DIGITAL MANUFACTURING PLATFORMS FOR CONNECTED SMART FACTORIES

D9.6 Contributions to SDOs, Associations and Clusters (Version 2)

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Abstract: This deliverable takes QU4LITY D9.5 as the base and reports about standardization activities that have been carried out in the project within the Task 9.2 *Standardization and Clustering* during the period of M1 – M39. The document provides an overview of the project's standardization activities and contributions to standardization bodies, associations and clusters, describes the current standardization landscape within the QU4LITY scope, and exhibits critical standardization gaps with regard to Industry 4.0.

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Contents

HISTORY

Version	Date	Modification reason	Modified by
1.1	25/08/2021	Document created, Inserted TOC and the first draft of the Executive Summary.	FHG IPA
1.1-2.0	25/08/2021 – 20/03/22	Added contributions from partners / authors (see front page)	FHG IPA
2.1	30/03/2022	First review	POLIMI, ATOS
2.2	04/04/2022	Second review	ILT
1.0	05/04/2022	Final version	FHG IPA

Executive Summary

This deliverable is the final report on the standardization activities of the project. It contains a list of activities with a detailed description of the partner's contributions (including relevant work topics and discussion details) in standardization bodies, industry initiatives, associations and networking with standards-focused clusters.

In the period between M1-M39, the project partners have participated in a number of events related to such important goals of QU4LITY standardization strategy as Industrial IoT, Artificial Intelligence, Smart Manufacturing, and others. Overall, the task counts more than 140 various tracked activities, including more than 80 general assembly meetings (one to two-day meetings) and standardization workshops of the SDOs/SSOs, as well as more than 60 remote working sessions in relevant standardization Task Forces and Working Groups.

The QU4LITY experts have been actively contributing to more than 19 various SDOs/SSOs and started (standardization) collaboration with 4 clusters. The main achievements are reflected in the work of such official standards developing organizations, initiatives, and associations as ISO, IEC, IDSA, euRobotics, CEN/CENELEC, ETSI, as well as the respective German and Italian national bodies as e.g. DIN/DKE, SCI 4.0 and many others, as acknowledged by EU Reg 1025/2012.

QU4LITY collaboration with other EU-funded projects and other networking activities (e.g. participation in standardization workshops, conferences, thematic webinars, etc.) were carried out during the whole period of the task.

Regarding networking with standards-focused associations and clusters, several respective activities are included in the deliverable. On the one hand, there is a joint DMP cluster that was funded by the EU through the DT-ICT-07 calls (including for e.g. such leading projects as ZDMP[1], EFPF[2], SHOP4CF, alongside with CSA OPEN DEI[3]) in 2019 and developed a common cluster strategy for cooperation in standardization topics. The deliverable provides detailed information on the working group activities of the cluster in standardization and describes the QU4LITY impact. On the other hand, there was a constant exchange with other relevant associations and industry initiatives, EU H2020 projects such as EFFRA, EU H2020 DIATOMIC, Connectedfactories2, MIDIH, BOOST4.0 and others regarding standardization activities. Further details are also described in the present deliverable.

[1] Zero Defects Manufacturing Reference Platform, Grant Agreement #825631
[2] European Connected Factory Platform for Agile Manufacturing, Grant Agreement #825075
[3] CSA OPEN DEI, Grant agreement #857065

1 Introduction

1.1 Purpose and scope

This document is the result of the QU4LITY Task 9.2 Standardization and Clustering which includes periodical reporting, i.e.:

- [M15] Deliverable 9.5 - *Contributions to SDOs, Associations and Clusters (Draft Report)*
- [M39] Deliverable 9.6 - *Contributions to SDOs, Associations and Clusters (Final Version)*

This deliverable aims at providing the *final report* on the standardization activities of the project. These activities include the project's participation and contribution to standardization bodies, industrial initiatives, relevant association and clusters. The main purpose of the document is to summarize accomplished standardization activities in the period between M1-M39 and to give a detailed description of the expert contributions made to the relevant standardization bodies, associations and clusters that have been performed by the project's partners.

The scope of the document is mainly motivated by the key findings of the project, which have the ability to be verified as valuable contributions to current European standardization strategy (see overall strategy described in Chapter 2). Therefore, the main work in the scope of this task is focusing on several areas to answer such specific questions as:

- What technical solutions have been made by the QU4LITY Large-Scale-Partners (Q-LSP) to ensure Zero Defect Manufacturing (ZDM) requirements (including motivation, specific requirements, concepts, definitions, specific requirements, identified gaps, etc.) towards development of standards?
- How the standardization gaps, i.e. missing standards or overlapping standards, are addressed by the Q-LSP?
- How can the project's ZDM technology fields (see D 2.7 in Task 2.4 *Standards Compliance and Interoperability Specification*) be further leveraged and incorporated into a common standards strategy of the project with the goal of promoting Q-LSP solutions within the Industry 4.0 standardization community with maximum effect?

1.2 Relation to other activities in the project

The current document intends to promote the QU4LITY concepts and technological solutions in terms of the project's standards strategy for Q-LSP. Therefore, this deliverable has a strong coupling (see Figure 1) with all tasks of WP2, including valuable contributions with regard to identified standardization objectives (see Chapter 2), including definition of ZDM requirements (T2.1) and technological set-ups (T2.2 and T2.3), analysis of standardization gaps and compliance rules (T2.4), vocabularies, interfaces, data models as well as reference architecture (T2.5 and T2.6). Further contributions relevant to standardization activities are identified in

WP3 - WP7, including use case description and interoperability requirements across specific standardization areas (WP6 and WP7), connectivity requests for industrial applications (T3.1, T5.4), AI and Big Data requirements (T3.3.), Edge/Fog in smart manufacturing environment (T3.4), cybersecurity, privacy and trustworthiness (T3.5 and T3.6); Industrial IoT and Smart Manufacturing (T4.1 – T4.5).

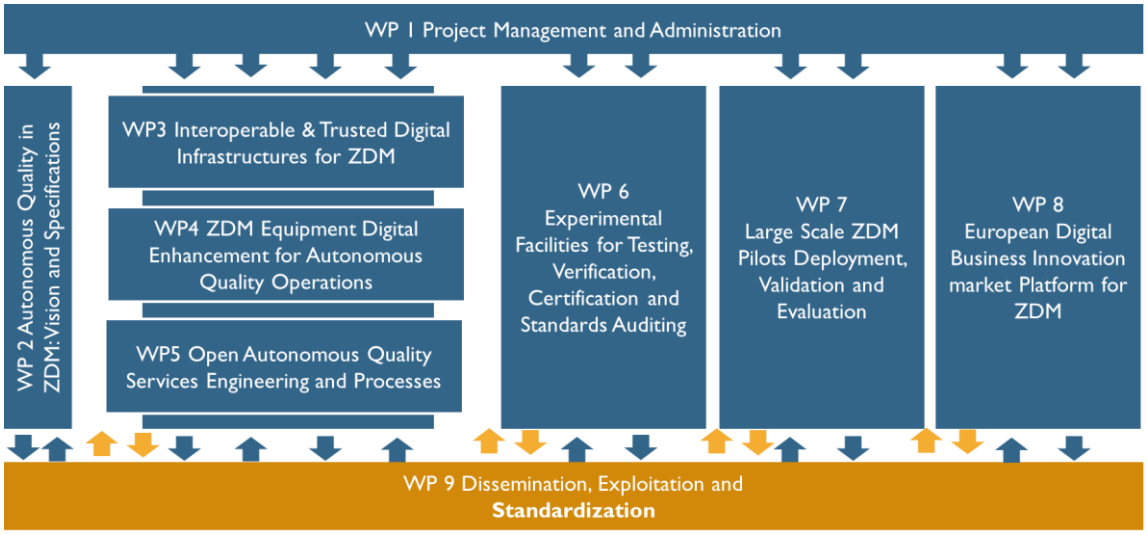

Figure 1 Allocation of WP9 activities in the project

1.3 Document structure

The document is organized in the following structure.

Following the introductory **Section 1**, **Section 2** reports on the overall standardization strategy of the project and specifies the standardization landscape. **Section 3** provides a report on various standardization activities (also including monitored activities) and contributions at international, national, and European level. **Section 4** reports on clustering activities regarding standardization, listing the recent standardization work and cluster roadmap activities. Additionally, this chapter gives an overview of the related network events pursuing a specific standardisation purpose and contains a detailed description of the work carried out. **Chapter 5** gives an overview and summary of the work done, provides some useful information on limitations and lessons learned.

Special focus in this deliverable is dedicated to exploitation plans regarding prominent activities.

2 QU4LITY Standardization Roadmap

This section reports on the overall standardization strategy aligned with the overall plan of the project and specifies the standardization landscape, clearly separating focus objectives regarding the common standardization landscape.

2.1 Overall strategy

2.1.1 Motivation and alignment with the EU standardization strategy

Common standards can help to boost the research developments, leading to a better market take up of the developed solutions, guaranteeing security and robustness of the integrated technologies. Standardisation contributes to compatibility, interoperability, quality and safety of products and processes. In order to be aligned with the Commission's standardization strategy, Task 9.2 QU4LITY agreed its work on the following key policies to be addressed in the project.

The Communication on ICT Standardization Priorities

To support the Europe's role in the global digital economy and define a comprehensive strategic and political approach to the standardization of ICT technologies, the European Commission adopted a Communication on a Digital Single Market strategy in 2012, which became one of its key priorities. Driven by the fact that the role of standardization as a bridge between research activities and the market has been increasingly recognized, both by EU institutions and by R&D stakeholders[4], and according to the integrated standardization plan[5][6], the Commission defined several key priorities for standardization with a focus on the technologies and domains that are critical to the Digital Single Market.

QU4LITY addressed the common challenges and aligned the project's standardization activities to the *ICT Standardization Priorities for the Digital Single Market*[7] as follows:

Challenge 1: Digital technologies change ever faster, frequently dramatically exceeding the pace of change in more traditional sectors and industries.
→ **Related QU4LITY accomplishments:** consortium partners promoted a harmonized setting of ICT standards to enable European innovators to compete and to bring new products to the global market (see Section 3.3.2); promoted the application of standards in pilots (see QU4LITY Deliverables D7.4 (MACHINE PILOTS) and D7.6 (PROCESS PILOTS)); contributed to harmonization activities at national, European and international level (see in particular Sections 3.1.2, 3.3.3 and 3.4.4).
Challenge 2: The technology convergence of physical and digital worlds blurs the boundaries between traditional sectors and industries, products and services.
→ **Related QU4LITY accomplishments:** consortium partners promoted standardized interoperable solutions based on open systems and interfaces to keep markets open, boost innovation, which would allow service portability in the Digital Single Market (in particular

[4] https://www.cencenelec.eu/research/tools/horizon2020/Pages/default.aspx
[5] Regulation (EU) 1025/2012 OJ L 316, 14.11.2012, p. 12.
[6] NOTE: One month ago (February 2022), the Commission adopted the new EU Strategy on Standardisation setting for future also other goals for global standards in support of a resilient, green and digital EU single market. This information was reviewed but not adopted in the task work.
[7] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016DC0176

through internal workshops and pilots' auditing activities); brought together different stakeholders to strike a balance in manufacturing industry and beyond (see Section 4.1.1); addressed different standard-setting bodies (see Chapter 4).
Challenge 3: The increasing complexity resulting from a proliferation of standards, and the diversity of technical communities involved in standard setting can slow down innovation.
→ **Related QU4LITY accomplishments:** consortium partners advised internally researchers and innovators to navigate through standards complexity. This helped a) to improve standard setting in complex technology environments of large scale-pilots reducing barriers to entry; b) to identify relevant standards establishing the link to new standards and mapping the key standards to QU4LITY technological areas (e.g. while defining a standardized reference architecture WP2); c) to identify and address standardization gaps.
Challenge 4: There are ever more bodies and organizations involved in standard or technical specification setting around the world.
→**Related QU4LITY accomplishments:** consortium partners a) could achieve deeper understanding of the current standardization landscape for ZDM and the European standardization strategy; b) helped to ensure the EU's standardization priorities and the Digital Single Market standardization priorities; c) contributed to the network of standardization events at the European level (see Chapter 4); d) addressed the EU's standardization priorities in clustering activities.
Challenge 5: European work on standardization cannot be viewed in isolation.
→ **Related QU4LITY accomplishments:** consortium partners used the opportunities to bring up standardization to the necessary level of political support (see Sections 3.3.2 and 3.3.3); b) participated in relevant standardisation activities at international, EU and national level association's activities and develop operational solutions together with representatives from various federal ministries in thematic working groups (see Section 4.2).

The Digitizing European Industry initiative (DEI)

The Digital Single Market strategy focuses on digitising the European industry, driven by new-generation information technologies such as the Internet of Things (IoT), cloud computing, big data and data analytics, robotics and others.

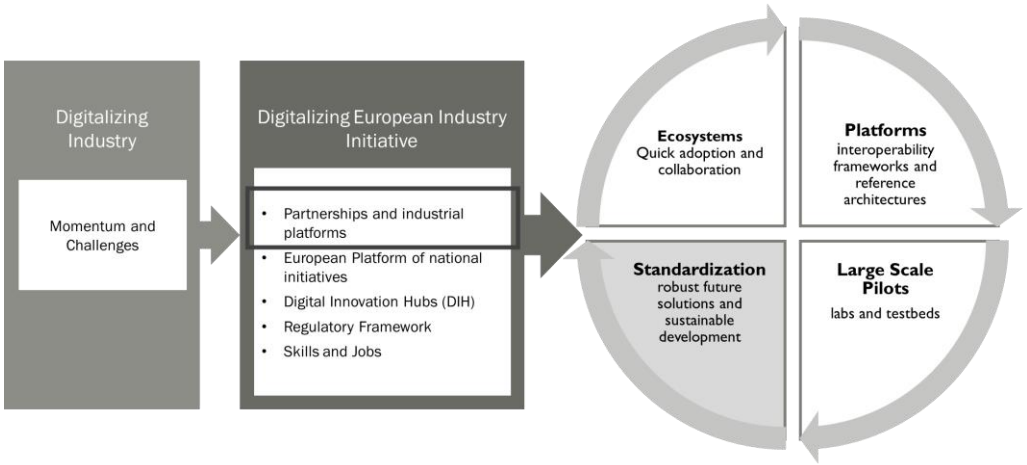

Figure 2 The role of standards in the DEI (Source: FHG based on [1]).

To support the digitisation of the industry, the EU is deriving several important pillars of action in the DEI, among which the establishment of partnerships to support the

development of digital industrial platforms and large-scale piloting takes the lead (Figure 2). Accordingly, robust future solutions and sustainable development are crucial requirements for strengthening the EU leadership.

The European Multi-Stakeholder Platform on ICT Standardization (MSP)

The European Multi-Stakeholders Platform on ICT Standardization[8] advises the Commission on the elaboration and implementation of the Rolling Plan on ICT standardization. In particular, its Advisory Expert Group, addresses the matters related to the implementation of ICT standardization policies, technical specifications in the field of ICT, and cooperation between standards developing organizations. In March 2018 the MSP and the DEI set up a joint Working Group with the aim to provide a comprehensive plan to foster standardization in support of the digitalization of European industry[9]. In alignment with the goals of the MSP DEI WG QU4LITY identifies the following activities for its Standardization Roadmap:

Goal 1: Identify the standardization needs in the manufacturing sector, which might serve as a blueprint for other domains in the future.
→ **Related QU4LITY accomplishments:** QU4LITY contribution to landscaping and characterisation of needs in the context of digitisation of manufacturing/industry; reporting on use of open source technologies; standardization gaps (see Sections 3.2.1 and 3.3.2).
Goal 2: Map the ongoing activities carried out by European Standardization Organisations, Standards Developing Organisations, fora & consortia, Large Scale Pilots, Public-Private Partnerships, the DE/IT/FR trilateral cooperation, research projects, etc. that are relevant to the digitalisation of European industry.
→ **Related QU4LITY accomplishments:** active contribution to standardization ecosystems in clusters, specifically its contributions with the key results and findings according to specified objectives of the group (see Section 4.1).
Challenge 3: Develop a model for the synchronisation of the various standardisation activities, at the Member State level and at the European level – and in a global context.
→ **Related QU4LITY accomplishments:** contribution to synchronization of standardization activities at EFFRA innovation portal (see Section 3.2.6).
Challenge 4: Propose a first roadmap taking into account national standardisation roadmaps and other existing work, and specifying concrete actions that may be included in the Rolling Plan for ICT standardisation.
→ **Related QU4LITY accomplishments:** contribution to Rolling Plan for ICT standardisation (see 3.3.2).

2.1.2 Derived standardization strategy plan

Based on the identified activities in the previous sections, a number of actions were set within the Task 9.2:

- **Auditing and support:** One of the key actions was to support and advise QU4LITY partners in their developments with regard to current standards and trigger relevant contributions for standardization work. This included a comprehensive analysis of SDOs/SSOs and other activities that helped to understand the current state of the standards landscape with respect to

[8] https://ec.europa.eu/digital-single-market/european-multi-stakeholder-platform-ict-standardisation
[9] https://ec.europa.eu/digital-single-market/en/news/report-workshop-standardisation-support-digitising-european-industry-initiative

QU4LITY. The main outcomes of this activities are described in the Deliverable in the respective QU4LITY impact sections (see Chapters 3 and 4).

- **SDO/SSO coordination and contribution:** The key action of this task was to push forward standardization activities at national and international level with regard to the project objectives and promote ZDM results and findings with regard to standardization.
- **Harmonization:** Another key action was to support national, European and international SDOs and industrial initiatives in consolidation, harmonization, and development of standards, i.e. promoting common standards for Industry 4.0 domain.
- **Coordinated cooperation and outreach:** One of the main activities was to interlink and cooperate with relevant associations and clusters, promoting relevant standardization results and other findings.
- **Sustainability and networking of the standardization results:** This activity aimed to promote the communication of project results related to standardization in the EU digital manufacturing community through networking events.

2.2 QU4LITY Standardization Roadmap

This chapter lists the crucial *standardization focus objectives of the project* (Q-SFO), which form the *QU4LITY Standardization Roadmap* (Q-SR) as a whole. The Q-SR is the result of a comprehensive analysis that specifies the mapping of possible standardization activities and normative gaps and that maps to the vision of the autonomous QU4LITY in the ZDM. Based on the Q-SR, the current developments and standardisation potential of the Q-LSP (i.e. possible contributions to standardization bodies, associations, industrial initiatives and clusters) could be examined and mapped across identified Q-SFO. The main aim was to extract standardization gaps in the given areas, align these with the relevant activities of the Q-SR and prepare relevant contribution items for submission (see Chapter 3) and use for promotion of the results (see Chapter 4).

2.2.1 Standardization focus objectives (Q-SFO)

The Q-SFOs were essentially derived from the key standardization areas of the RAMI 4.0 layers and the analysis results of Task 2.4 (consult QU4LITY Deliverable D2.8). Figure 17 in Appendix B shows specific standardization topics in the given areas.

A more detailed description of Q-SFOs, including the list of related standardization bodies is summarized further in Appendix B.

2.2.2 Alignment with the project phases

The data was collected and updated in two steps in alignment to the overall QU4LITY plan, as shown in Figure 3.

Step 1: D9.5 contributed to the first and second phases of the project with the aim to provide a detailed definition and specification of the QU4LITY concepts and technical validation of the Q-LSP equipment and applications. The work during these

phases included a) the definition of the Q-SR; b) the setting of project internal consulting and auditing activities for Q-LSP; c) the establishing of the first contacts to standardization bodies, associations and clusters; d) the validation of contribution potentials; and e) the active participation in various standardization activities.

Step 2: D9.6 (the present deliverable) completed the work of D9.5 and contributed to the remaining phases of the project. During these, a) the Q-SR was reviewed and updated; b) continued to audit and support the Q-LSP; c) continued active contributions to SDOs/SSOs.

2.2.3 Workflow description

In order to coordinate the activities of more than 25 project partners who very actively contributed to this task, internal (remote) workshops were held on a regular basis. These allowed to follow the current activities of all stakeholders between workshop periods and to exchange information on the current status and recent developments in the field of the identified standardization objectives. All current relevant activities were collected and regularly updated in the standardization activities matrix. The workshops were complemented by direct exchanges with other task managers and Q-LSP experts, who provided more detailed information on various aspects related to standardization activities.

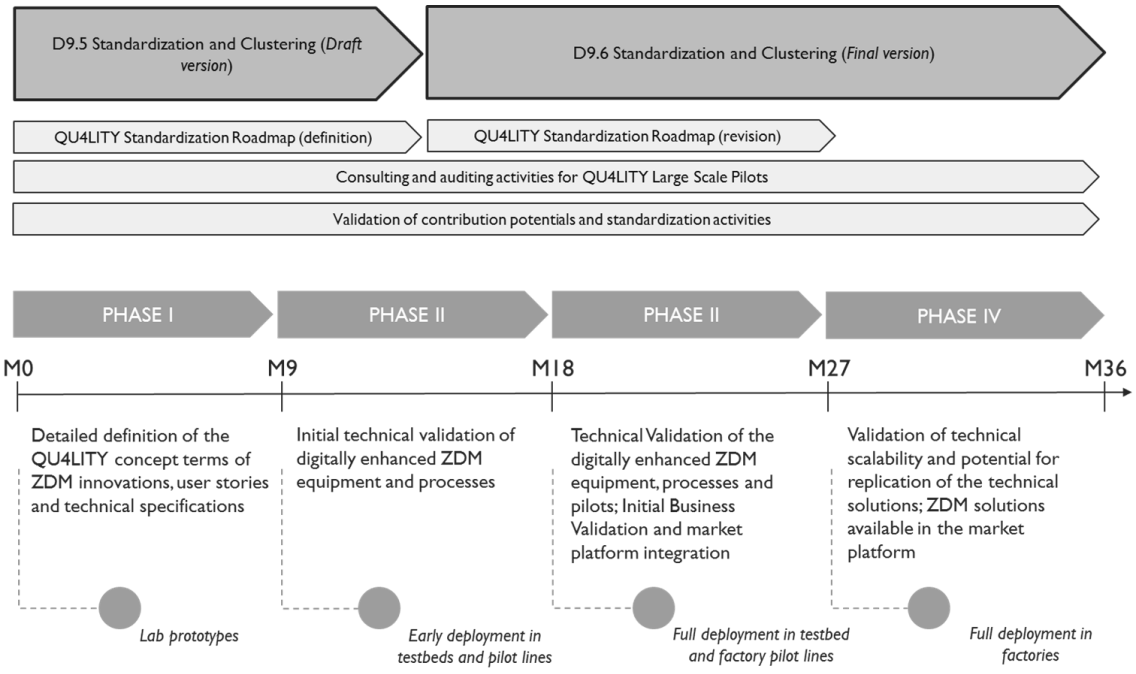

Figure 3 Alignment of the main activities with the overall project plan.

3 Report on standardization activities

This section lists various standardization activities and provides a detailed description of QU4LITY contributions.

3.1 Contributions at international level

3.1.1 IEC TC 65/ WG 23

Description and focus areas

IEC TC 65/ WG23 *Smart Manufacturing Framework and System Architecture* of IEC TC65 has the goal to address the basic concepts regarding Smart Manufacturing, in particular, to compose an SM framework of standards that can be used by TC65 in a harmonized way. Accordingly, the SM framework should cover SM system aspects throughout the whole lifecycle, consider interfaces between resources, products and delivered goods with enterprises, customers, energy providers, and others.

