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The European IoT Hub

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

D5.6 Impact Assessment- Guidelines for IoT collaboration sustainability

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Abstract

This deliverable provides an intermediate 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.

Document Revision History

Version	Date	Description of change	List of contributors(s)
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V0.2	13/09/2022	Input on the qualitative and quantitative aspects, sections 3, and 4	Manel Khelifi, FOR
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V0.5	16/09/2022	Global deliverable, release to EU-IoT partners and reviews	EU-IoT partners
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V0.7	22/09/2022	Integration of revisions	Manel Khelifi, Rute Sofia, FOR
V0.8	28/09/2022	Revisions by partners INTRA and AU (deliverable reviewers)	John Soldatos (INTRA), Emilie M. Jakobsen (AU)
V1.0	30/09/2022	Final version for submission	Manel Khelifi, Rute Sofia, FOR

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Nature of the deliverable:	R	
Dissemination Level		
PU	Public, fully open, e.g., Web	√
CI	Classified, information as referred to in Commission Decision 2001/844/EC	
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* R: Document, report (excluding the periodic and final reports)
DEM: Demonstrator, pilot, prototype, plan designs
DEC: Websites, patents filing, press & media actions, videos, etc.
OTHER: Software, technical diagram, etc

EXECUTIVE SUMMARY

This deliverable reports on the work done within EU-IoT Work Package 5, Task 5.3 (T5.3 Impact Assessment), and its purpose is two-fold. Firstly, to provide an assessment of the impact generated by the ongoing ICT-56 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.

The impact assessment described in this deliverable has been based on the EU-IoT impact assessment methodological framework (presented in Deliverable D5.5, September 2021), which defines and establishes the goals, processes, stakeholders, and impact categories of the impact assessment procedure, thus setting up the underlying structure and concepts to perform the impact assessment analysis.

Based on the proposed and tested impact assessment framework, this document provides first a qualitative analysis and secondly a quantitative analysis of the 6 ICT-56 flagship projects. As stated in D5.3, the aim of the EU-IoT impact assessment process is to assess the ongoing status of current (and future) assets produced by the ICT-56 projects. The expected impact of this analysis is a set of measures that can further assist in strengthening the impact of individual projects, and collaboration across projects. These projects started in October and November 2020 and are expected to be concluded by the end of 2023. Therefore, the current impact assessment analysis is not meant to be final. Instead, the aim is to derive a set of guidelines and recommendations that may assist the projects in strengthening their impact.

The final impact assessment version will be described in D5.7, due in March 2023.

It is important to also underline that the guidelines and recommendations provided in this deliverable derive from a qualitative and quantitative analysis concerning innovation assets, and future use-case and business exploitation. This should help all the *Next Generation IoT (NGIoT*) community stakeholders as well as the European Commission in directing future research and innovation investments and efforts.

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ABBREVIATIONS

Acronym	Definition
AB	Advisory Board
AI	Artificial Intelligence
CB	Coordination Board
CCIS	Culture, Creativity, and Inclusive Society
CCS	Civil Security for Society
CEM	Climate, Energy, and Mobility
CTF	Coordination Task Force
DIS	Digital, Industry, Space
EC	European Commission
EU	European Union
FBNRAE	Food, Bioeconomy, Natural, Resources, Agriculture, and Environment
ICT	Information and Communication Technologies
IoT	Internet of Things
KER	Key Exploitable Result
KPI	Key Performance Indicator
KPI	Key Performance Indicator
ML	Machine Learning
NGIoT	Next Generation Internet of Things
R&D	Research and Development
RIA	Research and Innovation Action
SDG	Sustainability Development Goals
SDO	Standards Development Organization

1 INTRODUCTION

The work carried out and described in this deliverable has been led by the EU-IoT Work package 5 "WP5 – Amplifier", Task 5.3. WP5 is responsible for durable and effective outreach and impact creation, helping ensure visibility and increased credibility and trust in the NGIoT efforts in a sustainable way. 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 actors in the European *Next Generation Internet of Things (NGIoT)* value creation chain, getting input from the *Coordination Board, CB* (WP2), the *Coordination Task-Force, CTF* (see T5.1), the *Advisory Board, AB* (WP2), and the *European Commission, EC*.

Task 5.3 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. During its first phase, T5.3 worked on the development of an impact assessment framework to help assess ICT-56 projects in terms of the output towards the *European Sustainability Development Goals (SDGs).* The impact assessment framework has been described in the EU-IoT Deliverable D5.5 (September 2021) [1], which also included an early-stage impact assessment analysis, as the ICT-56 projects were still in a very early stage of development.

This document is therefore the second deliverable of Task 5.3 (Impact Assessment) and, besides presenting a qualitative and quantitative impact assessment, it also provides a set of guidelines and recommendations aimed at assisting ICT-56 *Research and Innovation Actions (RIAs)* in further strengthening their impact, via measures that address both a comparative and cross-sectional approach.

More specifically, the deliverable provides a **qualitative and quantitative analysis of innovation, use-cases, and business exploitation aspects**, to assist the projects in better identification of areas of impact. Derived from such analysis, the deliverable provides a set of identified key drivers and eventual issues that projects may currently have to handle, proposing a set of guidelines to further strengthen their work and planned impact.

1.1 Deliverable Structure

The deliverable is organized as follows:

- Section 2 summarizes 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 covers a quantitative and qualitative analysis of business exploitation aspects for the ICT-56 projects.
- Section 6 provides highlights concerning project contributions.
- Section 7 provides a series of recommendations and guidelines aiming at further boosting the generated impact, and which shall be addressed by EU-IoT, and which shall be addressed by EU-IoT on the next phase of work.
- Section 8 concludes the deliverable, explaining next steps.

2 THE EU-IOT IMPACT ASSESSMENT FRAMEWORK

The EU-IoT impact assessment framework is based on a series of analytical processes that aim 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 *Research and Innovation Actions (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 [1]). A first analysis of the expected assets per project has been carried out 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.

By relying on the proposed tooling, the ICT-56 projects benefit from the following:

- Broader impact understanding, derived from an overall ICT-56 perspective, on the impact the projects are creating.
- Strengthen the focus towards the EU vision regarding SDG contributions.
- Identify relevant areas, groups, and entities such as Standards Developments Organizations and other audiences to further direct dissemination, communication, and exploitation.
- Identifying potential synergies between the participating projects.
- Provide an overview of the project's targeted or desired impacts.

2.1 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 the 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.

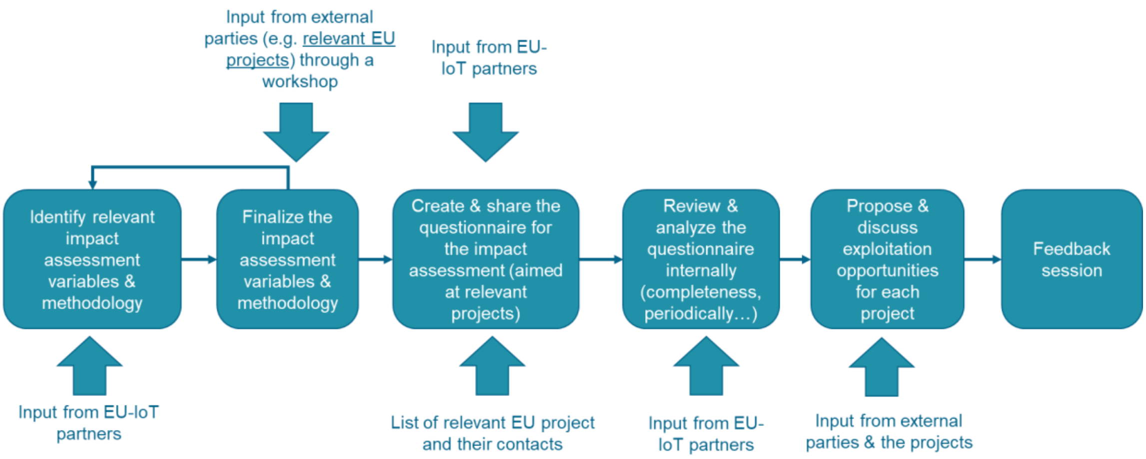

Figure 1: The EU-IoT impact assessment framework process.

The timeline for this process is illustrated in Figure 2.

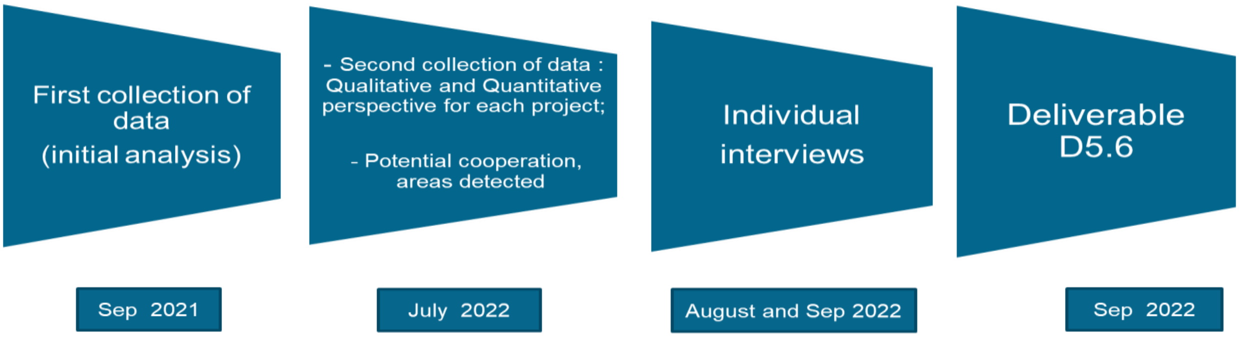

Figure 2: Timeline of the overall process of the impact assessment.

Moreover, the overall impact assessment has both a qualitative and quantitative component, as illustrated in *Figure 3*.

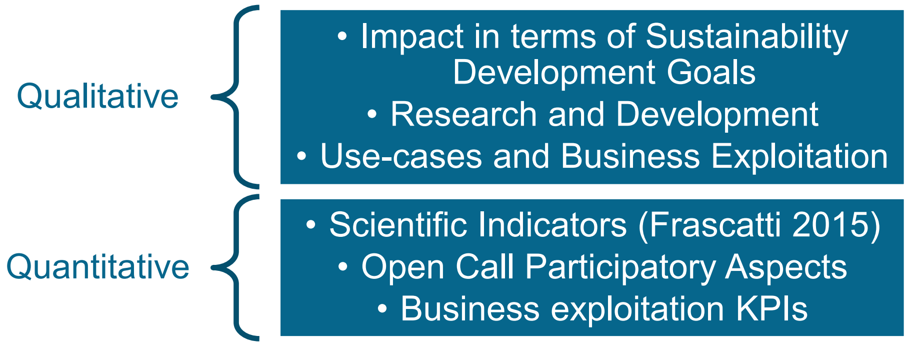

Figure 3: Qualitative and quantitative components of the impact assessment.

