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UNLOCK-CEI

Sector-specific service requirements, data flows and revenue streams in Cloud-Edge-IoT value networks

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D3.2 – Sector-specific service requirements, data flows and revenue streams in Cloud-Edge-IoT value networks

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Glossary of terms

Item	Description
AGV	Autonomously Guided Vehicles
V2I	Vehicle-to-infrastructure
RSU	Roadside Units
VRU	Vulnerable Road Users
V2X	Vehicle-to-X
ANM	Active Network Management
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
WP	Work Package
IoT	Internet of Things
IT	Information Technologies
SME	Small and Medium Enterprises
IIoT	Industrial Internet of Things
OEM	Original Equipment Manufacturer
SRIA	Strategic Research and Innovation Agenda
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
AENEAS	Association for European NanoElectronics ActivitieS
INSIDE	INSIDE Industry Association
TSO/DSO	Transmission System Operators/Distribution System Operators
HVAC	Heating, Ventilation and Air Conditioning
WG	Working Group
V2G	Vehicle to Grid
EV	Electric Vehicle
E.DSO	European Distribution System Operators
DER	Distributed Energy Resources
EASE	European Association for Storage of Energy
IRENA	International Renewable Energy Agency
DERMS	Distributed energy resource management systems
AGV	Automated Guided Vehicles
ITS	Intelligent Transport Systems
CCAM	Connected, Co-operative and Automated Mobility
V2X	Vehicle to X
DBV	German Farmers' Association
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 26th May, 2023.

Executive Summary

VDI/VDE-IT together with partners organised the first wave of the workshops to discuss the open market opportunities for information, data and revenue streams, new data-driven market design initiated by the European Data Strategy as well as new requirements stated by the European Green Deal.

The value chain adopter groups were invited to five virtual workshops designed for the industry sectors: Manufacturing, Agriculture, Healthcare, Transportation and Energy. Invited experts from the industry and participants of the workshops were asked to present and discuss example CEI use cases and elaborate on corresponding service characteristics.

The discussions and analysis of the evolving data-driven value chains/networks revealed new stakeholders, data, information and revenue streams, gaps, barriers and also potential business opportunities that would accelerate CEI adoption. Additional in-depth interviews with selected experts allowed to capture a more detailed and complete picture regarding CEI service offering under consideration of legal, political, economic and environmental aspects. Based on the collected insights, we formulated first recommendations for topic areas for upcoming large-scale pilots.

The final conclusion outlines the advantages of IoT, edge and cloud computing systems and presents an outlook for the next second workshop wave.

Table of Contents

List of Figures

1. Introduction

The main focus of this report is the interaction with the value chain adopter groups in order to collect and understand the demand needs regarding Cloud Edge IoT solutions and service requirements. The report builds on the results of the deliverables D 3.2 "CEI ecosystems overview with the value chain adopter groups", D 1.2 "Readiness Framework and Service Requirements", and currently updated D 1.1 "Cloud-Edge-IoT Demand Landscape".

During the preparation phase of the value chain adopter group events, we approached the industry associations and stakeholders that we identified in D 3.2 "CEI ecosystems overview with the value chain adopter groups". Our goal was to engage the major stakeholders: end users, ICT providers, system integrators, edge, cloud, sensor, chip and embedded systems vendors to cover the sector-specific value chains described in D 3.2. The stakeholders of the value chain adopter groups were invited to a series of workshops in order to collaboratively develop demand-pull business opportunities (see Objective 3.2)[1].

The results described in this report provide the end users with an overview about use cases and already running commercial or research pilot projects, to leverage the benefits of CEI technologies and how they can be applied in the agricultural, manufacturing, health, transportation and energy sector.

For the CEI technology providers and in particular for business developers, this report provides insights regarding potential business opportunities, data and revenue flows as well as potential gaps in the value chains/networks. The collected service requirements are important for commercial CEI users and providers as well as for the researchers involved in the scientific projects. The resulting service requirements will help to meet the specific demands on CEI service characteristics from the perspective of the agricultural, manufacturing, health, transportation and energy sector.

For the European Commission, this report encompasses first ideas regarding the topic areas for the large-scale pilots that would meet the demands of the analysed sectors and facilitate the adoption of CEI technologies.

This report is structured into introduction, methodology and sector-specific sections that focus on the value chains, service requirements and key insights distilled from the interaction with value chain adopter groups. The final conclusion provides a cross-sectoral overview about the data and revenue flows in the value networks and main service requirements.

2. Methodology

Together with partners, we organised the first wave of workshops consisting of five virtual events aimed at the target industry sectors: Agriculture, Manufacturing, Health, Transportation and Energy.

The workshops were conducted on the following dates:

Industry sector	Date	Number of registrations	Companies and organisations that actively participated in the discussions

[1] Objective 3.2 Collaboratively develop demand-pull business opportunities for CEI solutions. Leverage the value chain adopter groups for the aggregation of demand needs and the collaborative identification of potential business opportunities, building on the use cases and service requirements developed in Objectives 1 and 2, assessing potential benefits as well as barriers. The potential costs of migration to the Cloud-Edge-IoT will be examined. These results will update the Adoption Readiness Framework.

Manufacturing	16.02.2023	31	LMT (LT), Fraunhofer IIS (DE), AI Hub Noord (NL), eco Verband DE, Bosch (DE), esc-aerospace (DE)
Agriculture	17.02.2023	34	Wageningen University (NL), Bosch Sensortec GmbH (DE), Austrian Institute of Technology AIT (AT), FBK (IT), ATB Institut für angewandte Systemtechnik Bremen GmbH (DE)
Health	10.03.2023	45	Fresenius Medical Care (DE), University of Eindhoven (NL), Bosch Sensortec (DE), Six Square (CH), Philips (NL), ISEP (PT)
Transportation	17.03.2023	45	EasyMile (US),Traffico ltd (FI), Yunex traffic (DE), ISEP (PT), tsenso GmbH (DE), AVL(DE), ART (Ireland), FLIR (US), SCHWIETERING Ingenieure GmbH (DE), consider-it GmbH (DE), Schlothauer & Wauer (DE)
Energy	23.03.2023	41	Six Square (CH), Nydor System Technologies AE (GR), Noovle (IT), Yongatek Microelectronics (TR), Enercoutim (PT), Universitat Politecnica de Valencia (SP), Systems Research Institute (SP)

The participants of the first two workshops Manufacturing and Agriculture received in addition to the agenda also a power point presentation with instructions on the Adoption Readiness Framework.

The workshop agenda included a presentation of the survey results regarding the top CEI use cases that were identified and presented at the workshops by IDC. During the registrations to the workshops, the participants were asked, whether they would like to bring their own CEI use cases and discuss them with the participants. To support the discussions and validation of the Adoption Readiness Framework (ARF), we used a virtual interactive environment “concept board”. You will find the collected results of the discussion and validation of ARF in the Annex with supporting materials.

As a starting point for discussions, the coordinating partner IDC introduced the CEI Demand Landscape based on survey results regarding the top Cloud-Edge-IoT use cases that were relevant for Manufacturing and Agriculture respectively. After the introduction of the CEI use cases, the moderator guided the participants through the Adoption Readiness Framework in order to assess the level of CEI adoption regarding technological and organisational aspects, evaluate market demand, identify skills and talent requirement, consider regulatory and compliance factors, identify barriers and mitigation strategies towards decentralised Cloud-Edge-IoT infrastructures. The workshop structure for the manufacturing and agricultural domain was as following:

- Introduction of the top CEI use cases by IDC
- Round table of the participants and collection of use cases from the participants and expectations
- Self-assessment of technological readiness of the collected use cases
- Assessment of the use case adoption journey
- Assessment of use cases along the PESTLE (Political, Economic, Social, Technological, Legal, Environmental) dimension and five market forces (Porter)

Due to decreasing participation activity as well as feedback from the remaining experts regarding the range and complexity of the stated questions and the long duration of the workshop, we changed the design of the following workshops for the sectors Transportation, Health and Energy. Although the CEI Demand Landscape presented by IDC provided a good overview about the top CEI use cases, the participants expected to learn more about already existing CEI solutions, how they can be applied and how the end users can benefit from the data collected, transferred and processed in the CEI infrastructures.

The duration of the workshops was shortened to two and a half hours. The ARF aspects were focused on the use case implementation (Design, Installation, Operation, Value-Added Supplements, Maintenance, Disposal/Upgrade) and service requirements along the same dimensions.[2] To capture the economic perspective regarding potential business opportunities, legal, political or technical barriers, challenges and risks, we employed the value chain/network analysis methodology.

Value chain/network analysis

Value chain/network analysis methodology allows for visualisation and thus a better understanding of data, information and revenue flows between the stakeholders of a value chain or network.

We included the value chains and networks identified in the D 3.1 in the concept boards created for each sector and updated them during the interactive discussions with missing stakeholders, data, information and revenue flows, use case implementation and service requirements (see 9.3 Concept boards).

We invited experts and speakers to illustrate CEI use cases and solutions from industry and research projects to stimulate interaction during the discussions. The revised structure of the workshops was as following:

- Introduction of the top CEI use cases by IDC
- Round table of the participants and collection of use cases from the participants and expectations
- Invited presentations of Cloud-Edge-IoT solutions
- Discussion of the value chains and networks (business opportunities, challenges, gate keepers, suppliers and collaboration needs)
- Discussion of use case implementation (Design, Installation, Operation, Value-Added Supplements, Maintenance, Disposal/Upgrade)

The new workshop design contributed to more registrations and more active participation, better results and more positive feedback regarding the learnings from the workshop. After the workshops, we conducted additional in-depth interviews for all sectors (except healthcare) with experts from all five sectors to fill out the gaps in the value chain analysis and service requirements and to improve the quality of the collected data. The healthcare workshop provided sufficient information and covered all aspects that we addressed.

Based on our own expertise, we prepared the value chains/networks with data, information and revenue flows also for manufacturing and agriculture sectors and validated our input with external experts during the in-depth interviews. The interview guidelines can be found in the Appendix.

The workshop participants were recruited via invitations and announcement of the value chain adopter group events in LinkedIn, newsletters or personal contacts and invitations of the members of working groups, hosted by the industry associations such as EPoSS, CCAM, AIOTI, INSIDE, AENAES and the TransContinuum Initiative. We also approached the lighthouse projects and initiatives such as Gaia-X and AgriDataSpace, a preparation action funded by the European Union to build a Common Agricultural Data Space and invited their members to join the value chain adopter groups.

The structure of the following sector-specific chapters varies in the level of detail according to the use cases and topics addressed by the participants. As explained above, we supplemented the findings that we obtained in the workshops with in-depth interviews. This allowed us to validate the value networks and to gain more information about the data flows, business opportunities, barriers, vendor lock-ins, “gate keepers”

[2] *The experts assessed the Adoption Readiness Framework as a feasible approach. However, it was difficult for them to answer the questions during the workshops. We moved the ARF into a survey, which is currently under revision, in order to reduce the complexity and improve its usability.*

and service requirements. The resulting mix of the methodologies contributed to a more complete picture about the demands as well as adoption of CEI technologies.

3. Manufacturing

In Manufacturing, CEI technology is most often used in-house, i.e. in production environments, waste sites and warehouses, where sensors, controllers and robots are used for optimisation and automation, e.g. aiming for more economic or energetic efficiency, more throughput, better safety, better product quality or better working conditions for skilled production personnel. As of today, data-sharing is still not common in this sector. Both lack of trust and lack of technological capacity still limits the application of multi-stakeholder CEI use cases (e.g. for supply-chain optimisation).

In these applications, edge-computing serves to efficiently process large amounts of data that are recorded by sensor-networks, cameras or robots on the shop-floor. The pre-processing of data on the far edge, close to where it is recorded, decreases the volume of data dramatically, which in turn makes storage and real-time processing a lot less demanding. Locally implemented closed-loop systems can function more reliably in real-time if network connectivity is insufficient. Those edge-systems only occasionally make contact with the company-wide IT-infrastructure, e.g. for reporting statuses or for maintenance or updates.

CEI solutions in manufacturing can still not easily be transferred from one application scenario to the next. This is mostly due to the individual nature of the set-up and processes in each plant as well as to high regulatory demands and to the fact that solutions have to be integrated into a pre-existing grown IT-landscape, with a diverse range of standards, connectors and interfaces being commonly used across the ecosystem. Some proprietary pre-existing systems are also designed to make data or machine re-purposing deliberately hard. The uptake of CEI technologies in Manufacturing therefore nearly always involves extensive research and development. Whereas large manufacturing companies have internal divisions in charge of the design, installation and maintenance of CEI technologies, manufacturing SMEs usually have to work with a range of external service providers, who are trusted partners that have to interact closely with both management, IT and production staff. Apart from such solution providers (e.g. analytics, AI, robotics or automation service providers), also component suppliers (e.g. of sensors, robots, microcontrollers) and infrastructure providers (e.g. of technical platforms, network services or software services related to infrastructure) are parts of the value chain. According to the UNLOCK-CEI survey conducted by IDC in WP1 (see Deliverable D1.2), the most relevant use cases for the manufacturing domain are:

- **Asset Monitoring and Maintenance** involves the use of IoT-systems for identifying changes in manufacturing equipment. These systems aim at more efficient monitoring and maintenance of the assets, e.g. by prompting a maintenance process if a problem is detected or by suggesting different production parameters to the workers if changes are detected. As IoT sensor data tend to be high-dimensional, edge devices are often used for pre-processing. The survey identified Asset Monitoring and Maintenance as the most common current use case and the most common future use case if current usage and planned usages are taken together.
- **Autonomously Guided Vehicles (AGVs) and Robots** are used to automate the moving of parts and inventory in factories and warehouses. Apart from greater efficiency of production and intralogistics, such systems can also have safety benefits, e.g. by reducing accidents or preventing injury while performing straining, repetitive movements. Robotic systems that operate in the same environment as human workers (service robots) require very fast and reliable reactions to unpredictable events. The use of edge-computing is therefore necessary to fulfil the real-time demands of such applications. For the same reason, these types of applications are comparatively immature. According to the IDC survey (see D1.2), they are ranked #13 among the currently adopted manufacturing use cases. However, their potential, importance and foresight of increased

implementation of edge in the next few years, paves their way to the top three future use cases for manufacturing domain.

- **Visual Inspections and Quality Control** leverage the power of AI-based analytics to identify problems with manufactured goods and thus improved product quality, to improve costumer experience or to minimise the amount of reject. These systems are often based on high-dimensional sensor data, most commonly camera images that are usually pre-processed on edge-devices for dimensionality reduction. The AI-models are commonly trained, managed and updated from a (local) cloud. With #one in current usage, #two in importance and #three most common future use case (see D1.2), if current usage and planned usages are taken together, visual inspection and quality control are a runner-up to asset monitoring and maintenance in terms of being both attainable and desirable.

Overview of Manufacturing VCA workshop and interviews:

The discussion started with a presentation of an asset-monitoring use case presented by a representative from the German Fraunhofer Institute for Integrated Circuits (IIS) in which they had been active as research and development service providers. To get insights into value networks and revenue streams, two in-depth interviews were conducted. The first interview was done with a representative from the German aerospace manufacturing solution service provider Hanse Aerospace Wirtschaftsdienst GmbH. The use case discussed was an edge-system for automated control of a valve and a door to ensure occupational safety as well as product quality. It was based on a camera installed to monitor the surrounding premises (presence of people and safety masks). A follow-up use case for condition monitoring of the valve was also discussed, which uses the European Factory Platform (EFPF) as cloud-edge environment. The second use case was also an asset monitoring use case presented by both a representative of the Italian metal sheet manufacturer S.C.A.M.M. and two representatives of their research service provider Intellimech, also Italian. The output of an existing network of sensors on a fully automatic transfer line is used to detect anomalies in production and also to learn the skilled labourer's responses to those anomalies, for an assistance system that can prompt intervention and suggest suitable parameter settings based on historical data.

All end-using manufacturing companies involved were SMEs. Due to the fact that CEI research or solution service providers interact closely with the customer, the interview partners were familiar with the requirements of end-using manufacturing companies even in those cases where no end-user was directly involved in the discussion. All of the use cases involve close interaction with human workers in the production facilities during interaction, which drives many of the requirements (see Sect. 3.1.2)

3.1 Value chains and revenue streams

We narrowed our analysis down to CEI applications in m**anufacturing SMEs** that act as suppliers to manufacturing corporations further down the value chain (e.g. large **OEMs** in the automotive or aerospace sector), given that this is the user group that participated in our activities. Figure 1 depicts the value chain for this scenario as well as the data, information and revenue streams.

