D1.8: Standardization needs analysis and potential contributions

WP1 – Competence Centers and Technical Expertise Management

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Table 1: Document information

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Table 2: Document History

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Executive summary

This deliverable was written for the agROBOfood project. It details the initial view of the consortium on the existing standardization landscape in agrifood robotics. Six different areas of standardization in agrifood robotics are analyzed in this deliverable. Specifically, the areas communication protocols, robots themselves, robot safety, food safety, security and energy management are detailed. For each area, the relevant existing standards and needs of standardization are identified and documented. As robotics in agrifood sector is a relatively young development, standardization is sparse in most areas. The standards that exist are mostly derived from either large agricultural machinery or industrial automation. These standards are only partially applicable for agrifood robotics. The deliverable also identifies agROBOfood partners that are experts in the different standards and can help customers with interpreting and complying with these standards.

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1 Introduction

1.1 agROBOfood in a snapshot

More than 9 billion people in less than 40 years: this estimation highlights the challenge that the agrifood sector will need to address on a global level. This means that the production of food will need to be increased, while at the same time the environmental impact of that activity will need to be reduced to avoid detrimental consequences. Another parameter that comes into place is that of the workforce that is also under pressure, as fewer seasonal workers are available for labor-intensive seasons such as harvest. A way to address those challenges is to increase the use of robotic sensing and automation in the agrifood industry. This facilitates precision and organic farming methods with their reduced environmental footprint, automates the heavier and more repetitive jobs, reduces the need for seasonal workers, can supply 24/7 vigilance against pests and disease, increases food hygiene and improves food traceability.

More food is available at a lower cost, to feed the increasing population. agROBOfood will establish a network of robotics Digital Innovation Hubs (DIHs) in the agrifood domain, each bringing their own ecosystem of Competence Centres (CCs). Each of those have expertise either in the robotics, or in the agricultural or food sectors. By connecting these actors with their different strengths, each will contribute to providing a more joined-up set of automation options for food producers and wider markets for technology providers. This network will work together to foster robotics deployment in agrifood, improve the automation service offer across Europe and support SMEs and mid-caps in developing new robotics products for agrifood. In other words DIHs will act as centres of gravity, where various stakeholders such as developers, users, consultants and investors can interact and ensure synergy and cross-pollination of ideas.

The overarching goal of agROBOfood will be to increase the end user awareness of what robotics can do for them through the demonstration of Innovation Experiments (IEs), to develop a one-stop shop online and physically within reasonable working distance, providing access to appropriate services on a pan-European level to facilitate market introduction of new robotic technologies by maturing research prototypes to advise end users how to fund the digital transformation of their company to engage in standardization activities and promote open standards and platforms to connect to other robotics networks and projects through direct links and the Robotics Digital Innovation Hubs CSA.

1.2 Standardization needs analysis and potential contributions

The goal of the standardization need analysis was to analyze the standards that are important for the domain. The study would provide an overview of the standardization needs in each category. The analysis should identify the domain experts and the potential ways to contribute.

In order to achieve these goals, the agROBOfood consortium was asked to fill out a questionnaire with two questions concerning standards and standardization needs.

First, the consortium was asked in free text to name the standards, that are important for the agricultural sector. This yielded a list of standards, which was then discussed, amended and classified by technical experts in WP1. The following table shows the results as well as the technical experts for each of the identified standards or defacto standards. The experts were asked for each of the standards has provided a short summary to detail the contents of the standards. These can be found in the following section.

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Standard ID or Name	Category	Consortium expert
BroadR-Reach	Communication	AEF
ISOBUS	Communication	AEF, CEMA, Inesc Tec
MQTT	Communication	Fraunhofer IPA
ISO 22166	Robots	Fraunhofer IPA
ROS	Robots	Fraunhofer IPA
ISO 18497	Safety of Machinery	CEMA
ISO 17757	Safety of Machinery	CEMA
ISO 25119	Safety of Machinery	AEF, CEMA
ISO 62443	Security	Joanneum Research
ISO 22000	Food Safety	Fraunhofer IVV
DIN EN 1672-2	Food Safety	Fraunhofer IVV
FDA 21CFR 174-178	Food Safety	Fraunhofer IVV
ISO 50001	Energy Management	WUR
ISOXML	Data Format	CEMA

Table 3: Standardization needs analysis

Second, the consortium was asked to provide in free text what areas in the agrifood domain of robotics need standardization. These answers were analysed, classified into sections, converted into text and added to section 2 of this document.