QU4LITY impact

FHG IPA is an active member of the working group and has been actively promoting QU4LITY standardization results in the SM scope. Based on the identified QU4LITY roadmap objectives, FHG IPA contributed to the majority of the active WG Task Forces (TF). Among these, the contribution to the technical reports of TFs was one of the major QU4LITY activities. The general objective of the technical reports was to indicate the gaps in standardization. QU4LITY impact is summarized as follows:

- Table 8 (Appendix A): a detailed list of standards (based on QU4LITY D2.8 and updated) that were applied in the QU4LITY pilots and thus consistently examined for standardization gaps (see also references to pilots in further sections).
- Table 1 (Appendix A): QU4LITY core contribution activities in WG 23.

On the whole, FHG IPA attended 10 general assemblies of WG23, which were held in April 2019 (Paris), June 2019 (Frankfurt), December 2019 (Frankfurt), September 2020 (remote), October 2020 (remote), February 2021 (remote), May 2021 (remote), June 2021 (remote), December 2021 (remote) and February 2022 (remote). FHG IPA experts also actively contributed to more than 23 remote workshops of the listed TFs in the period from May 2019 till December 2021.

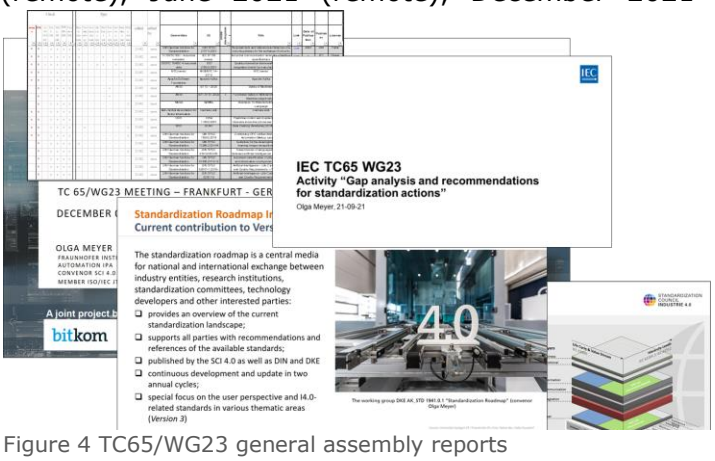

Figure 4 TC65/WG23 general assembly reports

In addition, QU4LITY experts attended 5 assembly meetings of the *DKE/AK 931.0.14 Smart manufacturing and Industrie 4.0* (German mirror

committee to WG 23) contributing to the development of SM concepts and Industrie 4.0 standards.

During the general assemblies in December 2019 and 2021 FHG IPA presented the current results regarding the German Standardization Roadmap Industrie 4.0 in order to promote current national activities and to take advantage of developments outside the TC65 WG23 and also held several meetings of one Task Force as lead (Figure 4).

Recommendations and exploitation of results

- *Exploitation:* Particularly noteworthy is the leading role of the FHG IPA in the newly established TF *Gap analysis and recommendations for standardization actions*. The major goals of the TF are to consolidate standardization requirements of the running WG 23 tasks and to formulate standardization requirements to be assigned to standards. FHG IPA will continue to promote QU4LITY findings in standardization in its further work.
- *Exploitation:* FHG IPA will continue to actively contribute to the standardization activities of the WG and utilize also final QU4LITY results and related requirements into the TF work and running technical reports.
- *Exploitation:* QU4LITY consortium partners will review the specific use case approach IEC TR 63283-2 where appropriate in their further research projects and promote WG23 standards.
- *Exploitation*: FHG IPA will continue to participate in further proposals of EU projects in the role of task lead regarding standardization of Smart Manufacturing and provide its valuable experience from the work accomplished in WG 23.
- *Lessons learned*: The work in an international working group is very time consuming, especially the leading role in a task force may require high efforts.

3.1.2 ISO/IEC JWG 21

Description and focus areas

Due to the substantive overlaps that exist within the work of ISO/TC 184 and IEC/TC 65, the two bodies formed the Joint Working Group 21 (JWG 21) "Smart Manufacturing Reference Model(s)" in July 2017, in which more than 70 experts from 13 countries take part. The aim is to bring about the harmonization of existing reference models and to develop Smart Manufacturing reference models, especially with regard to various aspects such as life cycles and the technical and/or organizational hierarchies relating to assets. Furthermore, the development of a fundamental architecture for Smart Manufacturing components as an essential part of the virtual representation of assets is planned. The contributions from the various countries are being consolidated, further developed and published in the form of unified and consistent models [2]**.**

QU4LITY impact

The objective of ISO/IEC TC 65 JWG21 to define a unique smart manufacturing model is still not completed since the work done has been addressed on creation of a meta-model which covers all of the aspects from smart manufacturing reference model

approaches such as e.g. RAMI 4.0 or Current Standards Landscape for Smart Manufacturing Systems by NIST.

The development of QU4LITY Reference Architecture based on RAMI 4.0 and specifications of other common prominent reference architecture models brought real alignment for QU4LITY project activities in WP 2, addressing specifically the needs of use case mapping and QU4LITY reference architecture structuring. Thus, this activity had a direct impact on the work of the majority of Q-LSP: e.g. ATOS, ENG in PRIMA regarding the operation to RAMI4.0 standards on the edge and connectivity to operation and control level; WHIRLPOOL Q-LSP regarding Industrial IoT and the implementation of vertical integration of data management; FAR-EDGE regarding the implementation of standard-based solutions with simulation services for validating automation architectures and production scheduling scenarios; and other.

Besides, QU4LITY also followed closely the creation of the former Task Force 8 Digital Twin and Asset Administration Shell within IEC ISO TC 65 JWG21 that aimed to link the needs of digital twin for industrial companies associated with the initiative of Asset Administration Shell. This activity made a starting input to the subsequent ISO/IEC JTC 1/SC 41 WG 6 (see ISO/IEC JTC 1/SC 413.1.3).

The latest QU4LITY impact was concentrated on the newly discussed activity related to further internationalisation of RAMI 4.0 concepts. There are initiatives running to convert IEC PAS 63088 into a Technical Specification based on the approach described in IEC 63339 ED1 Unified reference model for smart manufacturing.

In the context of harmonization, there are two activities of QU4LITY to be mentioned: ISO/IEC TR 63306-1:2020 Smart manufacturing standards map (SM2) - Part 1: Framework and ISO/IEC TR 63306-2 Smart manufacturing standards map (SM2) — Part 2: Catalogue. The catalogue is the result of a joint initiative of IEC and ISO through the joint SM2TF Smart manufacturing standards map Task Force with the goal of creating a standards catalogue modelled on the existing smart grid for companies involved in smart manufacturing to facilitate the search for standardized criteria. These two standards served as a comprehensive base for the analysis of the project's standards landscape.

Recommendations and exploitation of results

- *Recommendation:* It is recommended to address the currently developed standard IEC/DTR 63319 *A meta-modelling analysis approach to smart manufacturing reference models* in the project work. This could help to ensure that heterogeneous concepts are not developed into reference models in upcoming projects.
- *Recommendation:* In particular, the development of a uniform concept for reference models for smart manufacturing requires greater involvement of industrial companies and the development of process flows.
- *Exploitation*: QU4LITY consortium will be further promoting the results of IEC/DTR 63319 and the possibilities of the meta-modelling and look for opportunities to apply this and QU4LITY reference architecture mapping approaches in running or upcoming European projects.

3.1.3 ISO/IEC JTC 1/SC 41

Description and focus areas

The work of ISO/IEC JTC 1/SC 41 *Internet of things and digital twin* is of central interest for QU4LITY. On the one hand, the committee serves as a focus and promoter for the JTC 1 standardization programme on IoT and related technologies, including important topics like Industrial Internet of Things, cyber physical production systems, harmonization of industrial standards and related shop floor technologies. On the other hand, it provides a central point for developing of standards and concepts around digital twin, virtualisation of data and information modelling for interoperability.

QU4LITY impact

Harmonization activities around Industrial IoT

SC41/AG20 is a special advisory group that aims to coordinate liaisons activities between all internal and external SDO's, especially in the IIoT sector; proactively gather requirements and uses cases; promote the use of SC41 foundational and core standards by these SDO's; occasionally, assist in the socializing of activities, facilitate the set-up of joint projects.

Being a member of SC41/AG20 FHG IPA used an excellent opportunity to contribute to several current activities regarding the industrial IoT and harmonization. These activities include e.g. (1) attending the committee's meetings and active participation in the procedures; (2) participating in analysis and discussion of the current standards development projects; as well as (3) active work on the technical report ISO/IEC 30166.

In detail, the ISO/IEC 30166 Internet of Things (IoT) – Industrial IoT is e.g. a large-scale information guide on the current standardization activities and standardization landscape of SDOs, consortia and open-source communities in the field of IIoT. The document contains a detailed list of national and co-operative initiatives related to IIoT, as well as some activities in the common sense, partly related to the area of Smart Manufacturing. QU4LITY research on standards and related committees used the profound information of ISO/IEC 30166 in its research.

Further important issue being dealt with by the group was the mapping of standards according to their areas of application, which was of great interest to QU4LITY work in this task and was applied by QU4LITY during the mapping of standards (see detailed description in 4.1.1).

The final activity of the group included analysis of current and missing liaisons between its committees and other bodies, to which FHG IPA contributed with its research.

Digital twin

The newly established WG 6 of SC 41[10] specifically addresses standardization in the area of digital twin with a focus on concepts, vocabulary, use cases and a reference architecture. WG 6 has already 168 committee members from 19 national bodies, among which FHG IPA is an active member from the German side.

The work of WG 6 is directly related to the QU4LITY requirements regarding the interoperability among entities and their digital representation, i.e. digital twins, in several respective pilots: e.g. prototyping of digital twins in WP5, particularly, in GF with the setting up a digital twin for error compensation; CONTINENTAL, KOLECTOR, DANOBAT with the IoT interoperability within IoT network as well as edge and cloud integration specific requirements, and others.

Digital twin is a horizontal topic in SC 41 and has implications for many external TCs and SDOs. That is why the first task of the working group was to come up with a generic definition of digital twins and related terms. Additionally, SC 41 established an advisory group AG 27, which is expected to identify synergies with existing SC 41 activities and relationships as well as elaborate an overall standardization strategy. The group addresses among others life-cycle issues, standardization opportunities in virtual systems, devices and sensors. FHG IPA synchronized QU4LITY related activities via direct contact to German members of the advisory group.

At the end of 2021, SC 41 organized a workshop, which was held in a very short two-week timeframe and achieved important inputs from the WG members. This helped to kick-off the very agile development of a number of important standards. During this period FHG IPA reviewed a number of standards (see Appendix A, Table 2) and, in particular supported the concept of the semiotic triangle proposed by the German experts to WG 6.

Recommendations and exploitation of results

- *Recommendation:* It is recommended to address ISO/IEC 30166 if starting standards' research. The document contains a lot of helpful information to kick-off the research activities of the project.
- *Recommendation:* It is advisable to monitor liaison activities and cooperative exchanges between standardization bodies and committees. This can contribute to easier identification of relative activities on a given topic and can help experts to find their way through the jungle of ongoing and frequently changing standardization activities.
- *Exploitation:* FHG IPA will continue contributing to harmonization and standards mapping activities in SC 41 as there is still much effort required to improve the newly established processes (e.g. large number of emerging comments handled by an editorial team caused by a large number of participants in WG 6). Long-term processes should be considered in upcoming activities.
- *Lessons learned:* The standardization of the digital twin has just begun, but it is progressing very quickly. This leads to frequently changing requirements in

[10] Note: The first meeting of the WG 6 was organized in January 2021.

standardization and a large number of working drafts and requests regarding editing and review of documents. The future consortia and their standardization experts should have a high level of involvement in the working group activities for digital twins.

- *Lessons learned:* Interesting fact is the foundation of ISO/IEC JTC 1/SC 41/WG 3 *IoT Foundational Standards* that includes IoT and Digital Twin global vocabulary.

3.1.4 IEC TC 65/SC 65B

Description and focus areas

The WG 6 *Testing and evaluation performance* is a working group of IEC TC 65/SC 65B, which concerns the measurement and control devices. The WG has the goal to prepare methods of evaluating the performance of system elements and functions used in industrial process measurement and control with special regard for harmonization. Currently, the WG6 is working on IEC 61499.

The international standard IEC 61499 is addressing the topic of function blocks for industrial process measurement and control systems. The standard describes the modelling of distributed control systems based on Function Blocks worked out by the TC 65 / SC 65B/ WG 6.

QU4LITY impact

NXT has developed the first, industrial focused, automation software products based on the IEC 61499 standard for distributed systems. The software products include the engineering tool nxtStudio, runtime system for controlling hardware, runtime system for visualization devices and different software libraries.

NXT has been working for many years with the IEC 61499 standard. The practical experience and knowledge resulting from this work is why it is interesting to be part of the IEC 61499 working group as a full member. The group meets once a month to discuss the documents that are provided as possible input to the standard. Each input is being reviewed and discussed and if it is accepted it can either be part of the standard or of the appendix.

The IEC 61499 standard was first published in 2005 and this release also included a few Basic Function Blocks (FBs). While implementing the Standard NXT has extended the list of these predefined FBs which are provided to the users of the nxtStudio as part of a library. The users can take these FBs directly from the library and use them while creating their control applications.

NXT presented a description of all these FBs to the working group with the intension to put these in the standard.

In the scope of the QU4LITY project, NXT has worked with ASTI to identify a use case focusing on the AGVs from ASTI and the IEC 61499, based technology from NXT.

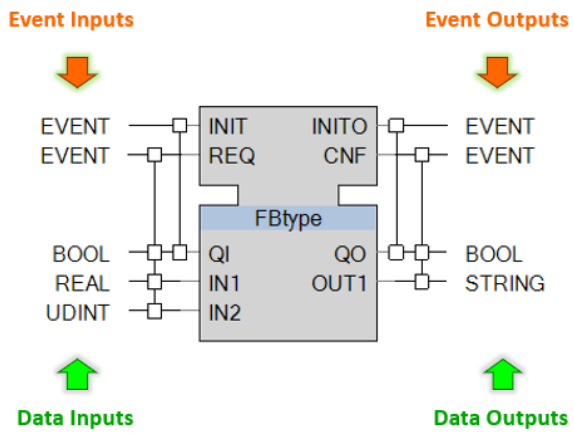

Figure 5 Function Block Model (Source: NXT)

In this use case the main goal is to remove the centric control logic, which is currently set in a traffic box, and distribute it among the AGVs. The idea is that the AGVs communicate among each other to avoid collision when for example crossing an intersection. To achieve this the distributed control communication from NXT based on the IEC61499 standard will be used.

In the first step a Linux PC with a softPLC running the IEC 61499 runtime system will be placed on top of the AGVs. Using the nxtStudio engineering tool an IEC61499 control application will be developed, and the application will be distributed among the corresponding AGVs by deploying the application to the softPLCs via the nxtStudio.

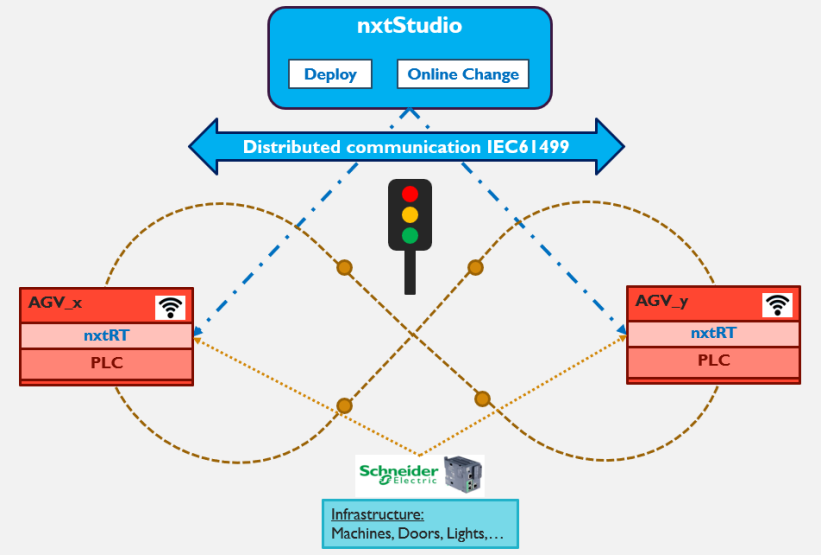

Figure 6 NXT & ASTI WP4 Use Case (Source: NXT)

In a later stage the goal is also to have a direct communication between the AGVs and the infrastructure like doors, machines or lights.

The distributed control application designed in the nxtStudio will include the FBs which are submitted to the working group. If the document describing the FBs is accepted to be part of the IEC 61499 standard, then the control application for this use case will be fully compliant with the standard.

Recommendations and exploitation of results

- *Recommendation:* One worth mentioned is that the current standard has only a few FBs defined. These are not enough to design a full control application. NXT will continue to provide further documents on the technologies and solutions to the working group based on the IEC 61499 standard to the working group.
- *Exploitation:* The developments and work done on standardization in QU4LITY will benefit NXT in several aspects. First is the direct impact when presenting the project results and the work on standardization to our customers.

- *Exploitation:* The other aspect is the impact on other NXT research projects, where the QU4LITY results will be the basis for further contributions to the IEC 61499 standard and creation of new use cases to demonstrate the developments implementing these extensions and their benefits.
- *Exploitation:* The third exploitation opportunity that the standardization work in QU4LITY brings is indirect and goes over the *universalautomation.org*[11], an independent, not-for-profit association that manages the implementation of an industrial automation shared source runtime based on the IEC61499 standard. This new level of shared technology provides the basis for an ecosystem of portable, interoperable, "plug and produce" solutions and creates an entirely new category within industrial automation. NXT will report the experience made in QU4LITY as "lessons learned" for other UAO members to benefit from them and include these in their further work.

3.1.5 IEC TC 65/SC 65 E

Description and focus areas

The IEC TC 65/SC 65 E scopes the devices and integration in enterprise systems. Currently, ten Working Groups (WG) and two Joint Working Groups (JWG) make up the SC 65 E working on developing international standards specifying the device integration with industrial automation systems and the industrial automation integration with enterprise systems. Since the last status presented in D.9.5, the SC 65E has reorganized the standardization effort to optimize the work and avoid duplicities. The activities of WG 11 (condition monitoring) have been integrated within other WGs, as well as the JWG 6 (device profile) and the ahG1 (smart manufacturing information models)

The specifications developed within SC 65 E address device properties, classification, selection, configuration, and commissioning, monitoring, and basic diagnostics. The standards also include transactions between business and manufacturing activities, which may be jointly developed with other international standardization groups such as the ISO TC 184.

QU4LITY impact

The utilization of standards developed in the SC 65E under the QU4LITY perspective were recommended to ensure quality improvement during the engineering, deployment and commissioning of the manufacturing systems, targeting to reach the ZDM.

In the same way, work developed in QU4LITY pilots is influencing and will influence as experience in the development of the standards under the SC 65E. Table 3 in Appendix A presents the groups working under the SC 65E, its target and the analysis of identified contributions matched to QU4LITY outcomes.

[11] https://universalautomation.org/

Recommendations and exploitation of results

- *Exploitation:* The outcomes of QU4LITY in the ZDM domain contribute to several international standards, particularly in the SC 65 E scope. Furthermore, the involvement of the project partners in the national and international standardization activities will influence its development beyond the project.
- *Exploitation:* In addition, the implementation of standards into commercial products gives project partners a competitive advantage compared to their competitors. Particularly in the interoperability domain, allowing them to integrate with other solution providers facilitating the reusability of systems, like in the utilization of programming standards such as the IEC 63111 or the IEC 61499 (WG 7) or the practices developed in the standards. End users will enhance productivity and ZDM implementation utilizing the standards' methodologies.
- The work developed in creating the standards under the SC 65 E goes beyond the project, the commitment from the project partners to contribute to the development of **open international standards**, making accessible for everyone. Furthermore, the development of the standards is continued in other EU projects such as OPTIMAI[12].

3.1.6 IEC TC 65/SC 65/ WG 9

Description and focus areas

The Working Group 9 (WG 9) of the IEC TC 65/SC 65 develops the IEC 62714, also known as AutomationML[13] (AML). The standard aims to create an engineering data exchange format, which allows exchanging information between the different engineering software tools deployed in a heterogeneous landscape. IEC 62714 relies on different standards already used in the industry domain, CAEX (IEC 62424, COLLADA (ISO/PAS 17506) and PLCopen XML (IEC 61131-10). AutomationML is XML-based, currently a World Wide Web Consortium (WWW) specification, for data format which offers meta-model as object-oriented concepts.

IEC 62714 extends the semantics of engineering data, enables exchangeability between the different tools, data extensibility and scalability from the machine level to the entire production facility, and shareability among different stakeholders (technology providers, system integrators and end users).

QU4LITY impact

The use of standardized engineering data exchange formats enhances the quality as the data can be shared and used between the different production phases from engineering to deployment and commissioning and during the production phase. QU4LITY can get an advantage with the standards developed under the working group 9 at the same time that the outcome of the project can provide input towards the ZDM.

[12] https://cordis.europa.eu/project/id/958264
[13] AutomationML stands for Automation Markup Language

Visual Components has an active role in developing the IEC 62714 standard as an active member in the IEC TC 65/SC 65/WG9. The Table 4 in Appendix A displays the status of the different parts of the standards and the contributions that the standard can introduce from QU4LITY.

Recommendations and exploitation of results

- *Recommendations:* Parts of the standard have been tested during the implementation of the pilots, obtaining promising results so far, and pushing the continuation of the implementation work. Despite the promising results in the pilot, the market the availability of engineering tools that support the IEC 62714 is still limited.
- *Lessons learned*: During the implementation of the project pilots the data exchange of information between the engineering tools has been increasing, and the utilization of the IEC 62714 has facilitated standardize data models and enhancing sharing providing seamless integration, which has enhanced ZDM as data continuity has been ensured.
  These promising results are encouraging the technology providers within the project to go towards the integration of the IEC 62714 within the commercial solutions. In parallel, the standard development is planned to be continued in the new projects under the Horizon Europe umbrella.

3.1.7 IDSA

Description and focus areas

IDSA

The objective of the *International Data Spaces Association (IDSA*) is to establish a standard for data sovereignty – for the trustworthy, self-determined exchange of data. To do this IDSA provides a reference architecture, a formal standard and reference implementations which include the sample code.

The result is a virtual data space (the International Data Spaces or in short "IDS") facilitating secure and standardized data exchange and data linkage in a trusted business ecosystem, which ultimately enables the creation of new smart-service scenarios and innovative cross-company business processes. Companies and organizations of any size and from any industry can benefit from this initiative and IDSA already counts over one hundred members from twenty countries across Europe and beyond.

To achieve this aim of creating a secure and trusted data space, IDS leverages existing standards and technologies, as well as governance models well-accepted in the data economy. In particular, with regard to standardization IDSA is driven by the following guidelines:

- OPEN DEVELOPMENT PROCESS: The International Data Spaces Association is a non-profit organization institutionalized under the German law of associations. Every organization is invited to participate, as long as it adheres to the common principles of work.

