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The European IoT Hub

Growing a sustainable and comprehensive ecosystem for Next Generation Internet of Things

D5.7 Impact Assessment- Guidelines for IoT collaboration sustainability - V2

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Abstract

This deliverable provides a final perspective on impact assessment of the ICT-56 projects and proposes a set of guidelines to boost collaboration and to increase impact.

Keywords: Impact assessment, qualitative analysis, quantitative analysis, collaboration recommendations.

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Disclaimer

EXECUTIVE SUMMARY

This deliverable reports on the work conducted under EU-IoT WP5, Task 5.3 (Impact Assessment). The aim of the work conducted in the task Is two-fold. Firstly, to provide an assessment of the impact generated by the ongoing ICT-56 Research and Innovation (RIA projects (in the following indicated as ICT-56 projects for the sake of brevity). Secondly, to provide a set of recommendations and guidelines towards collaboration across the different ICT-56 projects in view of increasing their overall impact.

This deliverable represents an update to EU-IoT Deliverable D5.6 [1] (September 2022), which is based on the EU-IoT impact assessment methodological framework (presented in D5.5 [2], September 2021).

D5.7 assesses the ICT-56 Research and Innovation (RIAs) based on a qualitative and quantitative analysis of different dimensions such as contributions towards SDGs, scientific output, business exploitation.

The key expected impact of this final analysis is a broad perspective that can guide active and future RIAs, and a set of guidelines and recommendations that can help strengthen the impact of individual projects and their collaboration. The recommendations are envisioned to the current ICT-56 RIAs and towards future Horizon Europe projects focusing on the IoT-Ede-Cloud continuum.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

Acronym	Definition
3GPP	3rd Generation Partnership Project (3GPP)
5G-ACIA	5G Alliance for Connected Industries and Automation
5G-IA	5G Infrastructure Association
6G IA	6G Smart Networks and Services Industry Association
AB	Advisory Board
AI	Artificial Intelligence
AIoT	Artificial Intelligence of Things
AIOTI	Alliance for Internet of Things Innovation IVZW
BDVA	Bid Data Value Association
CB	Coordination Board
CCIS	Culture, Creativity, and Inclusive Society
CCS	Civil Security for Society
CEM	Climate, Energy, and Mobility
CENELEC	European Committee for Electrotechnical Standardisation
CTF	Coordination Task Force
DIS	Digital, Industry, Space
EC	European Commission
ETSI	European Telecommunications Standards Institute
EU	European Union
FAIR	Findable, Accessible, Interoperable, and Reusable
FBNRAE	Food, Bioeconomy, Natural, Resources, Agriculture, and Environment
FL	Federated Learning
Gaia-X	A federated data infrastructure for Europe
ICT	Information and Communication Technologies
IEEE	Institute of Electrical and Electronics Engineering
IETF	Internet Engineering Task Force
IoT	Internet of Things
IoT	Internet of Things
IP	Internet Protocol
IRTF	Internet Research Task Force
ISO	International organisation for standardisation
IT	Informational Technology
ITU-T	International Telecommunication Union

KER	Key Exploitable Result
KPI	Key Performance Indicator
KPI	Key Performance Indicator
MEC	Multi-access Edge Computing
ML	Machine Learning
NGIoT	Next Generation Internet of Things
OECD	Organization for Economic Cooperation and Development
R&D	Research and Development
RIA	Research and Innovation Action
SDG	Sustainability Development Goals
SDN	Software Defined Networking
SDO	Standards Development Organization
SMEs	Small and Medium Enterprises
TRL	Technology Readiness Level
WoT	Web of Things

1 INTRODUCTION

The work conducted and described in this deliverable has been led by the EU-IoT Work package 5 “WP5 – Amplifier”, Task 5.3. WP5 is focused on handling and promoting content provided by all other EU-IoT Work Packages, while it aims to produce guidelines to ground the creation of an action plan for the development of a sustainable IoT ecosystem in close collaboration with key stakeholders of the European *Next Generation Internet of Things (NGIoT)*.

Task 5.3 (Impact Assessment) focuses on providing critical guidance in a forward-looking perspective to ICT-56 projects, via a continuous assessment of impact in terms of scientific output, business exploitation, and potential asset sustainability.

1.1 Deliverable Scope

This document is the third and final deliverable of Task 5.3 and is a follow-up of deliverable D5.6. It provides a final analysis of the impact of ICT-56 RIAs in terms of contributions across different dimensions, namely, scientific contributions; open-source contributions; contributions to standardization; selected assets; success stories; collaboration activities. In addition, deliverable D5.7, in comparison to deliverable D5.6 [1], introduces additional impact categories and sections/subsections as explained in sub-section 1.4. A summary of key differences is as follows:

- **Introduction of an analysis on Ethical Impact**: describes the ethical aspects tackled by the different RIAs to assist in an understanding of how to promote trust, fairness, and accountability, and to avoid potential harm or negative impacts.
- **Introduction of an analysis on collaboration efforts**: the key collaboration areas where the ICT-56 RIAs collaborated by coordinating their research efforts by developing common and joint events, publications, workshops, summer schools, and interaction across students in different projects. This can help to increase the impact and visibility of the projects and can promote knowledge exchange and collaboration between them.
- **New subsection in the section business exploitation assessment**: by providing an **example of one best asset, the type and characteristics of the asset, and its exploitation** to have a better vision of the main outcomes of the ICT-56 projects and their tangible products, and innovation that they are producing.
- **Improvement of the highlights on ICT-56 RIA contributions**: The RIAs’ contributions and their **most relevant success story related to a selected best use-case or asset.**
- **A set of guidelines to consolidate the IoT collaboration ecosystem and mitigate their identified challenges.**

The underlying premise of EU-IoT is to build a dynamic, efficient, and collaborative IoT ecosystem in Europe. Realizing this involves efforts by the consortium to help the ecosystem overcome barriers to the adoption of IoT-based solutions. The analysis conducted via the assessment of the impact of the ICT-56 flagship projects derived in this deliverable consolidates the guidelines for the collaborative IoT sustainability of the ecosystem.

The deliverable is public and will be made accessible to all projects. All information publicly provided will follow the rules of FAIR data management as stipulated in EU-IoT.

1.2 Deliverable Structure

The remainder deliverable is organized as follows:

- Section 2 provides a summary of the impact assessment processes of EU-IoT and is complementary to the detailed information provided in Deliverable D5.5.
- Section 3 covers a qualitative impact assessment analysis of the 6 ICT-56 projects, providing a mapping of contributions towards SDGs.
- Section 4 covers a quantitative impact assessment analysis for the ICT-56 projects, providing an analysis of innovation and scientific impact.
- Section 5 provides an analysis of use-cases and business exploitation aspects.
- Section 6 provides highlights concerning project contributions.
- Section 7 summarizes key findings; lessons learned and provides a series of recommendations and guidelines aiming at further boosting the generated impact in current H2020 RIAs and in future Horizon Europe RIAs.
- Section 8 summarizes the deliverable.

1.3 Differences Between D5.6 and D5.7

Deliverable D5.6 presented a qualitative and quantitative impact assessment of ICT-56 RIAs, based on collected information until July 2022. It also provided a set of guidelines and recommendations aimed at assisting ICT-56 RIAs in further strengthening their impact. It is composed of eight sections. Section 2 summarized the impact assessment processes of EU-IoT and complemented the detailed information provided in Deliverable D5.5. Section 3 covered a qualitative impact assessment analysis of the ICT-56 RIAs and provided a mapping of contributions towards SDGs. Section 4 focused on a quantitative impact assessment analysis for the ICT-56 RIAs and provided an analysis of innovation and scientific impact. Section 5 covered a quantitative and qualitative analysis of business exploitation aspects for the ICT-56 projects. Section 6 highlighted the projects contribution. Section 7 provided a series of recommendations and guidelines aiming at further boosting the generated impact.

The key differences between deliverable D5.6 and deliverable D5.7 are explained in Table 1.

Table 1: Differences between D5.6 and D5.7.

Impact assessment activity	D5.6	D5.7
Methodology for qualitative and quantitative assessment	Section 2	Section 2, **includes main findings from D5.6**
Qualitative impact assessment	Section 3, based on information collected until July 2022	Section 3, based on **information collected until March 2023** **New sub-section (3.1) on technological, business and societal objectives** **New sub-section (3.5) on contributions towards ethical aspects (3.5)** **New sub-section on collaboration activities**
Quantitative impact assessment	Section 4, based on information collected until July 2022	Section 4, **based on information collected until March 2023** **New sub-section (4.6) on selected assets as best contribution towards standardization**
Business exploitation	Section 5, based on	Section 5**, based on information collected until March**

Impact assessment activity	D5.6	D5.7
assessment	information collected until July 2022	**2023** **New sub-section (5.3) on selected best assets**
Highlights on project contributions	Section 6, based on information collected until July 2022	**Complete reformulation based on information collected until March 2023, including new section on success stories**
Recommendations and guidelines	Section 7, recommendations and guidelines to RIAs and to EU-IoT, to assist in strengthening collaboration sustainability	**New section 7 includes lessons learned, identified challenges, and recommendations towards collaboration sustainability**

1.4 Summary of ICT-56 Projects

The current deliverable is reporting on the input provided by all the ongoing ICT-56 projects (or ICT-56 RIAs), which are further described in section 3. The RIAs are:

- **ASSIST-IoT**[1]: aims at designing, implementing, and validating an open, decentralized reference architecture, associated enablers, services, and tools, to assist human-centric applications in multiple verticals.
- **INGENIOUS**[2]: aims to design and evaluate the Next-Generation IoT solution, with emphasis on 5G and the development of Edge and Cloud computing extensions for IoT, as well as providing smart networking and data management solutions with Artificial Intelligence and Machine Learning.
- **IoT-NGIN**[3]: aims to empower Edge Cloud with federated on-device intelligence, enforce interoperability and data sovereignty, ensure trust, cybersecurity, and privacy, and introduce novel human-centric interaction based on Augmented Reality.
- **TERMINET**[4]: aims to provide a novel next-generation reference architecture based on cutting-edge technologies such as SDN, multiple-access Edge computing, and virtualization for next-generation IoT, while introducing new, intelligent IoT devices for low-latency, market-oriented use cases.
- **VEDLIoT**[5]: develops an IoT platform that uses deep learning algorithms distributed throughout the IoT continuum, thus proposing a new platform with innovative IoT architecture that is expected to bring significant benefits to many applications, including industrial robots, self-driving cars, and smart homes.
- **INTELLIOT**[6]: focuses on the development of integrated, distributed, human-centered, and trustworthy IoT frameworks applicable to agriculture, healthcare, and manufacturing while enabling technologies such as 5G, cybersecurity, distributed technology, Augmented Reality, and tactile internet, focusing on end-user trust, adequate security, and privacy by design.

[1] https://assist-iot.eu/

[2] https://INGENIOUS-iot.eu/web/

[3] https://iot-ngin.eu/

[4] https://TERMINET-h2020.eu/

[5] https://vedliot.eu/

[6] https://INTELLIOT.eu/

All ICT-56 projects have started during October and November 2020 and are planned to finish by the end of 2023. Most projects are not yet igniting the business exploitation phase (as this aspect is usually developed in the final phase of the projects). Furthermore, most projects still have one open call active at the time being (second open call). Therefore, while the qualitative analysis conducted and presented in this document is relevant to assist in detecting areas of cooperation, the quantitative analysis does not fully reflect the final outcomes of the projects that will be produced following the end of the EU-IoT project.

2 BACKGROUND AND D5.6 INTERMEDIATE FINDINGS

2.1 EU-IoT Impact Assessment Methodology

The EU-IoT impact assessment framework has been based on a series of analytical processes that aimed at assisting in a better definition of areas or processes to tackle, as well as in identifying potential barriers and mitigation actions for the innovation assets being proposed and developed by the ICT-56 RIAs.

The EU-IoT impact assessment framework has been defined in consultation with ICT-56 RIAs during the first part of the project (Deliverable D5.5, September 2021 [2]). A first analysis of the expected assets per project has been conducted between November 2020 and September 2021, via a survey that collected information from RIAs, and via an initial set of talks with RIAs. This initial assessment has been described in Deliverable D5.5 and serves the purpose of validating the impact assessment framework proposed with a particular focus on the qualitative impact of SDGs [3, 4, 5].

This section is based on section 2 of D5.5 and explains the additional data that has been collected.

2.1.1 Overall Process and Timeline

The overall iterative process of analysis being conducted by EU-IoT in the context of WP5, T5.3 is described in Figure 1. As illustrated, an initial set of relevant variables and goals has been defined via discussions within the EU-IoT consortium and RIAs. Via WP2 and WP3, joint workshops involving RIAs have assisted in further understanding the different project objectives and proposed assets, and initial exploitation proposals. Specific surveys (2021 and 2022, refer to Annex I for the surveys' format) have been shared with RIAs and assisted in collecting relevant input for both a qualitative and quantitative impact analysis. The survey's data collection has been complemented with one-to-one Web conferencing meetings with RIAs, to collect further data and eventually complement and correct previously collected information. Then, results have been presented in different EU-IoT events such as dedicated sessions or workshops, to ignite awareness and to collect additional feedback.

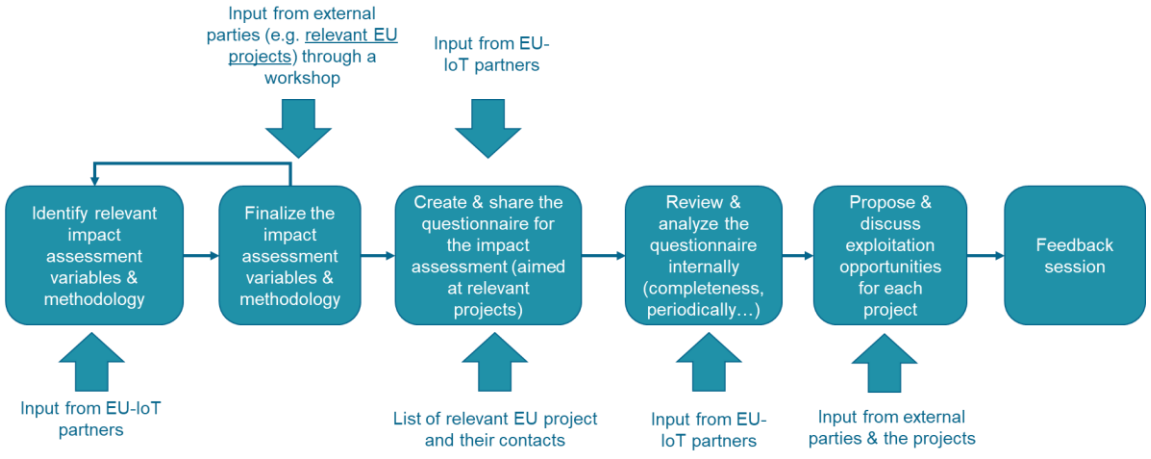

Figure 1: The EU-IoT impact assessment framework process.

Moreover, the overall impact assessment has both a qualitative and quantitative component, as illustrated in *Figure 2*.

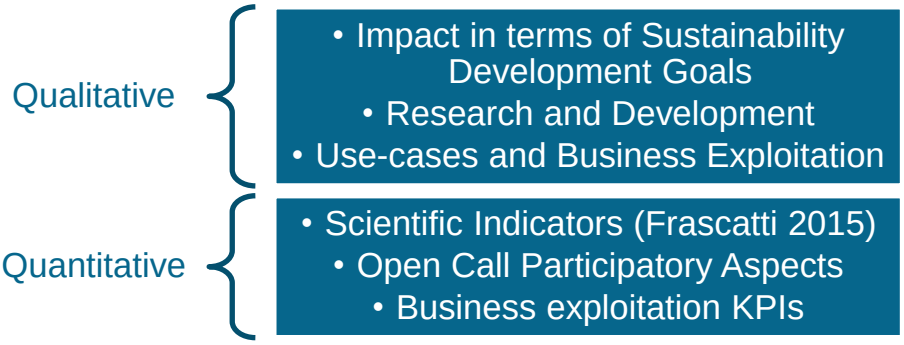

Figure 2: Qualitative and quantitative components of the impact assessment.

2.1.2 Qualitative Analysis Aspects

The qualitative analysis conducted in EU-IoT focuses on the contributions of the RIAs towards SDGs and the contributions towards the EU-IoT scope areas.

As explained in Deliverable D5.5, EU-IoT considers impact categories based on the **six clusters that compose Horizon Europe's second Pillar**, "*Global Challenges and European Industrial Competitiveness*, namely:

- Health.
- Culture, creativity, and Inclusive society.
- Civil Security for Society.
- Digital, industry, and Space.
- Climate Energy and Mobility.
- Food Bioeconomy, Natural Resources, Agriculture and Environment Impact.

The qualitative analysis components are illustrated in Figure 4. The expected outcome of the projects in terms of technology, skills training, business exploitation, and standards, and policies assets are firstly mapped to **the EU-IoT scope areas** which have been defined in WP2 Deliverable D2.1 [8] as:

- **Human/ IoT interfaces** relate to topics such as intelligence, digital interfaces (e.g., virtual reality), sensing digital (e.g., tactile internet), and robotics.
- **Far Edge** relates to topics such as intelligence at the far Edge, improving processing (e.g., low power devices), and context awareness.
- **Near Edge** relates to topics such as intelligence at the near Edge and improving processing (e.g., virtualization- digital twins).
- **Infrastructure** relates to topics such as improving processing (e.g., network virtualization) and intelligent networks (e.g., time-sensitive networking, 5G).
- **Data spaces** relate to topics such as efficient and secure data spaces (e.g., plug & play models for autonomous applications) and managing data spaces (e.g., data governance).

Then, for each of the six clusters, **a set of impact variables** have been added to each impact category, as illustrated in Figure 4, to reflect the various strategic orientations and impact areas mentioned previously. The impact variables have been derived from an EU survey related to the *"Horizon Europe First Strategic Plan 2021-2024"* [5] , as has been described in Deliverable D5.5.

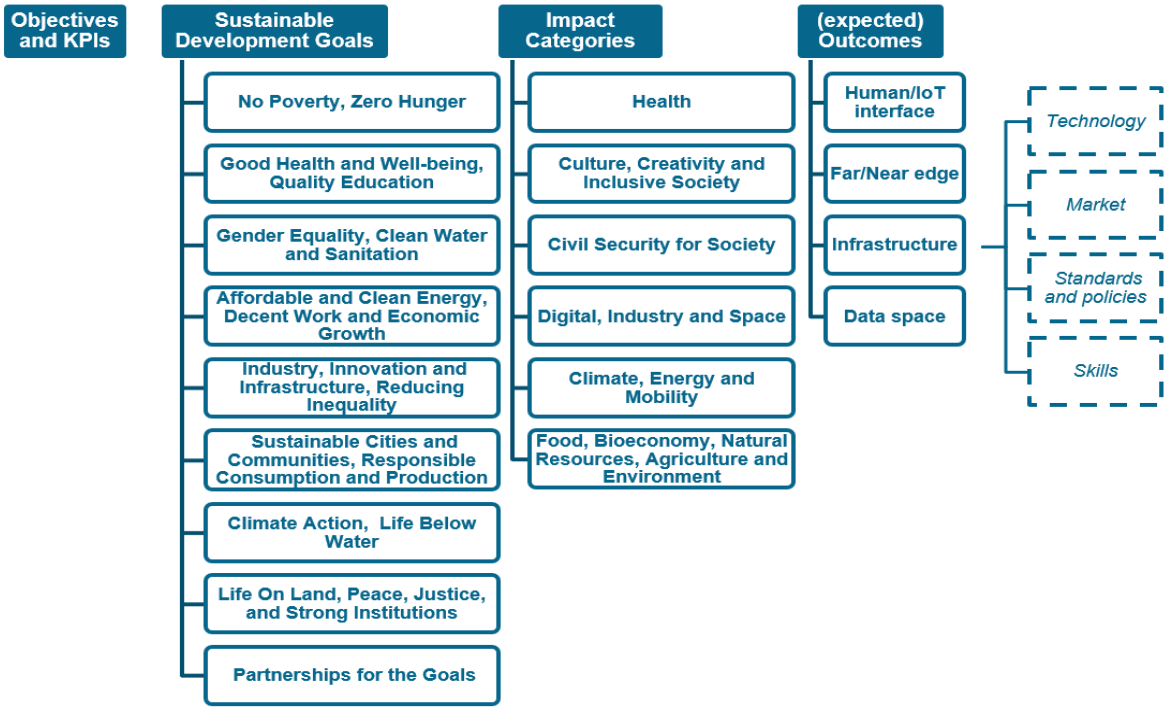

Figure 3: Qualitative analysis components.