In total we received 23 answers from experts of the agROBOfood consortium to the questionnaire we send out.

1.3 Overview of the document

The document is organized into two parts. The first part gives an introduction about agROBOfood and the need for standardization and its potential contributions. This part presented the background and motivation for this deliverable. The second part of the document provides a short overview of each standard and its assocaited sub modules as provided by agROBOfood experts. Six categories for standardization were identified based on the a questionnaire to the consortium members. The major standardization needs are in the domain of communication, robot middleware, safety of machinery, food safety, security, and energy management. The document also addresses the need for further standardization needs in each category. Section 3 concludes on the standardization needs in agrifood robtoics and Section 4 lists the next steps the agROBOfood consortium plans to take.

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2 Areas of standardization and needs in agrifood robotics sector

2.1 Communication Protocols

2.1.1 ISOBUS - (ISO11783)

Electronics are the key to making machinery more efficient, precise and economical. ISOBUS is one of the most important techniques here. The idea behind ISOBUS is 'plug and play' with any tractor-terminal-implement-combination. But in practice it is not quite that easy. How well the components of an ISOBUS system work together depends on what they have in common, i.e. the functionalities supported by all of them. The worldwide ISO 11783 (ISOBUS) standard defines the communication between agricultural machinery, mainly tractors and implements, and also the data transfer between these mobile machines and farm software applications. It is the most significant and comprehensive standard to date, but it leaves room for interpretation, which has led to a great number of innovative but proprietary ISOBUS solutions. In order to minimize the room for interpretation the AEF develops guidelines which add to the ISO standard and thus allow for precise definitions of ISOBUS functionalities. Ultimately this provides for clarity regarding the compatibility of ISOBUS products. The ISOBUS standard specifies a serial data network for control and communications on forestry or agricultural tractors and implements. ISOBUS is based on physical layer CAN and connect tractor and implement.

Figure 1: ISOBUS interface standard

Details:

Category	(Communication | Energy Management | Safety | Security | Carbon Assessment …)
Application domain	(Tractors and machinery for agriculture and forestry)
Title	Communication
Identifier	ISOBUS (ISO 11783)
Experts	AEF
Link	https://www.aef-online.org/about-us/isobus.html

Table 4: Details of ISOBUS

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Service providers

Partner	Contact
	Project team "Engineering & Implementation" of the AEF e.V. Information: office@aef-online.org

2.1.2 BroadR-Reach – High-Speed-ISOBUS

Ethernet exists in many forms, and with many performance levels ranging from below 10 Mb/s to well beyond 1 Gb/s. Automotive took a strong interest in Ethernet and commissioned the development of a special 100 Mb/s automotive variant of Ethernet (BroadR-Reach). That is of interest to the agricultural industry since it is designed with automotive requirements and regulations in mind. In the ongoing technology research by AEF project team High-Speed-ISOBUS, the best and most reliable technology supporting the Ag industry requirements is a wired Ethernet technology. In the wide variety of Ethernet technologies, the preferred solution is 1000BASE-T1. T1 – Ethernet is defined by IEEE as successors of the BroadR-Reach technology and therefore manufacturer independent. Compared to the more common desktop-style of Ethernet that uses 2-pair of wire for 100 Mb/s, or 4-pair for 1 Gb/s, the "-T1" Ethernet uses a single twisted pair. The reduction in wire and connector pin count translates to a lower probability of failure.

High Speed ISOBUS will cover the following Agriculture use cases:

- Command and Control like "Sophisticated Universal Terminal"(VT) and more precise TaskControl / SectionControl.
- Real-time Video for Remote Process viewing as an example.
- Bulk Data Transfer used for e.g. Guidance, Coverage and Prescription.
- Enhanced Service and diagnostic in mixed manufacturer systems and for RMI (Repair-Maintenance-Information).

