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UNLOCK-CEI

CEI ecosystems overview with the value chain adopter groups

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Glossary of terms

Item	Description
Value chain	In this document a value chain means a group of companies that interact and cooperate with each other to provide a product, a solution, or a service
Value chain adopter group (VCA)	A value chain adopter group is an approach to engage and receive feedback from industry constituency to requirements and demands for CEI technologies
Digital Continuum	Digital Continuum allows for seamless interaction of actors in a value chain using CEI technologies
AI/ML	Artificial Intelligence and Machine Learning
AR/VR	Augmented and Virtual Reality
6G IA	6G Industry Association
WP	Work Package
IoT	Internet of Things
IT	Information Technologies
SME	Small and Medium Enterprises
IPCEI	Important Project of Common European Interest
IIoT	Industrial Internet of Things
OEM	Original Equipment Manufacturer
SRIA	Strategic Research and Innovation Agenda
JU	Joint Undertaking
ETP4HPC	European Technology Platform for High-Performance Computing
TCI	TransContinuum Initiative
R&D&I	Research Development and Innovation
AIOTI	Alliance of Internet of Things and Edge Computing Innovation
BDVA	Big Data Value Association
ECSO	European Cyber Security Organisation
KDT	Key Digital Technologies
EPoSS	European Technology Platform on Smart Systems Integration
MSODE	Modelling, Simulation and Optimisation in Data-rich Environment
AENEAS	Association for European NanoElectronics ActivitieS
INSIDE	INSIDE Industry Association
ECS	Electronics Components and Systems
BATX	Baidu, Alibaba, Tencent, and Xiaomi
GAFAM	Google, Amazon, Facebook, Apple, Microsoft
IHI	Innovative Health Initiative
BVMed	Bundesverband Medizintechnologie
Snitem	Syndicat national de l'industrie des technologies médicales
NLP	Natural Language Processing
EMA	European Medicines Agency
TSO/DSO	Transmission System Operators/Distribution System Operators
HVAC	Heating, Ventilation and Air Conditioning
ETIP_SNET	European Technology & Innovation Platforms Smart Networks for Energy Transition
WG	Working Group
V2G	Vehicle to Grid
EV	Electric Vehicle

E.DSO	European Distribution System Operators
DER	Distributed Energy Resources
SmartEn	European business association integrating consumer-driven solutions to the clean energy transition
EASE	European Association for Storage of Energy
IRENA	International Renewable Energy Agency
DERMS	Distributed energy resource management systems
BDI	Bundesverband der Deutschen Industrie
SMI	Sistema Moda Italia
VDMA	German Engineering Federation
FKG	Scandinavian Automotive Supplier Association
ACEA	European Automobile Manufacturers Association
CEPI	Confederation of European Paper Industries
EFPIA	European Federation of Pharmaceutical Industries and Associations
CEFIC	European Chemical Industry Council
ERT	European Round Table for Industry
WEF	World Economic Forum
AGV	Automated Guided Vehicles
RFID	Radio-Frequency Identification
EDC	Eclipse Data Space Connector
GBA	Global Battery Alliance
ITS	Intelligent Transport Systems
AECC	Automotive Edge Computing Consortium
5GAA	5G Automotive Association
ITF	International Transport Forum
UITP	Union Internationale des Transports Publics
ACEA	European Automobile Manufacturers’ Association
EUCAR	European Council for Automotive R&D
CLEPA	European Association of Automotive Suppliers
2Zero	2Zero Partnership
ERTRAC	European Transport Advisory Council
CCAM	Connected, Co-operative and Automated Mobility
MaaS	Alliance Mobility-as-a-Service Alliance
CEDR	Conference of European Directors of Roads
HMI	Human Machine Interaction
V2X	Vehicle to X
DBV	German Farmers’ Association
COPA-COGECA	Comité des organisations professionnelles agricoles - Comité général de la coopération agricole de l’Union européenne
AFCC	Agri-Food Chain Coalition
CMEA	European Agricultural Machinery Association
COCERAL	Comité du Commerce des céréales, aliments du bétail, oléagineux, huile d'olive, huiles et graisses et agrofournitures
EIT	European Institute of Innovation & Technology
UAVs	Unmanned Aerial Vehicles
KPI	Key Performance Indicator
M	Month
D	Deliverable

Keywords

Cloud-to-Edge-IoT, Artificial Intelligence, Digital Continuum, Industry Constituency, Value Chains

Disclaimer

All mentioned URLs are proven to be valid on the 28th of November.

Executive Summary

This document is a direct outcome of WP3, which focuses on organising a proactive dialogue between demand constituencies and the providers of IoT-to-Edge-to Cloud technology to identify the actual needs along with observed opportunities and adoption barriers on the demand side. The report highlights the key points of the strategic research and innovation agendas of the leading cross-sector and sector-specific industry associations, focusing on potential "demand pull" drivers. It outlines mutual dependencies, requirements, and technological demands to make interactions between stakeholders along data-driven value chains more efficient. The report covers agriculture, health, manufacturing, transportation and energy as key domains for the adoption of CEI technology.

The cross-sector key insights and findings regarding "demand pull" drivers, observed opportunities and challenges in the upcoming years are the following:

- Digital twins, immersive communication, holographic telepresence, ubiquitous support for AI, augmented/virtual reality applications as well as a trustworthy and secure edge-clouding computing connectivity infrastructure for safe and secure personal mobile robotics are major "demand pull" drivers for CEI technologies.
- Real-time capabilities, low-latency performance on the edge, optimisation and complex problem solving and reasoning in the cloud are the main required features of the future Cloud-Edge-IoT Continuum. Seamless integration of application workflows, digital twins including physics-based simulations and AI/ML will be crucial.
- Due to climate change and the recent shortage of energy sources, energy and resource efficiency will become crucial for the competitive advantage of European companies. Therefore, new efficient hardware for data management and processing is needed to achieve the ambitious plans of BDVA regarding energy savings of 10% per year. 6G IA calls for AI-based optimisation of network management functions and more efficient radio technologies to return to similar energy consumption as 4G networks.
- The semiconductor industry represented by KDT, strives for flexible and open hardware interfaces and architectures in combination with efficient and light weighted AI/ML algorithms for embedded software and neuromorphic computing to meet these ambitious energy efficiency demands.
- The integration costs of already existing heterogonous tools and frameworks coming from different communities and vendors are very high. Europe faces fierce competition with Asian and American vendors who already announced their own IoT and Edge Computing strategies. Single vendor solutions require less integration efforts and lead to lock-in for the ICT providers and the end users. Open hardware and software communities as well as frameworks at infrastructure level will allow for new business opportunities, enable growth for SMEs and start-ups, and prevent the formation of oligopolies on the market.
- Current government actions such as the infrastructure investment programmes European Alliance for Industrial Data, Edge and Cloud as well as IPCEI CIS are enforcing a strong "technology push" for CEI infrastructures in Europe. The new updated computing und connectivity infrastructures will raise the "demand pull" for new service offerings and individual hardware and software solutions in the upcoming years.
- The identified demand-pull topic areas such as digital twins, AI and IoT have been part of the standardisation landscape for many years. The standardisation bodies need to focus their current attention on open APIs and standards for CEI infrastructures. The main GAIA-X objective is to provide an open, cloud-agnostic infrastructure for the European economy and prevent vendor lock-in effects. GAIA-X is a promising initiative that pursues standardisation of cloud-, edge- and AI services at the infrastructure level.

Observed opportunities and challenges regarding "demand pull"- drivers in the sectors are:

Health sector:

Opportunities

- Smart medical devices with embedded intelligence enable less invasive treatments and are more comfortable for the patient.
- Local processing of patient data on edge devices enhances privacy. This is especially important in the health sector as very sensible data is processed.
  In many settings, e.g. in the operating room or first aid, real-time processing is crucial for saving patients' lives. Edge devices with real-time capabilities provide reliable and fast decision assistance for doctors in first aid situations.

Challenges

- The biggest challenge is the access to high quality data. Health data is sensible and undergoes strict regulations, e.g. consent of the patient, regulations on different levels (health facility, country, EU). Ethical aspects play an important role, especially when monitoring patients at home.
- The security of wearables, edge devices and cloud services are crucial for transferring and using sensible health data of patients.
- The selection of a cloud provider or data centre has to be compliant with the country or organisation's data protection regulations.
- Heterogeneous infrastructure in clinics and hospitals is lacking interoperability, open systems and interfaces.
- AI-based assistance systems for diagnosis and treatments need to undergo a complex certification procedure according to the currently introduced AI act. As this is a time-consuming and costly process, it is a considerable risk for tech companies.
- Value chains in the health sector are complex and competitive: the actors may take on different roles collaborating in one area and competing in another.

Agricultural sector:

Opportunities

- CEI technologies are a major enabler for digital solutions that support both the ecological and effective production of crop and animal products. The main applications described are automated machinery, leveraging data from sensor for real-time decision-making and for individualised supply of crop and livestock.
- The main benefit are smart farming solutions that attend the plants and animals according to their individual needs. There is a market for robots that fully automate processes in field cultivation and animal care. Retrofitting existing agricultural machinery with CEI-based kits also offers potential for smart farming.
- Data Spaces and other cloud solutions offer space for data storage according to state-of-the-art and the possibility to share or sell data. The data spaces can ensure the data sovereignty of farmers and facilitate reports required by regulations based on the processed data, which helps to reduce the administration effort.
- As most farmers have limited or outdated IT equipment, there is a clear opportunity for widespread adoption of CEI technologies. In addition, farmers have a high demand for information regarding weather data, field management and yield forecasts, which offers opportunities for new digital services.

Local multi-sensor-systems operating on the edge allow farmers to deal with unstable internet connections and employ the full range of services for data collection and processing. Edge computing makes time-shifted data transfer possible. Due to pre-processing on the edge, the transfer also requires smaller data volumes for transferring to cloud computing data centres.

Challenges

- The agriculture sector is traditionally sceptical and a late adopter of new technologies.
  Unreliable and inadequate network coverage for mobile internet is one of the major and widely known inhibitors for CEI technologies in agriculture. Therefore, reliability in dead spots is key, e.g. with the help of edge computing.
  Without the possibility of seamless data collection in the field and in the barn, solutions such as AI-based applications for process optimisation and data sharing are difficult and costly to implement.

Transportation sector:

Opportunities

- Critical data in terms of latency, privacy and energy efficiency can be processed locally on an edge platform near the sensor and actors.
- Strategic and intelligent operations like planning, modelling, data analysis, software engineering and maintenance, AI calculations, preparation and control of software updates and even re-selling of data can be done in the cloud.
- CEI technologies open opportunities for new services in transportation (e.g. shared transport platforms, automated vehicles).
- As centralised functions continue to provide the opportunities for the smarter and powerful system parts, European actors should offer more cloud capacities of their own and establish a presence in edge technologies.

  Potential European cross-sector market players, which also serve the transport domain, especially as cloud providers, such as T-Systems, Bosch, Siemens, need to be strengthened as alternatives to international hyperscalers.

Challenges

- CEI technologies need cloud providers, and the initiative to introduce CEI technologies often comes from international hyperscaler companies (in Europe especially American companies like AWS, Microsoft, HP, Google etc.) as part of their marketing strategies.
- There is also a risk of vendor lock-in in the transport sector, as European IoT companies and users have only few alternatives when choosing a cloud provider.
- Many users from the public transport sector also have problems with the mass provision of data to international servers with limited control over the use of the data, as they have concerns about data sovereignty and data protection.
  Data owners should have the right and the choice to determine on which servers the data is processed, to be informed and to consent.
- In the transport sector, concerns about data sovereignty are especially high, as traditionally much of the data comes from the public sector (public authorities). There is a permanent dispute on whether the data should be generated and owned by public authorities or whether it should be bought from private service providers. There is a trend to have data servers of their own, which are under public control.

Energy sector:

Opportunities

- CEI technologies provide real-time data analysis to meet the exponential growth in the complexity of network operation, energy demands and the increasing integration of distributed energy resources, increasing efficiency and costs and turning consumers into prosumers.

- New tools such as blockchain can facilitate such local energy trading systems and even drive intelligent local energy communities forward.
- Real-time dynamic regulation of power supply to the different lines on which new elements such as electrical chargers or batteries now hang will support energy balance and remove boundaries between energy sectors, increasing flexibility and enabling the integration across entire systems.
- Digitalisation enables the active participation of consumers from all demand sectors in energy system operations.

Challenges

- To exploit the full potential of CEI technologies, fundamental changes in policy and regulation are needed to ensure that the benefits of the digital transformation of electricity are fully realised and the risks minimised.
  Data ownership, privacy considerations and cyber security are crucial for critical energy supply systems. New user-centric business models and economic disruption as well as standardisation need to be further developed in this rapidly changing ecosystem.

Manufacturing sector:

- CEI-technologies for manufacturing follow the industry 4.0 vision that involves cyber-physical systems connected by the Industrial Internet of Things (IIoT). It is a step towards transforming traditional factories into smart spaces.
- Manufacturers have currently realised the high value of production data used for process optimisation. On edge devices and platforms, the data can be processed close to the sensors and actors, thus improving the informative value.
- This is primarily needed for real-time applications, e.g. for adaptation of control parameters according to product quality data. Fog architectures are also applied to reduce the amount of data for further processing, e.g. in the cloud.

  For strategic and intelligent operations like planning, deep data analytics and AI applications, there is a need for cloud applications.

Challenges

- The cooperation with international hyperscalers is common and might be problematic in terms of data sovereignty. European actors should offer more and own high performance cloud capacities and establish a presence in edge technologies.
- Business models and revenue streams for many applications are unclear and not yet established in the value chains. The benefit of predictive maintenance solutions, for example, is often difficult to prove, resulting in an unpredictable market volume.
- A point of action is the data exchange along the value chains. In automotive, the OEMs can orchestrate their supply chain and set standards for the data exchange by including the demand in the contracts. However, in other sectors, the linkage in the network of companies and suppliers is more tangled. None of the actors is in the position to orchestrate and control the data exchange.
- Data consistency and quality is a challenge for all digital solutions, in the company as well as along the value chain, since the applications rely on sufficiently up-to-date data.

To receive feedback on favourable CEI services offerings, we will design and implement a series of workshops for interaction with industry associations to collect and aggregate their needs and views, and to provide input for the CEI Demand & Market Scenarios (T.2.2) and Demand Landscaping (T.1.1).

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1. Introduction

The converging IoT, edge computing and cloud computing technologies will require a shift in the current infrastructure, in which computing and storage capacities must increasingly be located at the “edge” of the network, close to the multiple data sources represented by smart devices.

National and European public authorities as well as industry associations recognised this emerging and promising trend for the European economy and established public-private partnerships, Joint Undertaking initiatives and investment programmes to engage the key actors and stakeholders from research and industry and to leverage the CEI market potential. This report provides a high-level overview of the demand-pull drivers and thematic areas that will foster the adoption of CEI technologies. The insights and findings will be used to prepare a proactive dialogue with the industry constituency.

1.1 How to read this document

The report contains an executive summary and four main chapters. The executive summary outlines the key insights and findings including observed opportunities and challenges for CEI technologies. It provides short and fast access to the subject matter for political or business decision makers.

This first chapter is the introduction to the document. Chapter 2 and 3 target innovation managers, business decision makers and domain experts who would like to be informed about potential thematic areas, applications, initiatives and already existing data-driven value chains that will contribute to CEI adoption in the market. Chapter 2 and 3 are dedicated to the leading industrial associations that form the starting point for establishing a pro-active dialogue with industry constituency.

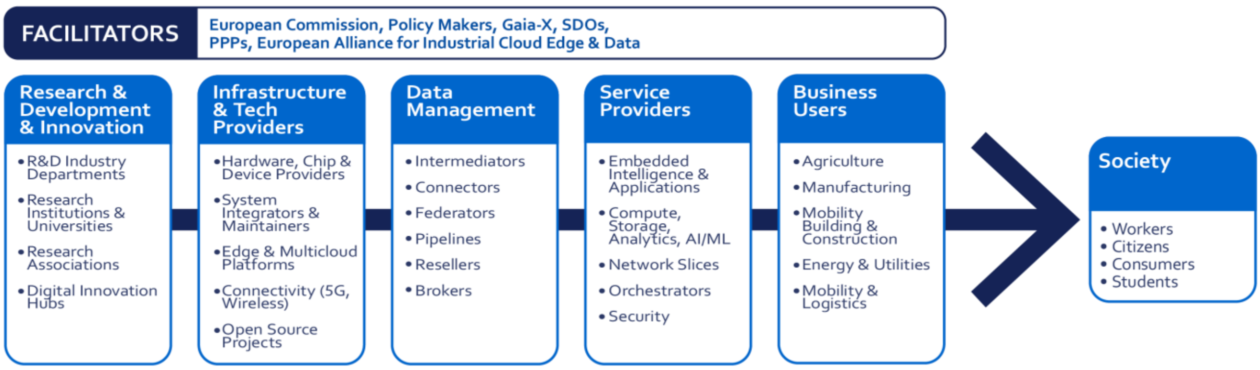

Figure 1: Overview of CEI ecosystem stakeholders

Chapter 2 covers the main cross-sector CEI stakeholder organisations and highlights the key points of their strategic research and innovation agendas (SRIAs) focusing on potential demand-pull drivers for CEI technologies. Chapter 2 outlines specific challenges, conditions, benchmarks, expected service features and applications. It concludes with observed common requirements, demands, facilitators and technological enablers for efficient interaction between the stakeholders along the data-driven value chains.

Chapter 3 covers the vertical sectors: agriculture, health, manufacturing, transportation and energy. Each sector-specific section describes the key facts included in the SRIAs and illustrates examples based on whitepapers, lighthouse projects or solutions that already entered the market. The selection of use cases is based on the results of Deliverable 1.1 (Demand Landscape). The sections outline the main stakeholders and interaction between them in the sector-specific value chains. Each section concludes with observed challenges and opportunities for demand pull drivers for CEI technologies and highlights specific domain characteristics.

Chapter 4 describes the "Value Chain Adopter Groups" approach that will be used to organise a proactive dialogue with industry stakeholders. It covers the setting of the planned events and the description of "Key Performance Indicators" for the successful engagement of the relevant stakeholder groups. Chapter 4 primarily addresses the project partners and the European Commission.

In the scope of this report, we will refer to the understanding and the definition of Cloud-Edge-IoT Continuum introduced in D4.1 (Technology Scoping Paper).

2. Industry cross-sector stakeholders

The leading cross-sector industrial associations and initiatives introduced in this chapter are actively building the emerging Cloud-Edge-IoT Continuum. The member organisations of the leading industry associations summarise their views on the future technological and societal challenges in the Strategic Research and Innovation Agendas and white papers. These documents target political decision makers and present common interests to tackle the identified common problems together in a pre-competition phase. This chapter outlines the main key facts mentioned in the corresponding SRIAs in terms of challenges, conditions, as well as required characteristics and features that will contribute to the adoption of CEI technologies.

The industry associations and technology platforms stand in continuous dialogue with solution providers, business decision makers, technology developers and research institutions. They cooperatively develop work programmes and calls for scientific projects under the umbrella of the Joint Undertaking initiatives (JU).[1] The main goal of JU initiatives is to meet the demand of industry and facilitate the adoption of R&D&I results from scientific industry-driven projects.

The recently founded (2020) TransContinuum Initiative (TCI) forms the current nucleus of HPC and CEI technologies. It unites eight major European industry associations to find, discuss and develop use cases that require all functions of the HPC-Cloud-Edge-IoT Continuum.

ETP4HPC, the European Technology Platform for High-Performance Computing recognised the benefits of the Digital Continuum for HPC and Big Data and took over the coordination of the activities of the TCI.

In the following sections, we will outline the central strategic areas and goals of the TCI member organisations and highlight the CEI stakeholders they represent.[2]

*2.1.1 **ETP4HPC** European Technology Platform (ETP) for High-Performance Computing (HPC)*

ETP4HPC – the European Technology Platform (ETP) for High-Performance Computing (HPC) – is a private, industry-led and non-profit association founded in 2012.[3] The members of ETP4HPC are **hardware and software providers for low-power microprocessors**, **high performance supercomputers and as of recently quantum computing technologies**. The targeted application areas for HPC include drug design, disease modelling, agriculture, aerospace engineering, energy, climate research such as the Destination Earth Initiative[4], optimisation of logistics and many more applications.