2.1.3 Quantitative Analysis Aspects

The quantitative analysis component focuses on the collection of relevant KPIs to assist in an objective assessment of scientific and innovation impact; open calls impact; business exploitation impact. For this purpose, the following KPI guidelines have been considered:

- For scientific excellence and innovation, **EU-IoT adopts the guidelines of the OECD 2015 Frascati Manual for research and development indicators [3]**, in a way that components the proposed project indicators. Such KPIs are widely used across Europe for the purpose of assessing the impact of *R&D.*
- For use-case and business impact assessment, **EU-IoT adopts common business KPIs in alignment with the CSA OpenDEI, input from the AB and from the Expert Group**.

2.2 D5.6 Findings Summary

The conducted analysis in D5.6 created a comprehensive picture that depicts the dynamic dimensions of the EU-IoT cluster landscape through the ICT-56 flagship RIAs. It provided a qualitative impact assessment analysis toward sustainable development goals by identifying the common areas of contributions, and relevant RIA output towards different aspects, e.g., scientific output, business models.

In addition, the quantitative analysis provided a comparative description of the collected information from different scientific KPIs reflecting the status of the projects until July 2022. It highlighted the excellent impact through relevant scientific publications and outputs as well as a particularly proficient level of knowledge maturity and contributions to technology transfer across the projects. Furthermore, most projects that displayed a greater adoption of assets by SMEs

have launched open calls, which proved to be a valuable mechanism for achieving innovative impact.

Regarding business exploitation assessment, D5.6 provides an initial perspective on the status of business exploitation. This analysis pointed out the overarching vision behind the business plan in terms of usability and interoperability where most of the projects were at an intermediate stage. Besides, all projects showed a high maturity level of the R&D and TRL as well.

Finally, a series of guidelines and recommendations to be implemented by EU-IoT during the final phase of its course has also been described in deliverable D5.6.

For **business exploitation**, it is relevant for projects to start considering the recommendations proposed in this deliverable, to take advantage of potential strengths, and mitigate the weaknesses that have been detected. Specifically, all projects expect a significantly fast time-to-market (1-3 years); however, there is product fragmentation, and this will hinder the potential of reaching out to the market as expected. In terms of asset maturity, the TRLs provided demonstrate that the technology can reach the proposed maturity.

In what concerns **engagement and cooperation,** D5.6 address the risks and proposed mitigation actions and highlights the need to consider dimensions such as greenness, openness, and skills training, as well as the potential of new business models that may derive from the open calls.

In what concerned **scientific output,** the ICT-56 RIAs showed excellence with an extremely good level of relevant scientific contributions in forefront areas such as AIoT, AI/ML integration and adoption across Edge and Cloud and considering software and hardware. The RIAs supported a significant level of PhD students, an aspect that is also relevant in terms of advanced training products in Europe. Specific joint actions, e.g., Summer/Spring/Winter training events jointly developed, may assist in speeding up impact, and in getting additional feedback from the scientific community.

3 QUALITATIVE IMPACT ASSESSEMENT ANALYSIS

3.1 Project main goals and scope

The main goals, scope and the main expected contribution of the ICT-56 RIAs are described in Table 2. Different scopes and themes are addressed in all projects but the most common is IoT infrastructure IoT infrastructure that enables the collection, processing, and analysis of data from various IoT devices. In addition, cybersecurity, in particular security, data privacy, and trustworthiness. Moreover, the integration of AI/ML across Edge-Cloud is also a common theme among all projects.

In addition, across projects, there are overlapping goals that reflects the common changes faced by these projects (e.g., need for robust infrastructure; real time monitoring; distributed approaches for learning; privacy preservation; architectural decentralization across Edge and Cloud) which can be the basis for cooperating across projects in sharing knowledge and resources like open calls, specific events, or event commonly written output (e.g., books) to describe the scope of the projects and accelerate the development of IoT technologies and bring the benefits of IoT to a broader range of applications and industries.

Table 2: The scope and main goals of the ICT-56 RIAs.

Project	Scope and main goals
TERMINET	TERMINET aims at providing a novel next generation reference architecture based on innovative technologies such as Software Defined Networking (SDN), multiple-access Edge computing (MEC), and virtualisation for next generation IoT, while introducing new, intelligent IoT devices for low-latency, market-oriented use cases. **Main expected contributions:** • SDN-enabled vMEC: The TERMINET virtualized Multi-access Edge Computing (vMEC) scheme is designed around three important objectives, i.e., the ability to (i) accommodate and abstract the heterogeneity of IoT devices, (ii) accommodate the on-demand and secure processing of data flows sourced by geographically distributed IoT deployments targeting also low-latency services, and (iii) provision dynamic traffic steering and control capabilities through a fully programmable and interoperable networking substrate. These three objectives establish the foundations of the SDN-enabled TERMINET vMEC scheme. • Distributed AI in NG-IoT: TERMINET aims to provide a set of innovative mechanisms and tools for moving AI to the Edge by using innovative ML technologies, avoiding data collection, and offering decentralised analytics, privacy by design and data protection. The key characteristic of the AI enabled Edge devices will be the embedded ML solutions, while coping with performance, privacy, and personalization. • Activity and gesture recognition mechanisms to improve the visualisation and interaction mechanisms for collaborative Immersive AR/VR devices: TERMINET will provide novel and effective ways to deliver hand gesture recognition in AR/VR systems utilizing Edge machine learning architectures. • Security and Privacy in ML & FL: TERMINET will develop novel techniques for extending trust assertion to establish dynamic trusted chains across multiple heterogeneous Edge devices. TERMINET aims to design and develop novel identity management tools and procedures, as well as data sharing services, based on blockchain technologies.
ASSIST-IoT	Transforming IoT, from a technology building block to **next-generation AI-driven, (semi-)autonomous, cross-domain technology**, requires addressing multiple technical, usability, business, or regulatory challenges. In response, **ASSIST-IoT is founded on** several pillars: I. **innovative IoT architecture**, to adapt to NGI paradigm, with a three-dimensional

	approach, including intelligence, security, and privacy by design, and providing support for decentralized decision-making. II. **moving from semantic interoperability to semantically-enabled cross-platform, cross-domain data transactions**, within decentralized governance, facilitating transaction security, privacy, and trust, supported by DLT. III. **development and integration of innovative devices**, supporting context-aware computing, to enable comprehensive decision making close to events; and IV. **Tactile Internet support** allowing low latency applications, like AR/VR/MR, and human-centric interaction with IoT components. **Main expected contributions:** • Port automation: (a) automated alignment of CHE; (b) truck (or other yard fleet assets available) location monitoring; (c) Augmented Reality and Tactile Internet HMIs for CHE drivers and (d) remote control of CHE. • Smart Safety at work: will make provisions for predicting potentially dangerous situations for construction workers, and by means of relevant decisions and actuation – will prevent them. • Cohesive vehicle monitoring and diagnostics (i) trusted third parties and onboard sensor' measurements for diagnostics and monitoring combined within specific testing and inspection facilities for providing cohesive monitoring of vehicle condition and to (ii) provide a human-centric interaction with the different vehicle users ranging from the driver to OEM engineering services, which is currently unavailable
IoT-NGIN	Internet of Things **Main expected contributions:** • Health • Culture, creativity, and inclusive society • Civil security for society • Digital, Industry and Space • Climate, Energy and Mobility • Food, Bioeconomy, Natural Resources, Agriculture and Environment
IntellIoT	IntellIoT will develop a reference architecture and framework to enable IoT environments for (semi-)autonomous IoT applications endowed with intelligence that evolves with the human-in-the-loop based on an efficient and reliable IoT/Edge- (computation) and network- (communication) infrastructure that dynamically adapts to changes in the environment and with built-in and assured security, privacy, and trust.
INGENIOUS	INGENIOUS (Next-GENeration IoT sOlutions for the Universal Supply chain) aims to design and evaluate the Next-Generation IoT (NG-IoT) solution, with emphasis on 5G and the development of Edge and Cloud computing extensions for IoT, as well as providing smart networking and data management solutions with Artificial Intelligence and Machine Learning. **Main expected contributions:** • To design and evaluate the NG-IoT solution, with a particular emphasis on 5G and the development of Edge and Cloud computing extensions for IoT in addition to providing smart networking and data management solutions with AI/ML. • Manufacturing sector: teleoperation MR-based cockpits for AGV driving, haptic gloves cockpit for remote and automated robots driving. • Terrestrial transport sector**:** low power ML-based sensors security-by-default constructed. • Maritime transport sector: sensorized container connected through a smart IoT

	gateway using satellite connectivity for real-time tracking
VEDLIoT	AIoT systems focusing on deep learning. **Main expected contributions:** • Heterogenous AIoT hardware platform • Flexible hardware accelerators • Distributed remote attestation. • Requirements framework for AIoT systems • Wide range of use-case demonstrations

3.1.1 Technological Objectives

The technological objectives refer to the specific goals and targets related to the development and implementation of technology within a project. These objectives typically focus on improving or creating new technology to achieve a specific outcome. Overall technological objectives consist of:

- Developing new software or hardware systems to improve operational processes.
- Implementing new technology improves sustainability or increases energy efficiency.
- Upgrading existing technology infrastructure to improve reliability, scalability, or security.
- Creating new products or services that leverage emerging technologies or innovative approaches.

Table 3 provides details on the most relevant technological objectives of the ICT-56 projects. For example, TERMINET intends to apply distributed AI at the Edge and foster AR/VR contextual computing and thus leverage the use of AI for advanced IoT-based AR/VR applications. IoT-NGIN is focusing on developing privacy-preserving federated MLs in the IoT and enhancing tactile and contextual IoT sensing/action towards a human-centric IoT, as well as IoT cybersecurity against data poisoning and ML-based anomaly detection. VEDLIoT aims to develop a cognitive IoT hardware platform and reconfigurable system architecture. ASSIT-IoT ensures the design, implementation, and validation of a NGIoT architecture, as well as the definition of decentralized security and privacy leveraging DLT and the implementation of intelligent distributed AI tools.

Table 3: ICT-56 RIAs technological objectives.

Project	Technological Objectives
TERMINET	TERMINET intends to bring (more efficient and accurate) decisions to the point of interest to better serve the final user targeting at: • applying distributed AI at the Edge by using accelerated hardware and sophisticated software to support local AI model training using federated learning, • reducing the complexity of the connecting vast number of heterogeneous devices through a flexible SDN-enabled middleware layer, • fostering AR/VR contextual computing by demonstrating applicable results in realistic use cases by using innovative IoT-enabled AR/VR applications, • designing and implementing IoT-driven a decentralised and distributed blockchain framework within manufacturing, for supporting maintenance and supply chain optimisation, • applying a vertical security by design methodology by meeting the privacy-preserving and trust requirements of the NG-IoT architecture.

Project	Technological Objectives
IoT-NGIN	• Define a scalable, secure, open, federated, and decentralised IoT meta-architecture for sensing, actuation, and smart behaviour, such as streaming and processing on-device or at the Edge Cloud. • Enhance IoT underlying technology offering IoT/5G optimization and a “by-design” secure Edge Cloud execution environment to support micro-services’ offloading and increase scalability. • Enhance IoT privacy-preserving federated ML and on-device ethical AI. • Enhance IoT Tactile & Contextual Sensing/Actuating towards a Human-Centric IoT • Enhance IoT Cybersecurity against data poisoning and ML-based anomaly detection
ASSIST-IoT	• Design, implementation, and validation of an NGIoT Reference Architecture • Definition and implementation of distributed smart networking component • Definition and implementation of decentralized security and privacy exploiting DLT. • Definition and implementation of smart distributed AI enablers • Definition and implementation of human-centric tools and interfaces
IntellIoT	• Create a self-aware and semi-autonomous multi-agent system over an optimized computation and communication infrastructure that manages compositions of IoT/Edge devices in closed-loop with the network. • Enable ultra-dependable low-latency communication over heterogeneous networks to enable tactile (real-time) and contextual (adaptive) interaction between IoT devices, humans, and services. • Enable semi-autonomous IoT applications by leveraging distributed AI algorithms under compute, storage, mobility, and bandwidth constraints and by integrating the human-in-the-loop for safety, assistance, and continuous improvement of AI. • Enable security, privacy, and trust by design with continuous assurance monitoring, assessment, and certification as an integral part of the system, providing trustworthy integration of third party IoT devices and services. • Development of a reference implementation of the IntellIoT framework, demonstrated and evaluated in the three use case areas: agriculture, healthcare, and manufacturing.
INGENIOUS	• To combine AI with IoT for realizing the Internet of Intelligent Things (IoIT), enabling smart networks and services for driving the digital transformation of complex industrial and logistics processes, improving business operational efficiencies • To assure protection of sensitive data for the new IoT platforms to close any discovered security breach, providing means for remote attestation to ensure software properties. • To develop a novel hardware and software architecture based on isolated components to provide security in the presence of untrusted components while also enabling secure and efficient updates. • To foster a new dimension of human-to-machine interactions by enabling tactile and haptic experiences, which will revolutionise the real time interaction of humans with their digital environment, representing a revolutionary level of development for manufacturing engagement. • To develop interoperability and data management layer for interconnecting and operating various IoT technologies
VEDLIoT	• Cognitive IoT hardware platform Goal: Scalable, Heterogeneous • Reconfigurable system architecture - Goal: Silicon to System • Co-Design for flexible hardware accelerators - Goal: 5x increase in resource efficiency. • Toolchain for distributed AI - Goal: 10 x efficiency improvement • Security, privacy, and trust by design - Goal: End-to-End trust • Robustness and (functional) safety - Goal: Guaranteed safety levels, SOTIF

Project	Technological Objectives
	• Wide use case coverage - Goal: VEDLIoT technology for all use cases, incl. Open-Calls

3.1.2 Business Objectives

The ICT-56 RIAs projects were asked to provide a maximum of five business objectives. Table 4 provides details on their contributions toward business objectives.

The projects provided relevant contributions. For example, IoT-NGIN, INGENIOUS, INTELLIOT contribute to transport and environmentally friendly mobility as well as to intelligent automation management that respects individuals' privacy. TERMINET targets smart IoT devices such as smart glasses, haptic devices, energy harvesting modules, smart animal monitoring collars, AR/VR environments, and autonomous drones, to support new market-oriented use cases. ASSIT-IoT aims to establish an innovative cooperation and business framework by defining, deploying, and evaluating real-world pilot projects.

Table 4: Business Objectives.

Project	Business Objectives
TERMINET	TERMINET intends to bring (more efficient and accurate) decisions to the point of interest to better serve the final user targeting at: • designing, developing, and integrating novel, intelligent IoT devices such as smart glasses, haptic devices, energy harvesting modules, smart animal monitoring collars, AR/VR environments, and autonomous drones, to support new market-oriented use cases and, • providing novel disruptive business models, while fostering standardisation activities for the IoT ecosystem. • strengthening the EU's global position in the IoT value chain.
IoT-NGIN	• Competitive Advantage through IoT business platforms. • IoT Business modelling & Opportunities in use case verticals. • Establish the IoT-NGIN sustainability via major enablers end established DIHs & ecosystems. • Ensure alignment with market needs through active links with and contributions to SDOs, clusters and communities. • Create a Nex-Generation IoT ecosystem through open innovation and knowledge sharing.
ASSIST-IoT	• Definition, deployment, and evaluation of real-life pilots. • Establishment of an innovative cooperation and business framework. • Impact creation: Showcasing ASSIST-IoT disrupting the current market.
IntellIoT	• Promote and exploit the IntellIoT framework through contribution to standards and open source as well as by building an active IoT ecosystem supported by two Open Calls and focused dissemination and exploitation activities. Respect to individuals' privacy by design.
INGENIOUS	To experimentally demonstrate the use of the new IoT technologies on the three supply chain scenarios contemplated in INGENIOUS, i.e., factory/warehouse, connected transportation, and smart port.

Project	Business Objectives
VEDLIoT	-

3.1.3 Societal Objectives

As can be observed in Table 5, TERMINET aims to contribute to the community's societal challenge in order to boost the diversity of connections between heterogeneous devices, as well as the cross-industry collaboration. ASSIST-IoT is supporting inclusive societies by promoting smart and sustainable growth and assisting the European Green Deal. INTELLIOT is improving the European citizen's quality of life and working conditions and hence improving the accessibility to IoT resources and services. INGENIOUS aims to extend the work developed in the project and contribute to different NG-IoT SDOs.

Table 5: Societal objectives.

Project	Societal objectives
TERMINET	• TERMINET aims to contribute to the community societal challenge to boost the diversity of connections between heterogeneous devices, as well as the cross-industry collaboration. Therefore, multiple services will be enabled and delivered automatically and contextually, whenever, and wherever required. • TERMINET contributes to “inclusive societies” by promoting “smart and sustainable growth” and to “strengthening Europe’s role as a global actor,” by bringing innovative solutions which are validated by industrial partners to the market.
IoT-NGIN	• Improved European citizens quality of life and working conditions in a Human-Centred digital Europe. • Improved Accessibility to IoT resources and services • Scientific Advancement & Impact creation • Social responsibility through efficient use of resources for delivery of technology to citizens • Respect to individuals’ privacy by design
ASSIST-IoT	• ASSIST-IoT will contribute to “inclusive societies” by promoting “smart and sustainable growth” and “strengthening Europe’s role as a global actor.” By bringing innovative solutions to the market, validated by industrial partners, ASSIST-IoT contributes to “inclusive societies” by “closing the research and innovation divide in Europe” and to “strengthening the evidence base and support for the Innovation Union and European Research Area.” • Regarding pilots being in-line with “European Green Deal” priority : (i) much effort is put into increasing the efficiency of sea terminals in terms of energy demand, and reducing the carbon footprint in port logistics, and one of the key aspects to achieve it, is improved automation. ASSIST-IoT can complement measures already in place, to facilitate more climate-friendly ecosystem, by providing interoperability and achieving better planning, thanks to reasoning, flexibility, adaptability for container movements, and efficiency within port premises, leading to major reduction in CO2 emission.
IntellIoT	• Improved European citizens quality of life and working conditions in a

	Human-Centred digital Europe. • Improved Accessibility to IoT resources and services. • Scientific Advancement & Impact creation. • Social responsibility through efficient use of resources for delivery of technology to citizens. • Respect to individuals' privacy by design.
INGENIOUS	To extend the work developed in the project and contribute to different NG-IoT SDOs.
VEDLIoT	-

3.2 Alignments Towards European Commission Policies

Table 6 provides a summary of the alignment of ICT-56 projects with EU policies. For each project, there are specific objectives and focus areas that align with the various policy initiatives of the European Commission. One of the relevant policy areas is security, as many projects have actively developed technologies and solutions aligned with this aspect. Other overlapping policies are relevant to the green deal which include clean and efficient energy, climate action, environment, resource efficiency and raw materials, smart, green, and integrated transport, which is evident as EU has been actively promoting the development if green IoT technologies and applications.

Table 6: ICT-56 projects alignment towards European Commission policies, where the first column provides Topics relevant to different EC policies.

Topics	TERMINET	IoT-NGIN	VEDLIoT	ASSIST-IoT	INGENIOUS	INTELLIOT
EU mission: **- Health, demographic change, and wellbeing** **- Food security, sustainable agriculture, marine and maritime, Bioeconomy**	In the context of the Next-Generation Internet of Things (NGIoT), TERMINET aims to provide a flexible, open, and decentralised next generation IoT reference architecture for new real-time capable solutions in compelling IoT domains such as the energy, smart buildings, smart farming, healthcare, and manufacturing	x				
Ethics and Data Governance Act		x		Data Governance Act. AI act		Core principles: Ethics & AI, Data Governance & Privacy, Interoperability, Accessibility

Topics	TERMINET	IoT-NGIN	VEDLIoT	ASSIST-IoT	INGENIOUS	INTELLIOT
Security	-In the context of the Alliance for Internet of Things Innovation, TERMINET ensures end-user trust, adequate security, and privacy by design by developing a Federated Learning Framework, utilizing attestation modelling, distributed and decentralised blockchain, and enterprise-level privacy.	x	Development of distributed remote attestation and End-to-End trust for AIoT systems (Objectives 6)		-Solutions for securing the design and implementation of embedded IoT computers and operating systems. -End-to-end secure communication channels by integrating remote attestation with state-of-the-art Transport Layer Security (TLS). - Improved integrity of supply chain data by recording events DLT networks	- European Data Strategy 2020, https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fitdigital-age/european-data-strategy
Safety			Development of a requirements framework for AIoT systems and guaranteed safety levels for AIoT applications (Objectives 7)		- Our Factory and AGVs use cases aim to improve the conditions of employees in hazardous conditions in industrial and logistics environments. Additionally, the Transport use case aims to track the asset health to predict failures and proactively apply the necessary measures to minimize the actual finally occurring disasters.	
EU green deal: **- clean and efficient energy** **- Climate action, environment, resource efficiency and raw materials** **- Smart, green, and integrated transport**	-In the context of the IoT and Edge Computing, TERMINET develops cutting Edge technologies such as Distributed Computing, Artificial Intelligence (AI), Virtual/ Augmented Reality and Tactile Internet towards building and sustaining a competitive ecosystem of European technology and system providers in IoT.	x	-Energy/ resource efficiency and energy-efficient processing: As stated in the project objectives (Objectives 1-5)	- Smart, green, and integrated transport.	- AGV / MR cockpits improving container handling in ports -Optimizing truck traffic in ports based on better predictions for vessel arrival times	
Europe in a changing world **- inclusive,** **- innovative,** **- reflective societies**		x				

Topics	TERMINET	IoT-NGIN	VEDLIoT	ASSIST-IoT	INGENIOUS	INTELLIOT
Other		Next Generation Internet		European citizens safety and security AI act	- Open Access research publications: all the papers and the non-confidential deliverables are open and publicly available. Additionally, an open platform has been released for testing and research purposes related to the M3 solution of Barkhausen Institut, as well as some software detailed in the correspondent section. -Information and communication Technologies: the main target of the project is to contribute into the automatization and digitalization of the supply chain putting emphasis to the adoption of 5G technologies, Cloud and Edge computing as key enablers.	Report IoT and Edge Computing EU funded projects landscape https://aioti.eu/resources/standardisation-resources/

3.3 Contributions Towards SDGs

Table 7 provides a summary of the contributions in terms of use-cases and asset application towards SDGs, rated 1 (not so relevant) to 5 (highly relevant), or not applicable (0). Over the next subsections, we further explain the concrete project contributions for each of the six impact categories, namely: Health; Digital, Industry, and Space; Climate, Energy, and Mobility; Food, Bioeconomy, Natural Resources, Agriculture, and Environment; Culture, Creative and Inclusive Society; Civil Security for Society.