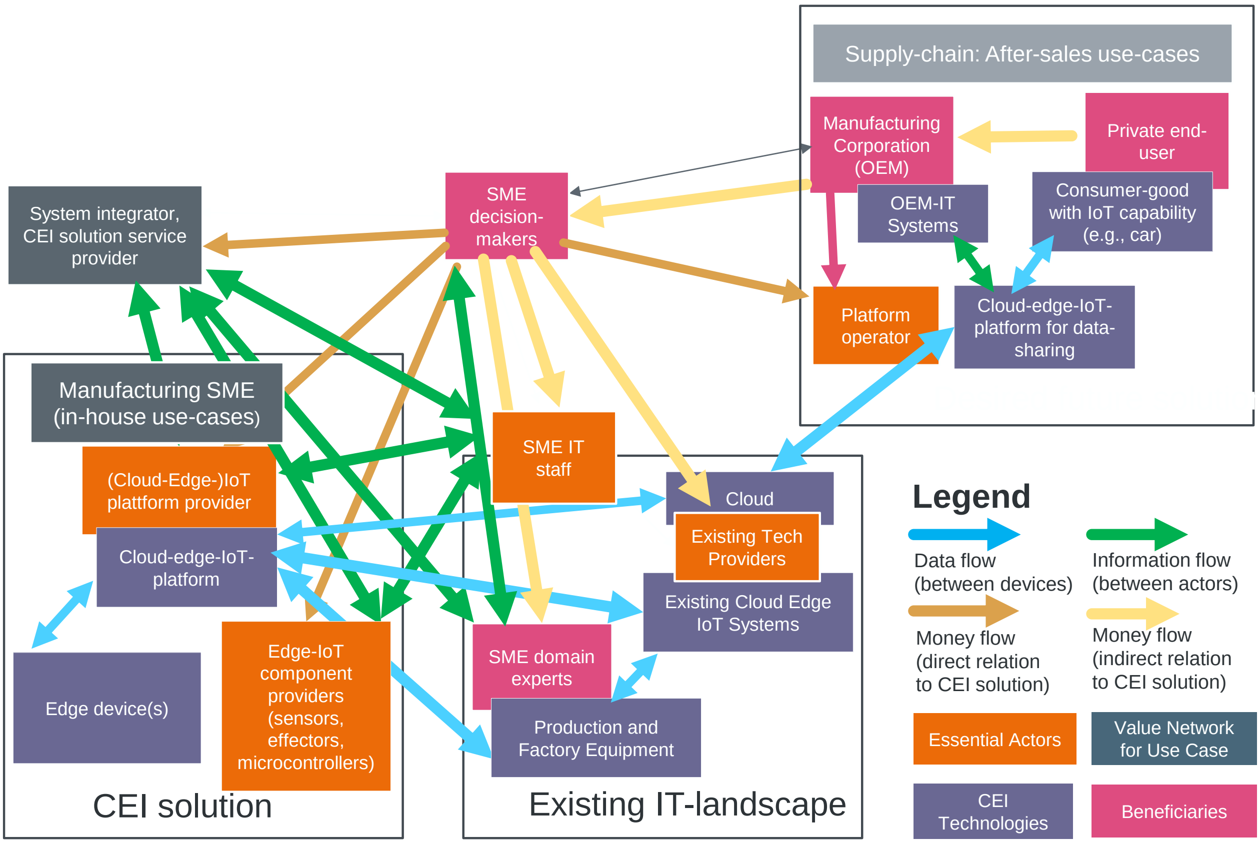

Figure 1: Value chain for internal CEI use cases in Manufacturing SMEs as well as for desired future after-sales use cases

The diagram focuses on the in-house use cases described above, which directly include an end-using manufacturing SME and its technology providers. The revenue streams in this case go from the SME to different providers involved with deploying the CEI solution to a given production setting. The OEMs play no direct role for these internal CEI use cases, but it was stressed that their changing requirements, e.g. in the face of the pending supply chain law, can serve as relevant enabling or limiting factors for the adoption or design of CEI technologies.

The adoption of internal CEI solutions in manufacturing is very laborious. It requires **extensive customisation of the solution** to a given specific production set-up and a difficult **integration of the solution into the production company's existing IT-landscape**, which involves a number of components from different suppliers and service providers, including **Cloud-Edge-IoT Tech providers** (pre-existing systems for asset control), **Cloud providers** (for the company IT-infrastructure) and others.

SMEs do not usually have the in-house expertise or internal resources to develop, deploy and evaluate CEI solutions, which is why **CEI service providers** (e.g. R&D service providers like our participants, system integrators for robotic solutions, AI or automation service providers, etc.) play a key role for the uptake of CEI use cases in the manufacturing sector. They oftentimes communicate with other technology providers on behalf of their client (see blue arrows above). The involvement of these service providers (can be one or several, e.g. one for analysis and one for system integration) is limited to the R&D phase and should rarely if ever have to be reactivated for system maintenance.

The deployment of a novel CEI solution typically requires **a technical IoT platform** (from commercial or open source providers), because setting-up and maintaining an own runtime-environment (such as a Kubernetes-environment) is often not feasible for an SME's IT department. Developers of **data connectors and interfaces for such platforms** were explicitly mentioned as central players. A possible purchase of additional IoT equipment (e.g. sensors, cameras, edge-microcontrollers) also brings in possible new **component suppliers** to the network.

As CEI solutions for the manufacturing sector are usually internal solutions, **company-internal actors** were also identified as central decision makers, even if they are not part of the value chain diagram. First and foremost, the **manufacturing domain expert** whose workflow is altered by the CEI system was mentioned by all participants as a central and decisive stakeholder (see requirements). Secondly and maybe more obviously, **company decision-makers** have to see that the company benefits from the system. Lastly, the **IT staff** also plays an important role during system integration and operation.

As an addition to the internal use cases that are most important in Manufacturing at present, we also included an after-sales CEI use case in the diagram (Figure 1) because it was described as a highly desirable future application in one of the interviews. It concerns CEI infrastructure that makes it possible to provide data-driven services to or receive data or information from stakeholders further down in the manufacturing value-chain, i.e. after the SME sold its product. Specifically, the OEMs and private end-users of their manufactured goods were mentioned as attractive target groups in this scenario. This use case requires that the consumer goods be equipped with CEI capability (as it is the case with cars nowadays) and that they connect to a platform that allows data-sharing or also deploying after-sales digital services to the consumer good. As this use case was only described in general terms, no revenue streams concerning those transactions are modelled. However, it is assumed that manufacturing companies pay for the enabling CEI infrastructure.

3.2 Service requirements

The service requirements expressed by the workshop participants and interview partners were mostly unanimous concerning the motivations, key requirements and pain points of manufacturing SMEs. We will briefly review these general points before diving deeper into individual requirements along the CEI-innovation lifecycle.

The participants were adamant that Manufacturing SMEs weigh several company goals in their cost-benefit analysis when deciding about the uptake of CEI solutions. The **economic bottom line** was of course important, but other relevant company goals were also mentioned, i.e. an improvement of workplace **safety** or **working conditions**, increased **automation** to address the skilled labour shortage, **preparation for a changing market** (achieving CEI-readiness for future use cases, increased company resilience, expectancy of new demands from OEMs, achieving ecological sustainability…), **marketing benefits**, and an early-mover **competitive advantage** or **distinction from the competition, e.g. by offering better products or a better customer service.**

The main pain points in the context of CEI technology uptake are:

- **Skilled labour shortage**: Domain experts in production are hard to recruit and to train. The existing staff is overworked, which limits production capacity. When domain experts leave or retire, their "guru knowledge" of the production processes leaves with them. This circumstance is, on the one hand, a driver of CEI use case adoption, as CEI systems can support the workflow of production workers, improve their working conditions and safety, automate (tedious) parts of their workflow or even learn some of their "guru-knowledge". On the other hand, it is also a limiting factor, as systems that create additional overhead for these workers (e.g. for data entry or because the system is complicated to use) or systems that are not perceived as trustworthy or useful by the domain expert are not viable. Domain experts therefore act as technology gate-keepers.
- **System integration and customisation:** As already mentioned, the uptake of CEI use cases by manufacturing SMEs today implies high costs for system integration and customisation. Even if there are economic advantages to be expected eventually, a lot of SMEs shy away from the often substantial **initial investment** associated with the uptake of CEI use cases. Similarly, the expectation of high maintenance costs can make company decision makers decide against deploying a solution

after a promising pilot study. Anything that can reduce these efforts and costs is a driver of CEI use case uptake. Manufacturing SMEs are also notoriously suspicious of any technology that involve data-sharing or carry a perceived risk of information loss, which is why they prefer on-premise solutions from trusted partners over use cases that involve cloud-infrastructure.

- **Innovation pressure and competition** are central drivers of CEI use case uptake. They should offer competitive advantages, which of course primarily implies economic benefits, but also includes marketing benefits or an increase in CEI readiness. Solutions are to be seen as one step in a larger digital transformation journey, and should therefore be designed to afford future innovation opportunities.
- Applications that involve **data-sharing along the supply chain**, such as the after-sales use case mentioned in one interview, hold a very large potential to generate additional value and thus provide early movers with a competitive advantage. Pioneering manufacturing SMEs therefore actively pursue this vision despite the understandable mistrust prevalent in this sector. They actively foster trust relationships with their partners and define terms and conditions for sharing data rather than sticking with a hard “no”.

Concrete requirements mentioned were the following:

Design

- Solutions must be tailored to fit into the processes and workflows on site.
- Solutions should offer competitive advantages/benefits for the manufacturing company, where goals range from more efficient production to better workplace safety or working conditions or the capacity to offer better products or better customer service in the after-sales phase.
- It is a plus if the system can learn the tacit expert knowledge (“guru-knowledge”) from the domain expert, e.g. optimal parameter settings for a machine, given certain variations in the input material.
- Manufacturing companies might require custom sensors or other IoT equipment in small lots, which vendors nowadays do not usually offer.

Installation

- Installation must be cost-effective. The main cost drivers are the costs of system integration and customisation associated with CEI use cases, so anything that can reduce these costs is beneficial. Advances in standardisation of data formats, data models and interfaces were most frequently cited as levers for progress in this area. Proprietary systems with proprietary interfaces as part of the existing IT landscape were named as limiting factors.
- For possible future solutions that might provide end-consumer data after sales, similar limitations apply: there has to be a reasonable ratio between the added value expected by the data and the costs of purchasing a data service.
- Installation of CEI use cases for manufacturing SMEs is not an event but a process – therefore, it is advantageous if not required, that staff on site (domain expert) be trained to a certain extent to evaluate what is going on from a CEI technology perspective (data and digital literacy, rudimentary workings of the system)

Operation

- The system has to work robustly in real-time (in terms of user experience, so tens of milliseconds of latency are okay, not in terms of time-critical asset control), even in the presence of internet hiccups. This implies that, unless an expensive communication solution is installed, only offline processes, such as AI-model-learning, should happen in the cloud.
- As these systems will usually not function fully automatically, a user-interface and good usability of the system for non-engineers (domain experts) is required. The system should integrate smoothly with and support the workflow of end-using domain experts.

- There should be no or minimal extra chores for the skilled labourer (such as adjusting the position of a component or entering data).
- The system should comply with all regulatory demands of the sector and with the quality requirements of the use case.
- The system should protect sensitive and personal data, thereby increasing the acceptance of end-using domain experts.
- For systems that connect with technology outside the SMEs premises, they have to strictly protect information security, be transparent about the data flows and make data usage control possible.

Value-added supplements

- The solutions should be scalable, i.e. should be transferable to other production lines.
- The CEI infrastructure and data connectors from one use case should pave the way for future CEI use cases, making it easier to innovate in the future.
- Specifically, the data available might be used to open up avenues for external monetarisation strategies, e.g. by offering improved customer service for the OEMs based on the data assets gathered during deployment of the initial CEI system, e.g. to assist their Q/A or to help them comply with the pending Supply Chain Act.

Maintenance

- Robust deployment (little maintenance requirements) is essential, as manufacturing SMEs usually do not have staff on site to perform system maintenance.
- The system should be designed in such a way that non-engineers are able to perform basic system maintenance tasks (no-code/low-code approaches).
- Customer service should be reliable, with a known and trusted contact person for the customer.

Disposal / Upgrade

- The system should have a long lifetime.
- Upgrades should be performed without interruption of the system.
- For major upgrades, training of on-site staff should be offered.

3.3 Key Insights

At least with our focus on manufacturing SMEs, most CEI use cases are in-house use cases, aiming to increase efficiency, reduce costs and/or to improve on non-economic company goals, such as improved working conditions or workplace safety. The value-chain in this case does not directly involve data or revenue flows from or to other players in the manufacturing ecosystem – the only stakeholders involved are the manufacturing SME and its different technology providers. Their main pain points are the skilled labour shortage, innovation pressure and high costs for installing and maintaining CEI solutions, which are due to the fact that solutions cannot easily be transferred from one application setting to another. Each installation requires extensive work by specialised IT-service providers. Therefore, the uptake of CEI use cases in the bulk of the manufacturing sector occurs gradually, company by company, use case by use case. Even if data-sharing is still uncommon, pioneering SMEs are starting to pursue use cases that also extend the company boundaries, sharing data with partners, and purchasing data from external sources or providing data-driven after-sales services. As these kinds of CEI use cases promise a lot of added value in the future, they should also be considered in innovation policy.

For an increased uptake of CEI use cases in this market, several key requirements have to be met:

- Apart from offering the company economic benefits on the long run, a reduction of the **initial installation costs is required for an increased market uptake of solutions**. SMEs operate on a tight budget, so the high installation costs due to extensive **system integration and customisation** are

oftentimes a deal breaker. Advances in data standardisation across the ecosystem were described as key factors for an increased transferability of solutions (which would result in a cost reduction).
- The solution should integrate smoothly into the **workflow of skilled domain experts**, supporting their work, not obstructing it or introducing new chores and obligations. This implies good usability of the system and a good user interface as well as a robust real-time functioning (i.e. a reliable Cloud-Edge-IoT platform is required; edge solutions are sometimes preferable) and minimal maintenance requirements. Staff training (digital/data literacy, operation of the system at hand) and the involvement of end-using domain experts into the design/installation process can be essential to ensure smooth longer term deployment.
- **Long-lasting, reliable customer service contacts** should be available for aftermarket care and larger maintenance requirements, as SMEs tend to not have own IT staff capable of maintaining the system.
- The system's IoT infrastructure should be designed to support also the efficient implementation of further CEI use cases.
- Sufficient and suitable innovation service providers and CEI technology providers must be available in the ecosystem to satisfy the demand
- Even if cross-company use cases, such as using after-sales data on manufactured goods or supply-chain optimisation, are at present not the most important for this sector according to the IDC survey, they hold a lot of untapped potential for generating value. Pioneering Manufacturing SMEs already start research and development in this area.

Points of action to accelerate the uptake of CEI use cases thus include:

- Professional associations and public bodies should boost existing standardisation efforts in the manufacturing sector, as this serves to reduce system integration costs, which is a major obstacle.
- Solution providers should additionally improve the transferability of their solutions by identifying aspects of the innovation work-flow or system design that can be re-used and standardised (e.g. ML-Ops, user-centric design workflows, software components).
- Solution providers should develop the systems to high standards in terms of robustness and user-friendliness, including low-code/no-code interfaces for basic system maintenance and adaptation.
- Solution providers should adhere to strict data security standards and offer solutions that decrease the risk of losing sensitive information to an absolute minimum.
- Solution providers, employers and public bodies should offer training of manufacturing professionals in digital and data literacy, so that they can participate in designing the innovation, e.g. by validating system behaviour, controlling data entry or performing basic maintenance or adaptation of CEI systems.
- Technical platform providers should improve the functional reliability of their product and post-market customer service. The EU and professional manufacturing associations should support those players in these efforts that adhere to Open Data and Data-Sovereignty standards, in line with European values and the strategy of the EC. Those solutions protect the interests of the manufacturing companies and ease their future uptake of CEI solutions.
- Boosting the amount of CEI Tech solution and component providers that cater to SMEs in the market, e.g. by offering suitable professional education programmes.
- Public bodies should financially support individual CEI innovation projects in SMEs to help them with the initial investment and thus boost CEI-readiness across the sector.
- Public bodies should specifically support pioneering use cases that explore data sharing across the manufacturing value chain such as optimisation based on after-sales data, providing after sales services and the optimisation of supply-chains. In selecting such projects to support, funders should pay special attention that the solutions are in line with European values concerning data-sharing and that all stakeholders (SMEs, private consumers, OEMs) see their interests respected by the solutions.

3.4 Conclusions

The requirements for future CEI solutions for Manufacturing thus have to be seen in two stages.

In-house use cases (stage 1):

CEI use cases in European Manufacturing SMEs to date are and will be for the predictable future, predominantly internal applications, aiming at optimisation, improvement or automation of the existing processes. To this end, partially autonomous systems and robots are deployed to shopfloors and warehouses. A limited research and development budget and heterogeneous, organically grown IT-landscapes with diverse and proprietary standards and interfaces imply high system integration costs for each solution and thus pose a critical limitation on the scalability and uptake of CEI solutions in Manufacturing. This implies the following central requirements.

