D2.1: ECOSYSTEM DEFINITION AND REQUIREMENTS

ANNEX 9: CLUSTER 4 DEFINITION AND REQUIREMENTS

This annex covers Cluster 4 - Smart Vineyards & Sustainable Winery Ecosystems, exploring how COP-PILOT leverages IoT, AI, and ML technologies to drive digital transformation across viticulture, winery production, and circular IoT device management within a federated computing continuum. It demonstrates how smart vineyard management, optimised production lines, and sustainable IoT lifecycle practices can collectively enhance operational efficiency, reduce environmental impact, and advance GDPR-compliant, EU-sovereign data ecosystems.

D2.1: Ecosystem definition and requirements

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Abstract	The COP-PILOT platform is an open collaborative system for managing services across IoT, edge and core computing environments. COP-PILOT is built to enable secure and intelligent operations that connect diverse sectors. This document brings together an ecosystem of technical blueprints and services models across 5 main domains to support the development of these infrastructures. With a focus on seamless cross domain integration, it lays the foundation for private edge deployments and digital ecosystems across Europe. This deliverable sets the direction for building a platform that drives smarter, more secure, and collaborative digital transformations across multiple industries.
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* R: Document, report (excluding the periodic and final reports)

DEM: Demonstrator, pilot, prototype, plan designs

DEC: Websites, patents filing, press & media actions, videos, etc.

DATA: Data sets, microdata, etc.

DMP: Data management plan

ETHICS: Deliverables related to ethics issues.

SECURITY: Deliverables related to security issues

OTHER: Software, technical diagram, algorithms, models, etc.

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CLUSTER 4 INTRODUCTION

Cluster 4: Smart Vineyards & Sustainable Winery Ecosystems is a piloting initiative designed to showcase how IoT, AI, and ML technologies can drive digital transformation in viticulture, winery production, and industrial sustainability. Operating within a federated computing continuum, the cluster addresses the challenge of uniting diverse data sources and operational requirements into seamless, adaptive, and scalable solutions. It places particular emphasis on integrating smart vineyard and winery management with the sustainable lifecycle management of IoT devices. On one hand, UC4.2 – Water Utilisation Efficiency introduces advanced irrigation techniques and predictive insights to optimise vineyard water management, while UC4.3 – Sustainable Optimised Winery Production Lines provides IoT-driven analytics to enhance the efficiency and energy performance of winery production processes. On the other hand, UC4.1 – Recycling, Maintenance, and Logistics of IoT Sensors addresses the recycling and reuse of IoT devices, tackling the growing challenge of electronic waste and ensuring that digital innovation aligns with circular economy principles and ESG objectives.

Originally conceived as a broad cross-sector initiative connecting agriculture, manufacturing, and recycling under a unified data management framework, Cluster 4 has progressively evolved to focus on the viticulture and winery domain. This refinement emerged from the recognition that the vineyard–winery ecosystem offers a highly representative, data-rich, and operationally diverse environment to demonstrate cross-domain integration. The combination of smart agriculture, production efficiency, and circular IoT device management creates an ideal living laboratory to validate the COP-PILOT platform’s capabilities across the IoT–Edge–Cloud continuum. The ambition of Cluster 4 is to enhance operational efficiency, reduce environmental impact, and reinforce EU-sovereign, GDPR-compliant data ecosystems that enable scalability and replicability. By integrating advanced orchestration platforms with sustainable practices, the cluster demonstrates how viticulture and agriculture can transition toward greener, more resilient operations.

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ANNEX 9.A: UC4.1 - RECYCLING, MAINTENANCE, AND LOGISTICS OF IOT SENSORS

Description

Short Description

This use case belongs to Cluster 4 (Portugal, Spain, Ireland, and Switzerland), with RedZinc (RZ) as a contributing partner. The main aim is to address the logistical, maintenance, and recycling needs of reusable IoT sensors. It seeks to extend the operational life of sharable IoT devices and uphold sustainability through a comprehensive digital management system covering multiple use cycles.

Complete Description

This use case focuses on managing the lifecycle of IoT sensors within different industrial environments, specifically targeting sustainability through sensor recovery, cleaning, re-certification, and redeployment. IoT sensors are widely used in both healthcare and agricultural sectors, including vineyards, where they support environmental monitoring, production logistics, and quality control. However, without a structured management system, these sensors often have limited reuse potential, leading to increased waste and higher operational costs.

The primary processes involve deploying sensors to operational sites such as clinical or vineyard facilities, triggering automated logistics for recovery after use, conducting comprehensive cleaning and functional checks, certifying sensor readiness for reuse, and subsequently redeploying them. Ultimately, when sensors reach the end of their lifespan, their components are sustainably separated and recycled. The use case aims to streamline these processes via the COP-PILOT orchestration platform, maximizing sensor lifespan and operational efficiency across multiple industrial domains.

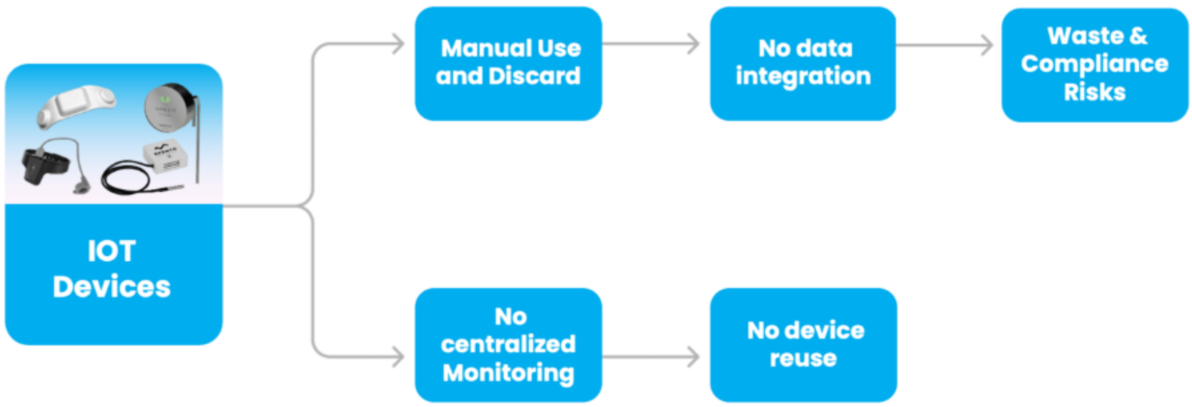

Figure 9.1: Current situation for IoT devices end of life process

I n the diagram we can see the scenario prior to the COP-PILOT project implementation. IoT devices used in both healthcare and agricultural environments were manually managed, typically involving single-use and subsequent discard, leading to significant waste. Additionally, there was no centralized monitoring system, resulting in limited data integration and visibility. Consequently, this led to inefficient asset utilization, environmental concerns, and potential compliance risks.

With the integration of COP-PILOT, RedZinc and partners deploy the Digital IoT Recycling Platform (DIRP) which enables the secure and scalable reuse of IoT sensors across multiple domains, particularly in healthcare and vineyards operations. This platform uses FIWARE-based IoT integration to ensure that devices are monitored throughout their lifecycle, from provisioning and active use to collection, sanitization, and redeployment.

RedZinc enables GDPR-compliant, monitoring capabilities into healthcare and recycling workflows, organizations can track IoT usage, initiate predictive maintenance, and recycle devices intelligently drastically reducing cost and environmental impact.

The following diagram highlights the intended post-implementation scenario facilitated by the COP-PILOT platform. IoT devices deployed in vineyards and healthcare environments are systematically integrated into the COP-PILOT infrastructure. This integration provides lifecycle monitoring, allowing for comprehensive tracking of sensor conditions, usage, and logistics. Following usage, sensors undergo systematic cleaning and recycling processes, maximizing sensor lifespan and sustainability.

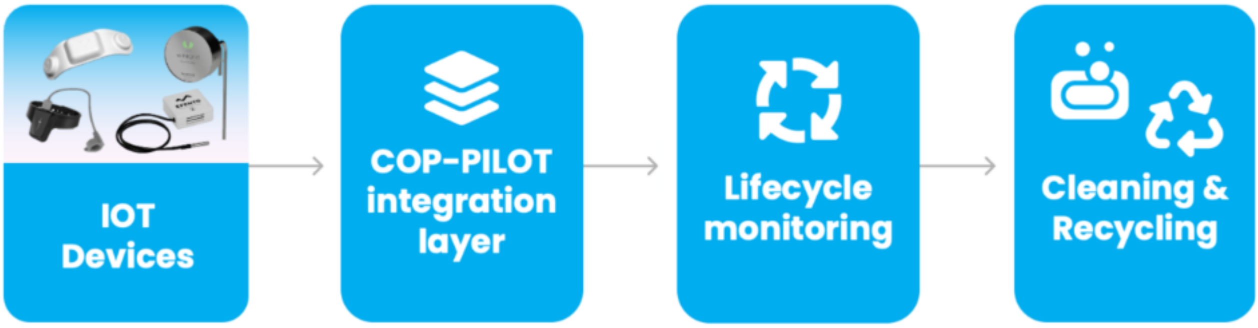

Figure 9.2: COP-PILOT target for in service and post service IoT lifecycle sensor management

Key steps required to execute the UC:

Register and deploy IoT sensors across healthcare, vineyard, and other industrial sites. This ensures device visibility, authentication, and trust establishment between each domain. Sensors are assigned unique identifiers and linked to their corresponding operational environment

Collect and monitor real-time sensor data through COP-PILOT analytics, enabling unified lifecycle monitoring. This includes tracking sensor status, usage duration, environmental conditions, and reuse cycles

Trigger automated workflows for either predictive maintenance, cleaning, or recycling, based on predefined lifecycle thresholds. The COP-PILOT orchestration platform manages these processes via secure partner notifications, ensuring each device or component follows the appropriate recovery or recycling path

Reintegrate cleaned or re-certified sensors into their respective environments to continue their operational lifecycle. Components reaching end-of-life are automatically routed to specialized recycling partners for safe and sustainable disposal.

Main actors and roles

Table 9.1: Main actors

Actor name	Actor type	Actor Description and Role
RedZinc (RZ)	IoT platform integrator	RedZinc leads the deployment of the Digital IoT Recycling Platform (DIRP) for healthcare and vineyards domains. It enables secure integration of IoT sensors, ensures GDPR-compliant data handling, and supports lifecycle monitoring and device reuse. RZ also contributes to the predictive maintenance workflows using the COP-PILOT platform.
Data generators	End users	Includes healthcare professionals and vineyard technicians who deploy and use IoT sensors in daily operations. These actors generate the primary data collected through monitoring activities (e.g., patient vitals, soil humidity, temperature, or device status) and feed it into the COP-PILOT infrastructure.
Decision makers	Management / Operational supervisors	Includes hospital administrators and vineyard managers who use aggregated analytics and dashboards to make operational and sustainability decisions. They leverage lifecycle and performance data from COP-PILOT to plan sensor reuse, procurement, and recycling strategies.
Sensors and edge devices	Data infrastructure components	The IoT devices and gateways deployed at healthcare or vineyard sites that collect and transmit data (e.g., ECG sensors, SpO_2, soil moisture sensors...). These components form the physical interface between the environment and the COP-PILOT orchestration platform.
COP-PILOT Platform	Platform Service	Provides end-to-end linking to IoT deployments and data services across domains. It enables RedZinc and partners to dynamically provision, monitor, and automate the sensor lifecycle across healthcare and recycling environments.

Ambition, Motivation and Objectives

Motivation

The key driver for this use case is sustainability and cost-efficiency in environments where IoT devices are heavily deployed, such as healthcare and vineyard operations. Currently, many sensors are either single-use or used inefficiently due to a lack of proper lifecycle management. This leads to excessive electronic waste, unnecessary procurement costs, and critical availability gaps when devices are in high demand. Addressing these inefficiencies is especially important in regulated environments such as healthcare and in resource-intensive agricultural settings like vineyards, where device reuse and reliability are critical for maintaining operational performance, environmental monitoring, and product quality.

We propose a new approach: implementing a systematic recovery, cleaning, retesting, and redeployment loop for IoT devices. By creating a closed-loop lifecycle and enabling real-time visibility of devices throughout their journey, the consortium aims to reduce waste, optimize resource use, and extend the service life of sensors. This will also enhance availability and reliability of connected devices while ensuring compliance with data privacy and safety regulations such as GDPR and MDR as well as supporting sustainable practices across domains.

Ambition

This use case aims to prove the feasibility of a fully automated circular logistics loop for IoT devices across both healthcare and vineyard environments. The ambition is to achieve this at scale, with minimal environmental impact and measurable cost savings. It will also demonstrate how high-value IoT assets can be remotely monitored and dynamically orchestrated across multiple usage cycles, locations, and custodians.

Furthermore, ambition extends beyond these initial domains. The solution is designed to be replicable and scalable to other IoT-intensive domains such as manufacturing, logistics, agriculture, or public safety—especially where sensors are deployed in short duty cycles. Demonstrating success in healthcare and vineyards will validate the robustness, trustworthiness, and business potential of the COP-PILOT platform.

UC Mapping with Project Objectives

We support Objective 3 by enabling auto-expansion and secure integration of new domains and devices, streamlining the onboarding and management of IoT sensors across healthcare and agricultural contexts.

We align with Objective 5 by demonstrating cross-sector collaboration and intelligent resource management through piloting in a real-world healthcare environment with measurable sustainability impact and replicable circular-economy practices.

UC Mapping with Project Innovations

We contribute to Innovation Area #1: Application-aware IoT device and data management, with real-time lifecycle tracking across domains.

We demonstrate Innovation Area #2: Secure and programmable resource/data service exposure using GAIA-X/IDSA-compliant federated frameworks for both clinical and agricultural data interoperability.

Rationale for the Use of the COP-PILOT Platform

The COP-PILOT orchestration platform enables automated multi-tenant service management, allowing dynamic allocation and reconfiguration of IoT resources across sites.

COP-PILOT's Secure Integration Fabric (SIF) ensures safe, encrypted communication of sensitive IoT data and supports interoperability with FIWARE and other open platforms, ensuring compliance with privacy and security standards while facilitating sustainability-driven innovation across domains.

Challenges addressed

Current challenges addressed

- **Reusable IoT Hardware:** Sensors deployed in healthcare and vineyard scenarios currently have minimal reuse cycles due to challenges in recovery, re-certification processes and environmental exposure.
- **Inadequate tracking & Logistics:** Existing systems lack comprehensive tracking capabilities, leading to inefficiencies and limited visibility into sensor location, maintenance status, and lifecycle progress across both clinical and agricultural sites.

- **Data Governance & Security risks:** Handling potentially sensitive health data, ensuring regulatory compliance (e.g., GDPR).
- **Environmental Sustainability Concerns:** Significant electronic waste (e-waste) is generated due to the limited reuse and disposal of IoT sensors.

Final use case ambitions

- **Reusable IoT Hardware:** Establish a robust system enabling IoT sensors used in healthcare and vineyards to be safely recovered, cleaned, re-certified, and re-deployed without compromising quality, safety or data integrity standards.
- **Enhanced Tracking & Logistics:** Provide real-time lifecycle and logistics tracking across multiple deployment sites (vineyards, hospitals, clinics...), enabling efficient asset management and operational optimization.
- **Secure Data Governance & Compliance:** Implement secure data channels and automated compliance mechanisms, fully addressing both healthcare privacy requirements and agricultural traceability standards.
- **Sustainability Goals:** Significantly reduce IoT sensor e-waste by enabling reuse cycles and component recycling, aligning practices with ESG principles and contributing to sustainable production in healthcare and viticulture.

Expected outcomes

- **Higher Sensor Recovery Rates:** Targeting 80% sensor recovery within a 12-month lifecycle (cleaning + retesting). It Aligns directly with COP-PILOT’s goal of promoting sustainable resource management and circular economy practices and supports COP-PILOT’s vision of cross-sector interoperability and circular economy across domains.
- **Operational Savings:** Cutting costs for hospitals and vineyards by reusing IoT assets. It matches COP-PILOT’s ambition to deliver economic efficiencies through automated orchestration and resource optimization.
- **Sustainability Improvements:** Lowering e-waste by reducing disposal of sensors and associated plastics. It supports COP-PILOT’s environmental objectives and demonstrates tangible contributions to ESG targets in healthcare and agriculture.
- **Digital Record & Analytics:** Enabling end-to-end visibility of each sensor’s condition, usage cycles, and compliance checks, supporting the project's commitment to creating a federated and transparent data governance framework, enabling cross-sector interoperability.

Key pain points

- **Regulatory & Quality Standards:** Ensuring sensors meet calibration, and environmental durability criteria before redeployment in healthcare or vineyard environments.

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- **Complex Multi-Site Logistics:** Coordinating sensor collection, inspection, cleaning, and re-shipment across geographically dispersed facilities.
- **Data Privacy:** Safeguarding patient data, environmental metrics and usage records in compliance with GDPR, relevant agriculture standards and healthcare regulations.
- **Scalability & Automation:** Scaling the entire process to handle large volumes of sensors while automating repetitive tasks and adapting to diverse use environments.

UC Diagrams

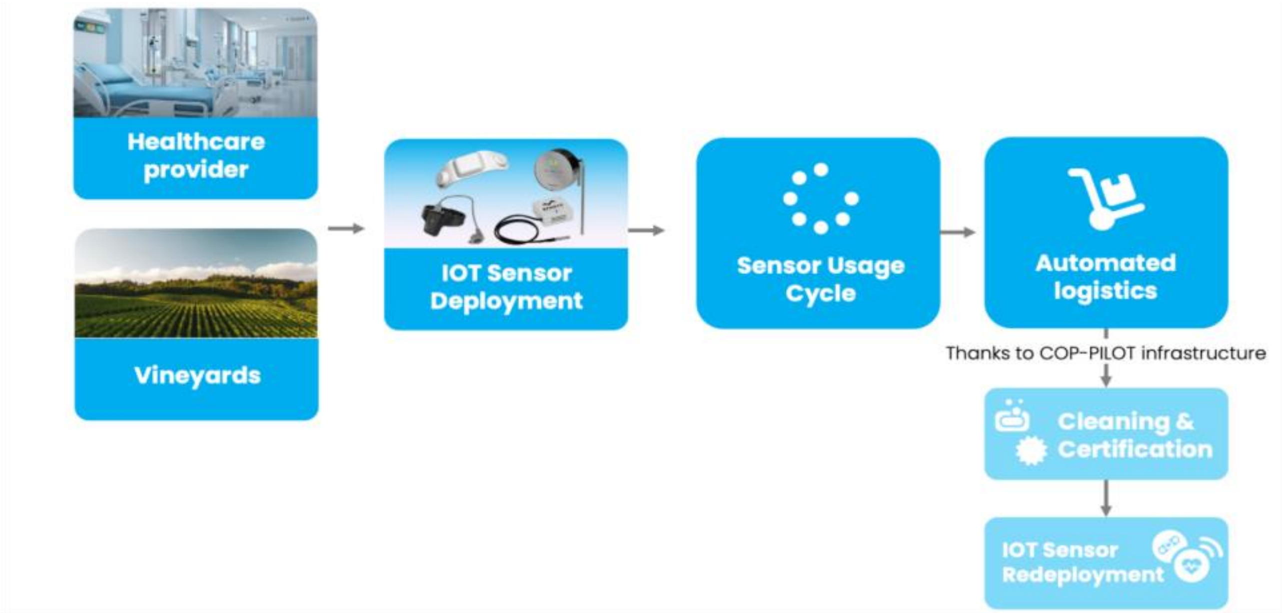

Figure 9.3: COP-PILOT infrastructure workflow

This diagram details the general workflow of our use case. Initially, healthcare providers as well as Vineyards deploy IoT sensors in different environments. After the sensors complete their usage cycle, an automated logistics request is triggered via the COP-PILOT infrastructure. Subsequently, sensors are collected, cleaned (physically and digitally), certified, and redeployed for further use. This cycle ensures maximum utilization and sustainable management of IoT sensor assets.

