, 53-90, 71, 302)	Field device tool (FDT) interface specification	SC 65E/WG 4
IEC 62541 series (part 1-24, 100)	OPC Unified Architecture	SC 65E/WG 8
IEC 62714-6 ED1	Engineering data exchange format for use in industrial automation systems engineering - Automation Markup Language - Part 6: AutomationML Components	SC 65E/WG 9
IEC 63270 ED1	Industrial automation equipment and systems - Predictive maintenance	SC 65E/WG 12

4.2.4. ISO/IEC JTC 1

Another relevant technical committee is the ISO/IEC Joint Technical Committee 1 (JTC 1), which deals with the standardization in the field of information technology. The ISO/IEC JTC 1 is divided into 23 subcommittees and 16 working groups.[25]
The most interesting subcommittee within is the ISO/IEC JTC 1 is the SC 41 with the title “Internet of things and digital twin”. This committee deals with Standardization in the area of Internet of Things and Digital Twin, including their related technologies.[26] This group provides guidance to JTC 1, IEC, ISO and other entities developing Internet of Things and Digital Twin related applications. The secretariat is held by the Korean Agency for Technology and Standards.[27] The technical committee is divided into five working groups. The most interesting ones for ALICIA are the following:

- *ISO/IEC JTC 1/SC 41/WG 3: IoT Architecture*
- *ISO/IEC JTC 1/SC 41/WG 4: IoT Interoperability*
- *ISO/IEC JTC/SC 41/WG 5: IoT Applications*
- *ISO/IEC JTC/SC 41/WG 6: Digital twin*

This ISO/IEC JTC1/SC 41 has published 43 ISO standards so far and currently works on 3 ISO standards. The standards shown in Table 16 are currently under development:

[24] https://www.iec.ch/dyn/www/f?p=103:7:408336511942763::::FSP_ORG_ID,FSP_LANG_ID:1452,25, last viewed on 09.10.2023
[25] https://www.iso.org/committee/45020.html, last viewed on 09.10.2023
[26] https://www.iec.ch/dyn/www/f?p=103:7:0::::FSP_ORG_ID:20486, last viewed on 09.10.2023
[27] https://www.iso.org/committee/6483279.html, last viewed on 09.10.2023

Table 16: Standards under development from ISO/IEC JTC 1/SC 41

Document number	Title	Stage code
ISO/IEC AWI 30149	Internet of things (IoT) – Trustworthiness framework	10.99
ISO/IEC AWI 30172	Digital Twin – Use cases	10.99
IS/IEC AWI 30371	Digital Twin – Concepts and terminology	20.00

4.2.5. ITU

The ITU is the International Telecommunication Unit, which deals with technical aspects in terms of telecommunication. There are eleven study groups, which carry out the standardization work.[28] Eight standards were identified as relevant for ALICIA. The following study groups could be of interest for ALICIA:

- *SG5 - EMF, environment, climate action, sustainable digitalization, and circular economy*

ITU-T Study Group 5 (SG5) is the leading study group on electromagnetic fields (EMF), environment, climate action, sustainable digitalization, and the circular economy. The international standards (ITU-T Recommendations) and related texts developed by SG5 provide guidance and specifications for the safe and sustainable use of information and communication technology (ICT), including ICT products (e.g., mobile phones), equipment (e.g., adaptors, cables) and installation (e.g., small base stations, data centers).[29]

- *ITU-T SG20: Internet of things (IoT) and smart cities and communities (SC&C)*

ITU-T Study Group 20 (SG20) develops international standards (ITU-T Recommendations) providing commonly agreed guidance for implementing the Internet of Things (IoT) and its applications, as well as smart cities and communities. Its work supports digital transformation in both urban and rural areas enabled by solutions in fields such as IoT, digital twins, and artificial intelligence. Standards developed by SG20 enable the coordinated deployment of IoT and address IoT implementation challenges related to interoperability, big data, and architectural frameworks and requirements for supporting various IoT systems.[30]

4.3. Standardization activities on European level

Of the standards that could be relevant for ALICIA, 48 documents at European level were included in the ALICIA dashboard. The main technical committees, which are responsible for these standards, are listed in Table 17 and are described in the following. Only TCs that published more than five standards of the ones included in the dashboard, are listed and described below. In addition, relevant standards under development are listed below.

Table 17: Relevant standard setting organizations and TC's on European level.

TC	Title
CEN/TC 322	Equipment for making and shaping of metals – safety requirements
CLC/TC 65X	Industrial-process measurement, control and automation

[28] https://www.itu.int/en/ITU-T/studygroups/2022-2024/Pages/default.aspx, last viewed on 09.10.2023

[29] https://www.itu.int/en/ITU-T/studygroups/2022-2024/05/Pages/default.aspx, last viewed on 09.10.2023

[30] https://www.itu.int/en/ITU-T/about/groups/2022-2024/Pages/sg20.aspx, last viewed on 09.10.2023

4.3.1. CEN/TC 322

This CEN/TC deals with standardization topics in the field of safety of equipment for making of iron, steel and non-ferrous metals and their shaping by rolling, forging, and extruding as semi-finished or finished products.[31] The committee is divided into five working groups and is coordinated by DIN. This TC has published 12 European standards so far, however, currently there are no activities ongoing.

4.3.2. CLC/TC 65X

This TC supports, contributes, and coordinates the preparation of international standards for systems and elements used for industrial process measurement, control and automation at CENELEC level. Especially this TC deals with the integration of components and functions into such systems, including safety and security aspects. The work of the committee is closely coordinated with the IEC TC65 and its subcommittees.[32]
The committee is divided into four working groups and is coordinated by DKE.
The most relevant working group is listed in the following:

- *CLC/TC 65X/WG 02: Smart manufacturing*

CLC/TC 65X has published 506 European standards so far and currently works on 90 CENELEC standards. 89 documents of these are planned as a European adoption of international IEC documents.

4.4. Standardization activities on national level

Of the standards that could be relevant for ALICIA, 69 documents at German national level were included in the ALICIA dashboard. TC's that published more than five standards of the ones included in the dashboard, are listed and described below.

- *VDA Quality Management Center*
- *VDI Society Production and Logistics*
- *Verband Deutscher Maschinen- und Anlagenbau e.V.*
- *VDI/VDE Society Measurement and Automation*

4.4.1. VDA Quality Management Center

The Quality Management Centre (QMC) in German Association of the Automotive Industry e.V. (VDA) is dedicated to the development of methods and systems of quality management systems for the automotive industry. All car manufacturers producing in Germany as well as a representative selection of automotive suppliers are represented in the QMA by their QM management and the VDA by its management.[33]

4.4.2. VDI Society Production and Logistics

The association of German Engineers (VDI) supports engineers by creating a standardized basis and developing national standards that are practice-oriented and technical. They publish up to 250 VDI-guidelines per year.[34]

4.4.3. Association of German Mechanical and Plant Engineering

The Association of German Mechanical and Plant Engineering (VDMA) is the largest network

[31] https://standards.cencenelec.eu/dyn/www/f?p=205:7:0:::FSP_ORG_ID:6303&cs=1BAAF3815BC2B20CFBF731F31B904BF67, last viewed on 09.10.2023

[32] https://standards.cencenelec.eu/dyn/www/f?p=305:7:0:25:::FSP_ORG_ID,FSP_LANG_ID:1257871, last viewed on 09.10.2023

[33] https://vda-qmc.de/en/ueber-uns/gremien/, last viewed on 10.10.2023

[34] https://www.vdi.de/en/home, last viewed on 10.10.2023

organization and supports the machinery and equipment manufacturing industry in Germany and Europe. The association represents the common economic, technical, and scientific interests of this industry.[35] Through the DIN Mechanical Engineering Standards Committee (NAM), the VDMA promotes the competitiveness of the mechanical engineering industry. This Standards Committee could be of interest for ALICIA. In addition, the Standardization Department coordinates the preparation of VDMA specifications.[36]

4.4.4. VDI/VDE Society Measurement and Automation Control

Measurement and automation technology is effective in reducing the power requirements of electronic devices as well as in the measurement and control optimization of large chemical plants. The group of the Association for Electrical, Electronic & Information Technologies (VDE) deals with topics such as manufacturing or energy technology, environmental plants, traffic systems, building automation or medical technology.[37] The group is active in developing rules and regulations as well as national standards.

4.5. Standards related to ALICIA

In this section an overview is given about the most important standards (top 25) for the identified and most relevant areas of the project. The top 25 standards contain the most keywords per area either in the abstract, title, or search terms. The list of all relevant standards can be found in annex 3. In addition, the responsible technical committee of each standard is listed. In the upcoming month, the ALICIA partners will be asked which standards they use for their work in the project. If there are standards that they would like to use but do not have access, DIN will make them available.

4.5.1. Area “Circular Economy”

Circular economy is a highly innovative topic and awareness regarding sustainability is increasing constantly. As the project is part of the call “CLIMATE NEUTRAL, CIRCULAR AND DIGITISED PRODUCTION 2022” and the topic “Digital tools to support the engineering of a Circular Economy” within the Horizon Europe Framework Program, part of the ALICIA standardization landscape should address circular economy.
There are a lot of new standards in the field of circular economy, especially from the year 2023. Table 18 lists the most relevant standards for ALICIA. All relevant standards in the field of circular economy can be found in appendix 3.

Table 18: List of top 25 standards relevant in the area of “circular economy”, cells marked in blue represent standards under development.

Document number	Title	Publication date	Author
ISO 14007	Environmental management - Guidelines for determining environmental costs and benefits	2019-10-00	ISO/TC 207
ISO 14009	Environmental management systems - Guidelines for incorporating material circulation in design and development	2020-12-00	ISO/TC 207
ISO/TS 14027	Environmental labels and declarations - Development of product category rules	2017-04-00	ISO/TC 207
ISO 14045	Environmental management - Eco-efficiency assessment of product systems - Principles, requirements and guidelines	2012-05-00	ISO/TC 207

[35] https://www.vdma.org/association, last viewed on 10.10.2023
[36] https://www.vdma.org/technical-rules-standards, last viewed on 10.10.2023
[37] https://www.vdi.de/tg-fachgesellschaften/vdi-gesellschaft-mess-und-automatisierungstechnik, last viewed on 10.10.2023

Document number	Title	Publication date	Author
ISO 14046	Environmental management - Water footprint - Principles, requirements and guidelines	2014-08-00	ISO/TC 207
ISO/TR 14047	Environmental management - Life cycle assessment - Illustrative examples on how to apply ISO 14044 to impact assessment situations	2012-06-00	ISO/TC 207
ISO/TR 14049	Environmental management - Life cycle assessment - Illustrative examples on how to apply ISO 14044 to goal and scope definition and inventory analysis	2012-06-00	ISO/TC 207
ISO/TS 14072	Environmental management - Life cycle assessment - Requirements and guidelines for organizational life cycle assessment	2014-12-00	ISO/TC 207
ISO/TS 14074	Environmental management - Life cycle assessment - Principles, requirements and guidelines for normalization, weighting and interpretation	2022-11-00	ISO/TC 207
ISO 20140-1	Automation systems and integration - Evaluating energy efficiency and other factors of manufacturing systems that influence the environment - Part 1: Overview and general principles	2019-09-00	ISO/TC 184
ISO 20140-2	Automation systems and integration - Evaluating energy efficiency and other factors of manufacturing systems that influence the environment - Part 2: Environmental performance evaluation process	2018-08-00	ISO/TC 184
ISO 20140-5	Automation systems and integration - Evaluating energy efficiency and other factors of manufacturing systems that influence the environment - Part 5: Environmental performance evaluation data	2017-04-00	ISO/TC 184
ISO 26000	Guidance on social responsibility	2010-11-00	ISO/TMBG Technical Management Board - Groups
ISO/DIS 59004	Circular Economy - Terminology, Principles and Guidance for Implementation	2023-04-00	ISO/TC 323
ISO/DIS 59020	Circular economy - Measuring and assessing circularity	2023-04-00	ISO/TC 323
ITU-T L.1022	Circular economy: Definitions and concepts for material efficiency for information and communication technology	2019-10-00	ITU International Telecommunication Union
ITU-T L.1023	Assessment method for circular scoring	2020-09-00	ITU International Telecommunication Union
prEN IEC 63366	Product category rules for life cycle assessment of electrical and electronic products and systems.	2023-03-00	CLC/TC 111X
EN 50693	Product category rules for life cycle assessments of electronic and electrical products and systems	2019-08-00	CLC/TC 111X
CWA 17807	Dismantling methods and protocols in a Circular Economy Framework - Composite recovery in the automotive industry	2021-10-00	CEN European Committee for Standardization
VDI 4431	Life-cycle management in the manufacturing industry	2001-07-00	VDI Society Energy and Environment
DIN SPEC 91472	Remanufacturing (Reman) - Quality classification for circular processes	2023-06-00	DIN SPEC (PAS, CWA)

4.5.2. Area “Industry”

In the field of “industry” a lot of relevant standards for ALICIA exist.
Table 19 lists the most relevant standards for ALICIA in the industry context. All relevant standards in the field of industry can be found in the annex 3.

Table 19: List of top 25 standards relevant in the area of “industry”.

Document number	Title	Publication date	Author
ISO 12100	Safety of machinery - General principles for design - Risk assessment and risk reduction	2010-11-00	ISO/TC 199
ISO 16100-3	Industrial automation systems and integration - Manufacturing software capability profiling for interoperability - Part 3: Interface services, protocols and capability templates	2005-12-00	ISO/TC 184
ISO 16100-5	Industrial automation systems and integration - Manufacturing software capability profiling for interoperability - Part 5: Methodology for profile matching using multiple capability class structures	2009-03-00	ISO/TC 184
ISO 16300-1	Automation systems and integration - Interoperability of capability units for manufacturing application solutions - Part 1: Interoperability criteria of capability units per application requirements	2018-10-00	ISO/TC 184
ISO 16300-3	Automation systems and integration - Interoperability of capability units for manufacturing application solutions - Part 3: Verification and validation of interoperability among capability units	2017-10-00	ISO/TC 184
ISO 16156	Machine-tools safety - Safety requirements for the design and construction of work holding chucks	2004-02-00	ISO/TC 39
ISO 17916	Safety of thermal cutting machines	2016-03-00	ISO/TC 44
ISO/TR 18161	Automation systems and integration - Applications integration approach using information exchange requirements modelling and software capability profiling	2013-07-00	ISO/TC 184
ISO/IEC TS 33073	Information technology - Process assessment - Process capability assessment model for quality management	2017-11-00	ISO/IEC JTC 1/SC 7
IEC 62541-7	OPC unified architecture - Part 7: Profiles	2020-06-00	IEC/SC 65E
EN 614-1+A1	Safety of machinery - Ergonomic design principles - Part 1: Terminology and general principles	2009-02-00	CEN/TC 122
CEN ISO/TR 22100-1	Safety of machinery - Relationship with ISO 12100 - Part 1: How ISO 12100 relates to type-B and type-C standards (ISO/TR 22100-1:2021)	2021-02-00	CEN/TC 114
EN 1550+A1	Machine-tools safety - Safety requirements for the design and construction of work holding chucks	2008-07-00	CEN/TC 143
EN 14656+A1	Safety of machinery - Safety requirements for extrusion presses for steel and non-ferrous metals	2010-04-00	CEN/TC 322
EN 14677	Safety of machinery - Secondary steelmaking - Machinery and equipment for treatment of liquid steel	2008-04-00	CEN/TC 322
EN 14681+A1	Safety of machinery - Safety requirements for machinery and equipment for production of steel by electric arc furnaces	2010-04-00	CEN/TC 322

Document number	Title	Publication date	Author
EN 16774	Safety of machinery - Safety requirements for steel converter and associated equipment	2016-04-00	CEN/TC 322
CWA 17907	European Connected Factory Platform for Agile Manufacturing Interoperability (EFPFInterOp)	2022-11-00	CEN European Committee for Standardization
DIN EN 60204-33	Safety of machinery - Electrical equipment of machines - Part 33: Requirements for semiconductor fabrication equipment (IEC 60204-33:2009, modified); German version EN 60204-33:2011	2011-11-00	German Commission for Electrical, Electronic and Information Technologies of DIN and VDE
DIN SPEC 16589	Information technology - Automatic identification and data capture techniques - Traceability Pointer to Process	2018-07-00	Information Technology and selected IT Applications Standards Committee
VDI/VDE 2193 Blatt 1	Language for I4.0 Components - Structure of messages	2020-04-00	VDI/VDE Society
VDI/VDE 2193 Blatt 2	Language for I4.0 components - Interaction protocol for bidding procedures	2020-01-00	VDI/VDE Society
VDI 3405 Blatt 6.2	Additive manufacturing processes - User safety on operating the manufacturing facilities - Laser sintering of polymers	2021-04-00	VDI Society Production and Logistics
VDI/VDE 3850 Blatt 3	Development of usable user interfaces for technical plants - Features, design and applications of user interfaces with touchscreen	2015-11-00	VDI/VDE Society Measurement and Automation
VDI 4499 Blatt 4	Digital factory - Ergonomic representation of humans in the digital factory	2015-03-00	VDI Society Production and Logistics

4.5.3. Area “Automation”

Automation is the biggest field within ALICIA, with 187 standards identified as relevant. As for this area of standards no further keywords were given, no further restrictions could be made. For this reason, it was not possible to list the most important standards (top 25) as was done for the other areas. The full list can be found in appendix 3.

4.5.4. Area “Digitalization”

In the field of “digitalization”, 56 standards were identified as relevant for ALICIA.

Table 20 lists the most relevant standards for ALICIA according to the keywords in the context of digitalization. All relevant standards in this field can be found in appendix 3.

Table 20: List of top 25 standards relevant in the area of “digitalization”, cells marked in blue represent standards under development.

Document number	Title	Publication date	Author
ISO 14306	Industrial automation systems and integration - JT file format specification for 3D visualization	2017-11-00	ISO/TC 184
ISO 16100-3	Industrial automation systems and integration - Manufacturing software capability profiling for interoperability - Part 3: Interface services, protocols and capability templates	2005-12-00	ISO/TC 184
ISO 16100-5	Industrial automation systems and integration - Manufacturing software capability profiling for	2009-03-00	ISO/TC 184

Document number	Title	Publication date	Author
	interoperability - Part 5: Methodology for profile matching using multiple capability class structures		
ISO 18828-5	Industrial automation systems and integration - Standardized procedures for production systems engineering - Part 5: Manufacturing change management	2019-01-00	ISO/TC 184
ISO 23247 series (part 1-4)	Automation systems and integration - Digital twin framework for manufacturing	2021-10-00	ISO/TC 184
ISO/IEC 30162	Internet of Things (IoT) - Compatibility requirements and model for devices within industrial IoT systems	2022-02-00	ISO/IEC JTC 1/SC 41
ISO/IEC TR 30166	Internet of things (IoT) - Industrial IoT	2020-04-00	ISO/IEC JTC 1/SC 41
ISO/IEC 30181 ED1	Internet of Things (IoT) - Functional architecture for resource ID interoperability	2023-03-00	ISO/IEC JTC 1/SC 41
IEC 62541-7	OPC unified architecture - Part 7: Profiles	2020-06-00	IEC/SC 65E
IEC 62832-3	Industrial-process measurement, control and automation - Digital Factory framework - Part 3: Application of Digital Factory for life cycle management of production systems	2020-10-00	IEC/TC 65
IEC 63278-2 ED1	Asset Administration Shell for Industrial Applications - Part 2: Information meta model	2023-03-00	IEC/TC 65
IEC/PAS 63088	Smart manufacturing - Reference architecture model industry 4.0 (RAMI4.0)	2017-03-00	IEC/TC 65
IEC PAS 63485 ED1	Intelligent Information Request and Delivery Specification (iiRDS) - A process model for information architecture	2023-02-00	IEC/TC 3
ETSI GR CIM 017 V 1.1.1	Context Information Management (CIM) - Feasibility of NGSI-LD for Digital Twins	2022-12-00	ETSI/ISG CIM Cross-cutting Context Information Management
CWA 17907	European Connected Factory Platform for Agile Manufacturing Interoperability (EFPFInterOp)	2022-11-00	CEN European Committee for Standardization
VDI/VDE 2193 Blatt 1	Language for I4.0 Components - Structure of messages	2020-04-00	VDI/VDE Society Measurement and Automation
VDI/VDE 2193 Blatt 2	Language for I4.0 components - Interaction protocol for bidding procedures	2020-01-00	VDI/VDE Society Measurement and Automation
VDMA 40210	OPC UA for Geometric Measurement Systems	2022-04-00	Verband Deutscher Maschinen- und Anlagenbau e. V.
VDI 4499 Blatt 2	Digital factory - Digital Factory Operations	2011-05-00	VDI Society Production and Logistics
VDI 4499 Blatt 3	Digital factory - Data management and system architectures	2023-02-00	VDI Society Production and Logistics
VDI 4499 Blatt 4	Digital factory - Ergonomic representation of humans in the digital factory	2015-03-00	VDI Society Production and Logistics

The following standards were evaluated by TU Graz as potentially highly relevant.

- ISO 16100-3:2005
- ISO 16100-5:2009

- ISO 23247 series (part 1-4)
- ISO/IEC 30162

Especially the interoperability aspect is highly relevant for ALICIA. The standards ISO 16100-3 and ISO 16100-5 could contribute to greater interoperability of software in the current applied MaRCO Ontology in WP1, and the ISO/IEC 30162 could be useful for ensuring greater interoperability of equipment. Further, the standard series ISO 23247 (part 1-4) could be relevant for WP3 and WP4 in the context of the creation of a digital twin in a manufacturing environment.

In addition to the provided list of standards the following standards were evaluated by ECI as potentially highly relevant:
The document *VDI/VDE 3711:2020 - Input and transfer of maintenance information for condition monitoring - Digitisation of offline information* provides information and considerations both for structures to assess and collect maintenance information for used assets which are to be included in the ALICIA marketplace as well as providing insights into challenges and solutions to digitizing offline information. Even though this standard specifically focuses on condition monitoring, the digitization of offline information as a general topic can provide insights into ensuring aspects related asset data, specifically offline information, are accurately represented in ALICIA.
In addition, the standard *ISO/TS 15926-12 - Industrial automation systems and integration - Integration of life-cycle data for process plants including oil and gas production facilities - Part 12: Life-cycle integration ontology represented in Web Ontology Language (OWL)* could potentially be important to identify how to properly integrate life cycle aspects of asset data models and asset data into ontologies within ALICIA. These ontologies don't necessarily focus on process plants as stated in the standard, but the information contained within could potentially have relevance for the integration of life cycle data in non-process plant related ontologies.

4.5.5. Area "Quality Management"

Quality Management is an essential topic, in general, but especially in the industrial context. Also for ALICIA it is important to consider the currently existing standards in the field of quality management in order to meet the current state-of-the-art. 25 standards are of relevance for ALICIA in this context. They are listed in Table 21.

Table 21: List of top 25 standards relevant in the area of "quality management".