Details:

Category	(Communication | Energy Management | Safety | Security | Carbon Assessment …)
Application domain	(Tractors and machinery for agriculture and forestry)
Title	(Communication)
Identifier	BroadR-Reach – High-Speed-ISOBUS
Experts	**AEF**
Link	https://www.aef-online.org/about-us/activities/high-speed-isobus.html

Table 5: Details of BroadR-Reach

Service providers

Partner	Contact
	Project team "High-Speed-ISOBUS" of the AEF e.V. Information: office@aef-online.org

2.1.3 ISOXML (ISO 11783)

ISOXML is a data format used by ISO11783 part 10, more commonly referred to as the Task Controller. It is the Task Controller software on the tractor display which communicates with the

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ISOBUS implement, telling it how much product (seed, fertilizer, etc) to apply based on which part of the field the tractor/implement is in. The Task Controller software is then recording all the work that the implement has done, what was actually applied and where, how many hay bales have been made, etc. All of this information is logged in the ISOXML data format. Use of this common format allows the farmer to export the data from the tractor display and import it into his/her Farm Management Information System (FMIS) of choice for analysis and record keeping. The FMIS can also be used to plan tasks, which might even include the creation of a prescription map for product application (seed, fertiliser, etc). These tasks are then exported from the FMIS and imported into the tractor display before the driver starts work. This is again using the ISOXML data format. The concept can be found in Figure 2.

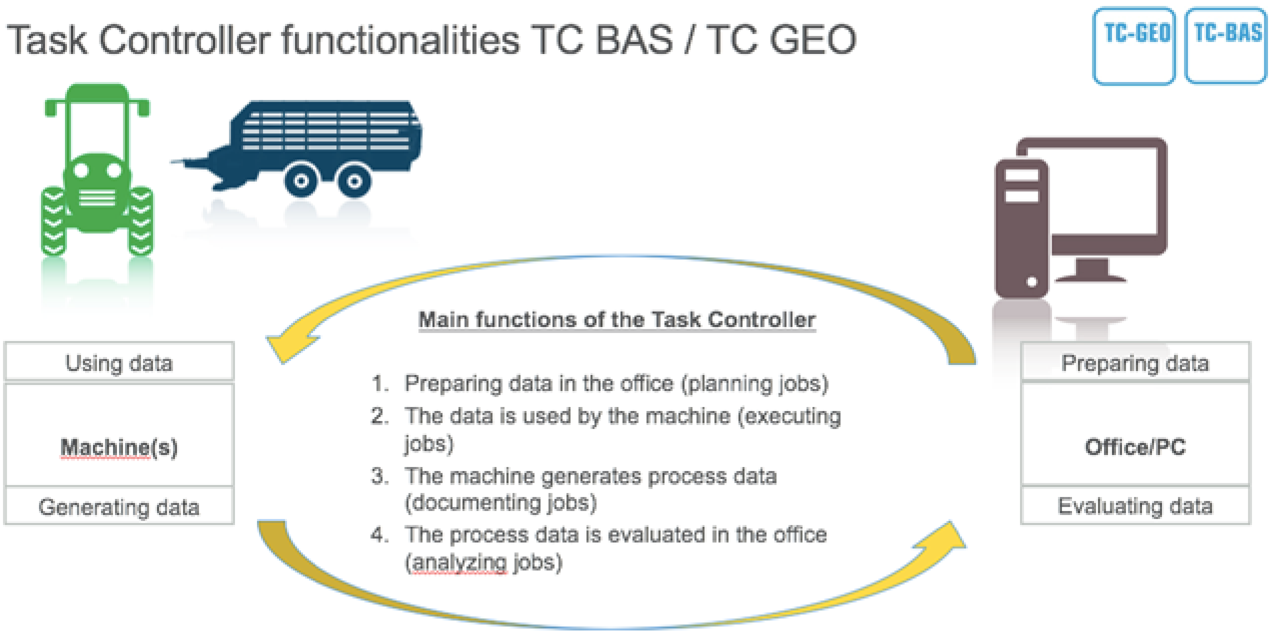

Figure 2: Task Controller functionalities

Details:

Category	Data
Application domain	Tractors and machinery for agriculture and forestry
Title	Communication
Identifier	ISOXML (ISO 11783)
Experts	AEF

Table 6: Details of ISOXML

Service providers

Partner	Contact
	Project team “Functional Safety” of the AEF e.V. Information: office@aef-online.org

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2.1.4 MQTT (ISO/IEC 20922)

MQTT is an open OASIS and ISO standard (ISO/IEC 20922) lightweight, publish-subscribe network protocol that transports messages between devices. The protocol usually runs over TCP/IP; however, any network protocol that provides ordered, lossless, bi-directional connections can support MQTT. It is designed for connections with remote locations where a "small code footprint" is required or the network bandwidth is limited. MQTT has security features integrated and works well in wireless networks.

Details:

Category	Communication
Application domain	Information Technology
Title	Message Queuing Telemetry Transport (MQTT) v3.1.1
Identifier	ISO/IEC 20922
Experts	Fraunhofer IPA

Table 7: Details of MQTT

Service providers

Partner	Contact
No providers in the consortium.	