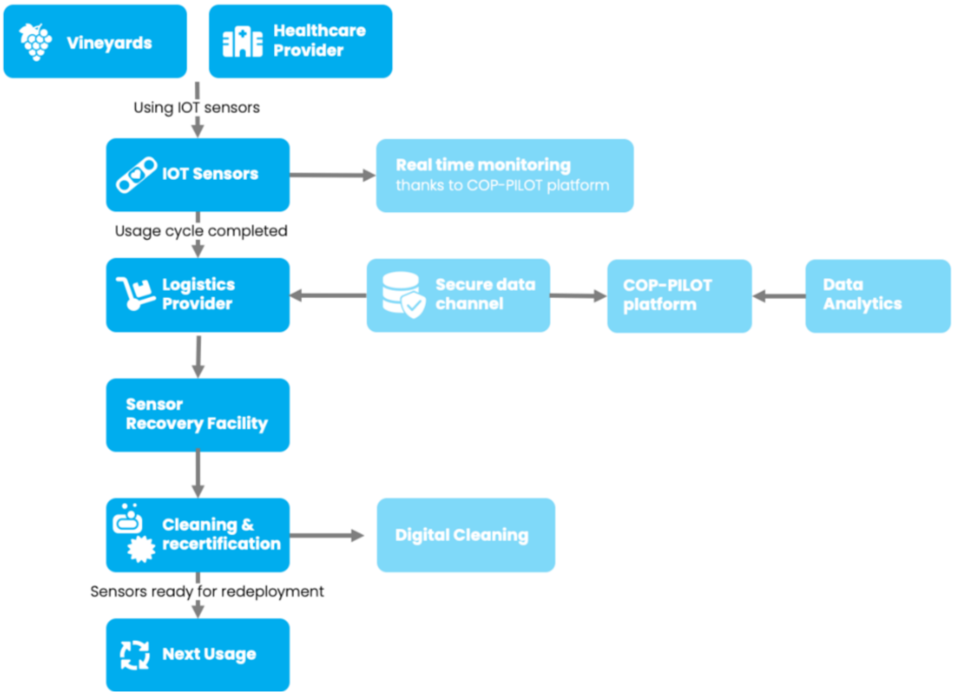

Figure 9.4: Use case System Diagram

This diagram provides a comprehensive view of the system's infrastructure and interactions for the Waste Management scenario. IoT sensors are deployed by healthcare providers and Vineyards in different scenarios and monitored in real-time through the COP-PILOT platform. Upon completing their usage cycle, sensors trigger automatic logistics requests managed securely through the platform. Sensors are then recovered, cleaned digitally, and re-certified for reuse, after which they enter the next clinical usage cycle.

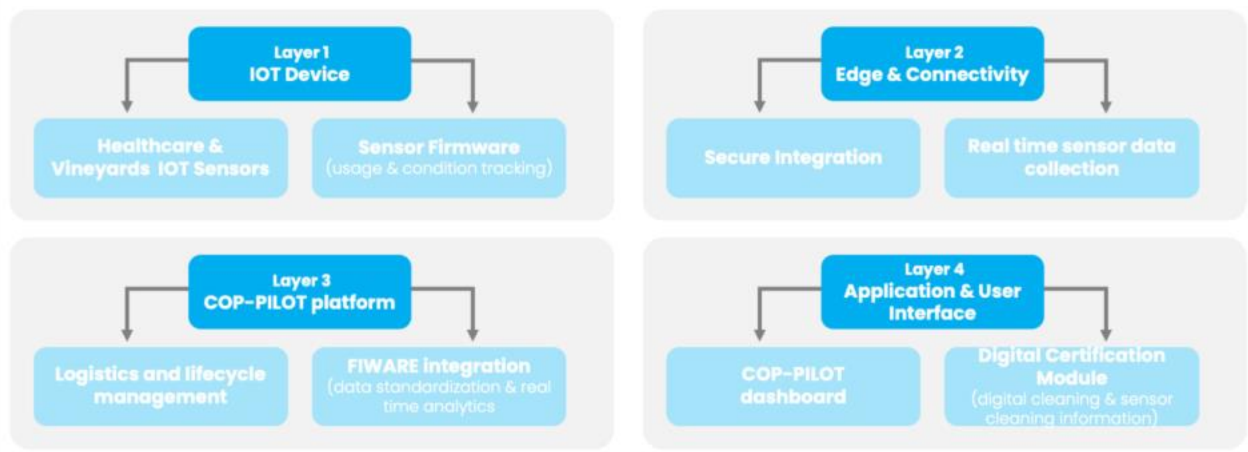

Figure 9.5: Use Case Architecture Diagram

This architecture diagram presents a detailed breakdown of the technological components involved:

- Layer 1 (IoT Device): Includes physical healthcare and Vineyards IoT sensors and embedded firmware for usage and condition tracking.
- Layer 2 (Edge & Connectivity): Encompasses secure integration fabrics and real-time sensor data collection capabilities.
- Layer 3 (COP-PILOT platform): Features advanced orchestration functionalities for logistics, lifecycle management, and integration with FIWARE for standardized data analytics.
- Layer 4 (Application & User Interface): Consists of the COP-PILOT user-friendly dashboard for lifecycle monitoring, as well as a digital certification module providing traceability of the digital and biological cleaning processes.

Scenario Process flowchart:

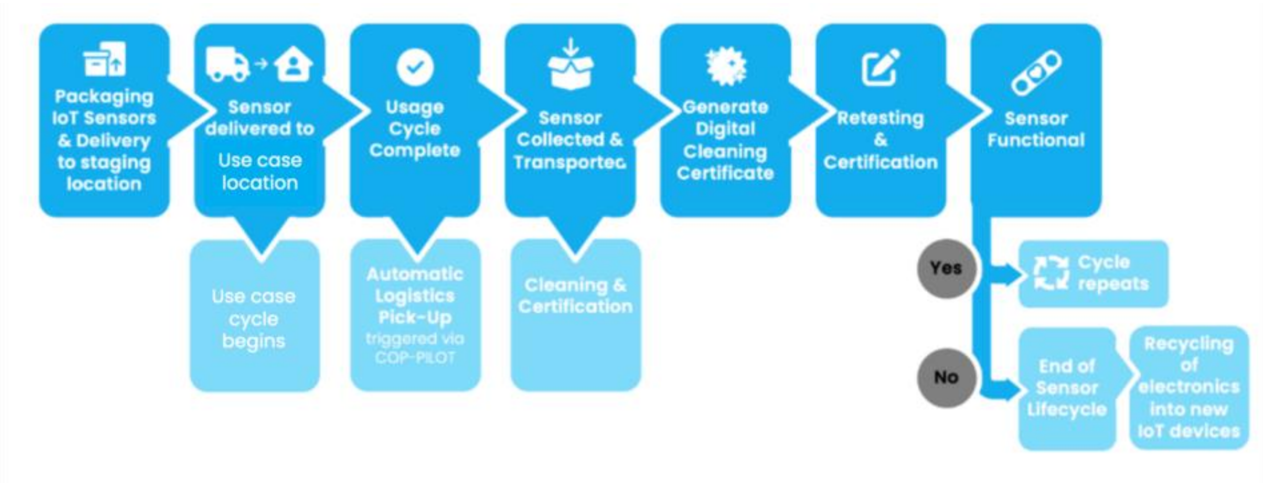

Figure 9.6: Current situation for IoT devices end of life process

This flowchart illustrates the detailed steps and decision points of the Waste Management and Sensor Recovery scenario. The process begins with packaging and initial delivery of IoT sensors to a staging location. From there, sensors are transported to patient locations, initiating the clinical usage cycle. Once the usage cycle is complete, an automatic logistics request is triggered through the COP-PILOT platform.

Sensors are then collected and transported to a recovery facility, where they undergo comprehensive digital and physical cleaning processes, and digital cleaning certificates are generated to confirm compliance and readiness. Following cleaning, sensors are retested and certified to verify functionality.

If a sensor passes functionality tests, it is redeployed, and the usage cycle repeats. If the sensor fails these tests, the lifecycle concludes; the sensor components are sustainably separated, with polymers disposed of responsibly and electronic components recycled into new IoT devices, ensuring environmental sustainability.

Scenarios description

- Sensor Waste Management and Recovery
- Packaging IoT sensors and delivery logistics to staging location.
- Sensor delivered to use case location.
- Usage cycle completed.
- Sensor collected and transported.
- Generate Digital cleaning certificate.
- Retesting and Certification.
- If Sensor is functional, the cycle repeats.
- If sensor is not functional, it is the end of sensor lifecycle.

No separate sub-scenarios are explicitly defined for UC4.1, but the cluster includes multiple cross-sector vantage points (for instance, agriculture or winery tasks in separate use cases). For UC4.1, focus remains on healthcare recycling and IoT logistics.

Scenario name:
Sensor Waste Management and Recovery
Step No.
Step 1
Step Event
Packaging IoT sensors and delivery logistics to staging location
Name of process/activity
Deploy IoT Sensor
Description of process/activity
Sensor provider deploys and activates IoT sensor, registering it within the COP-PILOT platform, then later the sensors are delivered to the staging location
Service
CREATE
Information producer (actor)
Use Case Provider
Information receiver (actor)
COP-PILOT Platform
Information exchanged (IDs)
Sensor ID, Location
Reference to Scenario number

1

Scenario name:
Sensor Waste Management and Recovery
Step No.
Step 2
Step Event
Sensor delivered to use case location
Name of process/activity
Deploy IoT sensors to the use case
Description of process/activity
Sensor is delivered to the use case location and the use case cycle begins
Service
CREATE
Information producer (actor)
Use Case Provider
Information receiver (actor)
COP-PILOT Platform
Information exchanged (IDs)
Sensor ID, Location, Deployment Timestamp
Reference to Scenario number
1

Scenario name:
Sensor Waste Management and Recovery
Step No.
Step 3
Step Event
Usage Cycle Complete
Name of process/activity
Usage Cycle Complete
Description of process/activity
Sensor finishes patient monitoring tasks and automatically triggers collection logistics via COP-PILOT
Service
REPORT
Information producer (actor)
IoT Sensor
Information receiver (actor)
COP-PILOT Platform
Information exchanged (IDs)
Sensor ID, Completion Timestamp
Reference to Scenario number

1

Scenario name:
Sensor Waste Management and Recovery
Step No.
Step 4
Step Event
Sensor collected and transported
Name of process/activity
Sensor collected and transported
Description of process/activity
Sensor is collected and transported in order to begin its cleaning and recertification
Service
REPORT
Information producer (actor)
IoT Sensor
Information receiver (actor)
COP-PILOT Platform
Information exchanged (IDs)
Sensor ID, Completion Timestamp
Reference to Scenario number
1

Scenario name:
Sensor Waste Management and Recovery
Step No.
Step 5
Step Event
Generate digital cleaning certificate
Name of process/activity
Generate digital cleaning certificate
Description of process/activity
Sensor gets a new digital certificate and states it has been cleaned
Service
REPORT
Information producer (actor)
IoT Sensor
Information receiver (actor)
COP-PILOT Platform
Information exchanged (IDs)
Sensor ID, Completion Timestamp
Reference to Scenario number

1

Scenario name:
Sensor Waste Management and Recovery
Step No.
Step 6
Step Event
Retesting and Certification
Name of process/activity
Retesting and Certification
Description of process/activity
Sensor is retested in order to ensure it works correctly
Service
REPORT
Information producer (actor)
IoT Sensor
Information receiver (actor)
COP-PILOT Platform
Information exchanged (IDs)
Sensor ID, Completion Timestamp
Reference to Scenario number
1

Scenario name:
Sensor Waste Management and Recovery
Step No.
Step 7
Step Event
If Sensor is functional, the cycle repeats
Name of process/activity
If Sensor is functional, the cycle repeats
Description of process/activity
After testing if the sensor is functional, the cycle repeats and the sensor life is expanded
Service
CREATE
Information producer (actor)
IoT Sensor
Information receiver (actor)
COP-PILOT Platform
Information exchanged (IDs)
Sensor ID, Completion Timestamp
Reference to Scenario number

1

Scenario name:
Sensor Waste Management and Recovery
Step No.
Step 8
Step Event
If sensor is not functional, it is the end of sensor lifecycle
Name of process/activity
If sensor is not functional, it is the end of sensor lifecycle
Description of process/activity
If after retesting the sensor is not functional anymore, its lifecycle ends and the sensor gets recycled
Service
REPORT
Information producer (actor)
IoT Sensor
Information receiver (actor)
COP-PILOT Platform
Information exchanged (IDs)
Sensor ID, Completion Timestamp
Reference to Scenario number
1

Requirements

Functional requirements

Table 9.2: Use cases functional requirements

Req. ID	Subject (+ Condition)	Commitment	Action + Object + {Constraint and/or Value}
4.1.FR1	Dashboard	Compulsory	The Dashboard must be browser based
4.1.FR2	Net App	Compulsory	The Net App must be located on cloud as a VM in "true" sovereign data centre.
4.1.FR3	Logistics Engine	Compulsory	The logistics engine must have a Unique ID for each sensor and each sensor kit/bundle
4.1.FR4	Logistics Engine Usage Cycle Events	Compulsory	The logistics engine must be able to handle up to 5 logistics event per usage cycle. A logistic event includes. Source address, Destination address. Shipping time. Shiping

4.1.FR5	Logistics Engine Cleaning Cycle Events	Compulsory	The logistics engine must be able to handle up to 1 digital cleaning and 1 physical cleaning per usage cycle
4.1.FR6	Logistics Engine Status	Optional	The status should show the status and location and next pending step within each usage cycle
4.1.FR7	Certificate	Optional	A digital certificate should be produced confirming physical and digital cleaning.
4.1.FR8	IoT Wallet	Optional	The data should be visible inside the IoT wallet for the sensor owner.

Non-functional requirements

Table 9.3: Use Case non-functional requirements

Req. ID	Subject (+ Condition)	Commitment	Action + Object + {Constraint and/or Value}
4.1.NFR1	Security (Data and Communication Security)	Compulsory	Must ensure secure encryption (TLS 1.3 or equivalent) for all sensor data transmitted and stored; compliance with GDPR and regulations.
4.1.NFR12	Ease of use and inclusivity (Dashboard Interface Usability)	Optional	Dashboard interface must be intuitive and inclusive for all users to be used requiring minimal training (usability score ≥80% in SUS scale)

Business requirements

Sustainability business requirements

Table 9.4: Use Case sustainability requirements

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
SR1	IoT sensor reuse	Compulsory	Ensure IoT sensors are reused multiple times across healthcare, vineyards and other sectors	Achieve ≥80% sensor reuse rate
SR2	Lifecycle transparency	Good to have	Track real-time status and lifecycle data for IoT sensors via orchestration platform	≥95% lifecycle transparency accuracy
SR3	Reduction of electronic waste	Compulsory	Enable reduction of IoT-related e-waste generation through circular economy practices	≥50% reduction of IoT device e-waste

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Societal business requirements

Table 9.5: Use Case societal requirements

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
SC1	Compliance with GDPR/MDR regulations	Compulsory	Ensure secure management and handling of sensitive data via COP-PILOT platform	100% compliance audits passed
SC2	Accessibility & Availability	Good to have	Improve availability of IoT sensors for use case providers	≥30% improvement in device availability
SC3	User-friendly IoT lifecycle platform	Compulsory	Provide intuitive and easy-to-use platform interface for lifecycle monitoring	≥80% positive user feedback in UX surveys

Market business requirements

Table 9.6: Use Case market (business) requirements

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
BR1	Reduction in IoT procurement costs	Compulsory	Reduce procurement and operational costs through efficient IoT sensor reuse and predictive maintenance	≥30% reduction in total IoT costs
BR2	Market scalability & replicability	Good to have	Validate solution scalability by applying successful IoT lifecycle management model to other verticals and EU regions	Successful implementation in at least 3 EU countries
BR3	Integration and maintenance efficiency	Compulsory	Ensure low-cost integration and straightforward maintenance of IoT devices through standardized orchestration workflows	Reduce integration time and costs by ≥40%

KPIs and KVIs

UC/vertical Specific

KPI: Achieve ≥80% reuse rate of IoT sensors deployed in different scenarios.

KVI: Demonstrate at least 95% accuracy in sensor lifecycle tracking (location, state, condition).

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Sustainability

KPI: Reduction of IoT sensor-related electronic waste by ≥50% compared to baseline (pre-project scenario).

KVI: Realization of a closed-loop logistics chain for IoT sensors, enabling reuse over multiple lifecycle cycles.

Environmental

KPI: Lower carbon footprint from IoT sensor lifecycle management by ≥40% through reduced manufacturing and disposal requirements.

KVI: Improved sustainability reporting accuracy through real-time lifecycle tracking analytics.

Societal

KPI: Increase availability and reliability of healthcare IoT sensors, improving sensor delivery effectiveness through timely and reliable device provision by at least 30%.

KVI: Enhanced public trust due to strict compliance with GDPR and healthcare regulations through secure data handling.

Operational and Efficiency

KPI: Achieve at least 50% reduction in sensor management administrative effort due to automated lifecycle monitoring and orchestration.

KVI: Decrease IoT sensor downtime by at least 30% via predictive maintenance workflows

Economic and business

KPI: Demonstrate a ≥30% reduction in IoT-related procurement and maintenance costs for use case providers.

KVI: Expand market opportunities by establishing a replicable IoT sensor management model applicable to multiple industries.

Scalability and EU Sovereignty

KPI: Validate scalability by successfully integrating IoT sensors across use case sites in at least three EU countries (Ireland, Germany, Spain).

KVI: Strengthen EU sovereignty by deploying exclusively European-based, standards-compliant (GAIA-X, IDSA) platforms and frameworks for data management and orchestration.

Legal and Ethics Requirements

UC activities are planned to involve:

- Involvement of volunteers (please provide more information under 1.4.8.1)
    - No volunteers will be involved in the UC.
- Data management (please provide more information under 1.4.8.2)

    - Simulated pilot data will be obtained. There will be no data related to a real person.
- Use of AI systems (please provide more information under 1.4.8.3)
    - There will be No AI processing.
- Other (please provide more information under 1.4.8.4)
    - None

Involvement of Volunteers

Not applicable

Data Related Activities

All data will be simulated pilot data. There will be no person related data

The data sets obtained will include:

- Kit data for IoT Sensors
- Location Data for IoT Sensors Kits
- Logistics Data for IoT Sensors Kits
- Status Data for IoT Sensors Kits

The data will be stored in Germany on a cloud platform. Data for the pilot will be processed in EU (Ireland, Spain, Portugal, Germany)

AI Systems

Not applicable

Other

Not applicable

IPR

There are no identified Intellectual Property Rights (IPR) issues associated with this use case. All software, including source code and associated developments produced within the scope of this project, will be classified as project foreground, thus freely accessible to the project consortium members in alignment with COP-PILOT's open innovation principles.

Specifically, the software and associated source code required for the successful implementation of Use Case 4.1 will be exclusively developed and produced by RedZinc (RZ). RedZinc will ensure full compliance with COP-PILOT's agreements regarding ownership, dissemination, and usage of the foreground intellectual property generated within this use case.