ETP4HPC and Big Data Value Association (BDVA) joint forces as private members of the EuroHPC JU to provide expertise and resources for globally competitive European HPC systems combined with strong Big Data and

[1] The scientific cooperation should tackle specific industry-driven research questions and provide solution to real world use cases.

[2] HiPEAC is a project that also belongs to the TransContinuum Initiative. HiPEAC provides a platform for cross-disciplinary research collaboration.

[3] https://www.etp4hpc.eu/

[4] https://digital-strategy.ec.europa.eu/en/policies/destination-earth

AI expertise. The ETP4HPC Research and Innovation Agenda contains a special chapter focused on the HPC-Cloud-Edge-IoT Continuum.[5] It highlights the demand for the seamless integration of application workflows across all IoT-Edge-Cloud-Supercomputer layers. Such workflows combine physics-based simulations, analysis of large data volumes with the subsequent processing results of AI/ML algorithms. There will be also a high demand for innovative tools that enable efficient deployment, scheduling and orchestration of the workflow components across the highly distributed and heterogeneous HPC-Cloud-Edge-IoT computing infrastructures.

Green Deal & Energy:

The biggest challenge is the energy consumption of high-performance computing infrastructures, which is very high and will still be increasing in the next years. According to the ETP4HPC SRIA, the energy consumption can be reduced in two ways: firstly, starting with resource and material efficiency by manufacturing hardware components and increasing the lifetime of systems, and secondly, by developing novel approaches for energy efficiency of management, storage and scheduling algorithms. Both approaches will contribute to financial and environmental savings and reduction of the CO2 footprint.

*2.1.2 **6G IA**, the 6G Infrastructure Association*

The 6G IA[6] focuses on the development of mobile communication standards, R&D&I projects, and technology skills and establishes collaboration with key vertical industry sectors to understand and meet the technological requirements and needs. The member organisations of 6G IA involve telecoms & digital actors, such as connectivity providers, manufacturers, research institutes, universities, and mainly ICT suppliers, system integrators and maintainers for vertical domains. 6G stands for the newly evolving generation of mobile infrastructures and networks. 6G IA initiated the Smart Networks and Services Joint Undertaking (SNS JU) Initiative to foster specific industry-driven R&D&I activities. The state-of-the-art 5G technologies meet the demand of industry for seamless connectivity, low latency as well as capability of transferring huge volume data for infrastructure owners and vertical service providers. 6G (or beyond 5G) envisions further advanced application areas such as **immersive communication, holographic telepresence, and especially ubiquitous support for AI, augmented/virtual reality applications**. The key vision of 6G is to provide a trustworthy and secure edge-clouding computing connectivity infrastructure that allows for **safe and secure personal mobile robotics**.

Green Deal & Energy:

The energy consumption of mobile communication systems is constantly rising due to the increasing demand for mobile connectivity, radio access network densification, support of multiple logical networks over the same HW infrastructure, mass deployment of edge and cloud components as well as massive increase of sensors. **ICT already contributes around 2.5 % of the global greenhouse gas emissions (GHG)** according to recent studies.[7] Therefore, one of the Key Performance Indicators for the upcoming 6G IA activities is to foster **energy efficiency** in network management functions including AI-based optimisation, **less energy demanding radio technologies**, as well as **sustainable business models** that foster energy efficiency in order to **return to the energy consumption at the level of 4G infrastructures**. The major features of the upcoming 6G focus on **reduction of energy footprint, trustworthy infrastructure, scalability, and affordability**.[8]

[5] https://www.etp4hpc.eu/pujades/files/ETP4HPC-SRA5_2022_web.pdf
[6] https://6g-ia.eu/
[7] https://www.itu.int/en/action/environment-and-climate-change/Pages/energy_efficiency-BAK.aspx
[8] https://5g-ppp.eu/wp-content/uploads/2021/06/WhitePaper-6G-Europe.pdf

*2.1.3 **AIOTI**, the Alliance of Internet of Things and Edge Computing Innovation*

The aim of AIOTI[9], the Alliance of Internet of Things and Edge Computing Innovation is to promote IoT and Edge Computing and other converging technologies along business-driven scenarios and use cases that support the objectives and challenges including EU Green Deal and data policies. The members of AIOTI involve IoT-platform providers, IoT- and edge computing providers as well as ICT suppliers, system integrators and maintainers for cross-sector applications and vertical domains.

The domain-specific groups: Agriculture, Buildings, Energy, Health, Manufacturing, Mobility and Logistics cover the topics regarding policy, standards as well as user requirements on Edge Cloud IoT technologies. The publications of the working groups address topic areas for IoT and Edge Computing such as **smart grids in the energy sector, agricultural robotics, AI-based data processing, smart sensing approaches, low power sensing and computing, AR/AV, Edge AI, industrial Edge Computing as well as services for energy-efficient data processing, monitoring and management of production lines and facilities**. The AIOTI experts recently published an analysis on the integration of IoT and edge computing in data spaces together with the resulting data space standards recommendations for **data space providers**.[10]

Green Deal & Energy:

Green Deal and Energy are important issues for AIOTI that are discussed in horizontal AIOTI working groups (e.g. Green Deal, Data Act, AI Act, EU Chips act etc.). AIOTI informs its members about the relevant standards regarding, for example, measurements of CO2 for products or impacts of Edge Computing on Green Deal and proposes scenarios and best use cases for the energy sector.[11]

*2.1.4 **BDVA**, the Big Data Value Association*

BDVA, the Big Data Value Association[12] (from 2021, ADRA – Data, AI and Robotics aisbl), is an industry-driven international not-for-profit organisation with more than 230 members.

The focus of BDVA lies on Big Data and Artificial Intelligence, services, platforms and data spaces, standardisation, and skills. BDVA/DAIRO is a private member of the EuroHPC Joint Undertaking. The members of BDVA share a common interest in research and development of data techniques and tools that allow for **collecting, storing, analysing, processing and visualising vast amounts of data**. BVDA outlines its plans and objectives in the annual European Big Data Value Strategic Research and Innovation Agenda.[13] BDVA builds and sustains an ecosystem of big data technology providers and users, who participate in EU lighthouse projects, employ testbeds and contribute to interoperability of standards and tools along emerging data driven value chains. BDVA established a cooperation with industry associations such as EU4HPC, AIOTI and 6G IA to find and leverage synergies in enabling digital technologies, from IoT to 5G, Cloud and High Performance Computing (HPC), Edge Computing and Big Data.

The areas with huge data volumes such as media, content, financial services, and the public sector belong to the demand pull for Big Data value creation. Energy, mobility, transport and logistics, manufacturing and production as well as healthcare mentioned in the BDVA SRIA as application domains with a strong demand for CEI technologies.

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[9] https://aioti.eu/
[10] https://aioti.eu/wp-content/uploads/2022/09/AIOTI-Guidance-for-IoT-Integration-in-Data-Spaces-Final.pdf
[11] https://aioti.eu/wp-content/uploads/2022/01/AIOTI-IG-Digital-for-Green-Vision-R1-Final.pdf
[12] https://www.bdva.eu/
[13] https://bdva.eu/sites/default/files/BDVA_SRIA_v4_Ed1.1.pdf

Green Deal & Energy:

BDVA pursues the Green Deal objectives and aims at **energy savings of 10 % per year** while processing the same amount of data (p. 89). From the BDVA perspective, new efficient hardware for data management and processing is needed to achieve significant energy reduction. On the other hand, the BDVA research and innovation efforts will address new tools and algorithms that need fewer resources and time to provide the same quality of analytics.

*2.1.5 **ECSO**, the European Cyber Security Organisation*

ECSO[14], the European Cyber Security Organisation aims at establishing a cooperation between public and private actors in order to foster the adoption of innovative and trustworthy European solutions (ICT products, services and software). Especially the alignment of demand and supply in the key sectors such as energy, health, transport, finances is in the focus of the strategic research and innovation activities**. Infrastructure and data protection, secure ID, implementation of the NIS2 Directive, especially regarding protection of critical infrastructures, trusted cloud services, 5/6G infrastructures and enhancing the security and trust level of supply chains** are the high priority topics of the ECSO strategic research and innovation agenda.

*2.1.6 **EPoSS**, the European Technology Platform on Smart Systems Integration*

EPoSS[15], the European Technology Platform on Smart Systems Integration was established in 2013 and has been ever since an industry-driven European Technology Platform on Smart Systems Integration and integrated micro- and nanosystems including integrated software and hardware design methodologies. EPoSS is a member of the Key Digital Technologies Joint Undertaking.[16] The member companies and research institutions involve mainly **hardware and chip providers, system integrators and maintainers**, who work together on future hardware and software design of smart chips and hardware accelerators for intelligent embedded systems and smart edge devices. The EPoSS working groups and taskforces involve a wide range of application fields, such as transport, healthy living, and manufacturing, internet of things, energy, natural resources and security. The EPoSS taskforce "AI at the Edge" recognised edge computing as an emerging and strong alternative to traditional cloud computing.

Green Deal & Energy:

In the White Paper "AI at the Edge", (2021)[17], the experts emphasised the features such as increased **real-time performance (low-latency)**, **reliable low-bandwidth communication**, **enhanced power efficiency** and **improved data security and privacy** that will drive the innovation and the demand for CEI technologies. Vehicle intelligence, autonomous inland waterway ships, optimisation and management of distributed energy sources, buildings as networked cyber-physical energy systems, Industry 4.0 and predictive maintenance, robotics, personalised medicine, drones for precision farming and many other applications will operate on and require a fully functional CEI Continuum. Especially, the broader **adoption of lightweight and energy-efficient AI/ML algorithms** will contribute to an increasing demand for smart and energy-efficient hardware solutions such as **neuromorphic computing** chips.

[14] https://ecs-org.eu/ (the web site is under maintenance)
[15] https://www.smart-systems-integration.org/
[16] https://www.kdt-ju.europa.eu/
[17] https://www.smart-systems-integration.org/publication/eposs-ai-white-paper

2.1.7 **EU-Maths-In**, the European Service Network of Mathematics for Industry and Innovation

EU-Maths-In[18], the European Service Network of Mathematics for Industry and Innovation sees high potential in CEI technologies, especially for business-to-business applications in Artificial Intelligence and the upcoming advances in computational hardware from high performance to edge computing. **Digital twins** – the virtual representation of the whole life cycle of a product or process is the core of these applications according to the EU-Maths-In SRIA.[19]

In the manufacturing and industry 4.0 domain, digital twins allow for highly efficient optimisation, process control, lifecycle management, predictive maintenance, risk analysis, and many other aspects. Digital twins can now combine the best features of mathematical models that do not require much data with data-intensive approaches such as AI/ML. In doing so, digital twins incorporate the complete knowledge and information of a product/system gathered during its life cycle. The information coded in digital twins should be able to travel back and forth through the Cloud-Edge-IoT Continuum: 1) to enable real-time performance on the edge or 2) to solve complex multi-optimisation problems in the cloud. To achieve the best performance, novel paradigms for Modelling, Simulation and Optimisation in Data-rich Environment (MSODE) need to be developed that allow for building automated modularised networks of model hierarchies capable of handling multiphysics and multiscale systems. A good example for the use of mathematical models in CEI Continuum is autonomous transport: mathematical models for real-time analyses and interaction with real processes can be executed safely and robustly on the edge – further optimisation and reasoning that is more precise takes place in the cloud.

2.1.8 Key Digital Technologies Joint Undertaking

Since 2017, the three Industry Associations AENEAS (Association for European NanoElectronics ActivitieS), EPoSS (European Technology Platform on Smart Systems Integration) and INSIDE (INSIDE Industry Association) unite hardware, chips and device providers, system integrators and maintainers to elaborate on major challenges and priorities for research development and innovation in the area of Electronics Components and Systems (ECS). All three organisations have joined forces under the umbrella of the Key Digital Technologies Joint Undertaking initiative.[20] They contribute to the annual ECS Strategic Research and Innovation Agenda (ECS-SRIA) with research needs from an industry perspective. Currently, only EPOSS joined the TransContinuum Initiative and actively contributes with its expertise to the development of the use cases that cover the HPC-Cloud-Edge-IoT-Continuum.

AENEAS[21] stands for Association for European NanoElectronics ActivitieS. It is an industry association and was established in 2006. The member organisations and companies operate in the field of micro- and nanoelectronics enabled components and systems.

INSIDE[22] (INSIDE Industry Association) is the European Technology Platform) for research, design and innovation on Intelligent Digital Systems and their applications. It was founded in 2004 as Artemis-IA and renamed as INSIDE in July 2021.

[18] https://eu-maths-in.eu/
[19] https://eu-maths-in.eu/wp-content/uploads/2022/03/EU-MATHS-IN-Strategic-Research-Agenda-2020.pdf
[20] https://www.kdt-ju.europa.eu/
[21] https://aeneas-office.org/
[22] https://www.inside-association.eu/

ECS Strategic Research and Innovation Agenda (ECS-SRIA) - Key aspects

In addition to the chapters covering core issues regarding e.g. process technology, equipment, materials and manufacturing, embedded systems, components and systems integration, the ECS-SRIA includes one cross-sector chapter dedicated to edge computing and embedded artificial intelligence.[23]

Climate change and the European Green Deal will push the demanded features of semiconductor technologies, hardware architectures, algorithms and embedded software towards memory size reduction, time for data treatment and lower energy consumption. **Multimode energy harvesting** (e.g. solar/wind, regenerative braking, dampers/shock absorbers, thermoelectric, etc.) is a promising approach for electrical vehicles and other battery- or fuel cells-operated vehicles in addition to **energy efficiency design, real-time sensing of integrity, energy storage and other functions.**

Another important aspect mentioned in the ECS SRIA is a **strong competition** with American GAFAM (Google, Amazon, Facebook, Apple, Microsoft) and Asian BATX (Baidu, Alibaba, Tencent, and Xiaomi) companies that started developing their chips for Deep Learning and AI processing (e.g. Intel Compute Stick, Google's Edge TPU, Nvidia's Jetson Nano and Xavier) or announced that they will do so. The US and Chinese governments also started initiatives and funding programmes to maintain a prominent position on the market and enhance their autarky from international and European high-tech imports. The European companies have to search for new niches and opportunities to keep their position and market shares in the global data-driven value chains.

There is a strong trend towards **open-source collaboration between software and hardware vendors and developers.** It involves not only smart systems and components, but also more complex computing infrastructures. The Open Compute Project[24], launched by Facebook in 2009, aims to combine the benefits of both hardware and software communities to design scalable and flexible computing infrastructures for the Cloud-Edge-IoT Continuum. The Open Compute Project Foundation (OCP) was initiated in 2011 to create an open environment for hardware and software experts to collaborate.

The European industry has the opportunity to prevent technological dependence on non-European closed processing technologies by joining the Open Hardware initiatives (Open Compute Project, RISC-V, OpenCores, OpenCAPI, etc.). The open ecosystem approach relies on technological knowledge of multiple actors and prevents the emergence of oligopolies on the markets. **Open hardware and software communities and initiatives** will allow for business growth of smaller companies and start-ups that will rely on the open high quality, trustworthy, transparent and secure components and solutions.

2.2 European Edge Cloud Infrastructure Initiatives

Further important initiatives funded by the European Commission are the European Alliance for Industrial Data, Edge and Cloud[25] and Important Project of Common European Interest on Next Generation Cloud Infrastructure and Services[26] under German and French co-leadership.

2.2.1 European Alliance for Industrial Data, Edge and Cloud

The European Alliance for Industrial Data, Edge and Cloud is a recent initiative for development, deployment and the future adoption of CEI technologies. The role of the Alliance is to bring together relevant stakeholders from the private and public sector. The objectives target the strategic investment roadmaps to enable the next generation of highly secure, distributed, interoperable and resource-efficient computing technologies.

[23] https://www.smart-systems-integration.org/system/files/document/ECS-SRIA2022_final-lores_%28final%29.pdf

[24] https://www.opencompute.org

[25] https://digital-strategy.ec.europa.eu/en/policies/cloud-alliance

[26] https://www.bmwk.de/Redaktion/DE/Artikel/Industrie/ipcei-cis.html

Another important function of the Alliance is to find agreements between different public and private stakeholders on cloud governance, especially related to public procurement of cloud services.

2.2.2 Important Project of Common European Interest on Next Generation Cloud Infrastructure and Services

The European Commission initiated the IPCEI-CIS in 2020. It relates to the implementation of the EU Data Strategy[27] with the goal "to develop data processing infrastructures, data sharing tools, architectures and governance mechanisms for thriving data sharing and to federate energy-efficient and trustworthy cloud infrastructures and related services". The focal goal of IPCEI-CIS is to enable a federated and vendor-agnostic cloud ecosystem and increase the distribution and decentralisation of data processing. The planned infrastructure investments will increase the "demand pull" for CEI hardware, software components and tools, while preparing the market for novel service offerings in upcoming years.

GAIA-X

Gaia-X aims at creating a trustworthy environment for data sharing and service provision between digital platforms, companies and public organisations. It develops rules, governance frameworks and standards for cloud-agnostic solutions, data spaces and federation services. The European GAIA-X Hubs involve vertical domains such as agriculture, health, smart cities, education and skills, construction industry, smart building and smart living as well as the energy domain. The manufacturing domain belongs to the Platform Industry 4.0, which is a German technology platform with specific focus on manufacturing and the automotive industry. GAIA-X Federation Services encompass basic functions such as Identity and Trust, Federated Catalogue, Sovereign Data Exchange, Compliance, Portal and Integration. Of particular importance is the Federated Catalogue that manages services from various clouds, data and AI service providers using common service self-description standards. GAIA-X acts as a technological and legal framework that facilitates the integration and dissemination of CEI service offerings and infrastructures.[28]

2.2.3 Observed opportunities and challenges

The outlined industry associations and initiatives are actively forming the technological landscape for CEI technologies. The strategic research and innovation agendas convey the following messages regarding demand pull drivers, enablers and facilitators that will foster the uptake of CEI technologies:

Digital twins, immersive communication, holographic telepresence, and ubiquitous support for AI, augmented/virtual reality applications as well as a trustworthy and secure edge-clouding computing connectivity infrastructure for safe and secure personal mobile robotics will be major demand-pull drivers for CEI technologies in the next years.

The required features of CEI are real-time, low-latency performance on the edge, optimisation and complex problem solving and reasoning in the cloud. Consequently, seamless integration of application workflows, Digital Twins including physics-based simulations and AI/ML will be crucial.

Climate change and the current shortage of energy sources set a strong demand for energy and resource efficiency. To achieve ambitious plans of BDVA regarding energy savings by 10 % per year, there will be a demand for new efficient hardware for data management and processing. 6G IA poses the demand for AI-based optimisation for network management functions and more efficient radio technologies to return to the similar energy consumption as for 4G networks.

[27] https://digital-strategy.ec.europa.eu/en/policies/strategy-data
[28] https://gaia-x.eu

The semiconductor industry represented by KDT, strives for flexible and open hardware interfaces and architectures in combination with efficient and light weighted AI/ML algorithms for embedded software to meet these ambitious demands.

The outlined industrial associations report a huge variety of offered tools and frameworks for hardware/software development and co-design on the market. The integration costs for tools and frameworks coming from different communities and vendors are very high. On the other hand, Asian and American competitors already announced their own IoT and Edge Computing strategies. Such single vendor solutions require less integration efforts but inevitably lead to vendor lock-in for ICT providers and end users. An alternative path to avoid single vendor dependencies are open hardware and software communities and frameworks at the infrastructure level. An open and collaborative environment will allow for new business opportunities, enable growth for SMEs and start-ups, and prevent the formation of oligopolies on the market.

The European funding programmes such as the European Alliance for Industrial Data, Edge and Cloud and IPCEI CIS are fostering infrastructure investments. In doing so, the current governmental actions are enforcing a strong “technology push” for CEI infrastructures in Europe. The new updated computing und connectivity infrastructures will raise the “demand pull” for new service offerings and individual hardware and software solutions in the upcoming years.