As corroborated by Table 7, the main contributions of ICT-56 RIAs fall, as expected due to the nature of the ICT-56 program, into *Digital, Industry, and Space (DIS)*. The next relevant set of contributions relates to *Climate, Energy, and Mobility (CEM)*. Projects such as INTELLIOT have also open calls in this context. The pillar of *Food, Bioeconomy, Natural, Resources, Agriculture, and Environment (FBNRAE)* most relevant set of contributions. This relates also with the nature of ICT-56 and with specific use-cases focused on Agriculture that several projects are addressing. Other contributions are being provided to Health. The main projects stating highly relevant contributions are TERMINET and INTELLIOT. Moreover, ASSIST-IoT and VEDLIoT have also a good level of contributions, followed by IoT-NGIN. *Civil Security for Society (CSS)* and *Culture, Creativity, and Inclusive Society (CCIS)* has been less addressed by projects, as expected due to the nature of ICT-56. Nonetheless projects such as INGENIOU, TERMINET and VEDLIoT mention a few contributions towards this category.

Table 7: Summary of overall SDG contribution levels, rated 1 (not so relevant) to 5 (highly relevant). 0 corresponds to not considered.

Category	1	2	3	4	5	0
Health		IoT-NGIN	ASSIST-IoT VEDLIoT		TERMINET INTELLIOT	INGENIOUS
Culture, creativity, and inclusive society	VEDLIoT					INGENIOUS IoT-NGIN ASSIST-IoT TERMINET INTELLIOT
Civil security for society	VEDLIoT			INGENIOUS		IoT-NGIN ASSIST-IoT TERMINET INTELLIOT
Digital, Industry and Space				TERMINET IoT-NGIN	INGENIOUS ASSIST-IoT INTELLIOT VEDLIoT ASSIST-IoT	
Climate, Energy and Mobility			ASSIST-IoT TERMINET	INTELLIOT VEDLIoT IoT-NGIN	INGENIOUS	
Food, Bioeconomy, Natural Resources, Agriculture and Environment			VEDLIoT	INTELLIOT IoT-NGIN	TERMINET	INGENIOUS ASSIST-IoT

3.3.1 Health Impact Category

Table 8 provides additional information concerning the concrete contributions that projects are providing to the Health impact category. INTELLIOT and TERMINET are the projects that have expressed having highly relevant contributions to health. In this context, INTELLIOT is, for instance, relying on federated machine learning to improve remote monitoring of patients and has an open call on Health. TERMINET applies ML to support training and personalization of treatments. Then, ASSIST-IoT is developing a pilot for safety at work integrating Edge computing and addressing integration across low latency networks. VEDLIoT has a smart mirror use-case and is focusing on its use for feedback to support aspects such as the elderly and their daily living based on real-time abnormal pattern detection. VEDLIoT focuses on the ML to hardware integration aspects as well.

Table 8: Contributions towards the Health category.

Sub-topic	Project	Comment
Staying healthy in a rapidly changing society	VEDLIoT	In a bigger context, the VEDLIoT smart mirror use-case is used in a smart home environment to support elderly citizen in their daily live.
	INTELLIOT	Prevention of cardiovascular diseases, increase of impact of rehabilitation
Living and working in a health-promoting environment	ASSIST-IoT	ASSIST-IoT holds a specific use case specially devoted to increasing the health and safety of workers in hazardous environments (in particular, in a construction site). In addition, several of the concerns in the maritime use case also orbit around comfort and safety of managers and CHE drivers. Furthermore, 2 Open Call projects have been funded tackling working environments following the spirit of ASSIST-IoT pilots.
	VEDLIoT	Within the VEDLIoT smart mirror use-case, abnormally detection is used to detect changes in daily behaviour which may lead to early discovery of diseases
Tackling diseases and reducing disease burden	TERMINET	Developing more efficient and personalised treatments by using medical knowledge from different departments inside a hospital.
	VEDLIoT	Within the VEDLIoT smart mirror use-case, abnormally detection is used to detect changes in daily behaviour which may lead to early discovery of diseases.
	INTELLIOT	applying of remote patient care / remote monitoring, empowering health care professionals and patients with better data.
Ensuring access to innovative, sustainable, and high-quality health care	TERMINET	Deploying advanced VR surgery training that will enable doctors to be fully immersed in a situation that is identical to a real operation and consequently offer the next level of education in this area.
Unlocking the full potential of new tools, technologies, and digital solutions for a healthy society	ASSIST-IoT	The innovation behind ASSIST-IoT pilot 2 lies under the provision of digital tools (enablers within ASSIST-IoT architecture and the GWEN hardware – gateway) to facilitate a better working environment in construction sites leveraging data sources such as position, movement, wearables, alerts, BIM files and Virtual Reality glasses and applications.
	TERMINET	Providing a higher level of medical education to health practitioners, leveraging diagnosis, and improving patient satisfaction and safety.
	VEDLIoT	Unlocking the full potential of new tools, technologies, and digital solutions for a healthy society: A use-case recently added to VEDLIoT via the open-call deals with a wearable's

Sub-topic	Project	Comment
		architecture for healthcare, i.e., epilepsy.
	INTELLIOT	Use of wearables and federated learning to improve treatment for cardiovascular patients.
Maintaining an innovative, sustainable, and globally competitive health related industry	INTELLIOT	Application of federated learning to remote patient monitoring.
Other		

3.3.2 Digital, Industry and Space Impact Category

Table 9 provides information on the tangible contributions achieved by all the projects towards DIS. Most projects consider digitization and emerging technologies as well as data privacy and security to be highly relevant topics. VEDLIoT focuses on energy efficiency and new AIoT architectures for predictive maintenance and energy distribution systems in their use cases. INTELLIOT contributes to the next generation of dependable and secure IoT technologies. ASSIST-IoT, provides an innovative architecture with emerging technology modules including frugal AI and data management components. INGENIOUS, aims to improve the digitalization and automation adoption in several key stages of the supply chain, as factories (Factory UC), transportation (Transport and Ship UCs), ports (Port Entrance and AGVs UCs) and secure information exchange (DVL/DLT UC).

Table 9: Digital, Industry and Space contributions per project.

Sub-topic	Project	Comment
Global leadership in clean and climate-neutral industrial value chains, circular economy and climate-neutral digital systems and infrastructures	ASSIST-IoT	The pilot 3A of ASSIST-IoT has as its final aim the reduction of CO2 (and other pollutants) emissions in fleet of cars by fine-grained monitoring (and applying AI algorithms) of high-fidelity sensors installed in cars. This is done via directly interacting with the open ECU of the car of the pilot and extrapolating (judiciously and with technology) the work to a virtual fleet of cars. This technology clearly would allow automotive companies to lead the environmental sustainability requests that the sector is requiring in the short future.
	VEDLIoT	VEDLIoT has a huge focus on energy-efficiency in all use-cases and develops energy-efficient processing for AIoT systems.
Globally attractive, secure, and dynamic data-agile economy	INTELLIOT	Data privacy and data security is an important element of INTELLIOT
Industrial leadership and increased autonomy in key strategic value chains with security of supply in raw materials	TERMINET	Providing efficient supply chain forecasting based on different types of production and sales data, adopting predictive analytics and federated learning techniques.

Sub-topic	Project	Comment
Sovereignty in digital technologies and in future emerging enabling technologies	ASSIST-IoT	ASSIST-IoT provides an innovative blueprint architecture with emerging technologies modules including federated learning (AI) and data management components. It includes emerging technologies such as encapsulation of lightweight containerized components via Helm charts, utilization of VR/XR glasses and other AR elements and demonstrating tactile use cases.
	INGENIOUS	Through its different use cases, the project aims to improve the digitalization and automation adoption in several key stages of the supply chain, as factories (Factory UC), transportation (Transport and Ship UCs), ports (Port Entrance and AGVs UCs) and secure information exchange (DVL/DLT UC).
	VEDLIoT	The VEDLIoT use-case for industrial IoT demonstrates novel AIoT architectures for predictive maintenance and power distribution systems. Use-case recently added to VEDLIoT via the open-call deal with DL-based laser welding, Industrial indoor localization and Edge-based reinforcement learning for power electronics.
	INTELLIOT	Contributing to the Next Generation of trustworthy and secure IoT technologies / NGIoT
	TERMINET	Providing reliable services that support maintenance tasks of equipment, adopting mixed reality technologies, the concept of digital twins as well as utilising operational data to predict future maintenance tasks and failures
Strategic autonomy in developing, deploying, and using global space-based infrastructures, services, applications, and data	ASSIST-IoT	ASSIST-IoT shifts the Cloud-native paradigm towards Edge and far-Edge equipment in IoT deployments. In addition, self-* tools are being developed to increase the autonomy of the computing ecosystem (always human-aware and supervised). All the previous will allow new IoT deployments to better leverage available infrastructure.
	TERMINET	Supporting maintenance tasks of industrial equipment, adopting mixed reality technologies, the concept of digital twins, and federated learning techniques to predict future failures and plan maintenance tasks
A human-centred and ethical development of digital and industrial technologies	IoT-NGIN	Validated through industry 4.0 use cases
	ASSIST-IoT	ASSIST-IoT solution has been designed with the highest ethical and data protection standards. In addition, all modules of the NGIoT solution delivered have included mechanisms to ensure safeguarding rights and freedoms of developers, users, and stakeholders.
	INTELLIOT	Human-in-the-loop is a key pillar of INTELLIOT; compliance of GDPR; AI to support health care professionals instead of replacing them
Other		

3.3.3 Climate, Energy and Mobility Impact Category

Table 10 provides detail on the contributions of the ICT-56 projects toward the CEM Impact category. The projects expressing highly relevant contributions are INGENIOUS and IoT-NGIN. VEDLIoT and INTELLIOT also express a good level of contributions, followed by TERMINET and ASSIST-IoT.

For example, IoT-NGIN, INGENIOUS, INTELLIOT, and VEDLIoT contribute to transport and environmentally friendly mobility as well as to intelligent automation management. TERMINET targets smart energy by transforming buildings into smart structures and optimizing their energy consumption and harvesting, using distributed AI techniques.

Table 10 :Climate, Energy and Mobility contributions per project.

Sub-topic	Project	Comment
A climate-neutral and resilient society and economy	ASSIST-IoT	Climate neutrality is tackled in the automotive sector and the maritime port sector. By having more efficient Container Handling Equipment (pilot 1), reduction of pollution in the port-city interfaces will be possible. On another note, decreasing environmental impact of the current vehicle fleets is sitting on top of worldwide priorities.
Clean and sustainable transition of the energy and transport sectors towards climate neutrality	TERMINET	Smart energy data can be combined with geo-spatial data to better plan which areas or buildings are best for installation of different types of renewable energy (e.g., solar panels, heat pumps etc). Transforming buildings into smart buildings and optimize their energy consumption and harvesting, by utilizing distributed AI techniques over the data collected by multiple IoT devices.
Efficient and sustainable use of energy, accessible for all	IoT-NGIN	
Climate-neutral and environmentally friendly mobility	IoT-NGIN	Validated through driver-friendly dispatchable EV charging
Safe, seamless, smart, inclusive, resilient, and sustainable mobility systems	INTELLIOT	Applying semi-autonomous operations of off-road mobile machinery in agriculture.
	INGENIOUS	Through the AGVs use case, the project aims to improve the security of workers in hazardous areas automatizing and enabling remote driving and control of automated guided vehicles for port areas. Additionally, the Transport use case targets the resilience of transport systems of the supply chain by developing low-powered ML-Edge sensors that monitor the health of the system and predicts failures to fix them before deriving into a disaster. In general, all the use cases of the project target smart management as an enabler for automation.
	IoT-NGIN	Validated through smart mobility cases in the Smart City sector.
	VEDLIoT	The automated emergency braking use-case in VEDLIoT adds a new building block for automated driving. A use- case recently added to VEDLIoT via the open-call deals with an AI framework for driving courses on motorbikes.
Other	IoT-NGIN	Ensuring stable grid operation through active monitoring and control.

3.3.4 Food, Bioeconomy, Natural Resources, Agriculture and Environment Impact Category

The contributions towards this pillar (rf. Table 11) are of an applicational nature. Different projects are developing agriculture use-cases, either directly or via open calls. The use-cases in this context allow assessing he proposed assets in terms of energy efficiency, or capability to scale (e.g., heterogeneous data set support) and allow also to evaluate new business models, as in the case of VEDLIoT (use-cases derived from open calls, e.g., an automated harvesting system for mushrooms). IoT-NGIN proposes a smart farming solution (smart irrigation & spraying, smart harvesting). TERMINET contributes with a user centric device for smart farming. IntellIoT also contributes with the automation of agricultural machinery.

Sub-topics that can be explored from a business perspective in a later phase concern "established innovative governance models to enable sustainability and resilience."

Table 11: Contributions to the pillar Food, Bioeconomy, Natural Resources, Agriculture, Environment.

Sub-topic	RIA	Comment
Climate neutrality	VEDLIoT	VEDLIoT has a huge focus on energy-efficiency in all use-cases and develops energy-efficient processing for AIoT systems.
Biodiversity decline is halted		
Sustainable and circular management and use of natural resources	TERMINET	Multi-collected and heterogeneous data coming from crops, livestock, or even better from mixed farming systems and coupled with AI capabilities is a promising approach that enhances agriculture systems' sustainability boosts their production and diminishes risks by identifying systems vulnerabilities before they harm it.
Food and nutrition security for all	VEDLIoT	Food and nutrition security for all: A use-case recently added to VEDLIoT via the open-call deals with AIoT Pollen analysis for the honey industry. Another use-case recently added to VEDLIoT via the open-call deals with an automated Harvesting System for Mushrooms.
Sustainable development of rural, coastal, and urban areas is achieved		
Established Innovative governance models to enable sustainability and resilience		
Other	INTELLIOT	Increase of the resilience of the agriculture sector, and particularly reducing the high number of work accidents through the automation of agricultural machinery
	TERMINET	User Centric Devices for Smart Farming

3.3.5 Civil Security for Society Impact Category

As can be seen in Table 12, INGE NIOUS, TERMINET and VEDLIOT have provided contributions to this impact category. INGENIOUS focuses on increasing cybersecurity via the application of DLT and smart contracts. TERMINET provides reliable services that support maintenance tasks of equipment, adopting mixed reality technologies, the concept of digital twins as well as utilising operational data to predict future maintenance tasks and failures. VEDLIoT provides distributed remote attestation and *time-of-check to time-to-use (TOCToU-save)* certification for IoT through their developed security features.

Table 12: Contributions to the pillar of civil security for society.

Sub-topic	Project	Comment
Reduced losses from natural, accidental, and human-made disasters	TERMINET	TERMINET provides reliable services that support maintenance tasks of equipment, adopting mixed reality technologies, the concept of digital twins as well as utilising operational data to predict future maintenance tasks and failures.
Improved passengers and shipments travel into the EU		
Crime and terrorism are more effectively tackled		
Increased cybersecurity and a more secure online environment	TERMINET	TERMINET ensures end-user trust, adequate security, and privacy by design by developing a Federated Learning Framework, utilizing attestation modelling, distributed and decentralised blockchain, and enterprise-level privacy.
	INGENIOUS	Through its DVL/DLT use case, the project aims precisely to improve security in the monitoring and exchange of information along the supply chain. This is accomplished by using different DLTs that keep track of every interaction as a smart contract. In addition to this, a data virtualization layer (DVL) has been developed for the abstraction and interoperation among data coming from different devices using different protocols and DLTs.
	VEDLIoT	The security features developed within VEDLIoT provide distributed remote attestation and TOCTOU-save certification for IoT
Other		

3.3.6 Summary, Contributions Towards SDG

Overall, the ICT-56 project contributions are well aligned with the nature of the ICT-56 program, as corroborated in Figure 4. The six projects propose relevant contributions across the six impact categories.

All projects expect highly relevant contributions to the impact category **Digital, industry, and Space**, which aligns with the call description, regarding digitization and emerging technologies as well as data privacy and security contributions.

Significant contributions are also expected in terms of **Climate, Energy, and Mobility**, where IoT-NGIN, INGENIOUS, INTELLIOT, and VEDLIoT contribute to transport and environmentally

friendly mobility as well as to intelligent automation management. TERMINET targets smart energy by transforming buildings into smart structures and optimizing their energy consumption and harvesting, using distributed AI techniques. ASSIST-IoT targets fleet management considering energy efficiency (reducing environmental impact) while optimizing engine parameters in a user-centric way.

In the Health category, TERMINET and INTELLIOT rely on federated learning to improve remote monitoring of patients and have an open call on Health. TERMINET applies ML to support training and personalization of treatments. Then, ASSIST-IoT is developing a pilot for safety at work integrating Edge computing and addressing integration across low latency networks. VEDLIoT has a smart mirror use-case and is focusing on its use for feedback to support aspects such as the elderly and their daily living based on real-time abnormal pattern detection. VEDLIoT focuses on the ML to hardware integration aspects as well.

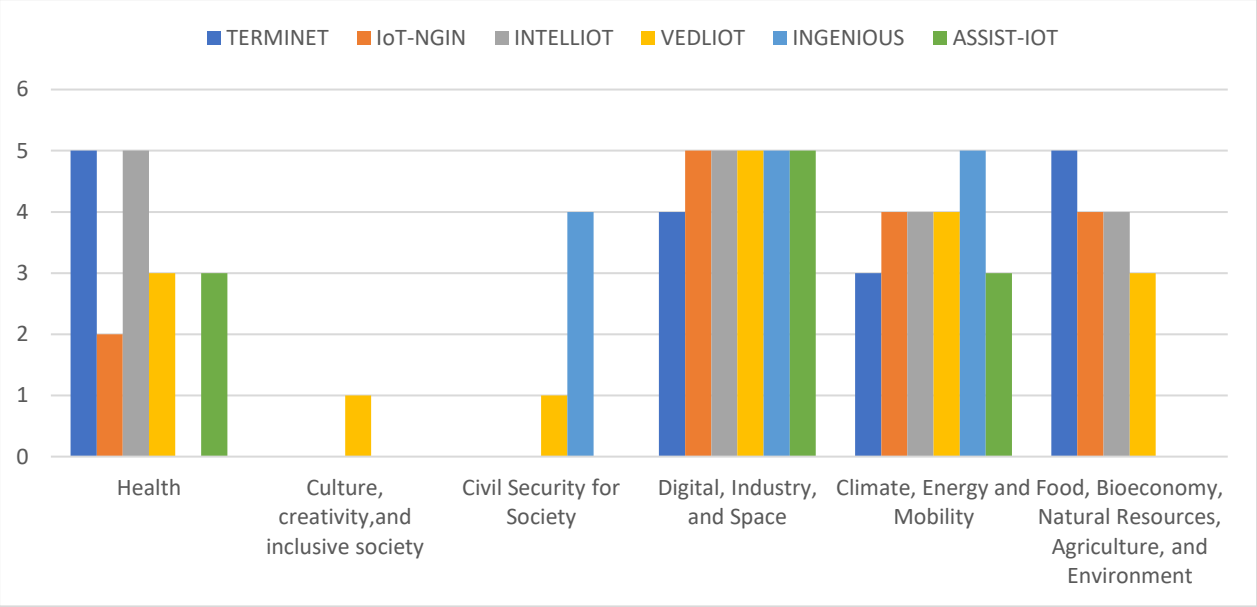

Figure 4: ICT-56 RIAs contributions to SDG impact categories, ranked 1 (not so relevant) to 5 (highly relevant); 0 (no contributions expected).