Risk identification and assessment

Table 9.7: Use Case risk assessment

Risks	Likelihood (L / M / H)	Impact (L / M / H)	Mitigation
1 Bugs in Code	H	L	Use multiple testing cycles
2. Alignment issues with highly complex COP-PILOT architecture	M	L	Active participation in formulation of the architecture
3 Immaturity of GAIA-X	M	M	Continuously monitor GAIA-X developments, maintain compatibility with alternative frameworks, and actively engage with GAIA-X community to influence and adapt to emerging standards.
4 GDPR and regulatory compliance issues in healthcare IoT data management	M	H	Implement regular compliance audits, engage GDPR/data governance experts, and provide ongoing compliance training for technical and operational teams
5 Sensor availability and supply chain disruption	M	M	Establish relationships with multiple IoT sensor suppliers and maintain strategic reserves to minimize operational disruption
6 Integration complexity with legacy healthcare IT systems	H	M	Conduct comprehensive system analysis and interoperability tests early, utilizing standardized APIs and middleware solutions for legacy integration

ANNEX 9.B: UC4.2 - WATER UTILISATION EFFICIENCY" TERRAVIEW GMBH

Description

Short Description

Aquaview (from here on known as "the system") is a sensorless soil moisture system. It utilises algorithms and ML to deliver precise soil moisture data with a 30m radius resolution. The system analyses satellite imagery and integrates it with weather data to provide highly accurate topsoil and depth moisture content data. It is crop-agnostic and offers historical data back to 2013, as well as future predictions of soil moisture for 7-14 days. Key features include real-time, high-resolution moisture readings, soil temperature approximation, daily data updates, customizable alerts, and a user-friendly interface. The system aims to optimise water use efficiency (WUE), reduce irrigation costs, and improve crop yields by providing precise insights into soil moisture conditions without the need for expensive and unreliable in-ground sensors. It effectively acts as a virtual moisture probe (VMP), allowing users to monitor soil moisture anywhere within their defined area of interest.

Complete Description

Pre-project description

Soil health is a significant concern, with issues such as soil erosion and the need to preserve healthy soil for sustainability. Too much water can compact the soil, while too little water can lead to dead topsoil. Additionally, the increasing cost of irrigation is a concern. Climate change further exacerbates these challenges.

Preserving healthy soil is crucial for sustainability, and the increasing cost of irrigation is an additional concern. The system contributes to improving soil health by providing highly accurate topsoil moisture content data, which helps in optimizing irrigation. This precise understanding of soil moisture content is crucial for maintaining soil health, as it prevents both overwatering and underwatering. Overwatering can compact the soil, while underwatering can lead to dead topsoil. By delivering precise 30m radius soil moisture data using advanced algorithms and ML enhancements, the system ensures that irrigation is done efficiently and effectively. This helps in preserving healthy soil and supports sustainable agricultural practices.

Figure 9.7: Challenges addressed

Final project description

The proposed system is predominantly a software solution that leverages remotely sensed data from satellites, processed and analysed using advanced algorithms and ML models. It aims to provide accurate soil moisture information and predictions without the extensive deployment and maintenance of physical hardware sensors in the field, though it can, and it is recommended to utilise data from such sensors for calibration purposes. In the case that depth soil moisture readings are required, **at least one hardware soil moisture sensor** is needed.

With the understanding of current soil moisture, historical patterns, and future predictions, the user can make better informed decisions about irrigation scheduling. By observing areas with low soil moisture, especially when coupled with predictions of continued dryness, the user can initiate or modify irrigation. Conversely, areas with adequate moisture or forecasts of rain can be spared, leading to optimization of water use efficiency (WUE).

Execution

User (e.g. vineyard manager) access the system's platform, likely through a web browser, and defining their area of interest. This initial step essentially tells the system which geographical area to analyse.

The system initiates the collection and processing of required data. This includes acquiring and analysing satellite imagery from various sources to calculate the Soil Moisture Index (SMI), a core indicator of soil moisture. The system accounts for and mitigates the impact of weather-related obstructions like clouds and shadows on the imagery.

Simultaneously, historical and predictive weather data are integrated from partner providers.

Furthermore, the system incorporates topographical details of the AOI, like slope, to enhance its analysis.

The ML models of the system are responsible for calculating soil moisture content at depth, whereas the topsoil moisture calculations are direct from image processing. To ensure consistency, even when satellite data isn't immediately available, the models backfill soil moisture values, providing a more continuous temporal resolution that can be as frequent as hourly. The system leverages these models to generate predictions of soil moisture for the upcoming 7 to 14 days, factoring in both historical patterns and anticipated weather conditions. This time window is largely dependent on the time resolution of the weather forecasts.

The user can then access the system's platform to interpret these processed insights through a user-friendly interface. They can visualise soil moisture maps, providing a spatial understanding of moisture variations across their vineyard. The virtual moisture probe (VMP) feature allows the user to obtain moisture readings for any specific point within their AOI. The system can provide access to historical soil moisture trends, dating back as far as 2013, enabling the user to understand long-term moisture behaviour on their land.

Main actors and roles

Table 9.8: Main actors and roles

Actor name	Actor type	Actor Description and Role
Service provider (e.g. Terraview)	Provider	The Provider is responsible for the entire system, including its design, development, and maintenance. They develop the advanced algorithms and ML models that process satellite imagery and weather data to generate soil moisture information. They integrate data from various sources, including satellite imagery and weather data providers.
End Users (Farmers, Vineyard Managers, Large Viticultural Operations)	End user	These are the end consumers of the system's soil moisture data and predictions. Users define their area of interest (AOI) within the system. They access and interpret the soil moisture maps, real-time readings, historical trends, and future predictions provided by the system to make informed irrigation decisions. Users can set customizable alerts for critical moisture and temperature thresholds.
Imagery and weather providers	Data Providers	These are the primary source of data for the system's sensorless soil moisture analysis. The system processes images from various satellite sources (e.g. Optical, SWIR, TIRS) to calculate the Soil Moisture Index (SMI). The system integrates data from weather data providers to blend with satellite information for more accurate analysis and predictions.
Irrigation systems	External system/service	While not explicitly an actor providing data to the system, irrigation systems are the technology that users act upon based on the system's insights. There is also potential for integration between the system and automated irrigation systems to enable data-driven adjustments to irrigation schedules.

Ambition, Motivation and Objectives

Motivation

The use case for Aquaview, focusing on water utilisation efficiency, aims to enhance and improve soil health for sustainability in agricultural practices. The additional costs of overwatering agricultural land from both environmental and financial perspectives also motivates the use case for Aquaview.

The Aquaview use case directly addresses the need for efficient water management in agriculture while aligning with broader project goals related to sustainability, technology integration, and market impact.

Ambition

It has the ambition to contribute to improving soil health by providing accurate topsoil moisture content data, which helps in optimising irrigation. This precise understanding of soil moisture is crucial for preventing overwatering, which can compact the soil, and underwatering, which can lead to dead topsoil. Moreover, it will contribute to optimising water use efficiency (WUE) by reducing water consumption without compromising crop yield or quality. It will also tackle challenges such as soil erosion, the need to preserve healthy soil for sustainability, and the increasing cost of irrigation, which are further exacerbated by climate change.

It also has ambition to deliver precise 30m radius soil moisture data using advanced algorithms and AI/ML enhancements, ensuring efficient and effective irrigation, by providing both backward-facing data analysis (revealing past behaviour) and forward-facing data analytics (predictive information), including recommended operator actions. Futhermore, it will support the UN’s Sustainable Development Goals (SDG) related to water, including sustainable management of water, sustainable consumption and production patterns, and the protection of terrestrial ecosystems. By providing historical data back to 2013, as well as future predictions of soil moisture trends, allowing planners to make informed irrigation decisions, it will provide a software-based virtual soil moisture probe that can be placed anywhere, self-maintaining, and significantly cheaper than hardware-based soil probes.

UC mapping with project objectives and innovations

The WUE/Aquaview use case aligns with several project objectives and innovations, including:

To design and implement an open multi-layer orchestration platform for the deployment and runtime management of collaborative applications, across heterogeneous domains and multiple distributed sectors. **Aquaview** benefits from this objective by utilising the platform for data processing and management of IoT and edge devices that might be used in its deployment.

To develop an “Auto-Pilot” IoT-to-edge-to-core cloud continuum tool, which allows for easy registration of new domains, automation of platform expansion, and secure integration of open IoT hardware. This objective aligns with **Aquaview's** need for a scalable and easily deployable system.

To create large scale piloting clusters serving as the basis for the integration of the platform framework and the interconnection of pilot use cases. The **Aquaview** use case would be tested in this infrastructure.

To analyse and validate the market potentials and the sustainability impact fingerprint for both the COP-PILOT platform and the targeted strategic piloting use case sectors. **Aquaview** contributes to this objective by showcasing sustainable water management practices in agriculture.

To maximise the impact and adoption of COP-PILOT, through specific standardisation and dissemination actions. **Aquaview** is a use case that will demonstrate the platform's capabilities and its potential for market adoption.

Rationale for the use of the COP-PILOT Platform

The use of the COP-PILOT platform is essential, as its orchestrator provides the necessary infrastructure to deploy and manage collaborative applications across distributed environments, ensuring both scalability and streamlined implementation.

The secure integration fabric ensures safe and reliable data transmission, which is vital for preserving data integrity and enabling a trustworthy digital transformation—particularly in the context of the wine industry.

Challenges addressed

Sustainable Agricultural Practices: By providing precise soil moisture data, Aquaview helps in optimizing irrigation, which in turn supports sustainable agricultural practices.

Cost Savings: With better irrigation planning and precise soil moisture data, farmers can reduce the costs associated with overwatering or underwatering their crops.

Expected outcomes

- **Improved Irrigation Planning**: Aquaview's timeline trends allow planners to see moisture retention trends over the last 10 years, helping them make informed decisions for future irrigation plans.

- **High Accuracy in Soil Moisture Data**: Aquaview has demonstrated accuracies of less than 1.5% deviation from ground control for surface moisture and less than 5% deviation for depth moisture. This high level of accuracy ensures that irrigation is done efficiently and effectively.

Key pain points

- **Precise Understanding of Soil Moisture Content**: Traditional soil moisture probes are expensive, provide only point data, and are often destroyed during field operations. Aquaview delivers precise 30m radius soil moisture data using advanced algorithms and AI/ML enhancements, ensuring a more accurate and comprehensive understanding of soil moisture.

- **Spatial Resolution**: Optimizing irrigation requires a precise sector-by-sector understanding of soil moisture. Most current satellite-based indices only deal with crop water stress and not soil moisture. Aquaview provides highly accurate topsoil moisture content data, which is crucial for effective irrigation planning.

- **Evapotranspiration Analysis**: Traditional methods focus on vegetation rather than soil state, which can lead to less accurate assessments of soil watering needs. Aquaview's approach ensures that soil moisture is accurately measured and managed.

UC Diagrams

Use Case Overview Diagram

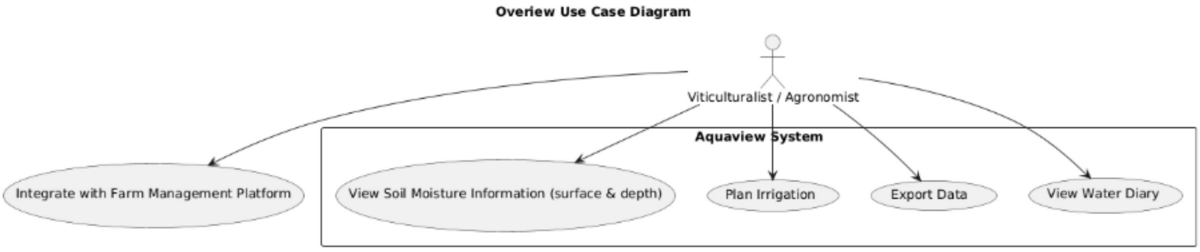

Figure 9.8: Use Case Overview Diagram

Use Case System Diagram

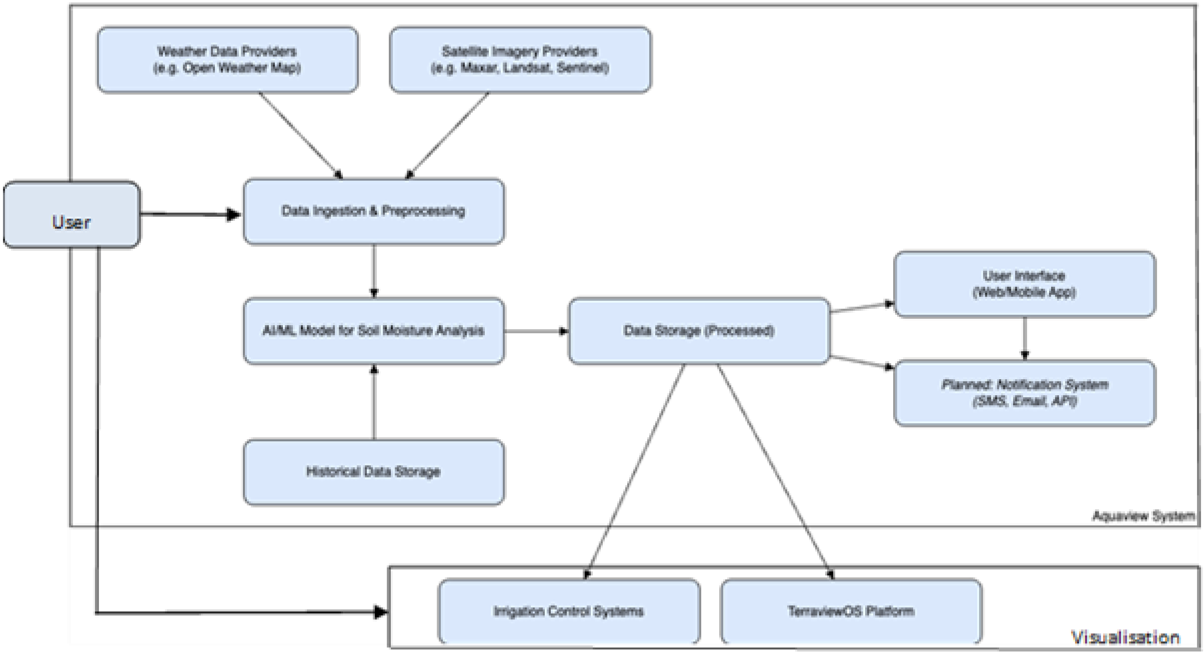

Figure 9.9: Use Case System Diagram

Use Case Architectural Diagram

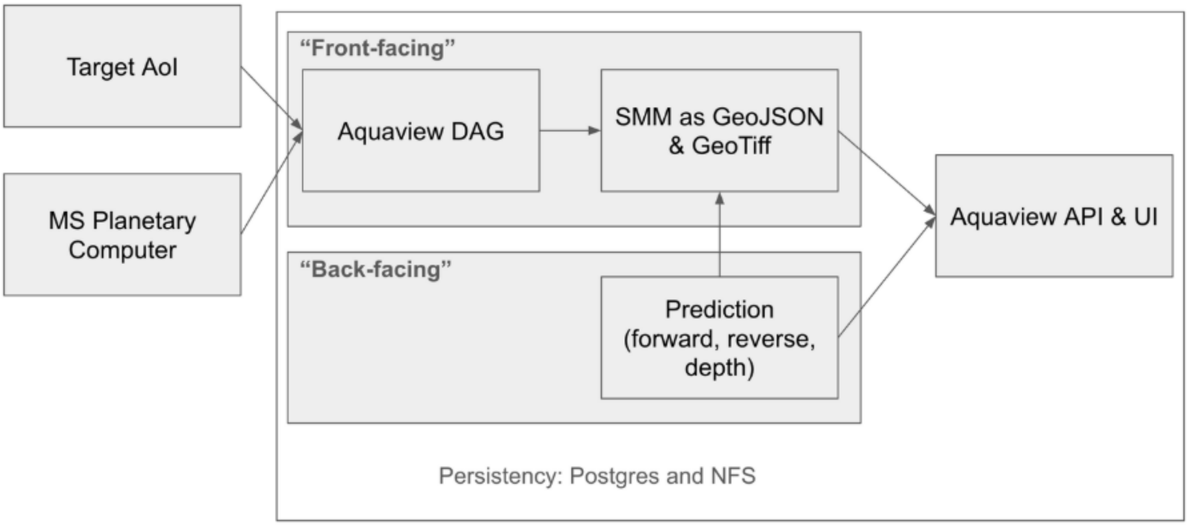

Figure 9.10: Use Case Architectural Diagram

The front-facing module is implemented with an Airflow directed acyclic graph (DAG). It is a workflow of a set of tasks required to arrive at the calculation of the soil moisture map and values. We show a simplified version of the diagram.

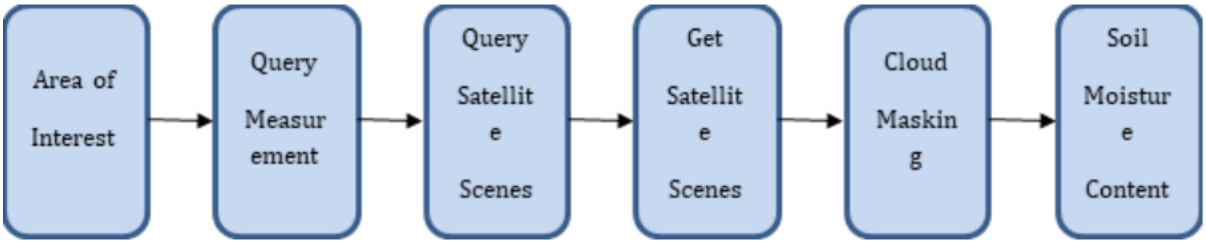

Figure 9.11: Airflow directed acyclic graph

With current or historic soil moisture maps and values available, these are then used by the back-facing module, which is responsible for all things related to prediction. In order to predict, two aspects are of focus: ground moisture forecasting and depth moisture forecasting.

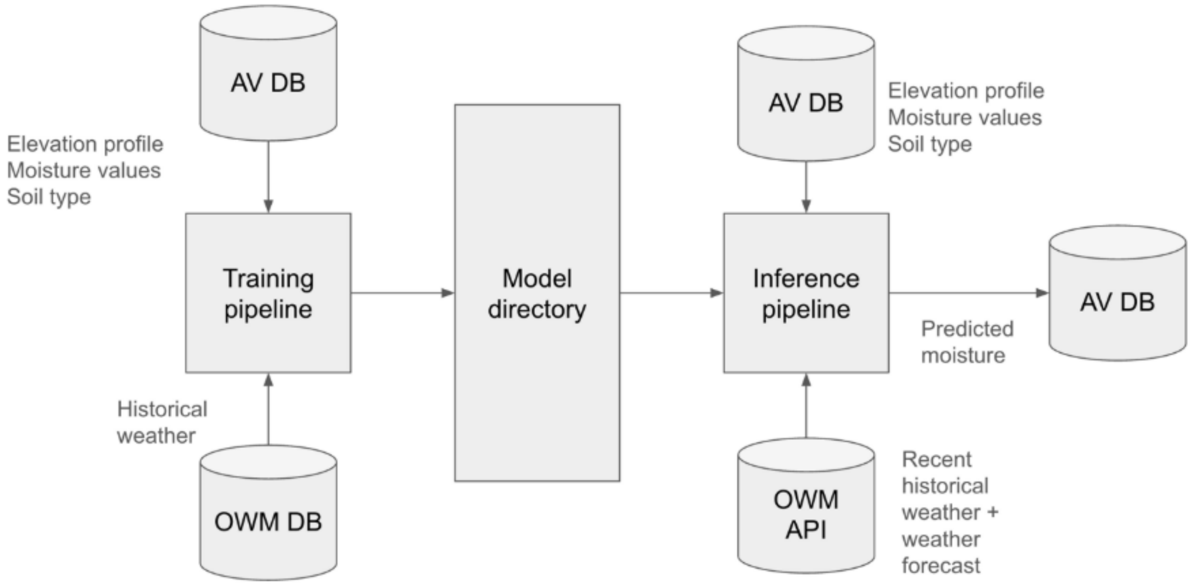

Figure 9.12: Back-facing module diagram

These are the two forecasting pipelines used to arrive at future predictions.