- CEI solutions have to work robustly and reliably in real-time. This implies, firstly, that architectures should rely on edge-computation to deal with large data volume and high velocity and bad connectivity at present. It secondly implies that real-time communication in cloud-edge systems should become more reliable in the future.
- CEI solutions at present should be realised as affordable on-premise-edge systems with a clear benefit to the company, to address both the limited budget and the prevalent fear of exposing sensitive or valuable data or information to competitors or customers.
- However, CEI solutions should also aim at increasing CEI-readiness, e.g. by adhering to current data interoperability standards or by deploying a local platform to manage service operation, update and maintenance company-wide, thus decreasing costs and effort for the uptake of future CEI use cases (internal and cross-company).
- Given the skilled labour shortage and the fact that CEI systems in Manufacturing are nearly always deployed as assistance systems that interact with skilled labourers, solutions have to be very user-friendly with the domain-experts as end-users in mind. CEI systems should strictly support these effective gate-keepers and integrate smoothly with the existing processes. Even if IT-service provider involvement is nearly always necessary for design and installation, operation, basic maintenance and update of the CEI solutions should be possible without their involvement. Where necessary, professional training of domain-experts (e.g. in data literacy) should be offered during design and installation. CEI technology provider customer service should be reliable and prompt for those cases where on-site staff cannot solve the issue by itself.

Cross-company and after-sales use cases (stage 2):

The uptake of internal use cases, which occurs company by company and use case by use case, boosts the CEI readiness and thus technologically prepares the sector for a more remote future, where data is shared across stakeholders along the value-chain, including material providers, OEMs and private end-consumers, which will make it possible to improve supply-chain efficiency and documentation, product quality and availability, and product-lifecycle management. The manufacturing companies see this future coming and feel the pressure to prepare for it, so as to keep up with the competition and to fulfill expected future demands for more transparency from their customers (OEMs), e.g. in the light of the pending Supply-Chain-Act or expected requirements to comply with sustainability regulations. Even if this scenario is more remote, the following requirements can already be identified.

- A fear of losing sensitive data or information is prevalent in the manufacturing sector. Both technological and organisational measures to prevent such information loss as well as the possibility to control data usage (who gets to access what when) should be afforded by providers of across-stakeholder CEI systems.
- Some data assets are more sensitive than others in Manufacturing and, in the light of a generational change and pressure from customers, the sector is slowly opening up. To boost uptake of across-

stakeholder CEI-use cases, applications that do not require sharing sensitive information are preferable at first. The after-sales use cases that were mentioned in one interview, where manufacturing companies provide services to or receive feedback data from either the OEM or private customers of the manufactured good or pose a promising avenue for innovation in this sense.

- The OEMs as well as large technology service providers hold disproportionate power in the manufacturing value-chain, which they might use to assert their company interests at the cost of the ecosystem as a whole, e.g. by pushing proprietary standards to protect monopolies or by reaping all or most of the benefits from a use case. To protect the interests of private end-consumers and manufacturing SMEs alike, CEI platforms for across-stakeholder use cases should be operated and governed by impartial stakeholders, adhere to European and open-data principles and strictly comply with pending EU legislation.

Possible topics for upcoming large-scale pilots to address these requirements include :

- Standardisation initiatives and CEI solution scalability (stage 1)
- CEI solution usability, HMI and professional training for manufacturing worker (stage 1)
- CEI infrastructure robustness and reliability (stage 1 and stage 2)
- Identification of across-stakeholder and after-sales CEI use cases with a large economic value to serve as best practices (stage 2)
- Fair CEI infrastructure for the ecosystem (stage 2)

4. Agriculture

With regards to employment and revenue, the agriculture sector is comparatively small. It was still selected as a value chain adopter group (VCA) in the Unlock-CEI project because of its strategical importance and criticality for Europe. Another important factor for choosing the agriculture sector was the market forecast of the sector in terms of the CEI adoption in upcoming years. The results of the survey conducted in WP1 by IDC show that even though the current CEI adoption rate in the agriculture sector is very low, the companies plan to adopt CEI in the next five years is very promising and comparable with sectors such as transportation and healthcare (see Deliverable 1.2). Therefore, it is predicted that agriculture, although currently lagging behind, will accelerate the adoption of CEI over the next five years to narrow the gap with other sectors.

The CEI use cases for agriculture, which were identified in the survey conducted by IDC (see Deliverable 1.2), provided a substantive basis for discussion in the conducted workshop. Their focal points lay on the operations at farms:

- ***Remote Asset Tracking and Monitoring (esp. animal tagging)*** – In the widespread area of a farm with a lot of mobile assets, their management is a major challenge. This includes the remote locating and monitoring of equipment and of livestock. Especially for animals, the health and condition monitoring is important to improve their welfare and the product quality In addition, it decreases losses of animals. Asset tracking for agricultural (ag) machinery can increase the efficiency of its usage and is a basis for predictive maintenance. The applications mainly need cloud solutions and have modest requirements on data and latency.
- ***Agricultural Equipment Automation*** – This area of applications strives to reduce human labour. In the long term, fully autonomous agricultural equipment could be an achievable scenario. The expected results are higher yield, lower labour costs, remote operation and both higher profitability and sustainability in the end. This requires sensors and actuators integrated in the mechatronic systems. On the software side, Artificial Intelligence (AI) is key to improve precision and enable machines to make decisions, despite the complexity of farm operations. Regarding the cloud-edge-

continuum, the on-board automation systems are on the edge, but usually combined with cloud solutions for management and updating purposes.

- ***Precision Agriculture*** – The varying environmental conditions are challenging for precise processes. The applications for precision agriculture utilise collected data on the field and crop to control and adjust automated solutions based on the local specifics. Therefore, the applications often integrate multiple data sources such as machine sensor data, information on soil conditions and weather data. Precision agriculture strives for higher yields of crops and / or reduce used resources e.g. water, energy and pesticides. Innovative applications combine cloud solutions with edge computing for on-device automation and use distributed data collection for field monitoring.

Overview of Agriculture VCA workshop and interviews:

During the workshop with the VCA, the participants were especially interested in precision agriculture solutions. The expertise of the participants covered a broad spectrum in this context: data platforms and lakes, electronic infrastructure, open-source applications for edge and cloud computing, environmental constraints and limitations, as well as cross-cutting topics such as safety, security and innovation uptake. Therefore, a concrete use case in precision agriculture was considered necessary to ensure a common understanding. It also helps to determine specific service requirements.

Autonomous weeding was selected, as first systems are already introduced to the market and all experts in the workshop were familiar with the topic. The goal of autonomous weeding is to reduce the use of pesticides. That prevents their undesired effects on humans and the environment. Instead, a robotic, highly automated system drives across the field. The robot has camera systems and / or other sensors to analyse the plant. This way, the robot can differentiate between crop and weed for the individual plants. Then it removes the weed selectively and mechanically, without damaging the soil structure and other plants unnecessarily.

The registered participants of the VCA workshop were researchers in agriculture and CEI technologies, agricultural associations, ag machinery manufacturers as well as CEI infrastructure and ICT providers. The most active participants in the discussion came from research facilities. Some topics were not covered in detail. Therefore, two interviews supplemented the wave one results on service requirements and value networks of precision agriculture use cases:

- The interview with an industry association covered a current initiative to build a cloud network. It enables the exchange of data collected from ag machinery of different manufacturers with software systems from various providers. This allows farmers to combine their data of farming equipment such as harvesters in one software solution, regardless of the equipment's manufacturer.
- The other interview explored the perspective on innovative CEI applications for precision agriculture. In the talk with employees from the development department of an OEM, they gave insights into their current projects on AI-controlled ag machinery for a new level of intelligently automated harvesting.

The following value network and service requirements depict the results of the discussions during the workshops and were finalised in the interviews.

4.1 Value chains and revenue streams

The following figure illustrates value network and revenue stream for precision agriculture applications, which was deducted from the discussion in the VCA workshop and both interviews:

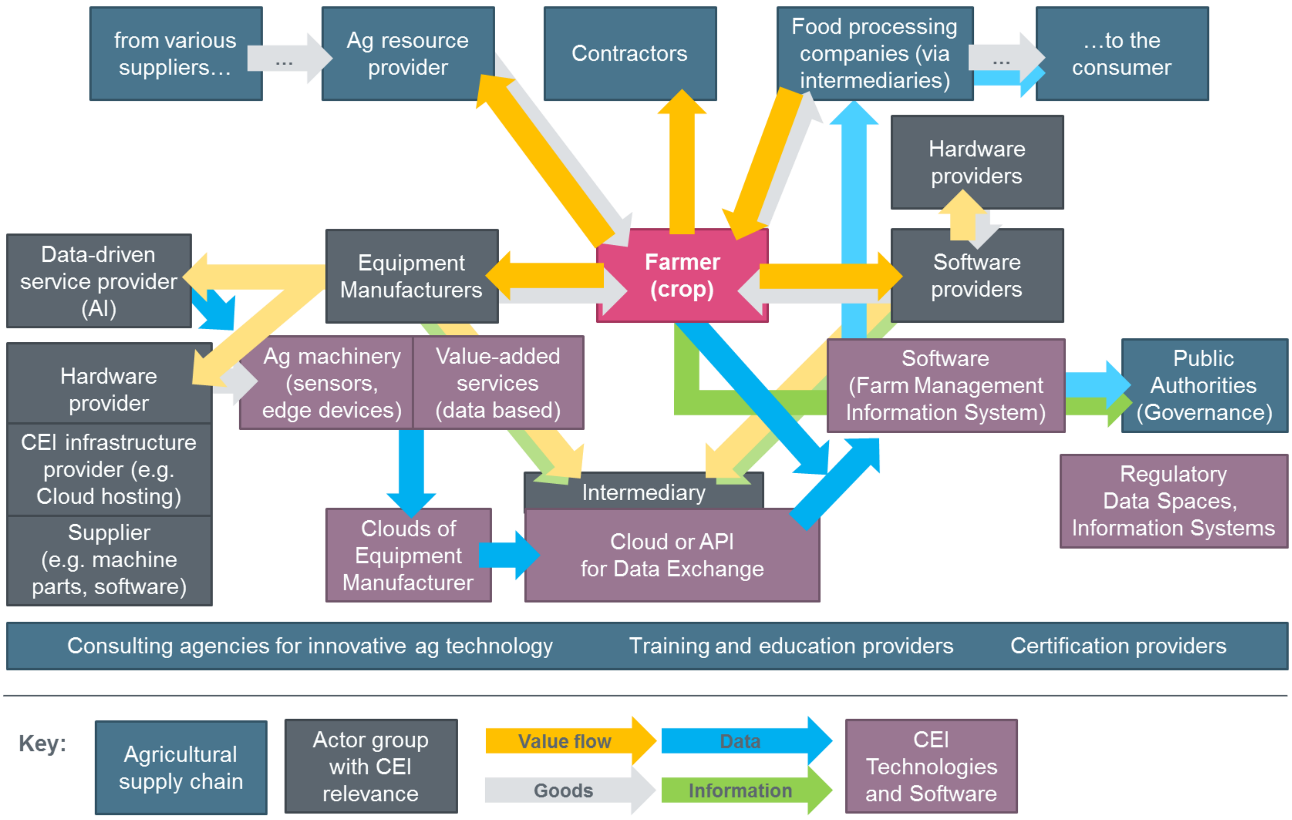

Figure 2: Agricultural value network for precision agriculture – actors, value flow, data streams and CEI technologies

For precision agriculture, CEI technologies are mainly integrated in the farm equipment. Therefore, the equipment manufacturer is essential for the uptake of CEI in agriculture. Based on the farmer's operation processes and requirements, they develop innovative solutions. The machines are typically offered in a hybrid service bundle, in combination with support, software and the fitting data-based services. When the machine is in operation, it collects data on the field and the processes. Experts differentiate telemetry data (tracking of machinery) and agronomic data (collected field data, information on the agricultural process).

As the figure shows, the farmer is the central actor (marked pink in the figure; focusing on crop such as grain and SMEs for the weed automation use case). But the equipment manufacturer is the lynchpin for realisation and operation of precision agriculture applications. The value and data flows depict this.

A farmer might use multiple software from various machine manufacturers, as they now use proprietary data structures and clouds. In addition, farmers use digital applications from other providers. These applications visualise, evaluate and process the data of farms, e.g. to meet the various reporting obligations to the authorities. Software systems are also used to aggregate and provide data on the origin of food for the supply chain (marked blue in the figure), in accordance with the European "Farm to Fork" strategy.

Farmers cannot easily and automatically integrate collected data, when equipment from various brands is used. The state of the art is that data is stored in the cloud of each machine manufacturer and has proprietary structures. Data exchange is often done manually, e.g. via USB. Manufacturers of ag machinery are currently making considerable efforts to increase interoperability. The diagram already shows the basic functionality of the future solution with the necessary data and value streams. An intermediary enables data exchange via cloud between all participants and their respective cloud and software systems. This initiative fights vendor lock-ins with the support of the participating OEMs.

When sensor data is collected from a machine in the process, it is usually pre-processed and evaluated using edge devices and IoT. In this way, decisions are made directly in the process. AI algorithms are also used at the edge, usually in offline mode, as an internet connection is unreliable in the field. The data collected by the machine control system is transferred to the cloud after the field has been cultivated. From there, the data is then transferred to the software, either directly or via the networking solution of an intermediary described earlier.

The machine manufacturers cooperate with various suppliers, e.g. specific hardware provider for sensors like lidar systems. The cooperation for software development is particularly interesting for CEI-application, e.g. creating and updating AI solutions. Numerous AI-based applications for precision agriculture are under development in (applied) research projects. In one interview, the experts stated that this cooperation with software companies raises questions, such as how to deal with long-term operation and update of AI algorithms. The partnerships with software providers are central to the realisation of the applications. The same applies to suppliers of quite specific hardware like control units and sensors. So, both supplier groups are potential gate keepers for the precision agriculture applications. The workshop participants stated that there are numerous offers from SMEs and start-ups in this context, but the procurement processes of ag companies need to evolve and adapt.

In addition, the supportive role of consulting agencies should not be underestimated in the value network, according to the interviewees from the ag machine manufacturer. The same goes for training and education providers. Both play a critical and supportive role in the innovation adoption process along the agricultural supply chain, as the experience with precision agriculture showed.

Status of CEI-Readiness in the Sector

Cloud is an established technology and integrated with existing systems, while IoT and edge are mainly provided by third parties and used selectively. The application of the continuum as a whole is not yet in widespread practice, although agricultural experts are quite informed and involved in the CEI-technologies. So, most products, processes and platforms are rated at TRL 3 to 4 (a middle technology readiness) and they are the main focus of many on-going research projects (concrete example from the interviews: AI-controlled machinery reached prototype state). On this basis, the organisations analyse the market, take first performance measurements and start to initiate partnerships. The experts in the workshop assessed the specific use cases themselves to have a comprehensive overview on pain points, goals and benefits. But they still have open questions on the revolving aspects around the practical implementation, such as scalability, collaborations and stakeholders.

4.2 Service requirements

This chapter describes the collected service requirements on CEI-based precision agriculture applications according to the phases of the life cycle: Purchase, Design, Setup, Operations, Maintenance, Upgrades and Disposal.

First, a short introduction to the perspective on the CEI continuum in this sector: CEI is the next logical step of digitalisation in agriculture to reach advanced precision. Precision farming applications are well established in the processes and ag equipment, also applying CEI technologies selectively. The aim is to optimise (sub-)field-level management regarding crop needs, environmental protection and economic factors such as process efficiency. Getting these applications to the level of plant-specific management is the main motivation for the inclusion of the CEI continuum.

Purchase

The development of new solutions is mostly “provider-driven” according to the workshop participants. The pressure to change and innovate comes from the regulatory side, in particular the increasing restrictions on the amount of pesticides and fertilisers permitted. In addition, concrete requirements are not only communicated by farmers. Manufacturers try to explore the farmer’s needs themselves. They test and improve their machinery and processes in practice. They also work in close cooperation with research institutes and facilities. The workshop participants recommended more involvement of farmers in the initial technology development. This could help to meet the farmer's requirements better. It would also support overcoming the stated "distinctive information and knowledge asymmetry" between ag machinery manufacturer and farmer.

For the purchase decision, costs and expected revenue are the most important aspects. The costs of new farming equipment is exceptionally high in comparison to the yearly revenue of farmers. SMEs were the main customer group addressed in the workshop, although the size of farms in Europe is increasing. That is why the cost-benefit ratio over the course of the lifecycle is decisive, as equipment is purchased to be used for decades. The purchase decision should include the cost of insurance for the machine, training expenses and reduced labour effort – only to name some examples for relevant operating costs. The complexity of this and of innovative CEI-based precision agriculture itself requires information of buyers and extensive support. Starting in the procurement process, consultants and manufacturers are required to "bridge the knowledge gap" according to the workshop results.

Design and Setup

When a farmer decides to buy equipment, her local situation is very determining. This must be accounted for in the design, selection and setup of the system. Most equipment such as harvesters are suited for a range of crops and processes. The integrated CEI-solutions are also required to fit the respective producing environment (e.g. open fields vs. green housing, weather conditions) and planned crop rotation. For example the control mechanisms and algorithms for identifying weed must be implemented for all crops the farmer wants to use the weed robot for. Also, the conditions on the field vary, e.g. the height and row spacing for crops. Both the mechanical design of the robot and the software must fit the planned range of conditions and crops.