Document number	Title	Publication date	Author
ISO 9000	Quality management systems - Fundamentals and vocabulary	2015-09-00	ISO/TC 176
ISO 9001	Quality management systems - Requirements	2015-09-00	ISO/TC 176
ISO 14001	Environmental management systems - Requirements with guidance for use	2015-09-00	ISO/TC 207
ISO 14004	Environmental management systems - General guidelines on implementation	2016-03-00	ISO/TC 207
ISO 14031	Environmental management - Environmental performance evaluation - Guidelines	2021-03-00	ISO/TC 207
ISO 14033	Environmental management - Quantitative environmental information - Guidelines and examples	2019-02-00	ISO/TC 207
ISO/IEC TS 33073	Information technology - Process assessment - Process capability assessment model for quality management	2017-11-00	ISO/IEC JTC 1/SC 7
IEC 62309	Dependability of products containing reused parts - Requirements for functionality and tests	2004-07-00	IEC/TC 56
IEC TS 63164-1	Reliability of industrial automation devices and systems - Part 1: Assurance of automation devices reliability data and specification of their source	2020-02-00	IEC/TC 65

Document number	Title	Publication date	Author
IEC TR 63164-2	Reliability of industrial automation devices and systems - Part 2: System reliability	2020-07-00	IEC/TC 65
ISO/IEC/IEEE 90003	Software engineering - Guidelines for the application of ISO 9001:2015 to computer software	2018-11-00	ISO/IEC JTC 1/SC 7
EN 100114-6	Rule of procedure 14: Quality assessment procedures - Part 6: Technology approval of electronic component manufacturers	1996-12-00	CLC/TC CECC/WG-QAP
EN 100114-6/A1	CECC Quality assessment procedure for electronic components - Part 6: Technology approval of manufacturers; Amendment A1	1999-02-00	CLC/TC CECC/WG-QAP
VDA Volume 2	Quality Management in the Automotive Industry - Securing the Quality of Supplies - Production process and product approval (PPA)	2020-04-00	VDA QMC
VDA Volume 3 Part 2	Quality Management in the Automotive Industry - Reliability Assurance of Car Manufacturers and Suppliers - Reliability methods and tools	2016-05-00	VDA QMC
VDA Volume 4 Section 2	Quality Management in the Automotive Industry - Quality Assurance in the Process Landscape - Section 2: Risk Analyses - Fault Tree Analysis (FTA), Failure Mode and Effects Analysis (FMEA), SWOT-Analysis (Strengths, Weaknesses, Opportunities, Threats)	2020-08-00	VDA QMC
VDA Volume 4 Section 3	Quality Management in the Automotive Industry - Quality Assurance in the Process Landscape - Section 3: Methods - Design for Manufacturing and Assembly (DFMA), Digital Mock-Up (DMU), Design of Experiments (DoE) – Trial Methodology, Manufacturing Feasibility Analysis, POKA YOKE, Quality Function Deployment (QFD), TRIZ, Economical Process Design and Process Control, 8D Method, 5 Why Method, Selection of Preventive Quality Management Methods	2020-08-00	VDA QMC
VDA Volume 4 Section 4	Quality Management in the Automotive Industry - Quality Assurance in the Process Landscape - Section 4: Process Models - Six Sigma, Design for Six Sigma (DFSS), Industrial Tolerance Process	2020-08-00	VDA QMC
VDA Volume 5	Quality Management in the Automotive Industry - Measurement and Inspecion Processes - Capability, Planning and Management	2021-07-00	VDA QMC
VDA Volume 5 Praxishandbuch	Quality Management in the Automotive Industry - VDA 5 Practical Guide	2022-04-00	VDA QMC
VDA Volume 5.1	Quality Management in the Automotive Industry - Traceable inline metrology in car body manufacture; Supplement volume to VDA 5, Capability of measurement processes	2013-00-00	VDA QMC
VDA Volume 5.2	Quality Management in the Automotive Industry - Capability of Measurement Processes for the Torque Inspection on Bolted Joints	2013-00-00	VDA QMC
VDA Volume 19 Part 2	Quality Management in the Automotive Industry - Technical cleanliness in assembly - Environment, logistics, personnel and assembly equipment	2010-10-00	VDA QMC
IATF 16949	IATF 16949: Quality management system requirements for automotive production and relevant service parts organizations	2016-10-00	VDA QMC
VDA Volume Qualitätsbezogene Kosten	Quality Management in the Automotive Industry - Quality-related costs - Failure costs and failure prevention costs, scope and implementation	2015-04-00	VDA QMC

The standard IATF 16949 is potentially of great interest to ALICIA in the area of quality management and to make sure that ALICIA is aligned with the state-of-the-art. This is because it places a particular focus on product and process development and includes the planning, reviewing and validation of designs, as well as the consideration of error risks and error prevention through the use of Failure Mode and Effects Analysis (FMEA). These aspects are crucial to developing innovative, high-quality, and safe products that meet customer expectations and legal requirements.
Although the standard contains specific requirements that only apply to the automotive industry, ISO 9001 is a general standard for quality management systems. Nevertheless, the specific requirements of ISO 9001 certified organizations can be met easily, as many requirements from IATF 16949 are based on ISO 9001.[38]

The use case partners (Continental & Comau), who represent the automotive industry, are therefore planning to use metrics from IATF 16949 for the digital services Digital Shadow / Digital Twin to be able to evaluate and to compare the machine condition in a standardized manner. The KPIs of the use case partners are shown in
Table 22 and Table 23.

Table 22: KPIs from the use case partner Comau

External KPIs	Technical efficiency
	Availability
	Cycle Time
	Quality of production
	Mean Time Between Failures (MBTF)
	Mean Time To Repair (MTTR)

Table 23: KPIs from the use case partner Continental

Subject	**KPI**
Engineering process	Budget
	Time
Line Performance	Cycle Time
	Units produced
	Overall equipment efficiency
Machine	Technical availability

ALICIA should also consider the volumes and guidelines of VDA, which support quality assurance, development, and production in the automotive industry. In many cases, they are closely linked to the international standard IATF 16949.[39] These aspects could play an important role in ALICIA's "In-Factory-Use-Phase" services to support the factory owner during installation, commissioning, and production. The VDA Volume 4 Section 2-4 contains, among other things, useful tools from Six Sigma and Design for Six Sigma (DfSS) that can positively enrich this phase. Six Sigma represents a scientific quality management method with the aim of reducing or optimizing errors and error performance in existing processes or products.
The method combines the following basic principles:

- a structured and standardized approach,
- process orientation,
- a holistic view of the customer needs,
- evidence of the cause-and-effect chain,
- integration into the work task, and
- support during application (means training company employees to become Six Sigma experts).

[38] www.smct-management.de/iatf-16949/, last viewed on 20.11.2023

[39] www.smct-management.de, last viewed on 20.11.2023

The five phases of a classic Six Sigma project are shown below:

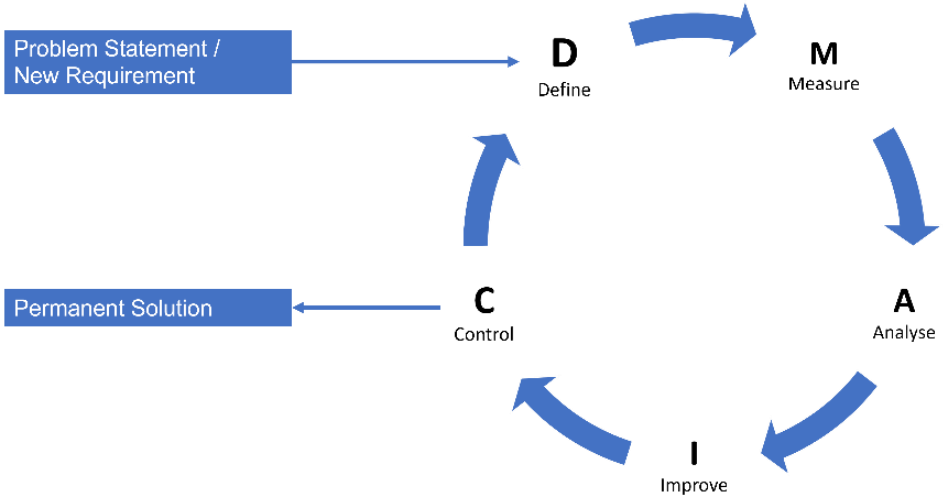


Figure 16: DMAIC-cycle as an expression of continuous improvement[40]

DfSS is a universal approach used for method-supported development in the product development process. As data-based decisions are also made here, numerous methods and tools from the classic DMAIC can be used in the product development process.[40]

4.5.6. Other Areas (e.g. social, ethical, artificial intelligence)

The following Table 24 shows a list of 12 standards relevant in terms of social, ethical or artificial intelligence, which might be relevant for ALICIA. Especially in the context of WP7, where the focus is on social, ethical and environmental assessments, these standards could be helpful.

Table 24: List of standards relevant in terms of social, ethical or artificial intelligence, cells marked in blue represents standards under development.

Document number	Title	Publication date	Author
ISO/IEC TR 24027	Information technology - Artificial intelligence (AI) - Bias in AI systems and AI aided decision making	2021-11-00	ISO/IEC JTC 1/SC 42
ISO/IEC TR 24368	Information technology - Artificial intelligence - Overview of ethical and societal concerns	2022-08-00	ISO/IEC JTC 1/SC 42
ISO/IEC FDIS 24392	Cybersecurity - Security reference model for industrial internet platform (SRM- IIP)	2023-04-00	ISO/IEC JTC 1/SC 27
ISO 26000	Guidance on social responsibility	2010-11-00	ISO/TMBG Technical Management Board - Groups
ISO/IEC 38507	Information technology - Governance of IT - Governance implications of the use of artificial intelligence by organizations	2022-04-00	ISO/IEC JTC 1/SC 40
ISO/DIS 59020	Circular economy - Measuring and assessing circularity	2023-04-00	ISO/TC 323
IEC TR 63283-4 ED1	Industrial-process measurement, control and automation - Smart Manufacturing - Part 4: Recommendations for the usage of new technologies	2023-02-00	IEC/TC 65
ITU-T L Supplement 52	Computer processing, data management and energy perspective	2022-10-00	ITU International Telecommunication Union

[40] Back, S., & Weigel, H. (2014). *Design for Six Sigma*. Regensburg: Hanser Fachbuchverlag

Document number	Title	Publication date	Author
EN 17161	Design for All - Accessibility following a Design for All approach in products, goods and services - Extending the range of users	2019-03-00	CEN/CLC/JTC 12
ETSI TS 103463-1 V 1.2.1	Access, Terminals, Transmission and Multiplexing (ATTM) - Sustainable Digital Multiservice Communities - Key Performance Indicators for Sustainable Digital Multiservice Areas - Part 1: Description of Key Performance Indicators	2020-05-00	ETSI/ATTM SDMC
VDI 2343 Blatt 7	Recycling of electrical and electronical equipment - Re-use	2014-12-00	VDI Society Energy and Environment
VDI 4605	Evaluation of sustainability	2017-10-00	VDI Society Energy and Environment

4.5.7. Consortial standards

There are also some consortial standards (see description in 2.3.4), which might be relevant for ALICIA. The most important organizations in the context of ALICIA which develop those consortial standards are described in the following.

IDTA

The industrial Digital Twin Association e.V. (IDTA) deals with the technology related to digital twins in the context of industry 4.0. The IDTA designs Asset Administration Shells and provides specifications in this field in order to allow the industry creating a digital twin[41]. Published open source software serves as basis for the industry, to create their own Asset Administration Shells.

OASIS

The Organization for the Advancement of Structured Information Standards (OASIS) is a global organization dealing with standardization projects for cybersecurity, blockchain, IoT, emergency management, cloud computing, legal data exchange, etc. [42] With MQTT OASIS developed a standard messaging protocol for the Internet of Things (IoT). It is designed as an extremely lightweight publish/subscribe messaging transport that is ideal for connecting remote devices with a small code footprint and minimal network bandwidth. MQTT today is used in a wide variety of industries, such as automotive, manufacturing, telecommunications, oil and gas, etc.[43]

MTConnect Institute

The MTConnect Institute is a not-for-profit standards development organization for the MTConnect standard. Companies and research organizations from manufacturing including automotive, aerospace, medical, and other industries as well as software developers, system integrators, and research organizations supporting those industries are member of this Institute.[44] The MTConnect standard (ANSI/MTC1.4-2018) is a domain specific semantic vocabulary for manufacturing equipment. Developers and system integrators use this information model to provide structured, contextualized data with no proprietary format. MTConnect data sources include things like production equipment, sensor packages, and other hardware.

GAIA-X, Catena-X, and Manufacturing-X standards

GAIA-X is a European cloud project whose core objective is to develop a secure and trustworthy standard for a cloud infrastructure. The architecture of GAIA-X is based on the principle of decentralization. GAIA-X is the interaction of numerous individual platforms that all follow a common standard – the GAIA-X standard. The aim is to create a data infrastructure that improves

41 https://industrialdigitaltwin.org/en/, last viewed on 20.11.2023

42 https://www.oasis-open.org/org/, last viewed on 10.10.2023

43 https://mqtt.org/, last viewed on 10.10.2023

44 https://www.mtconnect.org/, last viewed on 10.10.2023

both the digital sovereignty of users of cloud services and the scalability and competitive position of European cloud providers.[45]
In the automotive industry, the initiative “Catena-X” has set out to create a collaborative and open data ecosystem. Its goal is to enhance collaboration among various stakeholders along the supply chain, facilitate the integration of data and processes, and ensure data sovereignty. The development and adoption of common standards ensure interoperability, enabling a unified implementation of core processes such as circular economy practices, quality management, or CO_2 reporting.[46] GAIA-X and IDSA envisage a data ecosystem with data spaces from various industries. In this context, Catena-X can be classified as one of these data spaces within the GAIA-X ecosystem, thereby covering the data space of the automotive industry.[47]
The developed standards are consortial standards. The full list of currently published Catena-X standards can be accessed on the webpage of the Catena-X project.[48]
In October 2023, 56 Catena-X standards were published. The documents deal with the following topics related to the automotive industry:

- Data Discovery Services
- Semantics
- Data Chains
- Sovereign Data Exchange
- Product Lifecycle Management and Quality
- Sustainability
- Onboarding
- Business Partner Data Management
- Identity & Access Management
- Resiliency

Since October, 16 there is also an online live platform for collaboration within Catena-X.[49]

As the majority of the ALICIA platform's target user group and use case partners come from the automotive industry and industrial companies, such as Original equipment manufacturers (OEMs) (e.g. BMW, Mercedes, Volkswagen, etc.) as well as suppliers and service providers (e.g. Continental, Comau, ZF, etc.), and are already involved in Catena-X, informal standards from Catena-X could be important for ALICIA for strategic reasons to make the ALICIA platform more attractive to the market. This is because the existing concept for regulating data exchange ensures trust between data providers and data recipients. The Eclipse Data Space Connector (EDC) communication component, which implements the IDS standard and relevant protocols in connection with GAIA-X, was developed for this purpose.[46]

45 https://gaia-x.eu/, last viewed on 10.10.2023
46 www.catena-x.net/de, last viewed on 10.10.2023
47 www.tributech.io, last viewed on 10.10.2023
48 https://catena-x.net/de/standard-library, last viewed on 10.10.2023
49 https://catena-x.net/en/news-dates/artikel/go-live, last viewed on 20.10.2023

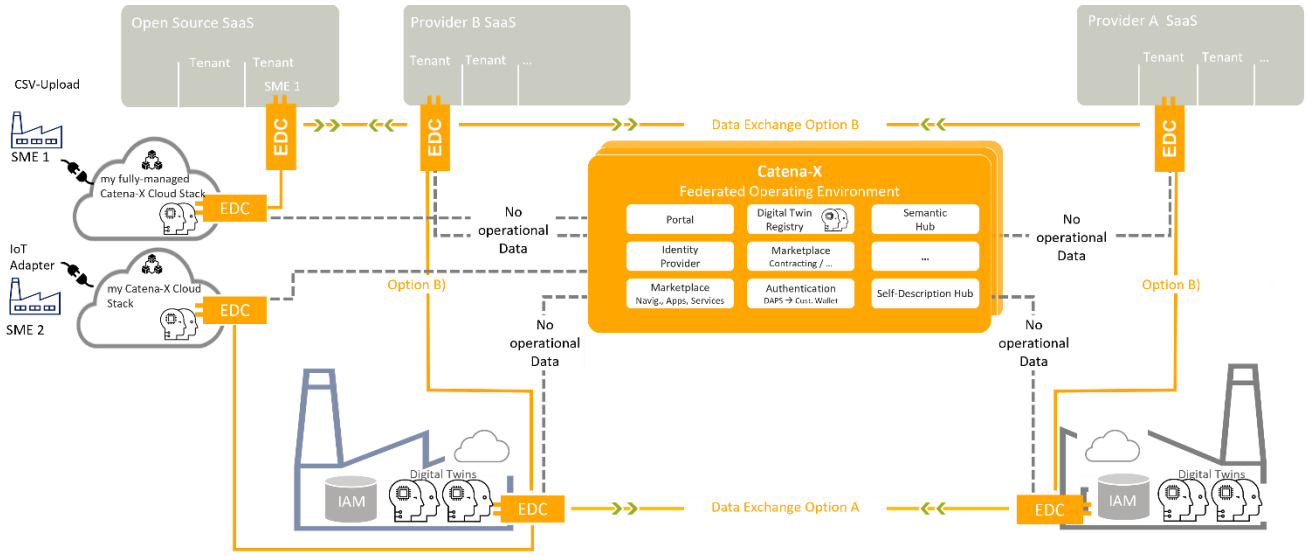


Figure 17: Data ecosystem according to Catena-X[50]

Catena-X serves as the foundation for other industrial sectors. Since the beginning of 2023, a new initiative, "Manufacturing-X," has emerged under the Industry 4.0 platform, which has been in existence since 2013, forming a network of companies, associations, unions, and research institutions. It is led by the German Federal Ministry for Economic Affairs and Climate Action and the Federal Ministry of Education and Research. The objective is to create a sovereign data space for the entire industry. This involves expanding the industry-centric approach of Catena-X to other industrial domains while aligning with the architecture and core services of Catena-X. Additional operator- and machinery-specific requirements, such as multilateral or real-time data exchange, will be incorporated. This development could be relevant for the ALICIA platform.[51]

At this point in the project, it is not possible to say which consortial standards from Catena-X, Manufacturing-X, etc. could be relevant for the work in ALICIA.

50 https://catena-x.net/de/angebote-standards/edc-die-zentrale-komponente-fuer-die-navigation, last viewed on 20.11.2023

51 www.digitalstrategie-deutschland.de, last viewed on 20.11.2023

4.6. Application of standards in ALICIA and alignment with the NIS 2 directive (new)

Standards used within ALICIA are listed in the following tables (Table 25 - Table 29) per WP with a short description of what they are used for in ALICIA and by whom. No standards are used so far within WP2 - *AI matchmaking engine* and WP8 – *Manage project, disseminate, exploit and communicate*.

Within **WP1** the standards listed in Table 25 are used.

Table 25: Standards used within ALICIA in WP1 - Specification, system architecture, factory-owner requirements

Standard	**Description of its use within ALICIA**	**Organization who uses the standard**
ISO 22400 series *Automation systems and integration — Key performance indicators (KPIs) for manufacturing operations management*	Systematic choice of sustainability KPIs	Mainly TUM (in workshop also TUG, YAG, Surplex, COMAU, Conti)
ISO 59004 *Circular economy — Vocabulary, principles and guidance for implementation*	Definition of circular economy terms	TUM, TUG
ISO/IEC 17025 *General requirements for the competence of testing and calibration laboratories*	Customer specific recognition programs	Conti
ISO 14001 *Environmental management systems — Requirements with guidance for use*	Environmental Management	Conti
ISO 50001 *Energy management systems — Requirements with guidance for use*	Energy Management	Conti
ISO 45001 Occupational health and safety management systems — Requirements with guidance for use	Occupational health and safety management systems	Conti
ISO 9001 *Quality management systems — Requirements*	Quality Management System	Conti
IAFT 16949	Quality Management System	Conti

For **WP3** – *Digital shadow / digital twin* ISO 22514-4 *Statistical methods in process management — Capability and performance Part 4: Process capability estimates and performance measures* is used for the calculation of digital twin KPIs for the process capability index CpK and the process performance index PpK.

The standards listed in Table 26 describe the technologies RAMI 4.0 and Asset Administration Shell, which are key technologies in enabling the ALICIA Plug & Produce Middleware, which is addressed in **WP4** of ALICIA, to be compliant to industry standards and ensuring state of the art implementation of the middleware components. The technologies partially described in these standards are used to implement the ALICIA middleware based on the most recent and cutting-edge industry 4.0 and smart manufacturing concepts. The Asset Administration Shell is the central technology of the middleware, enabling vendor independent, interoperable communication to production assets and unifying interfaces towards their data structures and functionalities. RAMI 4.0 is used as a reference architecture model for the middleware to ensure it is grounded in the reality of what the industry is moving towards, ensuring compliance with the latest technologies. These standards are used within ALICIA for the digital representation of assets and for connecting legacy equipment to the Plug & Produce middleware. Following data formats, information models,

schemes, and transmission protocols are used for information exchange between and within the digital services offered on the platform:

- RESTful API
- OPC-UA (https://opcfoundation.org/about/opc-technologies/opc-ua/)
- MQTT (https://mqtt.org/)
- AutomationML (https://www.automationml.org/)
- AMQP (Advanced Message Queuing Protocol) (https://www.amqp.org/)
- MTConnect (https://www.mtconnect.org/)
- EUROMAP (https://www.euromap.org/)
- IDS (International Data Spaces) (https://internationaldataspaces.org/)
- JSON (https://www.json.org/json-en.html)
- XML (https://www.w3.org/XML/Core/)
- RDF (https://www.w3.org/RDF/)

The standards IEC/PAS 63088, FprEN IEC 63278-1, IEC 63278-2 and DIN SPEC 91345 (RAMI 4.0) are used as reference for the modelling and development of the Asset Administration Shell (AAS) in ALICIA. RAMI 4.0 and AAS enable a fully mapped Digital Twin representation in Industry 4.0. Also, ALICIA considers both RAMI 4.0 and AAS for Digital Twin representation of manufacturing equipment. The Marketplace of MARKET 4.0, which is utilized and extended in ALICIA, already makes use of IDS connectors that will allow the ALICIA Platform components to exchange data securely.

Table 26: Standards used within ALICIA in WP4 - Plug & Produce Middleware and Adaptors

Standard	**Description of its use within ALICIA**	**Organization who uses the standard**
IEC/PAS 63088 Smart manufacturing - Reference architecture model industry 4.0 (RAMI4.0)	are used as reference for the modelling and development of the Asset Administration Shell, the technologies partially described in these standards are used to implement the ALICIA middleware based on the most recent and cutting-edge industry 4.0 and smart manufacturing concepts, used within ALICIA for the digital representation of assets and for connecting legacy equipment to the Plug & Produce middleware	ECI
IEC 63278-1 *Asset Administration Shell for industrial applications - Part 1: Asset Administration Shell structure*		
IEC 63278-2 *Asset Administration Shell for Industrial Applications – Part 2: Information meta model*		
DIN SPEC 91345 *Reference Architecture Model Industrie 4.0 (RAMI4.0)*		
IEC 62541 series *OPC Unified Architecture*	Internal OPC-UA Interfaces between asset adapters and AAS Platform inside middleware	

The ALICIA marketplace web app which is developed in **WP5** does not directly incorporate any standards developed by the official standardization organizations CEN and ISO. However, widely recognized consortial standards and best practices with regard to software development are used to ensure security, maintainability and performance. Those consortial standards are listed in Table 27 with a short description of its use within ALICIA.