Standardisation is an important vehicle for seamless cooperation among already established strong market players and smaller companies such as SMEs and start-ups. The focal point of the future standardisation activities should be linked to the emerging CEI infrastructures and services. GAIA-X is a promising initiative that pursues standardisation cloud-, edge- and AI services at infrastructure level to make interaction among stakeholders of data-driven value chains more transparent, reliable and efficient. The main GAIA-X objective is to provide an open, cloud-agnostic infrastructure for the European economy and prevent vendor lock-in effects.

3. Sector specific industry stakeholders

The experts for the value chain adopter groups will be recruited from the following industry associations, technology platforms, companies and lighthouse projects.

3.1 Health

3.1.1 Industry Associations and Stakeholders

Intelligent IT systems in the health sector hold the potential of simplifying and automating processes while making them also more reliable and safer, enhancing patient care, improving diagnostics and monitoring in different fields, supporting the decisions of doctors and thereby relieving the medical staff. The development of AI algorithms as well as edge, cloud and IoT technologies in the recent decades created new possibilities in many different domains. The possibility of analysing large amounts of data shows many benefits of deploying those approaches to deliver personalised treatments. On the other hand, the regulatory processes are strict and time-consuming. These need not to be seen as obstacles, but must be considered when it comes to the practical use of these CEI technologies in clinics, with the goal of improving diagnostics and therapies for patients. Many different stakeholders play an important role when it comes to bringing health-care technologies to the market. Those include companies focusing on software (algorithms to run on edge devices or as cloud services, e.g. AI algorithms), on hardware (producing edge devices) and on interconnection (ensuring the data transfer from or to edge devices or to the cloud). Regulatory bodies must ensure that developed systems (hardware, software, data transfer) are compliant to their guidelines, maintaining the focus on the benefits for the patients and the costs. Depending on the type of IT system, it may have to be implemented on site: in a clinic or a hospital and needs adaptation to the existing infrastructure and interfaces. This might be realised by an external company or in cooperation with the system developer and the hospital technicians. There are also actors who actually use the IT systems. That may be doctors or other (para-)medical staff, patients or even healthy people. Finally, yet importantly, insurance companies and public authorities strongly influence the choice of specific business models.

The following six different use cases illustrate the wide range of these technologies:

- **Remote health monitoring** (e.g. preventive lifestyle/medical screening, use of wearables or apps to monitor own health status, prediction of future potential pathologies)
- **Hospital asset tracking** (overview of condition and location of medical devices and other tools in the hospital setting to optimise logistics flows and increase safety, (predictive) maintenance of costly equipment, compliance to hygiene standards)
- **AI-enabled diagnosis and treatment systems** (early diagnosis of diseases, detection of abnormalities, prediction of course of disease, prevention and identification of risks, data analysis for best individual treatment, consideration of multimorbidity factors, seamless support for first responders and emergency services)
- **Telemetry and telemedicine** (patient monitoring and surveillance (at home or in hospital), especially monitoring of vital signs and compliance to medication, robotic-assisted rehabilitation)
- **Robots/AR-assisted surgery** (to reduce treatment errors, time to surgery and recovery time through minimally invasive surgery, computer-controlled/assisted or robotic mimicking of the surgeon' actions, advanced simulators for surgeon training, virtual assistants with natural language interface, image-guided surgery, AR/VR surgery, functionalised surgical tools, for instance with haptic feedback)
- **Regulatory compliance** (systems that are used for diagnostic purposes need to be approved by notified bodies; healthcare industry is known as heavily regulated)

Due to developments in recent years regarding increased computing power and the shift of computations to the cloud or to edge devices, changes in the health sector introducing new technologies are visible. The following major technological trends which create a demand pull for CEI technologies could be identified:

- **Connected and smart medical devices**: With the use of connected and smart devices, less invasive treatments and diagnoses that are more accurate become possible. Reliability and accuracy increases as devices can communicate with each other.
- **Decentralisation**: Patients can be monitored at home by using edge devices. More comprehensive and safe patient care is possible.
- **Use of artificial intelligence algorithms**: Big data can be analysed and used to improve the diagnosis of diseases and offer personalised treatments.
- **Digitalisation of processes and routines**: data can be collected more easily and can be used to further improve processes.
- **Increased adoption of cloud technologies:** The use of cloud technologies can simplify data exchange and collaboration across national borders. Furthermore, cost efficiency, availability and resilience increase.

Associations and Initiatives in the Health Sector

EPoSS[29] stands for "European Technology Platform on Smart Systems Integration" and is an industry-driven policy initiative. Its working group "Healthy Living" focuses on topics like disease prevention, healthy lifestyles, personal medical devices or remote monitoring of patients.[30] The key goals of the working group, which supports and enhances the use of CEI technologies, are the following:

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

[30] https://www.smart-systems-integration.org/organisation-management; https://www.smart-systems-integration.org/vision-mission

- improving performance
- simultaneously detecting multiple parameters (combine cellular and molecular diagnosis)
- increasing reliability
- fast, sensitive and specific analysis
- replace invasive technique (e.g., biopsies) with non-invasive tools (e.g., detection of skin diseases: image classification)
- support digitisation: search through evidences fast to find best treatment
- improving medical outcome (long term sensor-based treatment)
- increase usability[31]

For example, one of the main advantages of edge AI identified by the working group is that medical data can be processed on edge devices while maintaining privacy, as the data are processed locally and no cloud services are required. Furthermore, fast and real-time processing becomes possible.[32]

AIOTI[33] is a European alliance for IoT and edge computing innovation. The vision of its group "Health" is to enhance knowledge sharing in the medical domain and bring together initiatives with the goal to support healthy living. The use of AI and edge technologies is seen as a chance to cope with factors such as ageing population, chronic diseases, lack of health personnel, inefficiency of healthcare systems, healthcare inequities and sustainability. On the other hand, several risks and challenges are pointed out, including the lack of transparency and trust, algorithm errors, privacy and security, misuse of medical AI tools (due to a lack of skills and training), legal gaps in current regulations, limited data quality and a lack of clinical and technical integration and interoperability.

The Big Data Value Association (**BDVA**)[34] is an industry-driven international not-for-profit organisation. Within the BDVA there are several task forces and task force 7 "Application" is divided into several sub-groups, sub-group 3 being called "Healthcare". The group published a white paper with the results of a survey that covered the expectations of the health sector regarding the potential of AI.[35] The two top answers were "reduced cost in healthcare" and "improved quality of life and well-being". Another question was about the key areas and opportunities for AI. The top answers included "diagnostic support for physicians", "personalised medical care" and "medical image processing". On the other hand, "data security and anonymisation", "data availability" and "data quality and curation" were named as technical challenges.

The Innovative Health Initiative (**IHI**)[36] is a public-private partnership between the European Union and the European life science industries. The initiative's goal is the transfer of health research and innovation into benefits for patients and society. The IHI SRIA[37] highlights the importance of cooperation between the different actors across the whole value chain in order to efficiently use new and innovative technologies in the health sector. By 2030, the initiative aims to support at least 30 large-scale, cross-sectoral projects focusing on health innovations. Other goals are to fully use the potential of digitalisation in the healthcare sector and develop tools and mechanisms to enable better access, sharing and analysis of health-related data. To diagnose complex and multifactorial diseases as well as to discover interdependencies between diseases, a sufficient amount of high-quality data and digital analysis tools to analyse it are crucial.

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31 EPoSS Working Group "Healthy Living" (EPoSS ID Chapter Health)
32 EPoSS White Paper "AI at the Edge" https://www.smart-systems-integration.org/publication/eposs-ai-white-paper
33 https://aioti.eu/about-us/our-groups/health/
34 https://www.bdva.eu/sites/default/files/AI%20in%20Healthcare%20Whitepaper_November%202020_0.pdf
35 https://aioti.eu/about-us/our-groups/health/
36 https://www.ihi.europa.eu/about-ihi
37 https://www.ihi.europa.eu/sites/default/files/flmngr/IHI_Strategic_Research_and_Innovation_Agenda_3.pdf

The German Medical Technology Association (**BVMed**[38] - "Bundesverband Medizintechnologie") is an association, which represents around 250 companies in the medical technology sector, including the 20 largest medical device manufacturers worldwide. Core beliefs are that medical devices are indispensable for health and better life quality, and innovative medical technologies need to be made available as fast as possible to all patients who need them. In 2022, BVMed conducted an "Autumn Survey"[39] representing the current situation of German medtech companies: The companies see the highest potential for digital technologies in the areas of data analytics, smart and big data applications (39%), medical apps and digital health applications (26%) as well as cloud technologies and therapy monitoring (23% each). 39% of the companies already work with start-ups to develop digital solutions. Compared to the previous year, this share has increased by nine percentage points.

The French association **Snitem**[40] ("Syndicat national de l'industrie des technologies médicales") represents companies on all issues related to medical devices. Snitem is part of several national and European bodies (e.g. MedTech Europe) in order to represent its 560 member companies. There is a strong focus on ethics. Snitem's mission is, among other things, to represent the medical devices sector, to monitor the evolution of the sector and its environment, and to promote common approaches to foster medical technological progress, quality safety and development. Snitem publishes an information brochure on various topics, including "Digital in Healthcare". The September 2019[41] edition cites Natural Language Processing (NLP) as an important supporting tool for doctors. NLP enables translation, speech recognition, speech synthesis, automatic text analysis etc. For doctors, the advantage of using speech recognition is that they can summarise patient information quickly and naturally without having to type the information into a computer. The use of edge technologies facilitates the introduction of such solutions into the operating room.

On a different level, but also playing an important role in the further development of the healthcare sector in relation to CEI technologies, is the European Medicines Agency, responsible for evaluating and supervising medical products. The European Medicines Agency (**EMA**)[42] is a decentralised agency of the European Union. The goal is to ensure that available medicines are safe, effective and of high quality. Main topics are scientific evaluation, supervision and safety monitoring of medicines. The agency focuses on facilitating development and access to medicines, evaluating applications for marketing authorisation, monitoring safety of medicines across their lifecycle as well as providing information to healthcare professionals and patients[43]. In 2017, EMA developed a cloud strategy[44], which comprises the objective to migrate completely to the cloud by 2025. The following advantages of moving to cloud infrastructures were identified:

- facilitation of data exchange at European and global level, secure and regulated
- easy access to AI-powered data lake solutions and to state-of-the-art technologies -> many possibilities to analyse large amounts of data
- high level of availability and risk tolerance
- increased cost efficiency: high level of transparency regarding the services used and the generated expenses, no need to build and maintain large on-premise IT infrastructure

[38] https://www.bvmed.de/de/bvmed
[39] https://www.bvmed.de/de/bvmed/presse/medienseminare/medienseminar2022/ergebnisse-der-bvmed-herbstumfrage-2022
[40] https://www.snitem.fr/le-snitem/histoire-et-valeurs/ https://www.snitem.fr/le-snitem/missions-et-services/
[41] https://www.snitem.fr/wp-content/uploads/2020/12/Snitem-Numerique-en-sante-Web-1.pdf
[42] https://www.ema.europa.eu/en/about-us
[43] https://www.ema.europa.eu/en/about-us/what-we-do
[44] https://www.ema.europa.eu/en/documents/other/european-medicines-agency-cloud-strategy-accelerating-innovation-digitalisation-better-public-animal_.pdf

In addition to the benefits described, there are also some requirements to be considered when implementing a cloud infrastructure. These requirements include among others the need to comply with security and data protection requirements, regulations as well as enhancing the skills and competencies of the Agency's IT team through training programmes and recruitment strategies.

The company Archeon provides a good example of using digital technologies for enhancing medical care.[45] The goal is to use edge computing and AI technologies to assist first responders. Archeon developed a system that measures ventilation parameters and gives real-time feedback on the quality of manual ventilation given to the patient.

3.1.2 Value Chain/Network

In the healthcare industry, many different actors are interacting with each other, collaborating or competing in complex data-driven value chain networks. The outlined use cases and application areas highlight the value proposition of patient data and also data that result from the healthcare processes.

There is a huge amount of data collected by sensor in an operating room or at a hospital bed, sensors installed in the patient's home (telemetry and telemedicine, biochemical analysis in medical laboratories) or sensors integrated into healthy lifestyle wearables. Moreover, additional data can be generated by digitalisation (e.g. by letting patients fill out patient questionnaires online instead of handwritten on paper). The transformation of analogue (paper-based documents and forms) into digital data is the basis for subsequent data analysis. The quality of the data is essential as this affects the quality of the training results of AI/ML algorithms. Important actors in this step are manufacturers of sensors and wearables as well as companies who offer tools for the digitalisation and data capturing in the health sector.

There is a strong demand for efficient data pre-processing that involves data compression, anonymisation and pseudonymisation. Compressed and protected data saves bandwidth and energy when transferred to a centralised cloud. Edge computing or embedded intelligent devices allow for local processing and merging of data captured and generated by multiple sensors.

In the next step, ICT and connectivity providers offer services for data transition into cloud computing systems for further data processing or merging with additional sources. In hospitals exist a variety of legacy applications and systems incrementally developed for specific medical treatments and procedures. Often, the data needs to be transferred from one legacy system into another. Therefore, there is a strong demand for open interoperable interfaces and standards to facilitate this process.

Emerging data platforms collect and merge different data sources (e.g. from patients or even hospitals) into a single database for more precise data processing, analyses, and visualisation. Currently, interoperable data sharing formats, ontologies and especially standards for data quality are under development. Medical high quality data is crucial for obtaining reliable diagnosis results. Therefore, platform providers with high quality data offerings play a central part in the healthcare data economy. Furthermore, data spaces for data sharing among multiple platform providers can optimise the patient treatment processes in the healthcare system and allow for more precise diagnosis and successful treatment of seldom disease.

AI/ML applications and data-driven services enhance the performance of medical staff. They can also help people with prevention of disease and adopt a healthy lifestyle. Various smartphone apps are already on the market that are assisting and helping people to take care of their personal diet.

AI algorithms can analyse data and identify important insights, find abnormalities and help the medical staff to identify precise diagnoses and help to develop appropriate and successful treatment procedures. AI-based medical robotics surgery is another upcoming market trend. In addition, AI-based assistance and expert systems for first responders' situations are finding broader adoption by health carers. Care providers and

[45] https://www.archeon-medical.com/en/about/

assisting intelligent systems play an important role in the value chains and networks of the healthcare system that spans meanwhile all phases of our life.

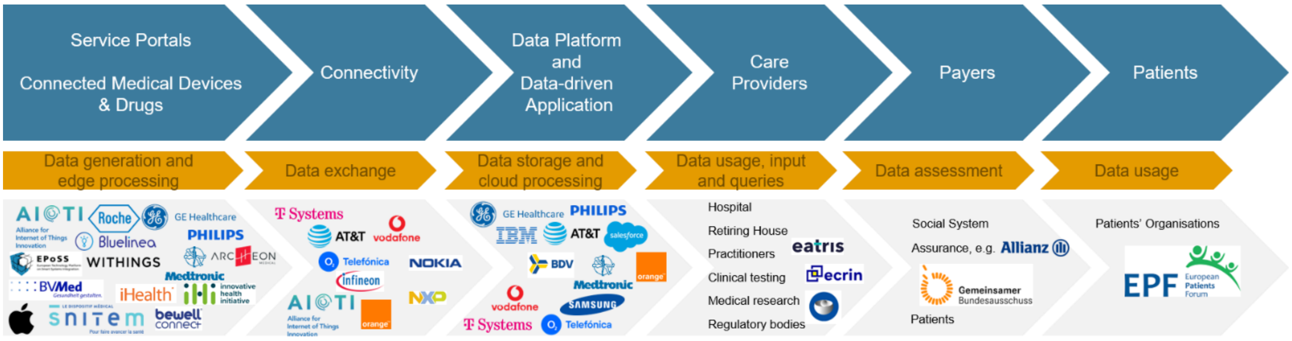

Figure 2: Overview of the value chain in the health sector

3.1.3 Application areas – opportunities and challenges

Observed Opportunities for CEI technologies in the health sector

Using CEI technologies in the health sector brings many advantages. The first step in this direction is the digitalisation and seamless connectivity of devices and IT systems that provide access to health data. An important "demand pull" driver are AI/ML applications that require availability and quality of data. Especially in the health sector, an aggregation and fusion of data sets coming from different sources opens novel opportunities to get new insights e.g. into disease processes and help to develop more personalised treatments. The emerging Edge AI algorithms operating on smart hardware devices hold further benefits. Smart medical devices with embedded intelligence enable more efficient treatments and are more comfortable for the patient. Furthermore, local processing of patient data on edge devices enhances privacy. This is especially important in the health sector as very sensible data is processed. In many settings, e.g. in the operating room or first aid, real time processing is crucial for saving patients' lives. Edge devices with real-time capabilities provide reliable and fast decision assistance for doctors in first aid situations. Another advantage of CEI technologies is the possibility to monitor patients at home. The number of visits to the doctor can be reduced, which is beneficial for older people who are less mobile. Medical staff receives more information about the health status and can provide better treatment.

Observed Challenges for CEI technologies in the health sector

Several challenges arise, when it comes to the use of CEI technologies in the health sector. The biggest challenge is the access to high quality data. Health data is sensible and undergoes strict regulations (e.g., consent of the patient, regulations on different levels like health facility, country, EU). Ethical aspects also play an important role, especially when monitoring patients at home. The goal is to guarantee broad access to advanced healthcare for a broader population. The security of wearables, edge devices and cloud services are crucial for transferring and using sensible health data of patients. The selection of a cloud provider or data centre has to be compliant with the data protection regulations of the country or organisation.

Another challenge is the heterogeneous infrastructure in clinics and hospitals that lacks open systems and interfaces. New AI-based assistance systems for diagnosis and treatments need to undergo a complex certification procedure in addition to the currently introduced AI act. As this is a time-consuming and costly process, it is a considerable risk for tech companies. ML algorithms are black boxes as they lack transparency, which means the resulting suggestions are difficult to explain. In such a sensible environment as the health sector, it is crucial to be able to explain reasons for a critical decision. Explainable AI is an emerging research area, which shows alternatives and solutions to this problem. Finally, value chains in the health sector are complex and competitive: the actors may take on different roles collaborating in one area and competing in another. This, and the high regulatory conditions, result in challenging market conditions especially for AI developers and medical device manufacturers.

3.2 Energy

3.2.1 Industry associations and industrial stakeholders

The energy sector is currently undergoing a major disruption. Especially the global goal of drastically reducing CO2 emissions poses new challenges for the energy sector and disrupts the entire value chain. The increased integration of renewable energy sources is changing the energy paradigm due to significant diffusion and variety of the energy produced. Digitalisation can facilitate a larger share of distributed energy resources, turning consumers into "prosumers"[46] and further decentralising the energy sector. This energy transition requires deregulation of the energy industry and making digitalisation key to resilience. New business models will offer innovative products and services to their customers. CEI opens up new opportunities such as energy optimisation, configuration and management of micro-grids or diffusion of charging systems for electric vehicles. New markets for energy demand management and peer-to-peer energy sales as well as new tools such as blockchain, facilitate local energy trading systems.

Leading utility providers are therefore modernising their processes, services and product offers to keep their market position in a rapidly changing ecosystem for the future management of complex, heterogeneous and large-scale energy generation, transmission, distribution and storage systems[47].

3.2.2 Technological trends and enabling CEI technologies in the energy sector

The biggest trend in the energy sector is its decarbonisation and the increasing decentralisation of the energy system. The energy system is transforming from a unidirectional system to an integrated energy system with multiple entry points and storages directly connecting different stakeholders, using the electricity system as its "backbone"[48] and increasing flexibility. Furthermore, new market players, who provide new digital communication infrastructures and services, supplement the traditional energy ecosystem.

The European Commission has identified five priority areas for the digitalisation of the energy sector.[49]

1. **Developing a European data-sharing infrastructure** to create a competitive market for energy services that value demand-side flexibility and support planning and monitoring of energy infrastructure.
2. **Empowering citizens** by providing them with tools for participation in the energy markets, tailored data-driven services and implementing reskilling and upskilling pathways for citizens.
3. **Enhancing the uptake of digital technologies** in the energy sector by mobilising research, fostering innovation and making use of complementary instruments to support the scaling up of piloted solutions.
4. **Enhancing the cybersecurity of the energy sector** facing real-time requirements, cascading effects and the mix of legacy technologies with smart/state-of-the-art technology.