- RE-USE OF EXISTING TECHNOLOGIES: Inter-organizational information systems, data interoperability, and information security are well-established fields of research and development, with plenty of technologies available in the market. The work of the International Data Spaces initiative is guided by the idea not to "reinvent the wheel", but to use existing technologies (e.g., from the open-source domain) and standards (e.g., semantic standards of the W3C) to the extent possible.
- CONTRIBUTION TO STANDARDIZATION: Aiming at establishing an international standard itself, the International Data Spaces initiative supports the idea of standardized architecture stacks.

Data Spaces Business Alliance (DSBA),

23rd September, 2021 BDVA, FIWARE, GAIA-X and IDSA Launched an Alliance to Accelerate Business Transformation in the Data Economy (see Figure 7). Gaia-X European Association for Data and Cloud AISBL, the *Big Data Value Association (BDVA),* FIWARE Foundation, and IDSA join forces to lead the adoption of data spaces across Europe and beyond. The new collaboration, called *Data Spaces Business Alliance (DSBA)*, is the first initiative of its kind, bringing together the necessary industry players to achieve a data-driven future in which organisations and individuals can unlock the total value of their data.

Having over 1,000 members combined, the Alliance's founding organisations represent leading key industry players, associations, research organisations, innovators, and policy-makers from local, national, European levels, and much more.

Dspaces are considered to be the key to achieving sovereign, interoperable and trustworthy data-sharing across businesses and societies – a fundamental step to the future data economy. With its rich, complementary set of players and skills, the Alliance can pull multiple levers that can simultaneously drive awareness, evangelise technology, shape standards and enable integration across industries.

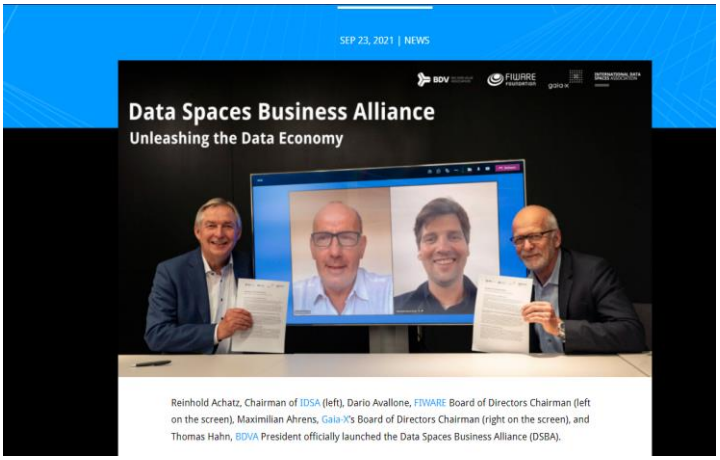

Figure 7 The launch of the Data Spaces Business Alliance

Whereas data sharing practice is gradually growing over time, organisations often face significant barriers that prevent them from leveraging direct benefits. Here, Data Spaces[14] steps in, bringing together data providers, users and intermediaries. Data spaces play such an important role in helping businesses to competitively extract value out of data also through

[14] https://design-principles-for-data-spaces.org/

Industrial AI, based on interoperability, portability, sovereignty, and trustworthiness.

The Alliance is working together in three major areas:

1. *Technology and architecture*: The Alliance defines a common reference model.
2. *Support:* The Alliance assists the existing organisations and data spaces by pooling their tools, resources and expertise in a focused way.
3. *Identification and characterisation:* The Alliance establishes a 'Data Spaces Radar' to actively scout potential data spaces.

DSAB standardisation activities: a) influence standards (European and Global standards); b) standards landscape; and c) liaisons.

QU4LITY impact

IDSA standardization work is greatly related to such Q-LSP as CONTI, DAN, KOL, MONDRAGON, PHILIPS, PRIMA, and SIEMENS. IDSA provides a Reference Architecture Model[15] (IDS-RAM) for data exchange and data sharing while maintaining data sovereignty for the provider of the data. The IDS-RAM Version 3.0 was published in April 2019. In 2018 IDSA and its members started to develop a formal standard at DIN, the DIN SPEC 27070. DIN SPEC 27070 specifies a security gateway for industrial data and services. It was published on February 21st, 2020 and IDSA started to implement the DIN SPEC as ISO standard[16].

The IDS-RAM and DIN SPEC 27070 are based on the accepted Standards EN ISO/IEC 27001, IEC 62443 and others. An overview on the relationship of IDS to existing standards and the intersection with other initiatives like RAMI 4.0 IIC and FIWARE can be found in a standards knowledge graph[17]. An overview is depicted in Figure 8.

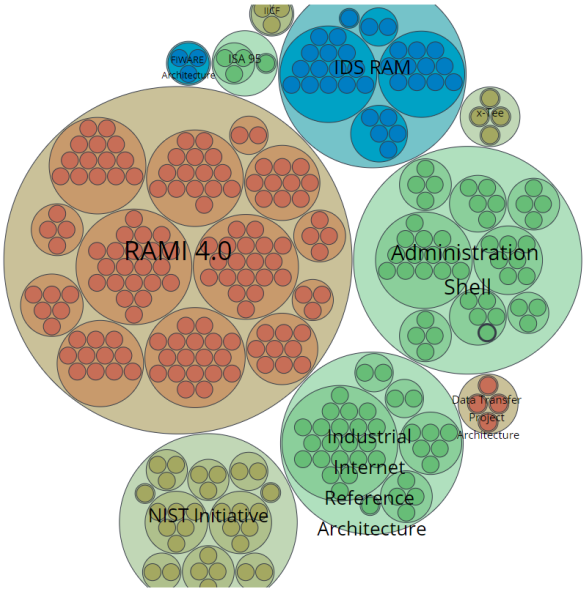

Figure 8 Overview on standards used in Industry 4.0

IDSA is an active contributor to standards for interoperability, trust and governance for data sovereignty and interweaves its work with other initiatives, e.g. IIC, Plattform Industrie 4.0, Data Trading Alliance[18], Robot Revolution and Industrial IoT Initiative[19], Industrial Value

[15] https://www.internationaldataspaces.org/ids-ram-3-0/
[16] https://internationaldataspaces.org/ids-is-officially-a-standard-din-spec-27070-is-published/
[17] http://i40.semantic-interoperability.org/sto-visualization/views/chart.html
[18] https://www.internationaldataspaces.org/idsa-and-data-trading-alliance-decide-on-data-quality-exchange/
[19] https://www.jmfrri.gr.jp/english/

Chain Initiative[20], GAIA-X[21], Big Data Value Association[22] (BDVA) and Data Sharing Coalition[23].

The IDS Information Model[24] reuses and links existing standards from the semantic web and makes them available in a comprehensive way for the use in the QU4LITY project and other projects and use cases.

Recommendations and exploitation of results

- *Recommendation:* IDSA provides an ontology for Meta Data for data exchange. This does not include vocabularies for the domain specific payload. These domain specific vocabularies have to be developed and linked to the IDS Information Model based on the linked data principles. The linked data principles refer to best practices for publishing structured data on the Web. Standards are used for the representation and the access to data on the Web, so that hyperlinks between data from different sources create a single global data graph. For Task 2.7 it was recommended to align its work on interoperability specifications with the above described activities.
  In particular, the four Linked Data Principles are:
  - to use URIs (Uniform Resource Identifiers) to name things;
  - to use HTTP URIs so that people can look up those names;
  - when someone looks up a URI, provide useful information;
  - to include links to other URIs.
- *Exploitation:* Further work for IDSA regarding the standardization topic would be efforts in the harmonization and linkage of data quality descriptions and in the development of domain specific vocabularies. The IDS information model reuses and links existing standards. This comprehensive structure could be standardized at W3C in the near future.
- *Exploitation:* In the coming months IDSA will work on the continuation of the current standardization work. This includes the work on the IDS-RAM 4.0 to be published in April 2022 and accompanying specifications for IDS Connector, IDS Meta Data Broker, IDS Clearing House and IDS Identity Provider.
- *Exploitation:* The standardization of the IDS Information model at W3C will be evaluated. As part of these activities, IDSA is co-organizing a workshop: Data Spaces & Semantic Interoperability on 3rd of June 2022, in Vienna, Austria.
  The purpose of this one-day workshop is to bring together researchers, decision makers and practitioners in the field of the development and operation of European data spaces, data markets and other web-based data management systems that allow data sharing, trading and data collaboration. The output document will summarize all the inputs and discussions about mainly (a) requirements for interoperability as well as (b) solution approaches for interoperability in data spaces, and thereby it will identify existing gaps in the field, and will be published freely available under an open license / under open access.

[20] https://iv-i.org/en/
[21] https://www.bmwi.de/Redaktion/DE/Publikationen/Digitale-Welt/das-projekt-gaia-x.html
[22] http://www.bdva.eu/
[23] https://datasharingcoalition.eu/
[24] https://github.com/IndustrialDataSpace/InformationModel

Program Chair: Sebastian Steinbuß, CTO of International Data Space Association. More information: https://www.trusts-data.eu/data-spaces-semantic-interoperability/.

3.2 Contributions at European level

3.2.1 MSP/DEI and CEN-CENELEC-ETSI SMa-CG

Description and focus areas

Smart Manufacturing Digitising European Industry is one of the challenges of the European economy but also one of the main supports to ensure its successful development. In this frame, standardization will have a key role, proposing coherent solutions across the different technologies (i.a. Internet of Things, cloud computing, big data and data analytics, robotics or 3D printing). To boost standardization activities at the European level, a joint MSP/DEI WG was set up in 2018 with the goal to bring together nominated representatives of the MSP on ICT standardization (see 2.1.1.3). This activity is greatly motivated by the recommendation of the MSP/DEI WG regarding the establishment of a platform for the synchronisation of the various standardization activities[25].

To ensure the best approach in this multifocal context, the CEN-CENELEC-ETSI Coordination Group 'Smart manufacturing' (CEN-CLC-ETSI/SMa-CG) was established. Decision ref: CEN/BT C143/2019 and CLC/BT D163/C081, applicable from: 2019-08-28 CCMC (Source: CEN/CENELEC newsletter, Nov. 2019[26]). The SM-CG advises on standardisation needs related to smart manufacturing to CEN, CENELEC, and ETSI. The Group shall not develop standardization deliverables itself, but may produce information material intended for the public domain after approval by the CEN/CENELEC/ BTs and ETSI Board. Furthermore, the SMa-CG aim is to provide information exchange with relevant initiatives including relevant EU projects.

QU4LITY impact

POLIMI and FHG IPA standardization experts have already established contact with the SMa-CG and actively participated in the meetings and presented QU4LITY results. The QU4LITY contribution to the WG activities can be described as follows:

- contribution to the current discussions of the WG regarding the current discussions about the strategic and political coordination (i.e. contribution to the platform development; support of information exchange between the SMa-CG and regional standardization activities; contribution to the coordinated approach to enhance visibility of CEN, CENELEC, ETSI, ISO and IEC activities, etc.);

[25] Source: Joint MSP/DEI Working Group on standardisation in support of Digitising European Industry (MSP/DEI WG) Final Report of the Joint MSP/DEI WG https://ec.europa.eu/digital-single-market/en/news/final-workshop-standardisation-support-digitising-european-industry-initiative-report-and

[26] https://www.cencenelec.eu/News/Newsletters/Newsletters/BT_Newsletter_November2019_Final.pdf

- contribution to the activities regarding standard monitoring (including the newest results of QU4LITY monitoring activities);
- contribution to the development perspectives (i.e. providing a link to projects' innovation and European R&D; contributing to standardization gap analysis with the current QU4LITY results and findings; supporting the development of/formulation of new possible activities based on the identified gaps, etc.).

Recommendations and exploitation of results

- *Recommendations*: The committee showed high interest in the project results. It is recommended to strengthen exchange between projects and committee.
- *Exploitation:* POLIMI as well as FHG IPA will continue to contribute to the SMa-CG and strengthen the existing cooperation and make further contributions to harmonization activities, especially to the development of the platform.

3.2.2 euRobotics

Description and focus areas

Topic Groups (TG) are part of euRobotics AISBL. euRobotics AISBL (Association Internationale Sans But Lucratif) is a Brussels based international non-profit association for all stakeholders in European robotics. One of the association's main missions is to collaborate with the European Commission (EC) to develop and implement a strategy and a roadmap for research, technological development and innovation in robotics.

euRobotics AISBL was formed to engage from the private side in a contractual Public-Private Partnership, SPARC, with the European Union as the public side. Where euRobotics AISBL represents the interests of the robotics community in Europe, SPARC disseminates its intentions through delivery of the Strategic Research Agenda (SRA) supported by the multiannual roadmap (MAR), and the updating of these documents to reflect new developments and markets (see **Error! Reference source not found.**).

Experienced delegates from the euRobotics member organisations, supported by external experts, work in 25 Topic Groups. Topic Groups develop suggestions and have to undergo a scrutinized procedure to be matched with given criteria. They identify gaps and challenges, describe the desired paths towards solutions, milestones to be reached at specified instants in time and with a specified quality. Topic Groups are the instrument to provide content to the Strategic Research Agenda (SRA) and the multiannual Roadmap (MAR) of euRobotics AISBL.

In view of the above description, Topic Group on Standardisation aims at promoting new standardization initiatives and creation of new working groups, specifically in the area of safety.

QU4LITY impact

Workshops, expert meetings, topic related editorial activities and promotion of new standards initiatives and creation of new working groups are common TG activities. JSI participated in TG Standardisation, where Dr. Andrej Gams is the Deputy

Coordinator. During the work of the TG JSI attended a workshop (WS) titled "TG Standardisation", which was organized as part of the European Robotics Forum 2020 ERF 2020. Furthermore, within the scope of the TG Standardisation, JSI a) has participated in collecting contributions to the euRobotics Roadmap 2030 – expected to be published in 2022 and b) was asked to provide feedback on standards under development.

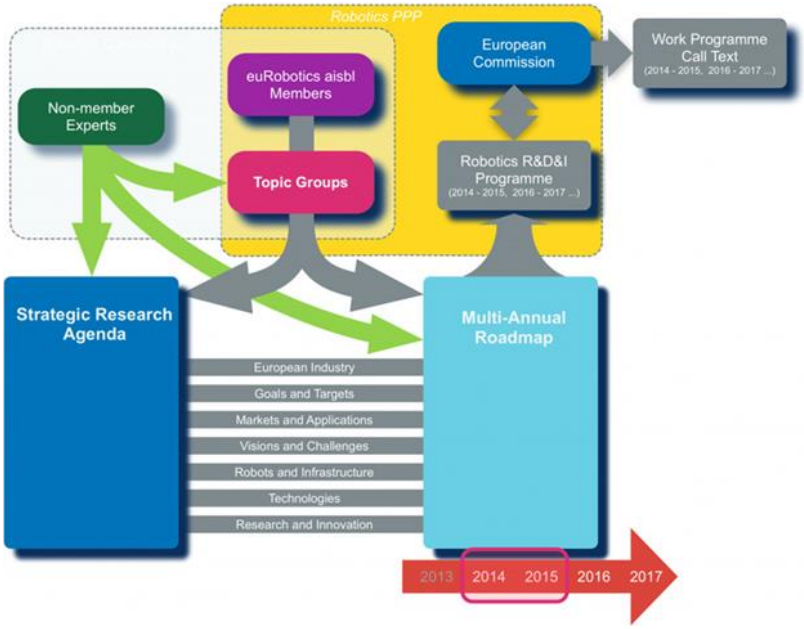

Figure 9 The Roadmapping process developed in SPARC (Source: euRobotics AISBL [3])

In particular, JSI participated in standardization activities with the aim to contribute in terms of the development and evolution of digital manufacturing standards in general. In this aspect, JSI participation dealt with a topic that was not per se related to ZDM, but was in some sense even more important, as safety of human operation in industrial environments was paramount to all else. This is motivated by the fact that the industrial robots are more and more performing tasks in collaboration with humans in flexible and reconfigurable working environments in manufacturing and beyond. In order to address the challenge of designing safety critical robot systems, ISO safety standards such series EN ISO 10218 or ISO/TS 15066 have been regularly updated and extended in the last years. New standardisation efforts have also been started on service robots for medical and household applications in order to specify general safety requirements before serial products enter the market. Apart from safety other standardization efforts focus on the harmonization of terminology and the interchangeability of robot components.

QU4LITY aims to enable fully autonomous production through introduction of human-robot interaction modules, their developments will be based on standards for collaborative robots. As stated in the project, ISO/TS 15066: 2016 is one of the standards that deals with collaborative robots. The purpose of this activity and, through extension, of this contribution, is to gather the parties interested in this topic and design a roadmap which will help include innovation companies, such as SMEs that stand to gain from the outcome of QU4LITY.

Recommendations and exploitation of results

- *Recommendation:* Currently a possible gap can be observed in ISO/TC 15066: 2016. This collaborative robotics standard is missing content on the field of wearable robotics. This will be discussed on the planned WS.
- *Exploitation:* TG will continue its regular activities in the advancement of standards on safety for collaborative human-robot action.
- *Exploitation:* QU4LITY partners will continue to promote the TG topic, update interested parties in current activities on the topics and define potential weaknesses and bottlenecks of the standards. For example, currently safety standards are missing content on the topic of wearable robots.

3.2.3 ECSO

Description and focus areas

The European Cyber Security Organisation (ECSO) is a fully self-financed non-for-profit organisation under the Belgian law, established in June 2016. ECSO is the private counterpart to the European Commission in implementing the contractual Public-Private Partnership (cPPP) on cybersecurity[27]. ECSO unites a variety of European cybersecurity stakeholders across the EU Member States, the European Free Trade Association (EFTA) and H2020 Programme associated countries. Its main goal is to develop a competitive European cybersecurity ecosystem, to support the protection of the European Digital Single Market with trusted cybersecurity solutions, and to contribute to the advancement of the European digital autonomy.

ECSO is engaged in taking concrete actions to achieve these objectives by:

- Collaborate with the European Commission and national public administrations to promote Research and Innovation (R&I) in cybersecurity;
- Propose a Strategic Research and Innovation Agenda (SRIA) and a Multiannual Roadmap with its regular updates;
- Foster market development and investments in demonstration projects and pilots to facilitate bringing innovation to cybersecurity market;
- Foster competitiveness and growth of the cybersecurity industry in Europe (large companies and SME) as well as end users / operators through innovative cybersecurity technologies, applications, services, solutions;
- Support the widest and best market uptake of innovative cybersecurity technologies and services for professional and private use;
- Promote and assist in the definition and implementation of a European cybersecurity industrial policy to encourage the use of cybersecurity solutions as well as secure and trustworthy ICT solutions to increase digital autonomy;
- Support the development and the interests of the entire cybersecurity and ICT security ecosystem (including education, training awareness, etc.).

ECSO members regularly take part in Working Groups and Task Forces and are tackling priority issues, as defined by the ECSO Board of Directors. ECSO's Working Groups are:

[27] https://ecs-org.eu/

- NAPAC: National Public Administrations Committee
- WG1: Standardisation, certification and supply chain management
- WG2: Market deployment, investments and international collaboration
- WG3: Sectoral Demand (Industry 4.0, Energy, Financial, Public Services / e-Government, Health, Transportation, Smart Cities, Telecom - Media & Content)
- WG4: Support to SMEs, coordination with countries and regions
- WG5: Education, awareness, training, cyber ranges
- WG6: SRIA and Cyber Security Technologies.

QU4LITY impact

QU4LITY aims to enable fully autonomous production. To achieve such grade of automation, multiple assets need to interact between them with low or no user intervention. To ensure that the interaction between such assets is guaranteed and to protect the production from unauthorized access and control, it is needed to know the activities made on ECSO and needs to be incorporated on QU4LITY.

To contribute to these objectives IKERLAN has been actively participating since the beginning of the project in ECSO's WG1: Standardisation, especially in the Connected Components subgroup, and WG3: Sectoral demand.

The activities of WG1 address (1) the roll-out of EU ICT security certification framework and its priorities, (2) recommendations on standards to support cybersecurity certification schemes, (3) security assessment guidelines of components, systems and services, (4) impact of security assessment along the supply / value chain in Europe for increased digital autonomy and (5) cooperation with EU and international bodies on standardisation and certification.

The activities of WG3 address (1) the industrial policy activities such as defining the needs of sectors for standardisation/certification, education, training and exercises, and local / regional impact, (2) support and accelerate the widest and best market uptake of innovative cybersecurity technologies and services in the different sectors, (3) support the use of innovative trusted cybersecurity solutions and services for major societal and economic challenges in Europe particularly in areas where Europe has a competitive advantage (4) improve risk management with better metrics (5) improve user's digital trust and facilitate information exchange and (6) develop the EU ICT security market and employment

Meetings of each WG take place every three or four months. The principal discussion point of the latest meetings was about the assessment of the security. Different security assessments exist; namely, self-assessment, made by a third-party and made by national third-party authority, and the decision on the type of option is under the responsibility of the manufacturer who should choose it after having conducted a risk analysis to measure the liability.

Recommendations and exploitation of results

- *Recommendation*: The activities of WG1 should be considered in the pilot's work in order to be compliant with the regulatory requirements and to protect the company assets. Particularly, the standard IEC 62443 should be adopted in the pilot. This standard focuses on security capabilities for Industrial Automation and Control Systems (IACS) and covers policies-&-practices for system integrators, secure development lifecycle, component specifications and security requirements-&-levels.
- *Recommendation*: The activities of WG3 should be considered in the pilot work development in order to be aware about the cybersecurity challenges, the SOTA and current cybersecurity technologies and services related not only to the ICT view but the sectorial view (e.g. Industry 4.0 & Industrial Control Systems).
- *Exploitation*: IKERLAN will continue its regular activities in the advancement of standards on cybersecurity for Industry 4.0 and Industrial Control Systems.
- *Exploitation*: The active participation in ECSO has yield results in the industrial security domain. On the one hand, on the application of industry best practices for the secure design, integration, and governance of next generation manufacturing systems. In this scenario, active collaboration among all stakeholders involved in the management of the production systems is needed, in which legal and security responsibilities must been assigned according to the ongoing EU ICT security legislation and framework (e. g. Cyber-Security Act). On the other hand, security of supply chain and third-party provider management. Based on the discussions, regulatory mechanisms are needed to address these risks, such as independent audits and certificates (both for sites and personnel), for example TISAX, which aims at verifying that a given organization security processes comply with the established security levels and, at the same time, enables the mutual recognition. IKERLAN has been working on the third-party management processes and procedures, both at organization and product level that will use in upcoming research (e.g. IDUNN) as well as in industrial projects.

3.2.4 EPoSS

Description and focus areas

EPoSS is the European Technology Platform on Smart Systems Integration. This private association is an industry-driven policy initiative defining R&D and innovation needs as well as policy requirements related to Smart Systems Integration and integrated Micro- and Nano-systems. A group of major industrial companies and research organisations (EPoSS Members) from more than 20 European Member States intend to co-ordinate their activities in the field of Smart Systems Integration. A main objective is to develop a common European vision and to set up a Strategic Research Agenda[28].

[28] https://www.smart-systems-integration.org/

Smart Systems Integration (SSI) is an assembly of technologies that build products from components, that combine functions in products and systems that connect and network systems to other systems, and, importantly, enable systems to receive and store a "knowledge base" – the software that makes them "Smart". Smart Systems combine cognitive functions with sensing, actuation, data communication and energy management in an integrated way. The enabling principles of these functions include nanoelectronics, micro-electromechanics, magnetism, photonics, chemistry and radiation.