The expected contributions towards **Food, Bioeconomy, Natural Resources, Agriculture, and Environment** reflect the application of technology in Agriculture use-cases. There is a good overlap in terms of smart farming solutions across the projects proposing contributions. In addition to Agriculture, VEDLIoT has a use-case added via an open call concerning AIoT Pollen Analysis for the honey industry, and the use of AI/ML for automated Harvesting System for Mushrooms. TERMINET, IoT-NGIN as well as IntellIoT provide contributions towards this pillar.

While societal impact is not a key driver of the ICT-56 projects, they are all addressing inclusiveness aspects (e.g., VEDLIoT) and security aspects towards **Civil Security for society** (INGENIOUS). Specific aspects that relate with societal impact, e.g., data privacy and trustworthiness, are visible across all projects.

3.4 Contributions Towards EU-IoT Scope Areas

This section provides input related to the main contributions of the projects to the 5 scope areas (rf. to sect 2.1) as illustrated in Figure 5 derived from Table 13, where the RIAs have been asked to weight the contributions based on a Likert scale from 1 (low impact) to 5 (high relevant impact).

Most projects tend to focus on the far Edge, near Edge, and Human/IoT interfaces. Infrastructure is the area that ranks next. Followed by Data Spaces, where two projects fit best. Overall, al projects provide good coverage across all EU-IoT scope areas, and they have renewed their

operation, solutions, and services towards different sectors to be aligned with the EU vision.

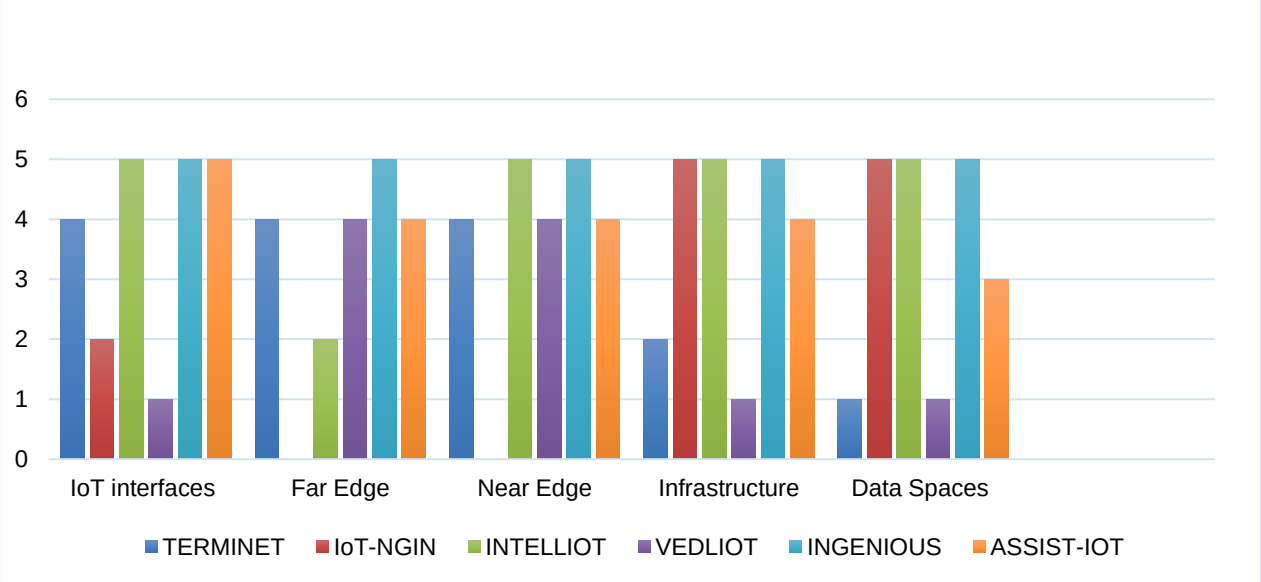

Figure 5: Contributions of projects towards EU-IoT scope areas, ranked 1 (not relevant) to 5 (highly relevant).

Table 13: Contributions of projects towards EU-IoT scope areas, ranked 1 (not relevant) to 5 (highly relevant).

EU-IoT scope area	1	2	3	4	5	(not applicable)
IoT interfaces	VEDLIOT			TERMINET	INTELLIOT ASSIT-IoT INGENIOUS	
Far Edge		INTELLIOT		VEDLIOT ASSIT-IoT TERMINET	INGENIOUS	
Near Edge				VEDLIOT INTELLIOT ASSIT-IoT TERMINET	INGENIOUS	
Infrastructure	VEDLIOT	TERMINET		ASSIT-IoT	INTELLIOT INGENIOUS	
Data Spaces	VEDLIOT TERMINET		ASSIT-IoT		INTELLIOT INGENIOUS	

3.5 Contribution towards Ethical Aspects

Identifying the potential ethical impact categories tackled by the RIAs, involves identifying the potential issues that may arise from the different ethical aspects such as privacy and data

governance, transparency, technical robustness, and safety, etc. This analysis helps to understand and describe the tackled categories as well as assessing the impact on broader ethical principles and values to the impact of developed technologies and assets by the ICT-56 RIAs. This, in turn, helps to promote trust, fairness, and to avoid potential harm or negative impacts. Thus, developing technologies that address the ethical issues identified in the analysis. This may involve developing guidelines to mitigate the potential harm or ensure ethical principles are upheld. As summarized in Table 14 and illustrated in Figure 6, different ethical aspects and topics were actively tackled by the RIAs especially in terms of privacy and data governance as well towards technical robustness, safety and legal issues.

Table 14: Ethical impact assessment.

Ethics Topics	RIA	Comment
Privacy and data governance	ASSIST-IoT	The project tackles data privacy specifically in pilot 2, where workers have participated in the execution of the trial. In addition, global measures such as data anonymisation and application of a FAIR-compliant DMP have also been put in action.
	INTELLIOT	Privacy conforms handling of patient data
	IoT-NGIN	Preparation of consent forms when applicable, anonymization principles and procedures put in place. There is a clear Data Management Plan.
	TERMINET	
	VEDLIOT	The local data processing within the project, in particular the Smart Mirror use case, has data privacy as a main feature and uses local processing to ensure this.
Transparency	TERMINET	
Technical robustness and safety	ASSIST-IoT	All software and hardware artefacts of the project have included a check on safety and robustness via unitary tests and have followed best practices and templates established in ASSIST-IoT.
	INTELLIOT	Advanced data security implemented
	IoT-NGIN	Safety procedures were addressed with the relevant partners
	TERMINET	
	VEDLIOT	The requirement framework developed within VEDLIoT foresees methods and monitors for robustness and safety within AIoT systems.
Diversity, non-discrimination, and fairness	TERMINET	
	VEDLIOT	One goal of the AIoT framework is to avoid using biased data in DL training.
Legal issues	IoT-NGIN	Potential misuse of research outcomes is included in a risk assessment scheme.
	INTELLIOT	GDPR compliant handling of patient data, informed consent of enrolled subjects, approval of pilot study by ethics committee (health care use-case)
	TERMINET	
Other	IoT-NGIN	Involvement of humans in the study was also addressed.

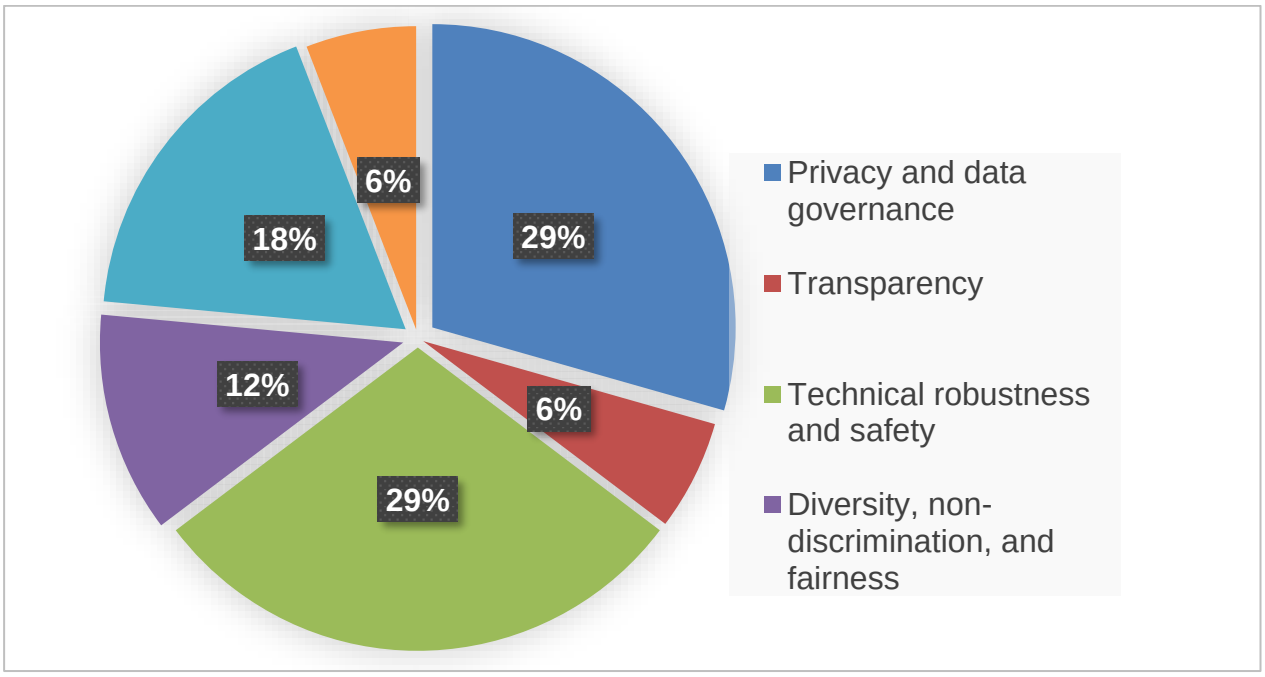

Figure 6: Relative distribution of ICT-56 Contributions towards ethical topics.

3.6 Collaboration Assessment

Table 15 provides an overview of different aspects of collaboration initiated by ICT-56 projects to show-case efforts aimed at establishing collaboration between them in different areas. This collaboration can be organized through joint publications, events such as Hackathons, workshops, conferences, etc. Mostly, the organization of collaborative events can contribute to knowledge sharing and the implementation of joint initiatives. Hence, several initiatives have been launched by the EU-IoT to consolidate this cooperation, and others have been initiated by the ICT-56 projects.

For instance, several NGIoT events were organized such as EU-IoT IDEAthon/Hackathon 2021/22, and the international CONANSENSE 2022 / EU-IoT Hackathon, organized in July 2022 by FOR with the support of EU-IoT and of the ICT-56 RIAs, along with other RIAs.

These events assist ICT-56 projects, developers, scientists, and researchers to present the latest advances and use-cases related to different projects to facilitate the development of new applications or services that benefit from the strengths of the technology of every project.

Similarly, EU-IoT has organized several workshops like EU-IoT Training Workshops Series (4 events) to facilitate discussions on interoperability challenges and solutions.

Table 15: Summary of collaboration activities, either triggered by RIAs or by external entities. A cumulative total per aspect is provided.

Collaboration aspects	Triggered by RIAs			External Events		Total
Number of Joint events (conf+ workshop,..)	TERMINET			3+7	1.IoT Week 2021 2.Next Generation IoT and Edge Computing Strategy Forum IoT Week 2022 1. HiPEAC 2022: DL4IoT Workshop	74

Collaboration aspects		Triggered by RIAs		External Events		Total
					2. NGIoT Thematic Workshop: Health and Care 3. EU-IoT Training Workshops Series (4 events) 4. HiPEAC conference 2023: DL4IoT Workshop EU-IoT Boards meeting in Brussels 2022 - Achieving Impact; Road to commercialisation	
	IoT-NGIN	3		0		
	IntellIoT	7+1	e.g., NG-IOT Events, CONANSENSE 2022 (Presentation main conference).			
	ASSIT-IoT	10 + 15		5+5	IoT Week, HipEAC, internal workshops…	
	INGENIOUS	5+4	AIoT and Edge Machine Learning Training Workshop 2x Enabling the Tactile Internet with IoT EU-IoT Training Workshop Series: NextGeneration IoT Architectures			
	VEDLIoT	6+3				
Joint Publications	ASSIT-IoT	3	whitepapers	1		5
	IntellIoT	0		0		
	VEDLIoT	1				
Joint Open Calls	IoT-NGIN			1	Both our open calls were disseminated via ICT-56 partners, but organized separately	1
Joint Hackathon	TERMINET			1	EU-IoT IDEAthon/Hackathon 2021/22	5

Collaboration aspects	Triggered by RIAs			External Events		Total
	IntellIoT	1	CONANSENSE 2022 / EU-IoT Hackathon			
	INGENIOUS	1	CONASENSE2022 and EU-IoT/EFPF Hackathon			
	VEDLIoT	1				
	IoT-NGIN	1				
Interaction across the students in different projects:Summer /Winter/Spring school						
Other						

Overall, the key developed collaboration across different areas between the ICT-56 projects, either with/without their initiatives and an aggregate perspective of this collaboration as illustrated in Figure 7, Figure 8, and Figure 9 respectively, can be reflected in many aspects such as the organization of different events, publications, hackathons, open calls, and collaborative actions involving students. This collaboration will foster innovation, build connections, and advance the IoT ecosystem.

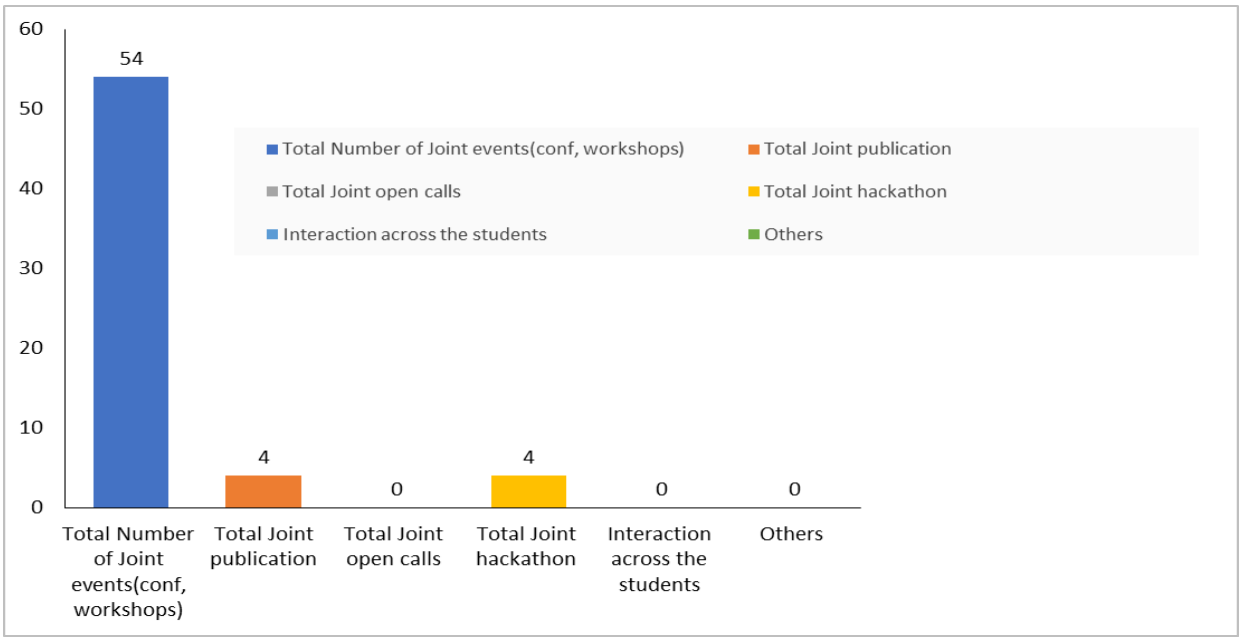

Figure 7: Collaborative initiatives triggered by ICT-56 RIAs.

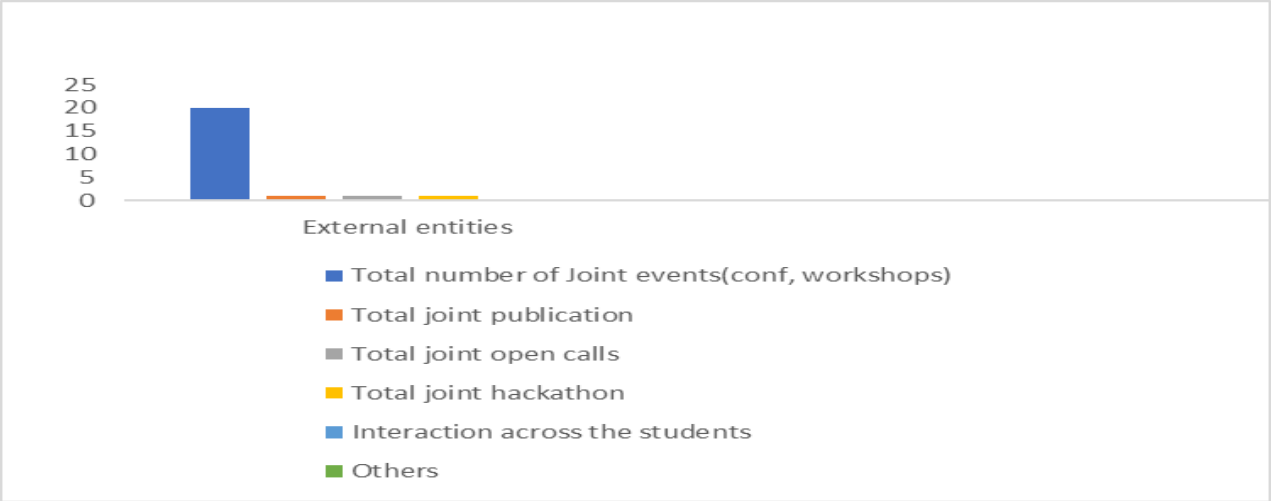

Figure 8: Collaborative initiatives where several ICT-56 RIAs were involved, triggered by external entities.

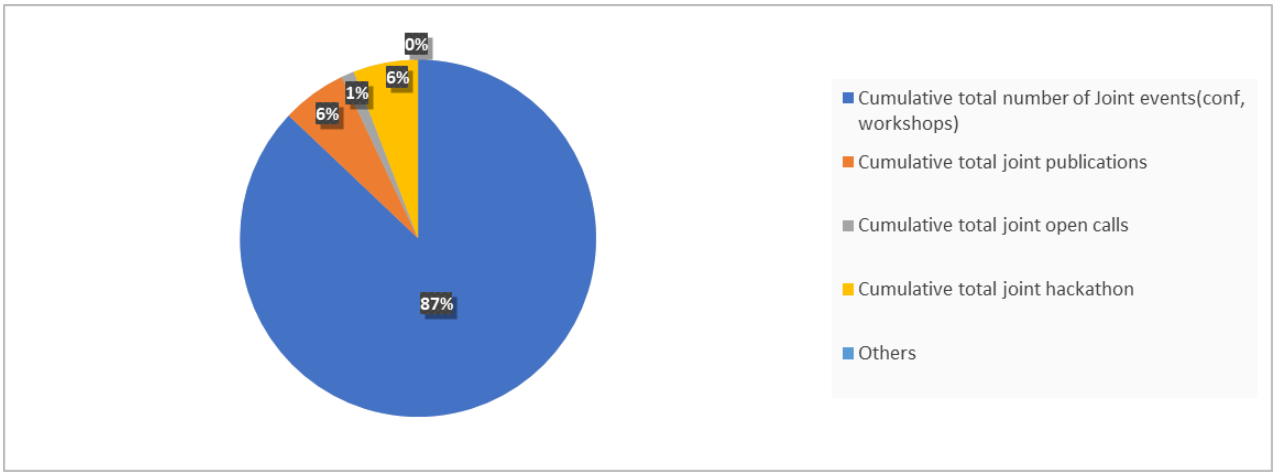

Figure 9: Relative distribution of main collaboration areas.

4 QUANTITATIVE IMPACT ANALYSIS

For the quantitative analysis, EU-IoT has collected different KPIs following the proposed methodology explained in Deliverable D5.5. This section provides a quantitative perspective concerning innovation impact, research impact, and business impact.

Even though EU-IoT will end in March 2023, many ICT-56 projects are still active and therefore, the results presented in this deliverable reflect the status collected until February/March 2023. This also comprises, for most projects, results derived from closed or still active open calls.

4.1 Innovation Impact Analysis

Table 16 provides a summary of KPIs per project. Projects that show a higher adoption of assets by SMEs have been running open calls, a tool that has been extremely valuable to generate innovation impact.