[46] Prosumer are stakeholders who can produce energy, e.g. using solar panels and consume energy, when solar energy is not available.
[47]https://www.reply.com/en/industries/energy-and-utilities/edge-computing-and-iot-to-achieve-energy-optimisation-and-launch-new-services
[48] https://smart-networks-energy-transition.ec.europa.eu/sites/default/files/documents/vision/VISION2050-DIGITALupdated.pdf
[49]https://ec.europa.eu/info/news/action-plan-digitalisation-energy-sector-roadmap-launched-2021-jul-27_en

5. **Supporting** the development and uptake of **climate-neutral solutions for the Information and Communication Technologies** sector as a complement to the European Digital Strategy focussing on measures that promote cooperation between the energy sector and the digital sector.

Promising technologies, already under use and expansion, include **artificial intelligence** and **advanced communication techniques for cyber-security**, increasing resilient energy system control, and optimal control of distributed generation and dispersed energy-storage devices as well as robust high-performance control devices.[50]

Furthermore, **analytics for data mining, machine learning, and digital twins**, amongst other software tools, are used to generate information to support network operators and market stakeholders to improve the efficiency of the energy markets. In the process, connected devices (Internet of Things, IoT) such as smart meters and sensors generate and collect information in the network for real-time monitoring and control, enabling data exchange between human users, devices and machines.

Multi-sided IoT platforms for energy system orchestration, advanced grid control room architecture with cross-sector approaches for energy system monitoring and control, IT systems for Transmission System Operators/Distribution System Operators (TSO/DSO) control to support real-time balancing and IT systems for cross-border trading enable many new use cases in the energy sector, such as:

- smart meters
- remote network management/maintenance (e.g. fault detection)
- remote workforce/field service technicians' monitoring/automation
- sensor-based asset diagnostics and maintenance
- connected drilling and extraction operations
- smart building (e.g. smart lighting/HVAC[51]/elevator for energy saving)
- regulatory compliance
- video security and surveillance
- process automation and optimisation

Further applications are smart asset management, virtual metering channels, Distributed Energy Resource (DER) management, energy supply contracts, real-time energy data exchange, forecasting methods, digital twins of the grid state, real-time automated demand response as well as integration of smart charging technologies.

3.2.3 EU associations

The following leading European (technology) associations are important drivers for business, policy, standardisation, research and innovation developments in their respective fields:

AIOTI

The Alliance for IoT and Edge Computing Innovation (AIOTI) aims to lead, promote, bridge and collaborate in IoT and Edge Computing and other converging technologies research and innovation, standardisation and ecosystem building, providing IoT and Edge Computing deployment for European businesses, creating benefits for European society. AIOTI comprises different horizontal and vertical groups, of which one is focussing on energy. The vision of the energy expert group is to enable the development and deployment of advanced IoT technologies, applications and services to address the energy transition towards a green, integrated energy system. Specific topics relate to standards and interoperability for smart grid deployment

[50] AIOTI, AIOTI Vision: IoT and Edge Computing impact on Green Deal. 2021. (https://aioti.eu/aioti-vision-iot-and-edge-computing-impact-on-green-deal/)
[51] Heating, Ventilation and Air Conditioning

and the development of open, flexible, highly participative, multi-sided energy markets, supported by e.g. distributed ledge technology/blockchain to manage the increasing variability of renewable energy sources and the overall increase in electrification, which leads to the need for increased flexibility on supply and demand side. Furthermore, CEI technologies can drive the empowerment of customers and the shift towards prosumers (consumers who also produce energy) forward.

ETIP_SNET

The European Technology & Innovation Platforms Smart Networks for Energy Transition (ETIP_SNET)[52], initiated by the European Commission, drives research, development and innovation to support Europe's energy transition through working groups (WG). ETIP_SNET visions a low-carbon, secure, reliable, resilient, accessible, cost-efficient, and market-based pan-European integrated energy system, powered by renewable energy sources and embodying full digitalisation and flexible electricity interconnections. The WGs are focussing on the following areas of interest:

- Reliable, economic and efficient energy system
- Storage technologies and system flexibilities
- Flexible generation
- Digitalisation of the electricity system and costumer participation
- Innovation implementation in the business environment

Within these WGs, specific CEI research tasks relate to market design for virtual power plants, energy management platforms (for TSOs & DSOs), such as:

- ICT infrastructure for demand control and aggregation as well as monitoring of distributed generation,
- Smart appliances, use of IoT technologies for monitoring and control as well as the development of virtual interfaces to all devices,
- Digital twins for energy systems, methods and tools for cyber security protection of grid infrastructures and functions, communication infrastructures for smart metering data,
- Real-time observability of renewable energy sources, flexibility provided by smart Electric Vehicle (EV) charging and Vehicle to Grid (V2G).

E.DSO

The association of European Distribution System Operators (E.DSO)[53] aims for customers' empowerment and the increase in the use of clean energy sources through electrification, the development of smart and digital grid technologies in real-life situations, new market designs and regulation.

One of E.DSO's main objectives is to ensure the reliability and security of Europe's electricity supply for consumers, while enabling them to take a more active part in our energy system. E.DSO focuses on guiding EU research, demonstration and innovation, as well as policy and regulation in Member States to support smart grids development for a sustainable energy system. Specific CEI topics of interest are:

- distributed Energy Resources (DER) and grid edge as game changers of the grid management paradigm
- smart meters as the reference point for the metering data
- devices (also edge devices and cyber-physical systems) connecting to the network and cybersecurity requirements

smartEn

[52] https://smart-networks-energy-transition.ec.europa.eu

[53] https://www.edsoforsmartgrids.eu/

SmartEn[54] is the European business association integrating consumer-driven solutions to the clean energy transition by:

- promoting system efficiency through the advanced management and integration of electricity demand and supply in homes and buildings, transportation, businesses and decentralised energy projects
- empowering energy prosumers by enabling them to participate in the energy market through flexible demand, storage, self-generation and the participation in community projects, and giving them control of their energy data
- encouraging innovation and diversity by enabling new market players and energy service offers that provide attractive choices for consumers and allow for healthy competition
- driving the decarbonisation of the energy sector through the cost-effective integration of renewable sources and smart electrification of heating, cooling and transport

The objectives will be supported by building a European data sharing infrastructure capable of supporting and assessing the contribution of demand-side flexibility towards a cost-effective, secure and future-proof transformation of the energy system.

EASE

The European Association for Storage of Energy (EASE)[55] supports the deployment of energy storage for a cost-effective transition towards a resilient, climate-neutral, and secure energy system. EASE aims at building a bridge between EU policy makers and the whole energy storage value chain to enable a carbon-neutral Europe through the increasing integration of energy storage into energy systems as a counterbalance to renewable energy resources, supported by building a European data sharing infrastructure that can support and assess the contribution of demand-side flexibility.

IRENA

The International Renewable Energy Agency (IRENA)[56] is an intergovernmental organisation that supports the transition to a sustainable energy future. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. IRENA encourages governments to adopt enabling policies for renewable energy investments, provides practical tools and policy advice to accelerate renewable energy deployment, and facilitates knowledge sharing and technology transfer to provide clean, sustainable energy.

3.2.4 Lighthouse projects

An increasing number of European research projects are addressing different emerging trends towards a climate-friendly, integrated, digitalised energy system. A step in this direction has been taken with the creation of the Energy Data Space, consisting of six EU data space projects, namely **OMEGA-X**[57], **SYNERGIES**[58], **ENERSHARE**[59], **OPEN DEI**[60] and **DATA CELLAR**[61], fostering interoperability within energy data spaces. The projects address the need for data sharing spaces, the development of data-driven business ecosystems,

[54] https://smarten.eu/
[55] https://ease-storage.eu/
[56] https://www.irena.org/
[57] https://omega-x.eu
[58] https://www.synergyh2020.eu
[59] https://www.inesctec.pt/pt/projetos/enershare#intro
[60] https://www.opendei.eu
[61] https://datacellarproject.eu

digital platforms, pilots and standards to enable the digital transformation of the energy system. This projects all promote public data spaces that will also support the creation, development and management of local energy communities in the EU.

Further European R&I projects such as **int:net**[62], **BD4NRG**[63] (Big Data for Next Generation Energy), **EUniversal**[64] and **FLEXGRID**[65] foster smart digital grid infrastructure as well as data-driven reference architecture for **AI-based edge-oriented scalable big data management and analytics** in smart energy grids in combination with renewable energy resources (int:net). Large-scale pilots focus on predictive analytics to forecast and increase the efficiency and reliability of power grid operations, optimise the management of distributed energy resources and increase the efficiency and comfort of buildings, and reduce the risk of energy efficiency investments (**BD4NRG**). **EUniversal** fosters a unique approach towards interoperability across Europe, enabled through the development of the concept of the Universal Market Enabling Interface. **FLEXGRID** develops an automated trading platform, which provides the composition and the operation of energy markets leading to different pilots for automated planning of DSO/TSO energy services, assets and policies as well as services for renewable energy source producers.

3.2.5 Value Chain/Network

The traditional linear value chain of the energy sector is changing towards an integrated ecosystem in which e.g., consumers turn into prosumers and feed energy into the system.

Therefore, energy will flow in several directions between users and producers. Traditional value chain segments are highly important; however, new players will enter the energy ecosystem. Especially, horizontal aspects such as IT as well as communication will rapidly gain in relevance.

Manufacturing for example parts of power plants, devices to produce renewable energy (wind turbines, solar cells) and parts of the grid system is the first step in the energy ecosystem. These value chain actors are specialised only in manufacturing. Specific use cases would be connected industrial equipment, connected supply value chains, cloud-connected workers, remotely controlled operations, smart predictive maintenance, monitoring, control and process automation as well as optimisation.

Energy generation and storage comprises different stakeholders that generate electricity, such as large (national) electricity providers, centralised renewable energy providers as well as prosumers (private or business) that store and/or refeed energy into the system. Strictly speaking, data centres, electric vehicles and smart homes can also be considered as increasingly important stakeholders. New relevant use cases include energy system monitoring and control, smart asset management, forecasting methods, connected drilling and extraction operations, process automation and optimisation, proof of origin of energy production and the virtual power plant.

Grid and transport mainly includes distribution system operators (DSO) and transmission system operators (TSO). With the continuous transformation towards a smart and integrated energy system, new players such as IT companies integrating software to support real-time balancing as well as configuration and management of micro-grids are playing an increasingly important role. Further applications for CEI technologies include management of distributed energy resources, digital twins of grid state, real-time energy data exchange, real-time automated demand response as well as smart grids, including control and optimisation of power flow, smart metering and distribution automation (energy flexibility).

[62] https://intnet-project.eu
[63] https://www.bd4nrg.eu
[64] https://euniversal.eu
[65] https://flexgrid-project.eu

Market involves the trading of electricity, including demand management, billing and contracts. Electricity supplier are the main players in this segment, with an increasing number of specialised IT companies joining the market. New CEI applications include the management of energy demand and the sale of peer-to-peer energy, smart asset management, smart billing as well energy supply contracts and local energy trading systems.

Energy use/consumption includes all private, public or business-related end users. It includes applications such as EV charging, smart homes/buildings (smart lighting etc.), smart metering supported by real-time energy data exchange and energy as well as demand response management. New ecosystem entrants support the implementation of flexibility services and cross-sectoral use cases such as smart cities.

The **IT** segment spans over the entire energy network promoting the transformation into a clean and integrated energy system. On the one hand, new players specialised in energy, such as infrastructure providers as well as hardware, chips and devices providers, system integrators and maintainers, edge and multi-cloud platforms, connectivity, service and application providers as well as software developer and blockchain companies are entering the energy ecosystem. On the other hand, well-known international technology providers such as AWS Energy, Google or Microsoft, IBM Flex Utilities Platform and SAP play a significant role, especially focussing on (energy) analytics, consumer engagement and innovation, empowering demand-side flexibility.

The boundaries between the different value chain segments soften within a rapidly changing energy sector towards an integrated energy system. Selected use cases, including relevant European actors are described below.

Smart asset management

Real-time data provided by sensors as well as analytic tools concerning assets health, supply and demand analysis helps to improve asset performance. Hereby, data-driven and business analytics tools and software are used to monitor conditions, costs, and performance of assets, as well as to define scoring methods and the areas of critical priority. Thus, they enhance the reliability, capacity, and availability of the assets, detect outage or potential failure and therefore minimise costs. Commercial examples to support smart asset management are the SAP Asset Intelligence Network and the Bosch IoT Suite with additional services related to connected home & building and connected energy as well as MindSphere by Siemens, Sense Reply.

Distributed energy resources management/Virtual power plant

Distributed energy resource (DER) management refers to the management and organisation of power grids based mainly on distributed energy resources, such as photovoltaic solar panels, behind-the-meter batteries, or a fleet of electric vehicles. The system behind this can also be referred to as Virtual Power Plant. They allow for better coordination so that all end users receive the most reliable power at the best possible price. Distributed energy resource management systems (DERMS) are also critical for integrating intermittent and unpredictable renewable energy resources like solar power into the grid and managing energy demand.

DERMS are used to simultaneously communicate with, control and coordinate DER devices in different locations to exchange energy data in real-time. When excess energy is fed into the grid because abundant solar energy is produced during the day, a DERMS can control batteries in the grid to charge them with the excess energy so that it is not wasted. If demand energy cannot be met, DERMS can control e.g. batteries to inject energy into the grid and control smart thermostats to lower the temperature in buildings, so the demand for energy is reduced. In this way, renewable energy resources can reliably be fed into the energy grid, providing flexibility solutions while reacting to energy demand in real-time. This can be implemented by line sensing, sub-station automation, feed-in and line equipment control, and optimisation. Moreover, not only stationary batteries, but also vehicle2grid solutions or independent energy communities can support the balancing of fluctuating energy demand and supply. Additionally, integrated smart forecasting methods can further increase the efficiency of the energy grid. Energy companies building increased competences in this field are: BayWa r. e., entelios, enelX, cyberGrid, Voltalis, Endesa, Enercoutim, Energy Pool, Fornius, gridX, iberdrola, e-EM Srl, next Kraftwerke, Piclo, Siemens, Sonnen Group.

Open energy marketplace

An open energy marketplace aims to integrate a digital layer with a physical layer and connect all the different actors (users, producers, DSO, TSO) of an integrated energy system. However, specific stakeholders address energy demand and response management, the sale of peer-to-peer energy, smart real-time billing for consumers, as well as energy supply contracts and local energy trading systems. Here, consumers and producers can feed in or extract energy depending in the real-time prices of the available energy. Furthermore, individual energy communities (Hive Power, i.LECO) are also supported. Active companies are BeChained, Energinet, Grid Singularity, Gridio, LITION ENERGY, Net2Grid, Nodes, Regalgrid, WattsDat, Tiko Energy.

Smart homes/buildings

Smart home/building solutions enhance living experience and enable both energy and cost savings. Technologies creating a connected home allow for e.g. temperature monitoring, consumption tracking, and home system setting, such as lighting and heating. Smart lighting systems for example provide energy-efficient outcomes using sensors and software. Lights/ballasts are connected to networks and are remotely controlled/monitored by a building management system. By integrating/analysing the data, the lights can be adjusted accordingly. These applications can also be integrated and connected to other systems (e.g., energy marketplaces, utility smart meters and analysis systems as well as integration of smart EV charging). This allows for more efficient energy use and cost reduction for consumers from the public sector. Commercial solutions already available on the market are e.g. Bosch IoT Suite, Cuculus GmbH, Elli, Emotion Srl, KnaufEnergy, Net2Grid, Schneider Electric, Siemens, Johnson Controls, Trane Technologies, Sonnen, Octopus Energy, Greenflux.

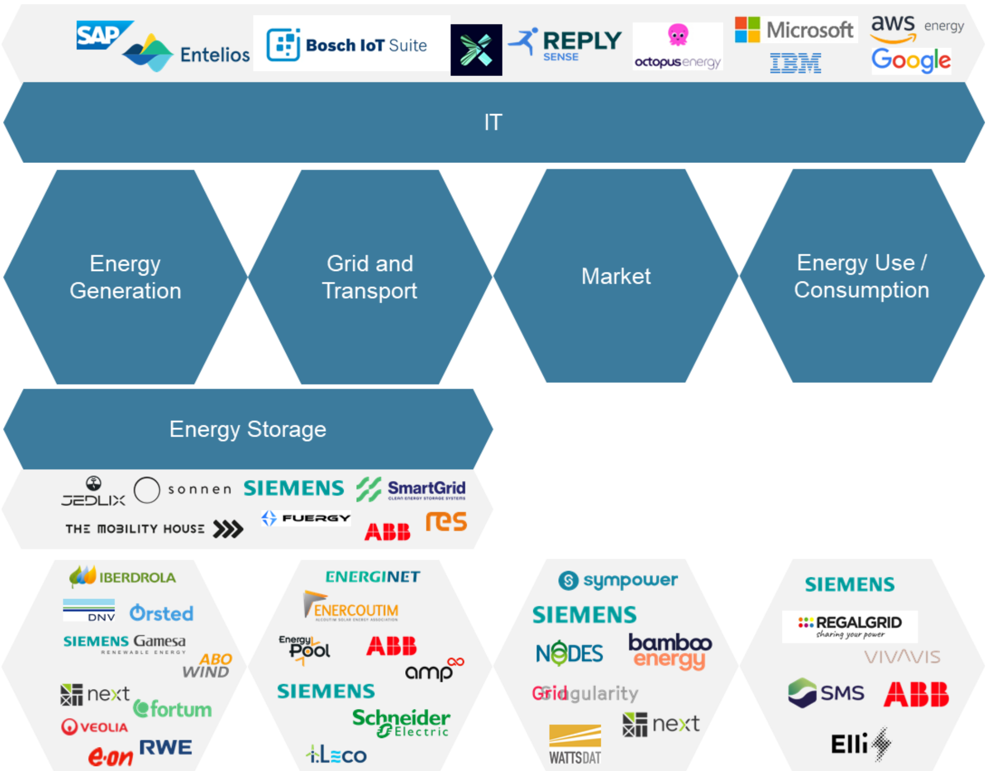

Figure 3: Overview of the value chain in the energy sector

3.2.6 Application areas – opportunities and challenges

The transformation of the energy sector has already started and will continue rapidly, driven by the goal of an environment-friendly, integrated energy system, which is both transparent and customer-oriented.

Observed opportunities for CEI technologies in the energy sector

Clear opportunities for CEI technologies are real-time data analysis to meet the exponential growth in the complexity of network operation, energy demands and the increasing integration of distributed energy resources, increasing efficiency and costs as well as turning consumers into prosumers. New tools may facilitate local energy trading systems and drive intelligent local energy communities forward. Real-time dynamic regulation of power supply to the different lines on which now hang new elements such as electrical chargers or batteries will support energy balance and remove boundaries between energy sectors, increasing flexibility and enabling integration across entire systems. Furthermore, digitalisation can enable the active participation of consumers from all demand sectors in energy system operations. However, to exploit the full potential of CEI technologies, fundamental changes to policy and regulation will be required to ensure that the benefits of the digital transformation of electricity are fully realised and the risks minimised.

Observed challenges for CEI technologies in the energy sector

The newly forming energy ecosystem also brings challenges. Data ownership, privacy considerations and cyber security are only a few to mention. Furthermore, new user-centric business models and economic disruption as well as standardisation need to be further developed in this rapidly changing ecosystem.

3.3 Manufacturing

In order to illustrate the range of CEI applications in the manufacturing sector, we will focus on specific branches: **automotive**, **machinery** and **electrical industry** (including chemical industry as suppliers). These sectors were chosen, as they cover major focal points of the European industrial landscape. Due to their size and extensive product range including discrete and continuous manufacturing, they are well suited to demonstrate the diversity of CEI applications for this sector. Examples and use cases from the wide field of manufacturing **consumer products** will supplement this.