2.2 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 projects 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.

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

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

- **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-centred, 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.

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 carried out and presented in this document is relevant to assist in detecting areas of cooperation, the quantitative analysis is still intermediate.

2.3 Qualitative Analysis Aspects

The qualitative analysis carried out 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 [2] as:

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

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

[5] https://vedliot.eu/

[6] https://INTELLIOT.eu/

- **Human/ IoT interfaces** relates 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 "Horizon Europe First Strategic Plan 2021-2024" [4], as described in Deliverable D5.5.

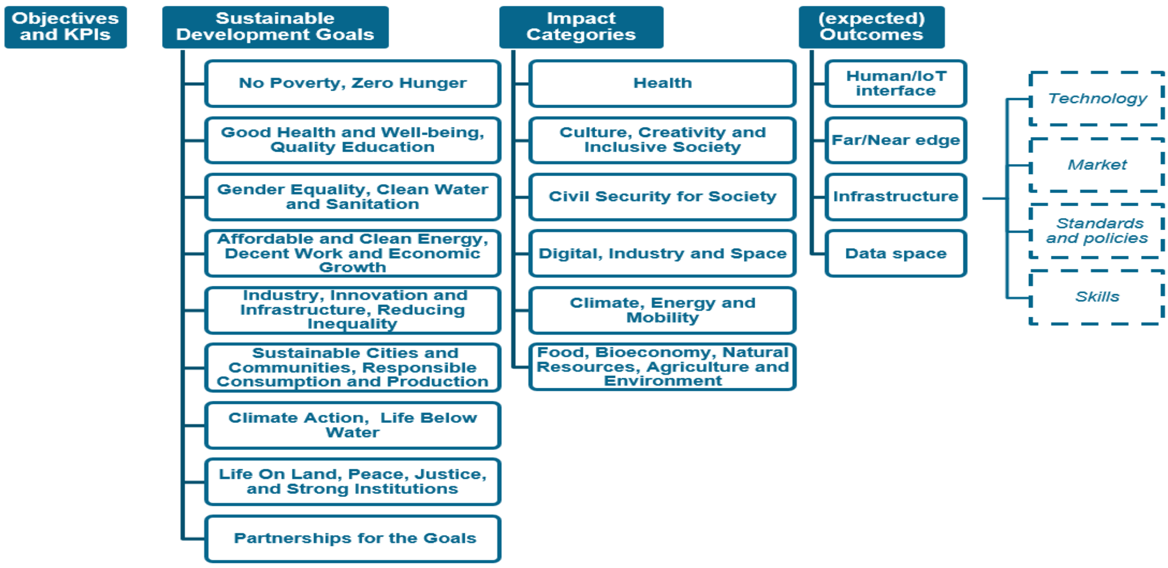

Figure 4: Qualitative analysis components.

2.4 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** [8], 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**.

2.5 Information and Data Gathering Methods

The impact assessment analysis has been developed based on a fully-fledged methodology using different approaches and instruments such as surveys, workshops involving RIAs, and direct talks with RIAs as illustrated in Figure 5 and further explained in the next sub-sections.

Figure 5: Information gathering methods.

2.5.1 Surveys

Two main surveys have been provided to RIAs via LimeSurvey[7]. The two surveys are provided as annexes to this deliverable.

The first survey results are available in Deliverable D5.5 and relate to the 2021 RIA early-stage data collection. This survey has been organized in four main sections. The first section collects general information about the projects such as the project's name, and objective start and end dates while the second section collects information about the impact categories and impact variables applicable to each project. The respondents have been encouraged to add comments in the form to explain the reasons behind the selection of the impact variables. The third section aims at collecting information about the outcomes. The outcomes are categorized in terms of technology, market, standards and policies, and skills. The respondent is then asked to select which EU-IoT framework area fits each outcome. The last final section collects general information about open calls such as dates and budget. The reason behind collecting such information is to customize and adjust the analysis and recommendation to projects that are planning to organize open calls by proposing for example use cases and topics for the experiments that would align with the intended project impact. In addition, the section collects information about the agreed-upon KPIs, target groups, and targets.

A second survey has been developed in late 2021 and early 2022, having been provided to RIAs in 2022. This survey is again organized in 4 different areas as follows:

- **G1: global project details**, e.g., dates, contacts, goals.
- **G2: qualitative impact analysis**, related to project contributions towards SDGs.
- **G3: quantitative impact analysis**, based on the proposed project indicators and based on the OECD 2015 Frascati Manual for research and development indicators.
- **G4: use-cases and business exploitation** analysis, based on KPIs aligned with the CSA OPEN-DEI.

[7] https://www.limesurvey.org/

2.5.2 One-to-one Meetings and Workshops

The data collected in surveys has been complemented with input collected in workshops (WP2, WP3) and with one-to-one meetings carried out via Web conferencing. The input collected has been verified by the RIAs both during the meetings and after.

The workshop minutes (WP3 and WP2 workshops) provide input to the collected data. Moreover, for the individual meetings, we have also proposed a document where RIAs could add further information.

3 QUALITATIVE IMPACT ASSESSMENT ANALYSIS

3.1 Global Project Overview

Table 1 provides details on each of the ICT-56 projects, namely, the projects' starting and ending dates, URLs, and contacts that have been used for the impact assessment.

Table 1: ICT-56 projects' Overview.

Acronym	Starting and Ending date	URL	Contacts
IoT-NGIN	01.11.2020-31.10.2023	https://iot-ngin.eu/	Ghasan Bhattib (Capgemini), Anna Duszynska-Trojanowska, CapgGemini (Capgemini),
INGENIOUS	01.10.2020-31.03.2023	https://INGENIOUS-iot.eu/web/	David Gomez-Barquero (Universitat Politècnica de València) Nuria Molner (Universitat Politècnica de València)
ASSIST-IoT	01.11.2020 - 31.10.2023	https://assist-iot.eu/	Carlos E. Palau (Universitat Politècnica de València)
TERMINET	01.11.2020-31.10.2023	https://TERMINET-h2020.eu/	Panos Sarigiannidis (University of Western Macedonia)
VEDLIoT	01.11.2020-31.10.2023	https://vedliot.eu/	Jans Hagenmeyer (Bielefeld University)
INTELLIOT	01.10.2020-30.09.2023	https://INTELLIOT.eu/	Vivek Kulkarni (Siemens) Gerald Fritz, Arne Broering (Siemens) Marin Lemschke (Siemens)

3.2 Project Main Goals

Table 2 provides a summary of the ICT-56 projects' goals. A common theme addressed in all projects is cybersecurity, in particular security, data privacy, and trustworthiness. Moreover, distributed *Artificial Intelligence (AI)* and *Machine Learning (ML)* approaches, and the integration of AI/ML across Edge-Cloud are also common themes among all projects.

Across projects, there are overlapping goals (e.g., distributed approaches for learning; privacy preservation; architectural decentralization across Edge and Cloud) which can be the basis for cooperating across projects, be it in terms of open calls, specific events, or event commonly written output (e.g., books). The articulation of these aspects can be supported by EU-IoT.

Table 2: Summary of project goals.

Project	Mains goals
IoT-NGIN	**Technological Objectives** • 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 • Enforce data sovereignty by making IoT data accessible in a trusted, auditable, and controlled way. • Validate the IoT-NGIN enhancements with diversified and heterogeneous use cases • Demonstrate flexibility and User Acceptance by integrating new 3rd party components & apps. **Business Objectives** • 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. **Societal objectives** • Improved European citizens quality of life in a Human-Centred Europe. • Improved Accessibility to IoT resources • Scientific Advancement & Impact creation
INGENIOUS	• 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. • For this purpose, the project will exploit some of the most innovative and emerging technologies in line with the standardised trend, contributing to the NG-IoT and proposing technical and business enablers to build a complete platform towards the future fully digitized supply chain management. • Project outcomes will be validated into 4 large-scale Proof of Concept demonstration, covering 1 factory in the North of Spain, 2 ports, the port of Valencia in Spain and the port of Livorno in Italy, and 1 ship traveling from Valencia in Spain to Piraeus in Greece, encompassing 6 uses cases.
ASSIST-IoT	• Design, implementation, and validation of an NGIoT Reference Architecture • Definition and implementation of distributed smart networking components • 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 • Definition, deployment, and evaluation of real-life pilots.

Project	Mains goals
	• Establishment of an innovative cooperation and business framework • Impact creation: Showcasing ASSIST-IoT and Disrupting the current market
TERMINET	• TERMINET aims at providing a novel next generation reference architecture based on cutting-edge 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. • 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, - 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, - fostering AR/VR contextual computing by demonstrating applicable results in realistic use cases by using cutting-edge 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 - providing novel disruptive business models, while fostering standardisation activities for the IoT ecosystem.
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 • Resource-efficient cognitive IoT solutions - Goal: 10 x improvement for Perf. and EE. • 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 • Wide use case coverage - Goal: VEDLIoT technology for all use cases, including open calls
INTELLIOT	• 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.

3.3 Key Contributions towards European Commission Policies

Table 3 provides a summary of the ICT-56 projects' key contributions toward EU policies. Next Generation IoT is one of the common policy areas. Additional overlapping contributions include Artificial *Intelligence of Things (AIoT),* Edge computing, energy/resource efficiency and green communications, health, and cybersecurity.

Table 3: ICT-56 projects contribution towards European Commission policies.

Project Name	Contributions towards EU policies
IoT-NGIN	• Next Generation Internet • Internet of Things • Artificial intelligence • Cybersecurity
INGENIOUS	• 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. • Health and safety at work: 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. • 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.
ASSIST-IoT	• EU Missions • EU Green Deal • EU Data Act and Data Governance Act
TERMINET	• 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 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. • 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
VEDLIoT	• Energy/resource efficiency and energy-efficient processing: As stated in the project's objectives (Objectives 1-5) • Security: Development of distributed remote attestation and End-to-End trust for AIoT systems (Objectives 6) • Safety: Development of a requirements framework for AIoT systems and guaranteed safety levels for AIoT applications (Objectives 7).
INTELLIOT	• European Data Strategy 2020, https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fitdigital-age/european-data-strategy • Core principles: Ethics & AI, Data Governance & Privacy, Interoperability, Accessibility

3.4 Contributions Towards SDGs

Table 4 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 4, the main contributions 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)* has the next most relevant set contributions. This relates also with the nature of ICT-56 and with specific use-cases focused on Agriculture that several projects are addressing.

A few 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)* have been less addressed by projects, as expected due to the nature of ICT-56. Nonetheless projects such as INGENIOUS mention a few contributions towards this category.