Scenarios Flowchart

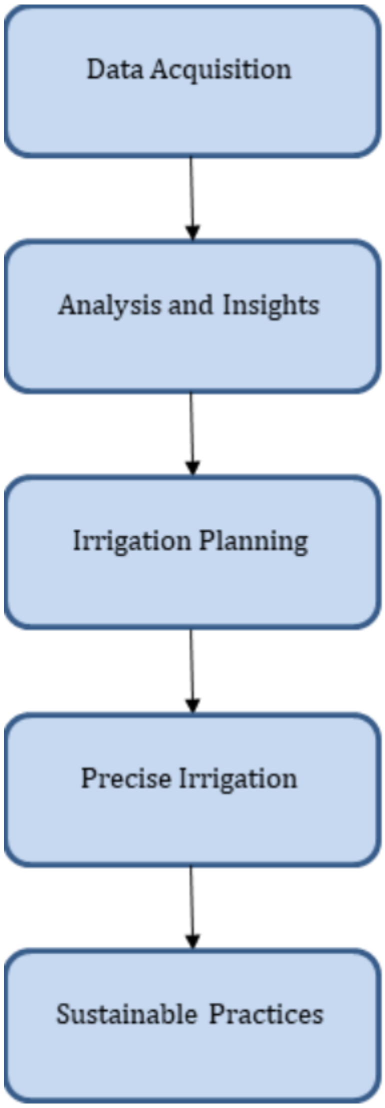

Figure 9.13: Scenarios Flowchart

Scenarios description

One common scenario where Aquaview can be used is in **optimising irrigation for agricultural lands**. In this scenario, Aquaview provides a system that enhances soil health and improves the efficiency of water use. The need for precise soil moisture data is critical in agriculture, as both overwatering and underwatering can negatively affect soil health.

Here's how the scenario unfolds:

1. **Data Acquisition**: Aquaview uses **satellite imagery** to calculate the Soil Moisture Index at the surface level, expressed as a volume of water divided by the volume of soil. This is supplemented by **on-site IoT soil moisture sensors** that provide specific data for accuracy and validation of satellite-derived data.

2. **Analysis and Insights**: The system analyses both past and present data. It uses advanced algorithms and AI/ML to process this information and provide **highly accurate topsoil moisture content data** within a 30m radius. This data provides a sector-by-sector understanding of soil moisture, which is crucial for optimising irrigation.

3. **Irrigation Planning**: Aquaview's system offers a **timeline view of moisture retention trends** over the last 10 years, helping planners make informed decisions for future irrigation plans. It also provides predictions for up to 14 days, allowing for proactive planning.

4. **Precise Irrigation**: Using the data, farmers can **precisely manage irrigation**, ensuring that water is applied only when and where it is needed. This prevents overwatering, which can compact the soil, and underwatering, which can lead to dead topsoil.

5. **Sustainable Practices**: By optimising irrigation, Aquaview contributes to **sustainable agricultural practices**, reducing water waste and promoting better soil health. This also helps in reducing the costs associated with irrigation.

Scenario name:
Optimising Irrigation and agricultural lands
Step No.
Step 1
Step Event
Grower request for moisture map
Name of process/activity
Data Acquisition
Description of process/activity
Grower wants to get moisture information of an area. Needed data is acquired from both IoT sensor and remote sensing sources.
Service
CREATE
Information producer (actor)
Grower
Information receiver (actor)
Edge device
Information exchanged (IDs)
Sensor ID, Location, Area, Date of analysis
Reference to Scenario number
1

Scenario name:
Optimising Irrigation and agricultural lands
Step No.
Step 2
Step Event

Data for grower request acquired
Name of process/activity
Analysis and Insights
Description of process/activity
Data is processed through AI model so that a detailed moisture map of the area of interest is produced.
Service
EXECUTE
Information producer (actor)
Edge device
Information receiver (actor)
AI Cloud service
Information exchanged (IDs)
Sensor Data, Remote Sensing Data
Reference to Scenario number
1

Scenario name:
Optimising Irrigation and agricultural lands
Step No.
Step 3
Step Event
New moisture map available
Name of process/activity
Irrigation Planning
Description of process/activity
Timeline of the historical moisture map and prediction map is given to the grower to optimise his irrigation plan.
Service
REPORT
Information producer (actor)
AI Cloud Service
Information receiver (actor)
Viewer cloud service
Information exchanged (IDs)
Historical moisture map, Prediction moisture map
Reference to Scenario number
1

Scenario name:
Optimising Irrigation and agricultural lands
Step No.
Step 4
Step Event
Timeline of moisture maps is reported on the platform
Name of process/activity
Precise Irrigation
Description of process/activity
Grower uses moisture map to irrigate the field only where it is needed.
Service
EXECUTE
Information producer (actor)
Viewer platform
Information receiver (actor)
Grower
Information exchanged (IDs)
Irrigation map
Reference to Scenario number
1

Scenario name:
Optimising Irrigation and agricultural lands
Step No.
Step 5
Step Event
Irrigation
Name of process/activity
Sustainable Practices
Description of process/activity
Optimised irrigation plan saves soil from issues related to overwatering as well as cost savings.
Service
REPORT
Information producer (actor)
Grower
Information receiver (actor)
Winery director
Information exchanged (IDs)
Soil review, operational costs
Reference to Scenario number
1

Requirements

Functional requirements

Table 9.9: Use Case functional requirements

Req. ID	Subject (+ Condition)	Commitment	Action + Object + {Constraint and/or Value}
FR1	Data Acquisition	Must	Download satellite data and capture on-site measurements.
FR2	Analysis and Insights	Must	Compute topsoil moisture content data
FR3	Data visualization	Must	Provide interactive moisture map visualisation for grower
FR4	Irrigation Planning	Must	Provide a timeline view of moisture retention trends over the last 10 years

Non-functional requirements

Table 9.10: Use Case non-functional requirements

Req. ID	Subject (+ Condition)	Commitment	Action + Object + {Constraint and/or Value}
NFR1	Compliance with Data Protection Laws	Must	Ensure all personal and location-based data collected, stored, or shared complies with GDPR and regional data laws.
NFR2	Scalability for Market Expansion	Could	The system must be modular and technically scalable, allowing deployment in different regions or agricultural domains with minimal configuration.
NFR3	User-Friendly Design	Must	The interface must be intuitive and accessible, including for users with limited digital literacy.

Business requirements

Sustainability business requirements

Table 9.11: Use Case sustainability requirements

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
SR1	Water Use Optimisation	Compulsory	Support system's irrigation insights to reduce water use.	≥20% reduction of water consumption
SR2	Reduction of Ground Infrastructure	Compulsory	Minimise reliance on hardware soil moisture sensors using satellite data.	≤2 needed sensors per location

SR3	Regenerative Agriculture Support	Compulsory	Provide insights that prevent over-irrigation and runoff.	≥20% reduction of water consumption while keeping same crop performance
SR4	Long-Term Soil Health Monitoring	Compulsory	Retain historical data for soil condition analysis.	Keep storage of 100% of recorded data
SR5	Stakeholder Inclusivity	Compulsory	Ensure access for both smallholders and enterprises; include multilingual support.	At least 2 supported languages
SR6	Energy Efficiency	Nice to have	Optimise backend system to minimise cloud resources	≥30% reduction of cloud resources consumption

Societal business requirements

Table 9.11:Use Case societal requirements

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
SC1	Compliance with Data Protection Laws	Compulsory	Ensure all personal and location-based data collected, stored, or shared complies with GDPR and regional data laws.	100% compliance with GDPR
SC2	User-Friendly Design	Compulsory	The interface must be intuitive and accessible, including for users with limited digital literacy.	≥85% positive user feedback in user surveys
SC3	Affordability for New Users	Compulsory	Provide free or low-cost entry-level tiers for small and first-time users.	≥50% cost reduction for new users

Market business requirements

Table 9.12: Use Case market (business) requirements

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
BR1	Long-Term Cost Effectiveness	Compulsory	The system must reduce operational costs over time compared to traditional sensor-based irrigation solutions.	Reduce costs by ≥ 30%
BR2	Scalability for Market Expansion	Good to have	The system must be modular and technically scalable, allowing deployment in different regions or agricultural domains with minimal configuration.	Successful implementation in at least 2 countries
BR3	Cost-Effective Maintenance	Compulsory	Backend and frontend components should require minimal manual	Reduce costs by ≥ 30%

			intervention, with automated diagnostics and updates.	
BR4	Increased Profitability for Clients	Good to have	The system should help users increase profitability through better yields, reduced water use, and operational efficiency.	Increase of profitability ≥ 10%
BR5	Failure Recovery & Redundancy	Compulsory	Implement robust data backups, fallbacks for cloud services, and alerting for data ingestion failure.	≥95% automated recover in case of data failure

KPIs and KVIs

UC/vertical Specific

KPI1: Reduction of Ground Infrastructure: ≤2 needed sensors per location

KVI1: Stakeholder Inclusivity: At least 2 supported languages

Sustainability

KPI1: Water Use Optimisation: ≥20% reduction of water consumption

KPI1: Energy Efficiency: ≥30% reduction of cloud resources consumption

Environmental

KPI1: Regenerative Agriculture Support: ≥20% reduction of water consumption while keeping same crop performance

KVI1: Long-Term Soil Health Monitoring: Keep storage of 100% of soil recorded data

Societal

KPI1: User-Friendly Design: ≥85% positive user feedback in user surveys

KVI1: Affordability for New Users: ≥50% cost reduction for new users

Operational and Efficiency

KPI1: Long-Term Cost Effectiveness: Reduce operational costs by ≥ 30%

KPI2: Cost-Effective Maintenance: Reduce maintenance costs by ≥ 30%

KVI1: Failure Recovery & Redundancy: ≥95% automated recover in case of data failure

Economic and business

KPI1: Increased Profitability for Clients: Increase of overall profitability ≥ 10%

Scalability and EU Sovereignty

KVI1: Scalability for Market Expansion: Successful implementation in at least 2 countries

KVI2: Compliance with Data Protection Laws: 100% compliance with GDPR

Legal and Ethics Requirements

UC activities are planned to involve:

☐ Involvement of volunteers (please provide more information under 1.4.8.1)

☒ Data management (please provide more information under 1.4.8.2)

☒ Use of AI systems (please provide more information under 1.4.8.3)

☐ Other (please provide more information under 1.4.8.4)

Involvement of Volunteers

No involvement.

Data Related Activities

The system receives input from electronic various sources:

- Satellite imagery (e.g. Optical, SWIR, TIRS).
- Historical weather data.
- Predictive weather data.
- Topographical information.
- Historical soil moisture content trends from satellite data.
- Historical Water Stress Index data.

This data is largely open except for the predictive weather data. Outputs from the system are also available to the user of the system via the user interface.

AI Systems

The system employs machine learning models to analyse data and generate predictions.

Machine learning provides data-driven insights and predictions to support decision-making by the user, such as the vineyard manager. While it can provide recommendations for irrigation, the ultimate decision on when and how much to irrigate appears to rest with the human operator. The machine learning does not autonomously control irrigation systems and requires human intervention as a standard feature.

The system's machine learning models can be further refined and improved over time as more data becomes available. The Virtual Moisture Probe (VMP) recalibrates every time new readings are available. The development plan includes ongoing refinement of the machine learning models using historical data and ground truth for validation.

Initially, ground-truth data from in-ground sensors is used for calibration and validation, although the aim is to reduce dependency on this over time.

The objective of the machine learning is to enable the optimisation of water use efficiency (WUE), leading to reduced water consumption, cost savings, and improved crop yields. The machine learning aims to provide predictive capabilities for soil moisture.

The system aims for a "human-mediated closed-loop system," ensuring safety and efficiency, which needs human oversight in the decision-making process, even if the machine learning provides strong recommendations. It is not seen at the moment that the system falls under the AI Act risk category. Direct integration to external systems would require a re-evaluation of this.

Other

Currently none.

IPR

Several Intellectual Property Rights (IPR) considerations have been identified for this use case. Data measured on site—such as sensor outputs and system-processed information—will be owned by the deploying company, while usage rights will be shared among project partners for research and development purposes. Algorithms and software developed during the project will remain the property of the respective developers but may be licensed for internal project use or future commercialization, in accordance with collaboration agreements.

Open-source technologies will be used wherever feasible, and any third-party software integrated into the solution will carry appropriate licenses to ensure compatibility, distribution, and interoperability. All partners will sign non-disclosure agreements (NDAs) to safeguard sensitive technical and commercial information. Strict controls will be applied to the dissemination of project outcomes, and joint ownership arrangements will be established when innovations result from collaborative work.

Risk identification and assessment

Table 9.13: Use Case risk assessment

Risks	Likelihood (L / M / H)	Impact (L / M / H)	Mitigation
Data availability	M	H	Make system robust to missing data to ensure continuity of deployed software. Implement strategy of replacement to face data missing.
Integration challenges with COP-PILOT architecture	M	M	Ensure the use of proper data mapping and standardization protocols supported by thorough compatibility testing. Collaborate with partners to oversee and manage the end-to-end integration process.
GDPR compliance	L	H	Involve GDPR experts, and deliver continuous compliance training for both technical and operational teams.

Security challenges	L	H	Utilize encrypted communication channels and implement robust authentication mechanisms. Conduct regular vulnerability assessments and ensure timely updates to security protocols to maintain system integrity.

ANNEX 9.C: UC 4.3 - SUSTAINABLE OPTIMIZED WINERY PRODUCTION LINES

Description

Short Description

IoT Wine Platform is an IoE (Internet of Everything) platform aimed at the wine industry for collecting, monitoring, and analyzing data generated in the wine and related products production process, ensuring complete control over the entire process.

The use case focuses on enhancing operational visibility, real-time anomaly detection, and predictive maintenance in a winery's bottling line. Currently, the winery operates with industrial machinery such as ABB robots, labelers, capsule machines, and bottle inserters, collecting production data mainly through manual or semi-automated processes, with limited real-time integration between systems and no AI-based diagnostics. Through COPILOT, the system will evolve to incorporate IoT sensors for real-time data acquisition, AI algorithms for anomaly detection and predictive maintenance, and NGSI-LD–based interoperability between ERP, MES, and IoT platforms. This will enable automated insights, reduce downtime, increase equipment efficiency, and ensure compliance with EU data sovereignty and GDPR standards.

For this use case, our focus will be on the comprehensive control of winery's bottling line, covering all its stages and sections.

To achieve this, we will install sensors connected to Raspberry devices that will collect and transmit real-time data on the process status. Additionally, OEE (Overall Equipment Effectiveness) metrics and manually entered data from operators will be integrated. This combination will enable more precise monitoring of operations, error detection, production time measurement, and optimization of the bottling line's performance.

Complete Description

Wineries currently rely on manual and fragmented methods to deploy, monitor, and maintain production systems. Each server is installed manually, services are deployed and configured one by one, and any IoT integration requires individual connection and adaptation. This leads to inefficiencies, delays, and a high probability of configuration errors. The process of updating dashboards and generating alerts is also carried out manually, limiting real-time responsiveness and scalability.

These limitations prevent wineries from responding quickly to operational deviations and reduce their capacity for predictive maintenance. There is no unified way to orchestrate heterogeneous devices or standardize communication across different components. As a result, the lack of automation slows down digital transformation and creates barriers to achieving the operational flexibility and efficiency demanded by modern production environments.

Co-funded by
the European Union

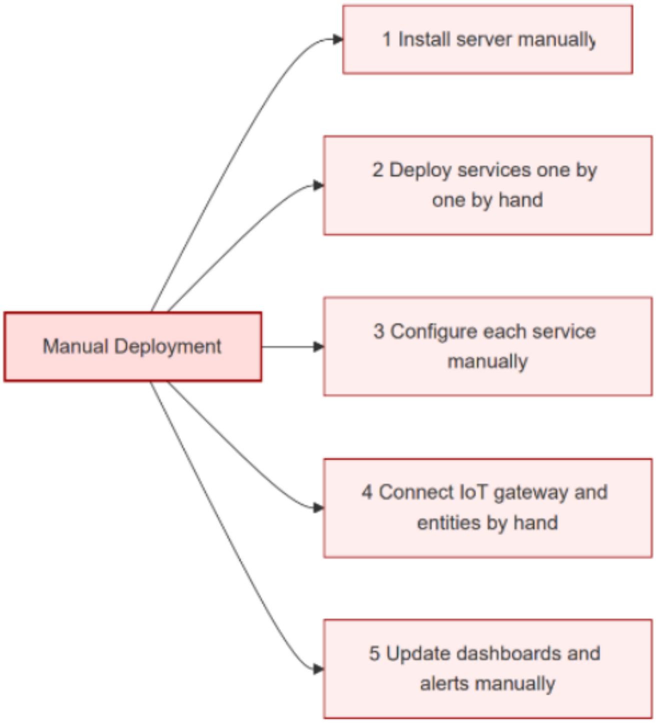

Figure 9.14: Manual Deployment

With the implementation of COP-PILOT, the use case will introduce an automated, scalable, and interoperable deployment process. The platform will enable automatic resource assignment, service deployment, and configuration. Data communication will be standardized, and security and interface compatibility will be enforced, ensuring seamless and safe operation across all system components. Through this orchestration, wineries will gain real-time control over production processes and will be able to perform historical analysis to support continuous improvement strategies.

The deployment and monitoring lifecycle will be fully automated. From sensor connection and service configuration to dashboard visualization and alert management, COP-PILOT will handle all orchestration processes. This will transform traditional operations into agile, data-driven environments, enabling predictive maintenance, optimized order management, and real-time production insights. COP-PILOT will thus demonstrate its ability to manage complex digital ecosystems and replicate the model in other agri-food sectors.

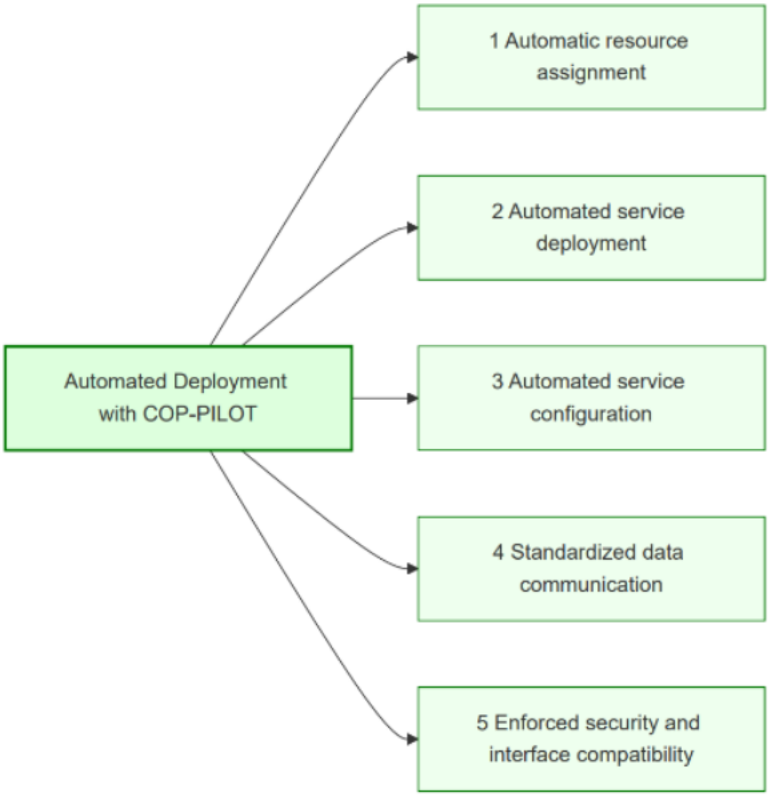

Figure 9.15: Automated Deployment with COP-PILOT

Main steps required to execute the use case:

- **Sensor and system deployment**: Install and calibrate sensors on the bottling line, connect them to Raspberry Pi GPIOs, and configure scripts to collect and transmit data.
- **Data orchestration and integration**: Use COP-PILOT to automate the deployment of services, configure IoT Agents, and normalize data to NGSI for use in the FIWARE context broker.
- **Monitoring and alerts**: Enable real-time visualization and monitoring through dashboards; configure alerts and automated actions in response to production anomalies or performance thresholds.
- **Order and performance management**: Integrate ERP and MES systems to automate production orders and calculate OEE metrics dynamically based on real-time data and historical trends.