Out of the six projects, INGENIOUS is the only project that does not recur to open calls. This has an impact in terms of the adoption of the project's assets by third parties. In fact, most entities that adopt project solutions are SMEs, derived from open calls. In comparison, many research entities have also adopted solutions. Hence, there is an overall adequate balance across industrial and research entities that have adopted the project solutions.

In terms of knowledge transfer, the projects still show an interesting development of KPIs. There are no IPRs, and licensing. However, the projects show a good level of generated products/services, and this should also require an analysis of the respective licensing models.

Table 16: Innovation KPIs per project.

KPI	TERMINET	VEDLIoT	IoT-NGIN	INTELLIOT	INGENIOUS	ASSIST-IoT	Total
SMEs that adopted the project solutions/services	12	3	5	6	0	8	34
Public entities that adopted the solutions/services	4	-	0	1	0	0	5
Research entities that adopted the solutions/services	7	7	0	5	0	8	27
Industrial organizations that adopted the solutions/services	4	2	0	4	0	9	19
Other stakeholders that adopted the solutions/services	-	-	0	0	0	7	7
Number of generated spinoffs	1	-	0	0	0	0	1
Number of generated patents	0	-	0	0	0	0	0
Number of generated licences	0	-		0	0	0	0
Number of generated new products/new product lines	1	-	0	0	1	9	11
Number of generated new services	1	6	0	3	0	10	20

4.2 R&D KPIs

Table 17 provides collected KPIs to assess the scientific impact of the ICT-56. As already explained, these numbers reflect the status of the projects until 01.03.2023.

Overall, there is an excellent level of R&D contributions. In terms of **Scientific Publications (A),** the projects have provided already 162 peer-reviewed international publications, out of which 59 were accepted in excellent international venues (international journals SJR Q1/Q2 or conferences CORE Rank A*/A/B). A particularly good level of scientific event organization has been reached by projects that have a stronger research orientation, e.g., TERMINET, INTELLIOT. **Organization of Events (B)** provides a good number of contributions, where some activities are already being jointly pursued by projects. Another relevant success area concerns **Advanced Training (C)** with 139 contributions, out of which 51 reflect active PhDs, 45 concern concluded MScs. Lectures and seminars amount to a total of 25, showing a good transfer from research towards educational products. In terms of **Knowledge and Technology transfer (D),** the contributions are extremely balanced across the different sub-indicators, e.g., talks and Webinars to industry, and invited talks and keynote speeches. As for Research **Demonstrators and Testbeds (E),** most contributions already have a TRL4-5.

Table 17: R&D KPIs per project.

R&D KPI	ASSIST-	VEDLIoT	IoT-NGIN	INTELLIOT	INGENIOUS	TERMINET	Total
A – Scientific Publications							162
Books	0	0	0	0	0	0	0
Book Chapters	3	3	3	0	0	0	9
Papers in international venues, SJR Q1 (Magazines, Journals) and CORE Rank A*/A	3	4	0	19	3	13	42
Papers in international venues, SJR Q2 (Magazines, Journals) and CORE Rank B	1	0	0	11	0	5	17
Papers in international venues, Magazines, Journals, Conferences	18	12	7		16	32	85
White Papers	6	0	0	0	0	3	9
B – Organization of Events							17
Conferences, workshops, symposia	4	4	0	2	0	1	11
Scientific committees, Technical Programme Committees, etc.	2	2	1	0	0	3	6
Guest editorial teams	0	0	0	0	0	0	0
C – Advanced Training							139
Active PhDs	6	8	2	12	1	22	51
Concluded PhDs	4	2	1	1	0	0	8
Concluded MScs	10	11	1	11	4	8	45
Summer schools, and similar events	0	4	0	3	1	2	10
Lectures and Seminars	8	1		10	4	2	25
D - Knowledge and Technology Transfer							100
Webinars, Demos, Talks to Industry	7	5	>15	3	23	1	54
Invited Talks and Keynote speeches	3	0	6	23	4	10	46
E – Research Demonstrators and Testbeds							52
Research demonstrators, testbeds, software, TRL2-3	0	3	0	0	0	7	10
Research demonstrators, testbeds, software, TRL4-5	0	7	13	0	5	2	27
Research demonstrators, testbeds, software, TRL6 and above	0	9	0	0	3	3	15
Others	0		0	0	0	0	0

Figure 10 provides an aggregate perspective on the current innovation impact created by ICT-56 projects, where SMEs and research entities are conducting the overall adoption. The key tool for this adoption relates to the open calls conducted by five out of the six projects.

In terms of scientific impact (rf. to Figure 10), the ICT-56 projects show an excellent impact via relevant tooling, such as an excellent level of relevant open access scientific publications, a very good level of mature knowledge, and technology transfer contributions.

Aspects that can be further worked on to strengthen the overall scientific impact in ICT-56 relate to the development of cross fertilization aspects, such as joint book development and joint event development, e.g., winter or spring schools. The strong level of active PhD students and the high number of concluded MSc theses are relevant aspects in the articulation of joint scientific events, with the assistance of EU-IoT.

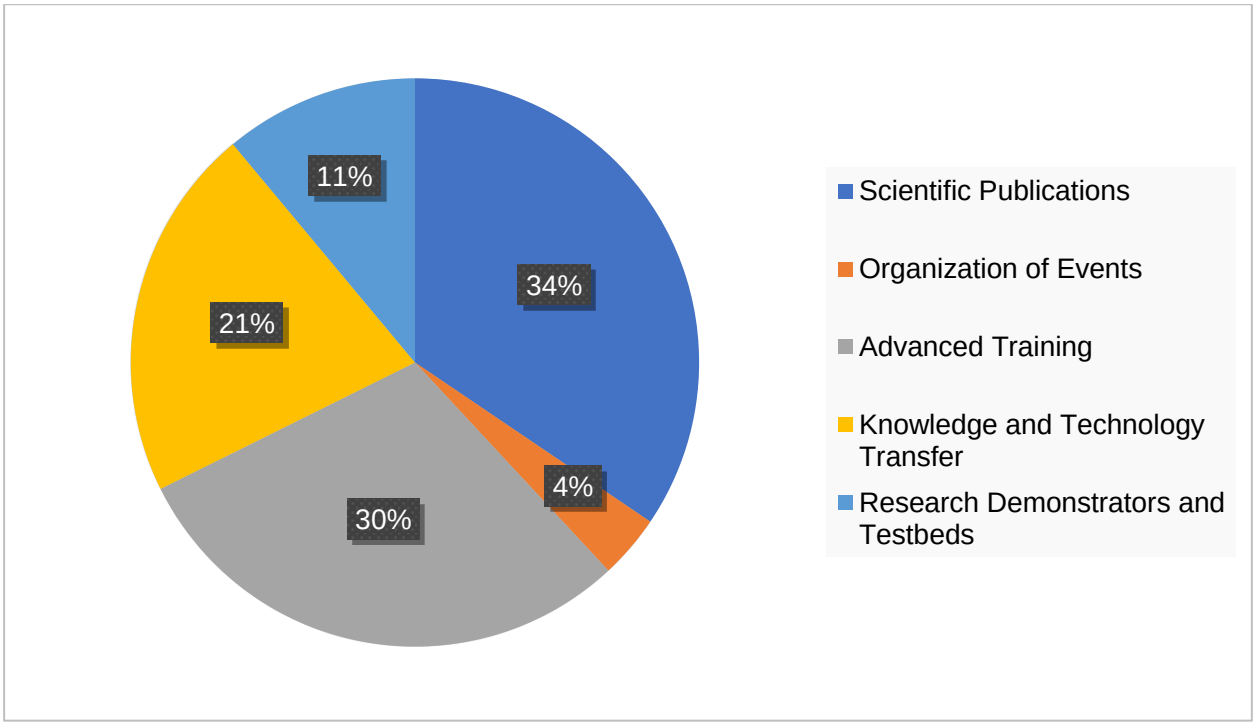

Figure 10: Relative R&D impact perspective of ICT-56 RIAs.

4.3 Standardization Contributions

This section provides input concerning the contributions that projects are developing toward *Standards Development Organizations (SDOs)*[7]. The contributions are split into two categories: i) **monitoring**, where projects attend specific SDO events and discussions, but are not directly contributing to specific outcome under development in an SDO; ii) **contributions**, where projects are effectively contributing to an SDO via white papers, reports, presentations, demonstrations, and other material.

Table 18 provides the summary of **SDO monitoring contributions** provided by the six RAIs, where the activity is measured via a grading of 0 (low activity) to 3 (high activity), while *Table 19* provides similar content concerning **SDO contributions** by RIAs.

Regarding **monitoring**, most projects exhibit a good level of monitoring activities across a broad range of relevant SDOs. Monitoring contributions require a significant level of staff involvement

[7] In EU-IoT, the term SDO refers to entities that develop standards and pre-standardisation entities as well as consortia that assist in the adoption of standards across different vertical domains.

and are time consuming. The current monitoring level is therefore too high in terms of potential impact. For instance, two projects (TERMINET and ASSIST-IoT) rely on a more selective monitoring methodology, where they focus on specific SDOs, e.g., IEEE.

The projects have also established remarkably interesting effort towards other SDOs that have been considered in EU-IoT (under WP3).

Table 18: SDO monitoring contributions impact assessment.

SDO	0 (low activity)	1	2	3 (high activity)
IEEE	INGENIOUS IoT-NGIN	VEDLIoT	INTELLIOT	ASSIST-IoT TERMINET
IETF	INGENIOUS IoT-NGIN VEDLIoT	TERMINET INTELLIOT	ASSIST-IoT	
ISO	INGENIOUS IoT-NGIN INTELLIOT	ASSIST-IoT VEDLIoT		TERMINET
ITU-T	INGENIOUS VEDLIoT INTELLIOT TERMINET	IoT-NGIN		ASSIST-IoT
IEC	INGENIOUS VEDLIoT INTELLIOT	ASSIST-IoT TERMINET	IoT-NGIN	
OASIS	INGENIOUS IoT-NGIN VEDLIoT INTELLIOT TERMINET	ASSIST-IoT		
W3C/WoT	INGENIOUS IoT-NGIN VEDLIoT	ASSIST-IoT		INTELLIOT TERMINET
3GPPP	VEDLIoT	ASSIST-IoT TERMINET	INTELLIOT	INGENIOUS IoT-NGIN
CENELEC	INGENIOUS IoT-NGIN ASSIST-IoT TERMINET	VEDLIoT	INTELLIOT	

SDO	0 (low activity)	1	2	3 (high activity)
ETSI	VEDLIoT		INTELLIOT IoT-NGIN	ASSIST-IoT TERMINET INGENIOUS
IRTF	INGENIOUS IoT-NGIN ASSIST-IoT VEDLIoT INTELLIOT TERMINET			
5G-ACIA	INGENIOUS ASSIST-IoT VEDLIoT TERMINET			IoT-NGIN INTELLIOT
5G-IA	IoT-NGIN VEDLIoT TERMINET		ASSIST-IoT	INGENIOUS INTELLIOT
AIOTI	INGENIOUS TERMINET	VEDLIoT	IoT-NGIN INTELLIOT	ASSIST-IoT
BDVA	INGENIOUS TERMINET INTELLIOT	VEDLIoT		IoT-NGIN ASSIST-IoT
Gaia-X	INGENIOUS VEDLIoT TERMINET		INTELLIOT	IoT-NGIN ASSIST-IoT
Other	INTELLIOT TERMINET		IoT-NGIN INGENIOUS ASSIST-IoT	VEDLIoT

For **SDO contributions** (rf. to Table 19), most projects provided contributions to SDOs. For instance, ASSIST-IoT is showing a high level of contributions towards relevant SDOs such as IEEE, ETSI, BDVA/DAIRO, and the other projects TERMINET, INGENIOUS, INTELLIOT, IoT-NGIN, VEDLIoT contributing also to specific SDOs.

Table 19: SDO contributions impact assessment.

SDO	0 (low activity)	1	2	3
IEEE	INGENIOUS IoT-NGIN VEDLIoT TERMINET		INTELLIOT	ASSIST-IoT
IETF	INGENIOUS ASSIST-IoT IoT-NGIN VEDLIoT INTELLIOT		TERMINET	
ISO	INGENIOUS ASSIST-IoT IoT-NGIN VEDLIoT INTELLIOT		TERMINET	
ITU-T	INGENIOUS IoT-NGIN VEDLIoT INTELLIOT TERMINET			ASSIST-IoT
IEC	INGENIOUS ASSIST-IoT IoT-NGIN VEDLIoT INTELLIOT	TERMINET		
OASIS	INGENIOUS ASSIST-IoT IoT-NGIN VEDLIoT INTELLIOT TERMINET			
W3C/WoT	INGENIOUS ASSIST-IoT IoT-NGIN VEDLIoT		TERMINET INTELLIOT	

SDO	0 (low activity)	1	2	3
3GPPP	ASSIST-IoT VEDLIoT TERMINET		INGENIOUS INTELLIOT	IoT-NGIN
CENELEC	INGENIOUS ASSIST-IoT IoT-NGIN VEDLIoT INTELLIOT TERMINET			
ETSI	INGENIOUS VEDLIOT		IoT-NGIN TERMINET INTELLIOT	ASSIST-IoT
IRTF	INGENIOUS ASSIST-IoT VEDLIoT INTELLIOT TERMINET			
5G-ACIA	INGENIOUS ASSIST-IoT VEDLIoT TERMINET	IoT-NGIN		INTELLIOT
5G-IA	INGENIOUS ASSIST-IoT IoT-NGIN VEDLIoT TERMINET			INTELLIOT
AIOTI	INGENIOUS IoT-NGIN VEDLIoT TERMINET	INTELLIOT		ASSIST-IoT
BDVA	INGENIOUS IoT-NGIN VEDLIoT INTELLIOT TERMINET			ASSIST-IoT

SDO	0 (low activity)	1	2	3
Gaia-X	INGENIOUS ASSIST-IoT IoT-NGIN VEDLIoT INTELLIOT TERMINET			
Other WIRELESS WORLD RESEARCH FORUM (WWRF)	INGENIOUS INTELLIOT	IoT-NGIN	ASSIST-IoT VEDLIoT TERMINET	

As shown in Figure 11, most projects are actively monitoring relevant SDOs such as IEEE, IETF, ITU-T. ETSI, ISO, CEN-CENELEC.

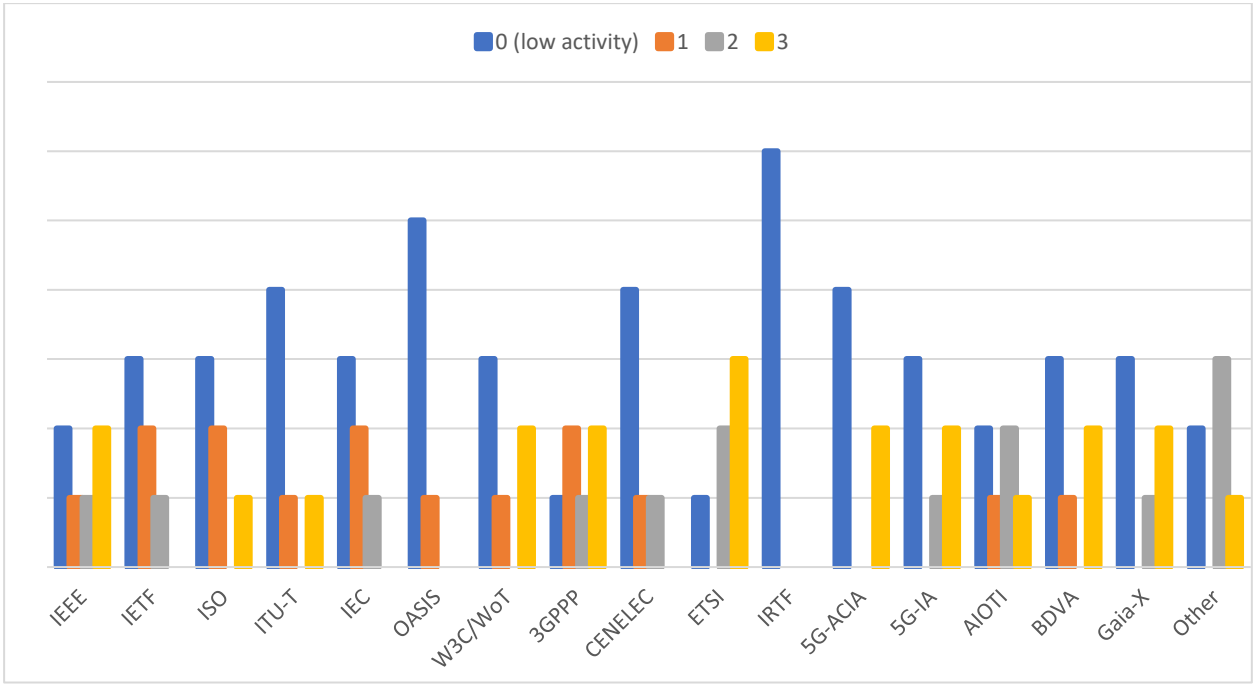

Figure 11 : Monitoring contributions towards key SDOs, by ICT-56 projects

In what concerns contributions to SDOs, Figure 12 provides aggregate results across a relevant set of SDOs. A good level of contributions (impact level 3) is being provided across most relevant SDOs, namely, IEEE, ISO, ITU-T, W3C/WoT, ETSI, etc.

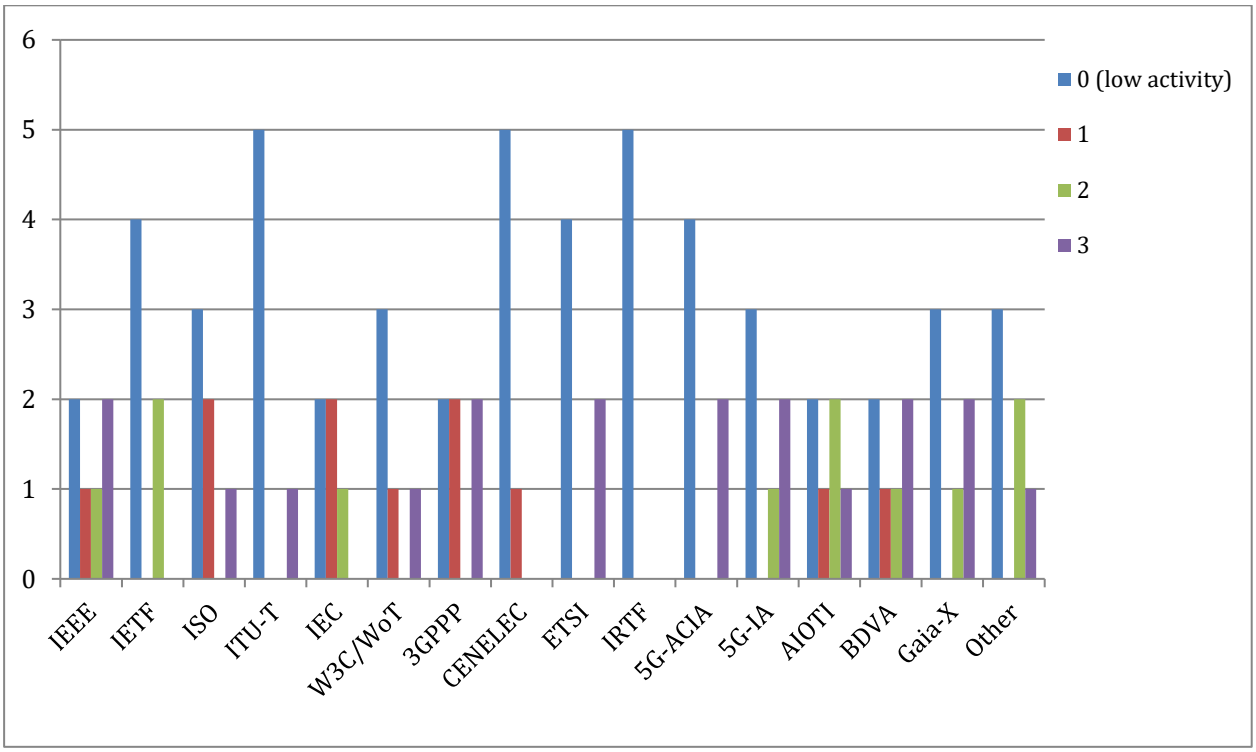

Figure 12: SDO contribution incidence by ICT-56 projects.

4.4 Open-Source Contributions

Table 20 provides an overview of the projects' open-source contributions. Three projects have open repositories via GitLab, Docker Hub, or GitHub. Then, ASSIST-IoT has a private repository, and TERMINET is also developing a software repository, not public but published open-access datasets in IEEE Dataport and Zenodo[8]. The licensing (open, open source) has not yet been clearly defined, apart from the assets developed by VEDLIoT. In addition, projects such as INGENIOUS and VEDLIoT are also providing open hardware solutions.

In terms of repositories, there is some fragmentation which may hinder impact and dissemination. Specifically, most projects have individual repositories related to each asset under the git of a partner, or multiple partners. IoT-NGIN has opted to create an open repository common to the project. A suggestion would be to follow this approach: individual partners can work on their own assets, and later push to the main, common repository of the project.