2.1.1 Further standardization needs

The consortium has identified a number of standardization needs that fall in the domain of Connectivity.

One specific need for standardization is a connectivity standard to connect different hardware across the sector. With ISOBUS there is a standard available for controlling devices and exchanging data at low-rate. Standardization is specifically needed for systems that need higher data rates due to elaborate sensory equipment. The need for communicaiton at high data rates is typically the case when developing autonomous or semi-autonomous robot solutions in any sector and also specifically in agrifood domain. These robot solutions need elaborate sensor equipment such as cameras and lidars to enable autonomous behaviour.

Another need for standardization is an over-the-air protocol standard for communication between different hardware. This need arises when working with multiple robots or drones that need to communicate over-the-air. Over-the-air transmission is lossy and requires protocols that can cope with package loss and or even temporary connectivity loss. Combination of protocols such as MQTT and 6loWPAN or 5G have high potential to be the basis for such a standardization effort in the agrifood domain.

Furthermore, a communication standard is needed for connecting robots to digital backends. As robot tasks are versatile in the agrifood domain we will see a number of specialised robot solutions in the furture. These different specialised robot systems will be present on a single farms but probably be stemming from different specialised manufacturers. These robot systems need to be connected to a farms management system. Subsequently, a standard for connecting robots to farm management systems is needed.

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2.2 Robots

2.2.1 Robot Operating System (ROS)

The Robot Operating System (ROS) is a flexible framework for writing robot software. It is a collection of tools, libraries, and conventions that aim to simplify the task of creating complex and robust robot behavior across a wide variety of robotic platforms.

ROS provides an open-source middleware that runs on Unix based platforms and provides functionality for hardware abstraction, low-level device control, and message passing between processes. ROS offers a variety of tools that allow the developers to visualize and record data, easily navigate through the ROS package structures, and create scripts to automate complex processes. The availability of several off-the-shelf third party modules and the re-usability of ROS have attracted the research communities and industries all over the world. A ROS system contains several running processes performing specific tasks that are connected using peer-to-peer topology at run-time. The tasks communicate with each other and share processed information using strictly typed messages. The main idea behind the ROS is to have a distributed system of individually designed running processes loosely coupled at run-time.

Details: Application domain	Tractors and machinery for agriculture and forestry
Title	Robot Operating System
Identifier	ROS
Experts	Fraunhofer IPA, EURECAT, WUR, INSEC TEC, TU Delft
Link	http://www.ros.org/

Table 8: Details of ROS

Reference Implementations: Implementations of the standard that can be used as a reference or example.

Name	Link	License
ROS	http://wiki.ros.org	BSD, GPL, MIT
ROS2	https://index.ros.org/packages/	BSD, GPL, MIT

Service providers:

Partner	Contact
ROS Industrial & Fraunhofer IPA	M.Sc. Dipl.-Ing. Christoph Hellmann Santos Nobelstraße 12, 70569 Stuttgart Tel: +49 711 970-1097 @: cmh@ipa.fraunhofer.de

2.2.2 ISO 22166 – Modularity for service robots

First part of a series of standards aiming to enhance reuse of hardware and software modules to efficiently and safely build application-specific robot solution in various application domains, excluding factory automation. Part one defines general requirements for build modular robot systems. It specifies guidelines for robot system designers / makers as well as suppliers of modules used to build robot systems. These guidelines aim at interoperability of modules from diverse manufacturers, including ensuring safe and secure operation of modules in contexts not precisely known when making the modules. The standard is not a safety standard in its own right, but gives guidance on how to employ other robotic and machinery safety standards in the context of modular robotics.The standard is currently under development and expected to be published in late 2020.

Details:

Application domain	Tractors and machinery for agriculture and forestry
Title	Robot Operating System
Identifier	ROS
Experts	Fraunhofer IPA, EURECAT, WUR, INSEC TEC, TU Delft
Link	http://www.ros.org/

Table 9: Details of ISO 22166

Service providers:

Partner	Contact
Fraunhofer IPA	Dr.-Ing. Björn Kahl Nobelstraße 12, 70569 Stuttgart Tel: +49 711 970-1097 @: bak@ipa.fraunhofer.de

2.2.1 Further standardization needs

The consortium has identified a number of standardization needs that fall in the domain for robotics. The standardization needs can be split into hardware and software isssues. The majority of standardization issues was identified with robot software.