Table 4: 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	INGENIOUS IoT-NGIN ASSIST-IoT INTELLIOT VEDLIoT	
Climate, Energy and Mobility			ASSIST-IoT TERMINET	INTELLIOT VEDLIoT	INGENIOUS IoT-NGIN	
Food, Bioeconomy, Natural Resources,			VEDLIoT	INTELLIOT	IoT-NGIN TERMINET	INGENIOUS ASSIST-IoT

Category	1	2	3	4	5	0
Agriculture and Environment						

3.4.1 Health Impact Category

Table 5 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 5: 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 includes a pilot for safety at work. Use of edge nodes, smart devices and enhancing protective equipment over low latency networks.
	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 utilising 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 nearly 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	IoT-NGIN	Validated through Open Call project using IoT-NGIN tools to extend the capabilities of wearable medical device for chronic disease prevention.

Sub-topic	Project	Comment
solutions for a healthy society	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 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		

3.4.2 Digital, Industry and Space Impact Category

Table 6 provides information on the tangible contributions achieved by all the projects towards DIS. Most projects consider digitisation 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 reliable and secure IoT technologies. ASSIST-IoT, provides an innovative architecture with emerging technology modules including frugal AI and data management components.

Table 6: 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	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.
Sovereignty in digital technologies and in future emerging enabling	IoT-NGIN	Validated through employee-friendly (safety & efficiency) industry 4.0 and digital powertrain and condition monitoring use cases

Sub-topic	Project	Comment
technologies	ASSIST-IoT	ASSIST-IoT will provide an innovative blueprint architecture with emerging technologies modules including frugal AI and data management components.
	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 infra-structures, 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	IoT-NGIN	Increased efficiency in industrial processes validated through Augmented Reality assisted build-to-order assembly

3.4.3 Climate, Energy and Mobility Impact Category

Table 7 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.

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.

Two sub-topics did not receive input from projects, namely, “a climate neutral and resilient society and economy” and “efficient and sustainable use of energy, accessible for all”. These specific sub-topics can be addressed via open calls, as well as when addressing the business exploitation modelling.

Table 7: Climate, Energy and Mobility contributions per project.

Sub-topic	Project	Comment
A climate-neutral and resilient society and economy		
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 optimise their energy consumption and harvesting, by utilising distributed AI techniques over the data collected by multiple IoT devices.
Efficient and sustainable use of energy, accessible for all		
Climate-neutral and environmentally friendly mobility	IoT-NGIN	Validated through driver-friendly dispatchable EV charging.
Safe, seamless, smart, inclusive, resilient, and sustainable mobility systems	IoT-NGIN	Validated through smart mobility cases in the Smart City sector.
	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 possible 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.
	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.
	ASSIST-IoT	ASSIT-IoT includes two pilots related with transport (automotive industry). On the one hand, enhancing vehicle (car) fleet management to reduce environmental impact and optimise engine parameters adapted to drivers' behaviour. On the other hand, the essential logistic node of maritime ports will be benefited from ASSIST-IOT with a better management of remote control over optimised Container Handling Equipment.
Other	IoT-NGIN	Ensuring stable grid operation through active monitoring and control.

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

The contributions towards this pillar (rf. to *Table 8*) 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 to test of the proposed assets in terms of energy efficiency, or capability to scale (e.g., heterogeneous data set support) and allow also to test new business models, as in the case of VEDLIoT (use-cases derived from open calls, e.g., an automated harvesting system for mushrooms). 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 8: Contributions to the pillar Food, Bioeconomy, Natural Resources, Agriculture, Environment.

Sub-topic		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	IoT-NGIN	Validated through smart farming solutions (smart irrigation & spraying, smart harvesting, etc.)
	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
	TERMINET	User Centric Devices for Smart Farming

3.4.5 Culture, Creative and Inclusive Society Impact Category

No input has been provided by projects, as this impact category is not directly related to ICT-56. Nonetheless, EU-IoT will specifically address this component and potential impact until its end, March 2023.

3.4.6 Civil Security for Society Impact Category

As can be seen in Table 9, only INGENIOUS has provided contributions to this impact category. INGENIOUS focuses on increasing cybersecurity via the application of DLT and smart contracts.

Table 9: Contributions to the pillar of civil security for society.

Sub-topic	Project	Comment
Reduced losses from natural, accidental, and man-made disasters		
Improved passengers and shipments travel into the EU		
Crime and terrorism are more effectively tackled		
Increased cyber-security and a more secure online environment	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.
Other		

3.4.7 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 6. 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, in particular 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 (reduce environmental impact) while optimizing engine parameters in a user-centric way.

Two sub-topics did not receive input from projects, namely, “a climate neutral and resilient society and economy” and “efficient and sustainable use of energy, accessible for all”. These specific sub-topics can be addressed via open calls, as well as when addressing the business exploitation modelling.

In the Health category, TERMINET and INTELLIOT rely on federated machine 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.

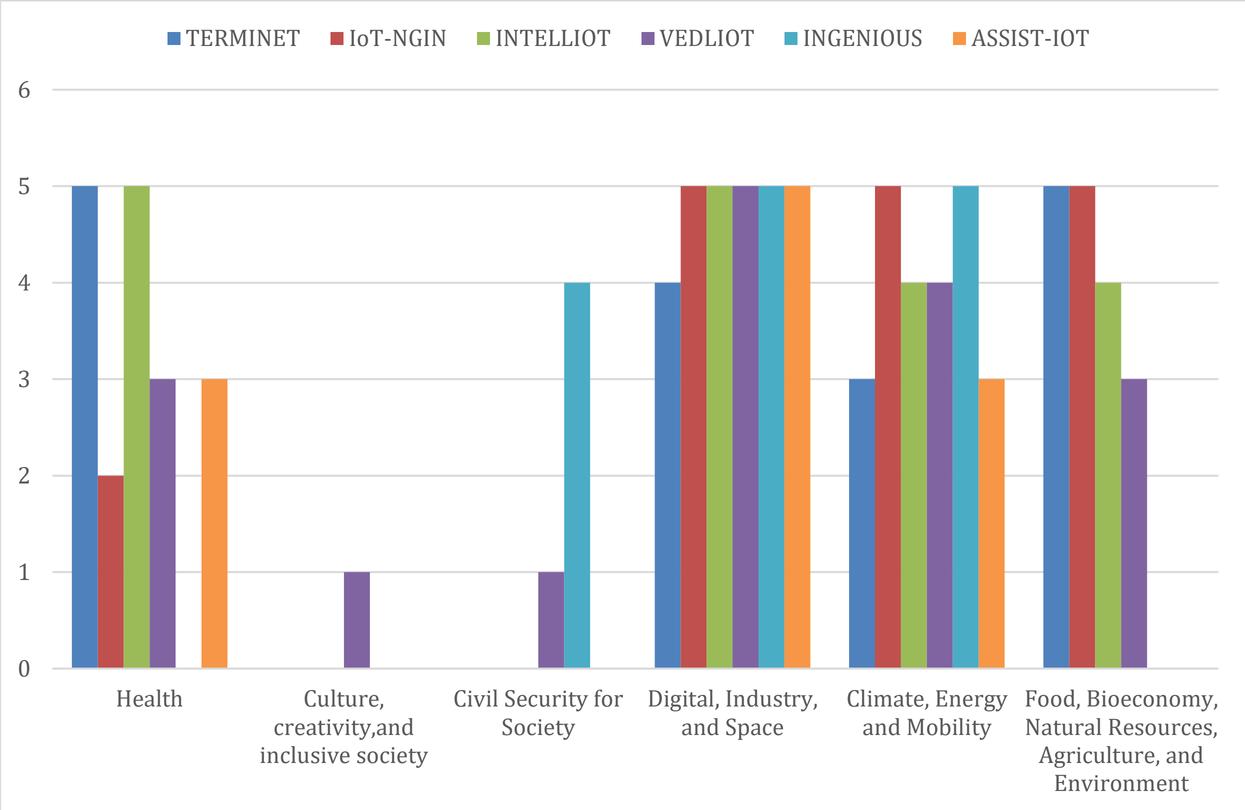

Figure 6: Projects' selected impact categories, ranked 1 (not so relevant contributions expected) to 5 (highly relevant contributions expected); 0 (no contributions expected).

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 also the use of AI/ML for automated Harvesting System for Mushrooms.

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.

3.5 Contributions Towards EU-IoT Scope Areas

This section provides input related to the main contributions of the projects to the 5 scope areas (rf. sect 2.3) as illustrated in *Figure 7*, where each proposed aspect has been weighted on a scale of 1 (low impact) to 5 (high relevant impact).

Most projects tend to focus on the far Edge, followed by the near Edge. Relevant contributions have been signalled also in the context of Human/IoT interfaces. Infrastructure is the area that ranks next. This homogeneity does not apply in the context of the area of Data Spaces, where two projects fit best. All projects provide a good coverage across all EU-IoT scope areas.

Therefore, this will enable the ICT-56 flagships projects to renew their operation, solutions, and services towards different sectors to be aligned with the EU vision and help to identify the potential synergies between them.

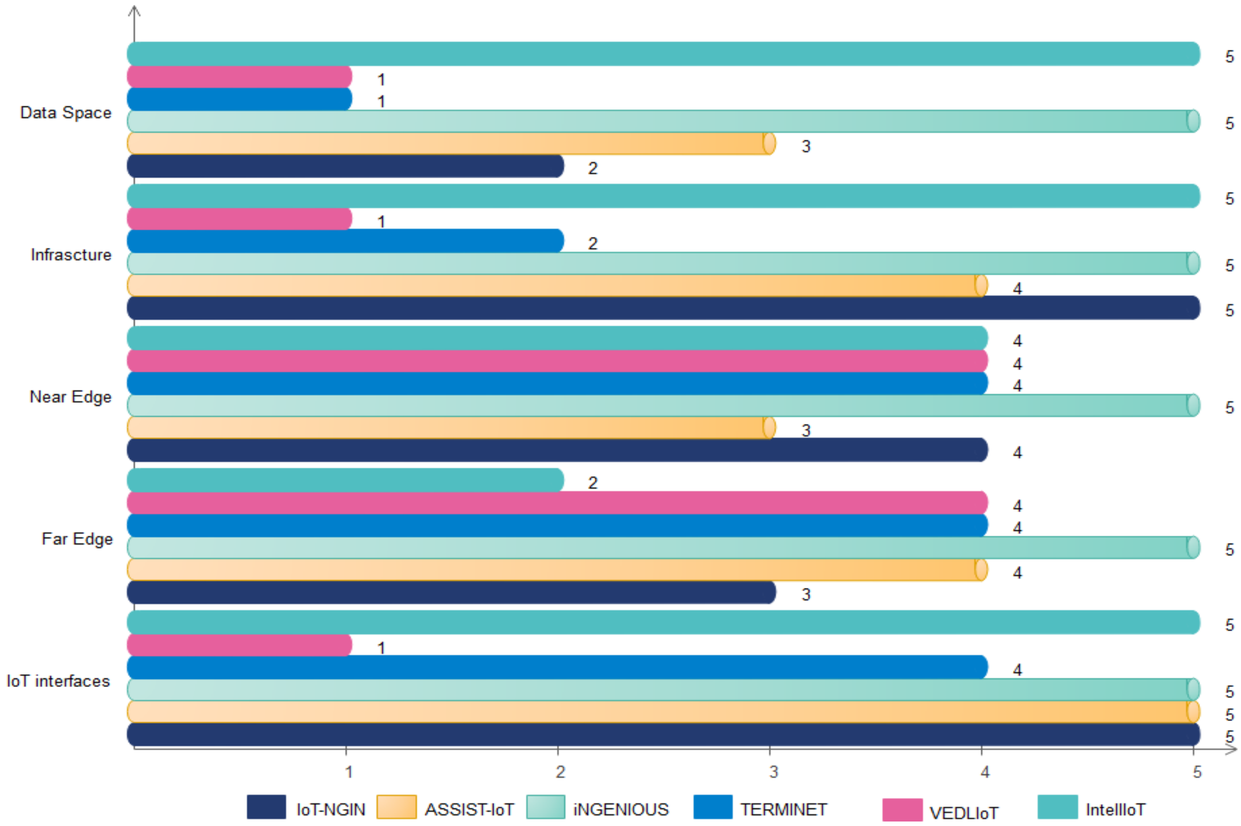

Figure 7: Contributions of projects towards EU-IoT scope areas, ranked 1 (not relevant) to 5 (highly relevant).