EPoSS, in its Strategic Research agenda, targets seven applications sectors: Transport & Mobility; Health & Beyond; Manufacturing / Factory Automation; Communications; Energy; Aerospace; Smart Systems for the Environment. In addition, it considers four cross-sector domains: Safety & Reliability; Security; Technologies Supporting Smart Systems; and Production Processes for Smart Systems.

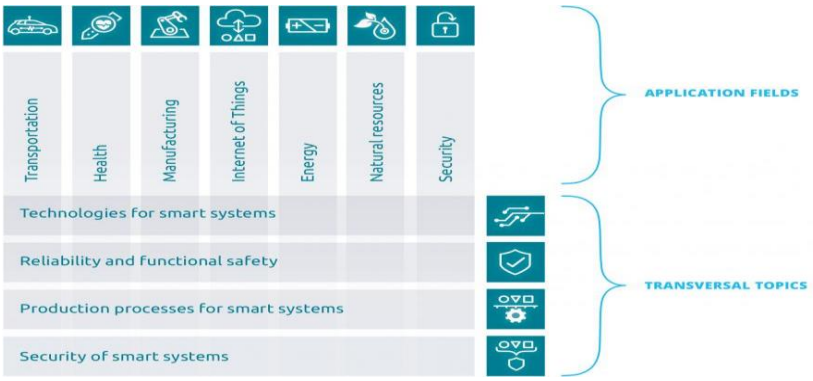

Figure 10 EPoSS Strategic Research agenda

Its 7 Working Groups reflect these areas of activity: WG Transportation, WG Healthy Living, WG Factory Automation and Robotics, WG Energy, WG Applied NMBS (nano-micro-bio systems), WG Natural Resources and the WG Key Technologies.

There is a close collaboration with CEN-CENELEC and both workshops "EPoSS StandarDays" and a webinar "Horizon2020 - How to address standardization in proposals" have been organised.

QU4LITY impact

As QU4LITY focuses on a shared data-driven ZDM product and service model for Factory 4.0, Quality, Reliability and Safety of products and manufacturing equipment, besides securing the data sharing between multiple assets became a major issue. Therefore, activities made in EPoSS were incorporated on QU4LITY.

In 2017, EPoSS issued a "Position Paper: Smart Systems for the Automated Factory"[29] in which it established the contributions that SSI can bring to the manufacturing industry in general and to the "Factory of the Future" PPP in particular. To contribute to these objectives, IKERLAN hosted and co-organised the EPoSS

[29] https://www.smart-systems-integration.org/publication/position-paper-smart-systems-automated-factory

Annual Forum in San Sebastian, October 17-19th, 2019. It hosted the meetings of all working groups and the conference programme included a special session on Manufacturing, with a Keynote contribution by Eduardo Beltrán de Nanclares of the Mondragon Corporation, titled "*Digitalisation and Industry 4.0 in MONDRAGON and their Application to Resources Efficiency*".

The EPoSS Identity Document, which was published in the second quarter of 2020, dedicated a complete chapter to Quality, Reliability and Safety. It identified the following 4 major challenges for smart systems in all application sectors, including in industrial manufacturing:

- Managing the complex variability of smart system parameters;
- Ensuring Agile/Easily adaptable Design for Reliability methodology;
- Integrating self-monitoring concepts for automated and autonomous systems;
- Ensuring safe and secure transfer/sharing of data.

Recommendations and exploitation of results

- *Recommendation*: The activities of WG Factory Automation and Robotics as well as the advancements on the challenges identified regarding the management of complex variability of smart systems, agile adaptable design for reliability methodology, integration of self-monitoring concepts for automated systems, and safe and secure sharing data should be considered to enhance the industrial processes at any level towards shared data-driven ZDM product and service model for Factory 4.0.
- *Exploitation*: IKERLAN will continue its regular activities in the advancement of requirements related to Smart Systems Integration.

3.2.5 FIWARE

Description and focus areas.

ATOS participates actively in FIWARE initiatives, from business to technical. From the business side, ATOS is platinum member of the FIWARE foundation and participates actively in FIWARE related events and fairs. From the technical side, ATOS is developing software based on FIWARE Generic Enablers, like MASAI, Atos Urban Data Platform and others.

FIWARE brings a curated framework of open-source platform components, which can be assembled together and with other third-party platform components to build Smart Solutions faster, easier and cheaper. A simple yet powerful API (FIWARE NGSI) enables the integration of components and provide the basis for the interoperability and replication (portability) of smart solutions[30].

As part of the FIWARE Smart Industry Mission Support Committee (SIMSC) we are fostering FIWARE usage in the industrial domain.

[30] https://www.fiware.org/

QU4LITY impact

ATOS impact in the standardization task was mainly to bring its knowledge gained during the definition of the FIWARE4Industry Reference Architecture, where ATOS is a key player, and the use of FIWARE-based components like MASAI (and asset demonstrated in the CON pilot, MASAI[31] is a data collector for Industrial domains based on FIWARE components."

Recommendations and exploitation of results

- *Exploitation*: One of the actions of the committee was to meet RAMI 4.0 experts from Industrie 4.0 Platform[32] to push NGSI-LD to be the chosen standard for AAS that provides the communication layer with the Industry 4.0 components (see also Section 3.3.5 regarding AAS). In this manner, ATOS was exploring the possibility of integrating MASAI with the International Data Space Association (IDSA), following the work already done by the FIWARE Foundation on the integration of the FIWARE Context Broker and IDSA.

3.2.6 EFFRA Innovation Portal

Description and focus areas

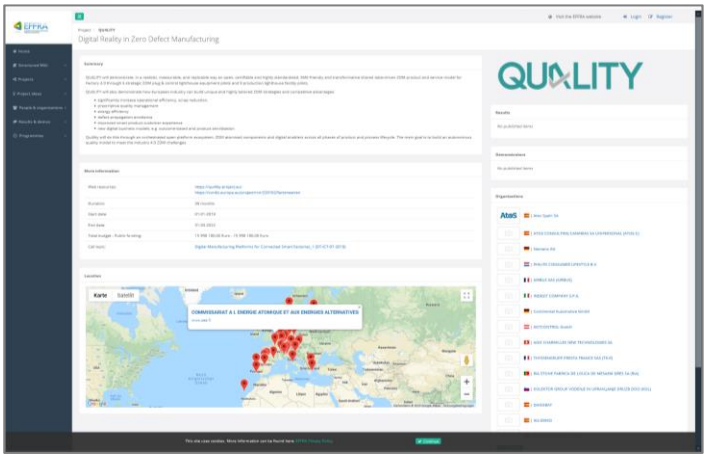

Figure 11 QU4LITY record in the EFFRA Innovation Portal

The EFFRA Innovation Portal[33] supports the sharing of information to the wider research and innovation community that is working on the digitalisation of manufacturing and the deployment of digital platforms for manufacturing in particular.

QU4LITY impact

QU4LITY established the project record in the EFFRA Innovation Portal (**Error! Reference source not found.**) which describes the main challenges, technologies and enablers as well as the main research priorities of the project. QU4LITY has been closely cooperating with EFFRA on standardization topic throughout the whole task and attended several meetings and events (i.e. as speaker on standardization topic). See additional results in this context described in section 4.1.1.

[31] https://marketplace.fiware.org/pages/solutions/5a6bac60ffca24dd063170ca
[32] https://www.plattform-i40.de/PI40/Navigation/DE/Home/home.html
[33] https://www.effra.eu/effra-innovation-portal

3.3 Contributions at national level

3.3.1 DIN NA 043-01-41 AA

Description and focus areas

DIN, the German Institute for Standardization, is the independent platform for standardization in Germany and worldwide. As a partner for industry, research and society as a whole, DIN plays a major role in paving the way for innovations to reach the market and advancing progress in innovative areas such as I4.0 [4]. DIN represents German interests as a member of CEN and ISO/IEC in European and international standardization since 1975.

NA 043-01-41 AA is a working committee at DIN. It was established to reflect the work of current JTC 1/SC 41. The working committee supports the information and coordination process for IoT and digital twin within the framework of standardization and forms an important link to other national committees and groups developing I4.0 standards. Such objectives as standardization of IoT-related terminology, use cases, reference architecture and various interoperability aspects in industrial field are in the scope of the committee's work.

QU4LITY impact

The contribution to this committee has a direct impact on the process of developing an international standard, as the work is reflected in the international activities of ISO/IEC JTC 1. International Standards are reviewed at regular intervals to ensure that they reflect the current state of science and technology and are applicable. FHG IPA is the committee member and has been regularly participating in committee meetings representing on QU4LITY interests.

Throughout the period, FHG IPA attended six general plenary meetings of the committee: March 2019 (Frankfurt), October 2019 (Frankfurt), March 2020 (online), October 2020 (online), April 2021 (online) and March 2022 (online) where FHG IPA reported on the latest developments in the German Standardization Roadmap Industrie 4.0 and presented the results of the latest work. Thus, an important link was established and a contribution made to the harmonisation of the two national activities. During the meeting, the FHG IPA specifically addressed the importance of the ZDM topic and discussed the possibilities for further cooperation.

Another key activity of QU4LITY was the screening and analysis of international standards with regard to IoT and digital twin, especially in industrial applications. QU4LITY analysed standards with regard to the data confidentiality and integrity (see e.g. FAGOR Q-LSP), IoT gateway standards (e.g. MONDRAGON-2 Q-LSP), shop floor control system and sensor networks (CONTINENTAL and PHILIPS), converters for interoperability (MONDRAGON-2, FAGOR, and CONTINENTAL), and other. In this context, the following standards have been processed for gap identification and reported to the committee as indicated in Table 5 in Appendix A.

Recommendations and exploitation of results

- *Recommendation:* With the development of the digital twin concepts, the work of NA 043-01-41 AA in Germany is gaining further importance. At the national level, the committee should receive enhanced support from industry and research in order to contribute the most necessary requirements with regard to missing standards for Industrial IoT und digital twin.
- *Recommendation:* It is recommended to use the ISO/IEC 30172 TR Digital Twin – Use Cases template while describing digital twins.
- *Exploitation:* The ISO/IEC 30172 TR know-how is currently exploited by FHG IPA in two running (national) projects and will be further promoted in the upcoming proposals at European level dealing with digital twin development.

3.3.2 DKE/K STD_1941 SCI 4.0 Expert Panel

Description and focus areas

One of the major goals of the German standardization strategy (see Figure 12) is to bring future-oriented topics into standardization on a worldwide scale through the networking of stakeholders and the establishment of new processes and open platforms for coordination [4]. Therefore, DIN and DKE organize standardization topics and coordinate teamwork beyond the borders of their own organizations, including consortia and other standards development organizations.

In this architecture, the Standardization Council Industry 4.0 takes over the coordination role between industry and standardization in Germany, and mediates between various standardization organizations (SDO) and other actors. The SCI 4.0 is an initiative originating from Bitkom, DIN, DKE/VDE, VDMA and ZVEI, built with the aim of initiating standards for digital production and coordinating them nationally and internationally. The SCI 4.0 regularly consolidates the knowledge from all involved parties and addresses technology gaps and needs identified by industry. The result of the joint work is the German Standardization Roadmap Industrie 4.0 (see Chapter 3.3.3).

Within the framework of SCI 4.0, The Expert Panel is a linking element that involves all relevant bodies and technical committees in the process. It performs the coordinating role in the implementation of the standardization roadmap, which includes a critical analysis and prescribes measures to implement the recommendations for action (see Section 3.3.3).

QU4LITY impact

FHG IPA is an active member of the committee. For the last period of time FHG IPA attended nine general meeting sessions of the committee: February and September 2019; January, May and September 2020 (F2F and remote); January, May and September 2021 (remote); and January 2022 (remote), where FHG IPA provided its expert contributions in the following areas:

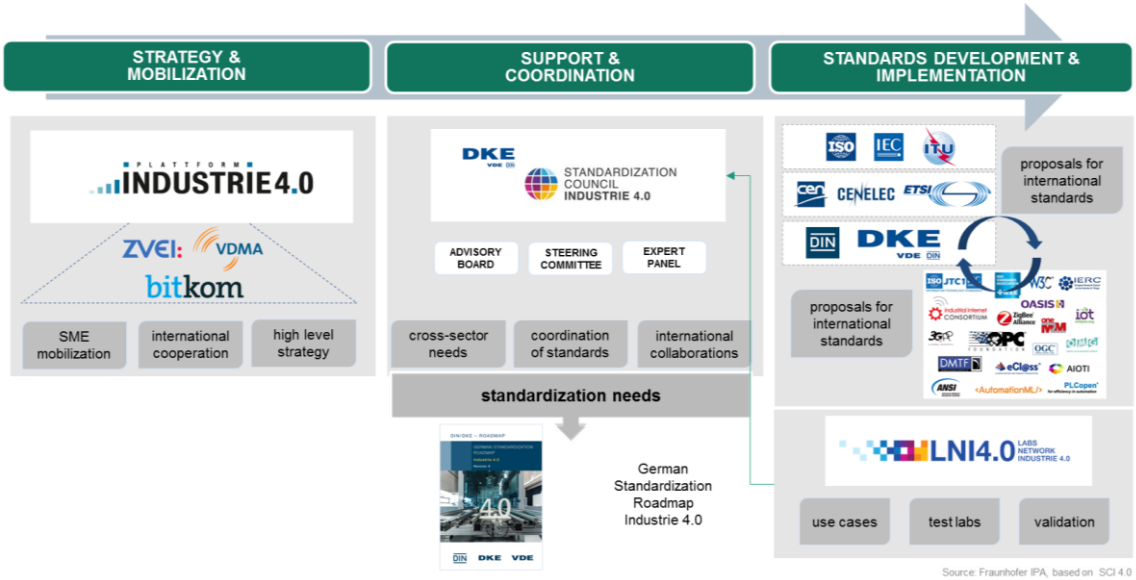

Figure 12 German standardization strategy Industrie 4.0 (Source: Fraunhofer IPA, based on SCI 4.0)

- Revision of the proposal for the ICT Rolling plan and identification of the gaps;
- Revision of the identified standardization gaps across various topics (incl. AI, security, interoperability, integration, industrial use cases, systems, etc.) with regard to the work done in 3.3.3;
- Linkage to recent research developments in ZDM context, drawing attention to the QU4LITY standardization activities and the ZDM topic;
- Several presentations of related QU4LITY standardization results and active participation in ongoing discussions on a variety of cross-cutting topics identified in the QU4LITY context.

Recommendations and exploitation of results

- *Recommendation:* In this context, it is worth to mention the collaboration of two joint white papers on Semantic Interoperability between AIOTI, ISO/IEC JTC1, ETSI, oneM2M and W3C that is targeting developers and standardization engineers. This work is recommended to consult while targeting the quick adoption of semantic technologies.
- *Recommendation:* If future strategic ideas and standardization gaps are identified in the course of the project work that are of interest to the ICT Rolling Plan, it is recommended (for German experts) that the committee be contacted. On its behalf, FHG IPA plans to continue to actively contribute to the committee work and link upcoming projects in the given process.
- *Exploitation:* The committee's work has proved very successful in terms of strategic orientation with regard to project work. This can also be transferred to ongoing projects and other activities.
- *Lessons learned:* The general recommendation concerning contribution to strategic committees is that it is a useful mechanism: a) to receive a qualified update on the latest changes in the standardization landscape; b) to get orientation to the newly developed standards and activities; e) to become an opportunity to enrich the standardization strategy with practical requirements.

3.3.3 DKE/AK STD_1941.0.1 Standardization Roadmap I4.0

Description and focus areas

The Standardization Roadmap for Industrie 4.0 [5] is one of the central communication media for Industry 4.0 (I4.0) in Germany. It enables the national and international exchange of information between standardization, industry, associations, research and politics [5]. The aim of the roadmap is to initiate a discussion between all stakeholders, to analyse current developments in the standardization process and to identify the need for standardization in various I4.0 areas. Thus, the document presents the outcomes of current standardization work at different layers, i.e. national, regional and international.

The main outcome of the roadmap is a list of recommendations for action that are coordinated with the experts of the Expert Panel (see 3.3.2). These recommendations are developed for all actors, including the national and international initiation and coordination of suitable standards as well as industrial stakeholder.

QU4LITY impact

FHG IPA (in a role of convener of the committee) contributed to the development of the 4th edition of the Roadmap[34] together with other experts from industry, research, science and politics. At the end of 2021, the committee was commissioned by the SCI 4.0 Expert Panel to prepare the progress report (2022) and the 5th edition of the Roadmap (due to 2023). The committee will continue to be led by FHG IPA.

Based on various focus areas of I4.0, more than ten working groups with various experts were set up to analyse the current standardisation landscape and draw up recommendations for the new edition. Thus, the Standardization Roadmap is addressing practically all topics which are in focus of QU4LITY work, i.e. reference architectures, vocabulary, interoperability, integration and communication of I4.0 systems and their aspects, artificial intelligence, trustworthiness and other. This work is related to the most of QU4LITY technologies. Prominent examples are e.g. standardization of technologies regarding communication, format data and service interoperability, information modelling (e.g. FAGOR, MONDRAGON), information visualisation (e.g. PRIMA and CONTINENTAL), ontologies (e.g. CONTINENTAL, WHIRLPOOL, AIRBUS, GF), big data architectures (MONDRAGON), standardization of communication protocols like OPC UA, UMATI, API REST, etc. (e.g. DAN, PRIMA, RIASTONE, FAGOR, SIEMENS, KOL), quality standards (e.g. CONTINENTAL, PHILIPS, RIA STONE), safety and security (e.g. PHILIPS, DANOBAT, RIA STONE, THYSSENKUPP), and other.

Throughout the period, FHG IPA led nine general plenary meetings of the committee: May, June, September and October 2019; July, September, October, and December 2021 (remote); and February 2022 (remote); and attended several remote editorial meetings. The key contribution of QU4LITY impacts can be reported as follows:

[34] The version is offered in various languages for free download at https://www.sci40.com/sci-4-0/normungsroadmap/

a) As a convener FHG IPA supported the experts and coordinated the process from the technical side.
b) As a working group leader FHG IPA led three working groups, made written contributions, and coordinated the work regarding such topics as reference architecture models, integration and interoperability, including data models, semantics, information models and vocabulary.
c) FHG IPA has contributed to ZDM challenges in QU4LITY project in the section regarding industrial cloud platforms (e.g. based on analytics of production data in the cloud technology provided by SINTEF and ATB in CONTINENTAL).
d) As a member of the editorial board FHG IPA reviewed the document and edited the comments, including the revision of the recommendations and their alignment with the latest QU4LITY results.
e) FHG IPA presented the Standardization Roadmap at the Hannover Fair (2020) per video message and took part in general discussions regarding the standardization needs and current challenges.

Recommendations and exploitation of results

- *Recommendation:* Among other gaps and recommendations in the 4th edition, it is worth to mention the lack of harmonization and poor linkage between research and standardization bodies. One can still observe a fragmented landscape for standards with regard to I4.0 activities.
- *Recommendation:* Though, a large number of liaisons has been agreed among relative bodies, there is still some double work in the committees, which has to be avoided. Thus, there is a need for harmonization in order to avoid the overlaps and establish a close exchange on related I4.0 topics.
- *Exploitation:* The activities of DKE/AK STD_1941.0.1 aim at contributing to the harmonization of I4.0 standards and closing the gaps. FHG IPA will continue to contribute to the committee's work (in particular, to the Progress Report (to be published in 2022) and to the 5th Edition of the Roadmap (to be published in 2023)) and bring the newest QU4LITY results and findings to the expert discussion. In this way, FHG IPA will contribute to a better link between research and standardization bringing its expertise to the recommendations.

3.3.4 SCI 4.0 Expert Council for Artificial Intelligence for Industrial Applications

Description and focus areas

In the standardization of artificial intelligence for industrial applications, many countries still face the challenge of coordinating and harmonizing activities in order to present a consolidated picture of the requirements and standardization needs in the context of AI and to be able to carry out corresponding standardization activities in a coordinated manner both nationally and internationally.

Artificial intelligence is a key element in German standardization strategy. Due to numerous international activities in this field, SCI 4.0 (see Sections 3.3.2 and 3.3.3) created a national *SCI 4.0 Expert Council for AI for Industrial Applications* [7] to

discuss and implement technologies and fields of application of AI in Industry 4.0 as well as possibilities of implementation using technical standards.

The working group of the Expert Council contributes to the development of the *German Standardization Roadmap on Artificial Intelligence* in the first edition. The Roadmap provides a comprehensive overview of the status quo, requirements and challenges, as well as the need for standardization on seven key topics related to artificial intelligence. The five overarching and central recommendations for action identified by participating experts are currently being implemented.

The roadmap is a "living document". A kick-off event on 20 January 2021 gave start to the second edition of the roadmap[35].

QU4LITY impact

German Standardization Roadmap on Artificial Intelligence (the 1st and the 2nd editions)

FHG IPA is a member of the Expert Council actively contributing to the German Standardization Roadmap on Artificial Intelligence. To the beginning of the project, FHG IPA established contact to the working group of the Expert Council, applied for the membership and discussed possible QU4LITY contribution areas. This exchange provided an opportunity to support the development of QU4LITY AI-related technologies and to help stakeholders to ensure compatibility with international AI norms and standards from the very beginning of the project.

Throughout the period, FHG IPA attended several general plenary meetings of the committee (1st edition and 2nd edition): February, March, and November 2020 (remote); February, March, November, and December 2021 (remote); February and March 2022 (remote) and contributed specifically to the technical requirements and formulation of standardization needs in the area of industrial automation. Key contributions were provided to the subgroup "Data Modelling & Semantics".

Analysis in context of DIN SPEC 92001-1

The newly published DIN SPEC 92001-1, *Artificial Intelligence – Life Cycle Processes and Quality Requirements – Part 1: Quality Metamodel* aims to ensure the quality of AI throughout its entire life cycle using a uniform concept. The document defines a quality metamodel that comprises and combines all key aspects of AI quality and provides a structural basis that can be used by QU4LITY technology providers to ensure the quality of AI in specific application situations. The metamodel is universally valid, i.e. it is not limited to a specific application, and covers AI quality aspects in a broad sense. This can be especially valid in the conception and development stages in order to prevent bias when information is processed [8].

DIN SPEC 92001-1 has been analysed by QU4LITY standardization experts on its applicability in the project context. The analysis of the goals and requirements shows that DIN SPEC provides opportunities to ensure robust, explainable, safe, secure and trustworthy AI applications. Thus, it was recommended to verify the alignment of the

35 https://din.one/display/KIB/2020/01/18/Normungsroadmap+KI%3A+Arbeitsgruppen+nehmen+die+Arbeit+auf

project work with the DIN SPEC quality model in the AI concepts of the project, especially regarding such task as T2.2, T3.3.

Analysis in context of ISO/IEC JTC 1/SC 42

ISO/IEC JTC 1/SC 42 is the respective international committee taken the lead role in standardization in the area of artificial intelligence. The committee is organized in the following working groups: WG 1 Foundational standards; WG 2 Big Data; WG 3 Trustworthiness; WG 4 Use cases and applications; WG 5 Computational approaches and computational characteristics of AI systems. In this context, FHG IPA analysed and identified several activities that were closely addressed and monitored by the experts of the task (see Appendix A, Table 6).