Software standardization needs:

An urgent need that was identified by the members of the agROBOfood consortium is a common software platform for robotics that fulfils the relevant industry standards. Currently, a large number of programming languages for robots exist such as Rapid, Karel, KRL most of them stemming from the 1980's. A standardized robot platform should enable a common, modern programming language for all components in a robot system and be independent of the hardware manufacturer. In terms of perfomance, it should provide sufficent real-time capabilities for standard robot applications such as motion control. A development in this direction is ROS/ROS2 that enables programming robots with a number of modern programming languages such as Python, C/C++ or Java.

Another software aspect that needs standardization is an elementary tool box for robot behaviours and tasks. Research has yielded solutions like behaviour trees (https://github.com/BehaviorTree/BehaviorTree.CPP) and actions (http://wiki.ros.org/actionlib) that could be the basis of robot behaviour and task standardization. For robotics there would be the need of standardising interfaces between robot tasks that are executed in agriculture (i.e. plant detection to weed eradication and similar interfaces).

An aspect that is more connected to robot system integration into agricultural production is the integration of agricultural robots in farm management systems:

- Predictive scheduling (level 4),
- Executive system (level 3),
- Supervision at the control level of robots (level 2)

Hardware standardization needs:

Consortium members think there is a need for a open reference robot platform for green houses.

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2.3 Safety of Machinery

2.3.1 ISO 18497: 2018 - Safety of highly automated agricultural machines

This document gives principles for the design, verification, validation and provision of information for use of a highly automated agricultural machine (HAAM). The purpose of this document is to assist in the provision of safety requirements, means of verification and information for use to ensure an appropriate level of safety for agricultural and forestry tractors and self-propelled machines with functions allowing highly automated operations. It also provides guidance on the type of information on safe working practices (including information about residual risks) to be provided by the manufacturer. This document is not applicable to forestry applications; mobile, semi-mobile or stationary machinery used for farm yard or barn operations; and operations on public roads including relevant requirements for braking and steering systems. Risks related to the communication between agricultural vehicles are also out of scope.

Details:

Category	Safety (by design)
Application domain	Highly automated machines and vehicles during agricultural field operations
Title	Agricultural machinery and tractors — Safety of highly automated agricultural machines — Principles for design
Identifier	ISO 18497: 2018
Experts	ISO
Link	https://www.iso.org/standard/62659.html

Table 10: Details of ISO 18497:2018

Service providers

Partner	Contact
No providers in the consortium.	VDMA (DE) federUNACOMA (IT) ANSEMAT (SP) AXEMA (FR) AGORIA (BE)

2.3.2 ISO 17575:2019 - Autonomous and semi-autonomous machine system safety

The standards describe the safety requirements of the machines in the application domain. It specifies safety criteria both for the machines and their associated systems and infrastructure, including hardware and software, and provides guidance on safe use in their defined functional environments during the machine and system life cycle. It also defines terms and definitions related to autonomous or semi-autonomous machine systems (ASAMS). It is applicable to (semi-) autonomous versions of the earth-moving machinery (EMM) defined in ISO 6165 and of mobile mining machines used in either surface or underground applications. It is not applicable to remote control capability (covered by ISO 15817) or function-specific automated features, except when those features are used as part of ASAMS.

Details:

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Category	Safety
Application domain	Autonomous machines and semi-autonomous machines (ASAM) used in earth-moving and mining operations,
Title	Earth-moving machinery and mining — Autonomous and semi-autonomous machine system safety
Identifier	ISO 17575: 2019
Experts	ISO
Link	https://www.iso.org/standard/76126.html

Table 11: Details of ISO 17575:2019

Service providers

Partner	Contact
No providers in the consortium.	VDMA (DE) federUNACOMA (IT)

2.3.3 ISO 25119:2010 Safety-related parts of control systems

ISO25119 sets out general principles for the design and development of safety-related parts of control systems (SRP/CS) on tractors used in agriculture and forestry and on self-propelled ride-on machines and mounted, semi-mounted and trailed machines used in agriculture. It can also be applied to mobile municipal equipment (e.g. street-sweeping machines).

It is based on a safety life cycle, which combines the most important safety-related activities in the concept phase, during series development, at the start of production (SOP), during operation and maintenance till decommissioning.

In order to guide the designer during design, verification, and to facilitate the assessment of the achieved performance level, ISO25119 defines an approach based on a classification of architecture with different design features and specific behaviour in case of a fault.