Main actors and roles

Table 9.14: Main actors and roles

Actor name	Actor type	Actor Description and Role
Winery / Production Plant	End User	The entity that implements the IoT solution to improve operational efficiency. It uses the collected data to optimize production, reduce losses, and enhance decision-making.
Production operators	Operator	Workers responsible for supervising the production line. They use the IoT platform to monitor machine status, receive alerts, and adjust when necessary.
Production supervisors	Decision Maker	They analyze the performance of the production line through the platform. They use metrics such as OEE to identify areas for improvement and optimize operational efficiency.
Management / Executive team	Executive Decision Maker	They use the data generated by the platform to define investment strategies, set priorities, and improve operational planning.
Sensors	IoT Device	Devices installed on the production line that capture real-time data, such as unit count, temperature, and machine status.
Raspberry Pi	Edge Device	A device that collects data from the sensors and transmits it to the messaging system.

Table 9.15: Components and roles

Component name	Component type	Role in the system
RabbitMQ	Message Broker	The entity that implements the IoT solution to improve operational efficiency. It uses the collected data to optimize production, reduce losses, and enhance decision-making.
FIWARE IoTAgent	IoT Data Processor	It receives data from RabbitMQ, normalizes it, and converts it into a format compatible with Orion Context Broker.
Orion Context Broker	Context Manager	It stores and manages the state of entities in real time. It provides data to the backend and other systems that require it.
Backend	Data Processor	It processes data from Orion and manages subscriptions to notify other systems and the front-end. It can generate alerts and send data to the user interface.
Front-End	Front-End	A web application or control panel that allows real-time visualization of production data, generates reports, and configures operational parameters.

Quantum Leap	Data Historian	It is responsible for storing historical data in CrateDB for further analysis and trend evaluation.
CrateDB	Database	A database used to store historical information of the production process, facilitating time-series analysis.

Ambition, Motivation and Objectives

The primary **motivation** of this use case is to support real-time decision-making in the wine production sector by consolidating heterogeneous data sources into a unified and actionable overview. By integrating sensor data, OEE metrics, and manual inputs, the solution will provide operators with timely insights to improve productivity, quality control, and process traceability.

A key driver behind this initiative is the need to overcome fragmented data ecosystems. The wine sector faces challenges related to data heterogeneity, lack of interoperability, and limited automation capabilities. This use case aims to address these pain points through scalable, real-time integration of production information, enabling digital transformation and supporting data-driven management strategies.

The **ambition** of this use case is to develop a flexible and interoperable digital platform that transforms traditional wine production through automation, visualization, and AI-based analysis. By doing so, it will enhance operational efficiency and lay the groundwork for future innovations in precision viticulture.

The ambition is not limited to technical improvements. The broader goal is to create a replicable solution for other agri-food sectors, validating COP-PILOT's orchestration capabilities in real-world environments and contributing to the industry's overall sustainability, competitiveness, and innovation potential.

Mapping with Project Objectives

Objective 3: Enables hierarchical and federated data management across IoT swarms, edge domains, and core infrastructure.

Objective 4: Validates the orchestration framework through large-scale deployment in wineries as real-world testbeds.

Objective 6 and 7: Contributes to market validation, sustainability impact, and adoption through standardization and dissemination

Mapping with Project Innovations

- Facilitates seamless integration of heterogeneous IoT systems using COP-PILOT’s orchestration framework.

Incorporates AI-driven analytics and automated responses for predictive maintenance and real-time production optimization.

Rationale for using the COP-PILOT platform

COP-PILOT provides a multi-level orchestration layer that ensures end-to-end data flow management—from edge data capture to centralized visualization—enhancing responsiveness and system coherence.

Its secure integration fabric enables reliable communication between distributed systems, ensuring scalability and robustness essential for real-world deployment in the wine industry.

Challenges addressed

The main challenge of this use case is to develop a comprehensive platform that unifies and optimizes all production and manufacturing processes in the wine sector.

In the specific case of the wine production process within the bottling line, one of the key aspects this use case addresses is real-time monitoring. In a dynamic production environment like a winery, having immediate data is crucial for supervising each stage of the process and detecting any anomalies instantly.

Following the COP-PILOT approach, it is essential to develop intelligent management and automation capabilities to oversee the production process, detect anomalies, and optimize the winery's performance without constant manual intervention through the implementation of IoT sensors, OEE data, and manually recorded inputs from operators.

Another critical challenge is the integration of heterogeneous data. Currently, production process information comes from multiple sources and systems, making it difficult to consolidate everything into a single control platform. This use case aims to unify all these data streams into a centralized Overview, allowing clear and accessible visualization of the entire production process. In line with COP-PILOT, we must address this challenge by creating a common framework that enables the seamless integration of various information systems, ensuring that network policies and service quality metrics (SLA) are met in a flexible and scalable manner.

Additionally, reliability in data transmission and processing is a key concern. The information captured by sensors must be transmitted and processed without interruptions, even in environments where interference may occur. To achieve this, it is essential to ensure a robust infrastructure that minimizes data loss and guarantees accurate information. One of the challenges to address, aligned with the COP-PILOT approach, is the need to enhance data plane visibility by enabling the integration and consolidation of information from multiple sources into a single control environment. This will facilitate more precise monitoring and optimize service quality, as proposed by COP-PILOT in its solution framework.

Decision-making in the winery must evolve from manual mechanisms to intelligent orchestration models capable of analyzing complex data and extracting valuable insights. Through COP-PILOT strategies, the platform will be able to perform advanced production analysis, optimize work orders, and anticipate operational failures based on real-time data.

Event management in the bottling line requires a shift toward an event-driven system that dynamically reacts to production changes and potential incidents. This approach, aligned with COP-PILOT, enables the reduction of downtime and the optimization of operational efficiency through advanced automation.

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Data collection and transmission within the winery require a high level of reliability and security, preventing data loss and ensuring continuous operation. In line with COP-PILOT principles, the infrastructure must be robust, scalable, and flexible, guaranteeing data protection and secure collaboration among the various stakeholders in the production process.

Expected outcomes

The expected outcomes of this use case align with COP-PILOT principles, addressing improvements in operational efficiency, scalability, and data integration in industrial environments through IoT technologies, Artificial Intelligence (AI), and Machine Learning (ML).

The implementation of this solution will optimize the management of the bottling line through real-time monitoring and immediate anomaly detection, enabling agile responses to reduce production disruptions. This translates into greater efficiency, in line with COP-PILOT's objectives of enhancing sustainability in industrial processes.

The developed platform will facilitate the modernization of the production environment through the use of IoT sensors and advanced software. Its modular and scalable design will allow the progressive integration of new data sources and devices, ensuring the system's evolution in alignment with COP-PILOT's digitalization and automation strategies.

The solution will adopt a data-driven approach by consolidating heterogeneous information into a unified platform, providing a comprehensive view of the IoT environment. By leveraging AI and ML, it will enable informed decision-making by analysing trends and predicting potential failures before they impact production. This proactive approach will ensure efficient maintenance and strengthen system reliability, fully aligning with COP-PILOT's vision of integrating intelligence into industrial process management.

Key pain points

The key pain points of COP-PILOT align closely with the challenges in this use case. One of the main challenges is data capture and synchronization, as collecting real-time, automated information from multiple devices and sensors can be complex. Variability in formats and transmission speeds makes integration into a single system more difficult. The COP-PILOT orchestration platform addresses this issue by offering architecture that enables the management of heterogeneous formats and ensures automatic data synchronization through standardized APIs, thus facilitating a consistent and accurate information flow.

Another issue is data fragmentation, since information is often scattered across different systems, complicating global analysis. This makes it harder to detect patterns or anomalies. COP-PILOT solves this issue through a federated architecture that centralizes information from various IoT sources, ensuring that data is accessible and analyzable, thereby enhancing decision-making and system efficiency.

Additionally, connectivity and robustness pose a challenge, as data transmission in environments with variable conditions can lead to data loss or corruption. Ensuring reliable communication is essential for system stability. The solution proposed by COP-PILOT is based on software-defined networks and Zero Trust Networking strategies, ensuring reliable and secure communication even in infrastructures with connectivity limitations.

Another significant challenge is device management and monitoring, as many solutions lack centralized tools to oversee the status and performance of IoT devices. Without efficient management, it becomes difficult to anticipate failures or disconnections that could impact the production process. COP-PILOT incorporates an infrastructure orchestrator that enables efficient and automated management, providing full visibility over the IoT ecosystem and ensuring that resources operate optimally with minimal downtime.

Finally, data storage complexity is a critical factor. Maintaining enough space to store large volumes of historical data requires scalable infrastructure and efficient resource management, ensuring data remains accessible without compromising system performance. COP-PILOT's distributed architecture optimizes information distribution and storage, enabling fast and reliable access without compromising the platform's overall performance.

UC Diagrams

Use case overview Diagram: It shows the generic idea and is intended for illustration purposes.

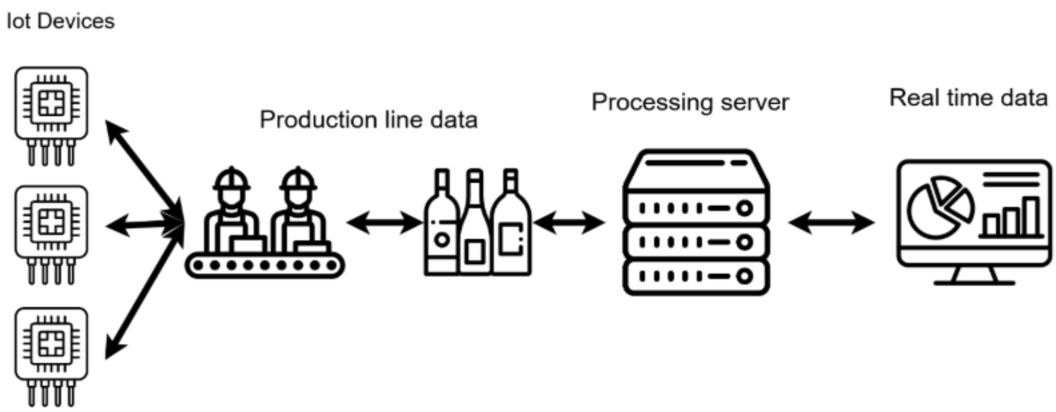


Figure 9.16: Illustrative diagram demonstrating how IoT devices capture production-line data, transmit it to a processing server, and ultimately present real-time insights on a dashboard.

Use Case System Diagram: It illustrates the overall system design including both the infrastructure and the interconnections between the physical components and the compute resources. It should reflect the scenarios that will be implemented.

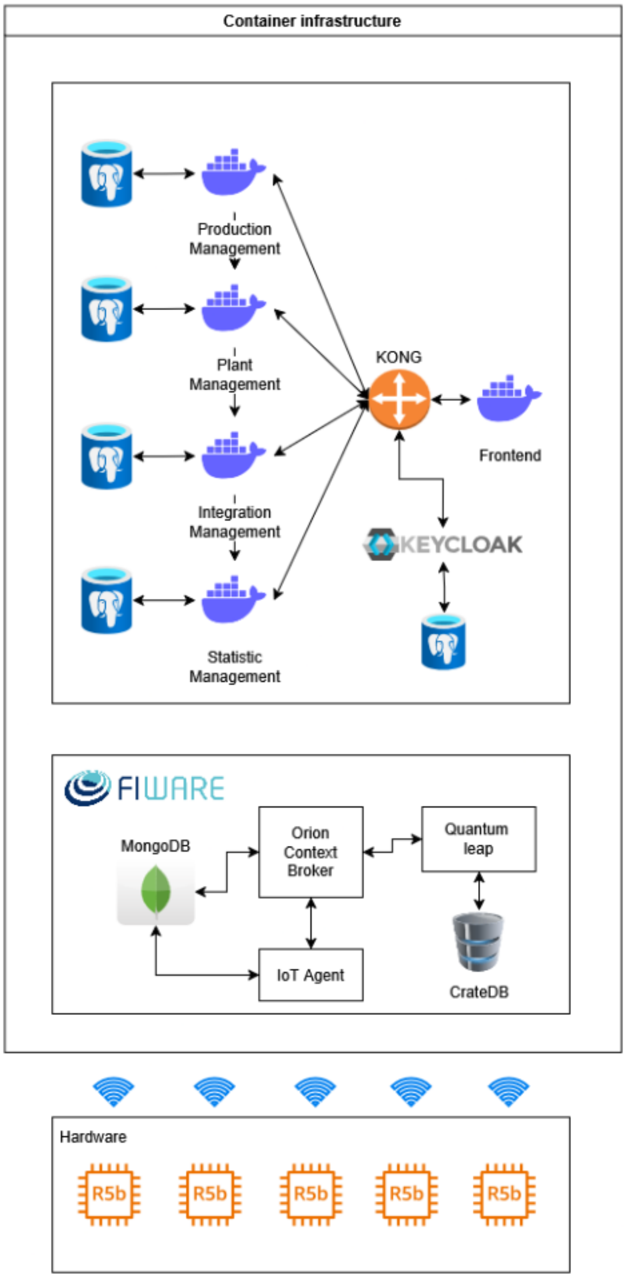


Figure 9.17: Overall architecture

This system diagram illustrates the overall architecture, including the container-based infrastructure, microservices, and their interconnections. It highlights the flow of data between physical hardware devices, FIWARE components (MongoDB, Orion Context Broker, and Quantum Leap), and supporting services such as Kong and Keycloak, demonstrating how production, plant, integration, and statistical operations are managed end-to-end.

Use case Architectural Diagram: It presents the various elements in a layered format. It should provide a mapping with the overall architecture.

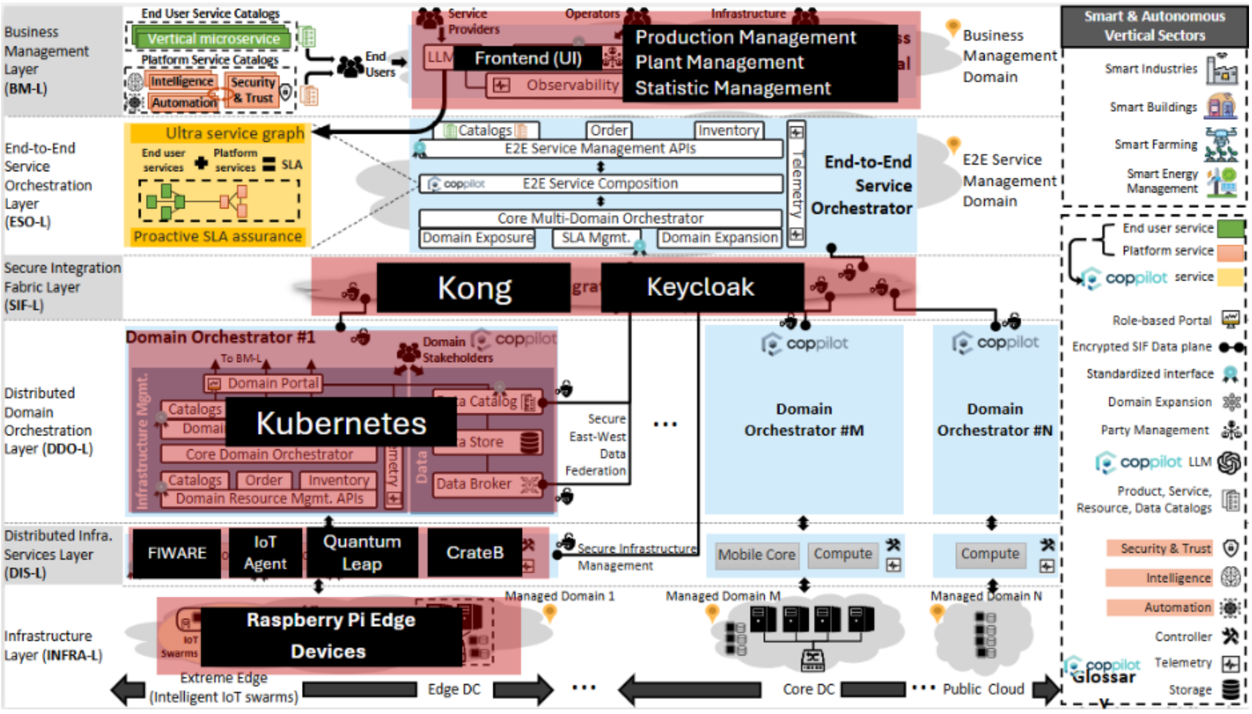


Figure 9.18: Architectural diagram

This architectural diagram illustrates a multi-layer system encompassing edge devices (Raspberry Pi), FIWARE components (IoT Agent, Quantum Leap, CrateDB), and distributed orchestration elements (Kubernetes, Domain Orchestrators). It highlights how Kong and Keycloak integrate with various management services (Production, Plant, and Statistic) to enable end-to-end service coordination, from the physical infrastructure layer up to the business management domain.

Scenarios Flowchart: This diagram depicts the flow of scenarios within the use case, illustrating the sequence of steps and decision points.

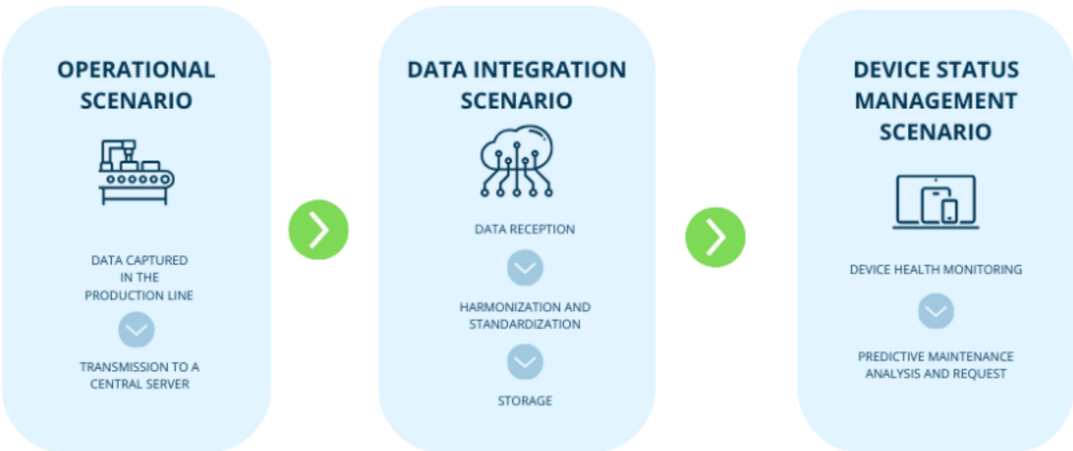


Figure 9.19: Scenarios

The diagram showcases the process of data collection, integration, and predictive maintenance in a production environment. IoT devices, such as Raspberry Pi with sensors, capture real-time data on environmental conditions and equipment performance, which is then securely transmitted to a central server for processing. This data is integrated from multiple systems (ERP, MES, IoT sensors) and standardized using COP-PILOT's Infrastructure Orchestrator (InfraOrch) to ensure interoperability, with the processed data stored in the Orion Context Broker for real-time decision-making.

Additionally, IoT devices monitor equipment health, and AI/ML algorithms analyze this data to predict potential failures. When an anomaly is detected, the system generates a predictive maintenance request, enabling early intervention to prevent disruptions.