4 QUANTITATIVE IMPACT ANALYSIS

For the quantitative analysis, EU-IoT has collected different KPIs following the proposed methodology summarized in section 2. This section provides a quantitative perspective concerning innovation impact, research impact, and business impact.

The projects are still active (rf. to section 3.2) and therefore, the results presented in this deliverable reflect the status collected until July 2022. This also comprises, for most projects, results derived from closed or still active open calls.

4.1 Innovation Impact Analysis

Table 10 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 impact in terms of the adoption of 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 initial development of KPIs. There are no IPRs, and licensing is also not mentioned. However, the projects show a good level of generated products/services (19 in total), and this should also require an analysis of the respective licensing models.

Table 10: 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	2	28
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	5	24
Industrial organizations that adopted the solutions/services	4	2	0	4	0	8	18
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	3	5
Number of generated new services	1	6	0	3	0	10	19

4.2 R&D KPIs

Table 11 provides collected KPIs to assess the scientific impact of the ICT-56. As already explained, these numbers reflect the status of the projects until 30.06.2022 only.

Overall, there is an excellent level of R&D contributions. In terms of **Scientific Publications (A),** the projects have provided already 133 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 very 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 110 contributions, out of which 42 reflect active PhDs, 37 concern concluded MScs. Lectures and seminars amount to a total of 22, 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 11: R&D KPIs per project.

R&D KPI	ASSIST-IoT	VEDLIoT	IoT-NGIN	INTELLIOT	INGENIOUS	TERMINET	Total
A – Scientific Publications							**133**
Books	0	0	0	0	0	0	0
Book Chapters	0	0	0	0	0	0	0
Papers in international venues, SJR Q1 (Magazines, Journals) and CORE Rank A*/A	1	3	0	13	3	11	41
Papers in international venues, SJR Q2 (Magazines, Journals) and CORE Rank B	1	0	2	11	0	4	18
Papers in international venues, Magazines, Journals, Conferences	9	10	3	3	16	26	67
White Papers	4	0	0	0	0	3	7
B – Organization of Events							**14**
Conferences, workshops, symposia	4	1	0	0	0	0	5
Scientific committees, Technical Programme Committees, etc.	2	1	1	0	0	3	7
Guest editorial teams	0	0	2	0	0	0	2
C – Advanced Training							**122**
Active PhDs	5	8	1	10	1	22	47
Concluded PhDs	1	2	1	1	0	0	5
Concluded MScs	7	11	1	9	4	8	40
Summer schools, and similar events	0	0	0	3	1	0	4
Lectures and Seminars	2	1	7	10	4	2	26
D - Knowledge and Technology Transfer							**61**
Webinars, Demos, Talks to Industry	4	5	7	2	23	0	41
Invited Talks and Keynote speeches	1	0	4	5	4	6	20
E – Research Demonstrators and Testbeds							33
Research demonstrators, testbeds, software, TRL2-3	0	3	0	0	0	7	10
Research demonstrators, testbeds, software, TRL4-5	0	7	3	0	5	2	17
Research demonstrators, testbeds, software, TRL6 and above	0	0	0	0	3	3	6
Others	0		0	0	0	0	0

Figure 8 provides an aggregate perspective on the current innovation impact created by ICT-56 projects, where the overall adoption is being carried out by SMEs and research entities. The key tool for this adoption relates to the open calls carried out by five out of the six projects.

In terms of scientific impact (rf. to *Figure 8*), 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 help of EU-IoT.

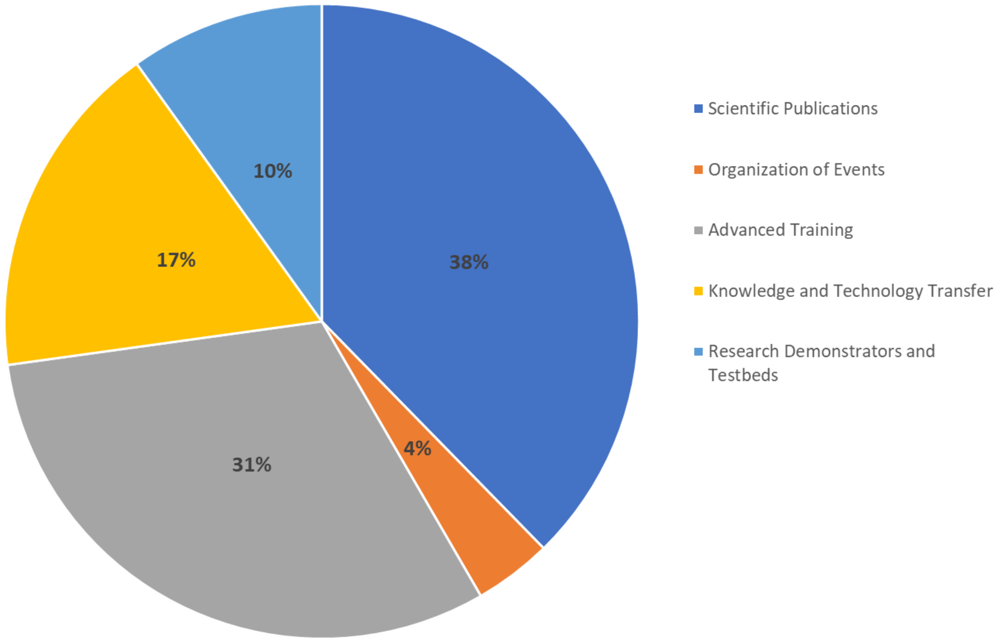

Figure 8: R&D impact perspective of ICT-56.

4.3 Standardization Contributions

This section provides input concerning the contributions that projects are developing toward *Standards Development Organizations (SDOs)*[8]. 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 12 provides the summary of monitoring contributions provided by the six projects, where the activity is measured via a grading of 0 (low activity) to 3 (high activity), while Table 13 provides similar content concerning SDO contributions by projects.

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

Regarding **monitoring**, most projects exhibit a low level of monitoring activities across a broad range of relevant SDOs. Monitoring contributions require a significant level of staff involvement and are time consuming. The current monitoring level seems therefore to be too high in terms of potential impact. Then, two projects (TERMINET and ASSIST-IoT) rely on a more selective monitoring methodology, where they focus on specific SDOs, e.g., IEEE.

The projects also signalled effort towards other SDOs that have not yet been considered in EU-IoT (under WP3). Therefore, an aspect to be tackled in the future is to collect such SDOs and understand better the reasons for the monitoring by the projects.

Table 12: 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		ASSIST-IoT INTELLIOT	
ISO	INGENIOUS IoT-NGIN INTELLIOT	ASSIST-IoT VEDLIoT		TERMINET
ITU-T	INGENIOUS IoT-NGIN VEDLIoT INTELLIOT TERMINET			ASSIST-IoT
IEC	INGENIOUS VEDLIoT	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 INTELLIOT	ASSIST-IoT TERMINET		INGENIOUS IoT-NGIN

SDO	0 (low activity)	1	2	3 (high activity)
CENELEC	INGENIOUS IoT-NGIN ASSIST-IoT INTELLIOT TERMINET	VEDLIoT		
ETSI	INGENIOUS IoT-NGIN VEDLIoT INTELLIOT			ASSIST-IoT TERMINET
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	VEDLIoT	INTELLIOT	IoT-NGIN ASSIST-IoT
Gaia-X	INGENIOUS VEDLIoT TERMINET		INTELLIOT	IoT-NGIN ASSIST-IoT
Other	INGENIOUS INTELLIOT TERMINET		IoT-NGIN ASSIST-IoT	VEDLIoT

For SDO **contributions** (rf. to Table 13), most projects have not yet provided contributions to SDOs. Exceptions to this are ASSIST-IoT, showing a high level of contributions towards relevant SDOs such as IEEE, ETSI, BDVA, and TERMINET, INGENIOUS, INTELLIOT, IoT-NGIN, contributing to specific SDOs.

Table 13: 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			

SDO	0 (low activity)	1	2	3
	INTELLIOT TERMINET			
W3C/WoT	INGENIOUS ASSIST-IoT IoT-NGIN VEDLIoT INTELLIOT		TERMINET	
3GPPP	ASSIST-IoT VEDLIoT INTELLIOT TERMINET	IoT-NGIN	INGENIOUS	
CENELEC	INGENIOUS ASSIST-IoT IoT-NGIN VEDLIoT INTELLIOT TERMINET			
ETSI	INGENIOUS INTELLIOT		IoT-NGIN TERMINET	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			ASSIST-IoT

SDO	0 (low activity)	1	2	3
	INTELLIOT TERMINET			
BDVA	INGENIOUS IoT-NGIN VEDLIoT INTELLIOT TERMINET			ASSIST-IoT
Gaia-X	INGENIOUS ASSIST-IoT IoT-NGIN VEDLIoT INTELLIOT TERMINET			
Other	INGENIOUS IoT-NGIN INTELLIOT TERMINET		ASSIST-IoT VEDLIoT	

In terms of contributions towards SDOs (rf. to Figure 9), most projects are not actively monitoring SDOs. Only a subset of them is monitoring ongoing activities within the context of ESTI, W3C/WoT, AIOTI, Gaia-X and BDVA.