The performance levels and categories can be applied to the control systems of all kinds of mobile machines: from simple systems (e.g. auxiliary valves) to complex systems (e.g. steer by wire), as well as to the control systems of protective equipment (e.g. interlocking devices, pressure sensitive devices).

Details:

Category	Safety
Application domain	Tractors and machinery for agriculture and forestry
Title	Safety-related parts of control systems
Identifier	ISO25119
Experts	AEF e.V.
Link	(https://www.iso.org/standard/57556.html)

Table 12: Details of ISO 25119

Reference Implementations

Name	Link	License
AEF e.V.	www.aef-online.org	-

Service providers

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Partner	Contact
AEF e.V.	Project team “Functional Safety” of the AEF e.V. Information: office@aef-online.org

2.3.1 Further standardization needs

In agrifood robotics safety plays a key role as humans and animals are endangered by autonomoously driving agricultural robots. Agricultural robots are a quite new development and relevant standards have been developed by the agriculutural machinery industry. Therefore, current standards are mainly focussed on large machinery (I.e. tractors) with autonomous behaviour. Therefore, the existing standards are difficult to apply to smaller agricultural robot systems. The standard most applicable standard for safety in agricultural robots is EN-ISO 18497 which is a type B1 standard. A C-standard for autonomous agricultural robots is not available at this point.

Another problem that is related to distributed systems such as agricultural robots is communication. Currently, the predominant bussystem for connecting components in agriculture ISOBUS does not provide a dedicated standardised safety layer. Transmitting safety ciritcal messages is possible and a safe black channel communication solution could be implemented on top of ISOBUS based on IEC 61158, IEC 61784-2 und IEC 61784-3-18. AEF also provides guidelines for members for implementing safe communication. However at this point a standardised solution for safety over ISOBUS is not available.

2.4 Food safety

2.4.1 FDA 21 CFR 174-178 - Code of Federal Regulations

The Food and Drug Administration (FDA) is a federal agency of the United States‘ Department of Health and Human Services. The §174.5 of Title 21 of the CFR contains general provisions applicable to indirect food additives. According to §174.6, substances used in food-contact articles (e.g., food-packaging or food-processing equipment) that migrate, or that may be expected to migrate, into food at negligible levels may be reviewed under §170.39 of this chapter. Adhesives and components of coating are regulated in Part 175. Subpart B contains adhesives and pressure-sensitive adhesives for use only as components of adhesives. Subpart C contains from §175.210 to §175.390 a list of substances for use as components of coatings.Subpart B of part 176 contains from §176.110 to §176.350 a list of substances for use only as components of paper and paperboard. Subpart B of part 177 contains from §177.1010 to §177.2000 a list of polymers for use as basic components of single and repeated use food contact surfaces. Subpart C from part 177 contains from §177.2210 to §177.2910 a list of polymers for use only as components of articles intended for repeated use. The part 178 of Title 21 of the CFR subpart B contains hydrogen peroxide solution and sanitizing solutions utilised to control the growth of microorganisms. Subpart C contains antioxidants and stabilisers. Subpart D contains from §178.3010 to §178.3950 a list of certain adjuvants and production aids, e.g. anticorrosive agents according to §178.3125.

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Category	General indirect Food Additives, Adhesives and Components of Coating, Paper and Paperboard Components, Polymers, Adjuvants, Production Aids, and Sanitizers
Application domain	food-packaging equipment, food-processing equipment, Certain Adjuvants and Production Aids
Title	Code of Federal Regulations
Identifier	FDA 21 CFR 174-178
Experts	Food and Drug Administration
Link	https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm

Table 13: Details of FDA 21 CFR 174-178

Reference Implementations

Name	Link	License
FDA	https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm	

Service providers

Partner	Contact
Fraunhofer IVV Dresden – Hygienic Design consultation services	Max Hesse

2.4.2 DIN EN1672-2:2009-07 - Food processing Hygiene requirements

The DIN EN 1672-2:2009-07 describes the general requirements regarding hygiene risks that emerge during the utilisation of food machines and throughout the manufacturing process. It covers the basic principles of hazards for food that can be evoked by the machines. The aim is that no hazards are developed for customers of the food. The terms of food hygiene, food sector, pray sector and no-spray sector are defined in the standard. The DIN EN 1672-2:2009-07 provides a list of significant hazards and describes an approach for the implementation of a hygiene-related risk analysis of food machines (including a schematic depiction of the procedure). The standard shows the requirements of construction materials and the (constructive) design. It describes the testing of compliance with the requirements referring to a comprehensive list and describes the minimum of requirements for the content of the user information. The DIN EN 1672-2:2009-07 gives examples for hygiene risks and recommends acceptable solutions in terms of design and/or installation of food machines.