Scenarios description

Operational Scenario
Step No.
Step 1
Step Event
IoT devices capture and transmit production data
Name of process/activity
Capture real-time production data
Description of process/activity
• **Data capture:** IoT devices (e.g., Raspberry Pi with sensors) collect real-time data on environmental conditions, equipment performance, and production status. This data is crucial for monitoring the production process and detecting anomalies early. • **Data transmission:** the captured data is transmitted securely to a central server for processing. Reliable and uninterrupted data transmission is essential for real-time analysis.
Service
CREATE
Information producer (actor)
Sensors
Information receiver (actor)
Raspberry Pi
Information exchanged (IDs)
Sensor readings (unit count, temperature, machine status)
Reference to Scenario number
Scenario 1

Table 9.16: Data Integration Scenario

Data Integration Scenario
Step No.
Step 2
Step Event
Data is collected from multiple systems
Name of process/activity
Harmonize and integrate production data
Description of process/activity
• **Data reception from multiple systems:** data from various systems (ERP, MES, IoT sensors) is received. This data is essential for creating a comprehensive overview of production activities. • **Data harmonization and standardization:** COP-PILOT's Infrastructure Orchestrator (InfraOrch) standardizes the received data using NGSI-LD to ensure interoperability across different systems. • **Data storage in Orion Context Broker:** the processed data is stored in the Orion Context Broker, providing centralized access for real-time decision-making.
Service
CHANGE
Information producer (actor)
InfraOrch
Information receiver (actor)
Orion Context Broker
Information exchanged (IDs)
Standardized NGSI-LD data
Reference to Scenario number
Scenario 2

Table 9.17: Device Status Management Scenario

Device Status Management Scenario
Step No.
Step 3
Step Event
IoT system detects an issue in a device
Name of process/activity
Trigger predictive maintenance
Description of process/activity
Device health monitoring IoT devices continuously monitor the health of production equipment, collecting key operational data (e.g., temperature, pressure).

Predictive maintenance analysis AI/ML algorithms analyze device health data to predict potential failures. Anomalies or unusual patterns trigger the prediction of upcoming device issues. Predictive maintenance request When a potential failure is detected, the system generates a predictive maintenance request, notifying the maintenance team for early intervention.
Service
EXECUTE
Information producer (actor)
Orion Context Broker
Information receiver (actor)
Maintenance System
Information exchanged (IDs)
Predictive maintenance request
Reference to Scenario number
Scenario 3

Requirements

List and description of the functional, non-functional and performance requirements for the UC.

Functional requirements

Table 9.18: Use Case functional requirements

Req. ID	Subject (+ Condition)	Commitment	Action + Object + {Constraint and/or Value}
FR1	Real-time monitoring of production line	Must	Capture and transmit sensor data from bottling line to central platform
FR2	Integration with Manufacturing Execution System (MES)	Must	Enable automated export/import of production orders between MES and ERP
FR3	OEE calculation and reporting	Must	Measure OEE metrics and provide real-time efficiency reports
FR4	Anomaly detection and alert system	Must	

			Detect deviations in production and trigger automatic alerts
FR5	Data visualization and dashboard customization	Must	Provide interactive, real-time data visualization for operators and managers
FR6	Remote access and control	Could	Allow users to monitor production data and configure parameters remotely

Non-functional requirements

Table 9.19: Use Case non-functional requirements

Req. ID	Subject (+ Condition)	Commitment	Action + Object + {Constraint and/or Value}
NFR1	Data security and integrity	Must	Ensure encrypted transmission and access control for sensitive production data
NFR2	System scalability	Must	Support increase in sensors, devices, and production lines without performance degradation
NFR3	High availability and fault tolerance	Must	Implement redundancy and failover mechanisms to ensure system uptime
NFR4	Compliance with industry standards	Must	Adhere to IoT security and data governance best practices
NFR5	Low latency data processing	Must	Guarantee real-time data processing for immediate decision-making
NFR6	User experience and accessibility	Could	Provide an intuitive and customizable UI for different user roles

Business requirements
Sustainability business requirements

Table 9.20: Use Case sustainability requirements

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
SR1		Compulsory	Optimize system algorithms to reduce processing power needs, affecting system	10% reduction in power usage of IoT devices based on

	Reduction of energy consumption		software and IoT device firmware	their energy consumption records.
SR2	Waste reduction in production	Compulsory	Detect and minimize production inefficiencies through real-time monitoring, affecting production line sensors, monitoring dashboard, and data processing module.	15% decrease in defective products based on production sensor records, quality control reports, and the defect tracking system integrated into COP-PILOT.
SR3	IoT device lifecycle management	Good to have	Implement monitoring of sensor health and predictive maintenance, affecting IoT devices, maintenance scheduling system, and sensor monitoring software	20% increase in device lifespan based on device status logs and sensor failure alerts.

Societal business requirements

Table 9.21: Use Case societal requirements

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
SC1	Data privacy and compliance (GDPR)	Compulsory	Ensure personal and production data is securely stored and processed, affecting data storage systems, user authentication modules, and audit logging components	Full compliance with GDPR and ISO 27001 based on access and data processing audit logs, and automatically generated compliance reports.
SC2	Workforce efficiency improvement	Compulsory	Automate repetitive monitoring tasks to allow workers to focus on high-value activities, affecting monitoring scripts, task scheduling modules, and user interfaces	25% reduction in manual data entry based on automated task system logs.
SC3	User accessibility	Good to have	Develop a multilingual and role-based dashboard for diverse users, affecting UI/UX components, language translation modules, and user role management system	System accessibility rating above 80% in user surveys based on user role system logs and monitoring of language and accessibility preferences.

Market business requirements

Table 9.22: Use Case market business requirements

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
BR1	Cost efficiency	Compulsory	Reduce manual work and optimize production with automation, affecting production control systems, workflow automation tools, and manual input interfaces	30% reduction in operational costs based on a before-and-after comparison using accounting records and ERP reports.
BR2	System interoperability	Compulsory	Ensure compatibility with existing winery ERP and MES systems, affecting API layer, data exchange modules, and integration middleware	Full API support for integration based on documented ERP/MES integration tests, successful API call logs, and validated system connectivity.
BR3	Market expansion potential	Good to have	Develop a scalable model for adoption in other processes, affecting deployment architecture, configuration templates, and documentation	Expansion into 1+ process based on scalability reports generated from the deployment environment.

KPIs and KVIs

UC/vertical Specific

So far, significant progress has been made in improving production monitoring, data integration, and maintenance processes. Although data collection is still largely manual, systems have been implemented to gather key information from machines and processes, allowing for basic production tracking. Synchronization between ERP and MES has been done manually, ensuring that data remains connected. Additionally, while downtime is not detected immediately, operations have been kept running without major interruptions. Preventive maintenance is also regularly carried out, minimizing significant failures. These advancements provide a solid foundation on which operational efficiency and responsiveness can continue to be built and optimized. The planned KPIs are as follows:

- Scenario 1: Real-time production monitoring
  - KPI1 – Data collection accuracy: ≥ 98% accuracy in capturing real OEE data, processed and rejected units from machines such as ABB Robot Outfeed, Capsule Machine, Labeler, Bottle Inserter, and Sealer.
  - KPI2 – System latency: ≥ 30% reduction in downtime detection time for the Labeler, Capsule Machine, Bottle Inserter, and Sealer.
  - KPI3 – Production cycle efficiency: Maintain pre-production time.
  - KVI1 – Operator response improvement: ≥ 30% reduction in the time to identify anomalies detected by the system.
- Scenario 2: Data integration and process optimization
  - KPI4 – Data integration success rate: ≥ 99% of production orders correctly synchronized between ERP and MES without manual errors.
  - KPI5 – Data synchronization time: <5 seconds from IoT data capture to database processing.
  - KPI6 – Reduction in manual data entry: ≥ 40% decrease in operator-entered records due to automation.
  - KVI2 – Decision-making agility: ≥ 20% reduction in average time required to adjust production based on analyzed data.
- Scenario 3: Predictive maintenance and anomaly detection
  - KPI7 - Reduction of total downtime per machine: Ensure that total downtime does not exceed critical values.
  - KPI8 – Fault resolution time: <15 minutes from anomaly detection to corrective alert issuance.

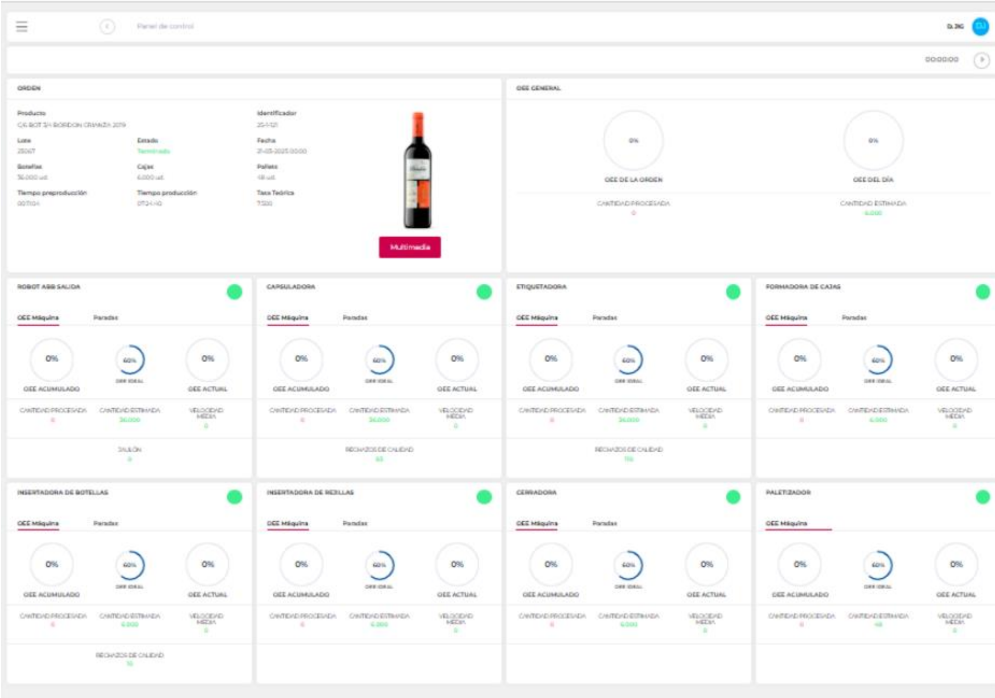
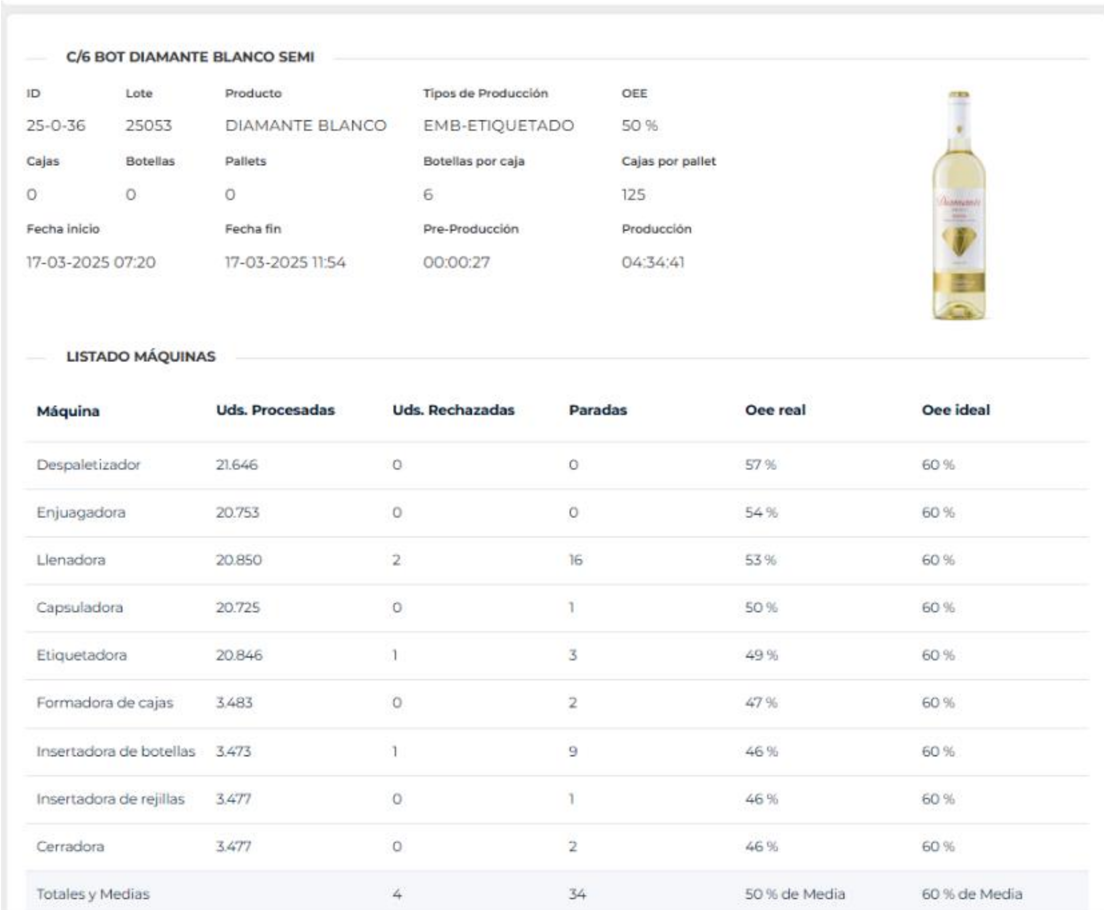


Figure 9.20: Platform visualization

Sustainability

- KPI1 – Reduction of bottle and box waste: Keep the number of rejected bottles below 0.5% of the total processed.
- KPI2 – Optimization of pallet usage: Reduce the number of panels used by 5% without decreasing storage capacity.



C/6 BOT DIAMANTE BLANCO SEMI

ID	Lote	Producto	Tipos de Producción	OEE
25-0-36	25053	DIAMANTE BLANCO	EMB-ETIQUETADO	50 %
Cajas	**Botellas**	**Pallets**	**Botellas por caja**	**Cajas por pallet**
0	0	0	6	125
Fecha inicio		**Fecha fin**	**Pre-Producción**	**Producción**
17-03-2025 07:20		17-03-2025 11:54	00:00:27	04:34:41

LISTADO MÁQUINAS

Máquina	Uds. Procesadas	Uds. Rechazadas	Paradas	Oee real	Oee ideal
Despaletizador	21.646	0	0	57 %	60 %
Enjuagadora	20.753	0	0	54 %	60 %
Llenadora	20.850	2	16	53 %	60 %
Capsuladora	20.725	0	1	50 %	60 %
Etiquetadora	20.846	1	3	49 %	60 %
Formadora de cajas	3.483	0	2	47 %	60 %
Insertadora de botellas	3.473	1	9	46 %	60 %
Insertadora de rejillas	3.477	0	1	46 %	60 %
Cerradora	3.477	0	2	46 %	60 %
Totales y Medias		4	34	50 % de Media	60 % de Media

Figure 9.21: Recorded metrics

- KVI1 – Renewable energy utilization: percentage of the system's power supplied by renewable energy sources (target: ≥ 30%).

Environmental

- KPI1 – Achieve a 5% reduction in material waste caused by failures in the Labeler, Capsule Machine, Sealer, and Bottle Inserter within the next operational year.
- KPI2 – Optimization of energy consumption on the production line: Adjust energy consumption in machines such as the case former or the grid inserter with OEE below 50%.
- KVI1 – Achieve at least 95% efficiency in storage utilization and data processing effectiveness, improving from an estimated current 85%.

Societal

- KPI1 – Reduction of manual intervention in production control: Decrease manual data entry in the Labeller, Capsule Machine, and ABB Robot Outfeed by automating the recording of processed and rejected units, aiming to reduce manual input from 30% to 24%, achieving a 20% reduction in manual intervention.

- KPI2 – Reduction in Human Error: ≥ 30% decrease in operational errors related to manual data handling.
- KPI3 – GDPR and Data Privacy Compliance: Full compliance with GDPR and ISO 27001 security standards.
- KVI1 – Employee Satisfaction Score: ≥ 85% positive feedback from workers using the system.

Operational and Efficiency

Scenario 1: Real-Time Operational Visibility

- KPI1 – System Uptime: Ensure ≥ 99.9% availability of the IoT platform to minimize monitoring disruptions.
- KPI2 – Data Processing Speed: Guarantee <2 seconds latency for real-time updates on production data.
- KPI3 – Alert Precision: Achieve ≥ 95% accuracy in system-generated alerts for detecting real operational issues.
- KVI1 – Reduction in Manual Reporting: Decrease operator-reported logs by ≥ 50% through automated data collection.

Scenario 2: Data Integration and Process Optimization

- KPI4 – Integration Accuracy: Ensure ≥ 99% success rate in synchronizing production data across MES, ERP, and IoT systems.
- KPI5 – Data Synchronization Time: Reduce time for data harmonization to ≤ 5 seconds between IoT devices and the central platform.
- KPI6 – Reduction in Manual Adjustments: Lower operator interventions by ≥ 40%, optimizing process automation.
- KVI2 – Decision-Making Agility: Reduce response time for process optimization by ≥ 20%, enhancing operational efficiency.

Scenario 3: Device Status Management and Predictive Maintenance

- KPI7 – Predictive Maintenance Accuracy: Detect potential failures with ≥ 85% reliability, reducing unplanned downtime.
- KPI8 – Downtime Reduction: Decrease unexpected production stoppages by ≥ 25% through real-time anomaly detection.
- KPI9 – Maintenance Response Time: Ensure <15 minutes from failure detection to maintenance alert issuance.

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Economic and business

- KPI1 – Reduction of production costs due to downtime: Minimize economic losses associated with downtime by reducing downtime-related costs by at least 10%.
- KPI2 – Increase the number of boxes per pallet by at least 8% compared to the current average, without compromising stability or safety.

Scalability and EU Sovereignty

- Scalability & performance:
  - KPI1 –Increase the number of sensors on the production line by 15%.
  - KVI1 – Seamless ERP & MES Integration: Ensure 100% compatibility with existing and future ERP/MES systems.
- EU Digital Sovereignty & Compliance:
  - KPI2 – EU Data storage compliance: 100% of operational data stored and processed within EU-compliant cloud infrastructures.
  - KPI3 – Open Standards & Interoperability: Ensure ≥ 95% of platform components follow open-source and EU-recommended standards.

Legal and Ethics Requirements

UC activities are planned to involve:

☐ Involvement of volunteers (more information under 1.4.8.1)

☒ Data management (more information under 1.4.8.2)

☒ Use of AI systems (more information under 1.4.8.3)

☒ Other (more information under 1.4.8.4)

Involvement of Volunteers

Not involved

Data Related Activities

The IoT Wine Platform collects and processes data to optimize production efficiency, detect anomalies, and improve decision-making. All data-related activities comply with GDPR, ISO 27001, and EU data sovereignty regulations, ensuring security, transparency, and lawful processing.

The platform gathers several types of datasets, including production data from IoT sensors, such as machine status, temperature, humidity, bottle count, and line speed. Additionally, operational efficiency data is collected, covering Overall Equipment Effectiveness (OEE) metrics, downtime logs, error reports, and maintenance history. User interaction data, such as manual entries from operators regarding maintenance reports, production adjustments, and quality control inputs, is also recorded.

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Data collection occurs automatically through IoT devices, ERP/MES system integrations, and manual operator inputs. Processing happens in real-time within an EU-compliant cloud infrastructure, with strict access controls. The primary goal of data collection is to enhance production monitoring, enable predictive maintenance, and support data-driven decision-making in wineries. All data is encrypted and stored securely, with role-based access controls (RBAC) ensuring only authorized personnel can view or modify specific datasets.

While the majority of the collected data pertains to industrial processes, any user-related data, such as login credentials or access logs, will be handled under explicit consent mechanisms. Transparency is maintained through audit logs, access tracking, and compliance reports, ensuring that users are fully aware of how their data is used.

Access to data is restricted to authorized winery operators, managers, and system administrators for monitoring and decision-making. Anonymized and aggregated datasets may be used for performance analysis, AI model training, and industry research. The platform does not share data with third parties unless required for regulatory compliance or industry benchmarking, in which case anonymization and strict security protocols will be applied.

Data retention policies ensure that operational and production data is stored for up to five years to allow for long-term trend analysis, while user-related data is retained for one year unless needed for auditing or compliance purposes. AI training datasets are kept for ongoing model improvement, with periodic updates and reviews. Security measures include end-to-end encryption for data at rest and in transit, a Zero Trust architecture with multi-factor authentication (MFA), and regular security audits to maintain data integrity.