Table 27: Consortial standards used within ALICIA in WP5 - Marketplace

Standard	Description of its use within ALICIA	Organization who uses the standard
OWASP	Ensures secure system design by addressing common vulnerabilities like XSS, SQL injection, and CSRF. Limited implementation focused on input validation.	INTRA Frontend and backend developers.

HTTPS	Provides secure communication between client and server by encrypting data in transit. Applied but not using advanced features like HSTS headers.	INTRA DevOps team developers and users
OAuth 2.0	Enables secure authentication and role-based access control by providing access tokens and session management. Basic usage through Keycloak.	INTRA Backend developers.
JSON Schema	Validates and standardizes API payloads to ensure consistency and seamless communication. Only used for specific backend endpoints.	Backend developers. IMT and LMS
Swagger	Documents API endpoints for developers and facilitates interoperability. Limited to listing endpoints without authentication details.	INTRA Backend developers and clients. Also, IMT and LMS
NGINX	Manages traffic securely by load balancing and reverse proxy functionality. Basic implementation for SSL termination and backend routing.	INTRA DevOps team.
Vitest	Performs unit testing for frontend functionality, ensuring isolated components work as expected. Limited test cases written for core features.	INTRA Frontend developers.
Cypress	Automates end-to-end testing of user flows to validate application functionality. Testing limited to login and basic user scenarios.	INTRA frontend developers.
Reusable Components	Ensures modularity and consistency in the UI by creating and reusing components across the application.	INTRA Frontend developers.
Private Properties/Methods	Enhances encapsulation and prevents unintended modifications to sensitive data or logic in the codebase.	INTRA Frontend and backend developers.
SonarQube Checks	Provides static code analysis to identify potential vulnerabilities, bugs, and code smells, improving overall code quality.	INTRA developers.

Within the used cases of CONTI and COMAU the standards and regulations listed in Table 28 are used for the development of the demonstators in **WP6**.

Table 28: Standards used within ALICIA in WP6 - Small scale testing, followed by demonstration

Standard	**Description of its use within ALICIA**	**Organization who uses the standard**
2006/42/EC *Machinery Safety Directive*	COMAU demonstrator: safety of demo robotic cell	COMAU
EN 60204-1 *Safety of machinery - Electrical equipment of machines - Part 1: General requirements*	COMAU and Conti demonstrator: safe design of electrical equipment	COMAU, Conti
EN 614-1 *Safety of machinery - Ergonomic design principles - Part 1: Terminology and general principles*	COMAU and Conti Demonstrator: ergonomic design of robotics cell	COMAU, Conti
EN 614-2 *Safety of machinery - Ergonomic design principles - Part 2: Interactions between the design of machinery and work tasks*	COMAU demonstrator: ergonomic design of robotized cell	COMAU
EN 953 *Safety of machinery - Guards - General requirements for the design and construction of fixed and movable guards*	COMAU demonstrator: design of safe protective guards for robotized cell	COMAU
ISO 12100 *Safety of machinery - Basic concepts, general principles for design - Risk assessment and risk reduction*	COMAU demonstrator: evaluation of risks in assembly cell design (general aspects)	COMAU

EN ISO 13849-1 *Safety of machinery. Safety-related parts of control systems. General principles for design*	COMAU demonstrator: safety in control systems design for robotized station	COMAU
2004/108/EC *Electromagnetic Compatibility*	COMAU demonstrator: design of assembly cell with reduced EMC issues	COMAU
EN ISO 13849-2 *Safety of machinery - Safety-related parts of control systems -Part 2: Validation*	COMAU and Conti demonstrator: safety in control systems for demo station	COMAU, Conti
EN ISO 10218-1 *Robots for industrial environments - Safety requirements - Part 1: Robot (ISO 10218-1:2011)*	COMAU and Conti demonstrator: safe design of robot configuration in assembly cell (general aspects)	COMAU, Conti
EN ISO 10218-2 *Robots and robotic devices -Safety requirements for industrial robots -Part 2: Robot systems and integration (ISO 10218-2:2011)*	COMAU demonstrator: safe design of robot configuration in assembly cell (robots integration aspects)	COMAU
2006/95/EC Low voltage directive	COMAU demonstrator: safety in electrical equipment design and installation	COMAU
EN ISO 13850 *Safety of machinery. Emergency stop. Principles for design*	COMAU demonstrator: safety in robots and auxiliary equipment installation	COMAU
EN ISO 13855 *Safety of machinery - Positioning of safeguards with respect to the approach speeds of parts of the human body*	COMAU demonstrator: safe human-robots interaction design	COMAU
ISO/TR 14121-2 *Safety of machinery - Risk assessment - Part 2: Practical guidance and examples of methods*	COMAU demonstrator: evaluation of risks in assembly cell design (specific implementation aspects)	COMAU

Within **WP7** the standards listed in Table 29 regarding LCA and circular economy are used.

Table 29: Standards used within ALICIA in WP7 – Framework conditions / prepare commercial uptake post project

Standard	**Description of its use within ALICIA**	**Organization who uses the standard**
ISO 14040 *Environmental management — Life cycle assessment — Principles and framework*	carrying out life cycle assessment	YAGMA
ISO 14075 *Environmental management — Principles and framework for social life cycle assessment*	Social LCA	YAGMA
ISO 59004 *Circular economy — Vocabulary, principles and guidance for implementation*	These standards are used in the context of T7.2 Investigate novel business models (ONGOING)	T*UG*
ISO 59010 *Circular economy — Guidance on the transition of business models and value networks*		
ISO 59020 *Circular economy — Measuring and assessing circularity performance*		
ISO/TR 59032 *Circular economy — Review of existing value networks*		

Consideration of the IEC 62443 Standards Series in ALICIA

As part of the review process, it was specifically asked whether the IEC 62443 series of standards for cybersecurity in industrial automation is applied within the ALICIA project. The analysis revealed that these standards are not explicitly used in ALICIA, as they are not directly related to the developed solution.
The IEC 62443 standard series *Security for industrial automation and control systems* primarily applies to industrial automation systems at the plant level, with cybersecurity responsibility typically managed by the end customer's plant IT. Consequently, this standard is generally referenced by system suppliers and integrators such as COMAU, but with limited direct impact. In the ALICIA project, the COMAU use case is limited to a virtual environment or a lab demonstrator, making specific application of IEC 62443 unnecessary. Nevertheless, in the future platform integration activities will involve the IT department to guarantee full compliance to IEC 62443 series and NIS 2 directive as well. In addition to this, COMAU is working on the topic of the new machinery regulation 2023/1230/EU (replacing Directive 2006/42/EC), where cyber security is also considered.
From the WP3 components perspective, the DS/DT API functions as a broker and KPI calculator without direct access to databases or additional data sources. The ALICIA Orchestrator serves as an interface between the ALICIA platform and digital tools, ensuring secure communication. For this purpose, IDS connectors will be integrated. To secure communication between the DS/DT API and the DIMOFAC platform from the WP4 framework, OAuth 2.0 is used to guarantee secure authentication.
Furthermore, general security principles, particularly from the ISO/IEC 27001 standard for information security management, influence security practices within the ALICIA project. The middleware is based on established technologies, including the ECI Framework for asset adapters and the DIMOFAC Digital Platform for the AAS platform, which themselves do not utilize IEC 62443 standards. Nevertheless, security mechanisms such as authorization and encryption are implemented to maintain a high level of security.
In summary, the IEC 62443 standards series is not directly applied in the current ALICIA project, as its specific requirements and architecture do not necessitate it. However, security measures are ensured through other recognized standards and established technologies.

Integration of the NIS 2 Directive in ALICIA

The integration of the NIS 2 Directive within the ALICIA project has been approached through multiple security measures and compliance strategies. The following key aspects highlight how the directive is addressed and implemented across different components of the platform:

- Platform-Level Integration
  To ensure compliance with the NIS 2 Directive, the ALICIA platform incorporates various security measures aimed at safeguarding data integrity, confidentiality, and resilience. These measures include:

  - Secure API Communication: Ensuring the integrity and confidentiality of real-time data exchanged through secure API channels.
  - Data Flow Protection: Implementing security controls to protect data flow between platform components and external services.
  - Threat Monitoring: Continuous monitoring of potential threats to align with the NIS 2 principles on critical service resilience and cybersecurity.
  - Operational Resilience: Adoption of robust measures to enhance platform resilience and secure operations.

- B2B Marketplace Compliance
  The ALICIA B2B marketplace aligns with the NIS 2 Directive by implementing stringent security policies. These policies cover multiple aspects of cybersecurity, including data protection, access control, and user authentication. The key security measures include:

- Access Control: Implementation of strict access control mechanisms to ensure that only authorized personnel have access to sensitive data.
- Encryption: Utilization of encryption techniques to protect data both in transit and at rest.
- User Authentication: Secure authentication mechanisms, including role-based access control, access tokens, and session management facilitated by Keycloak.
- Regular Updates: Continuous updates of software and systems to mitigate known vulnerabilities and ensure ongoing security compliance.

- Middleware and Subcomponents
  Currently, the middleware and its subcomponents do not have integrated measures specifically addressing the NIS 2 Directive.

Through these security measures, ALICIA ensures alignment with the NIS 2 Directive, reinforcing platform security, operational resilience, and compliance.

5. Methodology: Standardization potential workshop – the basis for the standardization strategy in ALICIA (new)

5.1. General

An overview of the standardization landscape relevant to ALICIA was provided already in the first year of the project (see Clause 4). This raised awareness within the consortium about existing standards, establishing a foundation for identifying standardization gaps. These gaps refer to missing standards within the existing body of standards, which are identified by the ALICIA project based on the consortium's expertise. Although ALICIA is a European R&I project, the focus was equally placed on both the European and international levels. Identifying these standardization gaps can lead to the proposal of new work items or the initiation of a CWA, should the project's results address these needs. This procedure forms the basis for the standardization strategy in ALCIA by defining how the project gets actively involved in standardization. This process provides a valuable pathway for translating project outcomes into standardization documents, ensuring their long-term dissemination.

5.2. Identification of standardization needs within ALICIA

To develop an effective standardization strategy for ALICIA, it is crucial to understand the challenges currently faced by the project partners and identify areas where standardization could help address these challenges. To explore this, a standardization potential workshop was held. To maximize synergies, this workshop was held in conjunction with another research project in which DIN is involved as a standardization partner: CircUits (GA No.: 101091490). CircUits aims to address the emerging semiconductor material crisis by supporting value chains in the automotive and mass electronics industries. The project develops digital solutions for the design, manufacture, and management of electronic components and end-of-life products.[52] Both projects are funded by the European Commission under the Horizon Europe framework under the topic: HORIZON-CL4-2022-TWIN-TRANSITION-01-07 - *Digital tools to support the engineering of a Circular Economy*. Given the overlap in topics between the two projects, the workshop was conducted jointly, providing an opportunity to identify synergies in their standardization needs and explore the possibility of initiating joint activities.

The three-hour virtual workshop brought together 15 participants from 10 organizations in the ALICIA project and 21 participants from 14 different organizations in the CircUits project. The session was facilitated using the "Conceptboard" tool, a virtual whiteboard that allows participants to collaborate simultaneously and efficiently.

The agenda for the workshop is shown in Figure 18. The workshop began with an introduction to its objectives, followed by presentations from the project coordinators of TUM (ALICIA) and POLIMI (CircUits) on their respective projects. Participants then familiarized themselves with the Conceptboard followed by an exercise on standardization, where the participants answered key questions about its purpose, importance, and the development of standards. DIN facilitated discussions, confirming participants' interest and basic knowledge of standardization.

[52] https://circuitsproject.eu/

CIRC-UITS Project 101091490 Project 101091577

DIN

Agenda standardization potential workshop

Time (CET)	Description	Contributors
1:00 – 1:10 pm	1) Welcome & Introduction	DIN
1:10 – 1:25 pm	2) Presentation of CircUits and ALICIA	POLIMI, TUM
1:25 – 1:45 pm	3) Familarization with „Conceptboard" & Introduction round (interactive)	All participants
1:45 – 2:15 pm	4) Basics on standardization (interactive)	All participants
2:15 – 2:30 pm	Break	All participants
2:30 – 2:35 pm	Group photo	All participants
2:35 – 2:45 pm	5) „Back to the future" – What does a successful project look like?	DIN
2:45 – 3:00 pm	6) Relevant technical committees for possible contribution (interactive)	All participants
3:00 – 3:45 pm	7) Standardization potentials • Identification of challenges & identification of potentials (interactive) • Presentation of ideas (DIN) • Rating of ideas (interactive)	All participants
3:45 – 3:55 pm	8) Outlook and next steps	DIN
3:55 – 4:00 pm	Feedback	All participants

Funded by the European Union

Figure 18: Agenda of the standardization potential workshop

After a break, DIN led an imagination game using a fishbone diagram to illustrate how research projects can contribute to standardization and transfer results effectively (Figure 19). This interactive approach helped engage participants and clarify potential activities within ALICIA.

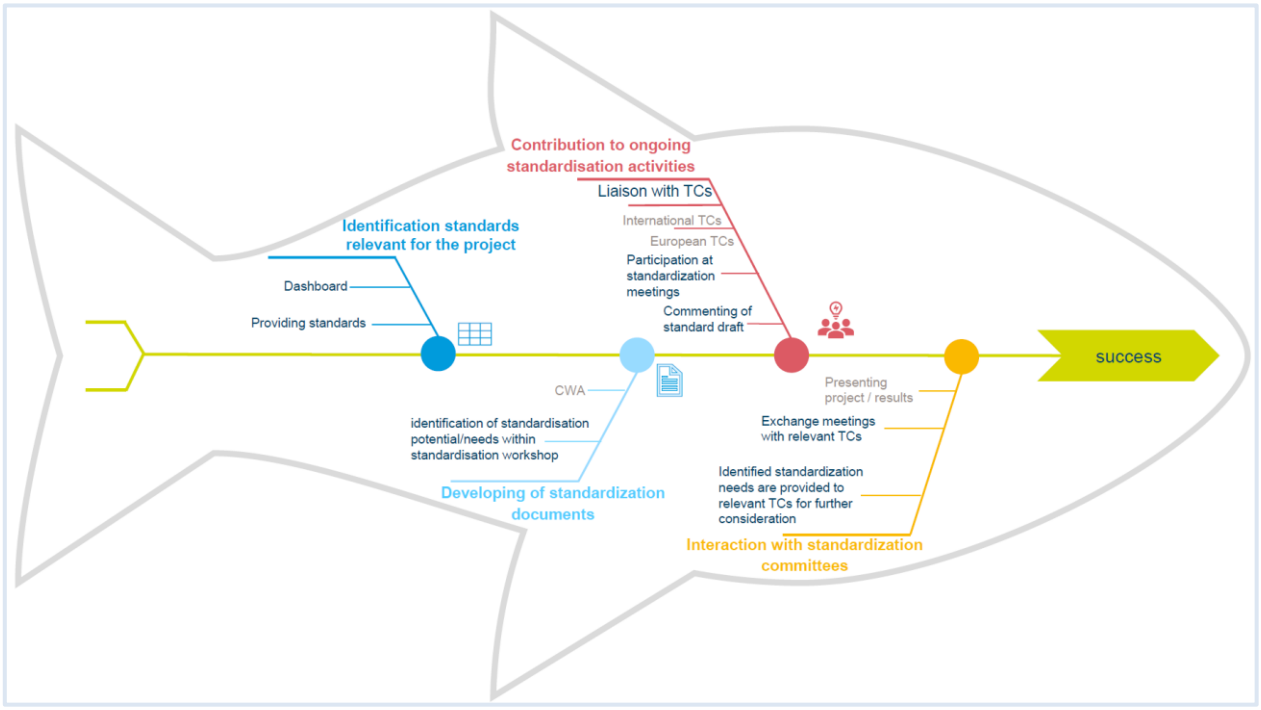


Figure 19: Fishbone diagram showing options for research projects to participate in standardization

At the standardization potential workshop, partners identified technical committees (TCs) of interest as a first step in defining focus activities. Relevant TCs from international and European levels were displayed on the Conceptboard, and partners marked their interest (Figure 20).

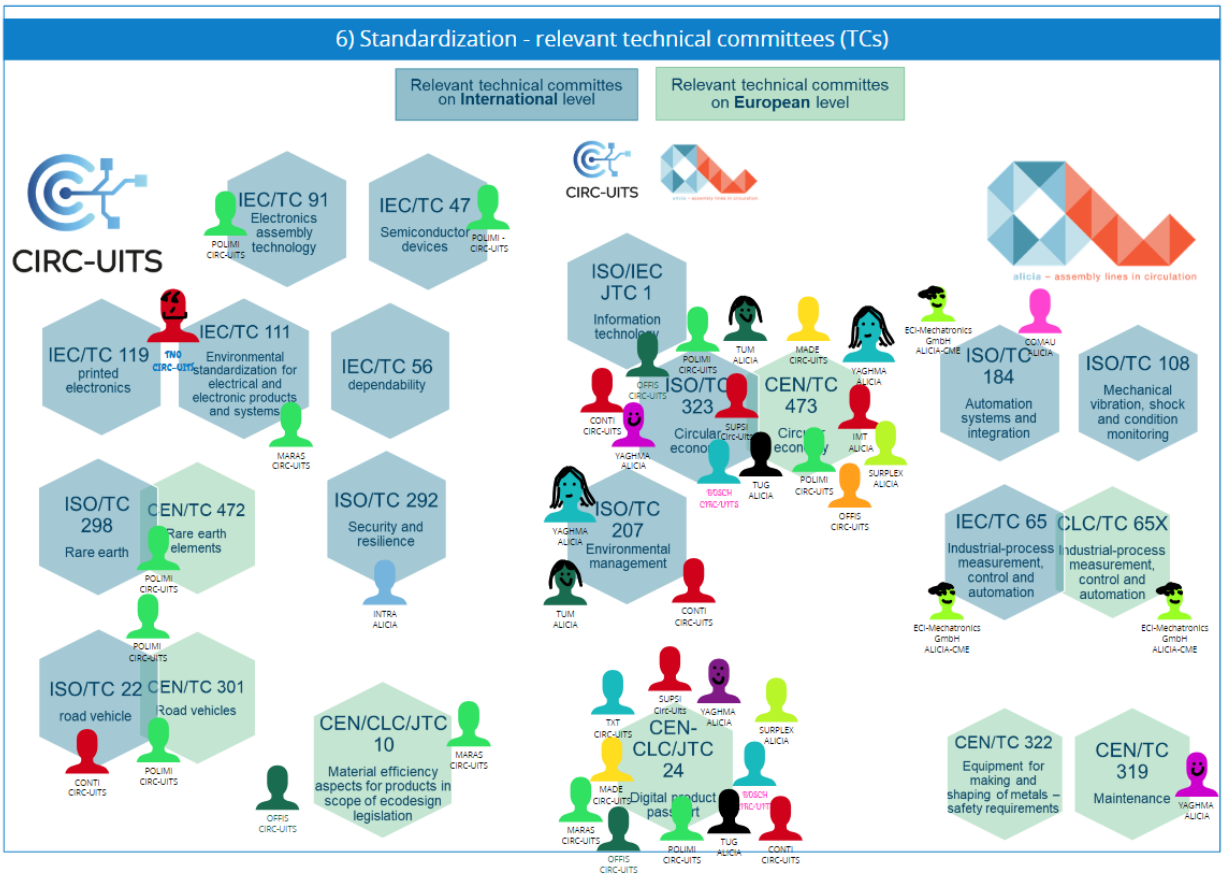


Figure 20: Excerpt from the workshop - Conceptboard showing the TCs in which participants are interested in.

Afterwards, the next steps for the interaction with the relevant TC's were outlined by DIN:

1. DIN gathers an overview of partner interests.
2. DIN invites relevant partners for further discussions.
3. DIN and partners evaluate potential contributions and define next steps.

Those steps and their outcome can be found in subclause 6.2.

To identify current challenges and potential standardization opportunities, the workshop used Conceptboard to collect initial ideas. Partners considered key questions on interoperability, quality standards, communication barriers, and methodologies. They recorded their thoughts on sticky notes.

Partners then categorized their ideas (Figure 21) within a matrix of standard types (e.g., terminology, testing, product standards) and thematic areas that were specified:

- Industry
- Circular Economy
- Digitalization
- Quality Management
- Others

This helped structure potential standardization topics and identify relevant gaps.

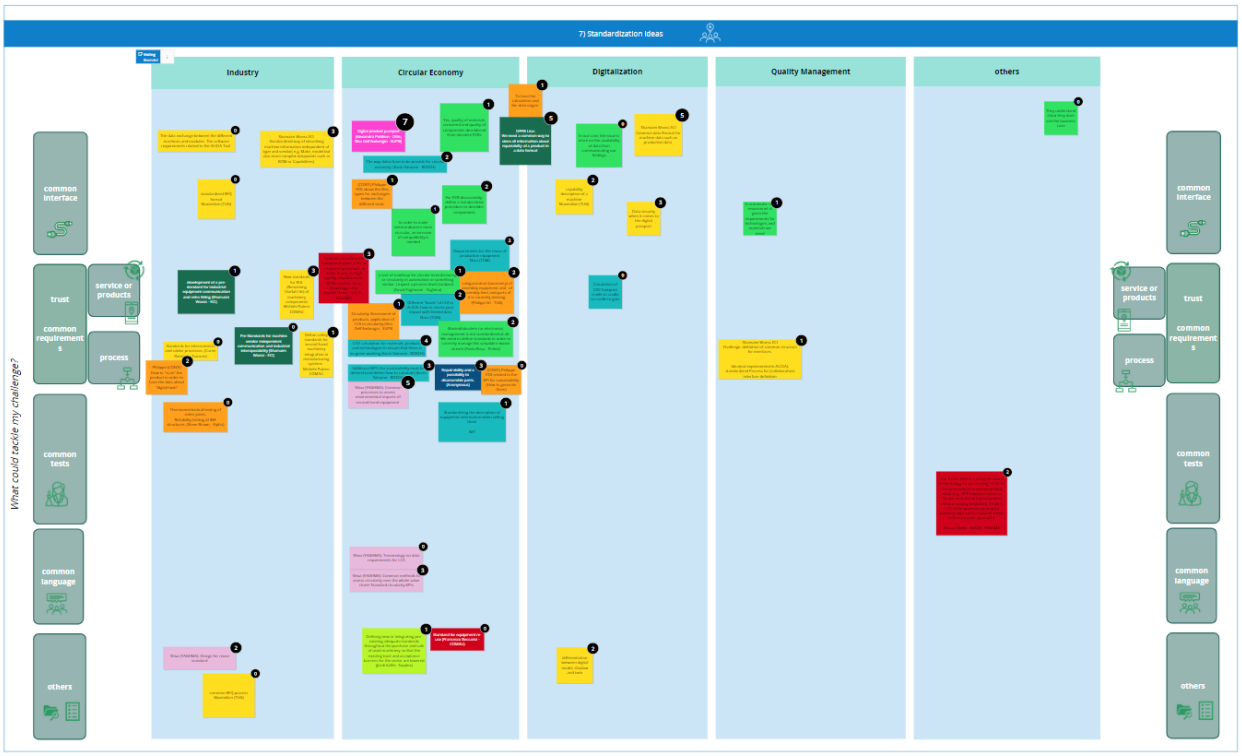


Figure 21: Matrix (types of standardization documents x topics) in which the partners have sorted their ideas. The content of this image is not subject of the figure and does not have to be readable.