Details:

Category	Hygienic Design, Food safety, Hygienic risks
Application domain	Food processing machinery
Title	Food processing machinery – Basic concepts – Part 2: Hygiene requirements
Identifier	DIN EN 1672-2:2009-07
Experts	Beuth Verlag GmbH // Deutsches Insitut für Normung
Link	https://www.beuth.de/de/norm/din-en-1672-2/116824498

Table 14: Details of food processing hygiene requirements

Service providers

Partner	Contact

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Fraunhofer IVV Dresden – Hygienic Design consultation services	Max Hesse @:max.hesse@ivv-dd.fraunhofer.de

2.4.3 DIN EN ISO 22000:2018-09 - Food safety management systems

The DIN EN ISO 22000:2018-09 is a global standard management system for food safety. The model of the process-oriented approach of the ISO 9001:2000 is integrated as well as the demands of the HACCP-standards. All information, obtained through a systematic hazard analysis, has to be supplied by the companies for any upstream, downstream and overall organizations. The ISO 22000 summarizes the basics of the system of the hazard analysis and the critical control points (Hazard Analysis and Critical Control Points – HACCP). All reasonably expected hazards have to be identified, assessed and controlled. It must be determined, which hazards have to be controlled within the own company and which have to be controlled by other companies inside the production chain until the customer. The prerequisite program is about the postulates and actions that are necessary for the manufacturing process as well as the treatment and the provisioning of safe food. The postulates relate to the infrastructure and the work environment. In the hazard analysis the company ascertains which strategy is to be used to ensure the hazard analysis by a combination of the prerequisite program and the HACCP-plan. The standard refers to the suppliers that supply the chain of the food production. Particular emphasis of the ISO 22000 is the documentation and the verification that all necessary measures for food safety are scheduled before the implementation, correctly controlled while the implementation and subsequently completely assessed with regards to the efficacy

Details:

Category	Food safety, Hygienic Design, HACCP, Pre-emptively program, supply chain
Application domain	Food safety management
Title	Food safety management systems – Requirements for any organization in the food chain
Identifier	DIN EN ISO 22000:2018-09
Experts	Beuth Verlag GmbH // Deutsches Insitut für Normung
Link	https://www.beuth.de/de/norm/din-en-iso-22000/286720651

Table 15: Details of ISO 22000:2018-09

Service providers

Partner	Contact
Fraunhofer IVV Dresden – Hygienic Design consultation services	Max Hesse @:max.hesse@ivv-dd.fraunhofer.de

2.4.4 Further standardization needs

The questionnaire to the agrobofood consortium did not reveal any standardization needs in the area of food safety. Together with experts from Fraunhofer IVV we identified the cause – food safety is not well represented in the consortium. It will be a prime target to acquire more knowledge in this sector for the updated report.

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2.5 Security

2.5.1 IEC 62443 - Industrial communication networks - Network and system security

IEC 62443 is concerned with security aspects in automation systems (broadly speaking).

It consists of the following sub-parts

1. Terminology, concepts and models
2.1. Establishing an industrial automation and control system security program
2.3. Patch management in the IACS environment
2.4. Security program requirements for IACS service providers
3. Security for industrial process measurement and control - Network and system security
3.1. Security technologies for industrial automation and control systems
3.3. System security requirements and security levels
4.1. Secure product development lifecycle requirements
4.2 Technical security requirements for industrial automation and control systems components

The standard describes a defence in-depth approach to industrial security comprising roles, responsibilities, security segments for all actors involved including end-users and component suppliers. Also, different component classes (ranging from embedded devices up to pure software components) are defined.

IEC 62443 views security as a continuous process that accompanies the development of an automation component as well as an integrated automation system.

Details:

Category	Security
Application domain	Industrial Automation and Control Systems (IACS)
Title	Industrial communication networks - Network and system security
Identifier	IEC 62443
Experts	International Electrotechnical Commission
Link	

Table 16: Details of IEC62443

Service providers

Partner	Contact
JOANNEUM RESEARCH	Bernhard Dieber Lakeside B13b 9020 Klagenfurt bernhard.dieber@joanneum.at

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2.5.2 Further standardization needs in security

Standardization of security has begun quite recently. Currently, only a security standard for industrial systems exists (IEC 62443). The standard was not written with a focus on agrifood robot systems applies only partially. Therefore, one major need in terms of standardization in agrfood domain is the development of applicable security standards.