Table 20: OSS contributions by ICT-56 RIAs.

Project	Repository/Asset(s)	URL
IoT-NGIN	• GitLab • Docker Hub	• https://gitlab.com/h2020-iot-ngin • https://hub.docker.com/u/iotngin
INGENIOUS	• Software: M3 operating system • Hardware: Trusted Communication Unit (TCU), Network-on-Chip	• https://github.com/Barkhausen-Institut/M3 • https://github.com/Barkhausen-Institut/M3-hardware

[8] IEEE Dataport, September 28, 2022, doi: https://dx.doi.org/10.21227/ehfm-9j20, andIEEE Dataport, doi: https://dx.doi.org/10.21227/w67n-0q72 .

Project	Repository/Asset(s)	URL
	(NoC)	
ASSIST-IoT	Not public	• https://assist-iot-enablersdocumentation.readthedocs.io/en/latest/index.html
TERMINET	Under development, not public	-
VEDLIoT	• Renode • Kenning • Twine: An Embedded Trusted Runtime for WebAssembly • PMP: Cost-Effective Forced Execution with Probabilistic Memory Pre-Planning • Gradsec • Renode-verilator-integration • Sire • WaTZ	• https://github.com/antmicro/renode-verilator-integration • https://github.com/antmicro/kenning • https://github.com/JamesMenetrey/unine-twine • https://github.com/JamesMenetrey/unine-watz • https://github.com/lindemer/pmp • https://github.com/aghiles-ait/Static_GradSec/tree/master • https://github.com/antmicro/renode-verilator-integration/ https://vedliot.eu/open-source-software/renode-verilator-integration/ • https://github.com/tiagorncarvalho/SIRE • https://vedliot.eu/open-source-software/watz/
INTELLIOT	• Hypermedia Multi-agent System (HyperMAS) that manages available artifacts and agents along with available procedural knowledge (i.e., agent plans). - HyperMAS - Examples of thing descriptions (TDs). • 5G Technology – OpenAirInterface (https://openairinterface.org/) technology based on the OpenAirInterface Software Alliance (OSA) license (like Apache 2.0) - 5G RAN. - 5G Core - Mosaic5G • IAKM – A repository for AI models (Apache 2.0 license)	• https://github.com/Interactions-HSG/yggdrasil • https://github.com/Interactions-HSG/example-tds • https://gitlab.eurecom.fr/oai/openairinterface5g/ • https://gitlab.eurecom.fr/oai/cn5g • https://gitlab.eurecom.fr/mosaic5g • https://gitlab.eurecom.fr/intelliot/iakm

4.5 Open Calls

The overall analysis of open calls is, in EU-IoT, coordinated by WP2. The numbers collected and presented in this section aim at providing a summarized quantitative perspective of the overall outreach and benefits that open calls have had so far for the ICT-56 projects.

Out of the six projects, all have open calls, except for INGENIOUS. Therefore, Table 21 summarizes the analysed items for all projects, except INGENIOUS. In addition, two projects have two open calls, VEDLIoT and IoT-NGIN. The KPIs in the table, therefore, provide an aggregate perspective, to assess the overall impact of the open calls, independently of the number of run open calls. However, we also highlight that the two second calls of VEDLIoT and IoT-NGIN are still open.

The open calls have been defined and counted in all projects with most project partners, an aspect that is relevant to ensure adequate future exploitation of assets and better integration of services or other assets, derived from third parties running to the open calls.

Table 21: Quantitative perspective on open calls KPIs.

Item/Project	TERMINET	VEDLIoT	IoT-NGIN	INTELLIOT	ASSIST-IoT	Total
Call 1 details (dates)	01.08.2022-31.10.2023	01.03.2022-08.05.2022	1.10.2021 - 30.12.2021	01.09.2021 - 30.09.2022	01.07.2022-14.10.2022	
Call 2 details (dates)	24.11.2022 31.01.2023	01.07.2022 - 30.06.2023	01.07.2022– 30.09.2022	01.10.2022 - 31.08.2023	01.09.2022-15.01.2023	
Number of involved partners	5	0	12	13	15	45
Number of involved components/products/services	0	7	22	19	40	88
Number of users experimenting the project solutions via open calls (entities)	0	12	15	20	20	67
Number of projects that expressed interest in the open calls.	0	30	95	370	70	565
Number of selected projects	0	10	15	10	7	42
Number of active projects	0	10	15	4	7	36
Total cascading funding (EU and percentage of budget)	400,000 Euros. 5%	840,000 Euros, 10.5%	750,000 Euros, (1st Open Call; 450,000 expected via the 2nd Open Call), 15% in total for both	860,000 Euros, 11%	900.000 Euros, 11.38%	
Sub-Projects						
New applications	0	10	5	6	7	28

Item/Project	TERMINET	VEDLIoT	IoT-NGIN	INTELLIOT	ASSIST-IoT	Total
Testing and validation of components or services	0	8	5	4	7	24
Usability of components or services	0	8	0	0	7	15
Skills training of components or services	0	0	0	0	-	0

4.6 Selected Asset as Best Contribution Towards Standardization

Table 22 provides a description of one relevant asset of the ICT-56 projects' effort as an example to highlight their specific contributions towards SDOs. Two projects, ASSIST-IoT and VEDLIoT, have been developing interesting standards that are already released. TERMINET, IoT-NGIN, IntellIoT, and INGENIOUS are also concretizing their efforts by developing other standards that consider the usability of the component or the service and that will be available soon.

Table 22: Selected RIA asset as best contribution towards SDO.

Item	TERMINET	VEDLIoT	IoT-NGIN	INGENIOUS	INTELLIOT	ASSIST-IoT
Name	TERMINET AGROMIND Dashboard	COM-HPC standard	5G-API for device management	5G Cellular IoT (CIoT) modem/chipset (features related to device reduced capability and satellite connectivity)	W3C WoT Working Group	Test methods for evaluation of the cognitive load resulting from implementation of smart textile systems based on innovative NGIoT architecture (ASSIST-IoT)
The contribution status: **- Under development**	Under development	Released, working on new spec revisions	Under development		Under development	Proposal of technical standard or technical specification submitted
- Already developed but not yet being exploited						
					Use Case related specifications	
- Being exploited						
Contribution detail **(Name of the organization, IEEE, IETF, etc)**	IEE, ISO 9001: 2008	PICMG	Ericsson based 3 contributions to 3GPP on the work of the IoT-NGIN project on this subject. All 3 contributions were accepted.	~20 contributions in RAN, RAN1 and RAN2 working groups of 3GPP	https://www.w3.org/TR/wot-usecases	CEN/TC248/WG 31
Usability of the component or service	The AGROMIND Dashboard is an advanced Data visualization dashboard this is intricately designed to aid the producer	Standard available, Module design guide available	Open published standards for this API are now available	enables low-cost (RedCap part) IoT devices to connect to internet through cellular networks and enables a wide range of IoT applications to be deployed in various locations and environments (NTN part)	5G MEC	

Item	TERMINET	VEDLIoT	IoT-NGIN	INGENIOUS	INTELLIOT	ASSIST-IoT
	keep track of field operations and status of their infrastructure while helping them achieve their production goals					
Open assets: **- open software** **- open hardware** **- License**				none (it will be internal proprietary product solution)		Methodology and tests Associated technological recommendation
	Commercial					
Other			Open standards			

5 BUSINESS EXPLOITATION ASSESSMENT

This section provides an overview on the ICT-56 projects' business exploitation status. For that, the section integrates a qualitative and a quantitative perspective.

5.1 Qualitative Analysis

To best characterize the status of the projects' business exploitation activities, all projects have been asked to provide information for a qualitative business impact analysis based on different indicators. Results are provided in Table 23. Each of the proposed features has been weighted on a scale of 1 (low impact) to 5 (high impact) regarding business exploitation.

As shown, most projects have characterized each of the features with a value between 3-4, which shows that the potential activities for business exploitation are on the right track.

Three projects (TERMINET, INTELLIOT, ASSIST-IoT) have also rated several features with high impact, namely, market innovation level, openness, trustworthiness, and interoperability.

Summarizing:

- Openness is a relevant criterion to all projects, while greenness has been rated lower.
- Overall good potential for business exploitation.
- Openness, and interoperability, rated as highly relevant across all projects.
- Greenness ranked with less relevance across all projects – should be addressed.
- 5 projects exhibit high levels of innovation in comparison to competitors.
- The business plan is at an intermediate stage for 5 projects, and at an early stage for 1 project.

Table 23: Use-case and business exploitation, characterization.

Feature	1	2	3	4	5
Entry barriers (rate the level of entry barriers to the market for your offerings)		ASSIST-IoT	VEDLIoT IoT-NGIN INTELLIOT	TERMINET	
Market innovation level (rate the level of innovation in comparison to competitors)			IoT-NGIN	TERMINET VEDLIoT INTELLIOT	ASSIST-IoT
Openness (rate the current level of accessibility for external users)			INGENIOUS	TERMINET VEDLIoT IoT-NGIN ASSIST-IoT	INTELLIOT
Greenness (rate the current level of accessibility for external users)	INTELLIOT	INGENIOUS	TERMINET IoT-NGIN ASSIST-IoT	VEDLIoT	

Feature	1	2	3	4	5
Business plan readiness (rate the level of the business plan readiness)	INGENIOUS		TERMINET VEDLIoT IoT-NGIN INTELLIOT	ASSIST-IoT	
Trustability and security (rate the level of security of the offered services)				VEDLIoT IoT-NGIN	TERMINET INTELLIOT ASSIST-IoT
Governance model replicability (rate the level of customization of the proposed governance model for exploitation of results)			TERMINET VEDLIoT IoT-NGIN		ASSIST-IoT
Interoperability (rate the level of adoption of open standards and open solutions)				VEDLIoT IoT-NGIN INTELLIOT INGENIOUS	TERMINET ASSIST-IoT
Other					

5.2 Quantitative Analysis

5.2.1 Expected Time-to-Market

The projects have been asked to characterize different aspects. Starting by the expected time-to-market (rf. To Table 24), most projects (4) expect to take between 1 and 3 years for most products to enter the market, thus showing interest in a fast entry. This will require adequate viability analysis and concrete business models to exploit the different products and to allow them to enter the market in a reasonable and reachable period.

Table 24: Expected time-to-market.

Feature	Project	Comments
Less than 1 year	INGENIOUS	• **INGENIOUS**: Less than 1 year for 5G-Rel 15 modem including the extended functionalities (2021) and 5G-core including extended functionalities (2022). End-to-end network slice management function (2022). Further details can be found in INGENIOUS D2.1 use-cases, KPI and requirements
Between 1 and 3 years	TERMINET VEDLIoT INGENIOUS ASSIST-IoT	• **TERMINET**: Some components are expected to reach the market earlier having high TRL. The TERMINET platform is expected to reach the marketing 2-3 years. • **VEDLIoT**: Between 1 and 3 years. 3 years for smart home, 2 years for industrial and automotive use-cases. • **INGENIOUS**: Between 1 and 3 years for low-power ML-enabled sensors (2023), haptic gloves including extended functionalities (2022), Consumer IoT modem/chipset solutions (2023). Rf. to

Feature	Project	Comments
		INGENIOUS D2.1. • **ASSIST-IoT:** Between 1 and 3 years. At maximum 1 year after the end of the project, but it is expected that partners and third parties include results of the project in their portfolio before this date.
Over 3 years	IoT-NGIN INTELLIOT	• IoT-NGIN Expected time to market between 3-5 years after the end of the project, given that it is a RIA and most services are targeted to reach TRL 5 • **INTELLIOT**: over 3 vertical domains

5.2.2 Expected Benefits, Indicative Distribution Rate

As a next step, the projects provided an average characterization of the distribution rate for the expected benefits of their overall products, which is presented in Table 25.

On average, the greatest benefits proposed by the projects relate to stakeholder integration and with cost reduction, closely followed by better performance. Increased social sustainability, or increased environmental sustainability, is not as significant.

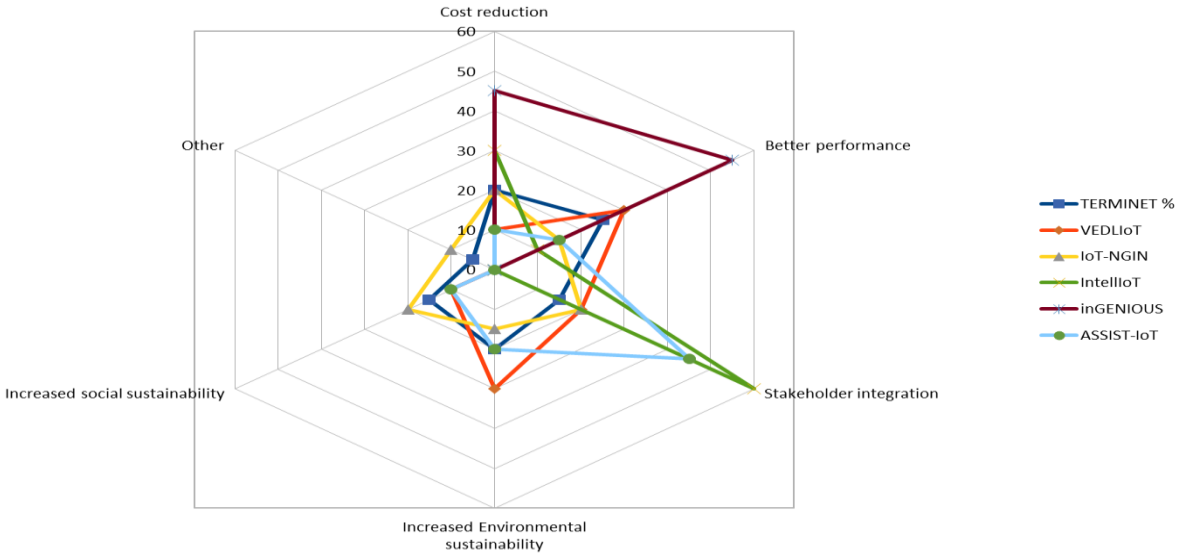

Figure 13: Indicative and relative distribution of benefits per project.

Table 25: distribution rate for expected benefits (cost reduction, better performance, improved sustainability, improved quality of life).

Item%	TERMINET	VEDLIoT	IoT-NGIN	INTELLIOT	INGENIOUS	ASSIST-IoT
Cost reduction	20	10	20	30	45	10
Better performance	25	30	15	10	55	15
Stakeholder integration	15	20	20	60	0	45
Increased Environmental sustainability	20	30	15	0	0	20
Increased social	15	10	20	0	0	10

Item%	TERMINET	VEDLIoT	IoT-NGIN	INTELLIOT	INGENIOUS	ASSIST-IoT
sustainability						
Other	5	0	10	0	0	-

5.2.3 Expected Assets, Quantitative Characterization

The expected projects per project are provided in Table 26. Three projects expect to provide many assets (over 10), while 2 expect between 5 and 10 assets. In addition, one project (INTELLIOT) integrates a less fragmented approach, proposing one framework with multiple components.

Projects with many expected assets risk fragmentation in terms of business exploitation potential and should therefore consider business models that could assist in a faster integration of many potential products.

Table 26: Number of expected products per project.

Expected nr of assets	Project	Comments
Less than 5	INTELLIOT	**INTELLIOT:** one framework with multiple components.
Between 5 and 10	VEDLIoT	**VEDLIoT:** Average number across the different use-cases
	INGENIOUS	**INGENIOUS:** 5G-Rel 15 modem including the extended functionalities (2021) and 5G-core including extended functionalities (2022). End-to-end network slice management function (2022). low-power ML-enabled sensors (2023), haptic gloves including extended functionalities (2022), CIoT modem/chipset solutions (2023). Further details can be found in INGENIOUS D2.1 use-cases, KPI and requirements.
More than 10	TERMINET	**TERMINET:** expected more than twenty products from the project (EI01 to EI23) such as Vertical Application Orchestrator, TERMINET SDN Controller & Dashboard, FINoT Platform, and New Generation of RTU devices.
	IoT-NGIN	**IoT-NGIN**: Based on our Key Exploitable Results (KERs)
	ASSIST-IoT	**ASSIST-IoT**: D9.6 provides the description of the 15 innovation elements identified at M18 and which the consortium expects to become offerings at the current date.

5.2.4 Competitor Characterization

Table 27 reflects the competitor characterization provided per project. Four projects signal having more than 7 competitors (indicative average across all products). RIAs such as ASSIST-IoT have already developed a full competition characterization. Moreover, other projects like INGENIOUS and VEDLIoT have an interesting analysis of competitors between 3 and 7. Therefore, an adequate characterization of competition is relevant to ensure a low time-to-market, for projects that are proposing many assets.

Table 27: Qualitative characterization of competitors across all projects.

Competitors	Project	Comments
None		
Less than 3		
Between 3 and 7	INGENIOUS	
	VEDLIoT	• **VEDLIoT**: averaged number across all products

Competitors	Project	Comments
More than 7	TERMINET IoT-NGIN INTELLIOT ASSIST-IoT	• **TERMINET**: There is a lot of competition in IoT platforms the most known competitors are the following: AWS IoT, Microsoft Azure, Oracle IoT, Google Cloud Platform, IBM Watson, Cisco IoT Cloud connect, Particle, Thinkworx, and Salesforce IoT Cloud • **IoT-NGIN:** Based on our Key Exploitable Results (more than 10), competitors are expected to be more in total. • **INTELLIOT**: multiple domains • **ASSIST-IoT**: D9.6 includes the description the 15 innovation elements identified at M18 and which the consortium expects to become offerings at this moment. More refinement is being performed and will be published at the end of the project resulting from spin-in innovation activities and the fine-tuning of Key Exploitable Results of the project.

5.2.5 Technology Readiness Level of Services/Assets

To achieve an adequate time-to-market, and to ensure a successful business exploitation it is relevant to understand the current maturity level of assets being developed. For this purpose, projects have also provided an initial insight into the current TRL levels of their assets, as detailed Table 28. At the current stage, it is not possible to provide a comparison across all RIAs, as some RIAs have provided concrete numbers, and others have provided relative numbers.

However, it can be seen also that projects such as TERMINET and INTELLIOT have already a clearer positioning in terms of expected technology maturity, in comparison to the other ICT-56 projects.

Table 28: Current TRL levels.

TRL	TERMINET	VEDLIoT	IoT-NGIN	INTELLIOT	INGENIOUS	ASSIST-IoT
2-3	0		Current for 50% of the KERs	2		
4	4 (GDPR Data protection mechanism, RINA-enabled IoT device, RF Energy Harvesting Prototype System, Attestation Gateway (AG))		Current for 50% of the KERs, targeted for 20% of the KERs	3		Targeted for 20% of the KERs
5	6(RINA-enabled IoT gateway, SDN-enabled container network interface, TECN DASO/BROKEL Securing Data Sovereignty and		Targeted for 75% of the KERs	10	1 (TrustOS)	Targeted for 80% of the KERs

TRL	TERMINET	VEDLIoT	IoT-NGIN	INTELLIOT	INGENIOUS	ASSIST-IoT
	Governance tool, Healthentia app theming, POLIcy MONitor (POLIMON), IoT Digital Twin Environment and Prediction Models)					
6	9 (Centralised Federated Learning System, FINT's Edge Accelerating Infrastructure, Secure, distributed, and trusted data sharing framework (DSF), Analytic Toolset for Forecasting (ATF), Secure, distributed, and trusted data sharing framework, TERMINET AGROMIND Dashboard, TERMINET SDN Controller & Dashboard, Bootstrapping Trust, and Integrity Measurement Tool (BIM), Intelligent Intrusion Detection System)	6 (DL accelerators for IoT, FPGA-based RISC-V system and accelerators, SecureCognitive IoT platform, Cognitive IoT microserver, Smart home use case, Automotive AI use case IoT)	Targeted for 5% of the KERs	6	1 (Smart IoT)	
7	8 (Vertical Application Orchestrator, Financial Modelling Toolset, Healthentia Clinical Dashboard, New Generation of RTU devices, IoT communication interface, Data composer, FINoT Platform)	3 (Secure IoT Gateway, VEDLIoT toolchain, Industrial IoT use case)		1	1 (5GC)	
8	Vertical Application Orchestrator, Financial Modelling Toolset, Healthentia Clinical Dashboard, New Generation of RTU devices, IoT communication	-	-	-	-	-

TRL	TERMINET	VEDLIoT	IoT-NGIN	INTELLIOT	INGENIOUS	ASSIST-IoT
	interface, Local Data Conector (LDC), FINoT Platform, Local Data Conector (LDC)					
9	1 : Smart glasses	-	-	-	-	-

5.2.6 Overall Cost Distribution Estimation

A final input requested to the ICT-56 RIAs was to provide an estimate for the overall cost distribution rates of expected services/products assuming the first three years of exploitation beyond the project lifetime. This estimation is currently provided as indicative as it reflects a high-level, aggregate perspective. For the next deliverable, such an estimate would require an analysis per project. The numbers provided are detailed in Table 29 and in Figure 14. Most costs are estimated to fall into personnel and infrastructure costs.