Major technological trends

Currently, Industry 4.0 is leading to the far-reaching interlinking of production and the produced goods. The Industry 4.0 applications strive for the realisation and increasing automation of highly flexible production processes. In addition, the processed production data is employed for assistance systems for the workforce in terms of (digital) skills and support of human-machine-interaction. The digital transformation in manufacturing covers not only the shop floor, but also cross-cutting functions such as procurement and service. The overarching goal is to achieve customer-specific products, while producing them similarly to mass production in terms of efficiency, costs including sustainability and competitive pricing. Indeed, a higher sustainability is increasingly moving into the focus of attention, influenced by the urgency of climate change and customer demands. Another trend goes towards data sharing along the value chain for a better coordination of material flows and customer requirements. In combination with this, the concept of product passports is on the rise – a continuous, digital monitoring of the product life cycle, e.g. to measure the CO2 footprint and improved processes.

CEI technologies play a key role in many technological concepts and use cases for these trends in manufacturing. Therefore, the demand pull for CEI applications is clearly evident in manufacturing. Cloud and edge computing are major enabler technologies for this visionary objective and for making the IT infrastructure more flexible and decentralised. Additionally, there is a need for ad-hoc data analysis including a feedback-loop with the automated production processes. Decisive to achieving the Industry 4.0 vision is self-learning and self-organisation of production systems. This requires each system to be able to collect data, communicate with other systems via the Internet of Things and process incoming data, ideally using data analytics, management and edge AI technologies.

There are various application areas in the outlined context, which create demand pull for CEI technologies, such as:

- **Intelligent process control:** For inline quality measurement, edge sensors are used to collect, filter and partly compute data of the process in near real-time and at the point of measurement. In this way, the production processes can adapt automatically and quickly to improve quality. Another more complex application is the orchestration of production systems based on varying product features. The networking and automatic and intelligent coordination of production systems (including robots, AGVs) with each other can be based on multi-agent software systems using cloud or fog architectures.
- **Digital twin applications:** Technologies for the digital representation of physical objects, e.g. production systems, are used to capture its current condition digitally and collect the data. On this basis, they deliver insights – run simulations, identify performance issues, reduce energy consumption and optimise the overall equipment efficiency. One specific application is *predictive maintenance*: By analysing the collected condition data in the context of the system's properties and components, it predicts failures of the system. Based on this, the maintenance plan is optimised to reach a higher performance of the production system as well as lower maintenance costs and increased sustainability.
- **Mobile assistance systems:** The management of production and of an increasing amount of information is a challenge. Assistance systems on mobile devices support workers in this task and allow for flexible support as well as for reducing human factor failures. They provide the processed information as decision support, e.g. as a dashboard for the operator of the machine. They benefit from the edge data analysis on premise and availability of additional data via cloud. Many use cases apply and sometimes even continuously enhance *AI solutions* in the cloud or fog, in order to gain more insights for the decision support.

3.3.1 Industry Associations and stakeholders

Overview on relevant associations

As indicated in the introduction, manufacturing has a heterogeneous product portfolio and value chains. This is reflected in the variety of industry associations on the national and European level.

On the national level, there are overarching industry associations such as **France Industry**[66] and the German **BDI** (Bundesverband der Deutschen Industrie.[67]) However, the focal points for collaboration lay on industry-specific associations, especially for nationally important industries such as the Italian **SMI** (Sistema Moda Italia[68]) for the textile and clothing industry, the German Engineering Federation **VDMA**[69] and the Scandinavian Automotive Supplier Association **FKG**.[70] For collaboration, an important initiative is the **Plattform Industrie 4.0**[71], a nationally funded German platform. The open think tank works on the technical foundations for Industry 4.0, such as the standard for the asset administration shell, a standardisation core for digital twin technology. The Plattform Industrie 4.0 initiative addresses the whole ecosystem of companies, trade unions, associations, science and politics. It is widely recognised in this regard in Europe.

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[66] https://www.franceindustrie.org/
[67] https://bdi.eu/
[68] https://www.sistemamodaitalia.com/en/
[69] https://www.vdma.org/
[70] https://fkg.se/?lang=en
[71] https://www.plattform-i40.de/

Examples of industry-specific organisations on the European level are the **ACEA** "European Automobile Manufacturers Association"[72], the **CEPI** "Confederation of European Paper Industries"[73], the **EFPIA** "European Federation of Pharmaceutical Industries and Associations"[74] and the **CEFIC** "European Chemical Industry Council"[75]. There are also cross-sector alliances at the European level: The **ERT** "European Round Table for Industry"[76] has members from 55 major industrial companies such as L'Oréal from France, Telefónica from Spain, KONE from Finland, Umicore from Belgium and BASF SE from Germany. They strive for European co-operation between industry, policymakers and further stakeholders. Another one is **Industrie4Europe**[77], an overarching coalition of 149 organisations from all over Europe, supporting and bundling their campaigns on the European level. Both organisations publish joint papers and declarations to influence the strategic decisions for the EU's industrial and manufacturing sector. On the other hand, there is **DIGITALEUROPE**[78], a trade association representing digitally transforming industries in Europe, which also includes the CEI stakeholders of the manufacturing sector. The main objective of DIGITALEUROPE is to develop KPIs that will guide and accelerate the digital transformation in Europe's industry. DIGITALEUROPE is also active in research and innovation projects e.g. on the digital product passport.

Public-Private Partnerships and Digital Innovation Hubs (DIHs) on European Level

In the following, we will introduce organisations that establish a dialogue and interconnect public authorities and economic actors. Public-private partnerships are long-term cooperations, regulated by contracts between public authorities and commercial companies. The "**European Partnership Made in Europe**"[79] is of high relevance for the manufacturing sector. The platform strives for sustainable, competitive and resilient value chains and circular economy by aligning national technology initiatives and supporting the transfer of research results to the industry. With specific sectors in mind, the PPPs "**Processes4Planet**" and the "**European Partnership for Clean Steel**" also aim at sustainable future development for the process industry, especially for steel production. Another important PPP is the **"European Partnership on Artificial Intelligence, Data & Robotics"**. It is oriented towards supporting research and deployment of the addressed technologies in the economy, to boost competitiveness as well as social and environmental improvements. The underlying vision for 2030: "European sovereignty in the development and deployment of trustworthy, safe and robust AI, Data and Robotics, compatible with EU values and regulations"[80], is based on their Strategic Research, Innovation and Deployment Agenda.

Furthermore, there is a tight **Network of European Digital Innovation Hubs**[81] all over Europe to facilitate the digital transformation, especially of SMEs. Many of them have specific focal points in manufacturing, e.g. the AI & Robotics Estonia (AIRE) in Tallinn, Estonia. Most DIHs have a more general Industry 4.0 orientation, such as the Hub4industry in Krakow, Poland or the MANUHAB in Patras, Greece. The range of services offered by

[72] https://www.acea.auto/
[73] https://www.cepi.org/
[74] https://www.efpia.eu/
[75] https://cefic.org/
[76] https://ert.eu/
[77] https://www.industry4europe.eu/
[78] https://www.digitaleurope.org/
[79] https://ec.europa.eu/info/sites/default/files/research_and_innovation/funding/documents/ec_rtd_he-partnership-made-in-europe.pdf
[80] https://ai-data-robotics-partnership.eu/
[81] https://digital-strategy.ec.europa.eu/en/activities/edihs

the Greek DIH includes AI technologies, robotics, additive manufacturing, mixed reality and digital skills – a typical example of a DIH's broad spectrum of topics for manufacturing companies.

Lighthouse Projects

The World Economic Forum (WEF) hosts the **Global Lighthouse Network** of lighthouse factories for Industry 4.0, which are at the forefront of digital transformation.[82] Manufacturing companies have to undergo a selection procedure in order to be included in this network. The goal is to showcase and learn from best practices for innovative technologies, new business models and transformative partnerships for advanced manufacturing that characterise this Global Lighthouse Network of factories worldwide. Even though most of these factories are based in America and Asia, examples for Europe are Danone in Opole, Poland and Henkel in Düsseldorf, Germany. Henkel produces laundry and home care, cosmetic products and adhesive technologies for consumers as well as the industry. To enhance efficiency in the production of this extensive product portfolio, the company is in need of interconnecting more than 30 production and 10 distribution sites in real time as well as continuously improving their production efficiency. Therefore, Henkel employs its own cloud-based platform for internal interconnectivity, data exchange and process optimisation. This resulted into major improvements of overall equipment efficiency, higher forecast accuracy and higher sustainability due to energy savings and reduced logistic costs.

3.3.2 Value Chains and Networks

In this section, we outline the high-level value chain and promising CEI application areas. We introduce stakeholders and actor groups and describe how they interact with each other in the data-driven value chains. The section concludes with the major opportunities and challenges for CEI technologies in the manufacturing sector.

Sector 1 – automotive industry

Automobile production has a major market share in the European manufacturing sector. Automotive OEMs and their suppliers are on the forefront of digital transformation. The production of automobiles is highly automated to reach the needed high quality standards e.g. the use of robots for manipulating components in production and Automated Guided Vehicles (AGVs) for efficient intralogistics. The high-tech product as well as the production systems provide big data for life-cycle-analysis and optimisation. Characteristic of the ecosystem in the automotive industry is the strong market position of the OEMs, which they use to orchestrate their value chains and realise concepts such as just-in-time logistics. The main CEI solutions for automotive production are modular systems and sensors, especially for traceability solutions, digital twins for virtual reality (VR) and simulations, connectivity between technical systems such as cobots, cloud and edge computing, IoT platforms for data exchange along the value chain and for (big data) analytics.

Exemplary use case: Renault

The WEF lighthouse Factory of the Renault Group in Cléon, France is a good example for CEI demand and adoption in the automotive industry. Production facilities for automotives are constantly facing the challenge of adapting the factory infrastructure that has been in place for over 60 years at the Cléon site.[83] The technical development of the product towards e-mobility, car sharing and autonomous driving determines the requirements on the production structures. The rollout of the digital transformation and the accompanying digital-driven organisational change affects the entire manufacturing network of 40 factories and 13 logistics sites in 16 countries. A major concept is the overall traceability of parts and parcels along the production steps in real time, the Full Track and Trace project. The data is collected to improve quality of products and to minimise stocks in logistics, based on technologies such as RFID chips and the LoRa protocol (short for Long Range, used for international digital communication). Renault is also leveraging partnerships with start-

[82] World Economic Forum (2019). Global Lighthouse Network: Insights from the Forefront of the Fourth Industrial Revolution, In collaboration with McKinsey & Company. Whitepaper.

[83] https://www.renaultgroup.com/en/innovation-2/industry-4-0-production-plants-shaped-by-the-future/

ups and universities for digital solutions. They achieved through know-how transfer a 45% increase in productivity.[84] Solutions like cobots allow robots to work alongside with humans and to realise task sharing in production steps based on real-time connectivity. The solutions are successfully integrated into the production flow.[83] A central part of Renault Cléon's digital strategy is the collaboration with Google Cloud. Assistance systems use the huge computing capacities for training train operators for production and maintenance with VR, for simulations and for testing optimisations of the production flow. The Cléon plant established a collaboration with start-ups to test novel approaches for training sessions and simulations.

Exemplary use case: Catena-X

The manufacturing industry is a primary contributor to the common European project GAIA-X.[85] Major European automotive companies participate in the GAIA-X lighthouse project Catena-X that aims at interconnecting the data ecosystem and reaching seamless, continuous data streams along the entire product life cycle making the value chains more resilient. Due to the increasing complexity of product and production processes, which is also reflected in the supply chains, there is a strong need for a platform to interconnect OEMs and suppliers. In addition, automobiles usually have a high commodity value and drive on the streets for many years. Therefore, OEMs have a considerable interest in collecting and deeply analysing the production and life cycle data for each automobile and throughout the whole value chain. The first application for Catena-X therefore is to ensure traceability across the involved companies in accordance with the Supply Chain Act. Technologically, Catena-X is based on the GAIA-X framework. In the current state of development, the Eclipse Data Space Connector (EDC) is used as central communication protocol for connecting the databases and data spaces. The participating companies will be able to operate in multi-cloud environments.

Key actor groups in the value chain

As described in the first use case, the OEMs are orchestrating the supply chains as well as their distributed sites. Their supply chains for parts are structured in different tiers, from suppliers for parts to components up to system and module suppliers. Over these tiers, the data exchange is key for today's automobile production. Therefore, CEI actors such as cloud supplier, federators of data spaces, and application providers for digital twin solutions and VR for training are essential. The collected data is crucial for efficient production, but also contributes to a variety of applications along the automotive life cycle such as (future) applications in transportation and autonomous driving.

Sector 2 - machinery and metal processing

In this sector, the classic engineering is in focus, the development, construction and production of machines and equipment. Metal processing is also integrated in this section to give a broad overview from material processing over manufacturing of parts to the entire production system. This sector plays a major role in the digital transformation of production, with the machines being a main source of data on the production processes. This is, of course, based on the sensors and actuator technology provided by suppliers (see section on sector 3). The main CEI solutions for engineering and machine production: AI for prediction and assistance systems, digital twins and simulations, e.g. as basis for machine learning models, and data driven platforms.

Exemplary use case: Smart Manufacturing

As described in the introduction, the Industry 4.0 vision of customer-specific products or more precisely zero-defect manufacturing in lot size 1, drives many digital transformation projects in manufacturing. For example,

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[84] www.gaia-x.eu

[85] GAIA-X is the European initiative for "the next generation of data infrastructure: an open, transparent and secure digital ecosystem, where data and services can be made available, collated and shared in an environment of trust" - https://www.data-infrastructure.eu/GAIAX/

the ongoing European research project **ZDMP** designs an SME-friendly platform for high precision, zero-defect manufacturing. The software serves as a bridge between the hardware and the application layer, which contains specific solutions for a production line such as data structures for digital twins, data acquisition modules and concrete analytic solutions. A concrete example is the application zParameterAnalytics, which calculates production and maintenance KPIs for predictive maintenance. With this modular approach, the platform targets various manufacturing sectors and it is applied in concrete, industry-led use cases. In one of the use cases, the project demonstrates the development of an alert system to prevent tool failure in production, smart tuning of process parameters and in-line 3D modelling for the production of moulds and tools.[86] These applications are implemented in milling machines of the Italian manufacturer FIDIA for the built-in electro spindles, which are produced by the consortium partner HSD from Italy. It displays clearly, how machine manufacturer and suppliers have to cooperate regarding smart manufacturing and how CEI technologies support this. They provide means for data exchange and for applications in the cloud that are accessible by all partners.

Exemplary use case: Predictive Maintenance

Using prediction algorithms and AI, predictive maintenance applications detect errors and possible wear out of parts at an early stage during production. Sensor data can then be used to plan maintenance cycles more precisely, while reducing machine failure and improving the overall equipment efficiency. Machine manufacturers provide various solutions for predictive maintenance on the market, such as the TRUMPF Condition Monitoring Center for laser machines. It collects the data of the machines to provide condition monitoring for dashboards on the current machine status as well as predictions for defects and maintenance planning (early warning and prognostics). For predictive maintenance, there is a high demand for edge devices that improve data quality and reduce the amount of data to speed up the further processing. Anonymised aggregation of data from multiple machines requires cloud technologies.

Outlook: Manufacturing-X

Taking Catena-X as a model, the SAP group and several mechanical engineering companies such as DMG-Mori and TRUMPF started the Manufacturing-X initiative to build the Data Space Industry 4.0. This data-driven platform will involve the Plattform Industrie 4.0 community, striving to include major industrial stakeholders in the future.[87] The main objectives of the initiative are focused on digital transformation of the value chain, supporting new business models and measuring CO2 emissions. Provided with sufficient investment and funding, Manufacturing-X strives to become the manufacturing data space, with interfaces to automotive industry (Catena-X) as well as other sectors.

Key actor groups in the value chain

In this value chain, machinery manufacturers build components into machines; system integrators assemble the machines into production lines and plants for manufacturing companies. The manufacturers of machinery therefore rely on a broad spectrum of suppliers from metal processing for parts to IoT devices and electric components as well as service providers, such as the edge platform provider. They cooperate with machine and component manufacturers to provide joint services for the plant operator, such as predictive maintenance services and assistance systems. The main demand for CEI-technologies is based on the unused data from production, which is produced and collected with high effort.

Sector 3 - electrical industry

Electrical components and microelectronics, cyber-physical systems and automation technology enables self-functioning and self-control of processes and machines almost without human intervention. These

[86] https://www.zdmp.eu/use-cases

[87] https://www.plattform-i40.de/IP/Redaktion/DE/Downloads/Publikation/Manufacturing-X.html

components are key for Industry 4.0 applications, especially industrial IoT-solutions that form the core of CEI applications. The electrical industry makes a significant turnover due to the demand for CEI technologies in manufacturing and other branches.

Exemplary use case: Robots and AGVs

Automation of production and intralogistics is a major market for robotics. KUKA offers planning and implementation of automated guided vehicles (AGVs) as a general contractor, particularly for the production of vehicle bodies in the automotive industry. This technology allows for flexible and at the same time automated networking of production cells equipped with robots. It provides transparency and optimisation of logistics, intelligently steered via the software KUKA AIVI. Simulations and virtual reality improve significantly commissioning processes and reduce faults. The IoT connectivity of the robots is used for coordination of the multi-AGV system, improving the efficiency of logistics and reducing the planning effort. To realise production cells, which are interconnected by the AGVs, edge technology offers the advantage of collecting and directly pre-processing data to reduce overall traffic in the 5G network.

Exemplary use case: Predictive Maintenance

For predictive maintenance, the automation and electrical engineering companies supply the needed automation technology and hardware components. Some provide also standalone solutions for predictive maintenance. One example is the Hitachi maintenance assistance system comprising hard- and software. They provide an IoT device with edge-AI capability for data collection and processing.[88] On that basis, the worker is assisted with information and data analysis for maintenance tasks on the data platform. It also supports data sharing between plant operator and machine supplier. There are various practical implementation projects; a prominent example is Siemens Industrial Edge. This platform provides edge management services to collect and analyse data from machines. Manufacturers and machine suppliers are enabled to exploit their collected data e.g. for predictive maintenance. Another example: Schneider Electric implemented a solution for Nestlé, which is based on Azure IoT Edge von Microsoft and is used to identify problems with components in real-time for proactive reaction.

Exemplary use case: Product Passport

A product passport is based on product-related data management according to the digital twin concept. Its application focuses on data exchange along the value chain and throughout the entire product lifecycle. It also allows the customers to access the appropriate product information. A prime example from industrial R&D is the battery passport – in both national research projects as well as the European IPCEI[89] projects on battery production. This is driven by the increasing production of electric vehicles (EVs), in which the battery accounts for a significant share in the value chain and is a major quality factor for the EV. Accordingly, Europe is working on establishing its own sustainable battery cell manufacturing. To achieve sustainability, European Union regulations will require the battery passport for all batteries sold and used in Europe from 2025 onwards. The battery passport contains a unique ID for each battery and the measured data especially on social and environmental aspects, such as CO2 footprint, water use, pollution, working conditions and legal compliance. It will cover data on the material from the mine, on production processes and on the ongoing life cycle. For detailed information: The Global Battery Alliance (GBA) published the Greenhouse Gas Rulebook in October 2022 to be one of the indicators for the battery passport. To collect and communicate the data, the battery packs have to be IoT-enabled. The distributed ledger technologies will ensure the integrity and validity of data shared in the supply chains.

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[88] Alliance for Internet of Things Innovation, WG Smart Manufacturing (2022): White Paper: Business Impact of IoT in Manufacturing Industries. Release 1.0.

[89] Abbreviation: Important Project of Common European Interest

Key actor groups in the value chain

The electronic component manufacturers are a key enabler of the digital transformation, not only for Industry 4.0. Therefore, innovation cycles in this sector are short and new products are very relevant to the market. The value chain of the electrical industry is particularly complex due to the high quality requirements. In addition, the supply of rare materials is crucial for the resilience of value chains. The international extraction and processing of these materials poses major challenges for stable supply chains and availability. Certain materials such as lithium are rare and the suppliers cannot easily be replaced in the value chain. Specific property and quality requirements are difficult to meet and fluctuating market prices contribute to the current instability.