DIN presented the ideas to the workshop audience, allowing partners to elaborate and collect feedback. Participants then ranked ideas using five votes each, identifying the top five for further development (Figure 22).

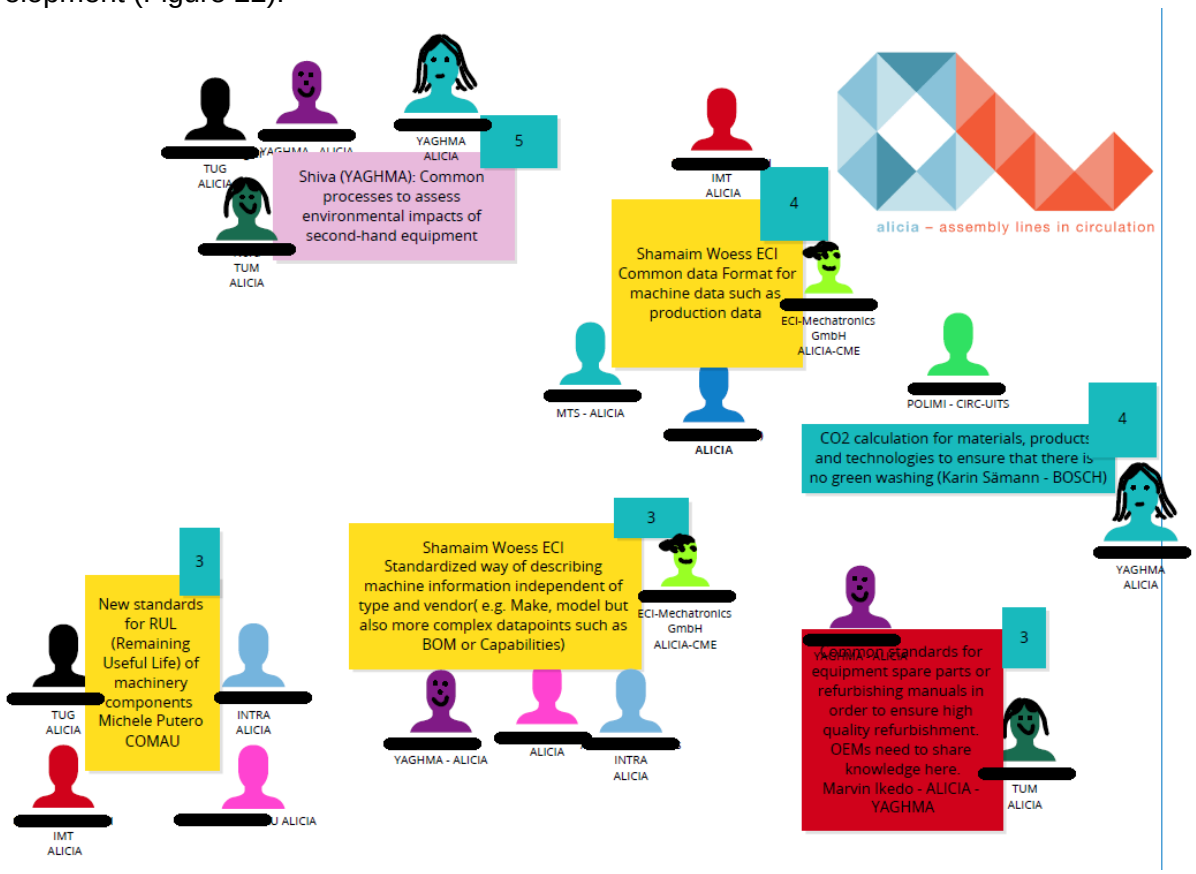


Figure 22: The ideas proposed by the ALICIA project and voted for most by all workshop participants.

DIN gave on overview of the next steps for the collected standardization potentials:

1. DIN checks for existing standards covering the ideas.
2. DIN invites relevant partners for further development.

3. Project partners refine the ideas.

The workshop concluded with an outlook, a summary of the next steps, and participant feedback.

The conduction of the next steps regarding the standardization potentials can be found in subclause 6.3.

The whole conceptboard from this workshop can be found in Annex 5.

6. Standardization strategy (new)

6.1. General

The standardization efforts within ALICIA have three main objectives. The first objective is to ensure that ALICIA's results align with the state of the art and, consequently, with the relevant applicable standards. The second objective is to foster interaction with experts outside the project, achieved through engagement with standardization committees. The third and overarching objective is the long-term dissemination and exploitation of the project results. This includes contributing to ongoing standardization activities and initiating new standardization efforts, which are closely linked to identifying standardization potential within the project.

The standardization activities for ALICIA therefore focuses on four key tasks: research of relevant standards, interaction with standardization bodies, contribution to ongoing standardization activities, and identification of standardization potential (Figure 23).

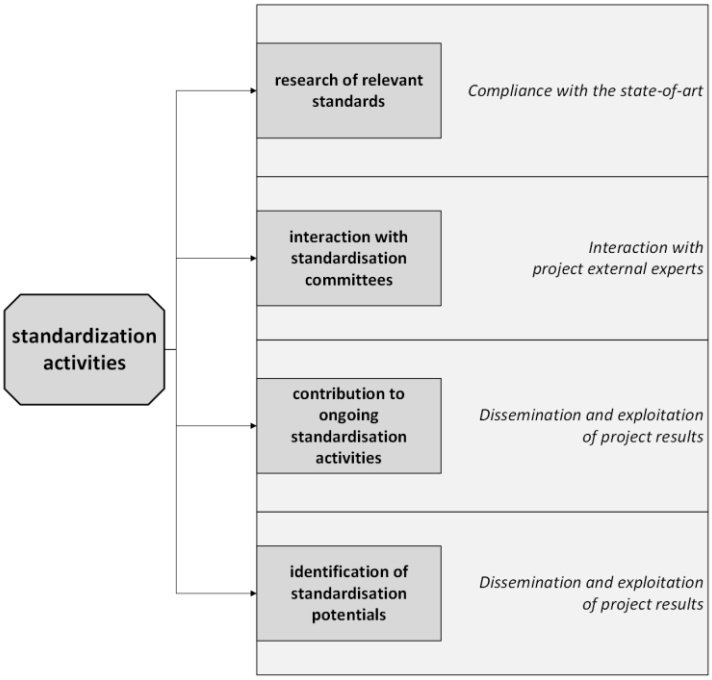


Figure 23: Subtasks of the standardization activities within ALICIA

The standardization strategy for the project focuses on the last three points, with research into relevant standards serving as the basis for these activities (see clause 4). In the following subclauses the three points of the standardization strategy for ALICIA are analyzed in detail.

6.2. Interaction with standardization committees and contribution to ongoing standardization activities

6.2.1. Interaction with standardization committees

Interaction with standardization committees serves as a key mechanism for disseminating research project outcomes to a broader community. European and international standardization committees bring together experts from various organizations, facilitating widespread information sharing. In addition to raising awareness about the ALICIA project and its activities, engagement with these committees provides valuable input for project development through discussions with those experts. Therefore, relevant and related TCs to ALICIA identified in clause 4 were contacted according to the interest of ALICIA partners and existing standardization projects. Figure 24 lists the relevant committees that were contacted, providing

information about the ALICIA project and requesting that this be shared with experts active in these committees.

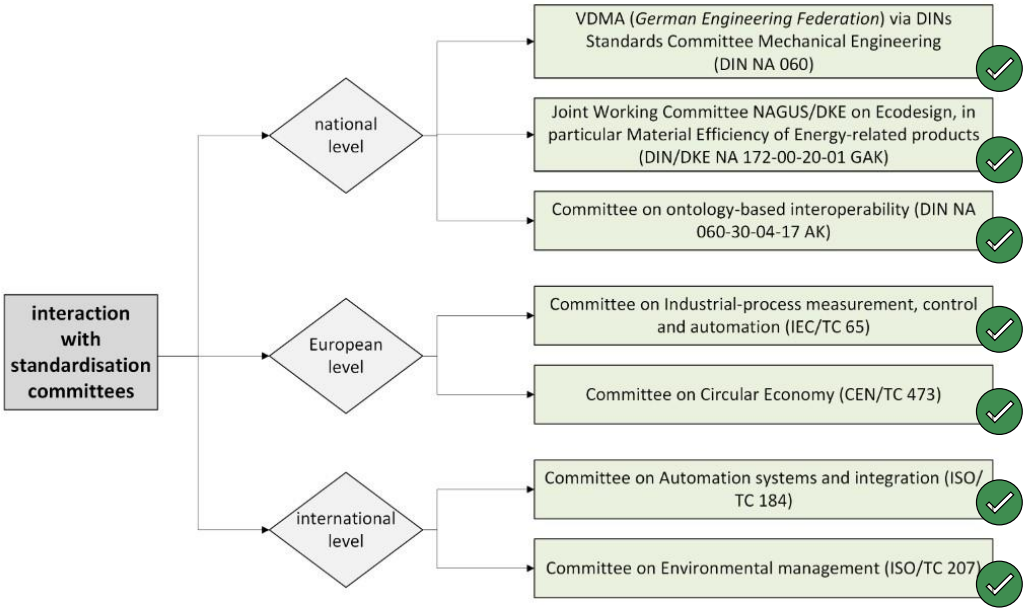


Figure 24: Relevant and ALICIA-related standardization committees that were contacted

Meetings were held with interested technical committees (TCs) to discuss the ALICIA project and explore possible synergies. In January 2024, ALICIA participated in the DIN NA 172-00-20 *Ecodesign, in particular, material efficiency of energy-related proucts* GA meeting at DIN in Berlin, where the project was presented, and experts had the opportunity to provide feedback and suggestions. In October 2023, an overview of the ALICIA project was given to the DIN NA 060, *DINs Standards Committee Mechanical Engineering*. In August 2024, ALICIA's identified standardization potentials were presented and discussed with DIN NA 060-30-04-17 AK *Ontology-based interoperability*, the German mirror committee of ISO/TC 184/SC 4/WG 26 on Ontology-based Interoperability. The project was also presented to ISO/TC 184, *Automation Systems and Integration*, in August 2024, where it was recommended that ALICIA should apply for liaison status with several working groups of this TC (see below). In November 2024, the project was presented to CEN/TC 473, Circular Economy.

Beyond dissemination and discussion of project results, engagement with these standardization committees also aimed to lay the groundwork for deeper collaboration through official liaisons. Establishing a liaison with a TC and its Working Groups (WGs) enables research projects to actively contribute to ongoing standardization efforts by participating in meetings, discussing draft standards, and influencing the drafting process. Additionally, such engagement provides access to committee documents, offering valuable insights for the development of project solutions.

In addition to the interaction with standardization committees, exchanges with the following research projects took place:

- CIRC-UITS - *Circular Integration of independent Reverse supply Chains for the smart reUse of IndusTrially relevant Semiconductors* (Horizon Europe Program: HORIZON.2.4 - Digital, Industry and Space Main Programme - HORIZON.2.4.1 - Manufacturing Technologies)
- AIDEAS - *AI Driven industrial Equipment product life cycle boosting Agility, Sustainability and resilience* (Horizon Europe Program: HORIZON.2.4 - Digital, Industry and Space Main Programme - HORIZON.2.4.1 - Manufacturing Technologies)
- DiMAT - *Digital Modelling and Simulation for Design, Processing and Manufacturing of Advanced Materials* (Horizon Europe Program: HORIZON.2.4 - Digital, Industry and Space Main Programme - HORIZON.2.4.4 – Advanced Materials)

In these projects, standardization plays an important role as well. Until the end of ALICIA, it will be monitored whether synergies can be used and standardization actions can be combined.

6.2.2. Contribution to ongoing standardization activities

The task of contributing to ongoing standardization activities is closely linked to interactions with these committees, particularly in shaping standards within WGs. A research project can participate in the drafting process by establishing a liaison with a TC and its WGs. However, before forming such a liaison, it is crucial to assess opportunities for contribution, ensuring that the TC's standardization efforts are at an appropriate stage to allow meaningful input from the project.

To facilitate this process, a standardization potential workshop was conducted, during which participants were invited to indicate their interest in specific TCs for potential liaison (see subclause 5.2). Table 30 presents the ALICIA partners' areas of interest. This served as an initial overview.

Table 30: Interest of ALICIA partners in related TCs

TC	**Interested ALICIA partners**
ISO/TC 292 – Security and resilience	INTRA
ISO/IEC JTC 1 – Information technology	CONTI
ISO/TC 323 - Circular economy / CEN/TC 473 – Circular economy	CONTI, YAGHMA, TUM, IMT, SURPLEX, TUG
ISO/TC 207 – Environmental management	YAGHMA, TUM, CONTI
CEN-CL/JTC 24 – Digital product passport	YAGHMA, TUG, CONTI, SURPLEX
ISO/TC 184 – Automation systems and integration	COMAU, ECI
IEC/TC 65 – Industrial process measurement, control and automation / CLC/TC 65X - Industrial process measurement, control and automation	ECI
CEN/TC 319 - Maintenance	YAGHMA

Subsequently, DIN conducted a survey for the ALICIA consortium, providing detailed information on the scope, structure, subcommittees, working groups, and active work items for each TC listed in Table 25. Consortium members were invited to participate in the survey and indicate areas of active standardization work they wished to contribute to.

Survey results highlighted ISO/TC 184, *Automation Systems and Integration*, as a key target for a liaison, as its working groups are developing standards at a stage where ALICIA can provide valuable contributions (Figure 26). To formalize this engagement, a liaison contract was sent to ALICIA in November 2024. However, due to formal complications, the contract has not yet been signed by the ALICIA consortium. Once finalized, TC members will be consulted for their approval of the liaison. Only upon agreement will ALICIA be granted the opportunity to actively participate in the standards development process. Consequently, this task remains ongoing, with meaningful contributions from ALICIA planned for the project's final year. The establishment of liaisons with the other listed TCs was not pursued further, either because there was little interest in the ALICIA consortium or there was no suitable ongoing standardization project in the relevant working groups. The project partner YAGHMA has already established a liaison with ISO/TC 323 *Circular economy* outside of the ALICIA project.

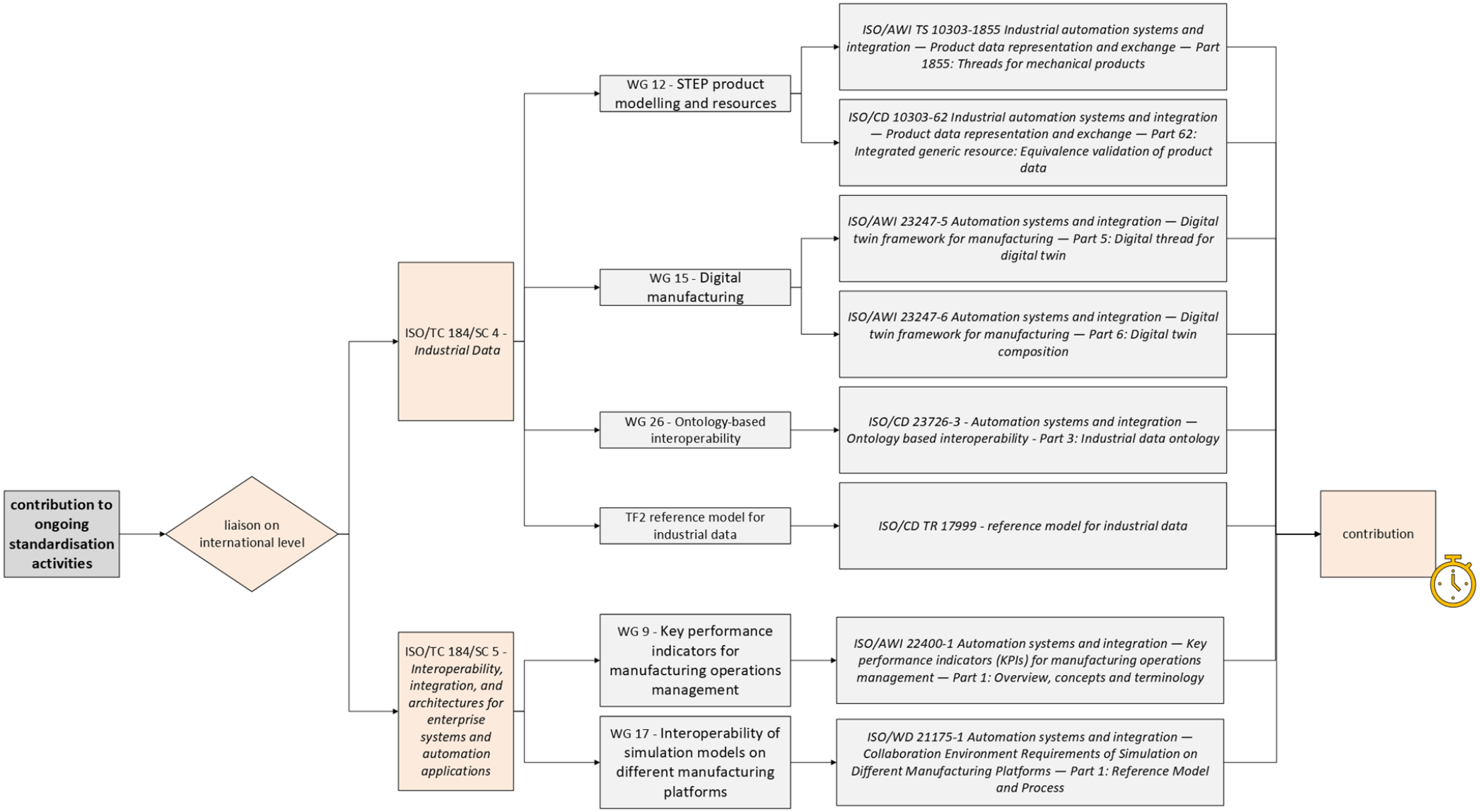


Figure 25: Subtask “contribution to ongoing standardization activities”

6.3. Identification of standardization potentials

The fourth task, identifying standardization potentials, is primarily aimed at maximizing the dissemination and impact of the project results by exploring opportunities for standardization. During the Standardization Potential Workshop (Clause 5), ALICIA participants identified several promising standardization opportunities:

- Common processes to assess environmental impacts of second-hand equipment
- Common data Format for machine data such as production data
- New standards for RUL (Remaining Useful Life) of machinery components
- Standardized way of describing machine information independent of type and vendor (e.g. Make, model but also more complex datapoints such as BOM or Capabilities)
- Requirements for the reuse of production equipment
- Common standards for equipment spare parts or refurbishing manuals in order to ensure high quality refurbishment
- Common methods to assess circularity over the whole value chain/ Standard circularity KPIs

Interested partners were invited to follow-up meetings to further explore these possibilities, including the potential development of a CEN Workshop Agreement (CWA). Given that the formal CWA development process typically takes about a year, early initiation is crucial. Key discussions focused on defining the scope, challenges, content, and target groups for potential CWAs. These discussions revealed opportunities to merge some of the identified potentials, leading DIN to draft preliminary scopes for possible CWA developments:

- *Common processes to assess environmental impacts of second-hand equipment*
  The planned CEN Workshop Agreement specifies the framework and methodology for assessing the environmental impacts of second hand equipment with a specific focus on the reuse processes of assembly line equipment. This methodological framework will provide guidelines on goal definition, boundary setting and defining unit of assessment for LCA of secondhand equipment. In that context circularity KPIs for reuse cycles and remanufacturing for different types of second hand equipment are defined. The general and specific environmental impacts which should be considered in that context are established. The specific points to consider when performing a hot spot analysis of reuse and the reuse process itself are defined in that document.
  The planned Workshop is intended to be used in general by LCA practitioners, like e.g. consultants, manufacturers or research projects, and circularity researchers. This document can be useful for manufacturing companies that want to buy new or used machines, research projects with a focus on circular economy and in the future authorities and policy makers.

- *Common data format for machine data*
  The planned CEN Workshop Agreement establishes a framework for a common data format for machine data such as production data or the condition of the machine, in order to describe the general properties of machines. A basis to create such structure files as a generic format is described in this document.
  In addition, this CWA defines the minimum set of requirements for information to describe a machine.
  The planned workshop is intended to be applicable for new industrial machines as well as second hand equipment and makes it possible to measure the health status of the machines.
  The target group of this document are machine manufacturers (e.g., OEMs), machine users and machine integrators.

- *New standards for RUL (Remaining Useful Life) of machinery components*
  The planned CEN Workshop Agreement defines an approach to estimate the remaining useful life (RUL) of industrial equipment like components, machines and manufacturing

systems. Besides a general framework for RUL different ways for a reliable calculation of the RUL and the type of data to estimate the RUL are specified. The parameters used for the described approaches are defined in this document as well as specific terms and methods to ensure a clear understanding between different stakeholders. The document describes approaches to define and evaluate if the production target is reached. The focus of this document will be on reuse and therefore the estimation of RUL for used machines to be integrated in a system is covered.
The target group of this document are first of all end-users, manufacturers, system integrators, equipment sellers and implementors of second hand equipment.

- *Requirements for the reuse of production equipment*
  The planned CEN Workshop Agreement is a guideline to consider the main aspects when reusing production
  equipment. Within this document it is described which requirements in terms of technical, energy and sustainability aspects should be considered, the document will provide definitions and measurement methods for technical and energy KPIs as well as cost effectiveness and viability of equipment reuse, which is important especially for the end user – impact on user (LCC calculation) and impact on society (LCA). The planned Workshop Agreement does not apply to safety related equipment. The planned Workshop Agreement is intended to be used by platform developers (like ALICIA), marketplace operators, system integrators, and the end user of an assembly line in general. The planned document is also important for equipment designers considering the circularity-by-design approach.

In May 2024, project partners were invited to participate in a survey, providing input on their potential involvement in each topic. Therefore, everyone had the opportunity to indicate the specific commitment they could imagine for the individual topics:

- Initiator of this specification: Supporting DIN while preparation of project plan and CWA Kick-off meeting for CWA, Main contact person regarding CWA topic until the CWA kick-off meeting, Have a expertise regarding the proposed topic of the CWA
- Main contributor: Contributing content to the CWA, Have an expertise regarding the topic of the CWA
- Contributor: Contributing content to the CWA or at least give feedback to the content and the developed document
- Not at all

The survey was filled in by 10 partners from the consortium (see Annex 6). One of the most promising ideas, "Common processes to assess environmental impacts of second-hand equipment," was selected for further evaluation. A dedicated meeting was held to outline the CWA development process and next steps. However, due to personnel changes within the organization initially expected to lead this initiative, a new initiator was required. Despite efforts to identify a replacement, no suitable candidate was found, making it impossible to proceed with the CWA. Similarly, for the other identified topics, no initiator could be secured despite extensive discussions. Since DIN's role is limited to overseeing the formal process and does not include technical leadership, the development of CWAs within ALICIA was ultimately not feasible. Consequently, in November 2024, it was decided that no CWA would be initiated within the project.