By following strict security, transparency, and compliance protocols, the IoT Wine Platform ensures that all data-related activities align with EU regulations while supporting the digital transformation of industrial wineries.

AI Systems

The IoT Wine Platform incorporates an AI-driven analytics system to optimize production efficiency, predict equipment failures, and detect anomalies in the bottling process. The AI is machine-based and operates at a semi-autonomous level, meaning that while it provides recommendations and automates certain tasks, critical decisions remain under human oversight. It is designed to continuously learn and improve, allowing for adaptability after deployment through iterative model updates based on real-time and historical data.

The system receives input from IoT sensors, MES (Manufacturing Execution Systems), ERP systems, and manual operator entries. It analyzes this data to predict maintenance needs, optimize production speed, and identify inefficiencies in the process. Additionally, it generates real-time alerts for deviations from expected performance, allowing operators to take immediate corrective action.

This system does not fall under the high-risk category of the EU AI Act, as it is not directly involved in safety-critical processes. Instead, it is considered a low-risk application, focusing on process optimization without autonomous decision-making in safety-sensitive areas. However, ongoing compliance with ethical AI principles ensures that risks are continuously monitored.

The training data includes historical production logs, sensor readings, maintenance reports, and operational efficiency metrics. Special attention is given to inclusion and diversity (I&D) in data collection, ensuring that models do not favor specific production conditions and maintain fairness in predictions. Bias prevention measures include balanced dataset selection, periodic audits, and fairness-testing algorithms.

Co-funded by the European Union

Integrating this technology into the IoT Wine Platform enables wineries to improve efficiency, reduce downtime, and make data-driven decisions, while ensuring compliance with EU regulations and ethical AI standards.

Other

Not involved

IPR

Several intellectual property (IPR) related requirements and issues have been identified. First, the data generated by IoT devices, such as sensor readings and information processed by the systems, will be owned by the company implementing them, with shared usage rights among project partners for research and development purposes. The algorithms and software developed during the project will be owned by the developers but may be licensed for use within the project framework or commercialized in the future, as agreed upon in collaboration contracts.

Additionally, open-source technologies will be used where possible, and any third-party software integrated into the solution will have the appropriate licenses, with no restrictions that could affect distribution or interoperability. All project partners will be required to sign non-disclosure agreements (NDAs) to protect technical and commercial results, and strict control will be maintained over the distribution of the developments. The parties will also agree on joint ownership of results when innovations are created in collaboration.

Risk identification and assessment

Table 9.23: Use Case risk assessment

Risks	Likelihood (L / M / H)	Impact (L / M / H)	Mitigation
Data transmission issues	M	H	Implement redundant communication channels and ensure robust infrastructure to minimize transmission errors. Regular testing and monitoring of data transmission processes.
Integration challenges with legacy systems	M	M	Ensure proper mapping and standardization protocols (e.g., using NGSI-LD) and conduct comprehensive compatibility testing. Leverage experienced integration partners to manage the process.
Security vulnerabilities	M	H	Use encrypted communication channels and implement advanced authentication mechanisms. Regular vulnerability assessments and updates to security protocols
Operational disruptions during deployment	M	H	Establish clear timelines and perform phased deployments. Ensure adequate training for operators and maintain a support team for troubleshooting.

ANNEX 9.D: UC 4.4 – AI-DRIVEN GREEN ENERGY VINEYARD MANAGEMENT

DESCRIPTION

In isolated and off-grid environments, access to reliable power is limited, making green energy sources such as solar or wind the primary means of sustaining digital infrastructure. These locations often host critical services that must remain operational despite fluctuating energy availability. As a result, managing energy efficiently becomes essential to ensure continuity and avoid service interruptions.

A key challenge in these settings is the need to accurately monitor and account for the energy consumption of all deployed devices. Each component, from edge computing nodes to communication modules, contributes to the overall energy load. Without precise visibility into consumption patterns, it becomes difficult to allocate resources effectively or prevent unnecessary energy drain.

The increasing reliance on advanced connectivity technologies like 5G and emerging 6G further complicates the situation. While these networks enable high-performance communication, they also introduce significant energy demands. Communication-related consumption must therefore be carefully managed to balance performance requirements with the limited energy budget available in off-grid scenarios.

In the absence of intelligent energy management, resources can be rapidly depleted, leading to service degradation or complete outages. Static configurations or always-on device operation are not viable in such constrained environments. Instead, adaptive strategies are required to ensure that energy is used only when and where it is truly needed.

To address these challenges, remote monitoring and control capabilities play a crucial role. Operators must be able to dynamically manage devices, including switching them on or off based on real-time demand. This level of control allows for more efficient use of energy and helps extend the operational lifespan of the system under constrained conditions.

Additionally, integrating predictive insights—such as weather-based energy forecasts—enables proactive optimization of energy usage. By anticipating future energy availability, systems can adjust workloads and device activity in advance, ensuring sustained operations even during periods of low energy generation. Together, these approaches form a comprehensive strategy for maintaining reliable services in energy-constrained, off-grid environments.

MAIN ACTORS AND ROLES

Table 9.24: Main actors description and role

Actor name	Actor type	Actor Description and Role
Mobile Network Operator (MNO)	Operator	Responsible for deploying and operating the 5G/6G infrastructure. Monitors network performance and leverages the system to optimize energy

		consumption while maintaining service quality.
Renewable Energy Provider	Energy provider	Supplies green energy sources such as solar or wind. Provides data on energy generation and collaborates in forecasting energy availability.
Energy Management Platform	Technology provider	Central system that monitors, analyzes, and optimizes energy usage. Runs predictive models and control mechanisms to balance consumption and energy availability.
IoT Solution Provider	IoT provider	Provides sensors (weather, soil, energy meters) that collect real-time data to improve monitoring accuracy and support decision-making processes.
Remote Site Operator	Site operator	Manages daily operations of the off-grid site. Uses remote monitoring tools to supervise device status, energy levels, and system performance.
5G/6G Infrastructure Vendor	Network equipment provider	Supplies network equipment such as base stations and radio units. Ensures devices support energy-efficient operation and remote control capabilities.
Weather Data Provider	Data provider	Delivers external weather forecasts that are used to predict future renewable energy generation and support proactive energy planning.
AI / Optimization Solution Provider	AI solution provider	Develops and trains advanced algorithms that optimize energy allocation based on demand, device profiles, and QoS requirements.
Connected Devices (IoT / Edge Nodes)	Device / End system	Devices deployed at the site that consume energy (e.g., sensors, edge computing units).

		Their operation is dynamically controlled to optimize overall energy usage.
End User	End user	Final consumer of the provided services (connectivity, applications). Benefits from reliable service continuity despite limited energy resources.

AMBITION, MOTIVATION AND OBJECTIVES

The primary motivation behind this use case stems from the growing need to ensure reliable digital service delivery in isolated and off-grid environments where conventional power infrastructure is unavailable. In such contexts, green energy sources like solar and wind are often the only viable options, but their intermittent and unpredictable nature creates significant challenges for maintaining continuous operations. Without proper energy management, critical services supported by 5G/6G connectivity risk degradation or failure due to energy shortages.

Additionally, the increasing energy demands of advanced communication technologies further exacerbate this challenge. 5G and future 6G networks, while enabling high-performance and low-latency services, introduce substantial energy consumption, particularly in radio access networks. This creates a pressing need for intelligent systems capable of monitoring, predicting, and optimizing energy usage in real time, ensuring that limited resources are utilized efficiently while maintaining required service levels.

This use case aims to deliver a fully autonomous and intelligent energy management framework capable of optimizing energy consumption across all devices and network layers in real time. By combining continuous monitoring, predictive analytics, and remote control, the system aspires to maximize the utilization of available green energy while minimizing waste. The ambition is to create a self-adaptive environment where energy allocation dynamically responds to both service demand and forecasted energy availability.

Furthermore, the use case envisions enabling scalable and sustainable deployment of 5G and future 6G services in energy-constrained environments. By integrating energy awareness into network orchestration and device management, it seeks to support the onboarding and operation of new services and devices without compromising efficiency. Ultimately, the ambition is to establish a blueprint for resilient, energy-efficient digital infrastructure in remote and off-grid scenarios.

Mapping with Project Objectives

Objective 3: Enables hierarchical and federated data management across IoT swarms, edge domains, and core infrastructure. Enable sustainable and energy-efficient operation of 5G/6G networks in off-grid and energy-constrained environments.

Objective 4: Validates the orchestration framework through large-scale deployment in wineries as real-world testbeds. Support intelligent orchestration and automation of network and computing resources based on real-time and predictive energy insights.

Objective 6 and 7: Contributes to market validation, sustainability impact, and adoption through standardization and dissemination by enhance service reliability and continuity through proactive energy management and dynamic adaptation to resource availability.

Mapping with Project Innovations

- Facilitates seamless integration of heterogeneous IoT systems using COP-PILOT's orchestration framework that incorporates AI-driven analytics and automated responses for predictive maintenance and real-time production optimization.
- Integration of real-time energy monitoring with AI-driven forecasting using combined weather and IoT data sources. Dynamic control of network elements (e.g., radio layers) based on energy availability and service demand.
- Cross-layer optimization combining energy, network performance, and QoS requirements within a unified framework.

Rationale for using the COP-PILOT platform

The COP-PILOT platform enables centralized orchestration and intelligent automation, allowing coordinated control of energy resources, network functions, and connected devices across distributed environments. It provides advanced analytics and AI integration capabilities, which are essential for implementing predictive energy management and optimization strategies. The platform supports scalability and interoperability, facilitating the seamless integration of heterogeneous devices, IoT systems, and 5G/6G infrastructure within a unified control framework.

Challenges addressed

The main challenges of this use case are the following:

- Limited visibility and reactive energy management vs. predictive and autonomous optimization: Currently, off-grid sites often rely on basic monitoring and manual intervention, leading to inefficient and reactive energy usage. The target ambition is to achieve full real-time visibility combined with AI-driven forecasting and automated decision-making, enabling proactive and optimized energy allocation.
- Static network operation vs. dynamic, energy-aware orchestration: Existing deployments typically operate with fixed configurations (always-on devices and radio layers), which quickly deplete limited energy resources. The envisioned solution introduces dynamic control of devices and network components, adapting their operation based on demand, QoS requirements, and predicted energy availability.
- Fragmented systems vs. integrated end-to-end energy management: Current solutions often lack integration between energy systems, IoT data sources, and network management platforms. The final ambition is to unify these domains into a single orchestration framework that enables coordinated, cross-layer optimization.
- Limited scalability vs. energy-aware service expansion: Today, adding new devices or services in off-grid environments increases the risk of overloading the energy system. The use case aims to support scalable deployments by incorporating energy-aware provisioning and lifecycle management, ensuring sustainable growth without compromising service continuity.

Expected outcomes

The main expected outcomes:

Improved energy efficiency and sustainability of off-grid 5G/6G deployments: The use case is expected to significantly reduce energy waste through intelligent monitoring, forecasting, and dynamic control. This directly supports project goals related to sustainable and green network operation, demonstrating how advanced orchestration can minimize the environmental impact of next-generation connectivity.

Enhanced service reliability and continuity in energy-constrained environments: By leveraging predictive analytics and automated decision-making, the system will maintain service availability even under fluctuating energy conditions. This aligns with project objectives focused on resilient and dependable network services, particularly in remote or underserved areas.

Demonstration of AI-driven orchestration for cross-domain optimization: The implementation will validate the use of AI and data-driven approaches within the orchestration platform to jointly optimize energy, network, and device management. This contributes to the project's ambition of advancing intelligent, autonomous network operations.

Scalable and energy-aware deployment of new services and devices: The use case will enable the onboarding and management of additional 5G/6G-connected devices without compromising energy constraints. This outcome supports project goals around scalability, flexibility, and efficient resource utilization in heterogeneous and distributed environments.

Key pain points

The current implementation of the use case faces several critical challenges that limit its efficiency, scalability, and reliability in energy-constrained, off-grid environments. These pain points primarily stem from the lack of integration across different system layers, insufficient predictive capabilities, and limited control over energy consumption. As a result, operations tend to be reactive rather than proactive, leading to suboptimal use of available green energy resources and increased risk of service disruption. Addressing these issues is essential to enable intelligent, autonomous energy management and to fully realize the potential of sustainable 5G/6G deployments through the COP-PILOT platform.

These are the main pain points:

Lack of integrated visibility across energy, network, and device layers: Currently, energy consumption, network performance, and device activity are managed in silos, making it difficult to achieve a holistic view of the system. COP-PILOT addresses this by providing a unified orchestration platform that aggregates and correlates data across all domains for informed decision-making.

Limited capability for real-time and predictive energy optimization: Existing solutions are largely reactive and lack the ability to anticipate energy availability or demand fluctuations. COP-PILOT introduces AI-driven forecasting and analytics, enabling proactive energy management and more efficient resource allocation.

Inability to dynamically control network and device operations based on energy constraints: Many deployments rely on static configurations, where devices and network components remain active regardless of actual need. COP-PILOT enables fine-grained, remote, and automated control (e.g., switching devices or radio layers on/off), reducing unnecessary energy consumption.

Challenges in scaling services under strict energy limitations: Adding new devices or services often risks exceeding available energy capacity. COP-PILOT supports energy-aware orchestration and provisioning, ensuring that system expansion remains sustainable and aligned with available resources.

UC DIAGRAMS

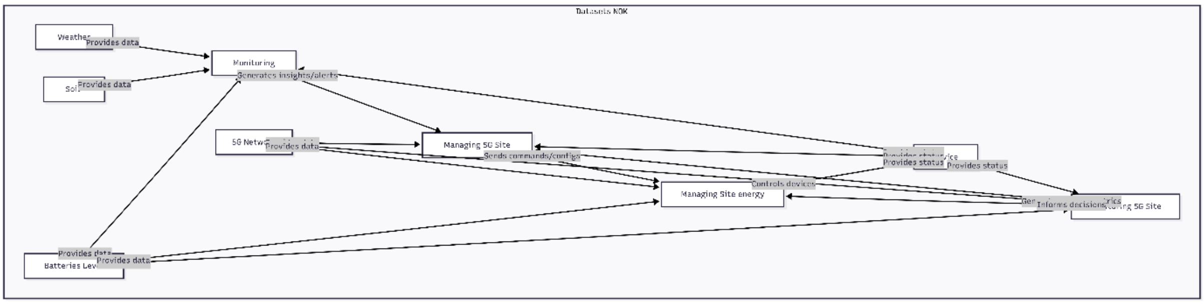
In the Use case we will have the following Datasets:

Datasets:

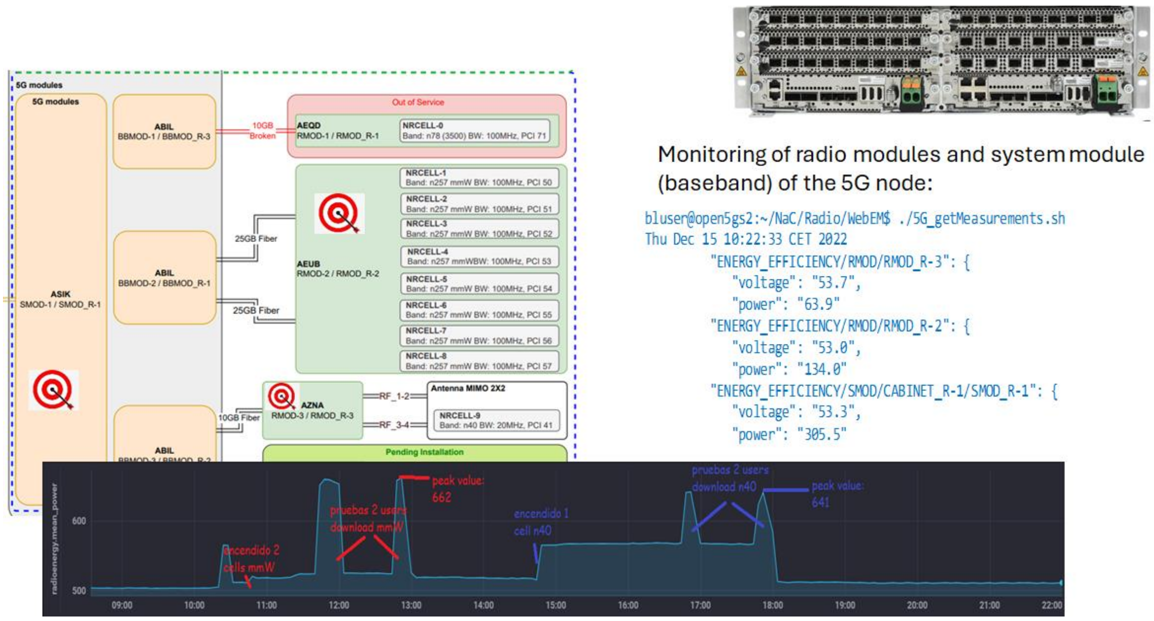
- A: Weather Sensors
- B: Soil Sensors
- C: Batteries Level Sensors
- D:5G Network Data
- E: Device status

And the following Processes Nokia:

- A: Monitoring Sensors
- B: Monitoring 5G Site Energy
- C: Managing 5G Site Network
- D: Managing Site energy Devices



The energy Datasets will integrate the following information:



SCENARIOS DESCRIPTION

Table 9.25: Operational Scenario

Scenario name
Integration of data capture and transmission of agricultural, radio & energy sensors
Step No.
Step 1
Step Event
Basic Integration into COP-PILOT of sensors
Name of process/activity
Capture real-time production data
Description of process/activity
Data capture: Energy, IoT devices (e.g., Computational Unit low energy SBC with sensors) collect real-time data on environmental conditions, equipment performance, energy consumption and production status. This data is crucial for monitoring the agricultural environment, the energy consumption, the batteries and detecting anomalies early. **Data transmission:** the captured data is transmitted securely to a central server for processing. Reliable and uninterrupted data transmission is essential for real-time analysis.
Service

CREATE
Information producer (actor)
Sensors
Information receiver (actor)
Low Energy SBC
Information exchanged (IDs)
Sensor readings (agricultural sensors, unit count, temperature, batteries KWh, radio status, machine status)
Reference to Scenario number
Scenario 1

Scenario name:
Integration into COP-PILOT of agricultural, radio & energy sensors
Step No.
Step 2
Step Event
Data is collected from multiple systems
Name of process/activity
Harmonize and integrate production data
Description of process/activity
Data reception from multiple systems: data from various systems (Radio Equipment Energy Sensors, Devices Energy Sensors, Agricultural Sensors, Batteries Energy sensors) is received. This data is essential for creating a comprehensive overview of current state of the site and of the site energy. **Data harmonization and standardization:** COP-PILOT's Infrastructure Orchestrator (InfraOrch) standardizes the received data using NGSI-LD to ensure interoperability across different systems. **Data storage in Orion Context Broker:** the processed data is stored in the Orion Context Broker, providing centralized access for real-time decision-making.
Service

CHANGE
Information producer (actor)
InfraOrch
Information receiver (actor)
Orion Context Broker
Information exchanged (IDs)
Standardized NGSI-LD data
Reference to Scenario number
Scenario 2

Scenario name:
Provision of connectivity and Quality devices in 5G Mobile Network
Step No.
Step 3
Step Event
The system interacts with 5G Mobile infrastructure to manage the creation of new devices connectivity or prioritization
Name of process/activity
Management of new Mobile Infrastructure connectivity and prioritization
Description of process/activity
A new Device is deployed in the area that requires connectivity, but it is not yet registered in the 5G network. One operator by using OpenSlice will register a new mobile IMSI user with a QoS level

OpenSlice will call the provisioning functions in NaC "Network as Code" API that receives the request and will interact with the real 5G network to provision and activite the required network resources
Service
EXECUTE
Information producer (actor)
Orion Context Broker & OpenSlice
Information receiver (actor)
Maintenance System
Information exchanged (IDs)
Predictive maintenance request
Reference to Scenario number
Scenario 3