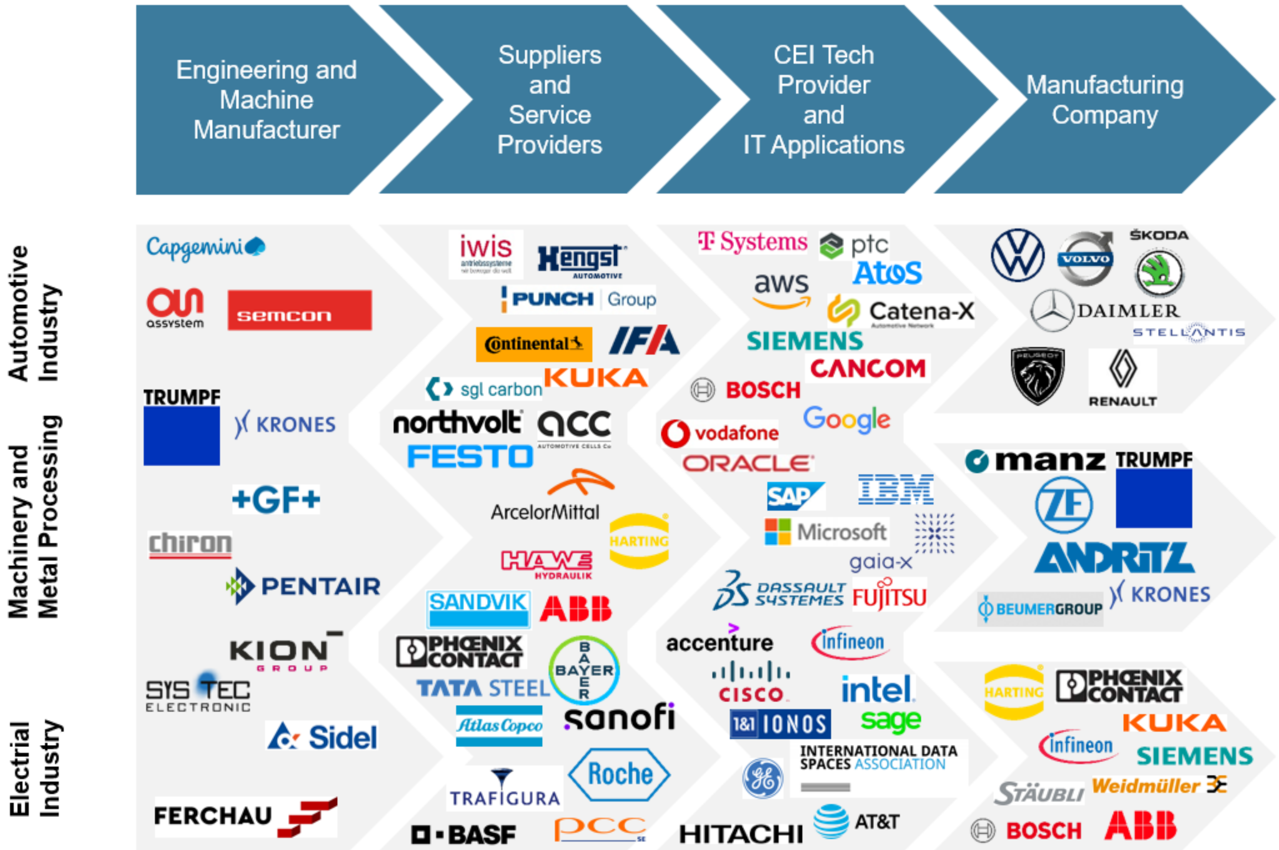

Figure 4: Overview of the value chain in the manufacturing sector

3.3.3 Application areas – opportunities and challenges

Observed opportunities for CEI technologies in the manufacturing sector

In manufacturing, CEI technologies are implemented following the Industry 4.0 vision that describes cyber-physical systems connected by the Industrial Internet of Things (IIoT) as a step towards making traditional factories into smart spaces. Currently, manufacturers have realised the high value of production data. Typically, they mainly apply the data for process optimisation. For the other applications described above, there is a need for further processing and analysis of the data to gain new insights. On edge devices and platforms, the data can be processed near the sensors and actors, improving the informative value. This is primarily needed for real-time applications, e.g. for adaptation of control parameters according to product quality data. Fog architectures are also applied to reduce the amount of data for further processing, e.g. in the cloud. For strategic and intelligent operations like planning, profound data analysis, AI-applications, there is a need for cloud applications. One prominent example are the presented predictive maintenance solutions for production systems.

Observed Challenges for CEI technologies in the manufacturing sector

In many use cases, the cooperation with international hyperscalers is common and might be problematic regarding data sovereignty. European actors should offer more and own high-performance cloud capacities and establish a presence in edge technologies.

Another challenge for the further establishment of CEI technologies in the sector is that business models and revenue streams for many applications are unclear and not established in the economy. The added value of predictive maintenance solutions, for example, is often difficult to prove, resulting in an unknown market volume. A point of action is the data exchange along the value chains. In automotives, the OEMs can orchestrate their supply chain and set standards for the data exchange by including the demand in the contracts. However, in other sectors, the linkage in the network of companies and suppliers is more tangled. None of the actors is in the position to orchestrate and control the data exchange. In this context, issues on data quality occur. For example, data consistency is a challenge for all digital solutions, in the company as well as along the value chain, since the applications rely on sufficiently up-to-date data. These aspects are of course not primarily influenced by CEI technologies, but are major hurdles for the applications.

3.4 Transportation

3.4.1 Industry Associations and stakeholders

In the transportation domain, a wide range of intelligent IT systems is necessary to operate, manage and optimise transportation systems, to provide seamless travel information services, to enable logistics processes, to plan, monitor and maintain the transport infrastructure, fleets and personnel. This includes all transportation modes (road, rail, waterborne and airborne transportation) concerning passengers and freight in long-distance transport, regionally and in urban areas. These IT systems cover potential application areas for CEI technologies as new IT technologies allow for applications that are more efficient. CEI will also support the introduction of the new technological trends described further below. The relevant sectors are grouped as follows:

- **traffic management and control** (includes the everyday operation of a transport mode in a transport network including data collection, data processing, data exchange, modelling, traffic monitoring and control, incident management, demand management, parking management, e-Call)
- **traveller Information, booking and payment** (includes intra and multi-modal information for trip planning, on-trip information, booking and payment)
- **fleet tracking, monitoring and management** (includes tracking, monitoring and management of fleets in freight transport, public passenger transport, shared transport services, micromobility, the management of automated vehicle fleets etc.)
- **freight tracking, monitoring and management** (includes tracking, monitoring and management of consignments related to the location, the status and specific properties of the consignment)
- **autonomous vehicles** (includes control and monitoring functions for highly automated vehicles as well as assistance, communication and entertainment functions for drivers and passengers)
- **remote asset maintenance** (includes the monitoring and maintenance support functions for the transport network)
- **enforcement of regulations** (includes functions for the monitoring compliance with regulations and enforcement)
- **video data detection, security and surveillance** (includes video-based technologies for traffic data collection, incident detection as well as security monitoring)

Intelligent Transport Systems (ITS) for the above-mentioned purposes have already been part of the transportation system for several decades. However, the **broader adoption of AI, more powerful communication networks and cheaper sensors** enable new technological trends that are creating opportunities for CEI technologies, especially, where traditional cloud services are reaching their limits in terms of latency, energy efficiency and security. Major technological trends in the transportation domain that create demand pull for CEI technologies would be:

- further **digitalisation** of traffic and transport control, management and information processes, **digital twins** of transport infrastructure
- a significantly **increased collection of traffic and transport data**, further **networking of systems**, creation of **transport data platforms** and **standard interfaces** (e.g. National Access Points for transport information in Europe, urban data platforms)
- **automation** of vehicles and operations in all modes
- **electrification** and **decarbonisation** (alternative fuels) in all transport modes including respective supply networks
- **integration of multimodal traveller information, booking and payment systems** (**Mobility as a Service - MaaS**)
- promotion of **shared transport modes** with respective **data platforms** (car sharing, ridesharing, ride pooling, bike sharing, shared micro-mobility)
- promotion of **public transport, cycling and walking** due to climate change
- **e-commerce platforms**
- upcoming concepts for **alternative, partly disruptive transport modes** (e.g. micro-mobility, cargo-bikes, delivery robots, urban airborne traffic, hyperloop)

Important International and European Actors

There are several organisations on national, European and international level, which support the introduction of data-driven systems in the transportation domain.

The introduction of information and communication systems in the transportation domain has a longer tradition. This tradition is reflected in a worldwide network of **Intelligent Transport Systems (ITS) organisations**, which are stakeholder networks for the promotion of networked IT-Systems in the transport sector. They mainly promote research, development, project implementation, information exchange and networking in traffic and transportation control, management and information as well as automation. These organisations bring together stakeholders from transport and infrastructure operators, vehicle manufacturers, IT-services providers and developers, telecommunication companies, research organisations as well as cities and regions. ITS organisations exist on international, national and regional level. CEI applications will certainly be part of the modern system portfolio, as modern networked computing systems and platforms.

There are also international organisations (e.g. the Automotive Edge Computing Consortium (AECC), see below), which **specifically promote the implementation for CEI applications** in parts of transportation domain.

There are also other associations, which promote modern networked IT systems in specific application fields, or **parts of the multimodal transport system**. The most relevant organisations are listed below. Whether they definitely promote CEI applications, often depends largely on the specific systems and architectures promoted by the system and service providers. The list contains a selection of important organisations, but does not claim to be exhaustive.

International Level

- **International ITS organisations**: There are three transnational ITS organisations which together cover the most important economic regions in the world: ITS Europe is represented by ERTICO in Brussels (www.ertico.com), ITS America represents North America (www.itsa.org) and ITS Asia-Pacific covers the Asia-Pacific Region including Australia (www.itsasia-pacific.com). The three organisations are in close co-operation with one another and with national ITS organisations in the respective regions.

- The **Automotive Edge Computing Consortium (AECC)** is an international industry association based in the USA, which is aiming at promoting the evolution of edge computing architectures in the automobile sector to support high-volume data services in connected vehicles. Members are key players in the automotive industry, high-speed mobile network providers, edge computing and wireless technology providers and stakeholders in the distributed computing and artificial intelligence markets (www.aecc.org).
- The **5G Automotive Association (5GAA)** is an international industry association which promotes the co-operation between stakeholders from the telecom industry and vehicle manufacturers to develop end-to-end solutions for mobility and transportation services based on the application of 5G mobile communication and data-driven solutions (www.5gaa.org). Mobile communication based on 5G provides the necessary connectivity for CEI applications.
- The **International Transport Forum (ITF)** (www.itf-oecd.org) is the transportation-related branch of OECD. The intergovernmental organisation is a think tank for transport policy and also monitors and assesses data-driven technology trends in multi-modal transportation.
- The **Union Internationale des Transports Publics (UITP)** (www.uitp.org) is the international association of public transport. It brings together the stakeholders of all sustainable public transport modes in urban mobility. Main stakeholders are the public transport operators all over the world. The public transport operators are also responsible for the everyday deployment of computing systems for fleet management, traffic and transport management, multi-modal transport information, booking and ticketing, asset management and maintenance as well as safety and security.

European Level

Automotive Industry:

- The **European Automobile Manufacturers' Association (ACEA)** is the association of Europe's 16 major car, truck, van and bus manufacturers. The organisation is the political voice of the European automobile industry and supports the European mobility transformation while at the same time ensuring that the auto industry remains a strong global and competitive player (www.acea.auto).
- The **European Council for Automotive R&D (EUCAR)** brings together European passenger car and commercial vehicle manufacturers. It facilitates and coordinates pre-competitive research and development projects and its members participate in a wide range of collaborative European R&D programmes (www.eucar.be).
- The **European Association of Automotive Suppliers (CLEPA)** represents more than 3,000 European companies which supply components and innovative technology to the automotive manufacturers for safe, smart and sustainable mobility (www.clepa.eu).
- The **2Zero Partnership (2Zero)** "Towards zero emission road transport" is a co-programmed partnership under the Horizon Europe programme aiming at accelerating the transition towards zero tailpipe emission road mobile across Europe (www.2zeroemission.eu). It continues the work of the European Green Vehicles Initiative. The organisation promotes European research projects aiming at energy efficiency and alternative powertrains. It co-operates with other European technology platforms like the European Transport Advisory Council **(ERTRAC)**, the European Platform for Smart Systems Integration **(EPoSS)** and the **Batteries Europe**.

Intelligent Transport Systems:

- **ERTICO – ITS Europe** is the European stakeholder organisation in the field of Intelligent Transport Systems (ITS). As a multi-stakeholder platform, the organisation supports European research and development projects that promote a sustainable, efficient and safe mobility based of a cooperation of stakeholders from the information and communication industry, vehicle manufacturers as well as transport and infrastructure operators (www.ertico.com).

- The **CCAM (Connected, Co-operative and Automated Mobility) Partnership** is a stakeholder organisation, which was co-programmed with the European Commission in the Horizon Europe Framework for the promotion of automation technologies in the mobility domain to create a more user-centred and inclusive mobility system, to increase road safety and to reduce congestion and the environmental footprint. Collaborative R&D projects will be promoted which allow research, testing and demonstrations of automated mobility (www.ccam.eu).
- The **Car2Car Communication Consortium** is a stakeholder organisation of European and international vehicle manufacturers, equipment suppliers, engineering companies, road operators and research organisations which is aiming at the promotion and implementation of co-operative V2X (Vehicle to X) applications. The work contributes to harmonised data communication in road traffic management and to the necessary connectivity for automation in road traffic (www.car-2-car.org).

Urban Traffic Management:

- **POLIS** is the leading network in European cities and regions for the development of innovative technologies and policies for local transport. The organisation has been active many European R&D projects related to the introduction of novel, data-driven urban and regional transport and mobility management systems (www.polisnetwork.eu).
- **EUROCITIES** is a stakeholder organisation of more than 200 cities in 38 countries, which co-operate with the aims to promote inclusive solutions for citizens and to enable a sustainable lifestyle in cities with a high quality of life. Sustainable IT-solutions in urban transportation, mobility and logistics are part of the supported projects and policies (www.eurocities.eu).
- The **MaaS Alliance** is a network which was established by **ERTICO – ITS Europe** for the promotion of **Mobility-as-a-Service (MaaS)** solutions in Europe (i.e. distributed, data-driven applications which build platforms and services which allow multi-modal end-to-end travel planning, real-time information, booking and payment in one app) (www.maas-alliance.eu).

Rail Transport:

- **Shift2Rail** is a European Joint Undertaking, which promotes innovative solutions in the rail sector to make it more competitive. Rail automation as well as information and communication systems are part of the programme. Shift2Rail made also an attempt to investigate highly innovative and disruptive transport systems like Hyperloop (www.rail-research.europa.eu).

Road Operators:

- The **Conference of European Directors of Roads (CEDR)** is a European organisation of national road administrations that is aiming at providing excellence in the management of roads. The operation and maintenance of the road infrastructure as well as traffic management are in the focus of the work. This organisation is also concerned with common European efforts to prepare the roadside preconditions for connected and automated transport. This also means enabling traffic control and management systems to support new data-driven functions (e.g. machine readability of road features, traffic data collection, digital twins of the road infrastructure, V2X infrastructure and connectivity) (www.cedr.eu).

Lighthouse Projects, Data Driven Platforms, Ecosystems driving Technological Innovation

CATENA-X: a German lighthouse project funded by the Federal Ministry for Economic Affairs and Climate Action for the digitalisation of supply chains in the Germany automotive industry. An open systems architecture will be designed which supports a common use of data across companies in the automotive supply chain. This requires the creation of a data ecosystem for a flexible and resilient management of supply chains. Data exchange will be open source and certified in order to guarantee data sovereignty, availability and security. Catena-X employs the GAIA-X Federation Services and the IDS-Connection (International Data Spaces Association) for data sharing (www.catena-x.net).

Mobility Data Space: a German initiative for the interconnection of data-driven platforms in the mobility and transportation domain on municipal, regional and national level in order to develop a mobility data ecosystem which supports multi-modal and inter-modal travel and transport information and management. The first step was done in the project MobilityDataSpace (funded by the German mFUND programme) where the Mobility Market Place (MDM) with several municipal mobility data platforms was supported. Further data-driven mobility platforms will be integrated in an open and decentrally organised data space according to the International Data Space (IDS) concept (www.mobility-dataspace.eu).

NAPCORE: a European project for the establishment of National Access Points (NAPs) in the EU for traffic and transport data form the Member States. Every EU Member State establishes a system which provides the standardised exchange of traffic and transport data (e.g. from road traffic or public transport) for use on European level by interested parties (e.g. service providers, road operators, public transport operators). These systems are connected to mobility data spaces, which connect multimodal mobility data platforms on municipal, regional and national level. The NAPCORE project supports the exchange of transportation data in standardised European formats e.g. DATEX II, SIRI) (www.napcore.eu).

C-ROADS: a European project for the establishment of co-operative V2X Services on the roads in Europe (www.c-roads.eu).

DEEZ – Platform (Germany): The DEEZ platform in Germany, which enables the national exchange of real-time public transport data between regions to cover all of Germany. It allows seamless online travel information in real time. In the near future, also the EU-wide exchange via NAPs will be possible.

Mobility inside (Germany): The data-driven platform enables the data exchange for a Germany-wide MaaS service offering multimodal travel planning, information and booking (www.mobility-inside.de).

The transport domain is one of strongest contributors to climate change, and it is the only domain, which so far could not successfully decrease its negative impact. Nevertheless, digitalisation can contribute to green transitions in the following directions:

- Digital applications that promote more frequent use of public transport, make it more attractive and performant (e.g. MaaS, automated trains and shuttles in public transport) and integrate it more closely with other modes of transport can be helpful.
- Digital applications which help minimise and control the use of private cars especially in urban areas would be helpful (e.g. traffic control and management).
- Digital applications can support the use of shared fleets and reduce car ownership.
- In freight transport, digital applications can bundle excessive deliveries caused by e-commerce.
- Digital applications can support green (decarbonised) fleets and alternative modes of transportation.
- The introduction of CEI could reduce energy consumption of data exchange and processing.

3.4.2 Data-driven Value Chains and Networks

In the following section, we have a first look at the actors in the value chain of the transportation-related CEI sector. Please note that the picture is not yet complete. We identified the actors in a first step and the following two figures show examples for the players in the specific sector.

We assume the following stages of the value chain:

- Planning and Engineering
- Equipment and Vehicle Manufacturers
- IT applications an Platform Providers

- Information and Communication Services
- Transport Operators

We have found actors for all eight sectors, which were introduced at the beginning of the transportation chapter. The following figures provide an overview of the value chains in the sectors with respective actors:

Figure 5: Overview of the value chain in the transportation sector (Part 1)

Figure 6: Overview of the value chain in the transportation sector (Part 2)

In the following text, we describe several identified CEI application areas from the sectors of the transportation domain. We highlight the CEI aspects in the application area and describe the main characteristics of the value chains. We introduce actor groups and stakeholders together with their share in the value chain.

<u>A - Sector Autonomous Vehicles/ Application Area: Highly Automated Driving</u>

Highly automated driving of road vehicles is one the application areas for CEI technologies, which are under implementation and test. For the automation, the vehicle practically becomes a “computer on wheels” with constantly updated software. The **automotive edge platforms** collect data from different sensor systems in the vehicle and enable vehicle functions like automated driving, safety and vehicle dynamics, HMI functions in the cockpit as well as data management and connectivity. Novel automated edge platforms change the whole system architecture of the on-board electronics. The application uses server-based architectures in which part of the functions are operated locally in the vehicle on the automotive edge platform and another part is operated centrally in the cloud at a cloud service provider. The cloud service provider provides a virtual workbench to develop, supply and maintain software-intensive system functions. For this purpose, scalable computing and machine learning capacities are offered in the cloud in order to serve whole vehicle fleets and to support software developers from OEMs and tier 1 suppliers (e.g. direct suppliers to the automotive OEMs). This allows the vehicle software to be developed and tested more efficiently. Later it can be installed safely and directly in the vehicles.

OEMs integrate the automotive edge platform into their vehicles. Key actor groups in the value chain are software developers who plan and update functions in the vehicles from the cloud-based data collected by the automotive edge platform. In the periphery, the tier 1 suppliers for sensor and computing systems become relevant; they also take part in the continuous development process with ICT suppliers. Mobile communication providers enable the required ubiquitous connectivity.