Of course, the application also has to be usable by farmers. They are used for Farm Management Information Systems (FMIS) and highly-automated machinery on the field. In the future, farmers are confronted with the complexity of the whole CEI-continuum. Therefore, seamless data flow and high usability is a fundamental requirement for convincing the farmer to buy and use the application. Ag machine manufacturers are aware of this and cooperatively develop the needed interoperability solutions for data exchange. Also, consultancies and training providers are often involved to inform on such ag innovations and prepare the purchasing decision.

Data-driven service providers will become key partners of manufacturers and the farmer's requirements will affect this relationship. This has an impact on the procurement processes of the machine manufacturers as well as on legal issues, for example with regard to product liability. The data-driven service providers will, for instance, develop AI algorithms based on the machine manufacturer's data. These algorithms are a central component of the product for which the machine manufacturer is legally responsible. Also, updates will be mandatory in the future. The selection of and cooperation with these service providers must be well considered, particularly in the area of AI.

In current research and development, legal issues are hindering the realisation and application in practice. For example, the interoperability issues of OEM clouds to exchange data: OEM clouds and machinery is needed because of safety issues (e.g. safety against hacking or technical errors such as corrupt data bases). In order for competing OEMs to cooperate for smooth data exchange, they require more than just secure systems. Legal clarity is needed. The contractual arrangements needed are quite complex and still raise open questions.

It is unclear how an AI-supported machine will be legally classified. The risk might be classified as high under the European Artificial Intelligence Act, analogous to fully autonomous driving vehicles. If this happens, the system would have to be certified and the range of functionalities might be restricted.

Further legal questions arise as from the comprehensive environment analysis via sensors. In an interview, the expert described this problem when using cameras. In this case, personal data could be processed incidentally, e.g. when passers-by are filmed. The resulting video data must already be pre-processed at the edge to make the people unrecognisable. An AI algorithm is required for this.

Operations

Naturally, the already mentioned requirements have an impact on operations. This section will focus on additional aspects.

Farmers need reliable systems, which means 24/7 availability of all functions, international access and robustness against the changing environmental influences such as dirt, weather and light. In addition, the offline operation of the machines is demanded. Many systems rely on suitably powerful edge applications for this purpose. Based on the collected sensor data, they compute decisions in real-time or up to real-time. For weed removing, the sensors capture plants in front of the robot. Cloud is only required for data upload and updates, when a powerful internet connection is available – unless the volume and speed of mobile internet connection would increase significantly. This needs to be internationally available and highly dependable. So, offline requirements are not expected to change in the near future.

The farmers as well as the software end users need a high usability and suitable support for the machine as a whole (mechanics, control unit, sensors and software). According to the workshop participants, the detailed operation of the CEI-part of the system is (or should be) no concern for the farmer, as it is completely outsourced to the manufacturer and his suppliers.

The exchange of all collected data (agronomic and telemetric) is required to be seamless and standardised. Currently, a lot of proprietary data formats are used and the needed interoperability of cloud systems and software solutions, as shown in Figure 2, has not been realised yet. The gate keepers are the manufacturers due to data security concerns. They are using proprietary interfaces, data structures and restricted access to sensible software and IT functions. In addition, the manufacturers provide branded FMIS compatible with the control units of their machines, which creates revenue from service fees.

The current latency and availability requirements on OEM clouds are low. The interviewees, who talked about their AI-controlled ag machine, were surprised by the amount of data collected during the tests of their prototype. They expect increasing performance requirements on the cloud services, especially regarding the data volume.

Legally, the manufacturer of the ag machinery ensures the product liability. This requires strict cyber security needs, e.g. against unauthorised tempering with the networking of automated machines. That is why secure OEM clouds collect the data, instead of freely accessible data bases. On the other hand, the farmers require to store and manage the data in software of their choice.

Nowadays, the collected and pre-processed data can be used for value-added services from the manufacturer. The market requires broader access, so that external service providers can use and expand this database, e.g. performing field analysis with humidity sensors or drones. Due to new and upcoming regulations, increasing data streams in the supply chain are expected. The CO_2 footprint for sustainability balancing of production, tracking and tracing of chemicals is a prime example. It is based on data from all steps of the value chain, which requires automated data exchange and standardised formats.

Maintenance and Upgrade

Ag equipment is purchased to be used for several decades. During this time, upgrades are central to ensure full operability and to fit future requirements such as changing regulations. Currently, most of the maintenance und updates is done by service personnel on site. In the future, it is required to update the software more often according to the interviewees. Therefore, providing digital updates over-the-air will become the common way. This requires an internet connection to the cloud, e.g. via the mobile 5G network.

One step further, even improving the software functions via updates can be required. This could mean that new software functions are added later or AI algorithms are trained further. The updated software ensures that the farmer can analyse and treat plants individually according to their specific needs. This also leads to the requirement of versioning software and for some cases, to allow the use of older versions for compatibility purposes. The same necessity for continuous retrofitting arises for the hardware. This is due to new developments of hardware, and updated algorithms might depend on that because of the growing computing power for AI in particular. A regular replacement of the control unit or other hardware of the machine is the consequence.

The disposal of ag machinery is mainly done by the provider and was not addressed further.

4.3 Key Insights

OEMs are the active designers of CEI integration in precision agriculture. They view the CEI-continuum as the next step in digitalisation, as applications of the individual CEI technologies are already established in practice. Cloud solutions in particular are commercially available and are becoming widely established. The manufacturers of ag machinery are researching how to use the CEI-continuum effectively, e.g. in combination with AI-algorithms calculated on edge.

The farmers are customers and users of the machines, thus the actual demand side. They see the CEI applications as an add-on to their equipment and select machines primarily according to the cost-benefit-ratio and the best field processing. Data-based applications are secondary, although increasingly relevant and effecting the cost-benefit-ratio. They act like consumers in this matter.

This situation is also due to the external motivation for improvements: The stricter regulations on pesticides and fertilisation are major influencing factors. Most farmers seem to be satisfied with their current machines and don’t want to invest in new ones, but there is a considerable need for action in the future. Innovative machines will make a significant contribution to comply with the emission limits. Furthermore, political initiatives such as the European “Farm-to-Fork” strategy call for data collection on field and subsequently, seamless data exchange along the value chain, e.g. for the lableling of product origin for the end consumer.

Another motivating factor for integrating the CEI-continuum is the continuous digitalisation. The availability of more detailed data allows informed and supported decision making for the farmer as well as automation of processes, striving for higher efficiency and effectiveness in the end. These efforts contribute to reducing the amount of biological and chemical substances on the field, while producing the amount of high-quality food that is needed for the nutrition of the world’s population.

The main hindering factor is the time and effort for the technical development of the needed solutions according to the broad spectrum of requirements (see previous section). Farmers are quite cost-sensitive. As the machinery is an expensive investment and used for decades, the procurement decision on new machines is challenging and needs consultation of manufacturers and consultants. In addition, the research raised a lot of legal questions.

In short, this list points out selected findings on the requirements for the large-scale pilots for precision agriculture: The solutions have to …

- be available 24/7, internationally and robust against environmental influences.
- be overall cost-effective for a long period of use to ensure economic operation of the ag machinery.
- offer both offline applicability and updateability, despite the upcoming mobile 5G networks.
- fit the upcoming cyber security norms, AI norms and standards.

- provide seamless data exchange, so interoperability and interconnectivity of machinery and cloud systems are fundamental.
- be built on a secure and reliably available (cloud) infrastructure as well as support processes from the manufacturer and partners.
- be continuously updated regarding soft- and hardware.

5. Transportation

The value chain adopter group workshop of the first wave for the transportation sector addressed demand-pull business opportunities for CEI solutions in the transportation sector including possible value chain adopters, use cases, further services requirements as well as related benefits and barriers. Afterwards, two interviews were conducted with experts who had also taken part in the workshop in order to verify and deepen the findings collected in the workshop.

As the functional scope of transportation sector is very divers considering transport modes in passenger and freight transport, the field of IT-solutions and thus conceivable CEI applications is very large. The CEI applications may concern transport networks, vehicles, traffic management, mobility services, data platfoms, logistics applications, fleet management, planning applications etc.

The workshop discussion with stakeholders started with the presentation of three use case examples which had been identified by the Unlock CEI coordinating partner IDC to set the starting discussion point:

Use Case 1: Port and Warehouse Automation

Ports and logistics hubs feature many moving elements (e.g. ships, trains, trucks, cranes, workers and operators). They also include third parties in relation to logistics business. The movement of freight, fleets and other resources must be carefully co-ordinated. IoT systems can monitor and track assets, freight and people to aid port and logistics operations. Autonomously guided vehicles (AGVs), drones and other assets may be integrated to further improve port operations.

The use case supports more efficient logistics operations, reduced loss, damage and theft, higher safety and security as well as a better visibility of port operations and integration with other systems.

Use Case 2: Fleet Tracking and Freight Monitoring

Freight tracking enables operators to optimise routes, monitor driver safety, schedule maintenance and to reduce theft. Operators can also monitor freight condition to ensure the safety of transported goods.

CEI applications in fleet tracking and freight monitoring contribute to more efficient supply chains for all types of goods.

Use Case 3: Autonomous Vehicles and Infrastructure

Automotive manufacturers add electronic driver aids to passenger, commercial and public transport vehicles on a path to fully autonomous operation. Using a range of sensors, vehicles can operate autonomously, communicated with nearby vehicles and share dare to and from the infrastructure to enable new safety features and to support traffic management.

Autonomous systems increase safety for passengers and other road users. These systems will also lead to an increase in efficiency and reduce labour efforts.

Overview of Transportation VCA workshop and interviews

More than 30 representatives from the transportation sector took part in the stakeholder workshop of the first wave. The interest in transportation-related CEI applications was high. The participants came from the following special areas: urban traffic management and traffic control, connected and automated driving, fleet management as well as ports operations and logistics. They represented application and service providers from the industry, system planners and consultants, research organisations and universities as well as automotive suppliers. There was a clear dominance of experts with traffic management background. The second largest, but much smaller stakeholder group came from area of port logistics.

At the workshop, two key note presentations were given by invited experts: María A. Burgos, Ph.D. (Prodevelop S.L., aerOS project) and Marc Schumann (Teledyne FLIR). The goal was to provide examples for CEI-based use cases in different transportation contexts. The presentations were aiming at opening up the discussion on CEI applications in the transportation sector, especially for the identification of business cases, value networks, actors, money and information flows, implementation obstacles as well as service requirements. The discussion after these presentations were also aiming at identifying ideas for innovation CEI pilot applications.

CEI - Use Case Presentation 1: Traffic Data Detection enhanced by AI/ Traffic Management Services in the Smart City (Teledyne FLIR)

The presentation was given by Teledyne FLIR, which offers a traffic data detection system that collects road traffic data in real-time using infrared cameras and thermal image processing software. The company offers a system which collects real-time traffic data (vehicle presence/counting, vehicle classification, speeds, headways, travel times) from both intersections from wider urban road networks. In combination with vehicle-to-infrastructure (V2I) roadside units (RSU), camera-based vehicle detection can also support connected and automated driving services. Data can be collected in edge platforms which are located on intersection level whereas the processing of data for wider urban areas (e.g. for traffic situation overviews) can be processed by functions in the cloud (e.g. using the Acyclica Platform or alternatively on city-based platforms).

Example 1: AI-supported traffic data detection and digital twins of the road traffic situation

There are varying quality requirements to road traffic data depending on the specific purpose in the application. Vehicle classification, for example, may require a high level accuracy which may be achieved by learning AI algorithms which process thermal images. This is also true for the presence and location of single vehicles. The goal for the future will be to provide an accurate real-time traffic situation based on the real-time location of single vehicles. Such a traffic situation can be depicted in a digital twin of an intersection or a road network. Based on the information in the digital twin, not only traffic information and prognoses will be possible but also traffic control decisions for traffic lights and other traffic control systems.

Example 2: Detection of vulnerable road users (VRU) with V2I RSU

VRU like pedestrians, cyclists or scooter drivers need to be automatically detected in order to give them better protection in traffic and to integrate them in V2X traffic control algorithms. A possible detection technology is a combination of an infrared camera and V2X roadside unit. Via the roadside unit, direct warnings about the presence of VRU can be given to vehicles in the vicinity. At the same time, this information can be used in the digital twin of the traffic situation to process it in traffic control algorithms taking into account the needs of VRU.

Example 3: Priority of Emergency Vehicles and Public Transport with V2I RSU

The public transport vehicles and emergence vehicles (ambulances, fire engines, police) obtain priority at traffic lights. New technologies enable this communication via a V2X on-board unit and a roadside unit at traffic lights. V2X technology enables a permanent two-way communication between a vehicle and the traffic control system which make priority treatment more efficient and reliable. The vehicles communicate with the traffic control system at local intersection level. If needed, data might be given to the central traffic management level which may be in the cloud.

CEI - Use Case Presentation 2: Smart Edge Services for the Port Continuum (Cyprus University of Technology)

The presentation was given by Prodevelop S.L., a project partner of the European project aerOS which has developed smart edge services for the port continuum. Two use cases were presented which deploy the CEI continuum in the environment of container handling and transhipment in seaports. The application have been demonstrated at the Eurogate Container Terminal in Limassol (Cyprus).

Example 1: Predictive maintenance of container handling equipment

The application is aiming at monitoring the current technical state of the transhipment equipment at container terminals (e.g. container bridges, straddle carriers) and the need for its maintenance. Data is collected by sensors on the crane or straddle carrier and stored there locally on an edge database. Predictive maintenance calculations are carried out at the equipment on the far-edge. At the level of the container terminal an edge server calculates the short-term maintenance needs for all pieces of transhipment equipment. A cloud server calculates a long-term prediction for maintenance needs. Both the edge server for short-term prediction and the cloud server for long-term prediction are trained with collected data.

Example 2: Risk prevention via Computer Vision in the Edge

The application is aiming at automatically detecting damage of containers during the transhipment process at the container terminal. Two video cameras mounted on the spreader locally scan the container for wholes, bents, open doors, rust, etc. Video data is recorded at the edge. Pre-trained ML models detect and classify the damage.

Two additional interviews (Consider-IT, a German consulting and engineering company in the field of digitalisation and Schlothauer & Wauer, a German engineering company in the field of urban road traffic control and management) have taken place with experts who had very actively taken part in the workshop discussion. These persons had already actively contributed to the workshop discussion and the aim of the interview was now to reflect on the value network (including data, information and money flows) as well as on involved actors, obstacles to the implementation of CEI applications and service requirements.

5.1 Value chains and revenue streams

Urban traffic management was the key domain of the impulse presentation by Teledyne FLIR. On the other hand, a significant part of the active workshop participants came from urban traffic management as well. Thus, the discussion at the workshop concentrated very much on possible CEI applications in the context of transportation in a Smart City.

As mentioned above, it was not possible to meaningfully model the value network and revenue streams for the whole transport sector based on this workshop discussion as there are too many different applications in many different functional areas. So we decided – also in accordance with the contributions obtained by the workshop participants – to concentrate on transportation in the Smart City context.

The figure below shows the model of the identified value network.

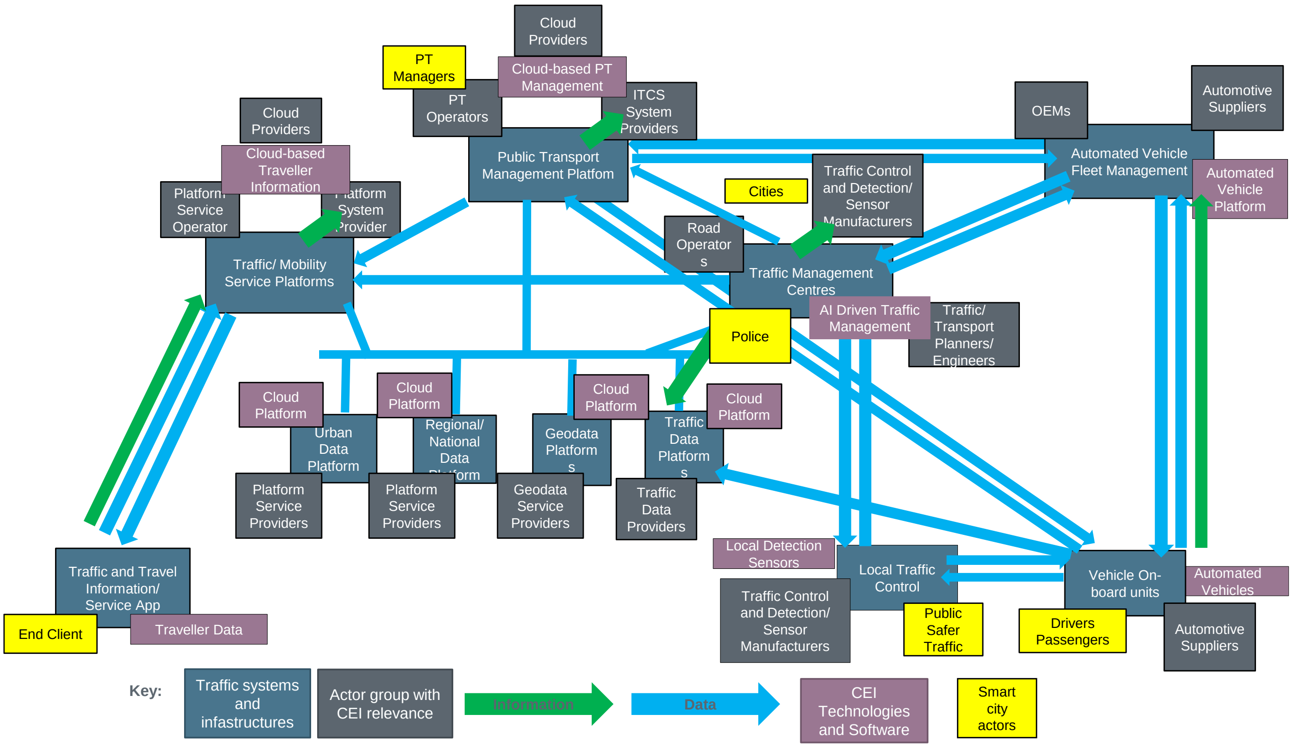

Figure 3: Model of the data and information streams in the context of transportation in the Smart City

Data and Information Streams

The graph above shows a simplified, generic model of the data and information streams in the context of transportation in the Smart City which resulted from the workshop discussions and which was in principle confirmed by the interview partners. The participants of the workshop and the interviewed experts had difficulties to provide a concrete and reliable information about the money and value streams. **The major investments in the CEI infrastructure are expected from the public sector**, e.g. local city governments. A higher quality of life for the citizens would attract more well educated people that would provide work force for industry and international companies.