Table 29: Estimated and aggregate cost distribution rates of services/assets, assuming the first 3 years of exploitation beyond the project.

Item	TERMINET	VEDLIoT	IoT-NGIN	INTELLIOT	INGENIOUS	ASSIST-IoT
Personnel costs	55	20	30	90	80	70
Logistics costs	10	10	10	2	0	10
Infrastructure costs	15	60	50	8	3	15
Others	20	10	10	0	17	5

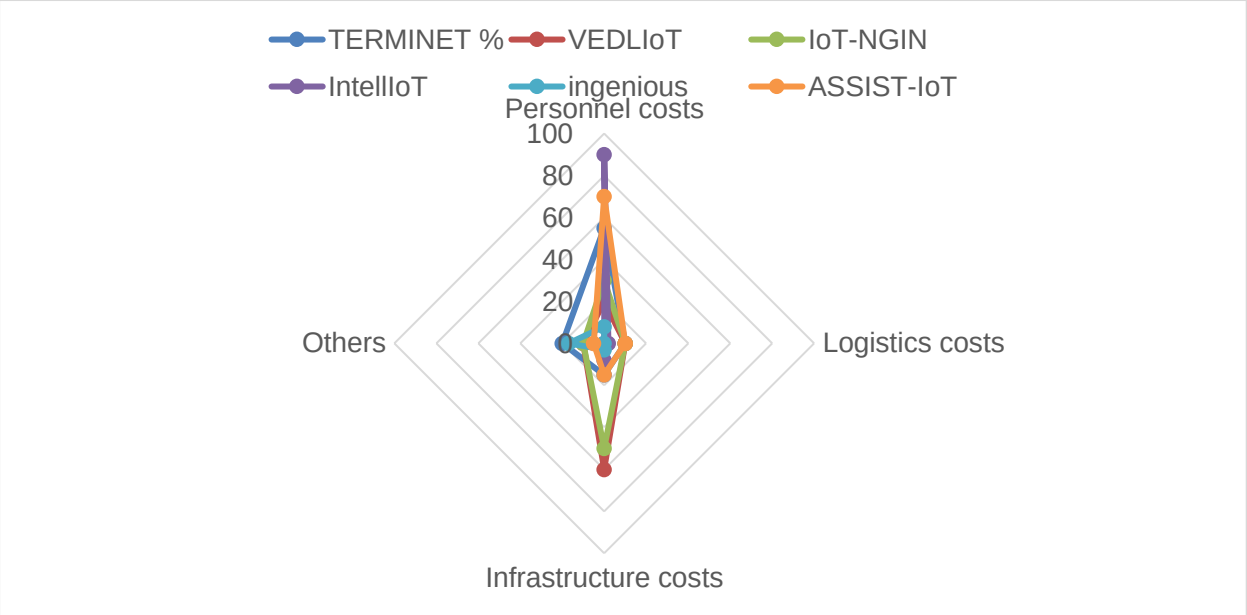

Figure 14:Estimated and indicative cost distribution perspective beyond the project lifetime.

5.3 Selected Best Assets

To provide a better vision of the main outcomes of the ICT-56 RIAs, they were asked to select

one asset as example. The tangible products, innovation that the ICT-56 projects produced, such as software application, services, research reports, a new product, innovation. Overall, highly relevant contributions have been signalled across all the ICT-56 RIAs, as summarized in Table 30.

Table 30: Selected best assets per ICT-56 RIA.s

TERMINET	ASSIST-IoT	IoT-NGIN	INGENIOUS	IntelliIoT	VEDLIoT
TERMINET AR-assisted end-to-end smart precision and smart animal monitoring platform	ASSIST-IoT architecture, which is a combination of methodology, guidelines, technologies selection, installation scripts and deployment instructions and recommendations.	5G resource management API	Solution for the interoperability in IoT domain (Data Virtualization Layer)	Semi-autonomous agricultural vehicle	The ARC detection use case of VEDLIoT partner Siemens

5.3.1 Features

This section provides input related to the main contributions of the projects to characterize the selected asset as most relevant examples as illustrated in Table 31, where each proposed aspect has been weighted on a scale of 1 (low relevant) to 5 (high relevant).

For instance, VEDLIoT and ASSIT-IoT proposed highly new and innovative assets, while TERMINET and INTELLIOT are proposing significantly improved assets. INGENIOUS is also considering a significantly improved asset. IoT-NGIN is providing a new service.

Table 31: Main characteristics of the selected assets.

Characteristics	1	2	3	4	5
Significantly improved product				INTELLIOT	VEDLIoT ASSIST-IoT INGENIOUS
Significantly improved service (except consulting services)		VEDLIoT		INTELLIOT	ASSIST-IoT
Significantly improved process			VEDLIoT	INTELLIOT	ASSIST-IoT
Significantly improved marketing method	VEDLIoT INTELLIOT	ASSIST-IoT			
Significantly improved organisational method	VEDLIoT INTELLIOT				ASSIST-IoT
New product			INTELLIOT	TERMINET	VEDLIoT ASSIST-IoT
New service (except consulting services)		VEDLIoT	INTELLIOT ASSIST-IoT	IoT-NGIN	

New process	INTELLIOT		VEDLIoT		ASSIST-IoT
Other				INTELLIOT	

5.3.2 Exploitation Aspects

RIAs have been asked about the type of exploitation of the asset, i.e., whether the RIA was expecting to go to commercial exploitation or exploiting the asset within the consortium. Table 32 summarizes the answers provided. Several projects are considering already commercial exploitation, while two projects are considering individual exploitation.

Table 32: Exploitation features relevant for the projects in the context of the selected asset exploitation.

Type of exploitation	TERMINET	VEDLIoT	IoT-NGIN	INTELLIOT	INGENIOUS	ASSIST-IoT
Introduced as new to the market (commercial exploitation)	X	X	X			X
Only deployed as new to the organisation/company (new internal processes implemented, etc.)					X	X
No exploitation planned						
If 'no exploitation planned' is selected, explain why not:						

5.3.3 Market Introduction Steps

Table 33 provides information concerning the selected asset introduction in the market, i.e., stages that are being considered by ICT-56 RIAs to bring the selected asset closer to a market stage.

As can be seen in Table 33 most ICT-56 RIAs have already developed the following steps: technology transfer; have business units involved and engaged with the asset introduction in the market; have developed market studies and prototypes. Several projects plan to validate prototypes in real environments.

In terms of spinning-off, TERMINET has launched a spin-off derived from the results of the project. Licensing models are also being considered by different projects. More complex aspects such as raising capital are also considered by 2 RIAs (TERMINET, INTELLIOT). Finally, all RIAs have plans to develop business models.

Table 33: Steps taken concerning the introduction of selected assets to the market.

Step taken	Done or ongoing	Planned	Not planned but needed or desirable	Not planned and not needed
Technology transfer	TERMINET VEDLIoT ASSIST-IoT IoT-NGIN INGENIOUS INTELLIOT			
A partner's research team and business units are both engaged in activities relating to this innovation	TERMINET ASSIST-IoT IoT-NGIN INGENIOUS	VEDLIoT	INTELLIOT	
Market study	VEDLIoT ASSIST-IoT INGENIOUS	TERMINET IoT-NGIN	INTELLIOT	
Prototyping in laboratory environment	TERMINET VEDLIoT ASSIST-IoT IoT-NGIN INGENIOUS INTELLIOT			
Prototyping in real world environment	IoT-NGIN	VEDLIoT ASSIST-IoT INGENIOUS INTELLIOT		
Pilot, Demonstration or Testing activities	TERMINET VEDLIoT ASSIST-IoT IoT-NGIN INGENIOUS		INTELLIOT	
Feasibility study	VEDLIoT IoT-NGIN INGENIOUS	TERMINET	ASSIST-IoT INTELLIOT	
Launch a start-up or spin-off	TERMINET			VEDLIoT IoT-NGIN INGENIOUS INTELLIOT

Step taken	Done or ongoing	Planned	Not planned but needed or desirable	Not planned and not needed
Licensing the innovation to a 3rd party	TERMINET INTELLIOT			VEDLIoT IoT-NGIN INGENIOUS
Complying with existing standards	IoT-NGIN INGENIOUS INTELLIOT	TERMINET VEDLIoT		
Contribution to standards	INTELLIOT	TERMINET VEDLIoT IoT-NGIN		INGENIOUS
Raise capital		TERMINET INTELLIOT	VEDLIoT	INGENIOUS
Raise funding from public sources			TERMINET VEDLIoT IoT-NGIN INTELLIOT	
Business Plan		TERMINET VEDLIoT IoT-NGIN INTELLIOT	INGENIOUS	

5.3.4 Greenness Aspects

Greenness is an important concern to promote environmental sustainability and reduce environmental impact, which is in line with the EU SDGs. To this end, ICT-56 RIAs were asked whether their assets were addressing climate mitigation and climate adaptation aspects. Table 34 provides a summary of the input collected from the ICT-56 RIAs.

For example, VEDLIoT considers energy efficiency as the focus of the hardware and toolchain. TERMINET is providing advice, and suggestions for good practices and climate change forecasts and considers carbon capture and storage management per producer and per production zone. INTELLIoT is proposing an electrified tractor that reduces the CO2 footprint during operation when used in the agriculture domain.

Table 34: The greenness aspects considered by ICT-56 projects.

Aspect	RIA	Comment
Climate Mitigation potential	VEDLIoT	Energy-efficiency is a key point for VEDLIoT, and a focus of the hardware and toolchain. The ARC detection use-case benefits from this, as the resulting product is designed in a low-power fashion.
	INTELLIOT	In the agriculture domain the electrified tractor reduces the CO2 footprint during operation.
	TERMINET	Providing advice, suggestions, suggestions of good practices and climate change forecasts
Not applicable for	IoT-NGIN	Not for the innovation explained and proposed as example

this innovation	INGENIOUS	-
Adaptation potential	ASSIT-IoT	Making process more efficient
	IoT-NGIN	For another UC of IoT-NGIN
	TERMINET	Carbon capture and storage management per producer and per production zone

6 HIGHLIGHTS ON PROJECT CONTRIBUTIONS

6.1 Selected Scientific Contributions

The projects have been asked to propose their 3-5 key R&D contributions, e.g., scientific papers or other forms of scientific output which are listed in Table 35, with the purpose of better summarizing the current scientific outcome of projects. As can be seen, the contributions are well aligned with the goals established for each project (rf. to section 3.1).

- IoT-NGIN key contributions show that the project is providing relevant input towards IoT Edge-Cloud architectures, considering cybersecurity and ML integration aspects.
- INGENIOUS key contributions show the relevant input being provided towards hardware integration aspects, including but not limited to acceleration and secure execution in Edge environments.
- ASSIST-IoT cites 5 key contributions related with self-organization and self-healing for autonomic IoT ecosystems. ASSIST-IoT also provides significant contributions toward cybersecurity.
- TERMINET cites valuable contributions towards orchestration and federated learning integration across Edge-Cloud, considering energy awareness and security/data privacy aspects.
- VEDLIoT selected contributions to show the relevant output concerning the design analysis of very AI-intensive environments, and their articulation with a design that considers data security aspects, energy awareness, and hardware acceleration.
- INTELLIOT cites work that shows valuable input towards intelligent IoT ecosystems, integrating learning capability, trustworthiness, and privacy preservation.

Table 35: Selected scientific contributions.

Project	Selected Publications
IoT-NGIN	• Federated Learning IoT cybersecurity tools: St. Bourou, A. El Saer, T.-H. Velivassaki, A. Voulkidis, Th. Zahariadis, "A Review of Tabular Data Synthesis using GANs on an IDS Dataset. Information. 2021", Information 2021, 12, 375. https://doi.org/10.3390/info12090375 • Self-sovereign Identities for IoT: N. Fotiou, V. A. Siris, G. Polyzos, Y. Kortesniemi, D. Lagutin, "Capabilities-based access control for devices using Verifiable Credentials.SafeThings 2022: IEEE Workshop on the Internet of Safe Things.2022", SafeThings 2022: IEEE Workshop on the Internet of Safe Things.2022- 2nd Best Paper Award, https://safethings-2022.github.io/accepted_papers/safethings2022-final6.pdf • Enhancing Cyber Security in IoT Systems using FL-based IDS with Differential Privacy (https://ieeexplore.ieee.org/document/9936912) • Secure execution at the Edge: N. Eiling, J. Baude, S. Lankes, A. Monti, "Cricket: A virtualization layer for distributed execution of CUDA applications with checkpoint/restart support" Concurrency and computation 2021, DOI: 10.18154/RWTH-2021-06501 • IoT-NGIN in OSM Ecosystem Research: https://iot-ngin.eu/index.php/2022/05/11/iot-ngin-in-osm-ecosystem-research/
INGENIOUS	• M. Sigmund, R. Bomfin, M. Chafii, A. Nimr, G. Fettweis, “Iterative Receiver for Power-Domain Non-Orthogonal Multiple Access with Mixed Waveforms,” WCNC 2022: IEEE Wireless Communications & Networking Conference • L. Vilanova, L. Maudlej, S. Bergman, T. Miemietz, M. Hille, N. Asmussen, M. Roitzsch, H. Härtig, M. Silberstein, “Slashing the Disaggregation Tax in Heterogeneous Data Centers with FractOS,” Conference: EuroSys’22, October 2021 • N. Asmussen, S. Haas, C. Weinhold, T. Miemietz, M. Roitzsch, “Efficient and Scalable Core Multiplexing with M3v”, Conference: 27th ACM International Conference on Architectural Support for Programming Languages and Operating Systems (ASPLOS’22), August 2021 • N. H. Mahmood, S. Böcker, I. Moerman, O. A. López, A. Munari, K. Mikhaylov, F. Clazzer, H. Bartz, O.S. Park, E. Mercier, S. Saidi, D. Moya Osorio, R. Jäntti, R. Pragada, E. Annanperä, Y. Ma, C. Wietfeld, M. Andraud, G. Liva, Y. Chen, E. Garro, F. Burkhardt, C. F. Liu, H. Alves, Y. Sadi, M. Kelanti, J. B. Doré, E. Kim, J. S. Shin, G. Y. Park, S. K. Kim, C. Yoon, K. Anwar, P. Seppänen, “Machine type communications: key drivers and enablers

Project	Selected Publications
	towards the 6G era", EURASIP Journal on Wireless Communications and Networking, June 2021 • R. Bomfin, M. Chafii, A. Nimr, G. Fettweis, "A Robust Baseband Transceiver Design for Doubly-Dispersive Channels," IEEE Transaction on Wireless Communications, December 2020
ASSIST-IoT	• ASSIST-IoT: A Modular Implementation of a Reference Architecture for the Next Generation Internet of Things. Szmeja, P.; Fornés-Leal, A.; Lacalle, I.; Palau, C.E.; Ganzha, M.; Pawłowski, W.; Paprzycki, M.; Schabbink, J. Electronics 2023, 12, 854. DOI: 10.3390/electronics12040854. • Alejandro Fornés-Leal, Ignacio Lacalle, Carlos E. Palau, Paweł Szmeja, Maria Ganzha, "ASSIST-IoT: A Reference Architecture for Next Generation Internet of Things Proceedings of the 21st International Conference on New Trends in Intelligent Software Methodologies, Tools, and Techniques (SoMeT_22), ISBN 978-1-64368-317-1 (online), published by IOS Press BV, The Netherlands • Óscar López, Jordi Blasi, Mikel Uriarte, Ignacio Lacalle, Gonzalo Galiana, Carlos E. Palau, Eduardo Garro, Maria Ganzha, Marcin Paprzycki, Piotr Lewandowski, Katarzyna Wasielewska, Konstantinos Votis, Georgios Stavropoulos, Iordanis Papoutsoglou, "DevSecOps Methodology for NG-IoT Ecosystem Development Lifecycle – ASSIST-IoT perspective." Submitted to and published in: Journal of Computer Science and Cybernetics, DOI: https://doi.org/10.15625/1813-9663/37/3/16245. • Ignacio Lacalle, Cesar Lopez, Rafael Vano, Carlos E. Palau, Manuel Esteve, Maria Ganzha, Marcin Paprzycki, Pawel Szmeja, "Tactile Internet in Internet of Things Ecosystems" Published in International Conference on Paradigms of Communication, Computing and Data Sciences (PCCDS 2021) – DOI: 10.1007/978-981-19-1677-9_69. • Kumar Nalinaksh, Piotr Lewandowski, Maria Ganzha, Marcin Paprzycki, Wiesław Pawłowski, and Katarzyna Wasielewska-Michniewska, "Implementing autonomic Internet of Things ecosystems – practical considerations" (PDF). Submitted and published in Springer proceedings of 16th International Conference on Parallel Computing Technologies (PaCT-2021) – Online proceedings: https://link.springer.com/chapter/10.1007/978-3-030-86359-3_32
TERMINET	• D. Pliatsios, T. Lagkas, V. Argyriou, A. Sarigiannidis, D. Margounakis, T. Saoulidis, and P. Sarigiannidis, "A Hybrid RF-FSO Offloading Scheme for Autonomous Industrial Internet of Things," IEEE INFOCOM 2022 - IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), 2022, pp. 1-6, doi:10.1109/INFOCOMWKSHPS54753.2022.9798011. • A. Liatifis, P. Sarigiannidis, V. Argyriou, and T. Lagkas, "Advancing SDN: From OpenFlow to P4, a Survey," ACM Computing Surveys, Just Accepted, Aug. 2022. doi: 10.1145/3556973 • P. Diamantoulakis, P. Bouzinis, P. Sarigiannidis, Z. Ding and G. K. Karagiannidis, "Optimal Design and Orchestration of Mobile Edge Computing with Energy Awareness," IEEE Transactions on Sustainable Computing, vol.7, Apr.-Jun. 2022. doi: 10.1109/TSUSC.2021.3103476. • V. K. Papanikolaou, N. A. Mitsiou, P. D. Diamantoulakis, Z. Ding and G. K. Karagiannidis, "Hierarchical Multiple Access (HiMA) for Fog-RAN: Protocol Design and Resource Allocation," IEEE Transactions on Wireless Communications, vol. 21, no. 2, pp. 960-975, Feb. 2022, doi: 10.1109/TWC.2021.3100538. • D. Pliatsios, P. Sarigiannidis, T. Lagkas, V. Argyriou, A. -A. A. Boulogeorgos and P. Baziana, "Joint Wireless Resource and Computation Offloading Optimization for Energy Efficient Internet of Vehicles," IEEE Transactions on Green Communications and Networking, vol. 6, no. 3, pp. 1468-1480, Sep. 2022, doi: 10.1109/TGCN.2022.3189413.
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INTELLIOT	• A. Bröring, V. Kulkarni, A. Zirkler, P. Buschmann, K. Fysarakis, S. Mayer, B. Soret, L.D. Nguyen, P. Popovski, S. Samarakoon, M. Bennis, J. Härri, M. Rooker, G. Fritz, A. Bucur, G. Spanoudakis & S. Ioannidis (2022): IntellIoT: Intelligent IoT Environments. Global Internet of Things Summit (GIoTS 2022), 20.-23. June 2022, Dublin, IE. IEEE. • Soret, Beatriz, Lam D. Nguyen, Jan Seeger, Arne Bröring, Chaouki Ben Issaid, Sumudu Samarakoon, Anis El Gabli, Vivek Kulkarni, Mehdi Bennis, and Petar Popovski, "Learning, Computing, and Trustworthiness in Intelligent IoT Environments: Performance-Energy Tradeoffs," in IEEE Transactions on Green Communications and Networking, vol. 6, no. 1, pp. 629-644, March 2022, doi: 10.1109/TGCN.2021.3138792. • Nguyen, Lam Duc, Israel Leyva-Mayorga, Amari N. Lewis, and Petar Popovski. "Modeling and analysis of data trading on blockchain-based market in iot networks." IEEE Internet of Things Journal 8, no. 8 (2021): 6487-6497. • A. Elgabli, J. Park, C. B. Issaid, M. Bennis, "Harnessing Wireless Channels for Scalable and Privacy-Preserving Federated Learning," accepted for IEEE Transactions on Communications, 2021. • Siddartha Rachakonda, Shiva Moorthy, Anshul Jain, Aleksandr Bukharev, Anca Bucur, Francesca Manni, Thaise M. Quiterio, Lex Joosten and Nancy Irisarri Mendez, "Privacy enhancing and scalable federated learning to accelerate AI implementation in cross-silo and IoMT environments", IEEE Journal of Biomedical and Health Informatics.

6.2 Success Stories

In addition to the relevancy of the mentioned scientific output, RIAs have provided information on success stories related with the deployment of their use-cases and assets.