Harmonization:

According to SCI4.0 [7], due to numerous international activities in the field of AI, it is important to initiate a national discourse that will allow an early involvement and co-design of international activities. In this scope, QU4LITY identified a need to contribute with its results to a common AI framework and will further support the SCI4.0 activities accordingly.

Recommendations and exploitation of results

- *Recommendation:* It remains essential that the link between R&D and industry and SDOs/SSOs becomes stronger. Investigation of industry practices, processes, and methodologies for the application of AI systems and collection of representative use cases remains a goal of standardization.
- *Recommendation* During the standards screening process, several basic standards on quality were identified and recommended for review in pilot projects and for use in other projects, such as the ISO/IEC 25000 series of standards, which provides a framework for assessing the quality of software products. See extended list of standards in Table 7[36] in Appendix A.
- *Recommendation:* Further standardization needs were detected that might need more detailed investigation in the following R&D activities[37]:
    - Investigate approaches to establish trust in AI systems through transparency, verifiability, explainability, controllability, etc.
    - Investigate engineering pitfalls and assess typical associated threats and risks to AI systems with their mitigation techniques and methods.
    - Investigate approaches to achieve AI systems' robustness, resiliency, reliability, accuracy, safety, security, privacy, etc.
    - Investigate types of sources of bias in AI systems with a goal of minimization, including but not limited to statistical bias in AI systems and AI aided decision making.
    - Study different technologies used by the AI systems including their properties and characteristics. Study existing specialized AI systems to understand and identify their underlying computational approaches, architectures, and characteristics.

[36] NOTE: Further standardization activities in the scope are described in 3.3.1.
[37] https://jtc1info.org/sd_2-history_of_jtc1/jtc1-subcommittees/sc-42/

3.3.5 Platform Industrie 4.0

Description and focus areas

Platform Industrie 4.0[38] promotes the development of I4.0 in Germany. Besides, through international cooperation, it contributes to global discussions and promotes standardization as well as the cross-border exchange for digitization in production. The platform includes experts from business, science, associations and the trade unions, and representatives from various federal ministries that work in various thematic working groups. The groups look at future-related issues in the areas of standardisation and norms, security of networked systems, legal frameworks, research, working arrangements and business models. Among others, the WG "Reference Architectures, Standards and Norms" develops the basis for uniform, open standards and carries their ideas into international standardization processes.

QU4LITY impact

FHG IPA is a member of a sub-working group GMA 7.20 that is contributing to the current work of the platform, especially in the context of the Asset Administration Shell (AAS). The Platform I4.0 working group is continuously developing specifications and publishing further work on AAS together with its partners.

Interoperability concepts based on the AAS and digital twin are of great interest to all QU4LITY pilots. CONTINENTAL's goal, for example, is to realize vertical interoperability, i.e. between multi-stage production lines by capturing, communicating, securely storing and visualizing holistic real-time data. WHIRLPOOL, for instance, focuses on seamless interoperability of equipment and human-operated processes across multiple quality stations. MONDRAGON is developing a framework in which physical cyber production systems and manufacturing processes are able to exchange data (sensed and pre-processed) with other parties across the whole supply chain. PRIMA is developing a new approach with a modular, adaptable signal processing system that can work at the edge and interacts with the data space and simulation tools via the PRIMA fleet management platform. Security and interoperability are the main topics of several pilot projects, such as FAGOR, IKERLAN, RIASTONE, and DANOBAT, which address data confidentiality and integrity, security architectures for the exchange of industrial data and services, security techniques, and the secure exchange and information storage in the production line.

Clearly, the lack of standardized mechanisms that can support this kind of vertical and horizontal integration of IoT components and manufacturing processes can greatly hinder interoperability among components. The necessity arises from the fact that communication partners change dynamically depending on environmental conditions and application requirements. During the development phase of the component and the overall system it is not yet known which components will interact within a system. For this reason, such bootstrap mechanisms are needed to support pattern formation at system runtime and to enable the communication of IIoT components from different manufacturers at vertical and horizontal integration. In

[38] www.plattform-i40.de/

this context the FHG IPA identified e.g. the current work of DIN SPEC 16593-2 mechanisms for bootstrapping, advertising and lookup of industrial IoT components that are of interest for its standardization activities. The aim of DIN SPEC 16593-2 is to define a uniform mechanism for the dynamic mediation of industrial IoT components, which makes it possible to find communication partners - independent of a concrete implementation technology of the IIoT component, such as AAS in an Industry 4.0 system.

During the last period of time, FHG IPA attended several general meetings contributing to the development of the DIN SPEC as well as supported the development of AAS related guidelines for submodel development.

Recommendations and exploitation of results

- *Exploitation:* FHG and other QU4LITY partners will continue conceptual development and delivery of specifications for broad application of AAS. Currently, FHG IPA is intensively exploring the concepts in national projects (e.g., InterOpera, FabOS, etc.) and supporting the further development of open source implementation and didactics concepts to support industry.
- *Lessons learned:* QU4LITY's participation in the ConnectedFactiories2 thematic workshop and the exchange with other EU projects on October 12, 2021 provided the opportunity to make new contacts and engage in fruitful discussions for further joint project in the field of AAS.

3.3.6 UNI

Description and focus areas

UNI – Ente Nazionale Italiano di Unificazione is the Italian standardization body, a private, non-profit association founded in 1921 to develop, approve and publish standards in all economic sectors (industry, trade and services) excluding electric and electrotechnical ones. UNI officially represents Italy in EU (CEN) and international (ISO) standards organisation as acknowledged in EU Reg. N. 1025/2012 and Italian law D.L 223 of 15/12/2017.

UNI is contributing smart manufacturing standardization landscape ensuring synchronisation of standardisation activities on vertical and horizontal level. Specific attention is given to ensure application reference architecture in manufacturing value chain, enhancing a cross sectoral approach (C2C, M2M, etc.). Several, also non-technical, issues are taken into account: quality management; safety; digital skills (e.g. manufacturing skills of KETs, M2M, etc.), people and organization enhancement; business modelling; social and ethical impact (e.g. ISO 26000:2020 Guidance on social responsibility, UNI/PdR 18:2016 Social responsibility in organizations - Guidance to the application of UNI ISO 26000), sustainability approach etc.. Finally, UNI is member of CEN/CENELEC/ETSI Smart Manufacturing Coordination Group.

QU4LITY impact

- Social responsibility. Codifying impact of QU4LITY approach on business modelling and value chain societal aspect. *UNI/PdR 18:2016 Social responsibility in organizations - Guidance to the application of UNI ISO 26000*[39] provides a detailed framework and guidelines;
- Responsible Research and Innovation (RRI). Support QU4LITY on approaching the issue of RRI where ethical and societal acceptability of the innovation is taken into account with a risk –based approach (e.g. Draft CWA - Guidelines to develop a roadmap to integrate Responsible Research and Innovation (RRI) in industrial strategies[40])
- Quality Management. Enhance impact of QU4LITY approach on quality management standard (e.g. UNI ISO 10005:2019 - Quality management - Guidelines for quality plans; UNI ISO 10000 series on quality management; EN ISO 9000 series on quality management systems);
- Sustainability. Enhance impact of QU4LITY on sustainability, enhancing use of ZDM approach to reduce obsolescence and prove the advantages of high-tech refurbishment and re manufacturing. Synergies with standardization activities foreseen in RECLAIM H2020 project[41], of which UNI is member, might be envisaged;
- Liaison with CEN/CENELEC/ETSI Smart Manufacturing Coordination as well as STANDICT.eu "Supporting European Experts Presence in International Standardisation Activities in ICT"42 initiative.

Recommendations and exploitation of results

- *Recommendation:* Harmonization: Overlap, redundancy and fragmentation must be avoided. Often there are several standardization activities ongoing in the same area in parallel, both at ESB and NSB[43], for and consortia (e.g. AIOTI, PPPs – BDVA) and SDO, not officially recognized. "Final Report of the Joint MSP/DEI WG" findings provide useful insights; coherence with EU "ICT standardization plan" must be ensured. On a global perspective recommendation provided by "Europe's contributions to ICT Standardisation globally"[44] of STANDICT.eu project must be taken into account.
- *Recommendation:* Business Modelling impact**,** to standardize (or update existing standards) on organization driver on a cross value chain level.
- *Recommendation:* Digital skills and education**,** enhancing standardized skills framework for manufacturing autonomous quality (AQ) and Zero Defect Manufacturing (ZDM) in Industry 4.0.

[39] http://store.uni.com/catalogo/uni-pdr-18-2016
[40] Document under development at CEN level: https://standards.cen.eu/dyn/www/f?p=204:7:0::::FSP_ORG_ID:2664646&cs=10CF8602B38CD0FEF15A9C5CF317F0DEB
[41] https://www.reclaim-project.eu/
[42] https://www.standict.eu/
[43] Recognized by Reg. EU 1025/2012
[44] https://www.standict.eu/sites/default/files/Final%20Impact%20Report%20Europe%E2%80%99s%20contributions%20to%20ICT%20Standardisation%20globally%20-%20Impacts%20from%20StandICT.eu%20funding.pdf

- *Recommendation:* Safety and risk assessment issue, connected to the implementation of QU4LITY approach in real manufacturing environment.
- *Recommendation:* Sustainability and circular economy (life cycle), which might be captured in AAS submodels and industrial symbiosis models (e.g. CWA 17354:2018 - Industrial Symbiosis: Core Elements and Implementation Approaches (SHAREBOX and EPOS).
- *Recommendation:* Engaging with stakeholders (e.g. Digital Innovation Hubs, SMEs) to assess and validate standardization need of value chain connected to smart manufacturing.
- *Recommendation:* Regulatory requirements: Take into account requirements as laid down in this Union harmonization legislation apply in the context of industry and hence equally in the context of digitizing industry. This legislation (e.g. Machinery Directive MD – 2006/42/EC) requires that products comply with essential requirements which define the results to be attained or the hazards to be dealt with but does not specify the solution for doing so. The precise technical solution may be provided by a standard or by other technical specifications. This flexibility allows manufacturers to choose the way to meet the requirements.
- *Exploitation:* POLIMI will further exploit synergies with UNI to promote standardization strategic activities at national, cross national, European and international level enhancing synchronization. Specific attention will be given to issues concerning harmonization and standards implementation.

3.4 Monitored standardization activities

3.4.1 Edge Consortia

Description and focus areas

The OpenFog Consortium[45] [10] is a consortium of high tech industry companies and academic institutions all over the globe aimed at the standardization and promotion of fog computing in various capacities and fields. The consortium seeks to create an architecture and approach to fog, edge and distributed computing. Through a series of working groups, the consortium is developing an OpenFog architecture, addressing security issues, and planning industry testbeds. The goal of the OpenFog Architecture is to facilitate deployments which highlight interoperability, performance, security, scalability, programmability, reliability, availability, serviceability and agility. As of January 2019, the OpenFog Consortium has been merged with the Industrial Internet Consortium (IIC) [10].

The Industrial Internet Consortium (IIC)[46] is a global, member supported program that promotes accelerated growth of the Industrial Internet of Things (IIoT) by coordinating ecosystem initiatives to securely connect, control and integrate assets and system of assets with people, processes and data using common architectures, interoperability and open standards to deliver transformational business and societal

[45] Note: OpenFog Consortium merged with the Industrial Internet Consortium (IIC) in January 2019
[46] https://www.iiconsortium.org/about-us.htm

outcomes across industries and public infrastructures. One of the main goals of the IIC is the development of testbeds to demonstrate the real-world implementation of industrial internet solutions.

QU4LITY impact

Edge/fog standards were in close focus of the project, particularly, regarding the development of edge/fog device and middleware technologies (e.g. GF and PHILIPS Q-LSP), edge analytics (RIASTONE and THYSSENKRUPP Q-LSP).

Reference Architecture Model

The IIC is promoting the technological development of networked machines and intelligent analytics. The newly published the Industrial Internet Reference Architecture (IIRA) [11] provides a very useful focus on a cross-industry reference model for digital application scenarios. IIRA provides a general framework at a high level of architectural description and design and ensures broad applicability in a variety of industry sectors. The OpenFog RA and IIRA address a number of specific system aspects, such as integration, interoperability, connectivity, data management and analytics that are important for QU4LITY.

IIRA has greatly inspired the development of the QU4LITY RA. In this context, FHG IPA worked closely together with Task 2.6 and contributed to the development of the basic concepts and design of the architecture.

Trustworthiness

Regarding autonomous systems and, especially, in context of quality assurance, it was also important to address trustworthiness requirements – security, safety, reliability, resilience and privacy – as described in [12]. In [13] IIC presents useful definitions and a number of the most recent practical tools for analysis and trustworthiness assessment. The given methods can be applied by QU4LITY as one of best practices for managing trustworthiness of IIoT systems.

Testbeds

The IIC can be added value to the QU4LITY consortium by monitoring the publications, blogs, case studies, IoT challenges and technical and white papers published on the website of the IIC. This information can provide a valuable source of input for the work to be performed inside the QU4LITY project. Many of these papers are publicly available on the website of the IIC and can be used as input for the developments, even if they are not directly focused on quality management, but more aiming at Industrial Internet of Things (IIoT), which is closely related to the work being performed inside the project. This is especially true for the work performed in WP3, where different technologies are developed close related to IIoT, such as connectivity, HPC, Cloud, Edge, AI and Big Data analytics. Additionally, the work being performed inside the testbeds is presented on the website, so this also offers the QU4LITY consortium a view in front runner development taking place within the industrial community.

The contribution network from QU4LITY to the IIC is rather limited, as no partner can directly contribute to the IIC standards. Nevertheless, the whole consortium was

monitoring the results of the IIC in order to identify possible gaps and communicate them with the IIC during events (e.g. trade fairs, conferences, etc.) where the IIC is present.

The IIC is focused on bringing together organizations and technologies necessary to accelerate the growth of the industrial internet by identifying, assembling, testing and promoting best practices. Therefore, it can offer the possibility to apply standards with related technologies into industrial related testbeds and use that to identify possible standardization gaps. For this reason, FHG IPA has become a member of the IIC Community Forum and has started to participate in the discussions regarding QU4LITY related topics, i.e. discussions focused on IIoT technology/emerging technologies, technology applications, specific innovations such as AI and digital twin, specific use cases, connectivity challenges, interoperability issues, etc.

Recommendations and exploitation of results

- *Recommendation:* It is recommended to further monitor the IIC activities (also regarding their testbed developments) as results from QU4LITY can be potentially integrated in available testbeds[47].
- *Exploitation:* QU4LITY standardization activities targeted primarily on bringing IIoT technologies (e.g. Cloud, Edge, AI, etc.) on the market. Using this concept, it becomes possible for QU4LITY partners to identify gaps in standards and indirectly use results from the IIC in contributing to existing and new standards.
- *Exploitation:* Additionally, possibilities to interact with the IIC are offered at events (trade fairs, conferences, etc.), where the IIC is attending. These events take place during the whole year and are spread over various countries. These events are highlighted at the website of the IIC[48].
- *Exploitation:* Finally, future standards related to edge computing will be considered for newly developed technologies deployed in edge computing. Upcoming projects will continue to track the developments at the IIC and potentially contribute to future standards with respect to edge computing.

3.4.2 World Wide Web Consortium (W3C)

Description and focus areas

The World Wide Web Consortium (W3C) is an international community that develops open standards. W3C develops technical specifications and guidelines through a process designed to maximize consensus about the content of a technical report, to ensure high technical and editorial quality, and to earn endorsement by W3C and the broader community[49].

QU4LITY impact

QU4LITY was interested in the recent developments of W3C, especially with regard to web architecture developments, semantic standards (i.e. specifications regarding

[47] https://www.iiconsortium.org/test-beds.htm
[48] https://www.iiconsortium.org/events.htm
[49] https://www.w3.org/standards/

vocabularies, creating of data stores, technology stack to support a "web of data"), and XML technology standards, which are useful to develop systems that can support trusted interactions over the network (aspects addressed by majority of Q-LSP).

Recommendations and exploitation of results

Recommendation: In 2018 W3C has launched the AI KR (Artificial Intelligence Knowledge Representation) Community Group[50] with the overall goal to explore the requirements, best practices and implementation options for the conceptualization and specification of domain knowledge in AI. The community group has been running the activity on the AI KI Vocabulary[51]. Possible double work with ISO/IEC JTC 1/SC 42 should be avoided.

3.4.3 CEN-CENELEC Focus Group on Artificial Intelligence

Description and focus areas

The Commission is putting forward a European approach to artificial intelligence. In April 2019 CEN-CENELEC launched the CEN-CENELEC Focus Group on AI. The European Commission's Communication 'Artificial Intelligence for Europe', COM (2018) 237[52], identifies the main challenges regarding the deployment, interoperability, scalability, societal acceptability/concerns, safety and liability of AI, and specifies a need for standardization in this area. The Focus Group had the goal to address big data in order to mirror the standardization work at international level, to initiate a high-level discussion on standardisation in the field of AI, and to address the development of a European roadmap for AI.

QU4LITY impact

QU4LITY was interested in the results of the Focus Group, especially with regard to the CEN-CENELEC roadmap for AI standardization and explicit requirements that could have an impact on the AI-specific use cases of QU4LITY.

To address the standardization needs, CEN and CENELEC have established the new CEN-CENELEC Joint Technical Committee 21 'Artificial Intelligence', based on the recommendations presented in the CEN-CENELEC response to the EC White Paper on AI and the German Standardization Roadmap for Artificial Intelligence[53].

Recommendations and exploitation of results

- *Lessons learned:* It is useful to address variable sources and not concentrate only on one specific committee even if it has a big influence. E.g. QU4LITY identified a need to review its standardization strategy and to harmonize it according to the finding in CEN-CENELEC Roadmap for AI Standardization.
- *Exploitation:* CEN-CLC/JTC 21 activities will be reported by QU4LITY to relevant IEC TC65/ WG 23 task force groups.

[50] https://www.w3.org/community/aikr/
[51] https://www.w3.org/community/aikr/welcome/ai-kr-task-list/vocabulary/
[52] https://ec.europa.eu/transparency/regdoc/rep/1/2018/EN/COM-2018-237-F1-EN-MAIN-PART-1.PDF
[53] https://www.cencenelec.eu/news-and-events/news/2021/briefnews/2021-03-03-new-joint-tc-on-artificial-intelligence/

4 Report on clustering and networking activities[54]

This chapter reports on clustering activities and related network events regarding standardization, in particular, describing QU4LITY standardization input within the given cluster activities and related workshop outcomes.

4.1 Clustering activities

4.1.1 DMP Cluster

Description and focus areas

The DMP (Digital Manufacturing Platform) cluster is an H2020 project cluster that was established with the aim of promoting cooperation between the projects of "DT-ICT-07-2018-2019: Digital Manufacturing Platforms for Connected Smart Factories". It includes upcoming projects focusing on AI and CSA, which were funded under the 2019 call. The DMP cluster is based on the joint initiative of the following EU projects:

- ZDMP (*Zero Defect Manufacturing Reference Platform*, GA#825631),
- EFPF[55] (*European Connected Factory Platform for Agile Manufacturing*, GA#825075),
- SHOP4CF (*Smart Human Oriented Platform for Connected Factories* GA#873087),
- DigiPRIME (*Digital Platform for Circular Economy in Cross-sectorial Sustainable Value Networks* GA#873111),
- KYKLOS4.0 (*An Advanced Circular and Agile Manufacturing Ecosystem based on rapid reconfigurable manufacturing process and individualized consumer preferences* GA#872570), and
- QU4LITY.

The cluster is coordinated and supported by the CSA ConnectedFactories2 (CF2) (Global-leading smart manufacturing through digital platforms, cross-cutting features and skilled workforce GA#873086).

Across the four main pillars: (1) Platform Building; (2) Large Scale Piloting; (3) Ecosystem Building; and (4) Standardization, the cluster strategy builds on eight collaborative topics, which discover common interests, i.e. potential synergies, among all cluster participants.

To achieve the objectives of the pillars, the working plan of the cluster is addressing several important actions: a) identification of synergy topics; b) identification of contacts for each topic; c) development of the action plan and specification of related

[54] Detailed information regarding cluster objectives, strategy and plan of the listed clusters will be provided in the Deliverables including QU4LITY Community Building Reports (D9.7 and D9.8). This Deliverable focuses only on standardization activities within the given cluster.

[55] (former eFactory)

objectives; d) identification of the time frames for each action; and d) regular revision of the action plan.

QU4LITY impact

Standardization is a key topic of the cluster. To investigate on the objectives of the pillar Standardization a special working group called *DMP Cluster Working Group 1 Standardization* (WG 1) was founded.

WG 1 aims to analyse and systematize common standardization activities in the ZDM areas of the member projects in order to promote the standards and their application in the large-scale pilot. The joint activities in the field of standardization are intended to increase the impact of the project and provide mutual benefits to the partners. The joint activities are planned to be facilitated by the exchange of best practices and experiences. In addition, projects within the cluster are collaborating to develop common strategies for interoperability and contributing to current standards for ZDM technologies.

In the first meetings, key contacts were identified to play the role of ambassadors for the jointly defined tasks. The common strategy describing the main objectives of each task was agreed in an action plan. Between 2020 and 2021, in addition to the six members of the cluster described above, other projects joined WG 1 and contributed to the common tasks:

- Change2Twin (*Create and Harvest Offerings to support Manufacturing SMEs to become Digital Twin Champions* GA# 951956),
- DAT4.ZERO (*Data Reliability and Digitally-enhanced Quality Management for Zero Defect Manufacturing in Smart Factories and Ecosystems* ID 958363),
- DAIS (*Distributed Artificial Intelligent System* ID# 101007273),
- DRYADS (*A Holistic Fire Management Ecosystem for Prevention, Detection and Restoration of Environmental Disasters* ID 101036926).

The following WG 1 tasks were in QU4LITY focus:

Task 1.0 Common standardization strategy (MEYER, FHG; CF2):

- *Goals*: The main goal of this task is to analyze the overall goals of the cluster with regard to standardization and settle a common standardization strategy.
- *QU4LITY contribution*: The deliverables of the task include the WG 1 common strategy, containing a list of relevant tasks. In addition, the task includes regular updates on lessons learned in the projects provided by all members (incl. QU4LITY). The regular exchange is intended to create a common understanding and to support the standardization work.

Task 1.1 Link to EC activities (GRUNEWALD, DIN; ZDMP):

- *Goals*: The main goal is to establish a link to EC activities and collect updates on relevant roadmap activities at the European level (e.g. participation at the event "Boosting Innovation through standards - Your gateway to the market" (13 November 2019, Brussels, Belgium)).
- *QU4LITY contribution*: QU4LITY provided regular updates on its European standardization activities, including short reports and upcoming event news.

Task 1.2 Common standards (MEYER, FHG; QU4LITY):

- *Goals*: The main goal of this task is to identify common standards used by projects and analyze, classify, and migrate these to the EFFRA Innovation Portal (WIKI) in accordance to the updated framework taxonomy.
- *QU4LITY contribution*: QU4LITY is responsible for this task. The result of this task includes a list of common standards and a classification roadmap. QU4LITY partners have proposed a framework for collecting the standards and are working on a clear methodology and the optimization of the submission process. The first draft of the roadmap was submitted by QU4LITY and included a list of about 200 standards. In addition, QU4LITY has performed a thorough analysis of the standards according to RAMI 4.0 and a classification according to different taxons (Figure 13). The project also provided a detailed analyses of the used standards and details of their mapping to the project's reference architecture.