The structure covers several possible use cases in urban transportation (e.g. all of the above described use cases from workshop presentation no. 1 by Teledyne FLIR and also the use case of automated and connected driving).

The table below provides more detailed information on the functional blocks of the model.

N°	Functional Block (in blue)	Definition	Associated Actors
1	Traffic Management Centres	contains all urban traffic control und traffic management functions on central level for the whole road network of a city or for larger network parts. This may also include AI Driven traffic management.	Road operators, police, traffic control system providers, traffic control system planners/engineers
2	Local Traffic Control	contains all traffic control and detection (sensor) systems which is fixed at certain locations in the road network. This may also include AI functions.	Road operators, police, traffic control system providers, traffic control system planners/engineers
3	Vehicle on-board units	contains all intelligent control and detection (sensor) systems on board a vehicle.	Automotive suppliers (of on-board units)
4	Automated vehicle fleet management	contains central functions for controlling and monitoring automated vehicle fleets.	Automotive suppliers, OEMs
5	Public Transport Management Platform	contains all control and management systems for public transport management.	ICTS system suppliers, PT operators

6	Traffic/Mobility Service Platform	contains a service platform which provides calculation for multimodal travel planning.	Platform service operators, platform service providers
7	Traffic and Transport Information/ Service App	contains an App for travel planning and information on a mobile or fixe device.	App developers, end users
8	Urban Data Platform	contains an open data space for the exchange of data on urban level.	Platform service providers, Platform service operators Cloud operators
9	Regional/National Data Platform	contains an open data space for the exchange of data on national and regional level.	Platform service providers, Platform service operators
10	Geodata Platform	contains a data space for map data (including HD road maps) location-based data.	Geodata service providers Cloud operators
11	Traffic Data Providers	contains traffic data from privately collected traffic data (e.g. FCD, PVD) from providers like INRIX, Google, TomTom.	Traffic data providers Cloud operators

Data Flows

The following table provides information on the content of the data flows

Direction	Data
1-2	Signal programme selection
2-1	Traffic data (vehicle counting, vehicle presence, vehicle classification, speed, density, headway), V2I messages
2-3	V2I messages (e.g. time to green)
3-2	V2I messages (e.g. Probe Vehicle Data)
3-4	Vehicle status, position
4-3	Vehicle software updates, routing, traffic information
1-4	Traffic information, incident warnings
4-1	Fleet position, emergency calls
5-1	Traffic information, incident warnings
4-5	Fleet position, emergency calls, vehicle parameters
5-4	Guidance for automated PT Fleet
3-5	Fleet position, emergency calls, vehicle parameters
5-3	Guidance for automated PT vehicle
5-6	Timetables, delays, incidents
4-6	Traffic information, incident warnings
6-7	Travel information, booking request, ticket
7-6	Travel information requests, booking, ticketing
From/to 8	Urban traffic and transport data
From 9	Traffic and transport data form other regions/ national / international
To 9	Urban traffic and transport data
From 10	Geodata; HD maps/ map updates
From 11	traffic data from private providers

The data spaces (N° 8 – 11) are universally connected to possible players who provide and receive data, sometimes according to the principle of broadcasting which becomes very complex. Therefore the model does not show point to point connections in this respect.

Furthermore, the three use cases mentioned by FLIR in presentation no. 1 can also be assigned to the model. However, they are **being practically developed and implemented** already now.

In the figure above, the necessary functions have been marked with purple blocks. They refer to components in the cloud, at the edge and local sensors.

Essential actors and potential gate keepers

The essential actors in the context of urban traffic management are road operators, traffic control/management/information system providers, traffic and system planners and engineers, the traffic police, public transport companies and operators of various data spaces for the exchange of the traffic and geo-data. If automated fleets are integrated, the cooperation with OEMs (automotive companies) und their system suppliers will become more and more relevant as cooperation with road operators needs to become closer. Looking at travel information services, respective IT-system providers will be important.

Important gate keepers or CEI applications:

- **Regulators** and especially **data protection officers** must create the respective framework. A problem is sometimes the storage of public traffic data of international servers in the cloud.
- AI and ML application which require strong and continuous data streams are most likely promoting the implementation of CEI applications as they minimise the data flows into the cloud.
- For the implementation of automated driving a closer co-operation between road operators and OEM must be developed.

Vendor lock-in

Urban traffic management systems are supplied by competing private companies and the systems are usually not open. It will be important that at least open and harmonised interfaces are agreed upon. One solution would be to exchange data via open data spaces.

On European level, there are different architectures for traffic control systems, depending on the country.

In the field of automated driving, OEMs also need to support an agreed architecture and interfaces. Initiatives are needed in the context of the development of the software-defined vehicle.

Value Streams (Money Flows)

The workshop participants observed that traffic management to a large extent is in the hand of the public sector. This entails that a significant part of data exchange is not charged. Mutual information exchange between parties without charging is possible.

Nevertheless, following value streams were identified:

The flow of traffic data from private data providers (INRIX, Google, TomTom) to public traffic managers and planners: The paradigm shift has already become obvious several years ago, when the private companies received more and more relevant data from navigation systems and mobile phones. So they come into the position to have – depending on the purpose – partly better traffic data than the public authorities. Nowadays, data is regularly bought by road operators.

- Road operators also have to pay a service fee if their traffic management software is located in the Cloud.
- Road operators buy systems and services from private supplier companies of traffic control systems.
- Traveller information services (e.g. MaaS) are partly not free of charge for the end user. In this case the service provider receives a service fee.
- There will be most likely a commercial relationship between the OEM and the Cloud services provider for the operator of vehicle edge platforms in automated driving. The concrete solutions, however, needs to be defined.

An interview partner observed that the money flows may change over time depending on the success of the applications and when new applications are introduced. For example, new demand management functions in urban traffic management (e.g. city tolls, new forms of road user charging, demand management/access control of robotaxis) could change money flows considerably. New business models will create new money flows.

Limitations of the depicted value network

Two limitations of the model have been discovered together with the interview partners:

- The model can only be a snapshot of the situation in relation to a certain development stage. New developments must be integrated over time and one must be aware of the point in time for which the model was made. Does it depict the state of the art or a particular stage of R&D?
- The model can only cut out a specific functional area of interest. Depicting the whole transport sector would either become very complex or so high-level that conclusions are hardly possible.
- The model does not distinguish between static, semi-static and dynamic data.

5.2 Service requirements

For an efficient Cloud-Edge-IoT infrastructure, the developers have to pay attention especially to the following service requirements:

Design

- The processing time must be considered. The CEI applications require support for real-time processing of relatively large data volumes (in relation to what is generated in traffic management systems today). The system must have the respective computational power.
- A modern traffic management system has to provide layers not only for cars, but include layers for all road users (e.g. cyclists and pedestrians).
- The system developers have to integrate the requirements concerning data protection and privacy.
- The system shall answer to all relevant regulatory and government issues.

Installation

- The number of sensors in traffic management will increase significantly with the introduction of CEI applications. Power supply at street level could become a problem. New energy sources need to be found and lamp poles need to be used.
- Solutions are needed for connecting new sensors to edge computers.
- It needs to be discussed how installation costs are covered.
- The CEI applications would require new and powerful communication capacities between city departments.

Operation

- The system must be able to cope with dynamic changes of traffic volumes.
- Data has to be real-time and correct. Therefore certification, rights management and data quality information is needed. Confidence in data is needed for many applications.
- A high data quality must be guaranteed at all times (e.g. also under bad weather conditions) using AI systems and fitting sensors.
- The data should be open and for free. On the other hand, security must be maintained.
- For the traffic data collection, the right position of the sensor is important.
- Data must be retrieve from various computers in the city.

Value-added Supplements

- The two-way communication between automated cars and traffic lights is a new value-added supplement.
- The CEI applications could contribute to a faster incident detection.

Maintenance

- The system developers should bear in mind that traffic control equipment (e.g. traffic controllers, traffic control centres) has a relatively long life cycle (on average ten years). This cycle is usually not in line with modernisation cycles of other computing equipment.
- The physical maintenance is relatively straightforward due to maintenance-friendly design.

Disposal/ Upgrade

- The long lifetime of the traffic control systems lead to a situation in which relatively old legacy systems are an issue. There must be a strategy to integrate and to replace them strategically. The full replacement of a traffic control system at all levels is a rare case.

5.3 Key Insights

The key requirements for the uptake of CEI in urban road traffic management are:

- The further digitalisation of traffic detection, control, management and information systems in European cities.
- The further integration of connected and automated driving into the urban transportation systems.
- The integration of intelligent, data-driven and AI-based technologies in traffic and transport-related applications.
- The adoption of CEI technologies by the leading industry which provides traffic control and management as well as systems for automated and connected driving.

The most enabling factor for the practical application of the use cases is the further automation of traffic detection, the introduction of connected and automated driving, improved and more powerful traffic management services (e.g. based in Digital Twins of the road infrastructure) through the use of Artificial Intelligence and Machine Learning. These kind of application require data collection in real-time based on a comprehensive sensor system and an intelligent data processing. Edge computing would allow a data analysis near the sensors.

The main challenges hindering the practical application of the use cases are:

- Cities must define their transport policy framework in which the traffic management goals are defined. Only then the suitable technological approach can be chosen.
- The regulatory framework data, especially concerning AI, data use in cloud services, data protection and privacy, need to be encrypted.
- The reluctance to use cloud services due to data protection issues (e.g. the FLIR Cloud platform Acyclica is not accepted in all German cities; alternative: a local platform on city-level).
- Making sure that road safety is guaranteed in highly automated AI systems.
- The data quality must be increased.
- Question: Would a AI-based traffic control system be fair to all road users?
- AI must not be a box: It must be transparent and trustworthy with defined rules.
- Type approval for automated AI systems – technologies must be harmonised before vehicles appear on urban streets. Certification and standardisation are the basis for acceptance.

As the workshop has shown, there are already CEI applications in operation (e.g. the operation of V2X roadside units) and CEI applications which are in development and near implementation (e.g. the improvement of camera data concerning vehicle classification). Nevertheless, there is a considerable potential e.g. concerning the establishment of Digital Twins which depict the real-time traffic situation in real-time for all road users and provide this data to traffic control algorithms.

The following topic areas would be good candidates for innovative European CEI large-scale pilots:

- AI-driven real-time traffic situation and traffic control based on real-time data on single road users
- Automotive edge platforms for automated software-defined vehicles

These use cases are **not yet available**, and currently discussed as a subject to research and development.

In short, CEI technologies can especially be useful in the context of new AI-related applications where a permanent real-time data flow can be expected between distributed system functions. This list points out selected findings on the requirements for the large-scale pilots for traffic management in smart cities:

- Decision support with predictions at strategic level, e.g. using global optimization in the cloud
- Decision support at tactical level, e.g. using edge computing systems connecting cross road infrastructures to identify accident and jams
- Traffic/pedestrian data detection and control at the local level to perform real-time actions as well as connected and automated driving

6. Healthcare

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 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:

- **Individual health monitoring:** e.g. preventive lifestyle/medical screening, use of wearables or apps to monitor own health status, prediction of future potential pathologies. This use case is built on the major trends of empowerment and healthier lifestyles in which citizens without specific medical prescription are willing **to take control of their health and to invest in it**. The regulatory framework may in this use case be lighter than in others as the devices used for the monitoring of health parameters may not necessarily be subject to the Medical Device Regulation. However, the current regulations on data privacy and protection apply.

- **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. This use case is particularly relevant for the **Internet of Things in large infrastructures** with a large inventory of heterogeneous devices (different types of devices, different generations, different producers, …).
- **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. This use case exemplifies the crucial role of digitalisation to ensure a **life-long personalised Continuum of Integrated Care**[3]. In this model, data are a link between the different phases of healthcare and enable improved personalised healthcare.
- **Home-care and telemedicine:** remote patient monitoring and surveillance, especially monitoring of vital signs and compliance to medication, robotic-assisted nursing and rehabilitation. This case may at first sight have similarities with the first case on individual health monitoring. However it follows another approach as the patient monitoring is mostly triggered by a health event requiring medical intervention. This case contributes to the **decentralisation of healthcare** in which data is playing the role of the binding agent between the nodes in the mesh and the different stakeholder groups, notably the informal caregivers whose role gains in significance in this model. Furthermore the edge-cloud continuum is crucial in managing the risks induced by decentralising healthcare.
- **Robots/AR-assisted surgery**: 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. This use case clearly aims at **increasing performances and proficiency** in healthcare with a focus on safety and reliability of medical interventions.
- **Regulatory compliance**: healthcare industry is known as heavily regulated. Systems that are used for diagnostic or therapeutic purposes need to be approved by notified bodies before market introduction and comply with market surveillance and (pharmaco-)vigilance once on the market. Clinical trials are widely used to assess safety and efficacy of diagnostics and therapies but are very resource and time intensive. **Digitalisation of clinical studies with the use of digital twins** and simulation tools may accelerate market introduction of new solutions while ensuring high standard in safety and making the link with the vigilance phase.

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:

- **Decentralisation**: Providing health care is not restricted to (few) dedicated places such as a medical office or a hospital anymore. Patients can be monitored and receive medication at home by using edge devices. More personalised, comprehensive and safe patient care is possible.
- **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. Connected and smart medical devices are the enabler for an Internet of Things in healthcare and strongly support decentralisation.

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[3] *Publication released: A model for a life-long personalised Continuum of Integrated Care revolutionising healthcare delivery | News | CORDIS | European Commission: https://cordis.europa.eu/article/id/428670-publication-released-a-model-for-a-life-long-personalised-continuum-of-integrated-care-revolu.*

- **Use of artificial intelligence algorithms**: Advanced algorithms are required to analyse the big data of medically relevant parameters generated at individual's level, to recognise patterns for improved early diagnostic of diseases, apply adapted and personalised interventions and help modelling and simulation.
- **Digitalisation of processes and routines**: Data can be collected more easily and can be used to further improve processes and build up digital twins.
- **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. In addition cloud technologies are crucial to cope with the complexity of healthcare and the tremendous amount of data as well as to capture and link the different layers of healthcare, from individual health to public and global health.

Overview of Health VCA workshop:

The workshop with a focus on the healthcare sector performed in the framework of UNLOCK CEI gave additional input to complement the overview of the value chain. Saša Marinkovic (Philips) presented an example use case "Edge-Cloud-based clinical applications platform for image-guided therapy and diagnostic imaging systems" to illustrate a novel CEI application that is developed in the scope of a KDT JU project TRANSACT[4]. The graphics below has been updated accordingly, with the addition of specialised clinics and informal care givers in the category of care providers. These two stakeholder groups do have specific requirements und utilisation of data. Similarly, public authorities and decision makers such as ministries or national health committees have been included in the payers group as they contribute to the funding of healthcare systems and decide on the allocation of resources. Finally and next to patients, we also added citizens to the last group as it is obvious that the switch from a reactive approach of healthcare toward a more proactive view (empowerment, healthy living, …) means that medically relevant data and cloud-edge services are highly relevant for all. Furthermore, the consumer market is strongly overlapping with the healthcare market at this level, letting people invest in their own healthcare. Consumers have therefore been added.