Further use cases of the ICT-56 RIAs, along with other frontrunners in the European IoT community, are documented as success stories and made available to the public in an online use case catalogue. The online use case catalogue can be accessed on the official website of EU-IoT / NGIoT[9].The EU-IoT use case catalogue gathers 30 IoT success stories that aim to inspire industry, innovators, IoT learners and policy makers by offering practical examples that lower the barriers for adoption of IoT technologies, eventually helping practitioners to understand how they can create the most optimal premises for themselves and for the ecosystem to succeed with IoT.

6.2.1 TERMINET

Figure 15: TERMINET AR-assisted smart precision platform.

A first innovation highlight concerns the **TERMINET AR-assisted end-to-end smart precision and smart animal monitoring platform** which includes an advanced data visualization dashboard that is intricately designed to aid the producer to keep track of field operations and status of their infrastructure while helping them achieve their production goals. This platform is utilized in TERMINET *UC1: User Centric Devices in Smart Farming*, aiming to provide a complete solution for Smart Animal Husbandry capable of monitoring different kinds of productive animals such as cows, sheep, goats, and horses in real-time.

The TERMINET AR-assisted end-to-end smart precision and smart animal monitoring platform

[9] https://www.ngiot.eu/use-cases/.

services include:

- Providing advice, suggestions, suggestions of good practices and climate change forecasts.
- Timely detection of abnormalities and diseases in real time.
- Real-time monitoring of arable land and agricultural land.
- Reduction of water used for irrigation.
- Reduction of fossil fuels used.
- Reduction of fertilizers used.
- Medicine cost reduction.
- Replacement of roughages for bovines.
- Measurement of distance travelled and grazing by each animal/welfare.
- The exact location of each animal using GPS.
- Physiology/ Zootechnical data of animals.
- Prediction of diseases based on real-time animal data & the movement pattern of each animal.
- Delineation of animals inside and outside virtual fences in real-time.
- Notification of theft or exit of animals outside virtual fences.
- Support real-time forecasts, warnings, and suggestions for changing weather conditions.

6.2.2 INGENIOUS

Figure 16: Pilot at the port of Valencia, INGENIOUS.

An **AI-based system for predicting port–city container traffic rates** is the success story of INGENIOUS.

A Cloud-based AI system was developed to predict vessel and truck traffic rates and turnaround times in sea ports. This capability is relevant e.g., for port and city traffic planning and hinterland logistics operators. The first components included in the solution are already offered as commercial services (TRL 8), while the system is deployed as an online demonstration (TRL 6) at the port of Valencia.

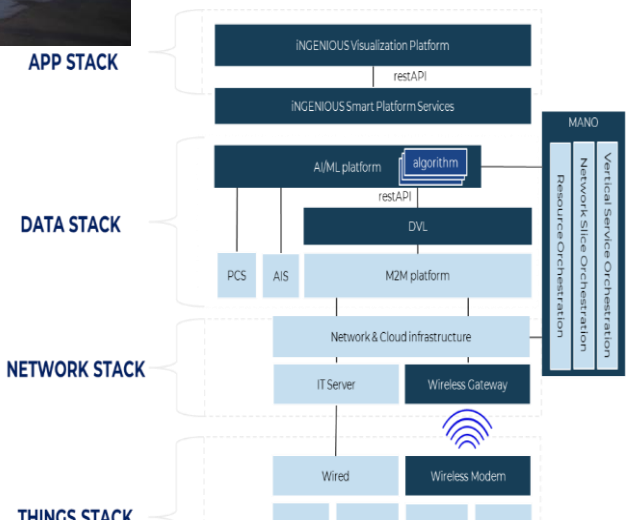


Figure 17: INGENIOUS AI-base system for predicting port-city container traffic rates.

The developed system (rf. to Figure 17) comprises multiple ML-based prediction modules using data from heterogeneous IoT and operations planning systems in the port ecosystem. As part of the development, C-based ML operations infrastructure and services were set up to allow scalable and automated machine learning model training, and data integration services were developed to allow online demonstration of the system.

The solution was integrated for demonstration as a Web application to a Cloud platform maintained by one of the project partners and is aimed to be piloted commercially using a *Software as a Service (SaaS)* licensing and delivery model after completion of the project.

6.2.3 IoT-NGIN

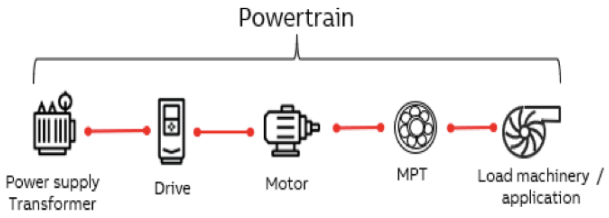


Figure 18: Digital powertrain concept in IoT-NGIN.

Digital powertrain and condition monitoring is another success story where the use case of an industrial partner is exploiting the contributions made by the IoT-NGIN project**.**

In the context of this use case, the term **powertrain** (rf. to Figure 18) is used to describe the equipment involved in transforming energy provided by a power source into useful work done by some machine. In industrial applications, such equipment typically includes an AC motor and a variable speed drive responsible for its control. Aside from direct process control, data gathered in such powertrain applications is also used for higher-level supervisory tasks and condition monitoring. The goal in this use case is to leverage IoT-devices, 4G telecommunication and Cloud platforms to utilize novel ideas in data engineering, analytics, and condition monitoring.

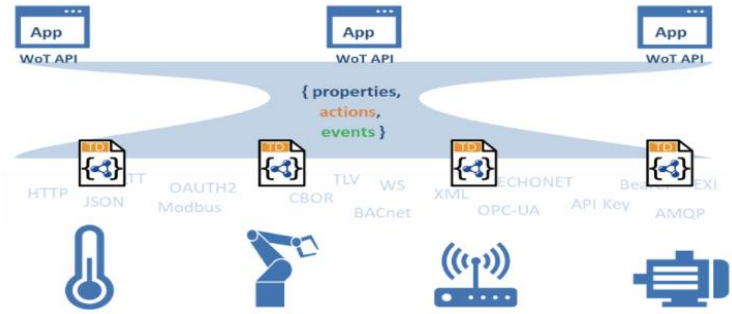


Figure 19: High-level design of the IoT-NGIN powertrain use-case components.

This UC uses technologies developed by IoT-NGIN which include: IoT device discovery and indexing (target TRL 5) and Semantic Twins (target TRL 5).

The use-case is still under development, and the following preliminary results have been obtained:

- Powertrains are measured by modified IoT-panels and several other sensors so that data can be gathered flexibly and utilized by IoT-NGIN components.
- A raspberry PI gateway device has been prepared, which can process and then forward data to IoT-NGIN components, avoiding integration problems down the line.
- An initial twin document has been prepared describing data endpoints of a powertrain ensemble using the W3C WoT model.
- A condition monitoring SW has been developed to collect and visualize data from powertrains.

6.2.4 ASSIST-IoT

ASSIST-IoT has selected as success story its **Gateway Enabler (GWEN)**.

The ASSIST-IoT GWEN is a universal gateway with a modular design. GWEN relies on Edge AI, i.e., it has computational power to operate AI algorithms at the Edge, memory physical network

interfaces, and Smart IoT device interfaces. GWEN is modular in the sense that a *system on module (SOM)* is used for the compute power which can be replaced by different versions with different memory sizes and different amount of CPU cores. An industry standardized SOM interface is used. This SOM is mounted at a carrier board. This carrier board has several fixed interfaces available, e.g., 1Gbps Ethernet, USB3, Wi-Fi 6, and 5G. Besides these fixed interfaces add-on modules can be plugged-in at the carrier board to implement dedicated interfaces, e.g., UWB for localization purposes. Linux is used as operating system with Docker as container runtime.

Key outcome is summarized as:

- Prototype that is being validated in three real-life pilots.
- HW design to replicate the board.
- Natively included software to support ASSIST-IoT enablers on top of it.

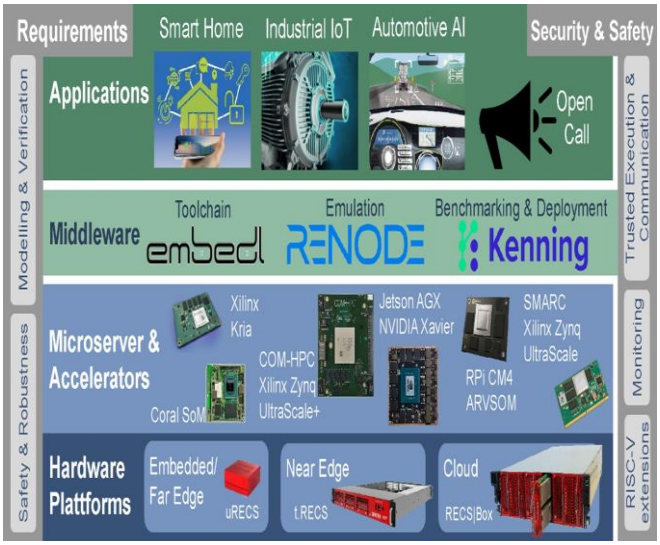
6.2.5 IntellIoT

Semi-autonomous agricultural vehicle (TRL 5-6) is one of the most relevant highlights for INTELLIoT.

The solution incorporates the human-in-the-loop in the intelligent IoT environment of a semi-autonomous agricultural vehicle, while improving safety, reliability, and security. Human intervention is then needed in uncertain situations, and it is especially valuable in the initial deployments of smart farming.

The INTELLIOT semi-autonomous agricultural vehicle system incorporates six software components from IntellIoT's focus areas, prototypes, and one demonstrator in the agricultural use-case. Most components, which includes software development, will be provided open source at the end of the project.

6.2.6 VEDLIoT



The **VEDLIoT hardware platform** (TRL 6) provides a modular, scalable hardware platform for heterogeneous computing on the cognitive compute continuum, from embedded via Edge to the Cloud. Unlike other solutions, it covers the complete spectrum of heterogeneous computing, integrating x86_64, ARM64, RISC-V, workstation and embedded GPUs, FPGA, and specialized accelerators in standardized computer-on-module form factors like COM-HPC. In addition, it integrates a sophisticated, multi-level communication and monitoring infrastructure. In this way, the VEDLIoT hardware platform can be used to provide a tailored hardware solution for a wide range of use cases, providing optimal performance and energy efficiency.

The platform is currently at a prototype level and is being used on VEDLIoT use-cases and open calls.

7 KEY TAKEWAYS AND RECOMMENDATIONS

Based on the conducted qualitative and quantitative impacts analysis carried out in coordination with the ICT-56 RIAs, a set of recommendations and guidelines provided and summarized in the next sections.

7.1 Lessons Learned

7.1.1 Towards Research and Development

- Collaboration in the dissemination of research findings can help to ensure that research has a positive impact on society (WP 5).
- There are interesting examples of scientific collaboration between the ICT-56 projects, as several events, conferences, workshops, and hackathons have been organized jointly. For example, a book coordinated by EU-IoT with focus on the project's main achievements is under publication with a release expected in April 2023. This collaboration between projects can help to accelerate scientific progress, promote innovation in Europe, and lead to improvements and greater impact.
- ICT-56 RIAs provide a good coverage across all EU-IoT scope areas**,** which will allow them to re-orient their solutions and services across multiple vertical domains to align with the EU SDG, and to assist in identifying potential synergies across different domains (e.g., agriculture, manufacturing).
- In terms of data sharing and integration, a large amount of data was generated by the ICT-56 projects which can be valuable resources for other projects. Collaboration in data sharing can help to promote data reuse and interoperability and can lead to new insights and innovations.
- Knowledge exchange and collaboration across projects help to promote innovation and disseminate knowledge and skills across projects which will build scientific capacity across Europe.
- Particularly important, valuable, and excellent scientific contributions and publications have been produced in the R&D sector, which covers a large portion of the derived publications in Europe, as well as a particularly good level of mature knowledge and contributions to technology transfer is generated.
- PhD/M.Sc. students in a large number have been supported by different RIAs. This shows that knowledge derived from RIAs is also being applied in educational products, thus increasing the impact of research in Europe.
- The RIAs tackled different and relevant ethical aspects such as privacy and data governance, technical robustness, and safety. The steps taken can be considered as examples to new projects.

7.1.2 Towards Innovation

- Remarkably interesting concrete levels of contribution towards standardization and concrete standards are already released and many others are under development.
- EU-IoT has assisted such consolidation by providing a mapping of current SDG contributions towards open entities such as IEEE, IETF, AIOTI, BDVA (rf. Deliverable D3.8).
- Relevant aspects such as openness and interoperability have been addressed across all ICT-56 RIAs, and most RIAs are developing assets that have a robust TRL level already, TRL 6 and 7.
- In terms of usability aspects, considered extensions of open calls (e.g., hands-on events,

tutorials) where usability of the products can be tested by third parties.

- Skills training in open calls is a relevant aspect since in traditional sectors such as manufacturing, SMEs are usually limited in terms of innovation skills.
- Development and application of innovative technologies can help to accelerate progress and promote innovation within the next generation of IoT.

7.1.3 Towards Business Exploitation

- Skills training tools should be considered as a relevant asset that can assist in the marketing of the produced assets in ICT-56 (rf. EU-IoT proposed business modelling tooling WP4).
- A high level of competition for the products being developed in different areas, so the ICT-56 should plan to conduct a competitive analysis to reduce potential barriers and ensure that the planned time-to-market can be met.
- Integrating greenness is a key component and aspect of the business exploitation and is currently being addressed by several ICT-56 RIAs.

7.2 Identified Challenges

Derived from the assessment conducted, EU-IoT has identified, together with the RIAs, several challenges to be tackled, which are summarized in Table 36.

Table 36: Challenges identified together with ICT-56 RIAs.

Challenge	TERMINET	VEDLIoT	IoT-NGIN	INTELLIOT	ASSIST-IoT	INGENIOUS
Market competition: How strong is competition in the target market?				X Difficulty in assessing the market for the derived assets	X Identified strong competition, difficulty in entry into market.	
Patchy, no major players					X SMEs focused on IoT platforms, Edge AI	
Several major players with strong competencies, infrastructure, and offerings	X			X (e.g., John Deere, Class)	X Strong, large competitors, e.g., Google	
Other		X				
Are there issues that could compromise the ability to exploit new products/solutions/services, internally or in the marketplace?	No	Yes Potential issues include required accuracy not reached (technical) and shift of business unit (commercial)	No	Yes Communication & connectivity in the field is one pre-requisite for the solution. COTS devices in the agriculture domain may not suffice the	Yes the emergence of a new, disruptive approach to computing that would set apart the	

Challenge	TERMINET	VEDLIoT	IoT-NGIN	INTELLIOT	ASSIST-IoT	INGENIOUS
[Yes] or *[No]*				computational requirements of the solutions developed in the project.	deployment of containerised applications in the field of IoT.	
Which are the external bottlenecks that compromise the ability of project partners to exploit new products, solutions, or services, internally or in the marketplace?						
Which are the external bottlenecks that compromise the ability of project partners to exploit new products, solutions, or services, internally or in the marketplace?					Reluctance to adopt new technologies, obligation to stick to legacy solutions, learning curve for non-skilled staff.	
Regulation		No	No			
Skills in the wider workforce		No	Yes			
Standards		Yes Successful market adoption can only be done if standards are meet, however, the current standards do not cover DC arcs, just AC arcs.	No	No Go to market would require certifying the solution for the market.		
Financing		No	No	No Financing the development of resolute HW devices (see above) may break the business model. The solution might be too costly for the target market.		
Trade issues (between MS, globally)		No				
IPR	Yes	No	*Yes (might be)*			
Others		No			*Reluctancy.*	

Challenge	TERMINET	VEDLIoT	IoT-NGIN	INTELLIOT	ASSIST-IoT	INGENIOUS
Indicate how many patents have been applied for by the project: Indicate a number from 0 to 10*]*	1	0 There are plans in that direction, and there have been workshops, however, this is still ongoing. Currently, 3 patents are planned	0	0	0	
How would you rate the level of commitment of relevant organization(s) to exploit the Asset ?						
Extremely low						
Low						
Average						
High	X	X		X	X	
Very High			X			
Collaborative contributions between the projects to technical aspects						
Extremely low				X		
Low						
Average	X					
High		X			X With INGENIOUs	
Very High			X		X With TERMINET	

7.3 Recommendations for Collaboration Sustainability

Derived from identified challenges, this section provides a set of recommendations envisioning ICT-56 RIAs and other RIAs:

- **Collaboration and coordination between the** projects related to technical aspects: collaboration and coordination among stakeholders can be challenging, particularly when there are divergent scopes, and not a clear match across use-cases.
    - **Tools such as Open Calls, or joint participation in external events may assist in faster convergence.**
    - **This can be led by future CSAs.**
- Most projects expect a **time-to-market between one and three years**. This will require adequate viability analysis and concrete business models to exploit the different products and allow them to enter the market fast.
    - **Joint workshops focusing on the business modelling aspects and debate of use-cases can improve this situation.**

- The indicative **distribution rate of expected benefits** is similar across projects. On average, the largest amount of benefits relates with stakeholder integration and with cost reduction.
    - **Increased social sustainability and cost reduction seem to be less relevant for the projects and should be addressed in future business modelling and exploitation activities.**
- Most projects expect **a high number of assets**, running the risk of potential **fragmentation**. The business modelling needs to consider such a high number and respective risk, and to dimension this aspect regarding the willingness to achieve a fast time-to-market, while addressing a high number of competitors across all projects.
    - **Business modelling at an early stage may assist in identifying convergence points and strengthening the key assets to be released.**
- **Estimated cost distribution** reflects a heavier investment towards **personnel** and **infrastructure** across all projects, and a lesser investment in terms of logistics. For the future, it is important to provide this estimate with a finer-granularity (per project) and to understand the relevancy of other components, such as distribution and logistics.
    - **Business modelling should take into consideration these features.**
- **Ethics and regulatory issues** can be complex and time-consuming to navigate.
    - **Recommendation is for future projects to consider setting up an Ethics Committee, with internal and external experts, which can assist in the navigation. As a starting point, we recommend the list provided in section 3.5.**
    - **Ethics handling plan should be an integrative part of future projects.**
- **Communication, dissemination, scientific outreach**: projects often struggle to communicate their research findings or implementation outcomes effectively, to maximize the impact and visibility of their outcomes.
    - **Regular discussion on events managed by different ICT-56 RIAs can increase the impact of scientific output across all RIAs.**
    - **Joint efforts in the support of students (e.g., summer schools) can also assist in increasing the impact of the work developed.**
- **Standardization**: efficient contributions to SDOs require an adequate entry plan, and a heavy investment on monitoring.
    - CSAs such as EU-IoT can assist RIAs in directions towards stronger contributions to standardisation. Rf. to EU-IoT D3.8 for concrete recommendations on this aspect.

8 SUMMARY

D5.7 provides an overall and complete perspective on the impact assessment conducted in cooperation with ICT-56 RIAs.

The conducted impact assessment has collected information on different contributions under development in ICT-56 and has provided a qualitative and quantitative analysis of the different contributions.

The overall work conducted across the last three years shows that the six ICT-56 flagship projects are having significant impact across the IoT-Edge-Cloud spectrum in Europe.

Scientifically, the output generated is highly relevant. Out of **162 peer-reviewed scientific publications**, circa 50% have been published in excellent international venues (international journals SJR Q1/Q2 or conferences CORE Rank A*/A/B).

Another relevant success area concerns **advanced training** with **139 contributions**, out of which 51 reflect active PhDs, 45 concern concluded MScs. Lectures and seminars amount to a total of 25, showing a good transfer from research towards educational products.

The assets developed by ICT-56 RIAs have already achieved a mature state, with demonstrators and testbeds already provided at a TRL 4-5 level.

Moreover, RIAs have already developed a series of steps towards **asset and business exploitation**.

ICT-56 RIAs that displayed a **greater adoption of** assets by SMEs have launched **open calls**, which proved to be a valuable mechanism for achieving innovative impact.

In terms of business **modelling and exploitation**, it would also be important to address the risks and proposed mitigation actions as described in section 7. Out of those, we highlight the need to consider dimensions such as greenness, openness, and skills training, as well as the potential of new business models that may derive from the open calls.

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LIST OF ANNEXES

- Survey 1 (pdf and xls), available here: https://drive.ngiot.eu/index.php/s/PwCMcTmoKPRPjzi?path=%2FEU-IoT-WP5-ImpactAssessmentMeetings%2FImpactAssessment2021
- Survey 2 (pdf and xls), available here: https://drive.ngiot.eu/index.php/s/PwCMcTmoKPRPjzi?path=%2FEU-IoT-WP5-ImpactAssessmentMeetings%2FImpactAssessment_2022
- Survey 3 (pdf and xls) available here:

  https://drive.ngiot.eu/index.php/s/PwCMcTmoKPRPjzi?path=%2FEU-IoT-WP5-ImpactAssessmentMeetings%2FImpactAssessment_2023