								RAMI4.0 transfer to EFFRA/WIKI						Factors						EFPF			ZDMP			QU4LITY		
Committee	ID	under development	Title	Link	Date of Public ation	Publis her	Licens e	Asset Layer	Integration Layer Communication Layer	Information Layer	Functional Layer	Business Layer	(tbd)	Human	Security & safety	Interoperability &	Quality	RA	AI	EFPF "in usage"	EFPF RA	EFPF Details	ZDMP "in usage"	ZDMP RA	ZDMP Details	QU4LITY "in usage"	QU4LITY RA	QU4LITY Details
DIN German Institute for	EN 61069 series		Industrial-process	Link	-	_	Private								x	x								---	---		Distributed Trustworthiness	Cyber Security in Industrial Environments
ANSI	B11.0 - 2020		Safety of Machinery	Link	2020	ANSI	Private								x									---	---		Digital models and Vocabularies	Description of industrial plants and components in
ANSI	B11.Tr10—20 2x	x	Functional Safety of Artificial	Link	-	ANSI	Private								x				x					---	---		Control Service	Control Service; design and integration of safety-
IEC/TC 65 Industrial-process	IEC 62443 series		Security for industrial	Link	-	ANSI, IEC,	Private								x					x		Two partners	x	Secure installation,	Information Security		Digital models and Vocabularies	e@Class: Supports the digital
CEN/TC 459/SC 3 Structural steels	EN 10219-1:2006		Cold Formed Welded structural	Link	2006	CEN	Private																	none	none		Digital models and Vocabularies	Information security management systems;
CEN/TC 459/SC 10 Steel tubes and iron	EN 10305-3:2016		Steel Tubes for precision	Link	2016	CEN	Private																	none	none		Control Service	PLC,HMI (Part 3: PLCOpen XML)
CEN/TC 459/SC 10 Steel tubes and iron	EN 10305-5:2016		Steel tubes for precision	Link	2016	CEN	Private																	none	none		Digital models and Vocabularies	CDD, Definition of the properties and associated
CEN/TC 319 Maintenance	EN 13306:2018		Maintenance – Maintenance	Link	2018	CEN	Private										x						x	Prediction and optimisation	Maintenance		Collaboration, Business and	SIS design: Specification, design,
CEN/TC 319 Maintenance	EN 16646:2014		Maintenance – Maintenance	Link	2014	CEN	Private										x						x	none	Maintenance		Factory Network/ Field and Proximity	Profiles for industrial communication networks

Figure 13 The mapping matrix of common standards

Task 1.3 Common lessons learned and recommendations (LORENZ, Austrian Standards; EFPF):

- *Goals*: The main goal of this task is to collect and analyze the common lessons learned and recommendations for standardization in the projects and, based on the results, compose recommendations for actions for the relevant standardization bodies and organizations.
- *QU4LITY contribution*: The contributed to the list of normative recommendations for actions and shared with the projects its key lessons learned.

Task 1.4 Joint CWA proposals and guidelines (GRUNEWALD, DIN; ZDMP):

- *Goals*: The main goal of this task is to identify and coordinate the joint CEN/*CENELEC* Workshop Agreements (*CWA*).
- *QU4LITY contribution*: Within the task QU4LITY contributed to three proposals for CWAs (incl. joint discussions, collecting of inputs, regular updates, etc.). Substantial effort was done to CWA DMP Terminology. This CWA was initiated by the Universitat Politècnica de València in a joint activity of such DMP Cluster Projects as ZDMP (main proposer), QU4LITY (co-proposer), and EFPF (co-proposer). Within the project QU4LITY experts attended 8 general assembly

meetings of the CWA group and contributed to more than 10 core group meetings, actively participating in discussions, analyses and formulation of ZDM terms. Besides, QU4LITY experts were invited to support CWA EFPFInterOp and contribute to the global collection of ZDM requirements.

Task 1.5 Joint standardization events (MEYER, FHG; QU4LITY):

- *Goals*: The main goal of this task is the coordination and support of joint standardization events for WG 1 members.
- *QU4LITY contribution*: The project consortium participated in the standardization workshops that were organized by EFFRA and ConnectedFactories2 where it regularly presented QU4LITY results. Among these are the Cybersecurity workshop (January 20th, 2020) and the ConnectedFactories Webinar - Standards for digital manufacturing (October 20th, 2020).

Task 1.6 Joint dissemination work (MEYER, FHG; CF2):

- *Goals*: The main goal of this task is the coordination and support of joint dissemination activities (joint work with the DMP Cluster WG Dissemination).
- *QU4LITY contribution*: QU4LITY contributed to preparation of the joint dissemination activities promoting the DMP Cluster.

QU4LITY regularly participated in the cluster activities and web meetings of the cluster. In particular, its experts attended the following joint meetings:

a) 6 joint assembly meetings (F2F and remote): September 2019; March, May, June and December (two meetings) 2020.
b) 4 cluster leads meetings: September 2020, January and October 2021.
c) 11 WG1 meetings (remote): January, May, June, September and December 2020; February, May, September and October 2021; and February 2022.

Recommendations and exploitation of results

- *Lesson learned*: The joint discussions of WG 1 meeting showed that standardization is one of the main topics in each project. Therefore, all projects were interested in starting synergy activities and learning from each other.
- *Exploitation:* QU4LITY identifies the common strategy as beneficiary. The consortium partners will continue to participate in the cluster activities. The next steps include final update of the common standards (also implementing Table 8, Appendix A in EFFRA portal) and internal review in the upcoming cluster meetings.

4.1.2 OPEN DEI Cluster

Description and focus areas

In the DT-ICT-13-2019: Digital Platforms/Pilots Horizontal Activities call, the CSA OPEN DEI (GA 857065) has been funded and started its activities since June 1st 2019. By leveraging on five pillars (platforms, pilots, ecosystem, standards and dissemination) of all the DT-ICT-07 … DT-ICT-12, OPEN DEI is offering coordination and support services to its ecosystem of projects. The major challenge for facilitating

standardisation activities in OPEN DEI is the definition of the scope (and the out of scope) in terms of ecosystem of projects in the four domains covered by the Focus Area: Manufacturing, Agrifood, Health & Care, and Energy. In the Manufacturing domain, OPEN DEI is following 6 Innovation Actions grouped in the Digital Manufacturing Platform DMP cluster, 3 funded under the 2018 call (QU4LITY among them), 3 funded under the 2019 call. In these last months, the OPEN DEI Task Force 3 has started, addressing reference architectures, interoperability and standards under the coordination of Fondazione Politecnico di Milano. A group of 20+ experts has been created and Manufacturing sector is represented by QU4LITY.

QU4LITY impact

The OPEN DEI approach to facilitate standardisation is threefold:

1. To coordinate and support existing initiatives in the Manufacturing domain. This is related to Plattform 4.0 RAMI reference architectural models and its Asset Administration Shell. OPEN DEI supports projects (QU4LITY) towards the adoption of such standards and coordinates the single project's actions in this direction, by e.g. participating in Coordination Groups or similar meetings
2. To coordinate and support ICT-driven standardization activities in particular those related to the Multi- Stakeholder Platform for ICT standardization, the StandICT project and the ICT Standards Synchronization report. OPEN DEI can help QU4LITY meet the respective stakeholders and open collaboration opportunities.
3. To promote the diffusion and participation to the standard "A standard for secure gateways for data and services" inspired by the IDSA (International Data Spaces Association), specified by DIN 27070 promoting the principle and data sharing model of B2B Data Sovereignty. Any QU4LITY use case involving B2B data sharing in trusted value network is a good candidate for adoption and contribution to the standard.

Recommendations and exploitation of results

- *Recommendation:* OPEN DEI recommendation to QU4LITY is to get in touch and collaborate with the other DMP cluster projects (see previous point) and to identify cross-domain topics which require broader standardization actions, like for instance those related to B2B data sharing, security or interoperability.
- *Recommendation:* OPEN DEI white paper "Design Principles for Data Sharing Spaces" is available since spring 2021 and needs to be discussed in the DMP projects, especially in QU4LITY and in the DFA ecosystem.
- *Exploitation:* OPEN DEI is regularly organizing meetings and events both at domain level (see Last October 20th, 2021 in Cernobbio c/o WMF World Manufacturing Forum) but also at cross-domain level by coordinating and supporting standardization multi-project WGs in the four domains. The new TF3 meetings will run till September, a new position paper is foreseen for the end of April 2022 (draft).

4.1.3 ForeSee Cluster[56]

Description and focus areas

ForeSee is a European Cluster for Sustainable Predictive Maintenance Solutions in the Factories of the Future. The ForeSee cluster consists of six EU funded projects, which are funded under the EU H2020 FoF-09 call: Novel design and predictive maintenance technologies for increased operating life of production systems. The main objective of the cluster is to create a roadmap for predictive maintenance, which may serve as a guideline for companies that want to adapt and adopt predictive maintenance solutions.

QU4LITY impact

The ForeSee cluster brought together six EU funded projects in the field of predictive maintenance. An overview of the maintenance domain was produced by the members of the cluster and the key aspects identified there were considered by QU4LITY**.**

In addition, ForeSee projects addressed predictive maintenance, and various methods were tested, some of which used Artificial Intelligence methods. Members of the ForeSee cluster were also active in standardisation communities, so interaction with them proved valuable in enabling QU4LITY to learn more from different sources and to reach out to more standardisation initiatives. ATLAS is appointed to be a QU4LITY representative. The activities of QU4LITY took place until 2021 and were exploited in 2022. During this period, ATOS initiated discussions on standardization and exchanged with cluster members to maximize the benefits for the project.

Recommendations and exploitation of results

- *Recommendation:* Standard MIMOSA needs to be enriched and having projects in contact will facilitate this.
- *Recommendation:* Some activities could be addressed jointly by several research projects. This would allow EU to save resources and not duplicate efforts. It will also allow us to go deeper than we do now into standardization issues.
- *Recommendation:* Improvement of collaboration for dissemination and communication activities, starting from Dissemination Managers level. This will allow to establish common channels for events, as well to end us with a plan for common events/efforts.
- *Exploitation:* A Handbook (Foresee cluster white paper on PdM) is released in July 2021 with an overview of the maintenance domain, which also contain a list of the most relevant current standards. Furthermore, the series of the Foresee webinars have been released as well presenting the European success stories on Predictive Maintenance that increased reliability of manufacturing equipment. The QU4LITY project build on these findings.

[56] http://foresee-cluster.eu/

- *Lessons learned:* Interaction between projects can result to the availability of more and more interesting resources and material for joint dissemination activities related to standardization (e.g. vocabulary days, trainings).

4.1.4 EFNMS[57]

Description and focus areas

EFNMS is the European Federation of National Maintenance Societies. It is a non-profit organization with the objective to improve maintenance for the benefit of people in Europe. EFNMS is an umbrella organization for the non-profit National Maintenance Societies in Europe.

Maintenance is of outmost importance for trade and commerce, for the environment, and for general health and safety. Maintenance is becoming a vital contributor in the era towards I4.0, being itself transformed to a Maintenance4.0 complex operation, closely related to physical Asset Management. It is an organization established in 1970, collaboration is possible throughout the QU4LITY project.

QU4LITY impact

ATLAS is an active contributor to EFNMS. ENMNS is an umbrella organization for the non-profit National Maintenance Societies in Europe. EFNMS provided the Body of Knowledge (BoK) in order to describe the maintenance landscape and identify the knowledge required at the levels of: Technical Director/ Physical Asset Manager, Maintenance Manager, Maintenance Engineers and Supervisor, Maintenance Technicians. The EFNMS-BoK Chapters currently are: Maintenance within Physical Asset Management, Maintenance Management, Maintenance Execution, Health, Safety and Environment in Maintenance, Maintenance Engineering Techniques, and Maintenance Support.

Building the Predictive Maintenance, Decision Support solutions and Remaining Useful Life (RUL) in QU4LITY have required to be up to date with the current standards and definitions in the field of maintenance, among others. Moreover, for the assessment of the QU4LITY results, it was required to use performance indicators as it was beneficial for the project to use KPIs that are in line with the current standards. Moreover, the definition of terms supported the QU4LITY semantic models.

Recommendations and exploitation of results

- *Recommendation:* Identified gap is the lack of harmonization of Key Performance Indicators (KPIs) between EU and USA standards. Standard: EN 15341, ISO 14224, VDI 2893.
- *Recommendation:* Encouragement of official involvement of CEN and other standardization bodies with European projects, not only as partners, but at in an aim to take advantage of funded R&D activities to a policy and direct

[57] https://www.efnms.eu/

interaction level. It is being done to some extent already and the results are very interesting and promising.

- *Recommendation:* Continuance of gaps analysis together with SMRP, the Society for Maintenance and Reliability Professionals.
- *Exploitation:* The findings of the EFNMS BoK as well as EN17007's MAINTENANCE PROCESSES, but also the Maintenance Key Performance Indicators and Maintenance terminology have been consulted as current standards and definitions in the field of maintenance in order to build the solutions in QU4LITY.
- *Lessons learned:* Even standards can be not clear enough. EFNMS identifies gaps and suggests improvements.

4.2 Networking activities

4.2.1 Interlinking with projects

Several projects that are focusing on standardization activities in similar areas were identified by QU4LITY partners as cooperation possibilities behind the cluster activities. Among these projects are DIATOMIC, ConnectedFactories2, MIDIH, BOOST4.0, KI-Marktplatz, SPEAKER, Level-up, Amable, AI4EU, DIH^2, Musketeer and MARKET4.0. Efforts were spent to establish a contact and exchange on standardization results. Detailed report about concrete standardization activities is summarized in Appendix D.

4.2.2 Trilateral cooperation

In March 2017 the Alliance Industrie du Futur, Plattform Industrie 4.0 and Piano Industria 4.0 agreed to work together on the digitalization of the manufacturing industry. Recent discussions show that the initiative is making progress in coordinating national initiatives, such as the standardization of the administrative shell (a common vocabulary to express functions in new industrial products) and on issues of ownership of industrial data. QU4LITY identified interest in these activities. As active members and contributors to the trilateral cooperation POLIMI and FHG IPA were monitoring the activities of the initiative's standardisation working group (WG1).

It is worth to mention the Position Paper "Recommendations of the Trilateral Cooperation between France, Italy and Germany on Digitalising the European Manufacturing Industry" [14]. The initiative presented its recommendations for a successful digital transformation of European industry, where it described the importance of a common European digital ecosystem and elaborated on necessary steps for a European data economy. Such QU4LITY related standardization goals as interoperability, common standards and integration were identified as crucial enablers for cooperation among companies and across borders.

4.2.3 GI/ACM INFORMATIK 2020 and 2021

The 50th and the 51st GI Annual Conference INFORMATIK events were organized in 2020 and 2021 respectively. The main focus was on scientific exchange on topics

that commonly receive special attention in science, practice and society. Especially, in this context, are to mention such Q-SFO as security, interoperability and artificial intelligence. The current standardization gaps and activities were discussed during the I4.0 Workshop on *Standardization of Automation and Control Systems* (IACS) that were organized during both events (see 4th GI/ACM Workshop[58] the 5th GI/ACM Workshop[59]).

FHG IPA was invited as the program committee member of the 4th GI/ACM Workshop and contributed with expertize to the technical discussions on standardization of IACS. In 2021 FHG IPA was an invited speaker of the 5th GI/ACM workshop and gave a keynote focusing on QU4LITY results and challenges from the national recommendations to global harmonization.

4.2.4 Seminar series »Industrie 4.0«

The Stuttgart Production Academy SPA regularly organizes technology seminar series. During the Seminar "Shop Floor Smartification" FHG IPA presented the current German national strategy and, specifically, aligned the recent QU4LITY standardization activities. The main goal was to network with the representatives of German industry.

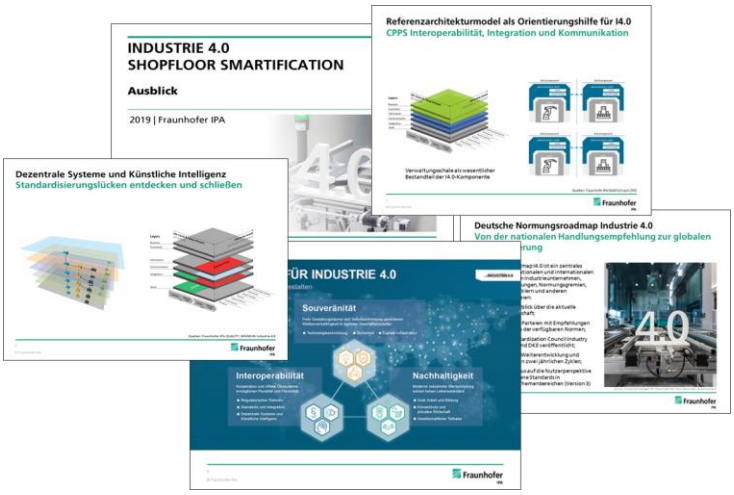

Figure 14 Shop floor smartification - Outlook - QU4LITY standardization activities

During the seminar FHG IPA initiated a discussion regarding the ZDM vision and current challenges and needs in the industrial field (Figure 14). General feedback is that the participants showed a very active interest in the recent developments in standardization and pronounced a wish to further extend the seminar topic with other specific information regarding standard (i.e. regarding recent AI standards as well as standardization in IIoT and smart manufacturing areas). FHG IPA will continue to integrate QU4LITY findings and results of its seminar activities of SPA.

4.2.5 euRobotics Workshop

JSI were co-organizers and participated in the TG: Standardization Meeting, organized within the scope of the European Robotics Forum 2020 (ERF 2020) on

[58] https://germany.acm.org/2019/02/20/4th-gi-acm-workshop-on-standardization-of-industry-4-0-automation-and-control-systems-according-to-iec-62443-iacs/

[59] https://informatik2021.gi.de/fileadmin/GI/Hauptseite/Aktuelles/Veranstaltungen/INFORMATIK_2021/00-6th_IACS-WS2021-fulltext-Announcement-210909.pdf

March 3rd in Malaga, Spain. The workshop was heavily influenced by the onset of the CoVid-19 pandemics, as all the invited speakers and even some co-organizers cancelled their participation. However, several people still attended the workshop, which was in the end organized as a round-table discussion. In the following the most important outcomes of the workshop are presented.

The main outcome of the workshop is that the euRobotics needs the TG on Standardization, which needs a bit of fresh air to jump-start the whole initiative. The TG will try to collect the lessons learned from all latest EU proposals in the areas of standardization. The effort from QU4LITY will be very helpful in this aspect. TG will invite coordinators of accepted robotics EU projects and collect information on how they approach standardization and which standards they used. A public repository will be created with an overview where someone that writes a new proposal can go and see which standards he/she has to promise that will use for whatever they promise to do in a new proposal.

Other future activities of the TG include dissemination activities to make the community aware of its existence and activities.

An additional workshop on roadmapping concluded that EU robotics finds standardization the #1 issue in the agenda of the next horizon Europe.

4.2.6 CEN/CENELEC

CEN/CENELEC Webinar for Standard Drafters

In order to boost the market uptake of innovation and research outcomes by using standardization as an enabler CEN and CENELEC invited researchers, technologists and innovators to workshops and online webinars, e.g. Boosting Innovation through Standards [60]. The main goal of the workshop was to link the two worlds and highlighting how each one is benefiting from the other. The consortium took part in the activity (see Figure 15) and discovered helpful information.

Figure 15 CEN and CENELEC events (Sources: based on news at www.cencenelec.eu)

[60] https://www.eu-ems.com/summary.asp?event_id=4417&page_id=10265

5 Conclusion

QU4LITY WP 9 is strategically set to communicate the project's results and to ensure maximum impact for the project through exploitation, dissemination and standardisation. Among these, Task 9.2 *Standardization and Clustering* sets the objective to ensure that the partners participate and contribute to standards development/setting organizations (SDOs/SSOs), in terms of the development and evolution of digital manufacturing standards in general and ZDM & quality management standards in particular. Hence, this deliverable reports in detail on the standardization activities of the project for the accomplished period of the task.

To achieve the main objectives, the task experts developed the *QU4LITY Standardization Roadmap*, in which they identified the central challenges of the task and derived appropriate measures. These activities helped to create a clear workflow among the experts involved and to identify important standardization objectives of the projects as well as the next steps.

On the whole, the experts of the Task 9.2 acted as an important link between the project WPs and standardization activities on the national, international and European levels. They provided reviews and recommendations (including the current report) for specific project activities with regard to possible standardization gaps and helpful references. Standardization experts were constantly involved in the key concepts of the project, e.g. composition of the QU4LITY Reference Architecture or the QU4LITY standard compliance analysis.

In total, the experts participated in more than 140 activities, including more than 80 general assembly meetings (one to two-day meetings) of the SDOs/SSOs, more than 60 remote working sessions and workshops with standardization focus.

In detail, the standardization activates were driven by the identified QU4LITY standardisation experts who contacted the SDOs/SSOs (such as ISO, IEC, ISO/IEC JTC 1, IDSA, euRobotics, ECSO, etc.), actively participated in regular committee/working group's meetings, and monitored relative activities. In addition, QU4LITY could promote the communication of the project results to the EU digital manufacturing community, i.e. clusters and associations (such as OPEN DEI, EFFRA, DMP Cluster, etc.), while allowing synergies with other projects, including those in which the partners are already participating.

The meetings/workshops' results were presented and discussed among the involved QU4LITY partners on a regular basis during the Task 9.2 Internal workshops. All partners were invited to participate and exchange with experts on standardization topics.

Finally, the experts will continue their standardization activities in the identified standardization bodies to further exploit the project's results.

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List of Abbreviations

Abbreviations	Explanations
AAS	Asset Administration Shell
AISBL	Association Internationale Sans But Lucratif
AIOTI	Alliance for Internet of Things Innovation
API	Application Programming Interface
BITKOM	Bundesverband Informationswirtschaft, Telekommunikation und neue Medien
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CD	Committee Draft
CPS	Cyber Physical System
CPPS	Cyber Physical Production System
CRM	Customer Relationship Management
CSA	Cloud Security Alliance
CWA	CEN/CENELEC Workshop Agreements
DIN	Deutsches Institut für Normung
DKE/VDE	German Commission for Electrical, Electronic & Information Technologies of DIN and VDE
DMTF	Distributed Management Task Force
ERP	Enterprise Resource Planning
ETSI	European Telecommunications Standards Institute
FB	Function Block
H2M	Human-to-Machine
I4.0	Industry 4.0
ICPS	Industrial Cyber-Physical System
IEC	International Electrotechnical Commission
IIC	Industrial Internet Consortium
IIoT	Industrial Internet of Things
IIRA	Industrial Internet Reference Architecture
IoT	Internet of Things
IoT RA	Internet of Things Reference
ISO	International Organization for Standardization
ITU	International Telecommunications Union
IVI	Industrial Value Chain Initiative
IVRA	Industrial Value Chain Reference Architecture
JTC	Joint Technical Committee
JWG	Joint Working Group
KPI	Key Performance Indicator
KOSF	Korea Smart Factory Foundation
LNI 4.0	Labs Network Industrie 4.0
M2M	Machine-to-Machine
MES	Manufacturing Execution System
MIIT	Ministry of Industry and Information Technology of China

MSP/DEI	The Multistakeholder Platform on ICT Standardisation (MSP) and the Digitising European Industry initiative (DEI)
MQTT	Message Queue Telemetry Transport
NA	Standards Committee (*germ*. Normenausschuss)
NIST	National Institute of Standards and Technology
OASIS	Organization for the Advancement of Structured Information Standards
OCC	Open Cloud Consortium
OCF	Open Connectivity Foundation
OMG	Object Management Group
OPC UA	OPC Unified Architecture
Q-LSP	QU4LITY Large-Scale-Partners
Q-SFO	QU4LITY Standardization Focus Objectives
RAMI 4.0	Reference Architecture Model Industrie 4.0
REST	Representational State Transfer
SC	Subcommittee
SCI 4.0	Standardisation Council Industrie 4.0
SDO	Standards Developing Organisation
SG	Study Group
SM	Smart Manufacturing
SOA	Service-oriented Architecture
SQuaRE	Systems and software Quality Requirements and Evaluation
SSO	Standards Setting Organisation
TR	Technical Report
VDMA	Mechanical Engineering and Plant Association
W3C	World Wide Web Consortium
WG	Working Group
ZVEI	Zentralverband Elektrotechnik- und Elektronikindustrie

Appendix A: References to standardization activities

This appendix summarizes references to QU4LITY standardization activities, including associated actions, decisions, gap analysis, and derived results.