[4] https://transact-ecsel.eu/clinical-app-store-and-surgical-planning-everywhere

Service Portals Connected Medical Devices & Drugs	Data generation and edge processing	*Associations*: AIOTI, EPoSS, BVMed, SNITEM, Innovative Health Initiative … *Industry*: Apple, Archeon, bewell connect, Bluelinea, GE Healthcare, iHealth, Medtronic, Philips, Roche, Withings …
Connectivity	Data exchange	*Associations*: AIOTI … *Industry*: AT&T, Infineon, Nokia, NXP, Orange, Telefonica, T-Systems, Vodafone …
Data Platform and Data-driven Application	Data storage and cloud processing	*Associations*: BDV … *Industry*: AT&T, GE Healthcare, IBM, Medtronic, Orange, Philips, salesforce, Samsung, Telefonica, T-Systems, Vodafone …
Care Providers	Data usage, input and queries	Hospitals, specialised clinics, retiring houses, practitioners, clinical testing (EATRIS, ECRIN …), medical research, regulatory bodies (European Medicines Agency, national agencies …), informal caregivers
Payers	Data assessment	Social security systems, insurance and assurance (Allianz …), patients, public authorities (ministries, joint committees (Gemeinsamer Bundesausschuss …)
Patients	Data usage	Patients' Organisations (European Patients Forum …), citizens, consumers

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

6.1 Value chains and revenue streams

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 sensors 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 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.

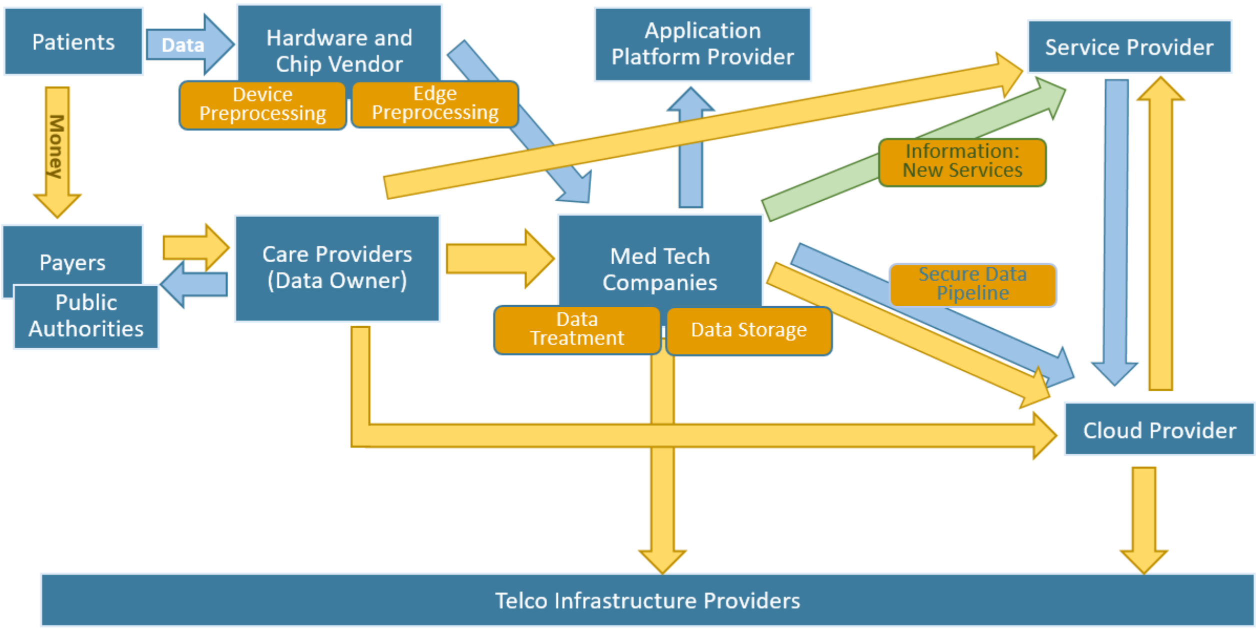

Figure 5: Overview of the value network in the health sector

Based on the value chain, the participants of the workshop developed an overview of the value network in the health sector. This network shows the different dependencies between the identified stakeholders, especially concerning money and data flow and gives better insight into the interconnectedness of different actors in the health sector. The diagram above highlights the key role of MedTech companies as they are at the centre of the network and at the interface of both money and data flows. Normally, care providers are the owners of the data and medical technology stakeholder act as the main stakeholder. Basic requirement for all interactions are the services provided by telco infrastructure providers. The network shows a possibility of how the different actors might interact. For specific use cases the interaction of actors might differ.

6.2 Service requirements

The healthcare sector induces a certain number of specific challenges when considering the potential cloud-edge IoT demand:

- **Highly regulated sector**: Specific and strong regulatory requirements and procedure for approval and vigilance. Complying with these regulatory requirements is cost-intensive and time-consuming, but in most cases also compelling.
- **High ethical constraints**: In healthcare, human lives and highly sensitive data are at stake. A responsible and compliant handling of data is paramount, taking into consideration the highest standards of data protection, confidentiality and security. This may result in difficulties in accessing data for cloud-edge solutions.
- **Lack of standardisation:** Apart from imaging and storage, the preconditions/requirements for other types of data (e.g. physiological) differ between hospitals or devices.
- **Complex governance:** Decision-making processes and money flows are lenghty and require the intervention of many actors with sometime diverging perspectives. Furthermore, remote management is a big challenge.
- **Very dynamic sector with high granularity:** The high level of research and the constant flow of innovation constantly remodel the sector and new value chains may grow fast. Continuous updates of applications are necessary to cope with the pace and avoid obsolescence. The huge number of recipients (patients and potential patients) implies challenges in the amount of data to handle.
- **Digitalisation of healthcare not extensively implemented:** Lack of best practices, guidelines etc.; requirements may sometimes not be fully known. There are only few reliable and scalable cloud providers; fragmented market for data storage -> limited choice. The old and heterogeneous pool of devices and IT infrastructure in hospitals implies connectivity and latency issues and induces challenges concerning interoperability and (high) investment costs.

Derived from these challenges, specific minimal service requirements for implementing edge, IoT and cloud systems in the health sector can be defined.

- **Interoperability**: *Required because of multiple stakeholder groups and non-overlapping of data and money flows; trend towards decentralised/personalised healthcare -> mix between consumer/medical applications*

Currently, existing infrastructure in the health sector is characterised by heterogeneity. When a new system or product is to be integrated e.g. in a hospital infrastructure, corresponding **software and hardware interfaces** must be implemented in order to be able to establish connections to already existing systems (which might differ greatly from each other) and the underlying hospital or clinic IT systems. Every care provider might have different preconditions and requirements which must be met (e.g. hospital regulations, existing devices (in different versions), cloud or on-premise). Therefore the development of a **modular system** with different options that can be customised for every care provider is recommended. On the one hand **backwards compatibility** represents an important requirement, on the other hand **openness of new systems** and products is crucial to allow future innovations. Especially when updating existing software and hardware, **continuity of service** needs to be guaranteed. It all concludes to the one most important question:

Who owns and maintains the hardware? This question needs to be addressed properly in order to ensure safe usage.

- **Usability** plays an important role as well. Users need to be able to use edge, IoT and cloud solutions as intuitively as possible. Designing products and services with respect to products already known by the user can help when it comes to enable easier and faster usage. Furthermore multiple target groups of users with different medical background and knowledge (professionals and non-professionals, patients, relatives …) need to be considered when designing products and services.
- **Regulation, privacy and security requirements**: Due to handling sensible (personal) data, those requirements are especially high in the health sector. Certification aspects need to be considered as early as possible. As certification procedures are time and cost consuming, aspects of recertification need to be checked when deciding on how much a device or service needs to be modified. IoT solutions might also help meeting those requirements: Data transfer can be reduced by running algorithms that use safety critical data directly on the edge device.
- **Performance, efficiency (costs):** Concerning those requirements end-to-end-performance needs to be taken into account. Solutions normally consist of a pipeline of different devices or services. In the health sector data are often needed in real-time. Therefore the goal is to ensure low latency throughout the whole pipeline (including hardware as well as software).

Today, a large number of different devices and services are used in hospitals and clinics. This leads to the challenge to find a way to effectively connect these systems. Edge, IoT and cloud solutions hold the chance to use the full potential of existing systems by letting them communicate with each other, sharing data and gaining new insights.

6.3 Key Insights

Challenges

- The health sector is highly regulated. Various requirements (EU, country, hospital) must be followed.
- Health data is sensitive data and decisions may have a severe impact on the health of patients. Therefore high ethical constraints are in place.
- Some subareas in the health sector do use consistent data types or interfaces, but all in all a lack of standardisation is present and needs to be handled.
- Complex governance represents another challenge. Many different stakeholders are involved in the health sector.
- New research findings and new (technical) innovations lead to a very dynamic sector with high granularity.
- At present digitalisation of healthcare is not extensively implemented.

Requirements

- There are several requirements that can be summarized under the term of interoperability: software and hardware interfaces, modular systems, backwards compatibility, openness of new systems, continuity of service and maintaining the hardware. These aspects need to be considered in order to implement consistent services.
- Systems have to be designed with a high level of usability in order to be able to use soft- and hardware efficiently and avoid mistakes that bare risks for the patients. Remote monitoring features will allow for more efficient maintenance of CEI infrastructures installed and deployed in the hospitals.

- Regulation, privacy and security requirements need to be considered. Compared to other sectors these are especially high in the health sector as wrong decisions might have a severe impact on patients.
- Performance and efficiency play a crucial role as well. If the costs of an innovative system are not affordable, it will not be implemented in health care.

The following questions need to be kept in mind when it comes to the further development of CEI solutions in the upcoming large-scale pilots in the healthcare sector:

Growing interconnectedness supports the shift from hospital care to home care. This leads to another shift; responsibility is transferred from the medical staff to the patient at home and his relatives. New questions arise:

- Which data is to be used?
- How to decide which data is relevant from a medical point of view?
- How to define data interfaces between medical staff and informal caregivers (relatives)?

7. Energy

The ongoing energy transition is essential for mitigating climate change, as outlined in the Paris Agreement[5]. The transition is being driven by various regulations at the national and international levels, including the European Green Deal.

However, the transition creates a new and different panorama full of changes for a previously stable value chain and market environment. With new roles in the energy system, new regulations and new possibilities. But also with stability and security concerns and several challenges, such as decentralisation, dependence on weather-dependent renewable energy sources, and energy flow in multiple directions. To address these challenges, the digitalisation of the energy sector and the implementation of Cloud, Edge and IoT (CEI) solutions have become necessary for a successful transition.

For the Energy sector the project partner IDC (see Deliverable 1.2) provided the following top use cases as a basis for discussion in the conducted workshop:

Smart Grids are used to effectively handle variable demand by utilising CEI devices to control and optimise power flow, detect faults, and manage power from utilities, independent and home energy production. The implementation of smart grids brings benefits such as efficient, safe, and reliable service, while also resulting in a resilient and efficient network, reduced peak demands, increased safety, and a more sustainable energy system.

Drone-based observation is a solution for remotely monitoring and maintaining infrastructure, particularly powerlines that can be damaged by encroaching trees. By using drones, the benefits include lower costs and more frequent observations, allowing maintenance resources to be efficiently targeted at current issues like tree branch removal. The outcomes of this approach are improved maintenance efficiency, reduced outages, and enhanced safety.

Employee safety monitoring is crucial in sectors with high-risk working conditions such as powerline repair and oil rig operations. By tracking employees' location, adherence to procedures, and proximity to machinery, safety can be improved, leading to fewer injuries and losses of trained personnel. Additionally,

[5] *https://unfccc.int/process-and-meetings/the-paris-agreement*

this monitoring promotes healthier and more productive workers, resulting in increased safety and the retention of skilled labor.

The experts who joined the workshop as well as the talk given by Natalie Samovich, (Co-Founder Resilient Group, Enercoutim, Chair WG Energy AIOTI Chair WG Smart Grids ETIP-SNET), concentrated on aspects of "the" big energy CEI use case **Smart Energy & Grid Management**.

While there was lots of participation with regard to service requirements and different evolving and emerging stakeholders in the energy ecosystem, the participants had difficulties to provide input on data, information and revenue flows in a highly dynamic and complex energy system. The in-depth interviews were conducted with E.DSO – European Distribution System Operators and bne - Bundesverband Neue Energiewirtschaft.

To fill out the information gap after the workshop, a special focus was given to the connections and revenue streams in the energy value network. The interviewed experts confirmed that a simplified value chain scheme does not reflect the complex multiple layers of smart grid and energy management CEI infrastructure requirements.

Following the workshops, interviews and discussions, the Energy sector has to be differentiated regarding the collected views on the data and revenue flows.

For a better understanding of the value network we will, firstly, focus on the specific challenges and different approaches for smart energy and grid management. The essence of the smart grid use case is hence given in a more general overview with regard to CEI solutions and market/technical approaches in the following section. Secondly, we will present further three use cases that illustrate how the requirements of a flexible, stable and efficient smart grid can be met by a market flexibility, technical flexibility and/or active network management approach.

7.1 Value chains

In the past, the energy value chain was linear, moving from energy generation to transmission network to distribution network and finally to energy use/consumers. Now the energy ecosystem needs the efficient and resilient integration of flexible energy generation sources and storage solutions.

To meet the overall challenges (**Flexibility**: Integration of flexible energy sources; **Stability/resilience**: Network observability, automation and controllability; **Efficiency**: Efficient use of energy), the consumption/generation has to be shifted to another moment and/or location. This can be achieved mainly by the following approaches:

- **Market flexibility** and/or
- **Technical flexibility** and/or
- **Active network management (ANM)**

Efficient and stable integration of flexibility sources into the energy system requires active grid management, **observability, automation and controllability of the grid and/or energy generation and/or consumption and/or storage** with different temporal and spatial granularity. To achieve this flexibility, the roles of existing stakeholders in the energy system need to evolve, while a range of **new market opportunities and demands** are created. On one hand, the evolution of old stakeholders' roles is necessary, presenting various challenges for grid providers. On the other hand, new stakeholders have emerged in the energy landscape. Prosumers, who are able to generate, consume, and/or store energy simultaneously, now play a major role. Another example of an emerging stakeholder are energy aggregators. These entities collect small amounts of energy from multiple sources, combine them and sell the resulting energy in larger quantities to wholesale buyers or grid operators.

The following figure shows the **non-linear value network** with **evolving stakeholders** that successfully operate on the existing energy market and **new emerging stakeholder** who disrupt the old business relations in the exiting value network.

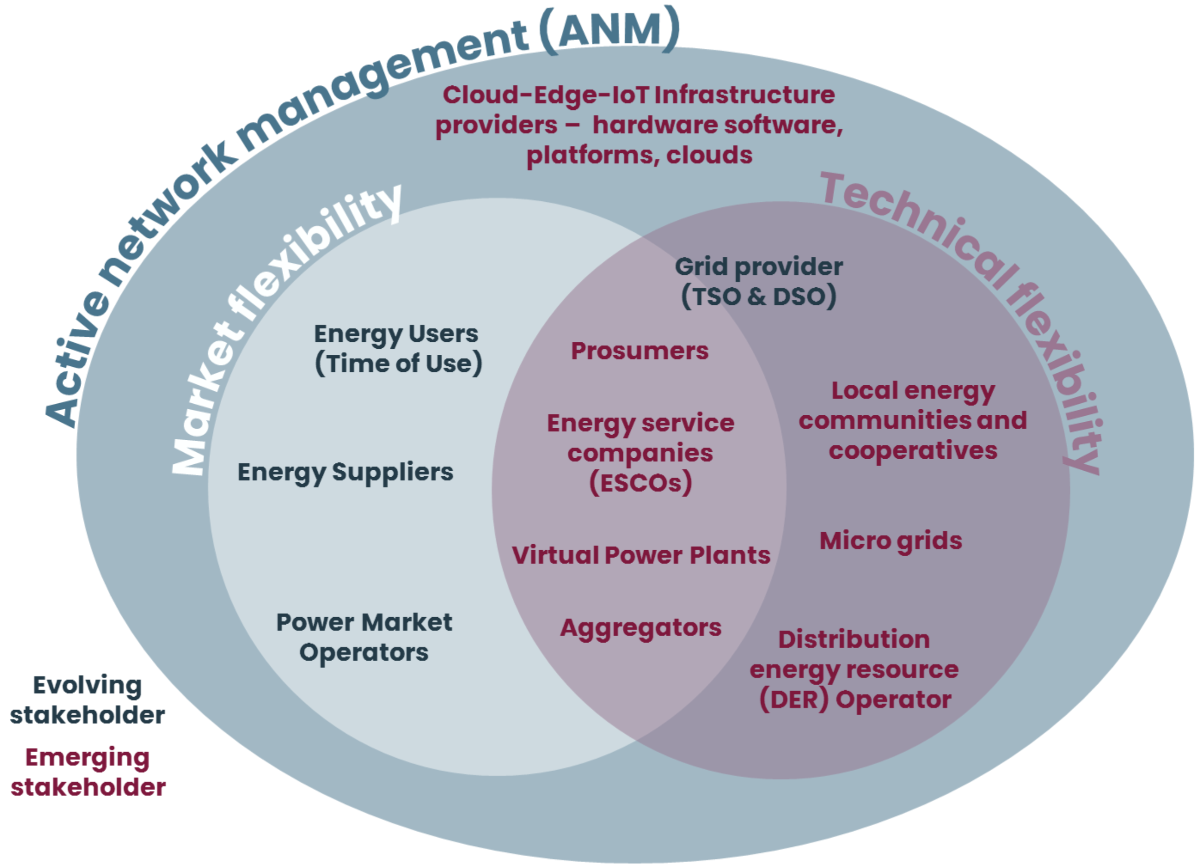

Figure 6: Stakeholder map considering evolving and emerging stakeholders as well as different approaches for a flexible, stable and efficient energy system

The new energy system's stakeholders need subsystems and Cloud-Edge-IoT (sub)infrastructures that are both self-contained units that build different parts of the overall interconnected system.