Scenario name:
Control and Management of Energy consumption on the deployed Site
Step No.
Step 4
Step Event
The system interacts with devices integrated with energy remote crontol for saving energy or change the energy level use to save energy
Name of process/activity
Management of new Mobile Infrastructure connectivity and prioritization
Description of process/activity
One operator by using OpenSlice integrated with NaC APIs will be able to:

• To switch on or off some devices when not required • To change the level or Radio power emission power • To switch on or off the 5G radio site
Service
EXECUTE
Information producer (actor)
OpenSlice & NaC
Information receiver (actor)
Maintenance System
Information exchanged (IDs)
Predictive maintenance request
Reference to Scenario number
Scenario 4

Scenario name:
Radio energy management trained by IA for mobile connectivity
Step No.
Step 5
Step Event
The system will integrate an AI system that was trained to save energy and to change the energy configuration of the site taking into account the forecast of energy availability
Name of process/activity
Radio energy management trained by IA for mobile connectivity
Description of process/activity
One IA trained algorithm will interact with OpenSlice and NaC to adapt the configuration of the 5G site to the current energy conditions of the site: Taking as input the following information:

• Need of connectivity of the site • Available energy history of the site • Forecast of green energy availability The trained algorithm will take the Control and Management of Energy consumption on the deployed Site in an autonomous manner.
Service
EXECUTE
Information producer (actor)
OpenSlice & NaC
Information receiver (actor)
Maintenance System
Information exchanged (IDs)
Autonomous network management in limited green energy environments
Reference to Scenario number
Scenario 5

REQUIREMENTS

Functional requirements

Table 9.26: Use Case functional requirements

Req. ID	Subject (+ Condition)	Commitment	Action + Object + {Constraint and/or Value}
FR1	Real-time energy, soil, and weather monitoring	Must	Capture and transmit battery, soil, and weather sensor data from rural 5G site to Nokia platform
FR2	Data integration and visualization	Must	Integrate sensor data into platform and provide real-time visualization and decision support for agriculture management

FR3	SIM provisioning and QoS configuration	Must	Provision new SIMs to network slices with different QoS profiles for IoT and AI video uplink
FR4	QoS verification and adjustment	Must	Monitor slice performance and adjust provisioning if QoS targets are not met
FR5	Energy-saving management	Must	Switch on/off 5G radio equipment and relocate applications when battery energy is low
FR6	AI-based energy optimization	Could	Use historical energy data to train AI model and optimize energy-saving actions for 5G equipment and applications
FR7	Monitoring and alerts	Must	Detect low battery or high energy demand and trigger automatic actions or alerts
FR8	Pilot outcome reporting	Must	Collect performance metrics and evaluate energy savings, QoS, and system operation per pilot

Non-functional requirements

Table 9.27:Use Case non-functional requirements

Req. ID	Subject (+ Condition)	Commitment	Action + Object + {Constraint and/or Value}
Req. ID	Subject (+ Condition)	Commitment	Action + Object + {Constraint and/or Value}
NFR1	Data security and integrity	Must	Ensure encrypted transmission and access control for sensor and battery data across 5G network
NFR2	System scalability	Must	Support additional sensors, devices, 5G sites, and applications without performance degradation

NFR3	High availability and fault tolerance	Must	Implement redundancy and failover for 5G radios, AI modules, and platform services to maintain uptime
NFR4	Compliance with industry standards	Must	Follow IoT, energy management, and data governance best practices for agricultural and connectivity data
NFR5	Low latency data processing	Must	Guarantee real-time processing of sensor, energy, and network data for immediate decision-making and alerts
NFR6	User experience and accessibility	Could	Provide intuitive dashboards and interfaces for operators, managers, and remote monitoring roles
NFR7	Energy efficiency of platform	Must	Minimize energy consumption of 5G equipment and platform servers through AI-driven optimization and smart scheduling

Business requirements

This document defines the business requirements for the Cluster4 pilot solution, which focuses on ensuring continuous service availability in remote and off-grid environments through intelligent energy management. The solution leverages real-time monitoring of energy production, storage, and consumption, combined with AI-driven forecasting and optimization, to allocate power efficiently across deployed devices and critical telecom infrastructure, including 5G and future 6G networks. By prioritizing devices, minimizing energy waste, and reducing reliance on backup power sources, the platform aims to deliver resilient, cost-effective, and environmentally sustainable operations that align energy availability with service demand while supporting operational efficiency and sustainability goals.

Business Requirement 1: Continuous Service Availability in Remote Areas. The solution must ensure uninterrupted service availability in remote and off-grid environments. This includes rural 5G sites and isolated infrastructure where conventional power supply may be limited or unreliable. The business requirement emphasizes the need for resilience in network connectivity and telecom operations, ensuring that critical services remain operational regardless of location or grid access.

Business Requirement 2: Intelligent Renewable Energy Optimization. The solution must optimize the use of renewable energy sources across all deployed devices. By intelligently managing solar, wind, or other renewable generation, it ensures that available energy is efficiently utilized to maintain continuous operation. This requirement supports sustainability objectives and reduces reliance on conventional energy, aligning operational practices with environmental and regulatory standards.

Business Requirement 3: Real-Time Monitoring and Power Allocation. The system must provide real-time monitoring of energy production, storage, and consumption. This monitoring capability allows for dynamic and efficient allocation of power to critical telecom infrastructure, including current 5G networks and planned 6G deployments. Accurate visibility into energy status supports decision-making for both daily operations and emergency scenarios, ensuring reliable service delivery.

Business Requirement 4: AI-Driven Forecasting and Optimization. The solution must leverage weather data, predictive analytics, and AI-driven optimization to align energy availability with service demand. By forecasting energy production and consumption patterns, the platform can proactively plan energy allocation, minimize downtime and preventing overuse of limited resources. This requirement addresses both operational efficiency and cost reduction, enabling proactive management of energy-dependent infrastructure.

Business Requirement 5: Device Prioritization and Energy Management. The system must enable prioritization of devices and services based on energy availability and operational criticality. During periods of constrained energy, the solution should intelligently switch off non-critical equipment and relocate applications to maximize operational efficiency. This reduces energy waste, prevents unnecessary power consumption, and ensures that the most critical services remain functional at all times.

Business Requirement 6: Sustainability, Cost Efficiency, and Resilience. The solution must deliver resilient, cost-effective, and environmentally sustainable operations. By minimizing dependence on backup power sources and optimizing energy usage, it lowers operational costs while supporting green energy initiatives. The business requirement highlights the need for a platform that combines energy efficiency with reliable service delivery, ensuring that network operations are both economically and environmentally responsible.

Sustainability business requirements

Table 9.28: Use Case Sustainability Requirements

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
SR1	Reduction of energy consumption	Compulsory	Optimize system algorithms to reduce processing power needs, affecting system software and IoT device firmware	Reduce operational costs and environmental impact
SR2	Automation management for maintenance	Compulsory	Implement full system automation for monitoring and maintenance scheduling, affecting production line sensors, IoT devices, and maintenance software	Reduce manual intervention, prevent failures, and lower maintenance costs
SR3	Energy cost and CO_2	Good to have	Implement energy-efficient operations and smart load management, affecting IoT devices, system software,	Lower operational costs and environmental footprint

	emissions savings		and energy management modules	

Societal business requirements

Table 9.29: Use Case Societal Requirements

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
SR1	Accessibility for new users	Compulsory	Ensure system interfaces, onboarding, and help resources are intuitive and inclusive, affecting UI/UX design, tutorials, and support systems	Enable new users to adopt system easily and reduce barriers to entry
SR2	Data protection and privacy compliance	Compulsory	Implement GDPR and regional data privacy compliance, affecting data storage, processing, and user consent workflows	Protect user data and comply with legal requirements
SR3	Affordability for new users	Good to have	Optimize pricing, subscription plans, and resource usage, affecting payment systems and cloud services	Increase accessibility for low-cost adoption
SR4	Improved workforce efficiency	Good to have	Provide automation tools, dashboards, and predictive analytics, affecting workforce management software and task allocation	Reduce manual effort and increase productivity
SR5	Improved quality of life for users	Good to have	Enhance system features for convenience, engagement, and well-being, affecting apps,	Deliver tangible societal benefits and user satisfaction

			notifications, and services	

Market business requirements

Table 9.30: Use Case Market (Business Requirements)

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
MR1	Long-term cost effectiveness	Compulsory	Optimize system architecture, maintenance, and resource usage to minimize total cost of ownership, affecting software, hardware, and cloud services	Reduce operational expenses and increase ROI
MR2	Reduced integration costs	Compulsory	Provide standardized APIs, modular components, and plug-and-play capabilities, affecting software modules, IoT devices, and third-party services	Ease integration of new services or devices, reducing time and cost
MR3	Market expansion	Good to have	Enable scalability of services and devices, supporting multiple regions and user segments, affecting system architecture and deployment workflows	Enter new markets and attract additional users
MR4	Increased profitability	Good to have	Implement features to improve revenue streams, optimize pricing models, and reduce downtime, affecting service delivery, billing system, and maintenance workflows	Maximize revenue while minimizing operational risks
MR5	Resilience and failure recovery	Good to have	Implement redundancy, backup, and automatic recovery mechanisms, affecting system	Reduce business risk and maintain service continuity

			software, hardware, and cloud infrastructure	

1.1 KPIS AND KVIS

UC/vertical Specific

KPI / KVI	Description	Functionality	Target / Threshold (KVI)
KPI1: Sensor data accuracy	% of energy, soil, and weather sensor readings within tolerance	Real-time monitoring of rural 5G sites	≥ 98% accuracy
KPI2: Data integration latency	Time to integrate new sensor data into the platform	Decision support dashboards	< 2 seconds
KPI3: SIM provisioning success rate	% of new SIMs successfully provisioned with correct QoS	Network slice management	≥ 99%
KPI4: QoS compliance rate	% of network slices meeting target QoS metrics	AI/IoT uplink performance	≥ 95%
KPI5: Energy-saving action execution	% of automated actions executed correctly	Battery energy management	≥ 95%
KPI6: Pilot reporting completeness	% of required metrics collected	Pilot outcome reporting	≥ 100%
KVI1: Critical alert response time	Time from alert to action	Automated monitoring	< 5 minutes
KVI2: Sensor uptime	% of time sensors are operational	Remote 5G sites	≥ 99.5%

Sustainability

KPI / KVI	Description	Functionality	Target / Threshold (KVI)
KPI1: Renewable energy utilization	% of total energy supplied by renewables	Solar/wind-powered sites	≥ 50%
KPI2: Backup power dependency	% reduction in generator/diesel use	Off-grid sites	≥ 20% reduction
KPI3: Device prioritization efficiency	% of non-critical devices switched off during scarcity	AI-driven energy management	≥ 90%
KPI4: Energy optimization via AI	% improvement in energy allocation	AI forecasting	≥ 15% efficiency gain
KPI5: CO_2 emissions reduction	Estimated CO_2 avoided	Sustainable energy management	≥ 10% reduction
KPI6: Green energy cost savings	€ savings from renewable usage	Rural site operations	≥ €5,000/month per site
KVI1: Renewable energy contribution per device	kWh per device from renewable sources	Remote monitoring	≥ 70%
KVI2: Energy waste reduction	% of energy consumption avoided	AI-driven optimization	≥ 15%

Environmental

KPI / KVI	Description	Functionality	Target / Threshold (KVI)
KPI1: CO_2 emission per kWh	Tons CO_2 emitted per kWh	Optimized energy usage	≤ 0.4 tCO_2/kWh
KPI2: Energy consumption per device	kWh per device per day	5G equipment and IoT sensors	≤ 1.5 kWh/device/day

KPI3: Waste energy reduction	% of energy avoided	Real-time optimization	≥ 15%
KPI4: Efficient resource allocation	% of renewable energy allocated to critical devices	Device prioritization	≥ 95%
KPI5: Environmental footprint index	Composite score (0-100)	Sustainability dashboards	≤ 25
KPI6: Grid dependency reduction	% reduction in reliance on conventional grid	Off-grid site operations	≥ 30%
KVI1: Maximum allowable energy overuse	% above allocated energy limits	Peak demand scenarios	≤ 5%
KVI2: Renewable energy reliability	% uptime of renewable power supply	Solar/wind systems	≥ 95%
KPI1: Accessibility for new users	% of users successfully onboarded	Operator training	≥ 90%
KPI2: Data privacy compliance	% compliance with GDPR & regional laws	Data handling	100% compliance
KPI3: User satisfaction score	Rating of platform usability	Operator/manager feedback	≥ 4.5/5
KPI4: Workforce efficiency improvement	% reduction in manual operational tasks	Automation scenarios	≥ 25%
KPI5: Quality of life improvement	Number of users benefiting	Rural connectivity	≥ 1,000 users/month
KPI6: Training completion rate	% staff completing training	System adoption	≥ 95%
KVI1: Number of user-reported issues	Issues per 100 users	Platform use	≤ 5/100 users
KVI2: Accessibility compliance	% compliance with accessibility standards (WCAG)	Dashboard and UI	≥ 95%

Societal

KPI / KVI	Description	Functionality	Target / Threshold (KVI)
KPI1: Accessibility for new users	% of users successfully onboarded	Operator training	≥ 90%
KPI2: Data privacy compliance	% compliance with GDPR & regional laws	Data handling	100% compliance
KPI3: User satisfaction score	Rating of platform usability	Operator/manager feedback	≥ 4.5/5
KPI4: Workforce efficiency improvement	% reduction in manual operational tasks	Automation scenarios	≥ 25%
KPI5: Quality of life improvement	Number of users benefiting	Rural connectivity	≥ 1,000 users/month
KPI6: Training completion rate	% staff completing training	System adoption	≥ 95%
KVI1: Number of user-reported issues	Issues per 100 users	Platform use	≤ 5/100 users
KVI2: Accessibility compliance	% compliance with accessibility standards (WCAG)	Dashboard and UI	≥ 95%

Operational and Efficiency

KPI / KVI	Description	Functionality	Target / Threshold (KVI)
KPI1: System uptime	% of time platform fully operational	Remote/off-grid areas	≥ 99.9%
KPI2: Fault detection and recovery	MTTD and MTTR	High availability & fault tolerance	MTTD < 5 min; MTTR < 15 min
KPI3: Data processing latency	Time from sensor to actionable insight	Real-time monitoring	< 2 s

KPI4: Energy-saving execution success	% of actions correctly executed	AI/automation	≥ 95%
KPI5: Network slice performance	% slices meeting throughput/latency	QoS verification	≥ 95%
KPI6: Maintenance cost efficiency	Reduction in maintenance cost/time	Predictive monitoring	≥ 20% savings
KVI1: Fault recovery success	% of incidents recovered without impact	System resiliency	≥ 99%
KVI2: Critical service uptime	% uptime for essential services	5G and IoT services	≥ 99.95%

Economic and business

KPI / KVI	Description	Functionality	Target / Threshold (KVI)
KPI1: Operational cost savings	€ saved through energy optimization	Rural/off-grid operations	≥ €50,000/year
KPI2: ROI of pilot deployment	Return on investment vs baseline	Energy management and AI	≥ 20% ROI
KPI3: Market adoption	# of new users/regions/devices onboarded	System scalability	≥ 3 regions/year
KPI4: Downtime cost reduction	€ saved from avoided downtime	Resilient operations	≥ €10,000/year
KPI5: Integration cost reduction	Reduction in cost/time to onboard new devices	Modular platform	≥ 25% savings
KPI6: Revenue from improved services	€ generated via optimized services	Operator offerings	≥ €20,000/year

KVI1: Payback period	Months to recover pilot investment	Financial evaluation	≤ 36 months
KVI2: Cost per user/device	€ per user/device per month	Operational efficiency	≤ €50/user/month

Scalability and EU Sovereignty

KPI / KVI	Description	Functionality	Target / Threshold (KVI)
KPI1: Sensor/device scaling	# of sensors/devices supported without performance loss	Platform scalability	≥ 500 devices/site
KPI2: Network expansion	# of new 5G/6G sites added while maintaining QoS	Rural/regional deployment	≥ 5 sites/year
KPI3: Data sovereignty compliance	% data stored/processed in EU	GDPR and EU regulations	100% compliance
KPI4: Multi-region operational consistency	% of services operating uniformly	Cross-site monitoring	≥ 99%
KPI5: Software/hardware modularity	% of modules supporting plug-and-play deployment	Integration of new services	≥ 90%
KPI6: Platform latency under load	Performance under increased devices/users	High-scale monitoring	≤ 2 s
KVI1: Max supported devices without degradation	# devices maintaining KPI targets	Scalability test	≥ 500 devices
KVI2: Cross-region SLA compliance	% of SLA targets met across regions	Operational reliability	≥ 99%

1.2 LEGAL AND ETHICS REQUIREMENTS

UC activities are planned to involve:

☐ Involvement of volunteers (more information under 1.4.8.1)

☒ Data management (more information under 1.4.8.2)

☒ Use of AI systems (more information under 1.4.8.3)

☒ Other (more information under 1.4.8.4)

IPR

Several intellectual property (IPR) requirements and considerations have been identified for this project iteration. The data generated by IoT devices, including energy, environmental, and device performance readings, will be owned by the implementing organization, with shared usage rights granted to project partners for research, pilot evaluation, and development purposes. Any software, algorithms, and AI models developed within the project will remain the property of the developers, but usage licenses may be granted to project partners for operational deployment or internal testing, in accordance with collaboration agreements. Commercialization rights and licensing conditions will be explicitly defined in partnership contracts to ensure clarity and prevent disputes.

In cases where innovations are generated through collaborative work, joint ownership arrangements will be agreed upon to clarify rights, responsibilities, and potential benefits. This includes AI optimization models, predictive maintenance algorithms, and energy management strategies developed by multiple partners. Such agreements will define usage, modification, licensing, and commercialization rights while respecting contributions from all parties involved.

Finally, the project will maintain a centralized IPR management framework, tracking data sources, software components, AI models, and collaborative developments. This framework will ensure compliance with IPR obligations, support auditability, and provide guidance for any future commercial exploitation. It will also facilitate the negotiation of licenses, permissions, and shared rights, ensuring that all partners have a clear understanding of ownership, access, and permitted use throughout the project lifecycle.

RISK IDENTIFICATION AND ASSESSMENT

Table 9.31: Use case risk assessment

Risks	Likelihood (L / M / H)	Impact (L / M / H)	Mitigation
Data transmission failures from IoT sensors	M	H	Implement redundant communication channels, monitor real-time data flow, and perform periodic network stress testing. Establish fallback protocols for critical energy and sensor data.
Integration challenges with legacy or heterogeneous systems	M	M	Standardize interfaces using APIs and NGSI-LD protocols. Conduct compatibility testing and leverage experienced integration partners for smooth onboarding of devices and software.
Security vulnerabilities (data breaches,	M	H	Use end-to-end encryption, multi-factor authentication, and role-based access control. Perform regular vulnerability

unauthorized access)			scans, penetration tests, and security audits.
Operational disruptions during 5G/IoT deployment	M	H	Follow phased deployment plans, provide thorough operator training, and maintain a dedicated support team. Monitor systems continuously and implement rollback procedures if needed.
AI model inaccuracies affecting energy allocation	M	M	Implement human oversight for critical actions, maintain explainable AI dashboards, and perform periodic model validation and retraining with updated data.
Power shortages or battery depletion at off-grid sites	H	H	Prioritize device operations using AI-driven scheduling, enable automatic load shedding for non-critical devices, and deploy backup energy sources where feasible.
Compliance risks with GDPR or regional regulations	L	H	Maintain clear data handling policies, ensure consent management for relevant data, and perform regular audits to verify compliance with EU and local privacy laws.
Failure of predictive maintenance actions	M	M	Schedule regular device inspections, use redundant monitoring systems, and cross-validate AI predictions with manual checks to prevent unexpected equipment failures.