Despite this, the identified standardization potentials and possible solution strategies remain highly valuable. To ensure these insights benefit the broader community, they will be publicly shared, encouraging other initiatives to build upon ALICIA's foundational work. To raise awareness among relevant standardization committees and external stakeholders, a whitepaper is planned. This document will provide a detailed analysis of the identified potentials and propose possible standardization pathways (Figure 26).

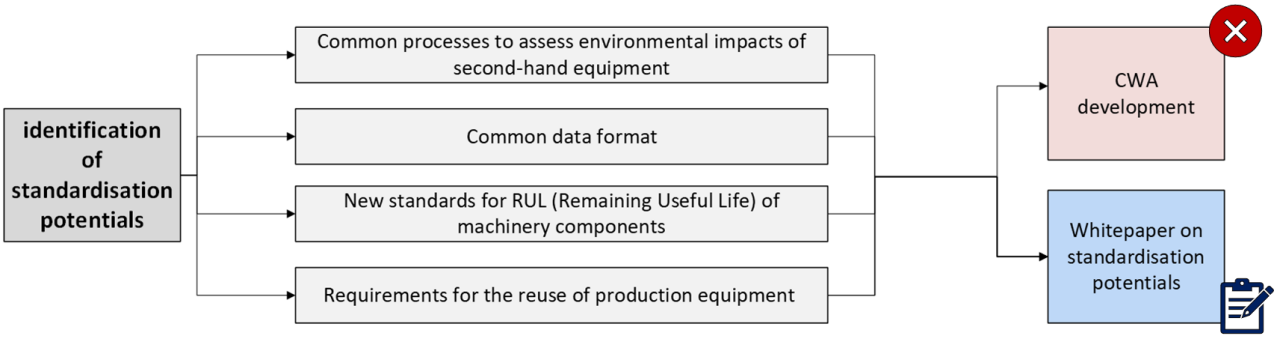


Figure 26: Subtask "identification of standardization potentials"

In the final year of the project, the standardization task will prioritize the dissemination and exploitation of results, ensuring that the project's contributions continue to support ongoing standardization efforts. By engaging with existing initiatives and leveraging the insights gained, ALICIA aims to maximize its impact on the standardization landscape.

With regard to the standardization of the ALICIA CME itself, it is acknowledged that it represents a highly complex framework encompassing multiple fundamental components, which makes standardizing the entire CME an intricate and multifaceted endeavor. Given the complex nature of the CME, it is indeed impractical to encapsulate its standardization within a single standard. Instead, it necessitates a series of interrelated standards that collectively define terminologies and establish foundational principles before delving into the standardization of individual key components.
The insights from our recent workshop illuminated the promising potential for standardization of the CME components. Nonetheless, it is apparent that the current landscape for standardization, particularly in areas related to the circular economy, is still nascent. This emerging status adds to the complexity of standardizing the elements of the ALICIA CME. The methodologies crafted within the project, such as those aimed at assessing the environmental impact of reused production equipment and deriving corresponding requirements, are primarily shaped by ongoing research initiatives. For these methodologies to evolve into universally accepted standards, it is imperative that they undergo practical application and validation not only by our use case partners but also other industry stakeholders.
To foster broader acceptance and transition towards standardization, it is envisioned to publish our standardization ideas and their potential benefits. Disseminating this information widely can catalyze greater engagement and concerted efforts within the broader standardization community, thus laying a more robust foundation for the eventual formalization of standards.
A significant challenge lies in the realm of workers' safety, which is notably impacted by the reuse of production equipment. Such safety-related issues extend beyond the scope of a specification like a CWA and must be addressed within Technical Committees (TCs), dedicated to developing comprehensive safety standards.
When considering standardizing a CME like the one developed within ALICIA the issue of "company secret" and maintaining confidentiality becomes critical. Companies often hold proprietary information and competitive intelligence that are fundamental to their operations. Balancing transparency for standardization purposes with the need to protect sensitive business information is paramount. To mitigate risks associated with company confidentiality, anonymizing data and focusing on aggregating findings can help in sharing valuable insights without compromising individual company secrets.

7. Summary and Conclusion (updated)

Generally, the present revised deliverable not only provides an overview of the standardization landscape related to ALICIA but also explains the standardization strategy for the project. Therefore, it summarizes the results achieved by February 2025 within ALICIA in Task 7.5 - *Standardization*.

The knowledge about existing standards is important for the project since it enables the development of solutions which are compliant with the latest standards and further paves the way for upcoming liaison activities with relevant technical committees. For this, a standards database in form of a dashboard was created, which includes 373 standards that could be relevant for the project. This dashboard provides the opportunity to search for specific standards and to identify standardization gaps. It is therefore used as the basis for the following activities in T7.5. Within this deliverable, the dashboard was used to describe the standardization activities on international and European level related to ALICIA. Focus was put on areas that have high relevance for the project. The standards used and its application within the project are described to show the alignment of ALICIA solutions with the state of the art.

Besides listing relevant standards, this deliverable offers an overview of the TC's that are working on standards related to the project. Since the interaction with relevant standardization committees is envisaged within ALICIA, an overview of current work items of the most relevant TC's is provided. This was taken as a basis for the interaction with relevant and related standardization committees to disseminate information about the ALICIA project and to analyze where in active involvement in ongoing standardization work makes sense. A stronger interaction in the form of a liaison is sought for ISO/TC 184 since this would offer the project the opportunity to integrate project results in current standardization work.

A workshop was held to analyze the need for standardization and thus the existence of possible standardization gaps in connection with ALICIA's work. Within this workshop several standardization potentials were collected. In subsequent meeting those ideas were discussed in more detail and a possible scope was developed for four potential standardization documents. Nevertheless, since no initiator for such a document could be found within ALICIA those potentials cannot be followed further into the development of a standardization document. It is planned to at least raise awareness to those standardization needs by writing a whitepaper where potential solutions in regard of standardization can be provided as a first basis.

Annex 1: Slides from the training “Basics on Standardization”

Basics on Standardisation

Training by DIN

04-11-2023

alicia – assembly lines in circulation

ALICIA – Project 101091577 – Horizon Europe

DIN Standards – well known

„A“ Paper sizes

For 95 years standard paper sizes have been used by manufacturers, sellers and consumers alike. These DIN formats have been adopted by almost all countries in the world and are now defined in DIN EN ISO 216.

Traveling the world: the ISO container

250 million ISO standard freight containers travel the world each year. ISO 668 is an excellent example of the impact of international standardization.

Made for business: ISO 9001

Quality management ISO 9001 helps organizations improve their processes and ensures a high quality of products and services.

Standardisation

*Standardisation is the activity of **establishing**, with regards to actual or potential **problems**, **provisions** for common and repeatable use, aimed at the achievement of the optimum degree of order in a given context.*

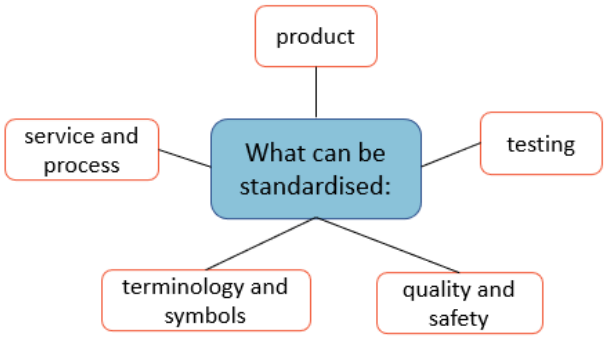
Source: EN 45020:2006 Standardization and related activities - General vocabulary (ISO/IEC Guide 2:2004)

Why are standards important for R&I projects?

What are the results from standardisation?

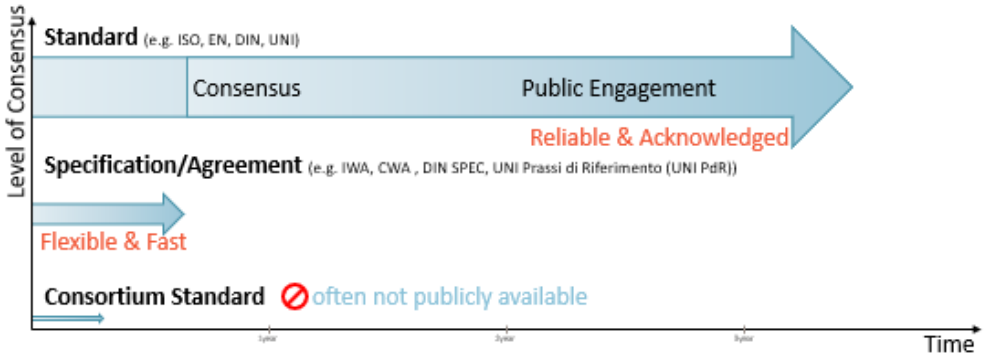
Deliverable of the standardisation process is a document

- ✓Voluntary
- ✓Open to the public
- ✓Broad participation
- ✓State of the art
- ✓Consistent



Standardisation deliverables

different types exist

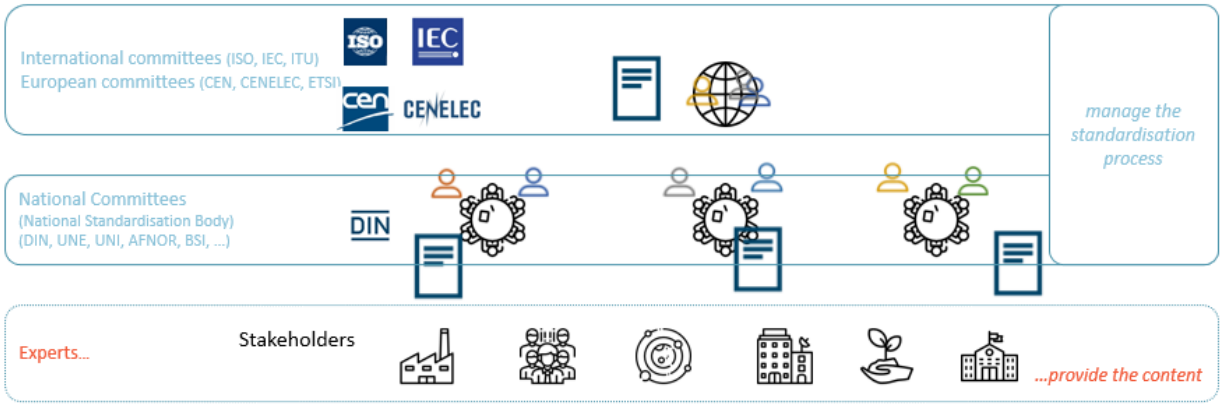


What are standards and specifications?

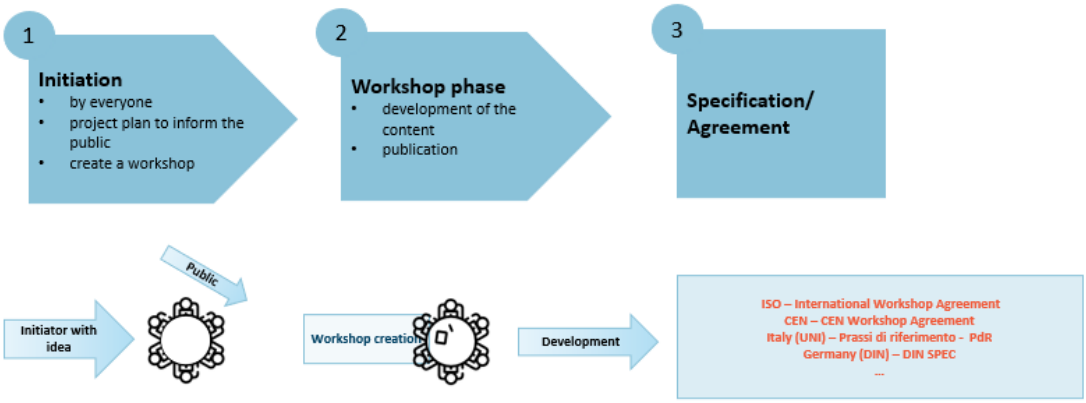
What is a standard?	What is a specification?
document that is approved by a recognized body and…	document agreed upon by the group of developers, which is designed to meet an immediate need and form the basis for future standardisation activities and…
• establishes a **common ground** • lays down **rules or guidlines** for activities or their results • creates **conformity** and order by **defining requirements** • developed by **all interested stakeholders** • produced by **consensus** • reflects the **state-of-the art**	• can be developed **outside the technical committee structure** • it is open to the **direct participation of anyone** • it offers **rapid** development opportunities • the **publication** within duration of project is possible

Standards are set by oneself; regulations come from „outside"!

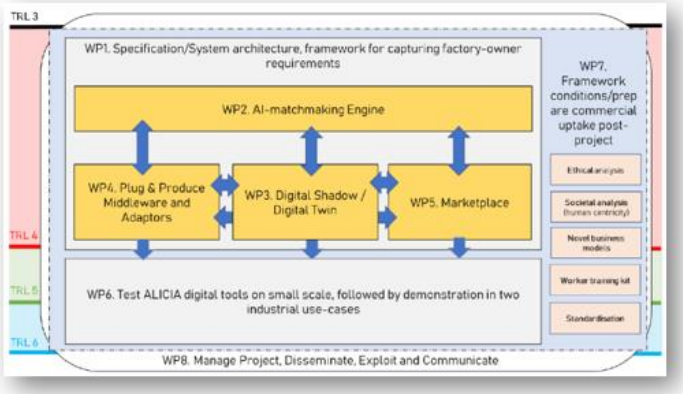
Development of standards



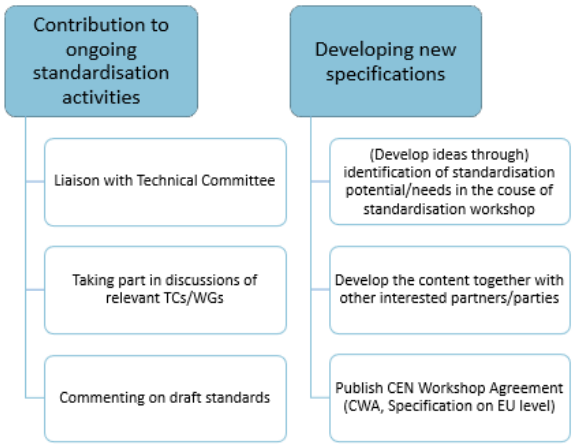
Development of a specification



How can we use this for ALICIA?



Participation – dissemination of ALICIA results



How we help you:

- Research of relevant standards
- Access to standards
- Liaisons with Technical Committees
- Identification of standardisation potentials
- Project management for your specification

Overview T7.5 Standardisation

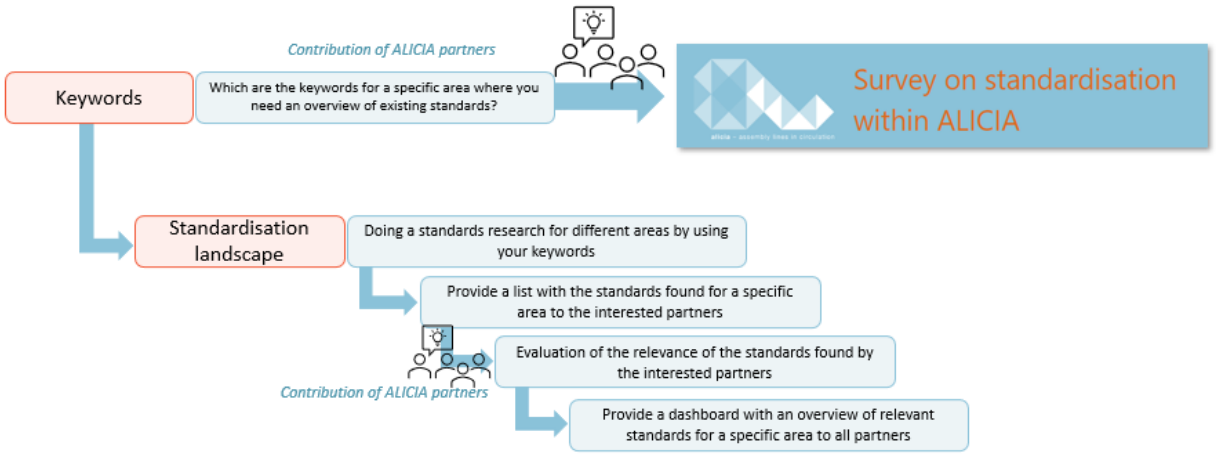
Identify standards relevant for the project
- Assessment of identified standardisation activities
- Provide insights from standards, standardisation work

Develop standardisation strategy
- Conduct standardisation potential workshops with the partners
- Comparison of identified standards with new potential topics
- Liaison with relevant standardisation committees

Performing standardisation activities
- Initiation of new standards / specifications (e.g. CEN Workshop Agreement - CWA)
- Contribution to ongoing standards development or update existing standards
- Dissemination of developed standards

What are the next steps?

Identify standards relevant for the project



Questions?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Annex 2: Survey partner's expertise on standardization

Have you ever been or are you currently active in a standardization committee or other organizations? AND If yes, in which one(s)?

Three persons from three different organizations have ever been active or are currently active in standardization, namely in the following standardization organizations: IEEE SMC (IEEE 7010), ISO/TC 299 Robotics, AAL Spain (Ambient Assisted Living Spain)

Have you ever developed a pre-standardization document such as a CWA (CEN Workshop Agreement)? AND If yes, please name the document/workshop.

One person has ever developed a pre-standardization document such as a CWA.

In which area do you apply or plan to apply standards as parts of your activities within ALICIA?

Nine of the participating persons apply or plan to apply standards as part of their activities within ALICIA, and the following Figure 27 gives an overview in which areas

Figure 27: Overview of areas in which the partners already use or plan to use standards for their work within ALICIA

Which standards do you already know / use within your activities in ALICIA?

The following standards are already known and/or used by the partners within ALICIA:

- ISO 14040 etc.
- VDI 2860
- ISO 9001:2015
- standards related to manufacturing systems design and safety of machines (e.g. EN ISO 10218-1-2, EN ISO 12100:2010 and other relevant standards)
- OPC-UA, MQTT, MT-Connect
- Catena-X, Gaia-X and Manufacturing-X Standards
- Some national DIN standards for data exchange

Is there something you would like to standardize within ALICIA? Or do you already know an area within ALICIA where standards are still missing?

- a sort of roadmap for circular manufacturing or circularity in automation or something similar
- Standardization of machine connectivity
- Sustainability, circular manufacturing, and digitalization of systems; manufacturing systems architectures, sustainable business models, digitalization of production systems
- Manufacturing systems architectures, sustainable business models, digitalization of production systems
- The data exchange between the different machines and modules
- The software requirements related to the ALICIA Tool
- Ontologies for assembly resources, resource description for Plug & Produce Middleware
- digital twin, request for quotation, equipment health assessment
- Data flow, AI component, and digital marketplace platform
- Defining new or integrating pre-existing adequate standards throughout the purchase and sale of used machinery so that the existing trust and acceptance barriers for the sector are lowered
- Standard for equipment re-use

Annex 3: Table of data of the ALICIA dashboard

List of relevant Standards for ALICIA, results outlined in red belong to the area "others", results outlined in dark green belong to the area "industry", results outlined in violet belong to the area "automation", results outlined in orange belong to the area "digitalization", results outlined in yellow belong to the area "quality management", results outlined in bright green belong to the area "circular economy"

document number	titel	publication date
ISO/IEC TR 24027	Information technology - Artificial intelligence (AI) - Bias in AI systems and AI aided decision making	2021-11-00
ISO/IEC TR 24368	Information technology - Artificial intelligence - Overview of ethical and societal concerns	2022-08-00
ISO/IEC 38507	Information technology - Governance of IT - Governance implications of the use of artificial intelligence by organizations	2022-04-00
VDI-EE 4030	Consideration of human reliability in the design of autonomous systems	2022-04-00
VDA Band 4 Abschnitt 3	Quality Management in the Automotive Industry - Quality Assurance in the Process Landscape - Section 3: Methods - Design for Manufacturing and Assembly (DFMA), Digital Mock-Up (DMU), Design of Experiments (DoE) – Trial Methodology, Manufacturing Feasibility Analysis, POKA YOKE, Quality Function Deployment (QFD), TRIZ, Economical Process Design and Process Control, 8D Method, 5 Why Method, Selection of Preventive Quality Management Methods	2020-08-00
ASAM ACI	Automatic Calibration Interface; Version 1.4.0	2014-06-30
ASAM GDI	Generic Device Interface; Version 4.5.0	2011-01-31
ASAM MDF	Measurement Data File Format; Version 4.2.0	2019-09-30
ITU-T Y.4500.11	oneM2M - Common terminology	2018-03-00
IECQ 03-3-2*CEIQ 03-3-2	IEC System of Conformity Assessment Schemes for Electrotechnical Equipment and Components (IECEE System) - Rules of procedure - Part 3-2: IECQ approved component products, related materials & assemblies scheme - IECQ approved component - automotive qualification programme (IECQ AC-AQP); Edition 3.0	2019-07-00
EN 100114-6	Rule of procedure 14: Quality assessment procedures - Part 6: Technology approval of electronic component manufacturers	1996-12-00
EN 100114-6/A1	CECC Quality assessment procedure for electronic components - Part 6: Technology approval of manufacturers; Amendment A1	1999-02-00
EN 1005-2+A1	Safety of machinery - Human physical performance - Part 2: Manual handling of machinery and component parts of machinery	2008-10-00
EN 1005-3+A1	Safety of machinery - Human physical performance - Part 3: Recommended force limits for machinery operation	2008-10-00
ISO/DIS 10218-1	Robotics - Safety requirements - Part 1: Industrial robots	2021-06-00
ISO 12100	Safety of machinery - General principles for design - Risk assessment and risk reduction	2010-11-00
EN 12102-1	Air conditioners, liquid chilling packages, heat pumps, process chillers and dehumidifiers with electrically driven compressors - Determination of the sound power level - Part 1: Air conditioners, liquid chilling packages, heat pumps for space heating and cooling, dehumidifiers and process chillers	2022-07-00
EN 12102-2	Air conditioners, liquid chilling packages, heat pumps, process chillers and dehumidifiers with electrically driven compressors - Determination of the sound power level - Part 2: Heat pump water heaters	2019-05-00
ISO 12620-2	Management of terminology resources - Data categories - Part 2: Repositories	2022-07-00
EN 12882	Conveyor belts for general purpose use - Electrical and flammability safety requirements	2015-08-00
ISO 13374-1	Condition monitoring and diagnostics of machines - Data processing, communication and presentation - Part 1: General guidelines	2003-03-00
EN 13675+A1	Safety of machinery - Safety requirements for tube forming and rolling mills and their finishing line equipment	2010-04-00
ISO 14123-2	Safety of machinery - Reduction of risks to health resulting from hazardous substances emitted by machinery - Part 2: Methodology leading to verification procedures	2015-11-00
ISO 14649-11	Industrial automation systems and integration - Physical device control - Data model for computerized numerical controllers - Part 11: Process data for milling	2004-12-00
ISO 14649-12	Industrial automation systems and integration - Physical device control - Data model for computerized numerical controllers - Part 12: Process data for turning	2005-12-00
ISO 14649-13	Automation systems and integration - Physical device control - Data model for computerized numerical controllers - Part 13: Process data for wire electrical discharge machining (wire-EDM)	2013-03-00
ISO 14649-14	Automation systems and integration - Physical device control - Data model for computerized numerical controllers - Part 14: Process data for sink electrical discharge machining (sink-EDM)	2013-03-00
EN 14656+A1	Safety of machinery - Safety requirements for extrusion presses for steel and non-ferrous metals	2010-04-00
EN 14677	Safety of machinery - Secondary steelmaking - Machinery and equipment for treatment of liquid steel	2008-04-00
EN 14681+A1	Safety of machinery - Safety requirements for machinery and equipment for production of steel by electric arc furnaces	2010-04-00
EN 14753	Safety of machinery - Safety requirements for machinery and equipment for continuous casting of steel	2022-03-00
EN 1550+A1	Machine-tools safety - Safety requirements for the design and construction of work holding chucks	2008-07-00
ISO 15519-1	Specification for diagrams for process industry - Part 1: General rules	2010-03-00
EN 15949	Safety of machinery - Safety requirements for bar mills, structural steel mills and wire rod mills	2012-02-00
ISO 16100-3	Industrial automation systems and integration - Manufacturing software capability profiling for interoperability - Part 3: Interface services, protocols and capability templates	2005-12-00
ISO 16100-5	Industrial automation systems and integration - Manufacturing software capability profiling for interoperability - Part 5: Methodology for profile matching using multiple capability class structures	2009-03-00
ISO 16156	Machine-tools safety - Safety requirements for the design and construction of work holding chucks	2004-02-00
ISO 16300-4	Automation systems and integration - Interoperability of capability units for manufacturing application solutions - Part 4: Capability unit assessment for the manufacturing application requirements	2019-12-00
DIN SPEC 16589	Information technology - Automatic identification and data capture techniques - Traceability Pointer to Process	2018-07-00
DIN SPEC 16592	Combining OPC Unified Architecture and Automation Markup Language	2016-12-00
EN 16774	Safety of machinery - Safety requirements for steel converter and associated equipment	2016-04-00
DIN EN 17071	Information technology - Automatic identification and data capture techniques - Electronic identification plate; German version EN 17071:2019	2019-05-00
EN 17161	Design for All - Accessibility following a Design for All approach in products, goods and services - Extending the range of users	2019-03-00
ISO 17916	Safety of thermal cutting machines	2016-03-00