The revenue streams in the energy system reflect the complex design of the current and evolving energy market. It encompasses private and industrial consumers, energy stock exchanges and variable "time-of-use" contacts. In addition, self-organised energy communities can operate independently from the energy stock exchanges and experiment with new business models and technical approaches.

Digitalisation needs to penetrate the energy system at all levels. As a result, the boundaries between specific and more defined CEI use cases and approaches that contribute to the overall challenges are often blurred.

For example, a certain level of technical soft and hardware infrastructure is a prerequisite for market flexibility, while some technical network management approaches are strongly linked to "time-of-use" pricing models (see Example 3). Furthermore, many new value chain adopters meet the aim of flexibility with a specific new CEI approach which can be seen as a separate CEI use case. Hence, a wide variety of approaches to flexible pricing and business models are already employed in commercial business solutions as well as developed and tested in various research projects.[6]

In the following, we will introduce examples given by the interviewed experts that pinpoint the approaches to achieve a flexible, stable and efficient energy system:

Example 1: Market flexibility using "time-of-use" tariffs

- **Approach**: Customers can offer and sell their flexibility regarding the electricity use. Time of use price can be static (determined in advanced e.g. night vs. day price) or dynamic (determined in real-time based on actual system conditions). It depends on the power market.
- **Setting**: The retailer provides static or dynamic "time-of-use" electricity tariffs to primarily private customers. These tariffs send customers price signals that reflect system conditions. Electricity use can be adjusted by manual or automated means.
- **Objective**: Time-varying tariffs serve as incentives for load adjustment, such as peak shaving. By implementing these tariffs, customers have the opportunity to save on their energy expenses while simultaneously benefiting the overall system.
- **Required (CEI) infrastructure & hardware**: For "time-of-use" tariffs advanced metering infrastructure, and dynamic pricing, linking retail and wholesale electricity market are necessary and can be further developed by digital technologies for automation of response.
- **Adoption of use case**: "Time-of-use" tariffs are already mainstream in various countries across Europe (Spain, Sweden, Norway, Denmark, Estonia, Latvia, Lithuania and emerging in Great Britain, Belgium, Italy and Austria).[7][8] Since smart meters are a requirement, the adoption of the use case is strongly dependent on the countries smart meter rollout. Furthermore, more sophisticated digital technologies for automation of response to price and potential necessary hardware are not widespread. "Time-of-use" can be used for Smart EV charging and comprise potentials for large scale load shifting in industry.
- To date across the European spot (day-ahead and intraday) markets, the vast majority of products traded are hourly products.[9] A higher time granularity or coupling to location could further improve grid stability.

Example 2: Technical flexibility and active network management for a rural energy community with battery to stabilise DSO

- **Approach**: A battery and management platform is used to shift the generation and consumption to other times on the DSO level to stabilise the DSO in a rural energy community.
- **Setting**: In regions where a high potential for distributed energy resources (DER) meets a low residential and commercial load, the challenges of the energy transition surface first. Hence, a low voltage network/DSO in a rural area in Northwest Germany with a high penetration of distributed energy resources (DER) was chosen for demonstrating the approach.
- **Objective:** In this approach the overall grid stability, reliability, and effectiveness is addressed by stabilising the local network. By coordination between local balancing mechanism and centralised grid operation, the grid stabilising effects in the local network can furthermore be extended to higher-level

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[6] *Examples of projects with different approaches given during the workshop and interviews for EU-funded research projects (https://coordinet-project.eu/; https://onenet-project.eu/; https://www.platone-h2020.eu/; https://euniversal.eu/; https://interconnectproject.eu/; https://intnet.eu/; https://beflexible.eu/; https://www.theflowproject.eu/ and commercial business solutions (https://www.tibber.com; https://kiwigrid.com/en/; https://www.next-kraftwerke.com/).*

[7] *IRENA (2019), Innovation landscape brief: Time-of-use tariffs, International Renewable Energy Agency, Abu Dhabi. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Innovation_ToU_tariffs_2019.pdf.*

[8] *Hildermeier, J.; Burger, J.; Jahn, A.; Rosenow, J. A Review of Tariffs and Services for Smart Charging of Electric Vehicles in Europe. Energies 2023, 16, 88. https://doi.org/ 10.3390/en16010088.*

[9] *IRENA (2019), Innovation landscape brief: Increasing time granularity in electricity markets, International Renewable Energy Agency, Abu Dhabi. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Increasing_time_granularity_2019.pdf.*

networks. Alternatively, the uncoupling of low and medium voltage networks can be used to strategically handle energy supply and export in bulk packages rather than relying on real-time exchanges.

- **Required (CEI) infrastructure & hardware:** This approach is suitable for e.g. an energy community with lots of PV installed on people's premises. For its realisation an open source platform to support the management from DSO side and a Large-scale battery installed at DSO level are required.
- **Adoption of use case**: A demo is funded under the Horizon 2020 as part of Platone Project[10].

Example 3: Technical and market flexibility, active network management illustrating how local flexibility market stabilises DSO

- **Approach**: Customers sell their flexibility. However, in this approach the price does not only depend on the day-ahead power price, but also on the DSOs status.
- **Setting:** For demonstrating this approach the metropolitan area of Rome with various users was chosen. Users include a wastewater treatment plant connected directly to the primary cabin, a virtual energy community in low-voltage, residential homes equipped with renewable energy sources, a business smart building and electric vehicle charging station pools.
- **Objective**: This approach addresses the smart grid challenges by implementing a complete end-to-end flexible environment, i.e. a real integrated market where, using highly innovative distribution network technologies like blockchain and new grid equipment, retail and business customers interact with both aggregators (to access new flexibility market options) and DSOs to become active players of a network-optimised management in an effective and efficient active distribution network.
- **Required (CEI) infrastructure & hardware**: For this approach an open source platform to support the management is needed at the DSO side. Additional sensors are required in the DSO grid for observability of the grids status. At the customer side additional devices to standard smart meters are required that allow bidirectional flow of information. The devices are used to submit bids and exchange signals about the grids condition (traffic light mechanism) with the adequate granularity necessary to participating in the market. Furthermore, the devices must be certified by the DSO to comply with cybersecurity criteria and use blockchain technology.
- **Adoption of the use case**: A demo was funded under Horizon 2020 as part of Platone Project[11]. As a next step, there will be a follow-up of this project in cooperation with the regulatory authority in Italy, because the regulation is not ready for this type of flexibility market.[12]

7.2 Service requirements

During the different phases of the smart energy ecosystem implementation (Design, Installation, Operation, Maintenance/Disposal, Upgrade), the service requirements can be grouped into aspects related to **regulation, interoperability, data privacy, cybersecurity** and **infrastructure.**

Furthermore, through all phases **OEM and Customer engagement** is crucial. This involves finding strategies to make secure data sharing appealing, such as collaborating with energy providers to analyse existing data. Additionally, it is essential to address concerns of consumers and prosumers that providing flexibility may have a negative impact on their products or business models. Furthermore, as consumers are diverse and scattered, efforts must be made to inform them about new solutions and services available to minimise

[10] https://www.platone-h2020.eu/
[11] https://www.platone-h2020.eu/

electricity costs and enhance their energy independence. And last but not least, the lack of **skilled workers** in the energy sector in general and especially with CEI skills must be addressed.

Design

For a successful design of the smart energy ecosystem a crucial requirement is a **regulatory framework** that focusses on the alignment and harmonisation on the local, national and European level to facilitate cooperation on all levels. Such a framework needs to induce collaboration along the value chain, force implementation of EU Regulation on the national levels and define standards for successful interoperability like installation requirements and restrictions. Furthermore, it should define new value chain adopter models, e.g. an independent aggregator model for smaller cases at residential level and must quantify the added value for flexibility solutions (e.g. remuneration for capacity/energy, reduction of purchase/rent cost in exchange for flexible services availability). In addition, regulation needs to incentivise grid flexibility by CEI updates and improvements (CEI infrastructure/platforms and additional sensors) of the existing infrastructure. E.g. for DSOs the current remuneration is related to the construction of new lines, i.e. the expansion of the grid itself, while no incentive for flexibility updates and digital solutions is given. Especially small DSOs find little capacity to implement digital solutions and potentially need support.

Another lacking fundamental aspect is the **interoperability** of infrastructure and platforms. This encompasses the **standardisation** of sensors, data formats, platforms, grid signals and communication standards. Communication standards are for example needed to enable/facilitate the communication between different DSOs, DSOs and TSOs, or other value chain adopters[13]. Furthermore platforms must be designed in a way that they can be integrated in systems that already exist.

Moreover the design of **IT infrastructure** for active network and data management is crucial. Open source IoT platforms are needed that serve as Control Room Architecture for Future Grids, overcome traditional SCADA systems (Supervisory Control and Data Acquisition) and can handle large volumes of data and serve to reduce inertia. For active network management (ANM), these IoT platforms need to enable observability, controllability and automation depending on location and time (granularity close to real-time) of the grid. ANM can then be used for e.g. voltage control, congestion management (demand/capacity exceeds the transfer capabilities), demand response, digital twins for load prediction or DER management. Furthermore, the IT Infrastructure needs to meet cybersecurity standards and should be able to make use of Artificial Intelligence.

Installation

For a smart energy ecosystem the installation of **infrastructure (hardware)** is necessary at various points. To allow for grid flexibility and predictive maintenance, a hardware basis for the observability, controllability, and automation of the grid is needed in the form of additional sensors. This includes, at the secondary substation level (medium to low voltage) for control of temperature, equipment status and status of the grid for real-time monitoring for power quality and load prediction as well as edge analytics for predictive maintenance. On the consumer/prosumer side, smart meters are needed for flexible tariffs and additional devices for bidirectional integration of electricity and information are needed. Furthermore, edge intelligence can facilitate more energy efficiency, e.g. through smart home solutions. Furthermore, the installation of energy accumulation resources, e.g. batteries or hydrogen can be used for smart energy management, and the large-scale introduction of EVs and charging infrastructure is one aspect.

Operation

[13] *Communication standards between TSOs and DSOs addressed by EU Project CoordiNET https://coordinet-project.eu/projects.*

Data privacy and cybersecurity are a detrimental factor for the successful transformation of the energy ecosystem. On the one hand, the data privacy of the consumers, e.g. IoT sensors and edge computing applications must be ensured. On the other hand, the energy sector is critical infrastructure which means that high requirements on safety and security for reliable electricity distribution apply during design and operation.

Maintenance/Disposal

Degradation of meters and infrastructure as well as treatment of batteries and accumulators have to be considered.

Upgrade

For the planning of future grids, **IT Infrastructure** in the form of open source IoT platforms is required for data exchange management across key actors[14]. This information is needed by prosumers and energy communities to make investment decisions, energy system infrastructure planners to develop long-term cross-sector plans and by energy system infrastructure operators and service providers to adjust energy supply and DER contracts.

This phase can also be seen as the initial phase that is the foundation for the design of a smart energy ecosystem.

7.3 Key Insights

The energy transition and the digitalisation of the energy sector are motivated by the need to mitigate climate change, and the **public sector is its main driver**. The transition adds complexity and the need to monitoring and controling to a well-established system with high safety and security requirements and long lifespan of its components, such as the grid and conventional power plants. Hence, aligning the regulatory framework with the right technical and financial incentives is very important to allow existing stakeholders to develop and new businesses to become value chain adopters. The COM has proposed a reform of the EU electricity market design to boost renewables, better protect consumers and enhance industrial competitiveness,[15] which still has to be discussed and agreed by the European Parliament and the Council before entering into force.

For example, while the smart meter rollout has taken place in most European countries and allows for time-of-use tariffs, many other solutions and business models exist only in theory or locally. Their potential in combination with regulation and market adaptions is far from being fully exploited. A major roadblock is the lack of data on all levels, but especially grid conditions, which are needed for active network and energy management as well as for planning future flexible grids. A stronger regulatory framework for the standardisation of CEI soft- and hardware is needed on the European level, but must also be implemented quickly on national and local levels.

7.4 Conclusion

For a successful energy transition, achieving the right balance between market flexibility, technical flexibility, and active network management will be essential. This requires finding the optimal sweet spot between infrastructural changes in the grid or at consumer/prosumer level and management optimisation, which can be achieved by leveraging technologies such as artificial intelligence to predict and manage the system with minimal additional hardware. There are different ways to advance with their benefits and challenges. Due to

[14] *Addressed by EU Project BD4NRG https://www.bd4nrg.eu/.*
[15] *https://ec.europa.eu/commission/presscorner/detail/en/IP_23_1591*

the complexity of the system there is no one-fits-all solution. But clearly not doing anything and simply trying to maintain the status quo is the worst option.

For a successful energy transition, achieving the right balance between market flexibility, technical flexibility, and active network management will be essential. The large-scale pilots should address the optimal sweet spot between infrastructural changes in the grid or at the consumer/prosumer level and management optimisation, which can be achieved by leveraging technologies such as artificial intelligence to predict and manage the system with minimal additional hardware. There are different ways to advance with their benefits and challenges. Due to the complexity of the system, there is no one-fits-all solution.

8. Conclusion and Next Steps

The discussions, presented CEI example use cases and the analysis of workshop results indicate that the main driver for adoption of CEI technologies are applications that require **low-latency**: Industrial IoT in manufacturing, agricultural machinery and precision agriculture, healthcare wearables for non-intrusive diagnostics, as well as management of highly complex distributed energy systems.

In all mentioned industry sectors, edge-computing serves to efficiently **process and analyse huge amounts of data using AI/ML** that are collected by sensor-networks, cameras, robots, drones or healthcare wearables. The pre-processing of data takes place close to it's source on the far edge. AI/ML supports with analysis, prediction, maintenance and management of highly distributed infrastructures and systems in different domains.

For example, SMEs in manufacturing sector are interested in understanding and analysing how their products are utilized by customers by capturing and analysing the data even in the "after sales" phase.

In the Agricultural sector, intermediaries enable data exchange via cloud between different value chain participants in respective Cloud Edge and IoT systems.

In the Transportation sector AI-driven real-time traffic situation and traffic control based on real-time data on single road users and automotive edge platforms for automated software-defined vehicles will contribute to uptake and adoption of CEI technologies.

In the Healthcare sector, 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 and MedTech data and hardware integrators with high quality data offerings will play a central part in the healthcare data economy.

In the Energy sector, efficient and stable integration of flexibility sources into the energy system requires active grid management, observability, automation and controllability of the grid and/or energy generation and/or consumption and/or storage with different temporal and spatial granularity. To achieve this flexibility, the roles of existing stakeholders in the energy system need to evolve, while a range of new market opportunities and demands are created. The digitalization of the Energy sector will contribute to the adoption of CEI technologies in order to collect and analyse data required for the efficient management of highly distributed energy systems.

Next steps:

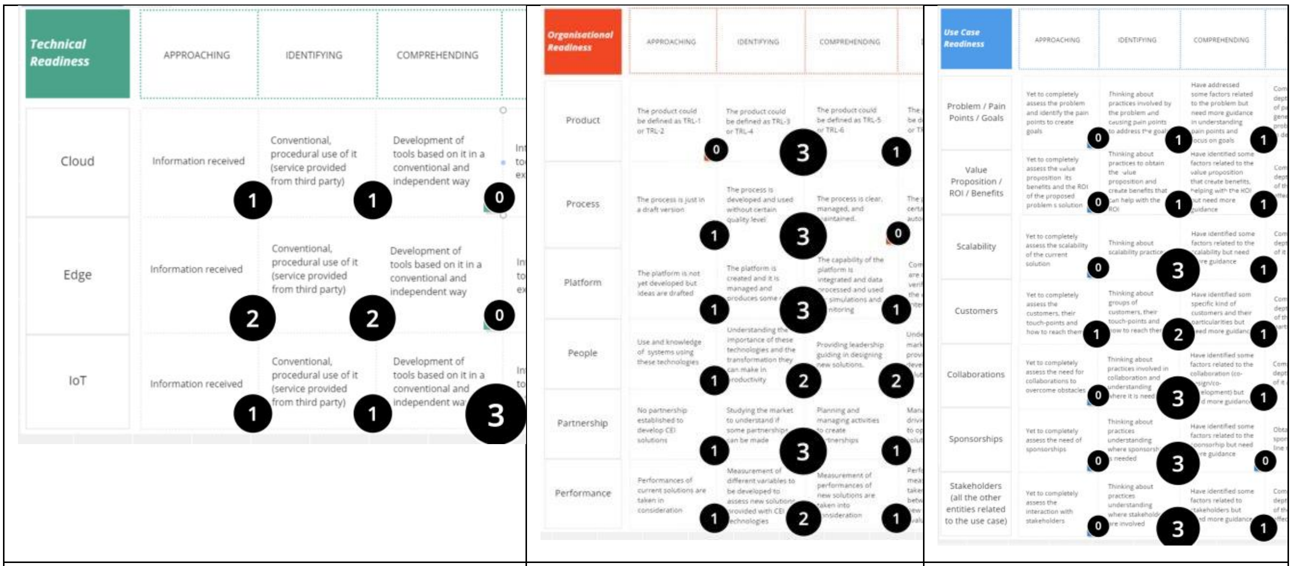
Following the Objective 3.3 we will derive from the value chain analysis and service requirements favourable CEI Market Scenarios to avoid predominance of vendor lock-ins and gate keepers. In the second workshop wave, we will discuss the range of CEI infrastructure choices and services and identify potential demand-pull pathways for adoption. Together with WP 4 “Community Engagement”, will organize a demand-supply dialogue and concertation to engage the potential “demand pull” drivers (for example, key actors such as system integrators and AI/ML solution provides) to participate in the planned large-scale pilots.