Table 1 QU4LITY activities in IEC TC 65/WG23 Task Forces

	Contribution to IEC TC 65/WG23 Task Forces
TF SM Markets and Innovation Trend Analysis	Standard: *(under development)* *IEC TR 63283-5: Industrial-process measurement, control and automation - Smart Manufacturing - Part 5: Market and innovation trends analysis (in preparation)* Contribution: raised a discussion regarding ZDM goals regarding specific market and innovation potentials; submitted a ZDM related contribution specifying the standardization gaps; participated in the editorial meetings; revised the document and contributed to editing of comments.
TF SM and New Technologies	Standard: *targeted technical report in preparation* Contribution: contributed to the analysis of the current trend technologies (incl. Digital Twin, AI, etc.); analysed the major impact on SM; analysed related standards and new technologies in pilots (e.g. missing standards for hardening, CONTINENTAL); gap evaluation and regarding application of OPC UA, MQTT; MTConnect in GF, IDECO, KOL, SYN, TID, SIEMENS (e.g. especially in SIEMENS evaluation regarding the application of OPC UA, MQTT take place to enable "real-time" quality prediction) and other Pilots' applications; digital Twin (e.g. Cognitive Digital Twin approach investigated by INNOVALIA)
TF SM Use Cases	Standard: *(under development)* *IEC TR 63283-2: Industrial-process measurement, control and automation - Smart Manufacturing - Part 2: Use cases* Contribution*:* analysis of SM use cases; participation in editorial meetings; contribution to editing of comments; mapping of Q-LSP use cases, including specific standardization gaps and recommendations regarding ZDM.
TF SM Terms and Definitions	Standard: *(under development)* *IEC TR 63283-1: Industrial-process measurement, control and automation - Smart Manufacturing - Part 1: Terms and definitions (in preparation)* Contribution: screening, harmonization and specification of terms and definitions in the scope of SM; analysis and alignment with ZDM requirements and acquired results in Task 2.5; participation of editorial meetings; contribution to edition of comments; synchronization with CWA activities in 4.1.1.
TF SM and Safety	Standard: *targeted technical report in preparation* Contribution: monitoring of the activities; recommendation: horizontal safety requirements need to be taken in account (PHILIPS).
TF SM and Cybersecurity	Standard: *(under development)* *IEC TR 63283-3 ED1: Industrial-process measurement, control and automation - Smart Manufacturing - Part 3: Challenges for Cybersecurity* Contribution: analyses of use cases; derivation of the requirements for cybersecurity and information security in SM context (e.g. PHILIPS); raised discussion regarding analysis of protection against cyberattacks (e.g. CON, MON and FAGOR).

Gap analysis and recommenda-tions for standardization actions	Standard: *targeted technical report in preparation* Contribution: contributed in the role of the convenor of the TF; held several TF meetings, incl. a kick-off meeting in December 2021; initiated a gap analysis matrix base on the QU4LITY gap analysis results.

Table 2 Reviewed standards in ISO/IEC JTC 1/SC 41 WG 6

Standard	Link
ISO/IEC ED1 30173 Digital Twin- Concepts and terminology	Link
ISO/IEC 30172 TR Digital Twin – Use Cases	Link
ISO/IEC JTC 1/SC 41-5 PWI Digital Twin – Reference Architecture	Link
ISO/IEC JTC1-SC41-7 PWI Digital Twin – Maturity model	Link
ISO/IEC JTC1-SC41-6 PWI Guidance for IoT and Digital Twin use cases	Link

Table 3 QU4LITY analysis of the activities in IEC TC 65/SC 65 E

Group	WG targets / QU4LITY expected contribution
WG 2 Product properties & Classification	The WG provides a method for standardizing the description of process control devices (measuring equipment) and specifies how to use the device descriptions for electronic data exchange between two computer systems. QU4LITY outcomes in ZDM can contribute to standards developed in this WG to the semantics in the process description.
WG 3 Commissioning	The WG targets the development of standards for commissioning, loop checks and Factory & Site acceptance/Integration Tests for Industrial Automation Systems. QU4LITY can contribute with the experience in ZDM developed in the project to remove production failure during the production factory life.
WG 4 Field device tool interface specification	The WG develops the standards to define the interfaces for both the vertical and the horizontal data flow, called Function Control and Data Access, in a framework of Client-Server architecture. QUALITY outcomes regarding interfaces and semantics can be used in the standards developed in this working group.
WG 7 Function Blocks (FB) for process control, EDDL and FDI.	WG 7 address function block development for process control and device integration. QUALITY contribution is linked to the work developed in the IEC 61131-3 and the IEC 61499.
WG 8 OPC – Open Platform Communications	WG 8 develops the standards to standardize a client/server interface between client applications and industrial automation/control Systems. From the QU4LITY perspective, communication between the different systems in the production facility is crucial to ensure ZDM. The experience developed in QUALITY will be determinant to contribute to standards developed under this working group.
WG 9 AutomationML - Engineering Data Exchange Format	See detailed description in the next section.

WG 10 Intelligent Device Management	This Working Group develops standards to provide procedures and an environment to effectively manage and use intelligent devices. The outcomes from QU4LITY can introduce new use cases to these standards towards ZDM.
WG 12 Predictive Maintenance	The standards developed by this working group scopes the structural models, procedures, methods, infrastructure, and data requirements for predictive maintenance of assets. Standards developed in working group 12 can be extended with the experience achieved in QU4LITY.
WG 13 Representation of electrical & instrument objects in digital 3D plant models during engineering	Working group 13 develops a standard on "Representation of electrical & instrument objects in digital 3D plant models during engineering". At the moment is not foreseen a contribution to this working group from the QU4LITY perspective.
WG 14 Modular Type Package (MTP)	This working group develops and maintain the series of standards related to "Automation engineering of modular systems in the process industry". At the moment is not foreseen a contribution to this working group from the QU4LITY perspective.
JWG 5 Enterprise-control system integration	The joint working group 5 develops publications of models for the manufacturing operations management (MOM) domain, including technology-independent models of hierarchies, activities, interfaces to other domains, exchanged information, messages, and transactions. QUALITY outcomes can be relevant in the current standardization activities under this join working group, such as the ISA 95 standard (IEC 62264), towards ZDM.
JWG 14 Energy Efficiency in Industrial Automation (EEIA)	The join working group 14 develops guidelines for the design and operation of energy-efficient systems in the field of industrial automation and industrial process control from a system point of view, in the fields of manufacturing and process control. At the current state of the project there is not a clear contribution of QU4LITY to this working group.

Table 4 QU4LITY activities in IEC TC 65/SC 65/WG9

Standard Part	QU4LITY contribution
IEC 62714-1:2018	*Ongoing activities*: The application of the standard in the plant topology is under active work within the pilot, utilization the standard in the ZDM goals. *Future activities*: Propose updates to the standard based on the outcome of the project pilots.
IEC 62714-2:2015	*Ongoing activities*: Part 2 is in the final review stage; it is expected that a new version will be released during 2022. In parallel to the review, data models are tested to develop the data sets used in the project. *Future activities*: Continue with the work in the project and update the data models to the final version used in QU4LITY.
IEC 62714-3:2017	*Ongoing activities*: COLLADA (ISO/PAS 17506), which is the base for part 3, is currently under review. Part 3 is considered to be used in

	some pilots of QU4LITY to exchange CAD data between different tools, which will improve the accuracy of the results. *Future activities*: Based on the results of the pilots, contributions to the standard are being proposed.
IEC 62714-4:2020	Ongoing activities: The new version of the part 4 standard was approved and is currently under active use. Future activities: The work within QU4LITY is being developed with the latest version of the standard. Future update to the part 4 will be proposed based on the outcome of the pilots' results.
IEC 62714-5:2022	*Ongoing activities*: Part 5 has completed the standardization process recently. *Future activities*: The pilot's outcome towards the development to part 5 will be proposed.

Table 5 QU4LITY activities in ISO/IEC JTC 1 /SC 41

Standard	QU4LITY actions and decisions
ISO/IEC 21823-2 Interoperability for IoT - Part 2: Transport interoperability	Revision and gap analysis. Identified applicability and reference to Task 2. Reported.
ISO/IEC 21823-3 Interoperability for IoT - Part 3: Semantic interoperability	Revision and gap analysis. Identified applicability and reference to Task 2. Reported.
ISO/IEC 20924 ED2 Internet of Things (IoT) – Vocabulary	Revision and gap analysis. Identified applicability and reference to Task 2. Reported.
ISO/IEC 30141 ED2 Internet of Things (IoT) - Reference architecture	Revision and gap analysis. Identified applicability and reference to Task 2. Reported.
ISO/IEC CD 30144 Internet of Things (IoT) – Wireless sensor network system supporting electrical power substation	Meeting discussion regarding industrial application and requirements
ISO/IEC WD 30147 Internet of Things(IoT) – Integration of IoT trustworthiness activities in ISO/IEC/IEEE 15288 systems engineering processes	Revision and meeting discussion; analysis of application performed
ISO/IEC DTR 30148 ED1 Internet of Things (IoT) - Application of sensor network for wireless gas meters	Revision and meeting discussion initiated
ISO/IEC WD 30149 ED1 Internet of Things (IoT) - Trustworthiness framework	Revision and gap analysis. Identified applicability and reference to Task 2. Reported.
ISO/IEC CD 30161 ED1 Internet of Things (IoT) – Requirements of IoT data exchange platform for various IoT services	Revision, gap analysis, discussion and comments (use of personal data, data portability, etc.) performed
ISO/IEC WD 30162 ED1 Internet of Things (IoT) - Compatibility requirements and model for devices within industrial IoT Systems	Revision; identified as relevant; further monitoring and gap analysis performed
ISO/IEC WD 30163 ED1 IoT - System requirements of IoT/SN technology-based integrated platform for chattel asset monitoring	Revision and meeting discussion initiated

ISO/IEC DTR 30164 ED1 Internet of things (IoT) - Edge Computing	Revision and gap analysis. Identified applicability and reference to Task 2. Reported.
ISO/IEC WD 30165 ED1, Internet of Things (IoT) – Real-time IoT framework	Revision and gap analysis. Applicability and reference to Task 2 was not verified.
ISO/IEC DTR 30166 Industrial IoT	Discussed the work of the editorial group, final actions and status. Identified as relevant for QU4LITY (as it reveals the IIoT status and the current standardization landscape and gaps).
21823-4 NP: Internet of Things (IoT) - Interoperability for Internet of Things Systems –Part 4: Syntactic interoperability	Revision performed
DIN SPEC 16593-2 Mechanisms for bootstrap, advertisement and lookup of industrial IoT components	Meeting discussion initiated. Applicability and reference to Task 2 has been verified. First request for contribution established (see also report in 3.3.5)
ISO/IEC 20005:2013 Information technology - Sensor networks - Services and interfaces supporting collaborative information processing in intelligent sensor networks	Revision, vote, comments performed
ISO/IEC CD 30144 Internet of Things (IoT) – Wireless sensor network system supporting electrical power substation	Revision, vote, comments performed

Table 6 QU4LITY activities in ISO/IEC JTC 1/SC 42

Standard	QU4LITY actions and decisions
ISO/IEC 20546:2019 Information technology - Big data - Overview and vocabulary	Identified relation to WP2 work. The document provides a list of terms regarding Big Data. Reported.
ISO/IEC TR 20547-2:2018 Information technology - Big data reference architecture - Part 2: Use cases and derived requirements	Identified relation to WP2 work. Examined the potential of possible gaps in the AI requirements. Reported.
ISO/IEC TR 20547-5:2018 Information technology - Big data reference architecture - Part 5: Standards roadmap	Identified relation to WP2 work. The document provides a list of existing standards, SDOs, and gaps regarding Big Data, as well as pathways on how to address the gaps. Reported.
ISO/IEC FDIS 22989 Artificial intelligence — Concepts and terminology	The document is under development. Identified relation to WP2 work regarding the conceptual alignment. Actively monitored. Reported.
ISO/IEC FDIS 23053 Framework for Artificial Intelligence (AI) Systems Using Machine Learning (ML)	The document is under development. Identified relation to T2.2 and T2.6 QU4LITY RA. Actively monitored. Reported.
ISO/IEC DIS 23894 Information Technology — Artificial Intelligence - Risk Management	The document is under development. Provides support for connected worker, CPS Plant, ZDM Working Management Framework. Actively monitored. Reported.

SO/IEC AWI TR 24027 Information technology - Artificial Intelligence (AI) - Bias in AI systems and AI aided decision making	Proposal stage at SC42/WG3. Applicability couldn't verified.
ISO/IEC TR 24028:2020 Information technology - Artificial intelligence - Overview of trustworthiness in artificial intelligence	Identified relation to WP2 work regarding security, safety, etc. Actively monitored. Reported. Published.
ISO/IEC TR 24029-1:2021 Artificial Intelligence (AI) - Assessment of the robustness of neural networks - Part 1: Overview	The document provides background about existing methods to assess the robustness of neural networks. Actively monitored. Reported. Published.
ISO/IEC TR 24030: Information technology — Artificial Intelligence (AI) — Use cases	Verified applicability for use case description. Actively monitored. Reported.
ISO/IEC 38507: Information technology — Governance of IT — Governance implications of the use of artificial intelligence by organizations	Still under development. Monitored for applicability (e.g. SINTEF). Reported.
ISO/IEC TR 24372: Information technology — Artificial Intelligence — Overview of computational approaches for AI systems	Published 2021. Actively monitored. Reported.
ISO/IEC TR 24368: Information technology — Artificial Intelligence (AI) — Overview of ethical and societal concerns	The document is currently in the DRT stage. Actively monitored (e.g. connected worker in SINTEF). Reported.

Table 7 Quality related standards in ISO/IEC JTC 1/SC 41

Standard	QU4LITY analysis
ISO/IEC 2500n – Quality Management Division	defines all common models, terms and definitions from the SQuaRE series; provides requirements and guidance for a supporting function that is responsible for the management of the requirements, specification and evaluation of software product quality
ISO/IEC 2501n – Quality Model Division	presents detailed quality models for computer systems and software products, quality in use, and data; provides a practical guidance on the use of the quality models
ISO/IEC 2502n – Quality Measurement Division	includes a software product quality measurement reference model, mathematical definitions of quality measures, and practical guidance for their application
ISO/IEC 2503n – Quality Requirements Division	specifies quality requirements, based on quality models and quality measures that can be used in the process of quality requirements elicitation for a software product to be developed or as input for an evaluation process
ISO/IEC 2504n – Quality Evaluation Division	provides requirements, recommendations and guidelines for software product evaluation, whether performed by evaluators, acquirers or developers
ISO/IEC 25050 – 25099 SQuaRE Extension Division	includes requirements for quality of Commercial Off-The-Shelf software and Common Industry Formats for usability reports

Table 8 Application of standards in pilots

Pilot	Standard	Date, License	QU4LIT application
CONTINENTAL	ISO/IEC 17788:2014 Information technology – Cloud computing – Overview and vocabulary	2014, PU	Analytics of production data in the cloud technology provided by SINTEF and ATB
CONTINENTAL PHILIPS, RIASTONE	ICS 03.120.10 Quality management systems (ISO 9001)	2015, PU	Quality management regarding production lines (automotive industry); implementation of Standard Operating Procedures (SOPs) for factory shop floor functions and activities; areas for improving efficiency and functioning of the factory shop floor; improved transparency and accountability for all operators involved in the operations of shop floor equipment's and machinery; allowed for the Operations, Management and Maintenance Teams to audit themselves against ISO 9001 standards.
CONTINENTAL PHILIPS	ICS 03.100.01 Risk management (ISO 31000)	2018, PU	Evaluation of risk based on partners technology; managing risks in an organisation where value is created and must be protected
MONDRAGON	IEC 63278-1 Asset Administration Shell for industrial applications - Part 1: Asset Administration Shell Structure	- , PR	Interoperability and information modelling
MONDRAGON	DIN SPEC 27070:2020-03 Requirements and reference architecture of a security gateway for the exchange of industry data and services	2020, PU	Secure exchange of industry data and services
MONDRAGON	ISO/IEC 21778:2017 Information technology — The JSON data interchange syntax	2017, PU	Interoperability and data formats
MONDRAGON, KOLECTOR, RIASTONE, SIEMENS, FAGOR	IEC 62541-5:2020 OPC Unified Architecture - Part 5: Information Model (Edition 3.0)	2020, PR	(including also other parts) Data modelling for ZDM digital press machine; data transfer between smart edge IoT devices and industrial machine and industrial MES/MOM system Sinapro.IIoT; transfer of data between ZDM-AQL edge devices, and Shopfloor Ceramics CIP Presses
KOLECTOR, SIEMENS, FAGOR	ISO/IEC 20922 Information technology – Message Queueing Telemetry Transport (MQTT) v3.1.1	2016, PR	Interoperability and communication: data transfer between smart edge IoT devices and industrial machine learning platform KiS and industrial MES/MOM system Sinapro.IIoT; publish data from press machine into the FAGOR DAS
KOLEKTOR	ROS Robot Operating System (ROS)	- PU	Workflow synchronization and transfer of data between smart edge IoT devices and robots.

KOLEKTOR	GigE Vision	2006, PR	Standard interface for industrial machine vision cameras in Digital Platform, KiS.
KOLEKTOR	ISO/TS 15066:2016, Robots and robotic devices — Collaborative robots	2016, PR	Ensure safe usage of the robot for the operator
PHILIPS	UDN 1596 Philips Information Security Policy	2015, PR	Ensure correct and secure information / data usage (production line / cloud services)
PHILIPS	ISO/IEC 27000:2018 Information technology — Security techniques	2013, PU	Ensure correct and secure information / data usage (production line / cloud services)
PHILIPS	ICS 13.020.10 Environmental management system (ISO 14001)	2015, PU	Create safe and healthy working environments (environmental compliance)
PHILIPS	ICS 03.100.01 Occupational Safety & Health Management System (ISO 45001)	2018, PU	Create safe and healthy working environments and improve health and safety and minimize risks (production line)
PHILIPS	ICS 03.100.01 Guidance on social responsibility (ISO 26000)	2010, PU	Sustainable development of new systems taking into account various aspects regarding social responsibility (production line)
PHILIPS	ICS 13.110 Safety of machinery (ISO 12100)	2010, PU	Safety in design of machinery and systems, in particular, principles of risk assessment and risk reduction (production line)
FAGOR	ECMA-404	2017, PU	Interoperability and data interchange syntax
FAGOR	Fagor Arrasate Proprietary Data Schema	2019, PR	Data modelling (Fagor DAS, FALINK, IKCLOUD)
FAGOR	VTT OpenVA	2018, PU	VTT OpenVA used as a part of the visual data analytics solution implemented in the FAGOR pilot
DANOBAT	MODBUS	- , PU	Realise data communication
DANOBAT	API REST	- , PU	Ensure interoperability and communication
DANOBAT	ISO/IEC 15408:2009 Information technology — Security techniques — Evaluation criteria for IT security	2009, PU	Apply evaluation criteria for IT security
DANOBAT	ISO/IEC 18045:2008 Information technology — Security techniques	2008, PU	Apply security techniques
GF	OPC 40501-1 UA CS for Machine Tools Part 1 - Monitoring and Job (ZIP/PDF)	2020, PU	Data provision from machine sensors, which are used for the implementation of predictive maintenance algorithms and services, as well as quality prognosis of the machined parts.
GF, AIRBUS	OWL Web Ontology Language	2009, PU	Semantic-driven digital twins for ZDM with OWL (publishing and sharing ontologies in the Web)

GF, AIRBUS	RDF - Resource Description Framework	2014, PR	Specification of the semantics of data based on XML in a standardized, interoperable manner; used as the exchange format for ontology import/export to/from graph databases
GF, AIRBUS	ISO/IEC 21838-2:Top-level ontologies (TLO) — Part 2: Basic Formal Ontology (BFO)	2021, PR	Definition of the common vocabulary used in all industrial domains and providing foundation for developing middle-level and application-level ontologies
GF	IOF-Core ontology	- , PR	Definition of the commonly used vocabulary used in most industry sector including manufacturing as the basis to create application ontologies for different pilots
RIASTONE, THYSSEN-KRUPP	ISO/IEC 27001:2013 - Information technology – Security techniques – Information security management systems – Requirements	2013, PU	Information security and cybersecurity with regard to the interchange and storing of databases in the production line
THYSSEN-KRUPP	ISO 13849-1:2015 - Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design	2015, PR	Apply for non-intrusive assets monitoring, CEA Tech
THYSSEN-KRUPP	IEC 61784 series - Industrial communication networks – Profiles	- , PR	Apply for PLC exchange interoperability, tKP
AIRBUS	ISO/IEC 19514:2017 Information technology — Object management group systems modelling language (OMG SysML)	2017, PR	Support for architecture design of assembling process (architecture design based on SysML)
AIRBUS	Apache Jena (Version 4.4.0)	2022 , PU	Semantic driven trade space framework (requirements engineering and management part)
AIRBUS	ReqIF/RIF Requirements Interchange Format, OMG Doc. Nr: formal/2016-07-01 (version 1.2)	2016, PU	semantic driven trade space framework (requirements engineering and management part)
AIRBUS	SPARQL	2013, PR	Semantic-driven trade space framework (discrete event simulation)
AIRBUS	OEE Industry Standard	2011, PU	Semantic-driven trade space framework (discrete event simulation & visualization part)

Appendix B: QU4LITY Standardization Focus Objectives (Q-SFO)

Figure 16 depicts focus areas across the QU4LITY's ZDM technology fields and related standards. The focus areas are described in details below.