ISO 18435-1	Industrial automation systems and integration - Diagnostics, capability assessment and maintenance applications integration - Part 1: Overview and general requirements	2009-08-00
ISO 18435-2	Industrial automation systems and integration - Diagnostics, capability assessment and maintenance applications integration - Part 2: Descriptions and definitions of application domain matrix elements	2012-09-00
ISO 18436-4	Condition monitoring and diagnostics of machines - Requirements for qualification and assessment of personnel - Part 4: Field lubricant analysis	2014-02-00
ISO 18436-7	Condition monitoring and diagnostics of machines - Requirements for qualification and assessment of personnel - Part 7: Thermography	2014-04-00
ETSI GS SMT 001 V 2.1.1	Surface Mount Technology (SMT) - Requirements for Embedded Communication Modules For Machine To Machine Communications	2015-06-00
ISO/TR 20218-1	Robotics - Safety design for industrial robot systems - Part 1: End-effectors	2018-08-00
ISO/TR 20218-2	Robotics - Safety design for industrial robot systems - Part 2: Manual load/unload stations	2017-12-00
ISO 20242-4	Industrial automation systems and integration - Service interface for testing applications - Part 4: Device capability profile template	2011-12-00
VDI 2048 Blatt 2	Control and quality improvement of process data and their uncertainties by means of correction calculation for operation and acceptance tests - Examples, especially retrofit measures	2018-06-00
ISO/TR 20527	Intelligent transport systems - Interoperability between interoperable fare management (IFM) systems and near field communication (NFC) mobile devices	2022-01-00
ISO/IEC/IEEE 21841	Systems and software engineering - Taxonomy of systems of systems	2019-07-00
VDI/VDE 2192	Interoperability in Industrie 4.0 systems - Quality of services - Characteristic parameters and influencing quantities	2021-10-00
ISO 22093	Industrial automation systems and integration - Physical device control - Dimensional Measuring Interface Standard (DMIS)	2011-05-00
CEN ISO/TR 22100-1	Safety of machinery - Relationship with ISO 12100 - Part 1: How ISO 12100 relates to type-B and type-C standards (ISO/TR 22100-1:2021)	2021-02-00
ISO 22385	Security and resilience - Authenticity, integrity and trust for products and documents - Guidelines to establish a framework for trust and interoperability	2023-02-00
ISO 23062	Foundry machinery - Safety requirements for molding and coremaking machinery and associated equipment	2022-07-00
ISO 23081-2	Information and documentation - Metadata for managing records - Part 2: Conceptual and implementation issues	2021-08-00
ISO/TR 23087	Automation systems and integration - The Big Picture of standards	2018-03-00
ISO 23952	Automation systems and integration - Quality information framework (QIF) - An integrated model for manufacturing quality information	2020-07-00
ISO/IEC FDIS 24392	Cybersecurity - Security reference model for industrial internet platform (SRM- IIP)	2023-04-00
ISO/TR 24463	Digital validation by effective use of simulation	2021-10-00
VDMA 24494	DISPO 015 - Bus interface between the high pressure metal die casting machine and extracting device	2012-03-00
VDMA 24495	DISPO 025 - Bus interface between the high pressure metal die casting machine and die spraying device	2012-03-00
ISO 26303	Machine tools - Short-term capability evaluation of machining processes on metal-cutting machine tools	2022-03-00
VDI/VDE 2645 Blatt 3	Capability test for bolting technology machines - Process capability test (PFU)	2019-02-00
VDI 2870 Blatt 1	Lean production systems - Basic principles, introduction, and review	2012-07-00
VDI 2885	Standardized data for maintenance planning and determination of maintenance costs - Data and data determination	2020-01-00
VDI 2889	Maintenance 4.0 - Diagnostic processes and methods	2022-04-00
ISO/TS 29002-10	Industrial automation systems and integration - Exchange of characteristic data - Part 10: Characteristic data exchange format	2009-12-00
ISO/TS 29002-31	Industrial automation systems and integration - Exchange of characteristic data - Part 31: Query for characteristic data	2009-12-00
ISO/TS 29002-4	Industrial automation systems and integration - Exchange of characteristic data - Part 4: Basic entities and types	2009-12-00
ISO/TS 29002-6	Industrial automation systems and integration - Exchange of characteristic data - Part 6: Concept dictionary terminology reference model	2010-04-00
VDI 3405 Blatt 6.2	Additive manufacturing processes - User safety on operating the manufacturing facilities - Laser sintering of polymers	2021-04-00
VDI/VDE 3850 Blatt 3	Development of usable user interfaces for technical plants - Features, design and applications of user interfaces with touchscreen	2015-11-00
VDI/VDE 3850 Blatt 2	Development of usable user interfaces for technical plants - Interaction devices for screens	2017-01-00
VDMA 40001-2	OPC UA for Machinery - Part 2: Process Values	2023-05-00
VDMA 40079	OPC UA interfaces for plastics and rubber machinery – Data exchange between injection moulding machines and robots	2022-01-00
VDMA 40100-2	OPC UA for Machine Vision - Part 2: Asset Management and Condition Monitoring	2022-11-00
VDMA 40210	OPC UA for Geometric Measurement Systems	2022-04-00
VDMA 40451-1	OPC UA for Tightening Systems - Part 1: Asset Management, Results and Basic Events	2022-01-00
VDMA 40501-1	OPC UA for Machine Tools - Part 1: Machine Monitoring and Job Overview	2022-09-00
VDMA 40502	OPC UA for Computerized Numerical Control (CNC) Systems	2019-11-00
VDMA 40540	OPC UA for Additive Manufacturing	2023-05-00
VDI 4499 Blatt 4	Digital factory - Ergonomic representation of humans in the digital factory	2015-03-00
DIN EN 60204-33*VDE 0113-33	Safety of machinery - Electrical equipment of machines - Part 33: Requirements for semiconductor fabrication equipment (IEC 60204-33:2009, modified); German version EN 60204-33:2011	2011-11-00
EN IEC 60812	Failure modes and effects analysis (FMEA and FMECA) (IEC 60812:2018)	2018-10-00
EN 61069-1	Industrial-process measurement, control and automation - Evaluation of system properties for the purpose of system assessment - Part 1: Terminology and basic concepts (IEC 61069-1:2016)	2016-10-00
EN 61069-3	Industrial-process measurement, control and automation - Evaluation of system properties for the purpose of system assessment - Part 3: Assessment of system functionality (IEC 61069-3:2016)	2016-10-00
EN 61069-4	Industrial-process measurement, control and automation - Evaluation of system properties for the purpose of system assessment - Part 4: Assessment of system performance (IEC 61069-4:2016)	2016-11-00
EN 61069-5	Industrial-process measurement, control and automation - Evaluation of system properties for the purpose of system assessment - Part 5: Assessment of system dependability (IEC 61069-5:2016)	2016-09-00
EN 61069-7	Industrial-process measurement, control and automation - Evaluation of system properties for the purpose of system assessment - Part 7: Assessment of system safety (IEC 61069-7:2016)	2016-09-00
EN 614-1+A1	Safety of machinery - Ergonomic design principles - Part 1: Terminology and general principles	2009-02-00
IEC 62541-5*CEI 62541-5	OPC unified architecture - Part 5: Information Model	2020-07-00
IEC 62541-6*CEI 62541-6	OPC unified architecture - Part 6: Mappings	2020-07-00
IEC 62541-7*CEI 62541-7	OPC unified architecture - Part 7: Profiles	2020-06-00
IEC 62541-8*CEI 62541-8	OPC unified architecture - Part 8: Data access	2020-06-00

IEC 62541-9*CEI 62541-9	OPC unified architecture - Part 9: Alarms and Conditions	2020-06-00
IEC 62714-1*CEI 62714-1	Engineering data exchange format for use in industrial automation systems engineering - Automation markup language - Part 1: Architecture and general requirements	2018-04-00
DIN EN IEC 62714-2	Engineering data exchange format for use in industrial automation systems engineering - Automation markup language - Part 2: Semantics libraries (IEC 65E/699/CD:2020); Text in German and English	2020-11-00
ISO/IEC 30162	Internet of Things (IoT) - Compatibility requirements and model for devices within industrial IoT systems	2022-02-00
EN 45554	General methods for the assessment of the ability to repair, reuse and upgrade energy-related products	2020-02-00
IEC 62541-11*CEI 62541-11	OPC unified architecture - Part 11: Historical Access	2020-06-00
IEC 62541-12*CEI 62541-12	OPC unified architecture - Part 12: Discovery and global services	2020-06-00
IEC 62541-13*CEI 62541-13	OPC Unified Architecture - Part 13: Aggregates	2020-06-00
IEC 62541-14*CEI 62541-14	OPC unified architecture - Part 14: PubSub	2020-07-00
IEC 62541-3*CEI 62541-3	OPC unified architecture - Part 3: Address Space Model	2020-07-00
IEC/PAS 63088*CEI/PAS 63088	Smart manufacturing - Reference architecture model industry 4.0 (RAMI4.0)	2017-03-00
prEN IEC 63278-1	Asset Administration Shell for industrial applications - Part 1: Asset Administration Shell structure	2022-05-00
IEC 65/977/CD*CEI 65/977/CD*IEC/TR 63283-4*CEI/TR 63283-4	Industrial-process measurement, control and automation - Smart Manufacturing - Part 4: Recommendations for the usage of new technologies	2023-02-00
IEC 65/992/CD*CEI 65/992/CD*IEC 63278-2*CEI 63278-2	Asset Administration Shell for Industrial Applications - Part 2: Information meta model	2023-03-00
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ISO 20140-1	Automation systems and integration - Evaluating energy efficiency and other factors of manufacturing systems that influence the environment - Part 1: Overview and general principles	2019-09-00
ETSI ES 203199 V 1.3.1	Environmental Engineering (EE) - Methodology for environmental Life Cycle Assessment (LCA) of Information and Communication Technology (ICT) goods, networks and services	2015-02-00
VDI 2343 Blatt 7	Recycling of electrical and electronical equipment - Re-use	2014-12-00
ISO 26000	Guidance on social responsibility	2010-11-00
DIN/TS 35807	Guideline for Life Cycle Assessment according to DIN EN ISO 14001:2015-11	2020-08-00
ECMA-370	TED - The ECO Declaration	2019-06-00
VDI 4431	Life-cycle management in the manufacturing industry	2001-07-00
EN 45554	General methods for the assessment of the ability to repair, reuse and upgrade energy-related products	2020-02-00
VDI 4605	Evaluation of sustainability	2017-10-00
EN 50614	Requirements for the preparing for re-use of waste electrical and electronic equipment	2020-02-00
EN 50678	General procedure for verifying the effectiveness of the protective measures of electrical equipment after repair	2020-03-00
EN 50693	Product category rules for life cycle assessments of electronic and electrical products and systems	2019-08-00
ISO/DIS 59004	Circular Economy - Terminology, Principles and Guidance for Implementation	2023-04-00
ISO/DIS 59010	Circular Economy — Guidance on the transition of business models and value networks	2023-04-00
ISO/DIS 59020	Circular economy - Measuring and assessing circularity	2023-04-00
IEC 62309*CEI 62309	Dependability of products containing reused parts - Requirements for functionality and tests	2004-07-00
IEC 62619*CEI 62619	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications	2022-05-00
IEC/TR 62921*CEI/TR 62921	Quantification methodology for greenhouse gas emissions for computers and monitors	2016-10-00
prEN IEC 63366	Product category rules for life cycle assessment of electrical and electronic products and systems.	2023-03-00
IEC 111/691/CDV*CEI 111/691/CDV*IEC 63366*CEI 63366	Product category rules for life cycle assessment of electrical and electronic products and systems.	2023-03-00
VDA 900-100	Guidance for Conducting Life Cycle Assessment Studies of Passenger Cars	2022-08-00
DIN SPEC 91472	Remanufacturing (Reman) - Quality classification for circular processes	2023-06-00

Annex 4: Stage Codes[53]

Stage	***Substage***						
				90 Decision			
	00 *Registration*	*20* *Start of main action*	*60* *Completion of main action*	*92* *Repeat an earlier phase*	*93* *Repeat current phase*	*98* *Abandon*	*99* *Proceed*
00 **Preliminary stage**	00.00 Proposal for new project received	00.20 Proposal for new project under review	00.60 Close of review			00.98 Proposal for new project abandoned	00.99 Approval to ballot proposal for new project
10 **Proposal stage**	10.00 Proposal for new project registered	10.20 New project ballot initiated	10.60 Close of voting	10.92 Proposal returned to submitter for further definition		10.98 New project rejected	10.99 Approval to new project approved
20 **Preparatory stage**	20.00 New project registered in TC/SC work programme	20.20 Working draft (WD) study initiated	20.60 Close of comment period			20.98 Project deleted	20.99 WD approved for registration as CD
30 Committee stage	30.00 Committee draft (CD) registered	30.20 CD Study initiated	30.60 Close of comment period	30.92 CD referred back to Working Group		30.98 Project deleted	30.99 CD approved for registration as DIS
40 **Enquiry stage**	40.00 DIS registered	40.20 DIS ballot initiated: 12 weeks	40.60 Close of voting	40.92 Full report circulated: DIS referred back to TC or SC	40.93 Full report circulated: decision for new DIS ballot	40.98 Project deleted	40.99 Full report circulated: DIS approved for registration as FDIS
50 **Approval stage**	50.00 Final text received or FDIS registered for formal approval	50.20 Proof sent to secretariat or FDIS ballot initiated: 8 weeks	50.60 Close of voting. Proof returned by secretariat	50.92 FDIS or proof referred back to TC or SC		50.98 Project deleted	50.99 FDIS or proof approved for publication

[53] https://www.iso.org/files/live/sites/isoorg/files/developing_standards/docs/en/stage_codes.pdf, last access: 16.10.2023

Stage	***Substage***						
				90 Decision			
	00 *Registration*	*20* *Start of main action*	*60* *Completion of main action*	*92* *Repeat an earlier phase*	*93* *Repeat current phase*	*98* *Abandon*	*99* *Proceed*
60 **Publication stage**	60.00 International Standard under publication		60.60 International Standard published				
90 **Review stage**		90.20 International Standard under periodical review	90.60 Close of review	90.92 International Standard to be revised	90.93 International Standard confirmed		90.99 Withdrawal of International Standard proposed by TC or SC
95 **Withdrawal stage**		95.20 Withdrawal ballot initiated	95.60 Close of voting	95.92 Decision not to withdraw International Standard			95.99 Withdrawal of International Standard

Annex 5: Conceptboard from the standardization potential workshop

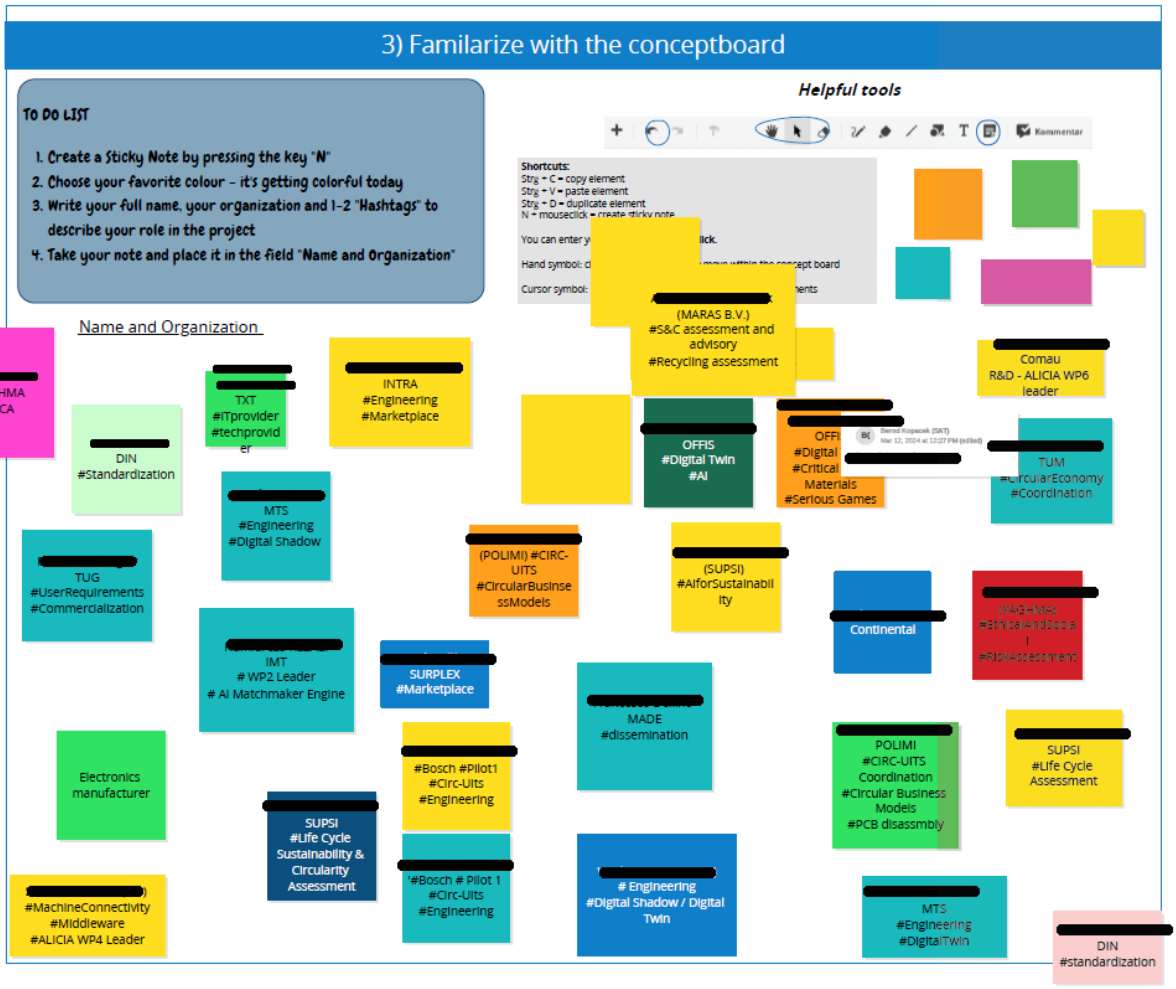
CIRC-UITS Project 101091490 Project 101091577