9. Annex

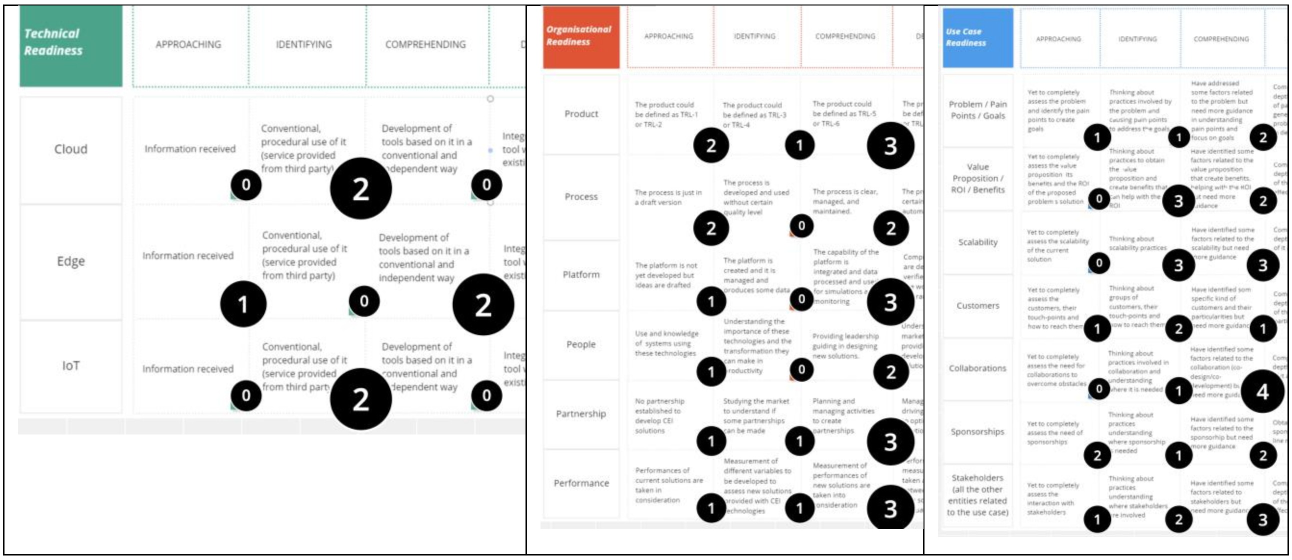
9.1 Preliminary Validation Results of Adoption Readiness Framework

In the first two workshops, the participants assessed the Adoption Readiness Framework. The following table includes the collected voting results regarding the adoption of Cloud Edge IoT (Technical Readiness), Organisational Readiness (Product, Process, Platform, People, Partnership, Performance) and Use Case Readiness (Problem/Pain Points/Goals, Value Proposition/Benefits, Scalability, Customers, Collaborations, Sponsorships, Stakeholders (all the other entities related to the use case).

9.1.1 Manufacturing



9.1.2 Agriculture



9.2 Interviews

Concept

The following interview guideline was developed based on the second workshop format and structured to fit a 60 minute talk. The questions aim at highlighting a concrete use case of the interviewee's choice in the field of CEI applications in the respective sector, gathering concrete requirements with regard to this use case, validate the input from the workshops and preparation (e.g. on the value chain) and overall deepen the information already gathered in conducted workshops.

Guideline

(1) Introduction

Personal introduction of both interviewer and interviewee

Introduction to UnlockCEI and to the motivation for the interview

(2) Use Case

Please tell us, which concrete application are you working on (interested in)?
What motivates you to work on this application and what hinders you in this process?

(3) Value Chain

Which role do (would) you play in the described use case?
How is the rest of the value chain for this use case structured?

(4) Adaption of the use case

Challenges and pain points: What hinders the practical application of the use case?
Enabling factors: Which facilitates the practical application of the use case?

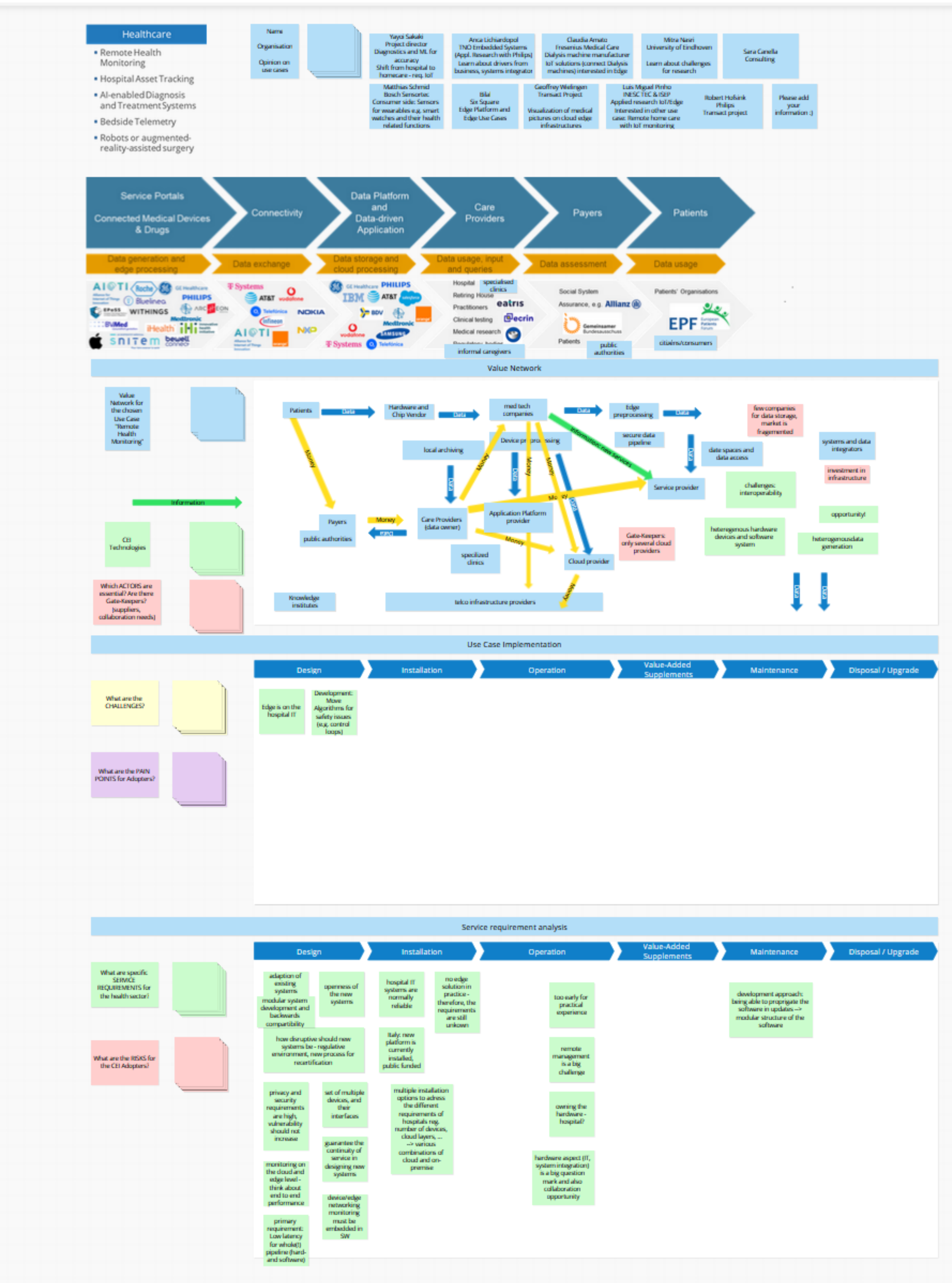
(5) Service requirements for your selected use case

Which are the main service requirements?

- … along the life cycle: Design, Installation, Operation, Value-added supplements, Maintenance, Disposal/Upgrade
- … from different viewpoints: Provider, Customer, User, Supplier

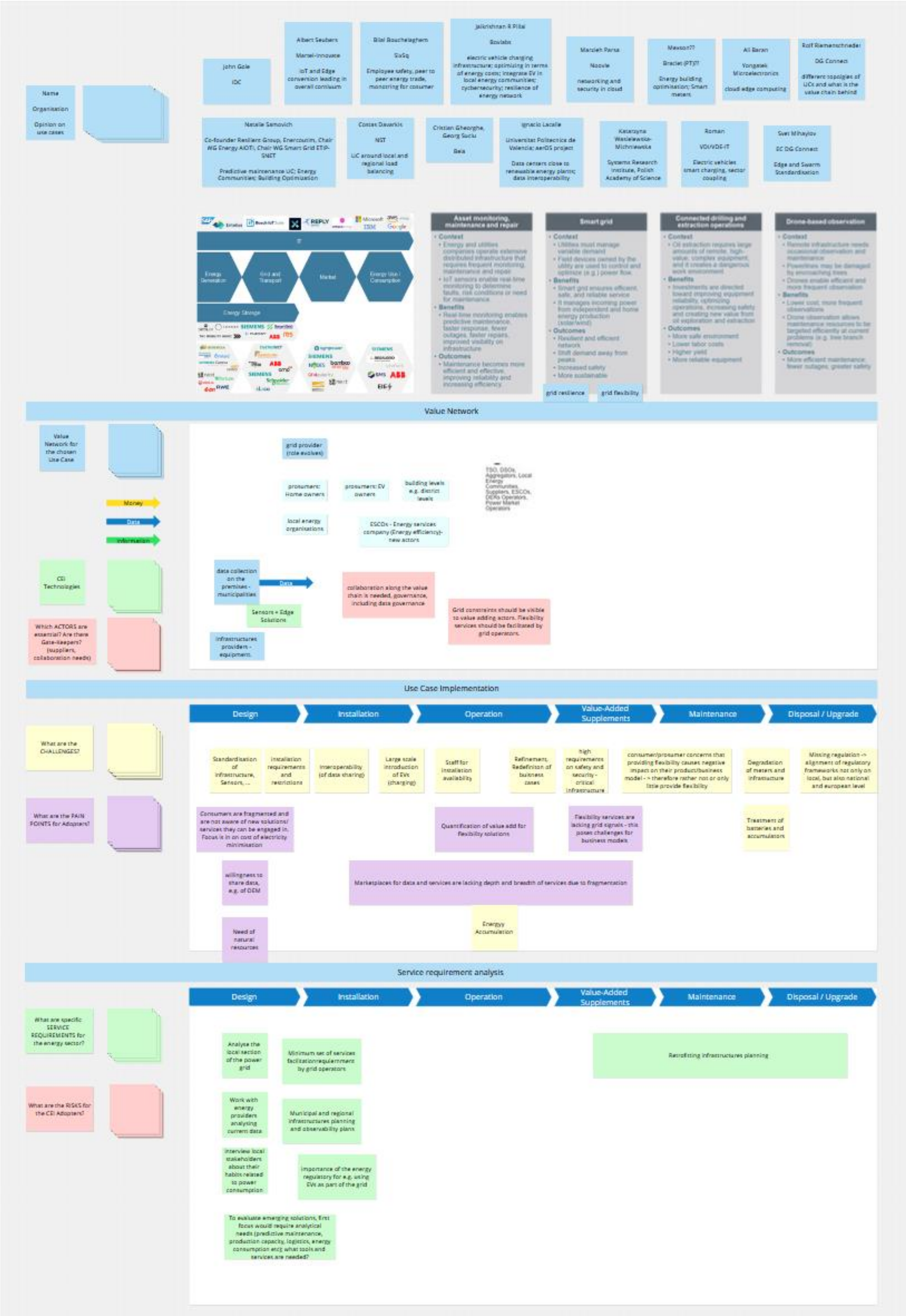
9.3 Concept boards

9.3.1 *Healthcare:*



9.3.2 Transportation

9.3.3 Energy


Name
Organisation
Opinion on use cases
John Gole
IDC
Albert Seubers
Martel-innovate
IoT and Edge conversion leading in overall continuum
Bilal Bouchelaghem
SixSq
Employee safety, peer to peer energy trade, monitoring for consumer
Jaikrishnan R Pillai
Ecolabs
electric vehicle charging infrastructure; optimizing in terms of energy costs; integrate EV in local energy communities; cybersecurity; resilience of energy network
Marzieh Parsa
Nocole
networking and security in cloud
Mewson??
Bracket (PT)??
Energy building optimisation; Smart meters
Ali Baran
Vongatek Microelectronics
cloud edge computing
Rolf Riemenschneider
DG Connect
different topolgies of UCs and what is the value chain behind
Natalie Samovich
Co-founder Resilient Group, Enercoutim, Chair WG Energy AIOTI, Chair WG Smart Grid ETIP-SNET
Predictive maintenance UC; Energy Communities; Building Optimisation
Costas Davarkis
NST
UC around local and regional load balancing
Cristian Gheorghe, Georg Suciu
Beia
Ignacio Lacalle
Universitat Politecnica de Valencia; aerOS project
Data centers close to renewable energy plants; data interoperability
Katarzyna Wasielewska-Michniewska
Systems Research Institute, Polish Academy of Science
Roman
VDI/VDE-IT
Electric vehicles smart charging, sector coupling
Svet Mihaylov
EC DG Connect
Edge and Swarm Standardisation
Asset monitoring, maintenance and repair
Smart grid
Connected drilling and extraction operations
Drone-based observation
grid resilience
grid flexibility
Value Network
Value Network for the chosen Use Case
Money
Data
Information
grid provider (role evolves)
prosumers: Home owners
prosumers: EV owners
building levels e.g. district levels
local energy organisations
ESCOs - Energy services company (Energy efficiency)- new actors
CEI Technologies
data collection on the premises - municipalities
Data
Sensors + Edge Solutions
Infrastructures providers - equipment
collaboration along the value chain is needed, governance, including data governance
Grid constraints should be visible to value adding actors. Flexibility services should be facilitated by grid operators.
Which ACTORS are essential? Are there Gate-Keepers? (suppliers, collaboration needs)
Use Case Implementation
Design
Installation
Operation
Value-Added Supplements
Maintenance
Disposal / Upgrade
What are the CHALLENGES?
Standardisation of infrastructure, Sensors, ...
installation requirements and restrictions
Interoperability (of data sharing)
Large scale introduction of EVs (charging)
Staff for installation availability
Refinement, Redefinition of business cases
high requirements on safety and security - critical infrastructure
consumer/prosumer concerns that providing flexibility causes negative impact on their product/business model - > therefore rather not or only little provide flexibility
Degradation of meters and infrastructure
Missing regulation -> alignment of regulatory frameworks not only on local, but also national and european level
What are the PAIN POINTS for Adopters?
Consumers are fragmented and are not aware of new solutions/ services they can be engaged in. Focus is in on cost of electricity minimisation
Quantification of value add for flexibility solutions
Flexibility services are lacking grid signals - this poses challenges for business models
Treatment of batteries and accumulators
willingness to share data, e.g. of OEM
Marketplaces for data and services are lacking depth and breadth of services due to fragmentation
Energy Accumulation
Need of natural resources
Service requirement analysis
Design
Installation
Operation
Value-Added Supplements
Maintenance
Disposal / Upgrade
What are specific SERVICE REQUIREMENTS for the energy sector?
Analyse the local section of the power grid
Minimum set of services facilitationrequirements by grid operators
Work with energy providers analysing current data
Municipal and regional infrastructures planning and observability plans
Interview local stakeholders about their habits related to power consumption
importance of the energy regulatory for e.g. using EVs as part of the grid
To evaluate emerging solutions, first focus would require analytical needs (predictive maintenance, production capacity, logistics, energy consumption etc); what tools and services are needed?
Retrofitting infrastructures planning
What are the RISKS for the CEI Adopters?