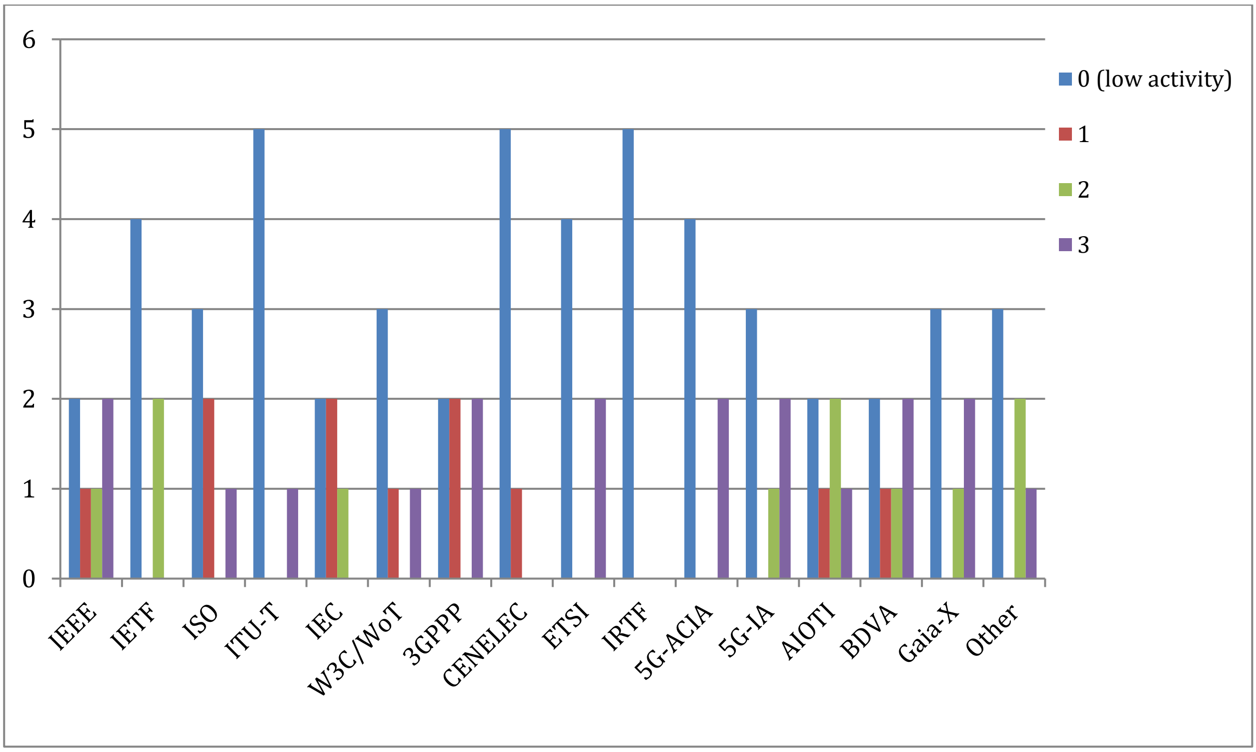

Figure 9: Monitoring contributions towards key SDOs, by ICT-56 projects.

Specific contributions by projects are mapped in *Figure 10*. A few projects are providing contributions towards IEC, AIOTI, 5G-IA, W3C. However, most projects do not yet have significant contributions towards SDOs.

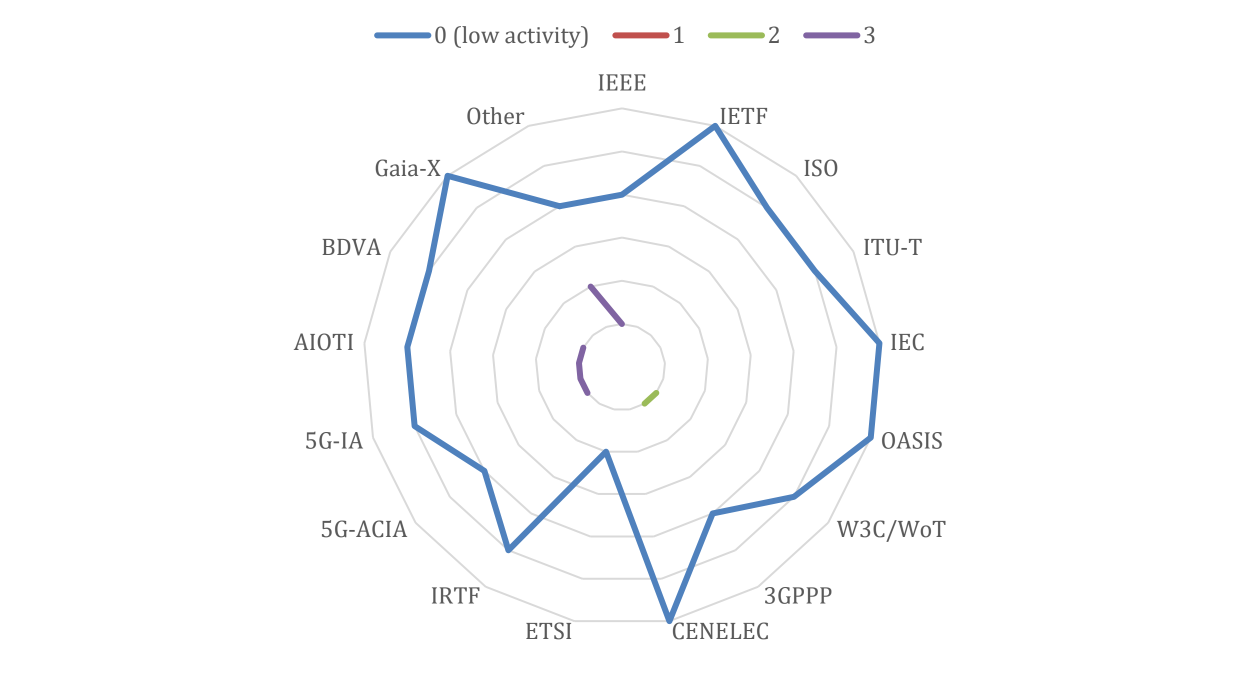

Figure 10: SDO contribution incidence by ICT-56 projects.

As observable in section 4, currently most projects are contributing with open assets (open software and hardware). However, the current repositories seem, in the majority, to fragmented (kept under the repositories of different partners). This may prevent a thorough use and dissemination.

4.4 Open-Source Contributions

Table 14 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. 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 14: Open contributions by projects.

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	• https://github.com/Barkhausen-Institut/M3

Project	Repository/Asset(s)	URL
	• Hardware: Trusted Communication Unit (TCU), Network-on-Chip (NoC)	• https://github.com/Barkhausen-Institut/M3-hardware
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	• https://github.com/renode/renode • https://github.com/antmicro/kenning • https://github.com/JamesMenetrey/unine-twine • https://github.com/JamesMenetrey/unine-watz • https://github.com/lindemer/pmp
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 technology based on the OpenAirInterface Software Alliance (OSA) license (like Apache 2.0) - 5G RAN - 5G Core - Mosaic5G - IAKM 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/iot/aiaas

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 *15* summarizes the analyzed 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.

In terms of open calls, the projects have a similar number of components applied in the calls. VEDLIoT is a project focused on hardware; therefore, the number of components registered is lower in comparison to the other two counterpart projects.

Table 15: Quantitative perspective on open calls KPIs.

Item/Project	TERMINET	VEDLIoT	IoT-NGIN	INTELLIOT	ASSIST-IoT	Total
Call 1 details (dates)	01/08/2022-31/07/2023	01/03/2022 – 08/05/2022	1/10/2021–30/12/2021	01/09/2022 – 01/11/2022	01/07/2022-14/10/2022	
Call 2 details (dates)	-	01.07.2022 - 30.06.2023	01/07/2022–30/09/2022			
Number of involved partners	-	12	12	-	15	39
Number of involved components/products/services	-	7	15	-	15	37
Number of users experimenting the project solutions via open calls (entities)	-	12	61	-	-	78
Number of projects that expressed in the open calls	-	30	5	200	37	272
Number of selected projects	-	10	5	4	7	26
Number of active projects	-	10		4	7	21
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
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

5 USE-CASE AND BUSINESS EXPLOITATION ANALYSIS

This section provides an overview on the ICT-56 projects' intermediate business exploitation status and related aspects in terms of use cases. 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 16*. 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 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 a very early stage for 1 project.

Table 16: 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	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 leel of adoption of open standards and open solutions)				VEDLIoT IoT-NGIN INTELLIOT INGENIOUS ASSIST-IoT	TERMINET
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 17*), 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 on a reasonable and reachable period.

Table 17: 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	• **INTELLIOT**: over 3 years 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 Figure 11 and Table 18. Given that the projects are at an intermediate stage of development, the numbers provided reflect an average across all projects and are indicative, requiring a thorough analysis per product on the next and final deliverable of T5.3.

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, are not as significant.

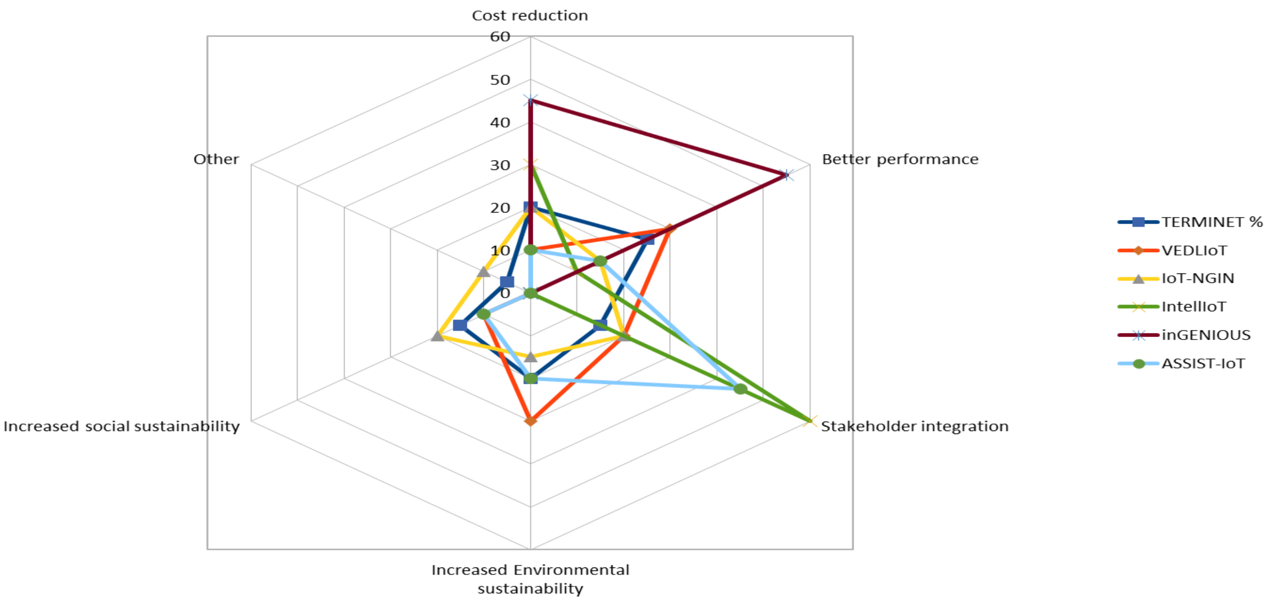

Figure 11: Indicative and relative distribution of benefits per project.