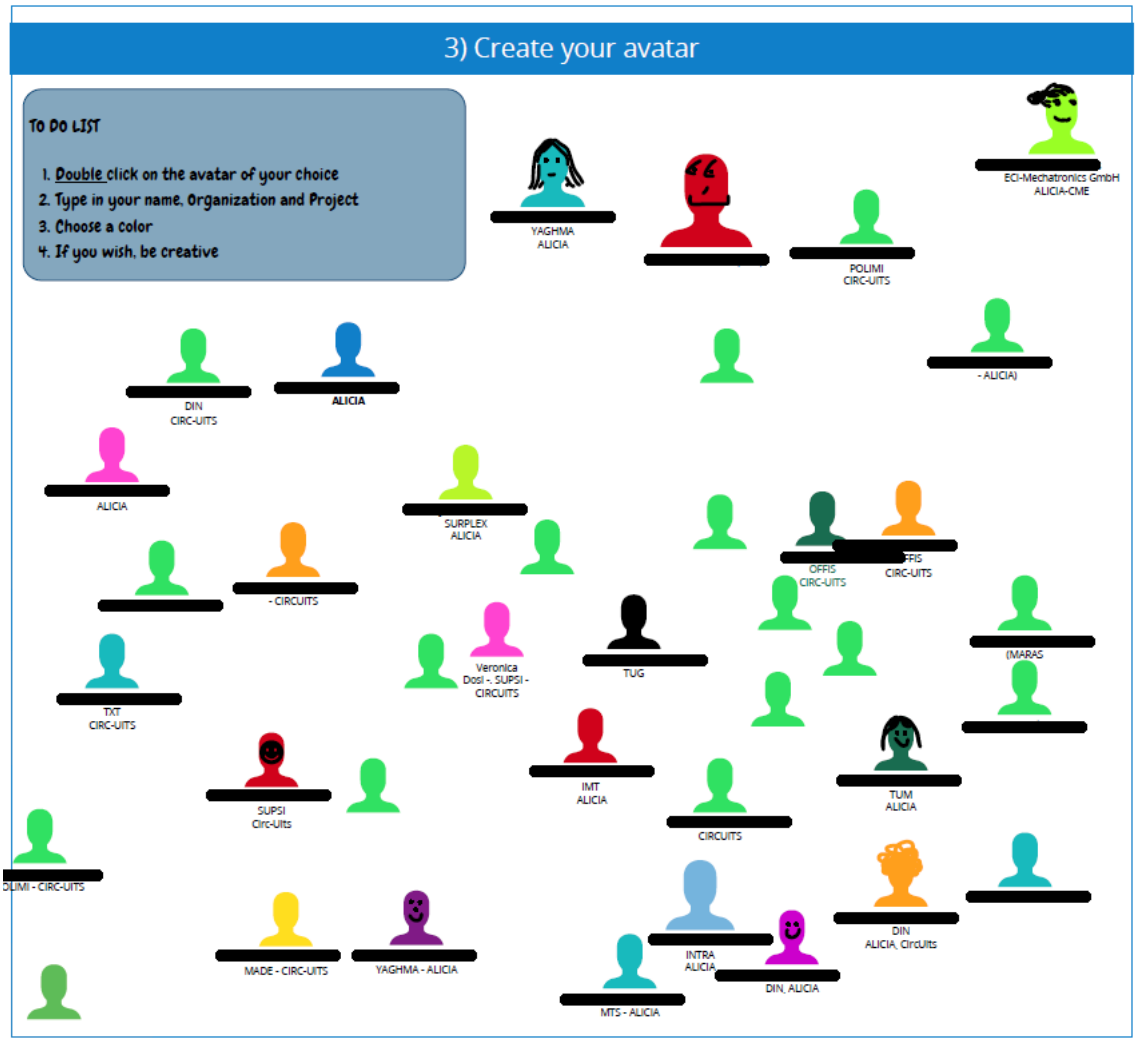
DIN

Agenda standardization potential workshop

Time (CET)	Description	Contributors
1:00 – 1:10 pm	1) Welcome & Introduction	DIN
1:10 – 1:25 pm	2) Presentation of CircUits and ALICIA	POLIMI, TUM
1:25 – 1:45 pm	3) Familarization with „Conceptboard" & Introduction round (interactive)	All participants
1:45 – 2:15 pm	4) Basics on standardization (interactive)	All participants
2:15 – 2:30 pm	Break	All participants
2:30 – 2:35 pm	Group photo	All participants
2:35 – 2:45 pm	5) „Back to the future" – What does a successful project look like?	DIN
2:45 – 3:00 pm	6) Relevant technical committees for possible contribution (interactive)	All participants
3:00 – 3:45 pm	7) Standardization potentials • Identification of challenges & identification of potentials (interactive) • Presentation of ideas (DIN) • Rating of ideas (interactive)	All participants
3:45 – 3:55 pm	8) Outlook and next steps	DIN
3:55 – 4:00 pm	Feedback	All participants

Funded by the European Union


3) Familarize with the conceptboard
To Do LIST
1. Create a Sticky Note by pressing the key "N"
2. Choose your favorite colour - it's getting colorful today
3. Write your full name, your organization and 1-2 "Hashtags" to describe your role in the project
4. Take your note and place it in the field "Name and Organization"
Helpful tools
Shortcuts:
Strg + C = copy element
Strg + V = paste element
Strg + D = duplicate element
N = mouseclick = create sticky note
Name and Organization
YAGHMA #LCA
DIN #Standardization
TXT #ITprovider #techprovider
INTRA #Engineering #Marketplace
(MARAS B.V.) #S&C assessment and advisory #Recycling assessment
Comau R&D - ALICIA WP6 leader
OFFIS #Digital Twin #AI
OFFI #Digital #Critical Materials #Serious Games
TUM #CircularEconomy #Coordination
MTS #Engineering #Digital Shadow
TUG #UserRequirements #Commercialization
(POLIMI) #CIRC-UITS #CircularBusinesssModels
(SUPSI) #AIforSustainability
Continental
YAGHMA #EthicalAndSocial #RiskAssessment
IMT # WP2 Leader # AI Matchmaker Engine
SURPLEX #Marketplace
MADE #dissemination
POLIMI #CIRC-UITS Coordination #Circular Business Models #PCB disassmbly
SUPSI #Life Cycle Assessment
Electronics manufacturer
#Bosch #Pilot1 #Circ-Uits #Engineering
SUPSI #Life Cycle Sustainability & Circularity Assessment
#Bosch # Pilot 1 #Circ-Uits #Engineering
Engineering #Digital Shadow / Digital Twin
MTS #Engineering #DigitalTwin
#MachineConnectivity #Middleware #ALICIA WP4 Leader
DIN #standardization

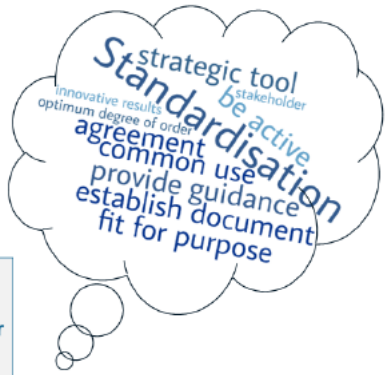

3) Create your avatar
To Do LIST
1. Double click on the avatar of your choice
2. Type in your name, Organization and Project
3. Choose a color
4. If you wish, be creative
YAGHMA
ALICIA
POLIMI
CIRC-UITS
ECI-Mechatronics GmbH
ALICIA-CME
DIN
CIRC-UITS
ALICIA
- ALICIA)
ALICIA
SURPLEX
ALICIA
OFFIS
CIRC-UITS
- CIRCUITS
TUG
(MARAS
Veronica
Dosi -. SUPSI -
CIRCUITS
TXT
CIRC-UITS
IMT
ALICIA
TUM
ALICIA
SUPSI
Circ-Uits
CIRCUITS
DIN
ALICIA, CircUits
INTRA
ALICIA
DIN, ALICIA
MADE - CIRC-UITS
YAGHMA - ALICIA
MTS - ALICIA

What is “Standardization“?

Standardisation…

activity of establishing, with regards to actual or potential problems, **provisions for common and repeatable use**, aimed at the achievement of the optimum degree of order in a given context

(Source: EN 45020:2006 Standardization and related activities - General vocabulary (ISO/IEC Guide 2:2004))



Standard…

document, established by consensus and approved by a recognized body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context

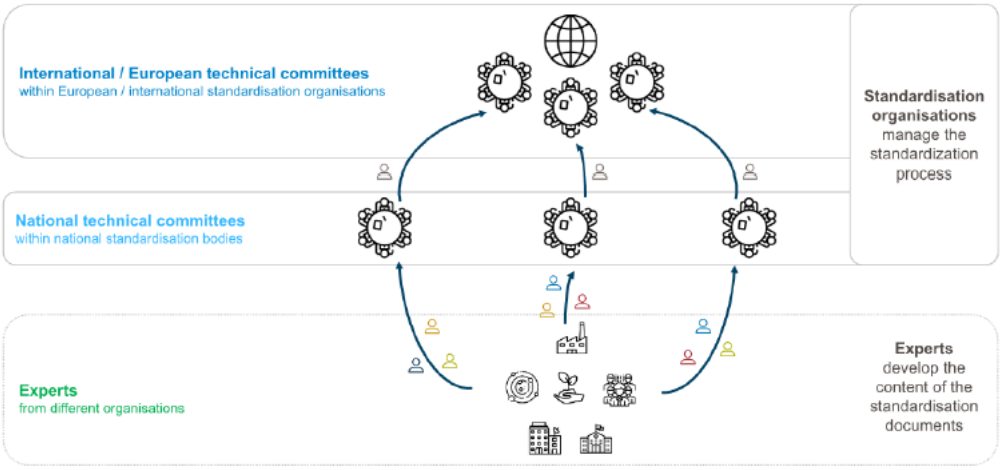
(Source: EN 45020:2006 Standardization and related activities - General vocabulary (ISO/IEC Guide 2:2004))

Why is standardisation important for R&I projects?

Why are standards important for R&I projects?

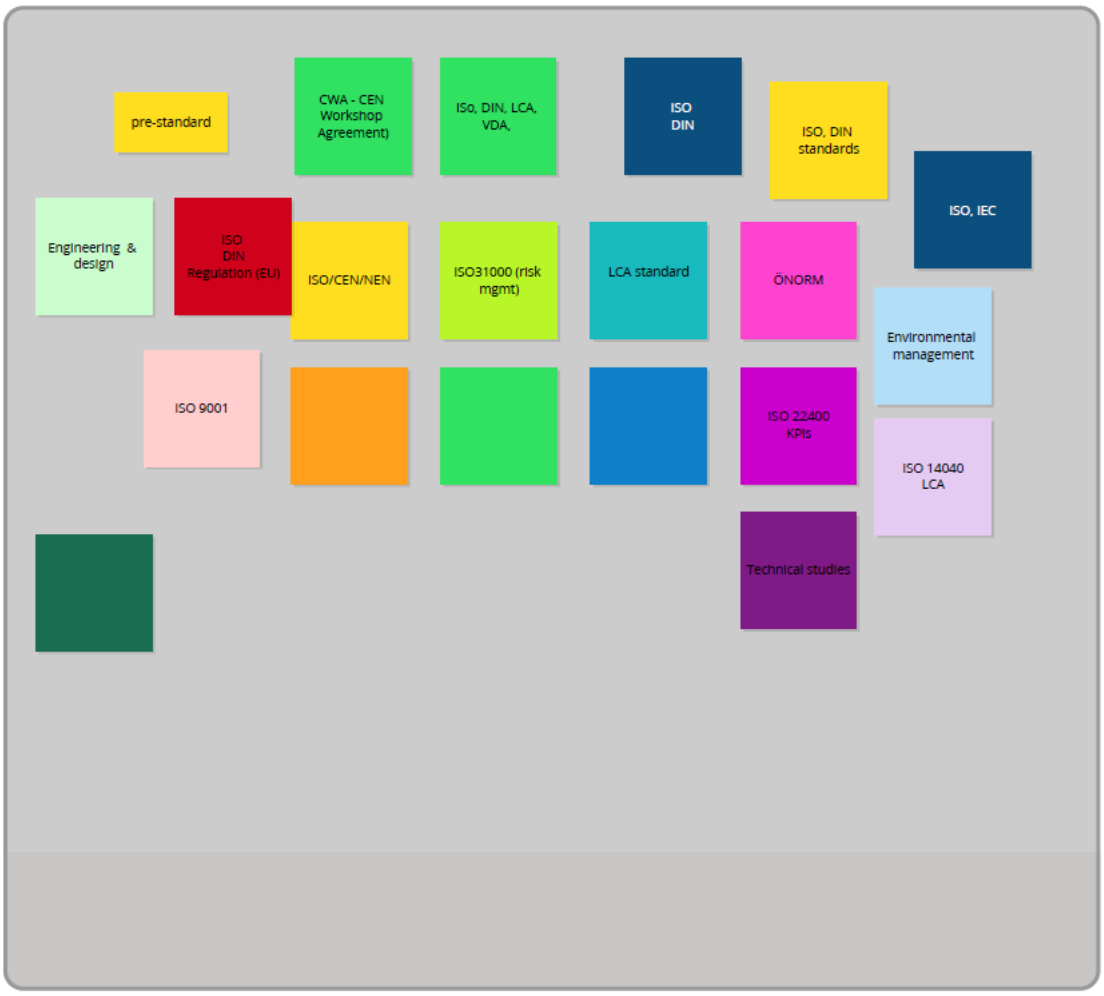
Where are standards developed?

Development of standardization documents in technical committees

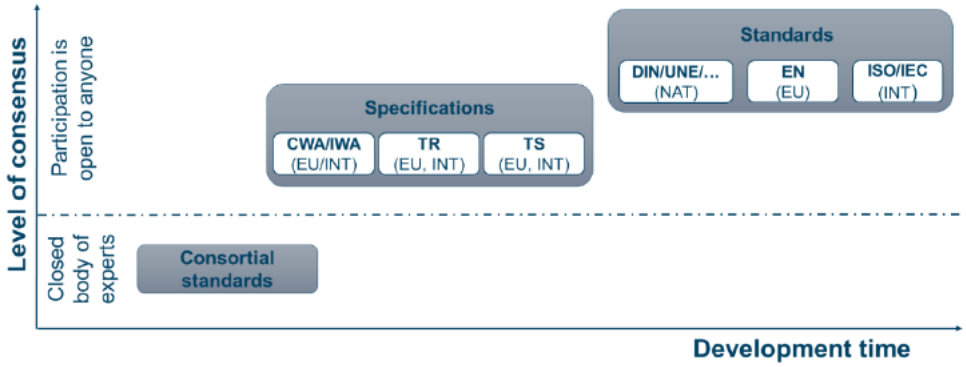


Standards development on national, European and international level

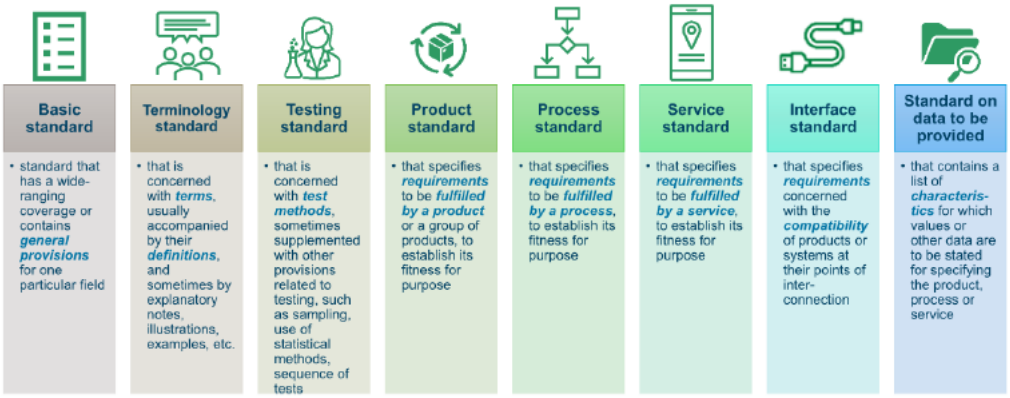
What type of standardisation documents do you know?



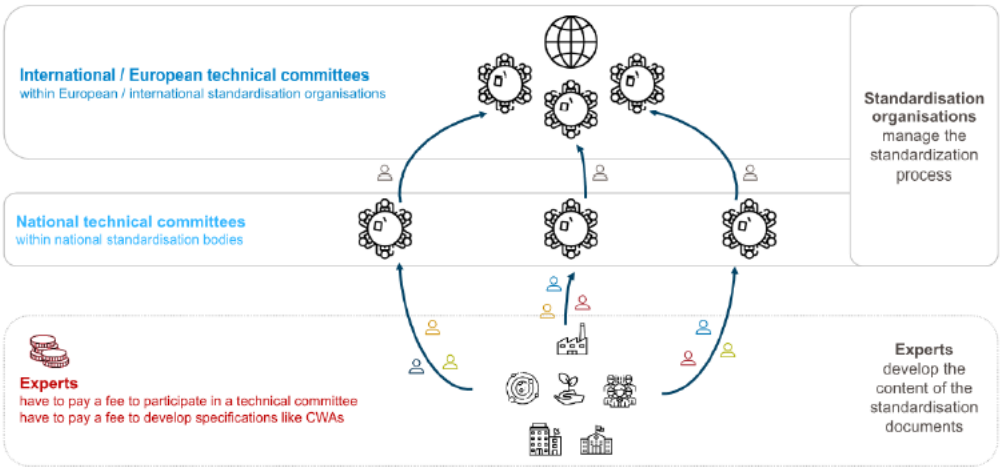
Types of standardisation deliverables



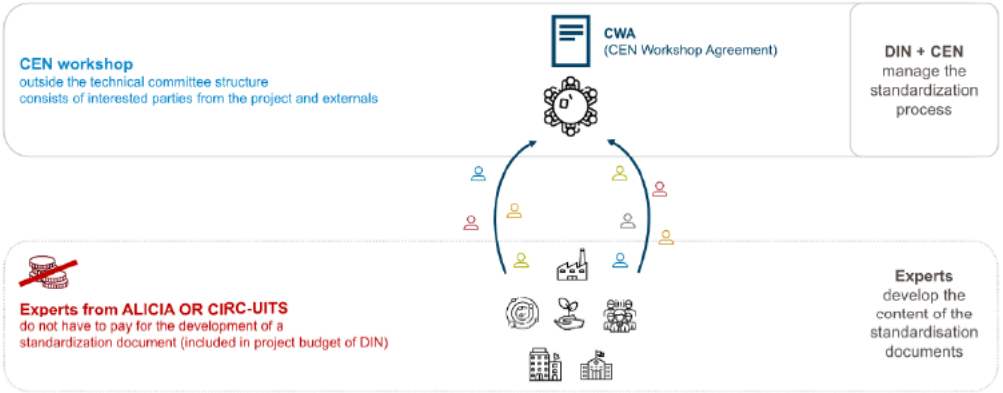
Types of standards

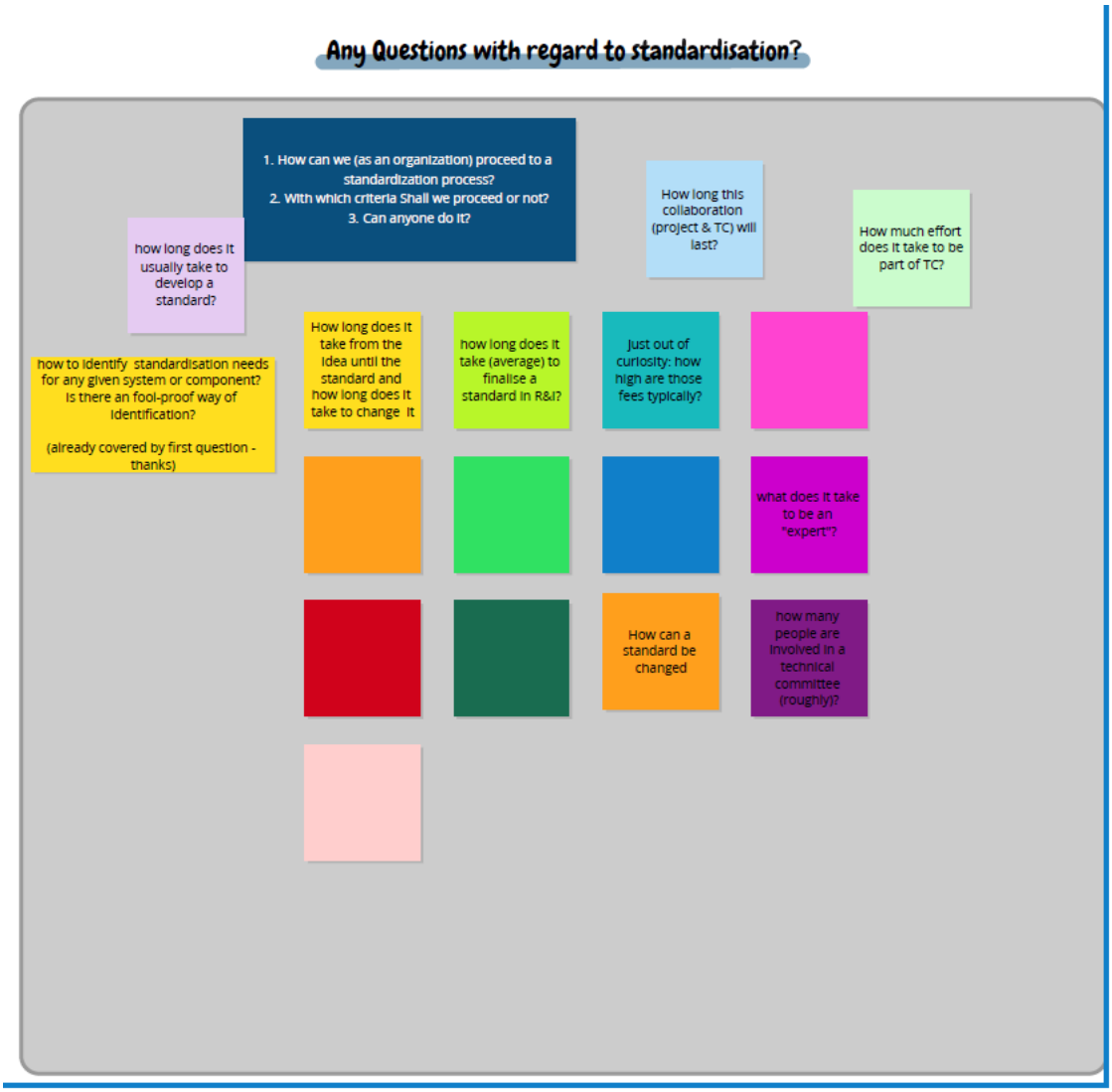


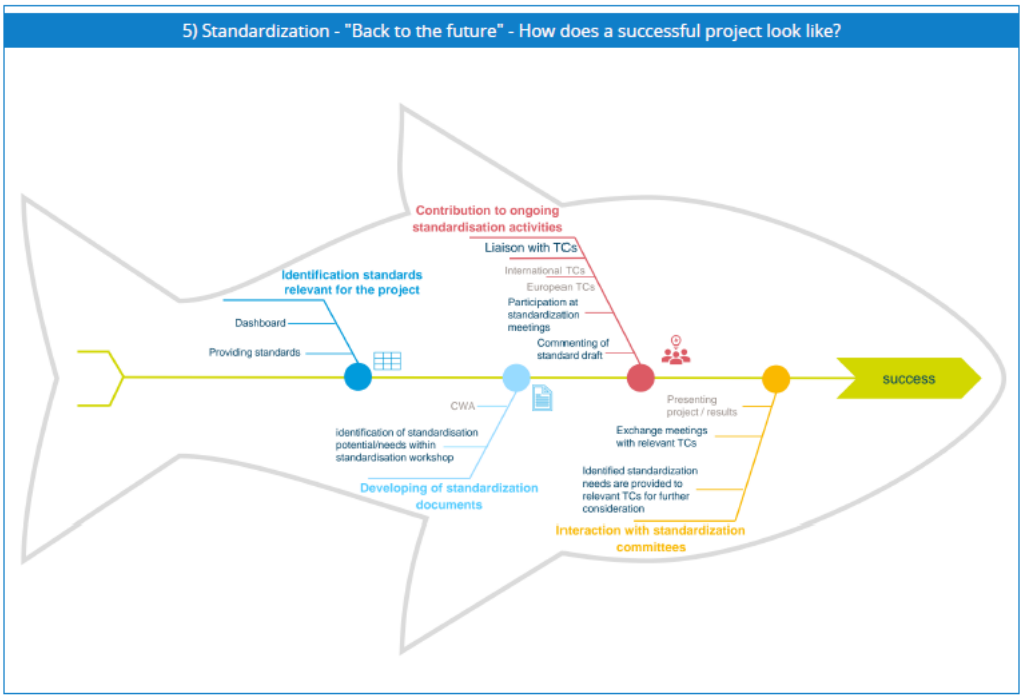
Development of standardization documents in technical committees