2.6 Energy Management

2.6.1 ISO 50001 – Energy Management systems

ISO 50001 is the international standard for certification of energy management systems. It guides an organization to develop and implement a policy to identify significant areas of energy consumption and commit to energy reductions. The standard does not require any specific performance criteria similar to any other management system standards published by the ISO. Energy assessment is an integral part of the process for complying with the standard.

ISO 50001 specifies requirements applicable to energy use and consumption, including measurement, documentation and reporting, design and procurement practices for equipment, systems, processes and personnel that contribute to energy performance. It is applied to all the variables that affect energy performance. This standard provides methodology for continual improvement in energy performance without explicitly specifying any performance criteria that has to be satisfied with respect to energy

The energy management system ISO 50001 is particularly suitable for organizations with a high energy consumption who want to systematically pay attention to measuring, monitoring and reducing this. Examples are energy-intensive industry, such as data centers, the paper industry and textile cleaning or organizations with a large floor area to be heated or cooled, such as colleges and supermarkets

Details:

Category	Energy Management
Application domain	General, all the variables that affect energy performance
Title	Energy management systems: Requirements with guidance for use
Identifier	ISO 50001
Experts	Wageningen University & Research

Table 17: Details of ISO 50001

Reference Implementations

Name	Link	License
Stichting Koninklijk Nederlands Normalisatie Instituu	https://www.nen.nl/NEN-Shop/Energiemanagement.htm	

Service providers

Partner	Contact
Wageningen Food & Biobased Research	Edo Wissink, M.Sc. Specialist refrigeration edo.wissink@wur.nl

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2.7 Other standardization needs for agrifood robotics

This section details further standardization needs that are not directly related to robotics but could lower the barrier for robot applications in the agrifood domain.

One major improvement that could lower the barrier for automation in greenhouses and on farms is more standardization in the facilities. This standardization need is specifically directed at the infrastructure of greenhouses and farms. Achieving autonomous robot behaviour is easier when working in standardised environments.

Data collection in the agrifood sector is difficult due to vendor specific data formats. Therefore, standardization in the data domain could help. Specifically, open to all vendor data platforms and data sharing facilities could be a major enabler for data driven food production.

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3 Conclusions

This report analysed the major existing standards for the agrifood robotics domain by leveraging the experts of the agROBOfood consortium. Agrifood robotics is still a relatively new development and is not yet widely adopted in the agrifood industry. Subsequently, standards that apply to agrifood robots have typically been developed with other machinery as focus. Especially, the agricultural machinery industry has developed a number of standards that applied to agrifood robots but were originally developed for tractors and other large machinery with autonomous functionalities. As the standards were not developed for agrifood robots they do not cover all necessary requirements for autonomous robots.

This currently leads to a lack of standardization for agrifood robotics specifically in the area of health and safety. Health and safety standards are particularly important for robot manufacturers as the machinery directive requires manufacturers to fulfil health and safety requirements when putting a product on the market. In the current situation, with no safety standard fully covering the safety requirements for autonomous agrifood robots, developing an autonomous robot that complies with the machinery directive poses a considerable effort and risk for robot manufacturers. A health and safety standard for agrifood robotics could lower the risks for the manufacturer.

Another general problem that has been brought up is the scattering of data formats, programming languages and communication standards. For example, each robot arm manufacturer has their own language for programming their robots. This effectively stifles the development of manufacturer independent robot applications and prevents the development of a strong robot application software industry. A development towards a common programming language for robotics is ROS/ROS2. The same is true for data formats. Most OEMs still use their own data formats for configuration and operations data and thus effectively stifle the development of a vibrant data space for agrifood data.

To conclude, there is huge potential in improving the standardization landscape in agrifood robotics.

4 Outlook

The agROBOfood consortium's next steps in terms of standardization activities are:

- **Coordinating the standardization activities:** The agROBOfood consortium has many experts in the area of agrifood robotics that can give valuable inputs for standardization but are not active in standardization. The consortium also has many expert organisations that are active in standardization committees (CEMA, AEF etc.). The goal here is to bring these experts together and create outlines for current and new standardization activities.
- **Gather information about needs from innovation experiments:** The current deliverable is solely based on information from experts. The goal here is to use the experiences from the agROBOfood innovation experiments to gather more information about standardization needs.
- **Further detailing of the standardization landscape in agrifood robotics**

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