Table 18: 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

Item%	TERMINET	VEDLIoT	IoT-NGIN	INTELLIOT	INGENIOUS	ASSIST-IoT
Increased social sustainability	15	10	20	0	0	10
Other	5	0	10	0	0	-

5.2.3 Expected Products, Quantitative Characterization

The expected projects per project are provided in Table 19. Three projects expect to provide a large number of products (over 10), while 2 expect between 5 and 10 projects. 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 19: Number of expected products per project.

Item	Project	Comments
Less than 5	INTELLIOT	**INTELLIOT:** one framework with multiple components.
Between 5 and 10	VEDLIoT 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 IoT-NGIN ASSIST-IoT	**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. **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 20 reflects the competitor characterization provided per project. five projects signal having more than 7 competitors (indicative average across all products). Projects such as ASSIST-IoT have already developed a full competition characterization. Moreover, a few projects have also started an initial analysis of competitors. An adequate characterization of competition is relevant to ensure a low time-to-market, for projects that are proposing a large number of products.

Table 20: Qualitative characterization of competitors across all projects.

Item	Project	Comments
None		
Less than 3		
Between 3 and 7	INGENIOUS	
More than 7	TERMINET VEDLIoT 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, Think-worx, and Salesforce IoT Cloud • **VEDLIoT**: averaged number across all products • **INTELLIOT**: multiple domains • **ASSIST-IoT**: D3.1 provides a thorough overview of the competition market for the solution as a whole and for the specific pilot sectors.

5.2.5 Technology Readiness Level of Products/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 21*. At the current stage, it is not possible to provide a comparison across all projects, as some projects 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 21: Current TRL levels.

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

TRL	TERMINET	VEDLIoT	IoT-NGIN	INTELLIOT	INGENIOUS	ASSIST-IoT
	Healthentia app theming)					
6	8 (Centralised Federated Learning System, FPGA acceleration, Distributed and Decentralised Blockchain Framework, Analytic Toolset for Forecasting Demand/Sales, Secure, distributed, and trusted data sharing framework, TERMINET AGROMIND Dashboard, TERMINET SDN Controller & Dashboard, Remote attestation tool)	1	Targeted for 5% of the KERs	6	1 (Smart IoT)	
7	7 (Vertical Application Orchestrator, Financial Modelling Toolset, Healthentia Clinical Dashboard, New Generation of RTU devices, IoT communication interface, Data composer, FINoT Platform)			1	1 (5GC)	
8	-	-	-	-	-	-
9	-	-	-	-	-	-

5.2.6 Overall Cost Distribution Estimation

A final characterization requested to the projects 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 22* and in *Figure 12*. Most costs are estimated to fall into personnel and infrastructure costs.

Table 22: Estimated and aggregate cost distribution rates of services/products, 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

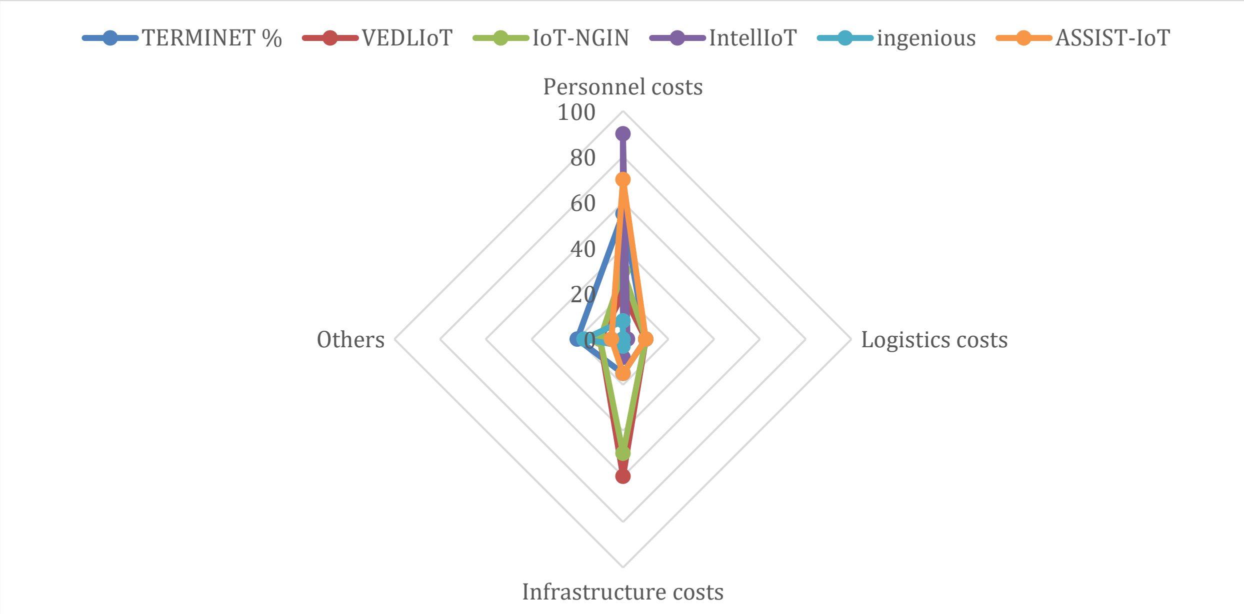

Figure 12: estimated and indicative cost distribution perspective beyond the project lifetime.

5.3 Summary

Across all projects, the following aspects have been identified as positive:

- Openness and interoperability are relevant criteria across projects.
- The qualitative characterization provided in section 5.1 shows that there is an overall good potential for business exploitation.
- five projects exhibit high levels of innovation in comparison to competitors.
- Business plan is at an intermediate stage for five projects, and at a very early stage for one project.
- TRL levels show a very good level of R&D maturity across all projects. Moreover, two projects (TERMINET and INTELLIOT) show an excellent level of technology maturity, mentioning many assets with high TRL (6-7).

Identified risks are:

- Greenness has been rated with less relevancy in comparison to other features across all projects, aspect that should be addressed in future business modelling and exploitation across all projects.

- 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 then to enter the market fast.
- The indicative distribution rate of expected benefits is similar across projects, in 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 products, running the risk of market potential fragmentation. The business modelling needs to consider such 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.
- 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.

6 HIGHLIGHTS ON PROJECT 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 23 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 3.2).

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 23: 5 key R&D contributions, e.g., scientific papers.

Project	List of publications
IoT-NGIN	• IoT meta-architecture (https://iot-ngin.eu/wp-content/uploads/2021/10/IoT-NGIN_D1.2_AALTO_V1.0_pending_EC_approval.pdf) • Machine Learning as a Service (https://iot-ngin.eu/wp-content/uploads/2021/11/IoT-NGIN_D3.1_v1.0_pending_EC_approval.pdf) • 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 Creden-tials.SafeThings 2022: IEEE Workshop on the Internet of Safe Things.2022", Safe-Things 2022: IEEE Workshop on the Internet of Safe Things.2022- 2nd Best Paper Award, https://safethings-2022.github.io/accepted_papers/safethings2022-final6.pdf • Secure execution at the edge: N. Eiling, J. Baude, S. Lankes, A. Monti, "Cricket: A virtu-alization layer for distributed execution of CUDA applications with checkpoint/restart support" Concurrency and computation 2021, DOI: 10.18154/RWTH-2021-06501
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 Cen-ters 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 Archi-tectural 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.

Project	List of publications
	Park, S. K. Kim, C. Yoon, K. Anwar, P. Seppänen, “Machine type communications: key drivers and enablers 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	• 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. This contribution reflects the NGIoT deployment human-centric via a single window-fashion framework to manage all aspects of the system (deployment, configuration, representation, results, users, network, devices…). It will be tested in the four UC of the project. • 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 and DOI: https://doi.org/10.1007/978-3-030-86359-3_32. This contribution shows how ASSIST-IoT will provide any NGIoT deployment to be self-healer, self-protected, self-aware, self-organised and self-configured as a system in an automated way, ranging from far edge devices to the cloud. It will be tested in the four UC of the project. • 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. This contribution provides co-living and co-operation of cybersecurity tools (authentication, identity management, threat detection) with modern DLT tools and concepts (Smart Contracts, logging, and auditing), in all nodes of the IoT deployment, all of that harmonised with data semantics to achieve sovereignty. It will be used in the development of every ASSIST-IoT component that will be integrated in the architecture and deployed in the 4 UC. • Alejandro Fornés-Leal, Ignacio Lacalle, Carlos E. Palau, Paweł Szmeja, Maria Ganzha, “ASSIST-IoT: A Reference Architecture for Next Generation Internet of Things”. Submitted to SOMET2022 conference. https://assist-iot.eu/wpcontent/ uploads/2022/02/ASSIST-IoT-Technical-Report-8-ASSIST-IoT-A-Reference-Architecture-for-Next-Generation-Internet-of-Things.pdf. The contribution reflects ASSIST-IoT blueprint architecture and will be used in the 4 UC. • Piotr Niedziela, Anastasiya Danilenka, Dominik Kolasa, Maria Ganzha, Marcin Paprzycki, Kumar Nalinaksh, “Sunday-FL – Developing Open-Source Platform for Federated Learning”. Submitted and published in IEEE Xplore: 2021 Emerging Trends in Industry 4.0 (ETI 4.0) – DOI: 10.1109/ETI4.051663.2021.9619338. This contribution Support the federation of learning to solve problems with AI under a collaborative, distributed fashion, sharing intelligence (models, results) among different nodes of an IoT deployment. It will be used in the 4 UC.
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.