A concrete example is the **Continental Automotive Edge Platform (CAEdge).** Here, Continental provides the Automotive Edge Platform with hardware and software. The cloud service provider is AWS. AWS also offers machine learning and scalable computing capacities. The group cooperates with VW as OEM. The Continental system is part of the cross-domain vehicle systems that are interoperable with other OEMs.

An alternative solution is the **Bosch IoT Edge Platform** with an own **Bosch IoT Hub** in the cloud. Bosch.IO offers a complete European CEI solution. The company points out that also functions as e-Call can be supported beyond software updates and communications.

In general, the following actor groups are necessary for the implementation of highly automated driving: OEMs (vehicle manufacturers), AV stack providers for vehicle platforms, component providers (processing, sensing, data/ connectivity, mapping, software and algorithms, security and safety), provider of development tools. The actors are listed in the following picture. Bosch and Continental can be found under AV stack providers and in different groups of component providers.

The following images shows the worldwide ecosystem (network) in the field of automated driving:

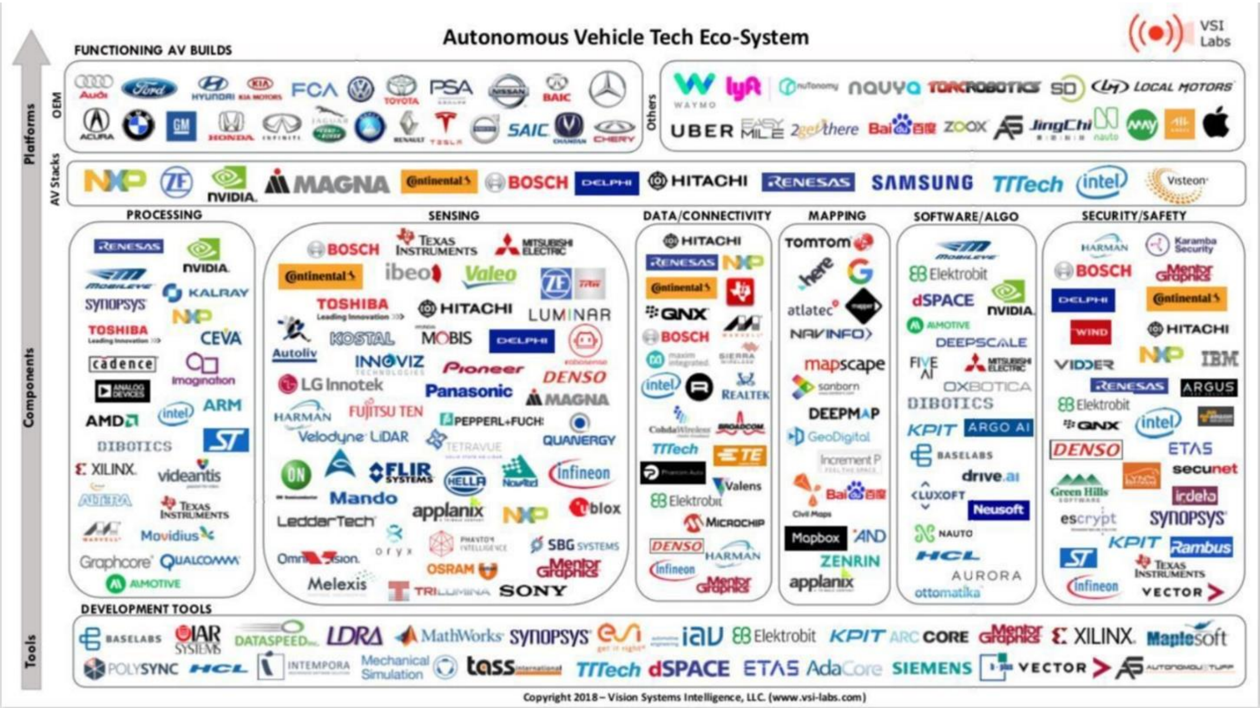

Figure 7: The ecosystem for automated driving (Source: Vision Systems Intelligence LLC)

The figure above provides an overview of key actors in the sector of autonomous vehicles. The AV Stack providers seem to be particularly interesting when looking for partners for large-scale pilots.

B - Sector: Video Data Detection, Surveillance and Security/ Application Area: Video Data Detection

Video systems can have several purposes in the transportation domain. The main use cases are:

- video monitoring of areas (e.g. platforms, stations) for security purposes
- video monitoring of transport networks for traffic monitoring in traffic control centres
- **video data detection** for
    - traffic data collection for statistics, vehicle classification and planning
    - number plate recognition, e.g. for road tolling
    - traffic data detection for traffic control, travel time and automatic incident detection

In the following, the last use case "video data detection" is considered. Video data detection needs special software for image processing in order to extract the requested information (e.g. number of vehicles, speed, vehicle type, number plate content) from the image. Running image processing in the cloud can create latency problems, increases data traffic and is prone to security and privacy problems. Therefore, edge computing is used in order to run the image processing on an edge computer close to the cameras. Only selected data is sent to the cloud server. For example, Images or number plates can remain on the edge computer, whereas traffic or vehicle data can be sent to the cloud for further analysis over larger geographical areas or a longer period of time.

The camera system of the company FLIR (www.flir.de) is an example for such a product. FLIR has been successfully selling their infrared traffic camera systems to several customers (e.g. road authorities, municipalities) for traffic data detection.

Main actor groups in the value chain:

- camera hardware (edge) and software manufacturers
- service Operators
- cloud operators
- user of generated information and data

C - Sector: Fleet Tracking, Monitoring and Management/ Application Area: Autonomous Vessels

Also maritime transport fleet management is an application area for CEI technologies. A ship of the next generation can be seen as a sophisticated sensor hub and data generator, producing and transmitting massive amounts of data. Modern ships require overall coordination and control with minimal on-ship human oversight.

These type of systems can be the basis for future fully automated ships. On each ship, a secure micro-cloud at the edge could be operated, distributed locally with other ships, connected centrally or even operated offline.

Main drivers of the Pratexo (pratexo.com) solution:[90]

- cloud/ edge provider: **Pratexo** (organisation: USA, Norway, Sweden)
- ASUS computer (AI and IoT specialist)
- ERICSSON (telecom provider)
- LuxML (business consultant)
- matellio – navigating ideas (software engineering, AI/ ML)
- Coral (Google AI platform)
- Ballista (technology consultant)

[90] https://pratexo.com/edge-computing-shipping/

- Wittra (IoT specialist)
- Bim Virtual (digital twin technologies)
- Attentec (IoT specialist)
- IC (SCADA specialist)

Main actors of the value chain:

- shipping companies
- CEI component and system providers
- telecom companies

This innovative approach could provide a basis for management and control of autonomous vessels in the future. It would make ship operations reliable, coordinated and optimised. Optimised ship operations promise 10 to 20 % in fuel savings and massive CO2 reductions.[91]

D - Sector: Traffic Management and Control/ Application Area: Co-operative Vehicle 2 Infrastructure Communication

In urban traffic control, the co-operative V2X (vehicle to x) systems become more and more commonplace. In Vehicle2 infrastructure systems, connected vehicles directly communicate with roadside elements of the infrastructure-based traffic control systems via so-called roadside units (RSU). For example, this way a vehicle can directly communicate with traffic lights. This allows for a wider range of cooperative traffic management functions, which involve the vehicle and the road traffic control system, e.g. the prediction of time to green at traffic lights, speed recommendations for single vehicles at traffic lights, requesting green for emergency vehicles, and collection of traffic data from probe vehicles, warning of road works and stationary traffic.

For this purpose, controllers of traffic lights are equipped with roadside units, which enable data communication with the on-board system of the vehicles. Normally, roadside units support a hybrid communication consisting of 4G mobile communication and WiFi. The direct WiFi communication is needed for all messages that require low latency. With the introduction of 5G, the deployment of mobile communication is supposed to be sufficient. The roadside units will then be equipped with edge computing that pre-processes all messages requiring low latency.

Main actors of the value chain:

- road operators (municipalities, road authorities)
- telecom providers (T-Systems, vodafone, Ericsson…)
- suppliers of traffic control systems (Siemens, Swarco, AVTStoye, Stührenberg, Kapsch…)
- developers of traffic control software
- suppliers of roadside units
- suppliers of on-board units
- automotive companies

One example for a main player in this use case is the provider of roadside units Commsignia.[92]

This application will enable a performant integration of traffic control systems in urban and interurban areas with connected and with automated road vehicles. The deployment of edge computing will support a lower latency in the transmission of data and enable more performant services.

[91] https://pratexo.com/edge-computing-shipping/

[92] https://www.commsignia.com/products/rsu/

3.4.3 Application areas – opportunities and challenges

Observed opportunities for CEI technologies in the transportation sector

A large advantage of CEI technologies in transport is that data that is critical in terms of latency, privacy and energy efficiency, is processed locally on an edge platform near the sensor and actors. On the other hand, more strategic and intelligent operations like planning, modelling, data analysis, software engineering and maintenance, AI calculations, preparation and control of software updates and even re-selling of data can be done in the cloud. This can be the basis for further automation and optimisation processes in the whole transport domain and only these technologies make new services in transport (e.g. shared transport platforms, automated vehicles) possible as they are designed today.

Furthermore, the collection of large amounts of data also from transportation systems centrally in the cloud, provides the opportunity to generate new added value AI-based automation services. Even if part of the data is pre-filtered by edge platforms, the cloud provider will remain in the position to decisively influence the design and operation of data-driven transportation systems. As centralised functions continue to provide the opportunities for smarter and more powerful system parts, European actors should offer more cloud capacities of their own and establish a presence in edge technologies.

Observed challenges for CEI technologies in the transportation sector

Initiative to introduce CEI technologies are increasingly coming from international hyperscaler companies (in Europe especially American companies like AWS, Microsoft, HP, Google etc.) as part of their marketing strategies. There are only few European alternatives, unfortunately without a global scalability. Thus, there is also a risk of vendor lock-in in the transport domain, as European IoT companies and users have only few alternatives when they want to choose a cloud provider.

Potential European cross-sector market players, which also serve the transport domain especially as cloud providers, such as T-Systems, Bosch, Siemens, must be strengthened as alternatives to international hyperscalers.

Many public transport users also have problems with the mass provision of data to international servers with limited control over the use of the data, as they have concerns about data sovereignty and data protection. This is especially true for video data from camera systems. Therefore, data owners should have the right and the choice to determine on which servers the data is processed, to be informed and to give their consent.

In the transportation domain, traditionally a larger part of data comes from the public domains (public authorities), where concerns about data sovereignty are especially high. There is a permanent dispute whether data should be generated and owned by the public authorities or whether they should be bought from private service providers. There is a trend towards having own data servers that are under public control.

3.5 Agriculture

Cultivating plants and livestock is the core of the agriculture sector. The whole value chain in the agriculture and food industries aims at securing the nutrition of the world population. In today's market, the agricultural industry is highly technologized and internationally intertwined to meet quality demands regarding food safety and product diversity. The controversial trend towards sustainability results in higher demands for regional products and natural ingredients, increasing the demand for organic food. Social sustainability factors are becoming important, represented by labels such as fair trade and organic seals. On the other hand, customers still require the availability of a broad spectrum of products. This includes exotic and so-called super food. The agricultural sector is both a major factor influencing and bearing the consequences of climate change: due to the high variety of customer and quality demands, today's agriculture has to be efficient and productive. This results in the widespread use of fertilizers, highly efficient crops, and the mass production of food, which is shipped all over the world. The resulting effects on climate affect soil properties and agricultural yields.

As a result, regulation in environmental areas is increasing. The same applies to hygiene, safety and transparency. The nutrition of the world population remains problematic. This is in spite of high efficiency gains in the agricultural sector over the past decade. Demographic shifts and global population growth contribute to this, as does climate change. Ecological responsibility in agriculture while ensuring nutrition for people globally is a major driver for innovation. To reach the EU goal of a climate-neutral continent by 2050, the farm to fork strategy[93] (part of the European Green Deal) strives for a robust and resilient food system. The goals for the aspired transition to sustainable food systems are "to reduce dependency on pesticides and antimicrobials, reduce excess fertilisation, expand organic farming, improve animal welfare, and reverse biodiversity loss".[94] This can be achieved by regulating the use and risk of chemical pesticides and fertilisers, and by increasing the share of organic farming in cultivated areas. The trends described affect the agriculture sector deeply and are leading to major structural change. The number of farms has decreased by 26% since 2007. Meanwhile, the average cultivated area is increasing. Although only a single-digit percentage of farms cultivate more than 100 hectares of land, they still manage 53% of the EU's agricultural area.[95]

Major technological trends

CEI technologies can support the aspired sustainability. In order to cover the range of CEI applications in the agriculture sector, the following value chain analysis covers the cultivation of crops, livestock farming and the interfaces to food processing. There are various application areas in the outlined context, which create demand pull for CEI technologies.

Sensor technology and automated control systems found their way into agriculture to realise automated control and process optimisation of agricultural machinery. This allows the targeted cultivation of sub-areas and the needs-based supply of livestock, so-called precision farming. Smart or digital farming is based on this, promoted in particular by CEI Technologies. The formerly individually automated machines are connected to each other via a local or a public mobile network. In this way, they can plan and act cooperatively by exchanging information and data. In a manufacturer's product system, even several machine types work together to exchange data. For example, data from the combine harvester collected during yield recording is available and can flow directly into a fertiliser calculation. This can then control the application rate on the fertiliser spreader. These functions are based on the Internet of Things, in which networked objects communicate with each other (machine-to-machine communication), and on cloud computing or edge solutions to analyse the collected data. An irreplaceable and basic prerequisite for these applications is a wireless connection to the internet, which is reliable in the field and in the barn. This is the only way to implement cloud applications and robust control of robots such as interlinked, autonomous harvesters. The 5G networks allow for coping with the growing number of devices.

Additionally to the collaborative management and control of automated harvesters and agricultural machines, CEI technologies also enable a growing individualisation of agricultural processes. Current scientific approaches address solutions for the optimal application of pesticides, fertilisers and livestock feed. This way, the farmers can analyse and meet the needs of every plant and animal individually. Machinery

[93] European Commission (2020). Farm to Fork Strategy. For a fair, healthy and environment-friendly food system.
[94] ibid. p. 5
[95] https://www.bauernverband.de/situationsbericht/3-agrarstruktur/36-agrarstrukturen-in-der-eu

sensors and devices for remote sensing, such as drones and satellites capture huge data volumes for this purpose. The need comes from the fact that the acreage of farms is difficult to capture in any other way, and AI is well suited to analysing the resulting image data – a significant advantage for automation. Cloud applications meet the resulting need for data integration and analysis. Assistance systems can provide the resulting information to the farmers or the agricultural machines apply it autonomously for process optimisation. In doing so, CEI technologies contribute to significantly lower material consumption and to environmental savings coupled with higher yields.

Besides the digitalisation of agricultural machinery, farmers increasingly use digital solutions. The main use is to sell their harvest and buy agricultural commodities. Online shops for farmers allow their customers to purchase crops and animal products directly from the farmer (crowd farming). This allows farmers to gain higher margins. For conventional farming, there is a clear trend towards online marketplaces for agricultural supplies and selling crops, such as **Unamera**[96] and **myAGRAR**[97]. There is also a need for digital services, for example yield forecasts. In particular, the crop and livestock management has to consider many aspects: complex framework conditions and regulations, e.g. the weather forecast and specifications for soil input of nitrate and other substances that these services can support. There are also emerging initiatives for data sharing in the agricultural industry. These strive to enable the exchange of data between machines, their manufacturers and farmers in distributed data spaces.

The identified application areas for CEI technologies in the agri-food sector are:

- asset/equipment/systems maintenance and repair
- asset/equipment/systems command and control
- visual inspection – quality/integrity
- video security and surveillance
- process automation and optimisation
- autonomous vehicles
- livestock monitoring
- agriculture animal tagging
- agriculture field monitoring

3.5.1 Industry Associations and stakeholders

Overview on relevant associations

As indicated in the introduction, the characteristic of the agriculture sector is the decentralised production of crop and animal products by mostly small farming companies and family businesses. Therefore, they form strong organisations on local, national and international levels.

Concrete examples for the national level are the **cooperativas agro-alimentarias**[98] in Spain and the **German Farmers' Association DBV**[99]. The European umbrella association **COPA-COGECA**[100] ensures that the interests of farmers and rural areas reach the European regulators and interests. It represents both crop and livestock farming and is a merged organisation of COPA, the united voice of European farmers' associations, and

[96] https://www.unamera.com/
[97] https://www.myagrar.de/
[98] https://www.agro-alimentarias.coop/
[99] https://www.bauernverband.de/english
[100] https://www.copa-cogeca.eu/

COGECA, the association of European cooperatives in the agriculture sector. This is done through publications on agricultural analysis like forecasts of crops, position papers on policy issues such as limits for certain ingredients in fertilisers. The other field of activity is the involvement in relevant EU platforms on nutrition as well as on required technologies. The association is a member of AIOTI, the Alliance of Internet of Things Innovation, regarding IoT applications on fields and in rural areas.

COPA-COGECA is also part of the **Agri-Food Chain Coalition** (AFCC)[101], an umbrella organisation for associations in the agriculture and food sector. Every group from the considered value chain is represented in the AFCC. It includes **CMEA aisbl**[102], the European Agricultural Machinery Association.

CEMA represents this industry by integrating 11 national member associations, adding up to 7,000 machine manufacturers. That comprises major players like Fendt[103] and CLAAS[104] as well as SMEs. They promote precision farming with smart equipment as a main way to produce the food needed for the growing world population. Another member of the Agri-Food Chain Coalition is **COCERAL**[105], the European trade association for products such as cereals, rice, feedstuffs and agro supply.

The **European Institute of Innovation & Technology** (EIT) is funded by the EU and runs a participation initiative to improve food and ensure high-quality nutrition, the **EIT Food.**[106] With their innovation community of 136 partners from business and research, they build a digital food supply network, support agri-food start-ups and SMEs, fostering talents in their academic programmes, innovate food products and engage with the public regarding a future-proof food system.

Public-Private Partnerships and Digital Innovation Hubs (DIHs) on European Level

In the **Network of European DIHs**[107], some partners are specialised in digital solutions for agriculture and food. There are the **Andalucía Agrotech Digital Innovation Hub**[108] from Spain, the **#DigiAgriFood** from Xanthi in Greece and the **AgroHub.BG** from Plovdiv in Bulgaria. Building on this infrastructure, the project **Smart Agri Hubs**[109] leverages a pan-European value-chain network, which integrates over 160 partners in the European agri-food sector. Its goal is to foster the agricultural innovation ecosystem and to support the digitisation of the European agriculture towards the described vision of smart farming.

In the following, we will introduce organisations that establish a dialogue and interconnect public authorities and economic actors. Public-private partnerships (PPPs) are long-term cooperations, regulated by contracts between the public authorities and commercial companies. The EU-funding programmes ICT-AGRI and ICT-AGRI-FOOD supported research and innovation. Building on that, these PPPs are under preparation to start in 2023 or 2024:

[101] https://agrifoodchaincoalition.eu/
[102] https://www.cema-agri.org/
[103] https://www.fendt.com/
[104] https://www.claas-group.com/
[105] http://www.coceral.com/
[106] https://www.eitfood.eu/
[107] https://digital-strategy.ec.europa.eu/en/activities/edihs
[108] https://www.andaluciaagrotech.com/
[109] https://www.smartagrihubs.eu/

- The **European Partnership Accelerating Farming Systems Transition** strives to support a network of living labs for long-term, real-life experimentation to gain knowledge on agroecology and improve the environmental effects of farming.

- The PPP **Agriculture of Data** will use digital means and data for environmental observation for EU-wide data for the agricultural sector, to improve sustainability and to monitor policies. The results can be both driver and enabler for the uptake of CEI technologies in the agri-food sector.

- The **European Partnership for Safe and Sustainable Food Systems** will be the platform to support the transition to a sustainable food system following the farm to fork strategy. The goal is to provide concrete solutions by connecting regional, national and European research and innovation programmes and actors and strengthen the EU leadership in this transformation.