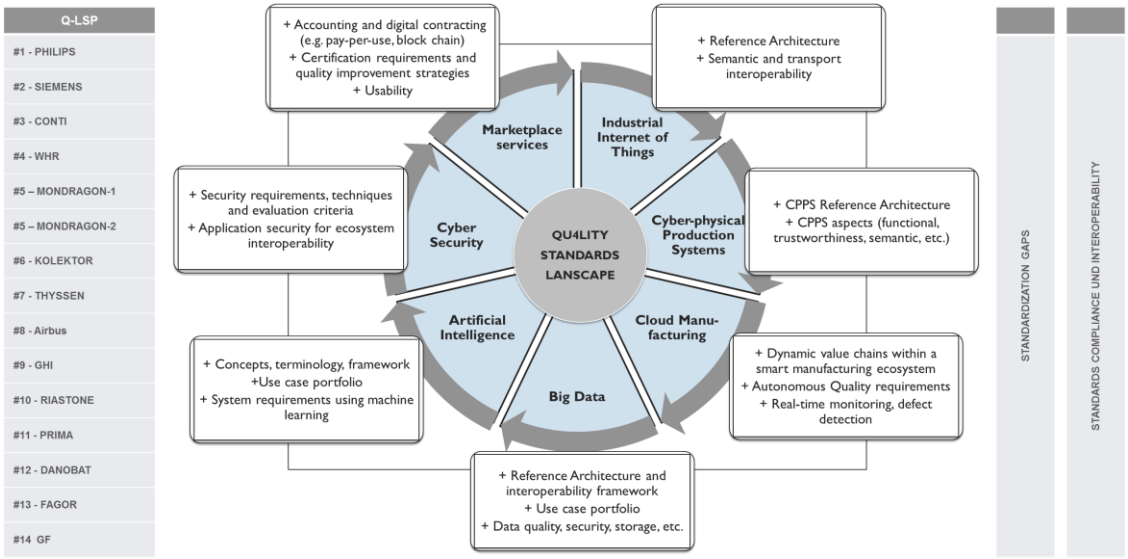

Figure 16 Focus areas across the QU4LITY's ZDM technology fields and identified standards (Ref. QU4LITY T2.4, D2.7)

Figure 17 maps Q-SFO to the RAMI 4.0 layers.

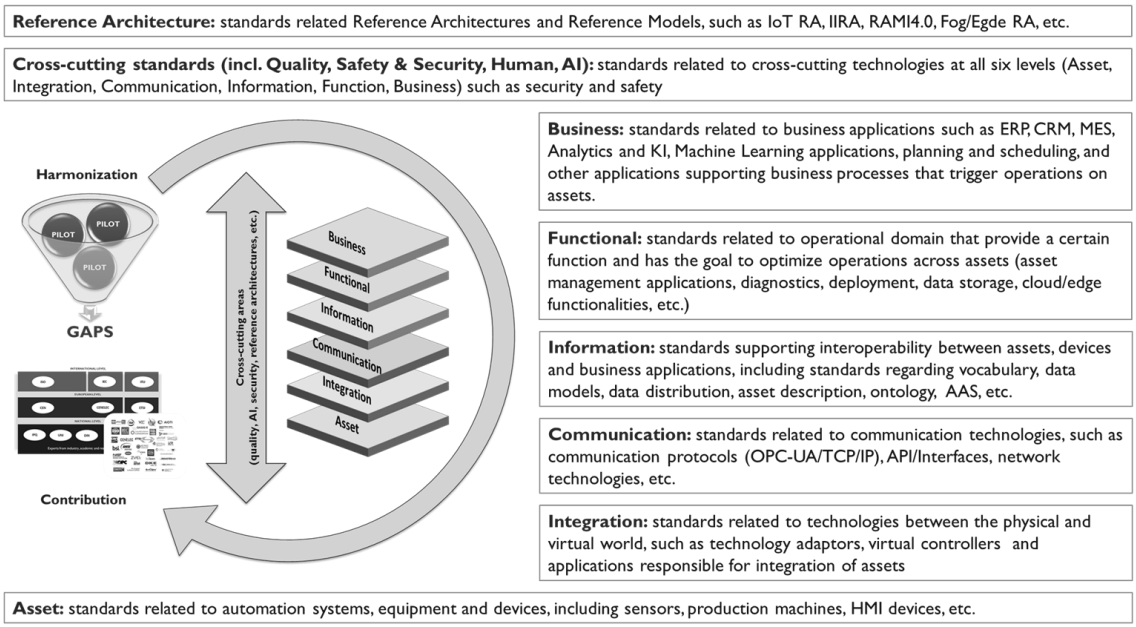

Figure 17 Standardization areas identified across RAMI 4.0 layers

Use Cases

This group focuses on standardization work related to use cases, their respective templates, and collection or contribution to use case catalogue of different

standardization objectives. Current work is observed in such committees as IEC TC 65/ WG 23[61], ISO/IEC JTC 1/SC 41/AG 25 Advisory Group on IoT use cases[62], ISO/IEC JTC 1/SC 42/WG 4 Use cases and applications[63], IIC, etc.

ZDM systems and their aspects

This group focuses on standardization of technologies for automation systems, equipment, and other devices in the manufacturing field as well as their characteristics. Among others in this scope there are such committees as e.g. ISA[64], ISO (e.g. ISO/TC 184 "Automation systems and integration"[65]; ISO/TC 251 "Asset management"), IEC (e.g. IEC TC 65 "Industrial-process measurement, control and automation"[66]); NIST (e.g. developing IT Asset management concepts[67]), IEEE (e.g. IEEE-IES Technical Committee on Industrial Agents TC-IA[68]), ISO/IEC TC 65/WG 24 Asset Administration Shell for Industrial Applications[69] as well as Plattform Industrie 4.0 AG 1[70], IEC TC 65 WG 16 Digital Factory[71] and other related German national bodies developing activities for Digital Twin [15–18]. At EU level CEN/TC 310 "Advanced automation technologies and their applications" and CEN/TC 114 "Safety of machinery".

Interoperability

Interoperability is defined by IEEE as the "*ability of two or more systems or components to exchange information and to use the information that has been exchanged*" [19]. In the Industry 4.0 vision, production assets speak and interconnect digital ecosystems in an interoperable manner [20]. Such interaction/ interlinking occurs on different layers that include not only semantic interoperability but also technical interoperability, syntactical interoperability, and pragmatic interoperability [21]. In terms of RAMI 4.0 (Figure 17), the following three layers can be linked as key elements and grouped in one objective for this purpose:

Integration

This group takes in account standards related to technologies between the physical and virtual world as one of the key components for a successful interoperability. In particular, it focuses on specific aspects ranging from system engineering requirements and going to vertical and horizontal integration in a company's IT-architecture. Very active in this field are such committees and groups as ISO/IEC JTC 1/SC41[72] Internet of Things and digital twin; W3C WoT[73]; ISO/TC 184/SC 5 "Interoperability, integration, and architectures for enterprise systems and

[61] https://www.iec.ch/dyn/www/f?p=103:14:8783874618691::::FSP_ORG_ID,FSP_LANG_ID:22639,25
[62] https://www.iec.ch/dyn/www/f?p=103:14:5509086430291::::FSP_ORG_ID,FSP_LANG_ID:25676,25
[63] https://www.iso.org/committee/6794475.html
[64]https://www.isa.org/standards-and-publications/isa-standards/list-of-isa-standards-committees/
[65] https://www.iso.org/committee/54110.html
[66] https://www.iso.org/committee/604321.html
[67] https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1800-5.pdf
[68] https://tcia.ieee-ies.org/
[69] https://www.iec.ch/dyn/www/f?p=103:14:14333902908203::::FSP_ORG_ID,FSP_LANG_ID:25623,25
[70] https://www.plattform-i40.de/PI40/Navigation/EN/ThePlatform/Structure-Organization/PlatformWorkingGroups/platform-working-groups.html
[71] https://www.iec.ch/dyn/www/f?p=103:14:14333902908203::::FSP_ORG_ID,FSP_LANG_ID:8253,25

[72] https://www.iso.org/committee/6483279.html
[73] https://www.w3.org/WoT/

automation applications"[74] [75] developing standards for industrial automation, eCl@ss[76] and IEC 61360 The Common Data Dictionary CDD[77] standardizing the classification of products and services and their seamless integration into I4.0-conform architecture; IEC TC 65 E Devices and integration in enterprise systems[78] and ISA focusing on integration aspects and boundary between the automation control systems and production management systems; and others.

Communication

This group includes standards related to communication technologies - communication protocols, interfaces, network technologies - and includes i.e. Time Sensitive Networking (TSN), the 5th Generation Mobile Networking (5G) that are worthwhile to look at, and bearing some standardization potential. The Time-Sensitive Networking (TSN) Task Group (TG) is a part of the IEEE 802.1 Working Group (WG)[79] and is working on standards to is to provide deterministic services through IEEE 802 networks.5G technology is promoted among others by the 5G Alliance for Connected Industries and Automation 5G-ACIA[80] and 3GPP[81]. Other related standards are actively developed by IEC, e.g. IEC TC 65/SC 65C "Industrial communication networks"[82], OPC Foundation[83] and IEC/SC 65E WG 8 OPC unified architecture[84], IETF[85], ETSI[86].

Information

This group includes standards supporting interoperability between assets, devices and business applications. This includes standards regarding data modelling (e.g. Automation ML[87] and its related standards CAEX, COLLADA, and PLCopen XML), semantics (e.g. semantic interoperability standardization activities by ETSI[88], standardized semantic web stack of the W3C[89]), terminology and vocabulary in industrial field (e.g. ISO/IEC JTC 1/SC 41 Internet of Things and digital twin, IEC TC 65 WG 23 TF Vocabulary[90]), standardization activities regarding ontology (e.g. OMG[91], W3C, IDSA[92]), industrial data standards and standards for data integrity and quality developed by ISO/TC 184/SC 4 Industrial data[93] etc.

[74] https://www.iso.org/committee/54192.html
[75] https://www.iso.org/committee/54192/x/catalogue/p/0/u/1/w/0/d/0
[76] https://www.eclass.eu/
[77] https://cdd.iec.ch/
[78] https://www.iec.ch/dyn/www/f?p=103:29:3473343401301::::FSP_ORG_ID,FSP_LANG_ID:1250,25#1
[79] https://1.ieee802.org/tsn/
[80] https://www.5g-acia.org/5g-for-industry/
[81] https://www.3gpp.org/specifications
[82] https://www.iec.ch/dyn/www/f?p=103:30:0::::FSP_ORG_ID,FSP_LANG_ID:1376,2
[83] https://opcfoundation.org/
[84] https://www.iec.ch/dyn/www/f?p=103:14:14333902908203::::FSP_ORG_ID:2559
[85] https://ietf.org/standards/
[86] https://www.etsi.org/committees
[87] https://www.automationml.org/o.red.c/home.html
[88] https://www.etsi.org/newsroom/news/1672-2019-10-aioti-iso-iec-jtc1-etsi-onem2m-and-w3c-collaborate-on-two-joint-white-papers-on-semantic-interoperability-targeting-developers-and-standardization-engineers
[89] https://www.w3.org/Consortium/
[90] https://www.iec.ch/dyn/www/f?p=103:14:14333902908203::::FSP_ORG_ID,FSP_LANG_ID:22639,25
[91] https://www.omg.org/spec/ODM/About-ODM/
[92] https://www.internationaldataspaces.org/our-approach/
[93] https://www.iso.org/committee/54158.html

Smart Manufacturing

Current standards landscape for smart manufacturing systems focuses on the standards upon smart manufacturing systems need to rely. Smart Manufacturing standardization landscape comprises standards within and across the manufacturing lifecycle dimensions: product, production system, and business and provide manufacturers guidelines on how to quickly adapt to rapid technological changes, to maximize the flow of data throughout the enterprise and to elevate product quality while optimizing use of resources. Such committees and groups as IEC SyC SM Smart Manufacturing[94], IEC TC 65, ISO TC 184, as well as DIN, UNI, NIST [22], IEEE SA, ITU-T [23] are currently fostering standardization topics on smart manufacturing.

Fog/Edge/Cloud Computing

This group involves standards related to operational domain that provide a certain function and has the goal to optimize operations across assets (asset management applications, diagnostics, deployment, data storage, cloud/edge functionalities, etc.). Worthwhile to mention among others the work of ISO/IEC JTC 1/SC 38 Cloud Computing and Distributed Platforms[95].The group includes the latest standardization activities in the field of Edge Computing ISO/IEC JTC 1/SC 41 that need to be monitored and analysed. See also Appendix C.

Harmonization and cross-cutting activities

This group includes standards that are related to cross-cutting technologies at all six levels, including such objectives as i.e. reference architectures and models, safety, security, artificial intelligence, human and work.

Reference Architecture Models

Worth to mention in this group is the work of ISO/IEC JTC1/SC41 that recently has developed an IoT Reference Architecture standard as well as the updated standard "The Industrial Internet of Things: Reference Architecture"[96] by IIC, and, finally, further developments concerning RAMI 4.0[97] standard.

Artificial Intelligence and Big Data

The focus in this group lies on activities of the newly established committee ISO/IEC JTC1/SC 42[98] that is currently dealing with standards regarding Artificial Intelligence as well as related standardization work of NIST in the area of Big Data.

Cybersecurity and trustworthiness

Trustworthiness has been identified by ISO/IEC SC 41 by following characteristics: security, safety, reliability, resilience and privacy [12]. For instance, NIST is explored trustworthiness and its dimensions and classified trustworthiness as a critical concern that stakeholders have about Industry 4.0 systems and their deployment [24].

[94] https://www.iec.ch/dyn/www/f?p=103:186:0::::FSP_ORG_ID:22328
[95] https://www.iso.org/committee/601355.html
[96] https://www.iiconsortium.org/pdf/IIRA-v1.9.pdf
[97] https://www.plattform-i40.de/PI40/Navigation/EN/ThePlatform/Structure-Organization/PlatformWorkingGroups/Reference-Architectures-Standards-Norms/reference-architectures-standards-norms.html
[98] https://www.iso.org/committee/6794475.html

Industrial security standards are being actively developed by ISO/IEC (e.g. ISO/IEC JTC 1/SC 27 "Information security, cybersecurity and privacy protection[99]", IEC TC 65 WG23 Taskforce Cyber Security[100], ISO/TC 292 Security and resilience[101], incl. Supply Chain Security, etc.). The concepts of privacy and trustworthiness are addressed by such groups as *CEN/CENELEC JTC 13/WG 5* „Data Protection, Privacy and Identity Management"[102], ISO/IEC JTC1/WG 13 "Trustworthiness"[103], CEN/CENELEC JTC 13 "Cybersecurity and Data protection"; CEN/TC 224 „Personal identification and related personal devices with secure element, systems, operations and privacy in a multi sectorial environment"[104]; ETSI TC CYBER (Security)[105]; ECSO "European Cybersecurity Organisation", IDSA developing standards for international data spaces, NIST[106] activities with regard to cybersecurity, etc.

[99] https://www.iso.org/committee/45306.html
[100] https://www.iec.ch/dyn/www/f?p=103:29:3473343401301::::FSP_ORG_ID,FSP_LANG_ID:1250,25#1
[101] https://www.iso.org/committee/5259148.html
[102] https://standards.cen.eu/dyn/www/f?p=CENWEB:7:0::::FSP_ORG_ID:2416754&cs=140A091203C84C7307DB4D06AB289BE3E
[103] https://www.iso.org/committee/45020.html
[104] https://standards.cen.eu/dyn/www/f?p=204:7:0::::FSP_ORG_ID:6205&cs=1FB1CC5B5F03F85F0ECCECA7598551CFC
[105] https://www.etsi.org/committee/cyber
[106] https://www.nist.gov/

Appendix C: Other Edge Consortia

The QU4LITY consortium is aware of other Edge Computing consortia present, who are all looking into pushing edge technology into the market. Below, there is a small overview of some of the more present ones and they will be monitored for their developments and the standards they are targeting.

EdgeX Foundry

EdgeX Foundry[107] is an open source project building a common interoperability framework to facilitate an ecosystem for Internet of Things (IoT) edge computing. Hosted by The Linux Foundation, the vendor-neutral project enables interoperability across tools and solutions from an ecosystem of over 60 member organizations. It delivers the flexibility, security and scalability that businesses need in order to confidently build and deploy IoT solutions that can adapt to changing business needs.

Edge Computing Consortium (ECC)

The Edge Computing Consortium (ECC)[108] is an Asian initiative, founded by six industry entities, namely Huawei Technologies Co., Ltd, Shenyang Institute of Automation of the Chinese Academy of Sciences, China Academy of Integration and Communications Technology (CAICT), Intel Corporation, ARM Holdings, and iSoftStone Information Technology (Group) Co., Ltd. The ECC is dedicated to advancing cooperation among industry resources from government, vendor, academic, research, and customer sectors, and pushing forward the sustainable development of the edge computing industry.

European Edge Computing Consortium (EECC)

The newly planned European Edge Computing Consortium[109] (EECC) aims at supporting small, medium-sized and large enterprises in Europe and all around the world to adopt edge computing technologies. In particular, the focus thereby is on the augmentation of Operational Technologies (OT) with Information and Communication Technologies (ICT). Its main mission is to push the adoption of the Edge Computing paradigm within manufacturing and other industrial markets. Its goal is to utilize and contribute to existing solutions and standards that are applied within the industrial manufacturing industry.

[107] www.edgexfoundry.org
[108] http://en.ecconsortium.org/Index/index.html
[109] https://ecconsortium.eu/

Appendix D: Joint Activities with Projects

DIATOMIC

DIATOMIC aims to establish a sustainable ecosystem to facilitate innovation in Advanced Microelectronics (AME) and Smart System Integration (SSI). The project supports the sectors health, agrifood and manufacturing, all of which are under-digitized and of prime importance for society and the economy. The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 761809.

FHG IPA prepared a contribution to the DIATOMIC Webinar on the 2nd of December 2019 where it aligned the benefits of standardization and gave practical steps of how to apply standards in the manufacturing applications and research development. QU4LITY project and its standardization activities were used as a best practice example.

ConnectedFactories2

The ConnectedFactories2 (CF2) project establishes a structured overview of available and upcoming technological approaches and best practices. After the success of ConnectedFactories pathways for digital transformation, its successor CF2 is aiming at considering archetypical transformation journeys of manufacturing industries in several cross-cutting aspects such as interoperability, security and standards adoption. The project will continue to identify present and future needs, as well as challenges, of the manufacturing industries. QU4LITY was in close contact with the responsible task for standardization (in WP1, LSEC) and contributed to beneficiary cooperation.

MIDIH

The MIDIH 4.0 project aims at implementing the fast, dynamic, borderless, disruptive side of the I4MS innovation coin by jointly working as a "one stop shop" of services, providing industry with access to the most advanced digital solutions, the most advanced industrial experiments, pools of human and industrial competencies and access to "ICT for Manufacturing" market and financial opportunities in the area of CPS/IoT.

MIDIH works within the framework of I4MS with 4 main ambitions in the area of standardisation. First, raise awareness about IoT/CPS/FI components and assets deployment in industry with security guidelines and recommendations developed in cooperation with ENISA. Second, standardization of data models for data exchange in cooperation with ETSI and under the umbrella of IDSA architecture. Three, guarantee data quality with the new standard IEEE P2510 for sensors / devices data quality certification to enable reliable and trustable solutions based on new technologies, at the same time that creating new business models and services (e.g. devices certification in data quality) by DIHs. Fourth, synergies and cooperation with industry clusters and associations to guarantee sustainable and open access to all the results at the European research and innovation (SMEs, industries and start-ups) ecosystem.

BOOST4.0

BOOST4.0 is the largest European initiative in Big Data for industry 4.0. Its aim is to guide the European manufacturing industry in the introduction of big data in the factory, providing the industrial sector with the necessary tools to obtain the maximum benefit of Big Data. The BOOST4.0 project will use the standardization and standards to provide information to the work packages inside the project, ensuring compatibility and interoperability with already existing technologies w.r.t. big data on the market. Standardization will also be used as a tool for dissemination of the project results and to establish interaction with market shareholders. The task will also perform standardization monitoring. Finally, BOOST4.0 will also deal with interaction, contribution and attendance to relevant standardization technical committees (ETSI, GSMA, W3C, OPC UA, IEC) and future standardization developments, like e.g. ZVEI Industrie 4.0 administration shell definition. As a large part of the QU4LITY consortium was also involved in the BOOST4.0 consortium, the two consortia had a natural interaction and targeted to share results regarding standardization and have the possibility to learn from each other and provide added results to standardization activities.

KI- Marktplatz

20 research institutions and companies will develop a digital platform for artificial intelligence in product development, through which providers, users and experts can network and develop solutions. The German Ministry of Economy and Energy is allocating EUR 11 million in funding, and the partners are investing an additional EUR 5 million. Over 130 consortia participated to the contest and ten of them were recommended for funding.

SPEAKER

The aim of the SPEAKER project is to set up a leading language assistance platform "Made in Germany" for business-to-business applications (B2B). The platform is planned to be open, modular and scalable and should provide technologies, services and data through combinable service interfaces. The SPEAKER platform is embedded in an extensive ecosystem consisting of large-scale industry, medium-sized companies, start-ups and research partners, which ensure a high level of innovation and strengthen Germany's digital sovereignty in a core area such artificial intelligence (AI).

Level-up

LEVEL-UP will offer a scalable platform covering the overall lifecycle, ranging from the digital twins setup, modernisation actions to diagnose and predict the operation of physical assets, to the refurbishment and remanufacturing activities towards end of life. In-situ repair technologies and the redesign for new upgraded components will be facilitated through virtual simulations for increased performance and lifetime.

Amable

EU SMEs/mid-caps face clear barriers in the uptake of Additive Manufacturing (AM) related to lack of skilled human resources, and lack of access to know-how, equipment, infrastructure and markets. The principal objective of this project is to overcome those barriers and enable the uptake of AM technologies by SMEs/mid-

caps leading to the development of innovative business and service models and new value-chain models in a fully digital environment – thus bringing their ideas and business cases to life and making their innovations Additively Manufacturable (AMable). To achieve this objective, partners with expertise right across the AM value chain have been brought together from the four corners of the EU.

AI4EU

AI4EU is the European Union's landmark AI project, which seeks to develop a European AI ecosystem bringing together the necessary knowledge, algorithms, tools, and resources, making it a compelling solution for users.

DIH²

DIH2 is a network of 26 DIHs, with a target to reach over 170 DIHs. The sole aim of the network is to spark incremental (cut 50% cost of advance robotics solutions, double the growth of robotics market) and disruptive (maximum productivity & optimum agility) innovations in over 300,000 Manufacturing SMEs and Mid-Caps. It will support SMEs in their Agile Production challenge (50% increase in productivity) and unleash their digitalization potential by enabling robot solutions that are more cost effective at lower lot sizes.

Musketeer

The massive increase in data collected and stored worldwide calls for new ways to preserve privacy while still allowing data sharing among multiple data owners. Data can continue to be stored in different locations with different privacy constraints, but shared securely. The MUSKETEER cross-domain platform will validate progress in the industrial scenarios of smart manufacturing and health. MUSKETEER strives to (1) create machine learning models over a variety of privacy-preserving scenarios, (2) ensure security and robustness against external and internal threats, (3) provide a standardized and extendable architecture, (4) demonstrate and validate in two different industrial scenarios and (5) enhance data economy by boosting sharing across domains.

MARKET4.0

MARKET4.0 will offer advanced web-presence of production equipment SMEs extended with additional functionalities such as simulations, VR/AR capabilities and also will be a P2P Industrial Data Space that offer smart user-services, a secure API to try and test the Digital Twin of the production equipment, on top suppliers' and customers' data that enable the direct transaction between market peers (supplier-tosupplier, supplier-to-customer, customer-to-suppliers and more) during the whole B2B phases from equipment search to procurement and commissioning. MARKET4.0 will create trust in the business transaction between the SME production equipment manufacturer and the customer, as indicated in the Industrial Data Space (IDS) reference architecture.

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