Project	List of publications
	• 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.
VEDLIoT	• A. Khurshid, S. D. Yalew, M. Aslam and S. Raza, ShieLD: Shielding Cross-zone Communication within Limited-resourced IoT Devices running Vulnerable Software Stack. IEEE Transactions on Dependable and Secure Computing, 2022: The work describes some aspects of the security mechanisms developed in VEDLIoT. • M. Rothmann and M. Porrmann, A Survey of Domain-Specific Architectures for Reinforcement Learning. IEEE Access, vol. 10, 2022.: The work reports on the accelerator benchmarking and evaluation done within the project. • Hans-Martin Heyn, Eric Knauss, Amna Pir Muhammad, Olof Eriksson, Jennifer Linder, Padmini Subbiah, Shameer Kumar Pradhan, Sagar Tungal, Requirement Engineering Challenges for AI-intense Systems Development. 2021 IEEE/ACM 1st Workshop on AI Engineering - Software Engineering for AI (WAIN), May 2021.: The work describes the requirement framework developed within VEDLIoT and applied to the main project use-cases, especially the automative use-case • Jämes Ménétrey, Marcelo Pasin, Pascal Felber, Valerio Schiavoni, WaTZ: A Trusted WebAssembly Runtime Environment with Remote Attestation for TrustZone. 42nd IEEE International Conference on Distributed Computing Systems (ICDCS'22), July 2022.: The work describes some aspects of the security mechanisms developed in VEDLIoT. • P. Trancoso, F. Qararyah, S. Zouzoula, A. Casimiro, A. Bessani, J. Cecílio, S. Andersson, O. Brunnegard, O. Ekiksson, R. Weiss, F. Meierhöfer, H. Salomonsoon, E. Malekzadeh, D. Ödman, A. Khurshid, P. Felber, M. Pasin, V. Schiavoni, J. Ménétrey, K. Gugala, P. Zierhoffer, E. Knauss, H. Heyn, VEDLIoT: Very Efficient Deep Learning in IoT. Design, Automation and Test in Europe Conference (DATE 2022), March 2022.: The paper describes the overall VEDLIoT project and vision.
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

In addition to the relevancy of the mentioned scientific output, there are a few additional highlights relevant to mention.

A first innovation highlight concerns the setup of a spin-off of University of Western Macedonia (coordinator of **TERMINET**), "**METAMIND INNOVATIONS I.K.E**[9]" (rf. to section 4.1) The spin-off has been established in June 2021 by Prof. Panagiotis Sarigiannidis, Associate Professor in the Department of Electrical and Computing Engineering and by doctoral candidates who are

[9] https://metamind.gr

conducting research, financed by European and national funds, under his supervision. The research products that have been developed and are going to be utilized by METAMIND INNOVATIONS concern:

- Software tracking cyber-attack threats for critical infrastructures.
- Software activating a network of honeypots for critical infrastructures.
- Platform detecting irregularities (stress) in intelligent agriculture applications.

By exploiting the early outcomes of TERMINET, METAMIND has been invited by the Region of Western Macedonia[10] for providing precision agriculture services to farmers/producers and related start-ups of the region of Western Macedonia, Greece.

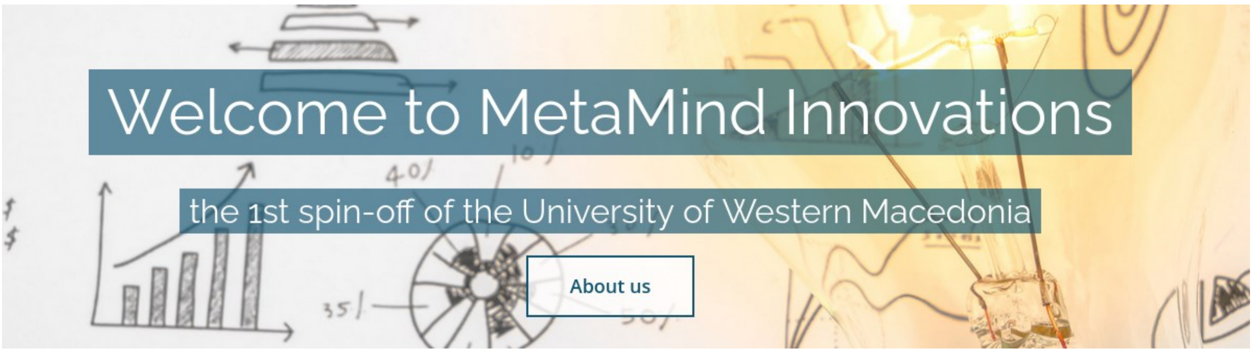

Figure 13: MetaMind Innovations, the first spin-off of University of Western Macedonia, supported by TERMINET activities.

For the specific case of remote monitoring in Precision Agriculture, METAMIND provides the Agrominds toolkit (see figure 14).

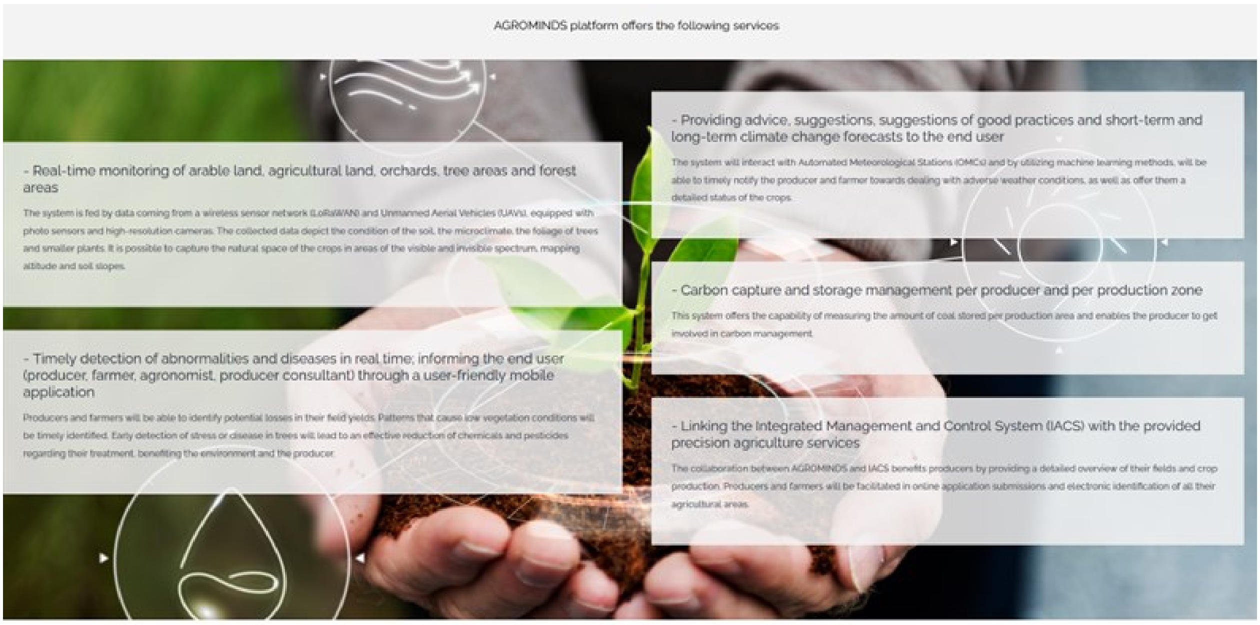

Figure 14: Agrominds toolkit supported by TERMINET.

[10] https://en.pdm.gov.gr

Another innovation highlight concerns the high TRL levels (6 and above) for technology of the projects TERMINET and INGENIOUS already achieved at the current stage. **INGENIOUS** will demonstrate all the described use-cases in real logistics and maritime environments: ports of Valencia and Livorno, robots' factory environment, and commercial COSCO ship. Currently, all of its use-cases have already been demonstrated in the lab environment, as is the case of the MTR INGENIOUS for control of AGVs[11], illustrated in *Figure 15*.

Figure 15: the INGENIOUS demo control of AGVs, MTR INGENIOUS.

A relevant highlight is also the development of the Medium.com "**Next Generation IoT Magazine**"[12] open blog by project INTELLIOT.

Figure 16: The medium.com Next Generation IoT magazine under development by project INTELLIOT.

[11] https://www.youtube.com/watch?v=wNmF1COX8go

[12] https://medium.com/next-generation-iot-magazine

Another highlight concerns the success of the open calls of project VEDLIoT, which have already resulted in the adoption of products for 10 new applications, of which we highlight the use of AIoT for pollen analysis, and automated harvesting for mushrooms[13], as these are representative of the use of advanced innovation in traditional industry.

Figure 17: VEDLIoT, the MushR project developed in open calls.

From IOT-NGIN, we highlight the available open-source contributions (TRL4-5)[14] in the context of cybersecurity.

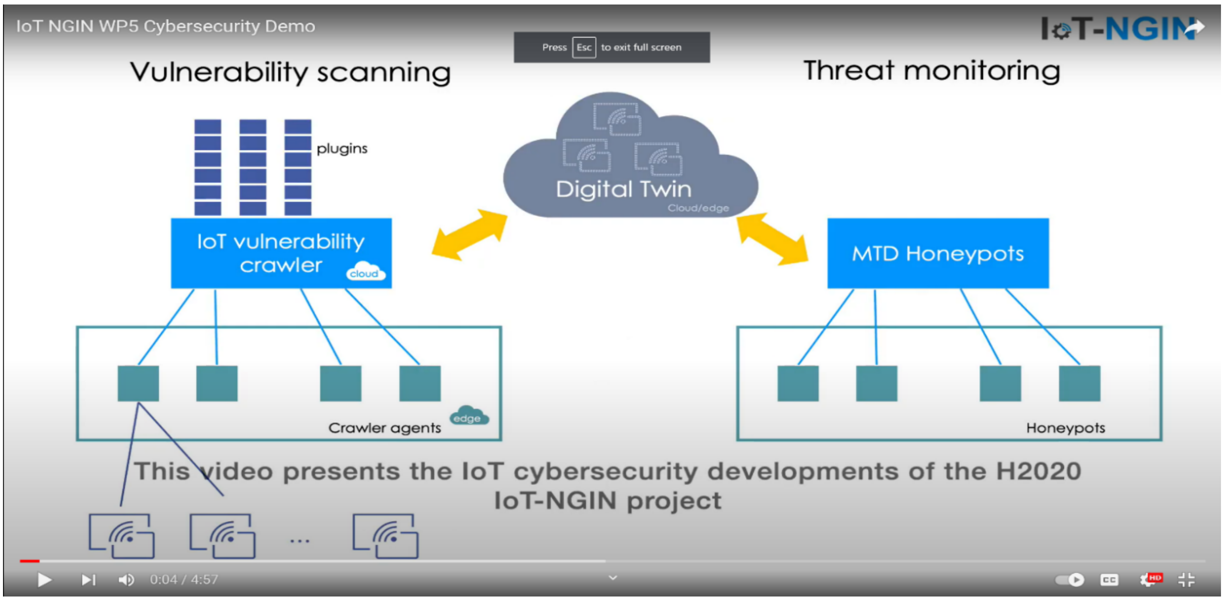

Figure 18: IoT-NGIN contribution in the context of cybersecurity

[13]https://etce-lab.com/index.php/mushr-a-smart-automated-and-scalable-indoor-harvesting-system-for-gourmet-mushrooms/

[14] https://gitlab.com/h2020-iot-ngin

ASSIST-IoT is developing several pilots ((i) Port Automation, (ii) Smart Safety of Workers and (iii) Cohesive Vehicle Monitoring and Diagnostics) where AR/VR, and AI/ML are used to improve the overall processing. We highlight the pilot concerning worker health and safety, and the recent use of AR/VR for EDBE alerts[15], as illustrated in figure 19.