Lighthouse Projects

The **AFarCloud**[110] project developed a distributed platform framework for autonomous farming, as shown in the following depiction of digital agriculture:

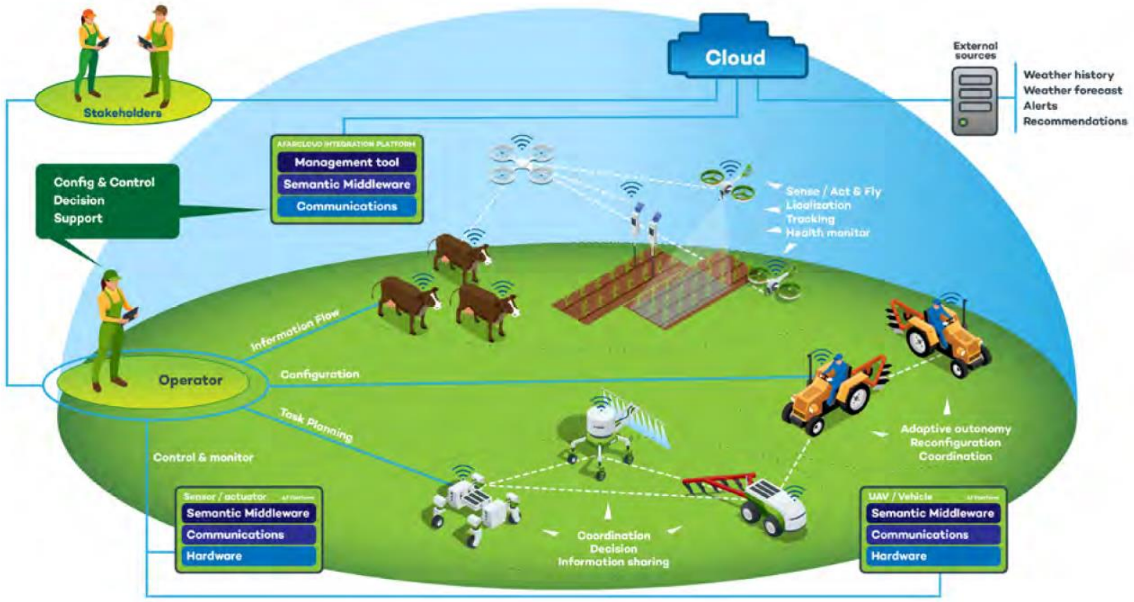

Figure 8: Concept from the project AFarCloud to aggregate farming in the cloud
[Martinez-Ortega, J.; Ferrari, G. (2022). Successes of the AFarCloud project. Inside Magazine, 02 (April 2022), 12-15]

The technical development focused on the enabling technologies of cooperative cyber-physical systems. The cloud-based platform comprises three elements: (1) the farm management system, which provides applications for robots, e.g. a management tool for planning the cooperative flights of unmanned aerial vehicles (UAVs) for data acquisition, (2) the semantic middleware for data management and knowledge extraction and (3) the hardware layer. The framework supports precision farming with robots in combination with existing machinery on the farm, enabling the farming vehicles to work cooperatively for increased

110 http://www.afarcloud.eu/

farming efficiency. The aim is to optimise growth and harvesting processes and to improve livestock management and soil quality, as shown in laboratory trials and demonstrators.

The coordination and support action **OPEN DEI**[111] (Digitising European Industry) is part of the digital transformation strategy of the EU. It supports large-scale pilots and platform projects by aligning the reference architectures for open platforms. One of the five focus areas is the Agri-Food Sector.

Besides the already mentioned **Smart Agri Hub**[112] project, the EU project **ATLAS**[113] is allocated in this area. The title ATLAS is short for Agricultural Interoperability and Analysis System. The consortium from business and research develops an open interoperability network that is able to integrate sensor data of in-field sensors, machine data over various manufacturers and data from livestock behaviour analysis. For applications, autonomous guided vehicles (AGVs) can be equipped with developed multi-sensor boxes to measure the properties of crop on the field.

Another already closed project in this focus area is **Internet of Food & Farm 2020**[114]. Its goal is to make precision farming a reality by developing and piloting the needed technologies, including IoT, cloud, edge and AI applications. The dairy use case illustrates this clearly: the data on the feeding patterns of cows helps to detect health issues early. The project applies data also to improve the calibration of the sensors for milk quality monitoring. Another application is a smart collar for cows, which monitors their activities and detects the heat stress level of the cows. All these IoT technologies and developed cloud- and AI-based services improve milk quality and the animal welfare leading to higher production efficiency.

The agricultural data infrastructure is in the focus of many national activities, such as the German research project **Agri-Gaia**[115] and the French initiative **agdatahub**[116] in the context of data infrastructure on the European level. The EU project **AgriDataSpace**[117] involves agricultural associations, research institutions and data space providers. The project aims to pave the way for a European data space for the agriculture sector. The project focuses on building an ecosystem and setting up a multi-stakeholder governance scheme to ensure security, trust and transparency.

3.5.2 Data driven Value Chain

In this section, we outline the high-level value chain and promising CEI application areas. We introduce stakeholders and actor groups and describe how they interact with each other in the data-driven value chains. The section also includes examples from food industry, which process the produced crops and animal products. In the end, it concludes with the major opportunities and challenges for CEI technologies in the agriculture sector.

Overview of the value chain with exemplary representatives of the relevant stakeholder groups

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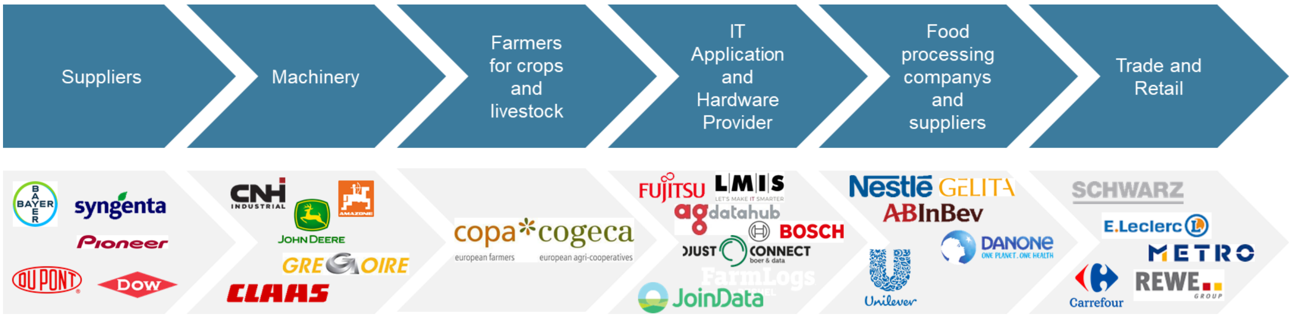
[111] https://www.opendei.eu/
[112] https://www.smartagrihubs.eu/
[113] https://www.atlas-h2020.eu/
[114] https://www.iof2020.eu/
[115] https://www.agri-gaia.de/
[116] https://agdatahub.eu/en/
[117] https://agridataspace-csa.eu/



Key actor groups in the value chain

Suppliers for agro supplies like seeds, fertiliser and pesticides and manufacturers for agricultural machinery provide the farmers with needed goods and machinery. Since farmers cultivate a high diversity of crops and use various cultivation methods, their requirements for supplies have a broad spectrum. From organic to genetically improved, the suppliers must offer a broad product portfolio. Agricultural engineering companies also provide a correspondingly wide range of options for configuring agricultural machines, which is also reflected in the IoT-platforms for the machines.

On the other side of the value chain, the food processing industry is the main purchaser of agricultural products from farmers. The produced food is then sold at retail or at wholesale to companies. Regarding the production, the consistent quality of the agricultural products is key to reach the aspired properties for the food. Therefore, supplier management and incoming inspection is particularly important in the food industry. Further, quality management is also applied in the production process with inline quality measurements, in order to comply with the comprehensive regulations for food safety.

The IT application and hardware provider support the data collection and management along the value chain. However, digital applications are mainly used locally and not yet along the entire value chain. The following section highlights innovative applications in agriculture.

Applications in crop and livestock farming: data spaces

The data space concept already found adoption on the market in the agricultural sector. In the Netherlands, **Join Data**[118] offers a data platform that provides data sovereignty to the farmer. The non-profit organisation strives to put the farmer in charge of his own data. Using the platform, farmers can collect and manage the captured data. They can grant permissions to specific data sets for other actors. For example, granting access to milk yield for a cooperative, which supports sale and logistics, or granting the permissions to feed suppliers. Even public authorities can get access to the Join Data platform.

Another solution in this area is **DjustConnect**.[119] It is currently focussed on the dairy market and was founded by the Belgian Innovative Business Network Smart Digital Farming and companies from the Belgian dairy industry. DjustConnect provides farmers with a cloud-based data platform for sovereign data management. The farmer can grant permissions for data access or data sharing and get an overview on the information using the DjustConnect dashboard. Moreover, the platform addresses data providers (e.g. laboratories, control authorities and machine manufacturers) and data consumers and operates as a market place for agricultural data. The farmers and other actors from the value chain can buy and sell data via this platform. The technological basics for this are cloud and edge applications for data collection, API-interfaces for connectivity. Currently the DjustConnect platform runs on Microsoft Azure Cloud. The application itself is cloud-agnostic and can be operated with any other cloud providers.

118 https://join-data.nl/en/
119 https://www.djustconnect.be/en

Applications in crop and livestock farming: smart farming

The leading manufacturers of agricultural machinery offer solutions for precision and smart farming. As an example, **CLAAS**[120] provides optional functions for machinery such as assistance systems and autonomous driving. The product portfolio comprises automatic steering systems, monitoring and management systems and solutions for subfield-specific cultivation. For the subfield-specific fertilisation, the machine is equipped with a sensor and measures the intensity of leafy greenness as well as the density of plants. Based on this, the devices on the agricultural machine processes the data and applies the amount of fertiliser that corresponds to the calculated nitrogen demand. The points of action regarding smart farming are manifold: to develop more precise calculation procedures, using AI and new data sources such as satellite data. Driving this demand is the need for higher efficiency in combination with the increasing ecological regulations.

Besides machine manufacturers, IT providers also offer solutions in this area. **Agvolution GmbH**[121] is a German start-up for climate-intelligent crop management based on IoT-solutions. The solution of Agvolution assists in making cultivation decisions based on climate data and risks. For this purpose, the company offers the application **FARMALYZER** that forecasts plant growth. It takes a wide range of available climate data into account, from soil information to remote sensing data and weather data. A multi-sensor system is an integrational part of the platform for data collection and processing.

Applications in crop and livestock farming: robotic farming

There is a considerable need for the automation of crop cultivation and livestock handling due the shortage of personnel in agriculture and increasing migration of the rural population to the cities. Consequently, there is a clear trend towards automation and robotisation in the agricultural industry. It ranges from special vehicles, which are still driven by humans, such as the tracked vehicles for fruit plantation, orchards and vineyards as well as for forestry to fully automated, self-driving robots, for example from the Italian company GEIER. An innovative solution from Denmark is **FARMDROID**[122] that handles precise seeding and mechanical weed control fully automatically. As a basis for weed control, the robot tracks the position of the seeded plants via GPS. The field robot is already used in practice, e.g. for kale farming and in several countries. It runs entirely on solar cells for a CO2 neutral operation. The retrofitting of mobile agricultural machinery to become (semi-)autonomous and intelligent is the new approach pursued by the German company **Robot Makers GmbH**.[123] The company cooperates with manufacturers of series machines and upgrades them with hardware and software solutions such as sensors, computing devices and a dashboard for configuration and control. Robot Makers provide automation kits for mowing, viticulture and orcharding. The main feature of the solution is the upgrade of existing machines with little effort and cost.

3.5.1 Application areas – opportunities and challenges

Observed Opportunities for CEI technologies in the agriculture sector

CEI technologies are a major enabler for digital solutions that support both ecological and effective production of crop and animal products. The main applications described are automated machinery, leveraging data from sensor for real-time decision-making and for individualised supply of crop and livestock. The main benefit are smart farming solutions that attend the plants and animals according to their individual needs. There is a market for robots that fully automate processes in field cultivation and animal care. Retrofitting existing agricultural machinery with CEI-based kits also offers potential for smart farming. Since automated control of agricultural machinery is already common, the machines already provide a good basis for expanding the functions, e.g. new sensors for row surveillance for viticulture and control of each nozzle

[120] https://www.claas-group.com/
[121] https://en.agvolution.com/
[122] https://farmdroid.dk/en/welcome/
[123] https://robotmakers.de/en/

for fertiliser application. Data Spaces and other cloud solutions offer space for data storage according to the state-of-the-art and the possibility to share or sell data. Even though most farmers use the web for buying commodities and sometimes even selling harvest, data spaces currently emerge. The political support for data spaces and the build-up of the European ecosystem is a valuable opportunity for the stakeholders in the value chain. The data spaces can ensure the data sovereignty of farmers and facilitate reports required by regulations based on the processed data, which helps to reduce the administration effort. As most farmers have limited or outdated IT equipment, there is a clear opportunity for widespread adaption of these data spaces. On top of that, farmers have a high demand for information regarding weather data, field management and yield forecast, holding opportunities for new digital services. Such offers can also convince farmers to use data spaces.

Observed Challenges for CEI technologies in the agriculture sector

The agriculture sector is traditionally sceptical and a late adopter of new technologies. This also applies for cloud, edge and IoT solutions. One reason is the rural area that holds many challenges for digital applications. The unreliable and insufficient network coverage for mobile internet is one of the major and widely known inhibitors for CEI technologies in agriculture. Therefore, reliability in dead spots is key, e.g. with the help of edge computing. Local multi-sensor-systems operating on the edge allow farmers to deal with unstable internet connections and employ the full range of services for data collection and processing. Edge computing makes time-shifted data transfer possible. Due to pre-processing on the edge, the transfer also requires smaller data volumes to cloud computing data centres. However, without the possibility of seamless data collection on the field and in the barn, solutions such as AI-based applications for process optimisation and data sharing are difficult and costly to implement.

4. Value Chain Adopter Groups

Data-driven value chains require a seamless and reliable interaction among the outlined actors and stakeholders, who contribute with services or goods to a final consumer product (e.g., a self-driving car) or a service (e.g., transportation). Our approach is based on the concept of value chain adopter groups (VCA) that involve both CEI technology providers (e.g. IoT chip and connectivity providers) and sector specific ICT suppliers (e.g. data spaces, platforms or multi-sensory ICT for agricultural machinery). In the highly interconnected and dynamic value chains, the actors depend and affect each other regarding all aspects of the CEI Continuum: connectivity service offerings, application, hardware and software requirements.

The idea is to establish a more efficient and seamless interaction among the actors along the value chains in the targeted verticals. Common understanding of data flows and data-driven revenue streams will facilitate the interaction among the actors for CEI and facilitate cooperation and adoption. The final goal is to enhance the stability and efficiency in the verticals as well as cross-domain value chains regarding performance, integration costs, and environmental savings. Special attention deserves the challenge of avoiding the vendor lock-in due to the dominating presents of American and Asian hyperscalers on the market. The feedback of VCA members regarding potential gaps, challenges and impediments should leverage cooperation between scientific community and industry along (or across) the vertical value chains in the planned large-scale pilots.

To activate and engage the evolving industry constituency in VCAs, we will approach the identified organisations and stakeholders and organise a series of interactive events in cooperation with WP2. Market scenarios and guidance, WP4. CEI Technology Developer Engagement and WP5: Communication. The VCAs are encouraged to contribute to the resulting recommendations for large-scale pilots in order to meet the demands of the industry.

Two "waves" of workshops will address the targeted five sectors: manufacturing, energy and utilities, transportation (including mobility and logistics), agriculture and healthcare. We already set up a registration form for expression of interest to join the value chain adopter groups and approached the associations that belong to the TransContinuum Initiative.

A cross-domain expert panel will be organised to discuss the recommendations for large-scale pilots with invited experts and the European Commission.

The previous chapters illustrated the CEI application areas and stakeholders in the five target sectors. The following resulting value chains depict the planned structure for the value chain adopter groups (VCA) in the upcoming workshops.

4.1 Wave 1 workshops

Virtual sector-specific workshops "wave 1" will build on the demand landscape provided by Work Package 1 (IDC) and involve the Blue Ocean Strategy methodology, particularly "Strategy Canvas" and "Buyer Experience Cycle". The goal of the workshops is to provide an overview of the demand landscape and highlight the major business drivers in the verticals. The agenda will involve the flow of the data-driven revenue streams among the CEI stakeholders and potential vendor lock-ins. Discussion about potential gaps will indicate business opportunities and incentive cooperation among the participating experts. We expect a minimum of ten participants from different European countries in each sector-specific VCA, overall a minimum of 50 experts. The expected results of wave 1 workshops will be domain-specific needs and refinement of the business cases or new potential opportunities and will be incorporated in the Readiness Framework, Work Package 2.

4.2 Wave 2 workshops

In the wave 2 workshops, we will present preliminary service requirements to the established value chain adopter groups to trigger feedback and refinement ("yes, that is important; no, not important; you are missing something") and assess the relative desirability of different service offers that might be made by specific types of players. Newsletters, information on updates of CEI demand landscape, and dissemination events will maintain the interest of the value chain adopters by keeping them informed on project activities and insights. For example, would buyers in the logistics/mobility domain be more willing to purchase vehicle location services from a truck manufacturer, a mobile communications company, or a US hyperscale cloud provider – or would they prefer to integrate their own solution to control the flow of associated data? The wave 2 workshops will capture key legal, social and ethical (trustworthiness) issues expected to affect both deployment and adoption. Many of these issues will already be reflected in the Readiness Framework, but newly identified factors will be incorporated into a revised Framework.

Same as the "wave 1" workshops, we expect a minimum of ten participants from different European countries in each sector-specific VCA.

4.3 Cross-domain expert panel

A cross-domain expert workshop (wave 3) will be convened to validate the synthesised market scenarios. The combined expertise of this group will enable it to work with a complex set of buyer preferences and elucidate overarching patterns in the validated service requirements, pointing to likely market structures, the pathways that will result in those structures, and the actions and decision points that will favour those pathways. Possible future market structures will be evaluated for their desirability as well as for their feasibility, based on the maturity of the required technology (reported by the Supply CSA) and the availability of required ecosystem actors (e.g. knowledgeable and trusted system integrators). We will discuss the role and the alignment of open infrastructures such as Gaia-X standards, open-source software, and large-scale pilots in de-risking these market development pathways and accelerating deployment and adoption.

For the final discussion, we expect a minimum of 20 participants from different European countries.

4.4 KPIs measurement and contribution to project KPIs

WP3 targets the following KPIs, which target the engagement of the relevant stakeholders from the CEI supply side and from the sector-specific ICT providers from the targeted industry domains. The following table includes the description of the KPIs and the execution plan.

KPI	Target and Deadlines	Plan	Other supported/connected KPIs
KPI 3.1: Organise 5 value chain adopter groups	at least 10 stakeholders actively contributing to the project's collaborative events	M7-M16	KPI 1.3 Identification of top 3 CEI use cases (WP1)
KPI 3.2 Successful organisation of 11 Value Chain Adopters (VCA) collaborative events (1+1 event for each of the 5 Value chain groups plus a cross-domain final event)	at least 50 stakeholders actively contributing to the project's collaborative events	M7-M16	KPI 2.1 Develop 25 service requirements (WP2) KPI 2.2 Achieve High Evaluation Score for Service Requirements (at least score 4.0 in a scale 0 to 5 in terms of responsiveness to users' requirements) as rated by Value Chain Adopter groups (verified in D3.3). KPI 5.4 Multi-stakeholder community database (WP5)
KPI 3.3 80% of Value Chain Adopter groups and other stakeholders contributing to the final D.2.5 Demand Position paper.	at least 35 stakeholders actively contributing to the project's collaborative events	M20	KPI 2.1 Develop 25 service requirements (WP2) KPI 2.3 Develop 5 Market Scenarios Validated and Evaluated for Desirability by Cross Domain Expert Panel (verified in D2.3). KPI 2.4 Identify 10 key actions, decisions or framework conditions assessed by experts to have the most influence on the development of desirable future market scenarios (verified in D2.3).

Table 1: Key Performance Indicators for Value chain adopter groups