Development of standardization documents within a research project

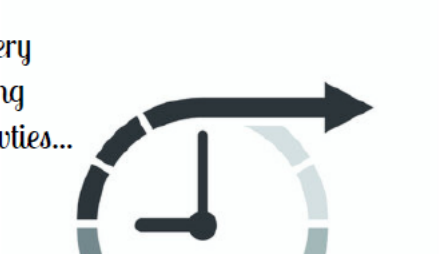


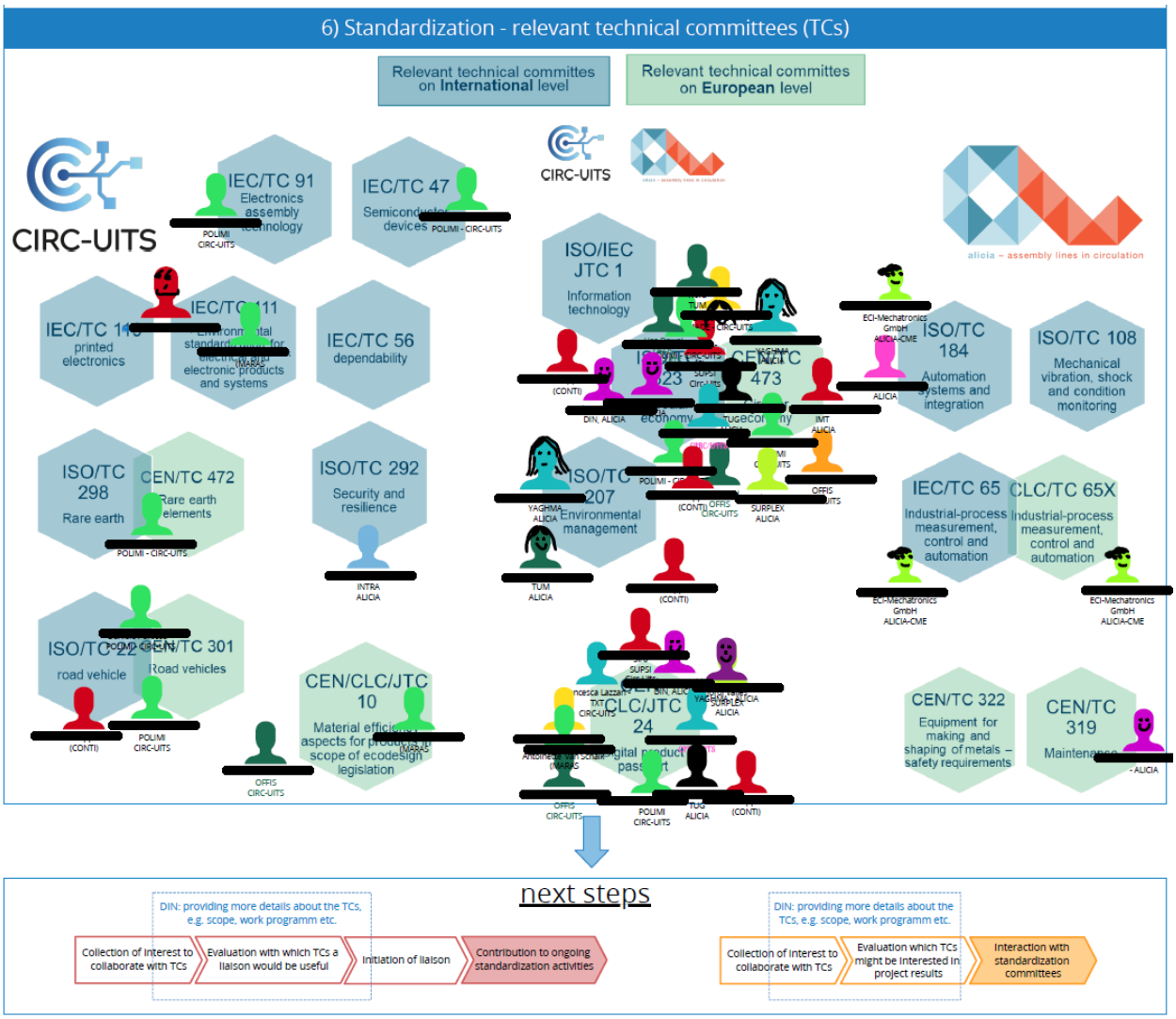

Any Questions with regard to standardisation?
1. How can we (as an organization) proceed to a standardization process?
2. With which criteria Shall we proceed or not?
3. Can anyone do it?
How long this collaboration (project & TC) will last?
How much effort does it take to be part of TC?
how long does it usually take to develop a standard?
how to identify standardisation needs for any given system or component? Is there an fool-proof way of identification?
(already covered by first question - thanks)
How long does it take from the idea until the standard and how long does it take to change it
how long does it take (average) to finalise a standard in R&I?
Just out of curiosity: how high are those fees typically?
what does it take to be an "expert"?
How can a standard be changed
how many people are involved in a technical committee (roughly)?

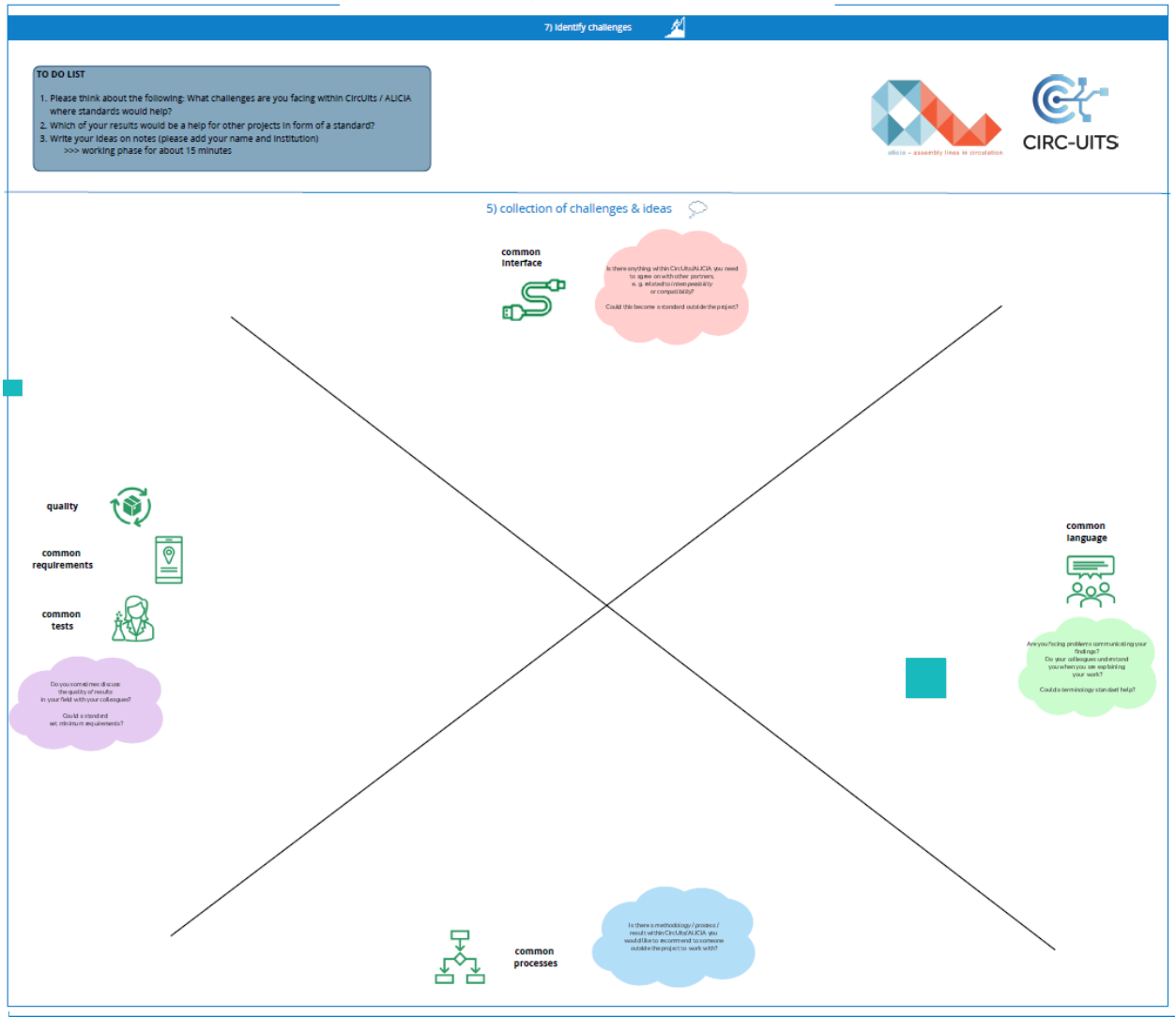


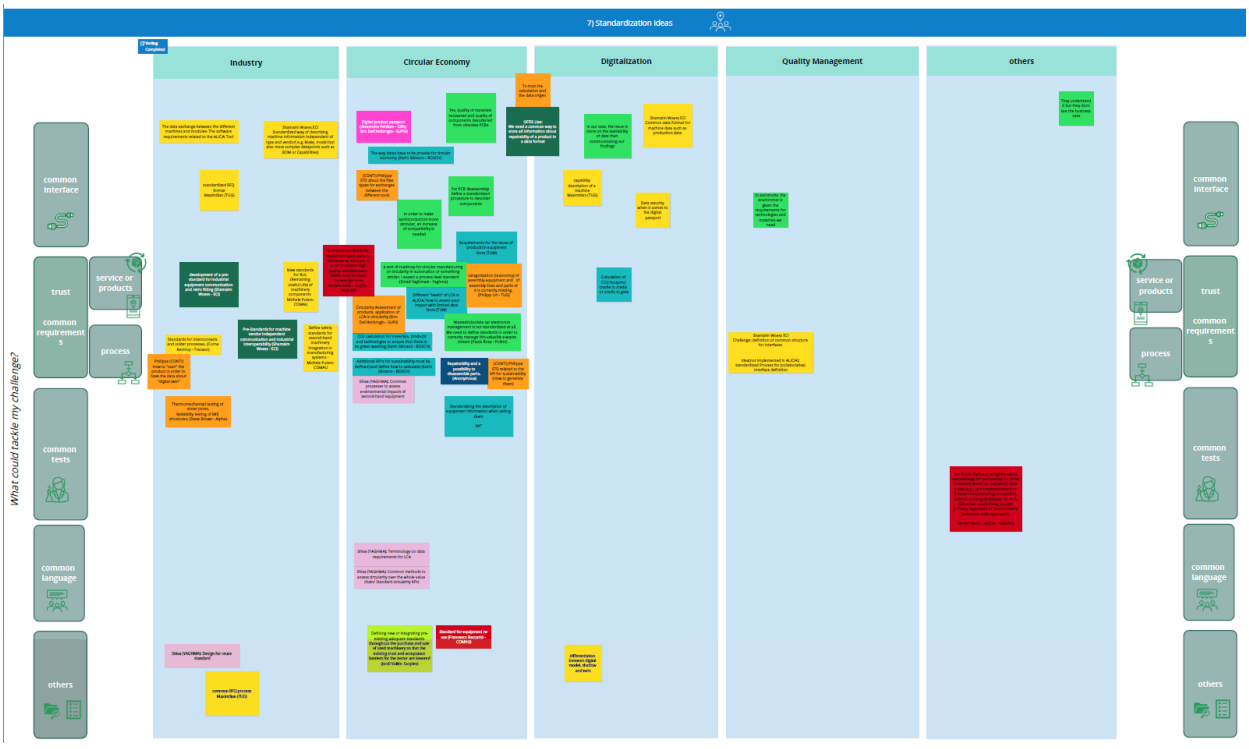
Imagine yourself at the final review meeting in 2025...

...the project was very successful regarding standardization actitivties...



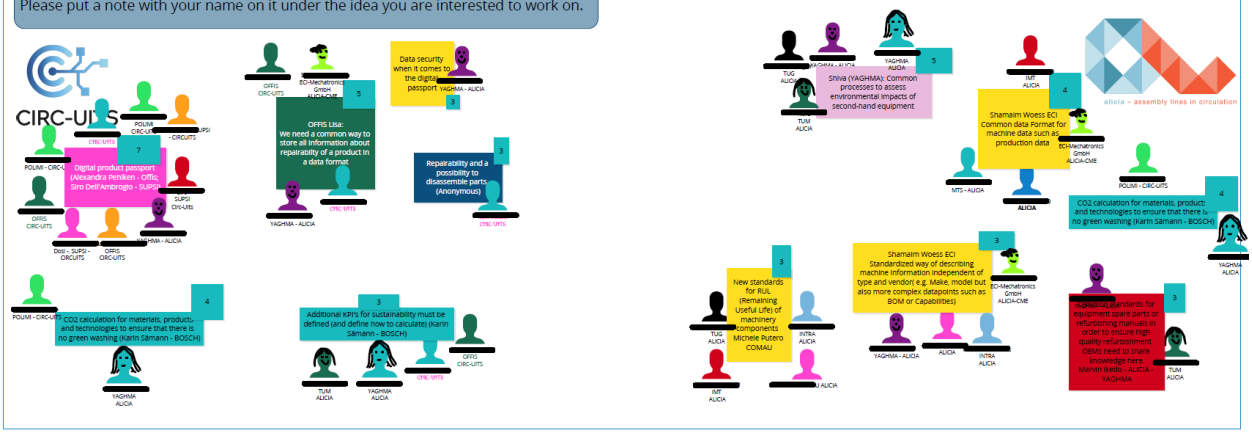

6) Standardization - relevant technical committees (TCs)
Relevant technical committes on International level
Relevant technical committes on European level
CIRC-UITS
IEC/TC 91
Electronics assembly technology
IEC/TC 47
Semiconductor devices
ISO/IEC JTC 1
Information technology
IEC/TC 56
dependability
ISO/TC 184
Automation systems and integration
ISO/TC 108
Mechanical vibration, shock and condition monitoring
ISO/TC 298
Rare earth
CEN/TC 472
Rare earth elements
ISO/TC 292
Security and resilience
ISO/TC 207
Environmental management
IEC/TC 65
Industrial-process measurement, control and automation
CLC/TC 65X
Industrial-process measurement, control and automation
ISO/TC 22
road vehicle
CEN/TC 301
Road vehicles
CEN/CLC/JTC 10
CLC/JTC 24
CEN/TC 322
Equipment for making and shaping of metals – safety requirements
CEN/TC 319
next steps
DIN: providing more details about the TCs, e.g. scope, work programm etc.
Collection of interest to collaborate with TCs
Evaluation with which TCs a liaison would be useful
Initiation of liaison
Contribution to ongoing standardization activities
DIN: providing more details about the TCs, e.g. scope, work programm etc.
Collection of interest to collaborate with TCs
Evaluation which TCs might be interested in project results
Interaction with standardization committees


7) Identify challenges
TO DO LIST
1. Please think about the following: What challenges are you facing within CIrcUIts / ALICIA where standards would help?
2. Which of your results would be a help for other projects in form of a standard?
3. Write your ideas on notes (please add your name and institution)
>>> working phase for about 15 minutes
alicia – assembly lines in circulation
CIRC-UITS
5) collection of challenges & ideas
common interface
Is there anything within CircUitsALICIA you need to agree on with other partners, e. g. aligned to interoperability or compatibility?
Could this become a standard outside the project?
quality
common requirements
common tests
Do you sometimes discuss the quality of results in your field with your colleagues?
Could a standard set minimum requirements?
common language
Are you facing problems communicating your findings?
Do your colleagues understand you when you are explaining your work?
Could a terminology standard help?
common processes
Is there a methodology / process / result within CircUitsALICIA you would like to recommend to someone outside the project to work with?

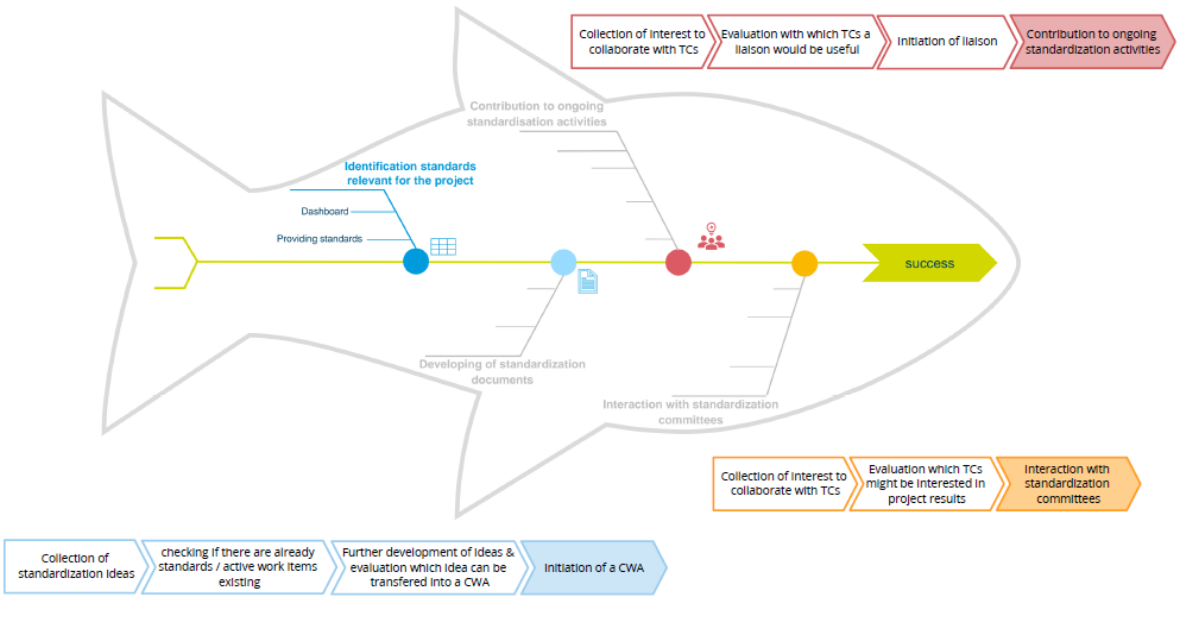

7) Standardization ideas
What could tackle my challenge?
Industry
Circular Economy
Digitalization
Quality Management
others
common interface
trust
common requirements
service or products
process
common tests
common language
others

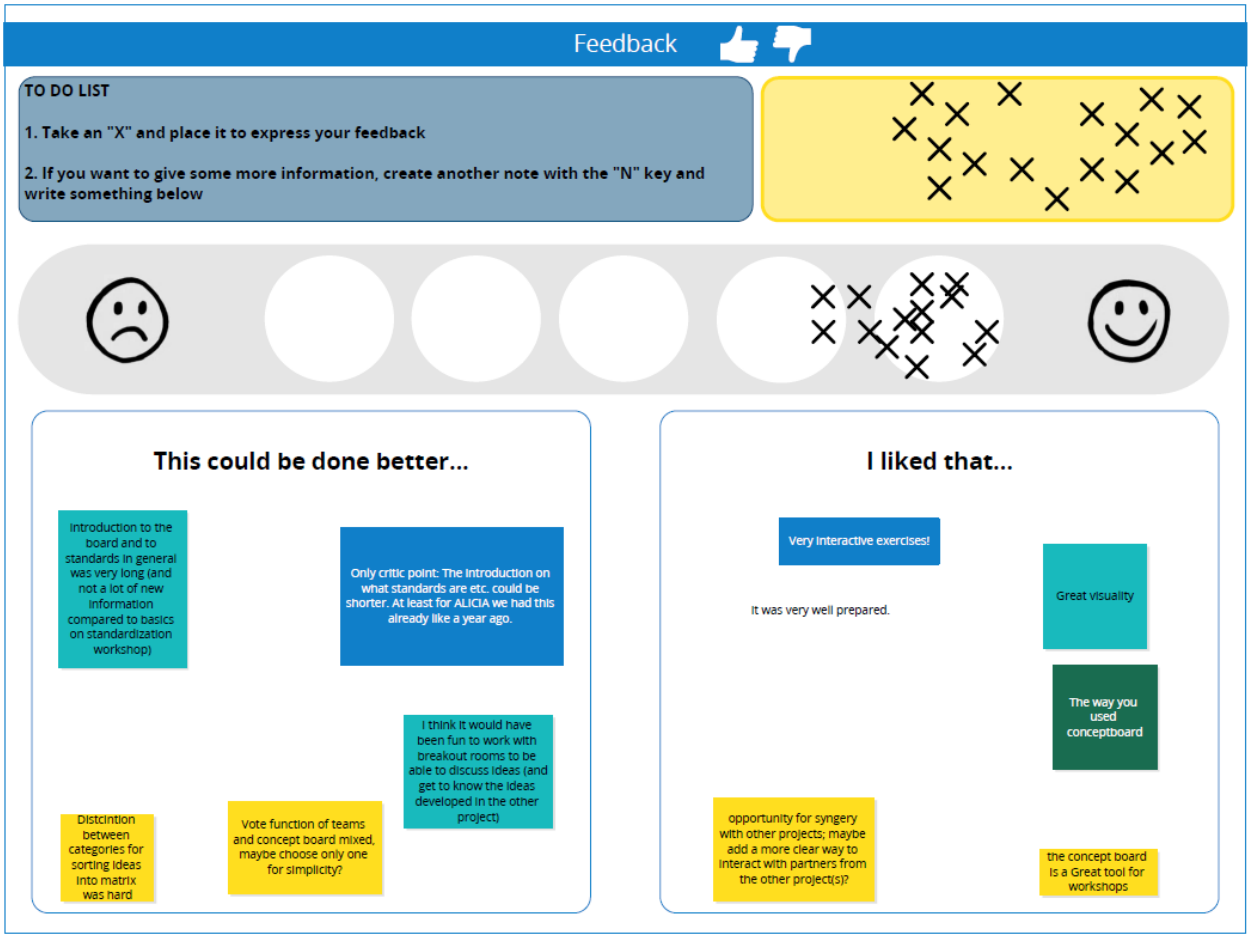
7) Top 5 Ideas

TO DO LIST
Please put a note with your name on it under the idea you are interested to work on.



8) Outlook - How to make ALICIA/CircUits successful?




Feedback
TO DO LIST
1. Take an "X" and place it to express your feedback
2. If you want to give some more information, create another note with the "N" key and write something below
This could be done better...
Introduction to the board and to standards in general was very long (and not a lot of new information compared to basics on standardization workshop)
Only critic point: The introduction on what standards are etc. could be shorter. At least for ALICIA we had this already like a year ago.
I think it would have been fun to work with breakout rooms to be able to discuss ideas (and get to know the ideas developed in the other project)
Distcintion between categories for sorting ideas into matrix was hard
Vote function of teams and concept board mixed, maybe choose only one for simplicity?
I liked that...
Very interactive exercises!
It was very well prepared.
Great visuality
The way you used conceptboard
opportunity for syngery with other projects; maybe add a more clear way to interact with partners from the other project(s)?
the concept board is a Great tool for workshops

Annex 6: Results of the survey to participate in the CWA development of the collected standardization ideas

Topic	Involvement of ALICIA partners
Common processes to assess environmental impacts of second-hand equipment	• Initiator of this specification: 1 • Main contributor: 1 • Contributor: 4 • Not at all: 4
Common data format for machine data	• Initiator of this specification: 0 • Main contributor: 1 • Contributor: 4 • Not at all: 6
New standards for RUL (Remaining Useful Life) of machinery components	• Initiator of this specification: 0 • Main contributor: 0 • Contributor:6 • Not at all: 4
Requirements for the reuse of production equipment	• Initiator of this specification: 0 • Main contributor: 1 • Contributor: 5 • Not at all: 4