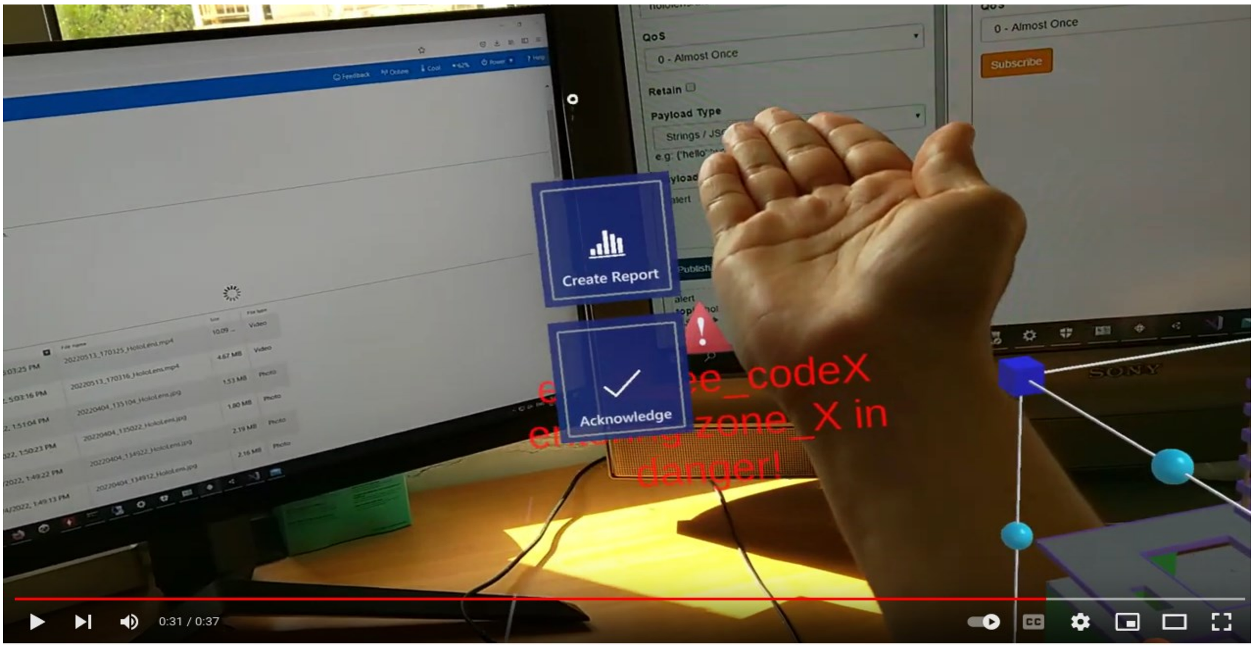

Figure 19: ASSIST-IoT, pilot for worker safety, AR/VR application to support alerts.

[15] https://www.youtube.com/watch?v=VeqICk1su1s

7 RECOMMENDATIONS TOWARDS IMPACT AND COLLABORATION

Based on the conducted qualitative and quantitative impacts analysis as well as the use cases and business exploitations aspects of all the ICT-56 projects, a set of recommendations and an action plan are provided and summarized in *Table 24.*

Table 24: Recommendations and proposed actions for the projects.

Nr	Description	Proposed action	Related sections	Related EU-IoT WP
Recommendations towards SDG Impact				
	Projects show a significant overlap in specific areas, which may lead to stronger impact towards SDG.	EU-IoT (WP5, WP2) can propose a set of events focused on the main overlapping areas, to bootstrap cooperation across different projects. All 6 projects seem to focus on security, privacy, and trust when developing their solutions and reference architectures as well as distributed AI/ML and Edge and Cloud computing; therefore, we foresee and recommend working together on these common themes to align the developed work, share experience and expertise, and/or complement each other work whenever possible.	3.3	WP2 and WP5
	Contributions towards consolidated knowledge in the form of book chapters and books is very low.	EU-IoT to assist the coordination of specific books (2) involving all projects	4.2	WP5 and WP3
	Overall, there is a good level of supported PhD and MSc students. Interaction across the students in different projects, e.g., via a Summer/Winter/Spring school will boost the impact.	EU-IoT to assist with the coordination of a joint Spring or Summer school in 2023	4.2	WP2, WP4
Innovation recommendations				
	Current level of concrete contributions to standardization is low	RIAs should reduce the effort in monitoring and consider the development of an action plan towards concrete SDOs, e.g., IETF EU-IoT can assist such consolidation by providing each project with a mapping of current SDG contributions towards open entities such as IETF, AIOTI, BDVA	4.3	WP3
	Projects are proposing open solutions for both software and hardware. However, several projects have the	Projects should consider keeping a single repository (e.g., under GitLab or GitHub)	4.4	WP3

Nr	Description	Proposed action	Related sections	Related EU-IoT WP
	assets under different partners	where all contributions could be available. EU-IoT will add the current projects to the open-source catalogue (WP3).		
	Open call results show that such tooling is relevant to boost adoption and increase impact of developed assets. However, usability aspects seem to be in an initial stage	Projects should consider extensions of open calls (e.g., hands-on events, tutorials) where usability of the products can be tested by third parties	4.5	WP2
	Skills training in open calls is not yet considered as relevant.	In traditional sectors such as manufacturing, SMEs are usually limited in terms of innovation skills. Skills training tools should be considered as a relevant asset that can assist adoption of products in ICT-56	4.5	WP4
Business Exploitation Recommendations				
	Business exploitation plans are still at either an early or intermediate stage of development, while projects express a proposed time-to-market between 1 and 3 years	Business modelling tools can assist projects in a better intermediate design of future exploitation	5.1	WP4
	Several projects expect to release many products (more than 10)	The business exploitation design needs to consider high fragmentation in terms of products, and address also tooling that may assist a better product integration to increase the chances of success	5.1	WP4
	Most ICT-56 projects state having a high number of competitors for their products across different domains. A few projects have already developed a thorough competition analysis	Projects should consider addressing a thorough competition analysis, to reduce potential barriers and ensure that the expected time to market can be reached	5.1	WP4
	Greenness is a lesser relevant factor in terms of business exploitation	EU-IoT (WP4) can assist projects in understanding how to integrate greenness as a key component of business exploitation.	5.1	WP4
	Initial estimates for cost distribution show a higher incidence in personnel and infrastructure.	Projects need to consider additional factors that may impact cost distribution, including distribution and dissemination aspects.	5.1	WP4

8 SUMMARY AND NEXT STEPS

This deliverable is an intermediate version of the deliverable D5.7 expected to be completed in March 2023. It focuses on applying the impact assessment framework proposed and validated as described in deliverable D5.5, by providing a second qualitative and quantitative analysis of the current and prospective state of assets, and business exploitation aspects of the ICT-56 projects. This analysis is not definitive as the projects started in October and November 2021 and are active until September (INTELLIOT) and October 2023. An exception is INGENIOUS, that will end in March 2023.

The conducted analysis created a comprehensive picture that depicts the dynamic dimensions of the EU-IoT cluster landscape through the ICT-56 flagship projects. It provided a qualitative impact assessment analysis toward sustainable development goals by identifying the common areas of the project's contributions and their inputs for each cluster based on a set of impact variables described in Deliverable D5.5. 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. An analysis for use-cases and business exploitation aspects were also provided. This analysis pointed out the overarching vision behind the business plan in terms of usability and interoperability where most of the projects are at an intermediate stage except for one which is in an early state. Besides, all projects show 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 have also been described in section 7, and which are summarized in *Figure 20*4.

The technological contributions have the potential to significantly impact the key competitiveness sectors in Europe with relevancy towards use-cases that concern Health, Climate, Energy and Mobility, Digital, Industry, and Space, and Agriculture. Societal impact and Civil security for society have been detected as areas with low contributions from ICT-56 projects. This was expected due to the nature of the ICT-56 projects.

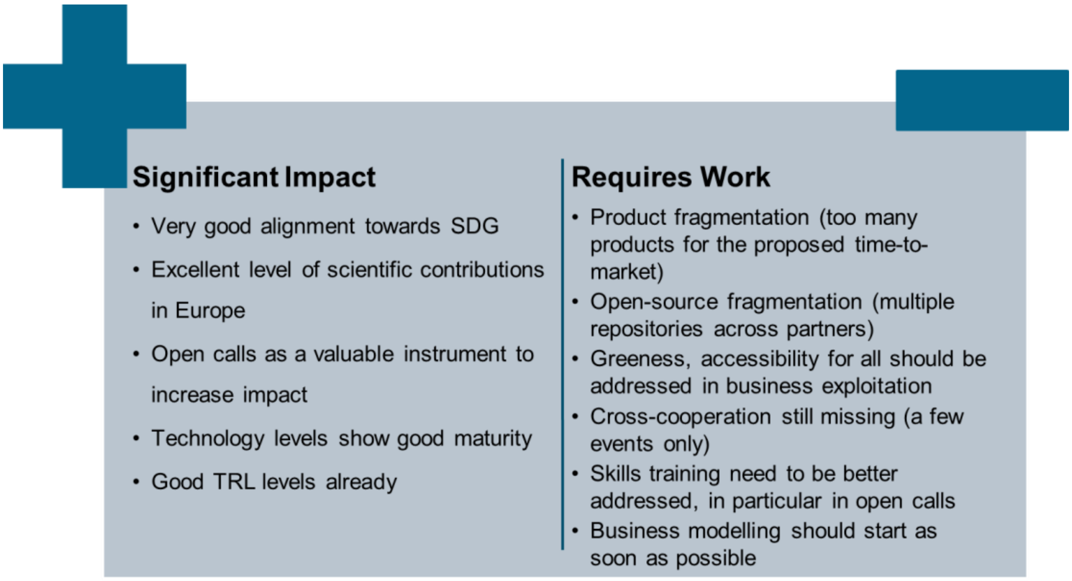

Figure 20: Summary of the impact assessment.

Overall, ICT-56 projects are progressing adequately and show an extremely good level of relevant scientific contributions in forefront areas such as AIoT, AI/ML integration and adoption across Edge and Cloud, across software and hardware. The projects support a significant level of PhD students, 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.

In terms of use-case and business exploitation impact analysis, 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 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.

The first next step for the work under development in T5.3 relates with the actions proposed in Table 21. An action plan with a concrete timeline until March 2023 will be developed, to understand how to best support the proposed actions.

Another step consists of collecting additional information in early 2023, to assess the further development of the projects, understand whether the proposed action plan is expected to bring benefits and understand, and analyze eventual benefits in more in-depth. Risk detection and mitigation will also be checked to derive the relationship between planned actions and desired impact.

Finally, Deliverable D5.7 due in March 2023 shall summarize the updated status and derive a set of recommendations and guidelines to enhance potential synergies between the projects or external entities, improve the level of knowledge sharing and establish cooperation between them, having in mind the final stages of the projects, after the closure of EU-IoT.

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10 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