



D7.2 Validation Report and Lessons Learnt

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List of Acronyms

Abbreviation / acronym	Description
AI	Artificial Intelligence
AutoML	Automated Machine Learning
CP-ABE	Ciphertext-Policy Attribute-Based Encryption
CSV	Comma Separated Values
DCBA	Device Continuous Behavioural Authentication
DoA	Description of Action
DPIA	Data Protection Impact Assessment
Dx,y	Deliverable number y belonging to WP x
EC	European Commission
EC	European Commission
EU	European Union
FIDES	Name of a pilot/platform (Blockchain-based Data Storage and Sharing)
GDPR	General Data Protection Regulation
KPI	Key Performance Indicator
LLM	Large Language Model
ML	Machine Learning
MLOps	Machine Learning Operations
MP4	Multimedia file format
NIST	National Institute of Standards and Technology
PAT	Privacy Assurance Tool
PDP	Policy Decision Point
PEC	Privacy Enhancing Component
PEP	Policy Enforcement Point
RENOPS	Energy optimization tool/platform
SEDSS	Self-encryption and Decryption with Multi-Factor Information Recovery Mechanisms
SSI	Self-Sovereign Identity
TRL	Technology Readiness Level
TSM	Trustworthiness Scoring Module
TXT	Text file
WP	Work Package
XAI	Explainable Artificial Intelligence

Executive Summary

Consolidating and integrating all the TANGO partners' efforts in terms of the framework's realization, this deliverable provides a comprehensive evaluation of the project's results and impact. It focuses on assessing the Technology Readiness Levels (TRLs) of individual components, evaluating the achievement of the Key Performance Indicators (KPIs) set for the framework's efficiency, and validating the platform's performance and results, as verified during its implementation in the different pilots and use cases. Its' main focus is to show how the core directions set by the project - security, trustworthiness, and energy-efficiency in information sharing - have been ultimately achieved, particularly in a multifaceted domain involving different industries, multiple partners and varied technologies. The Deliverable can be considered a verification report of the alignment with the project's objectives described, in the Description of Action (DoA), and with the requirements identified in Work Package 2 (WP2).

To facilitate the assessment of results, the methodological framework followed is based on structured questionnaires for both the TRLs and KPIs evaluation. This data collection strategy ensures consistent, transparent and evidence-based reporting for all partners. Through this approach, the partners can provide detailed insights about the components and respective technologies used. Therefore, the systematic tracking of KPIs across all Work Packages is reinforced by partners' insights on the integration progress, component functionality, validation environments, repeatability, and end-user feedback. The quantitative input is further complemented by qualitative input from partners during the final validation phase, thereby offering a comprehensive review of TANGO's feasibility and usability.

The core findings of this deliverable highlight the maturity status of each component and the achievement of measurable impacts. As analyzed, many components like privacy-preserving technologies, AI-based analytics, and blockchain-based information sharing progressed gradually to higher TRLs, with several reaching TRL 7, after being successfully implemented in the pilots. Furthermore, the KPI analysis verifies that most of the measurable objectives have been achieved or even exceeded, like for example the deployment of multiple privacy assessment tools, the delivery of energy-efficient AI and blockchain solutions, or the integration of more than ten trustworthy digital technologies. Lastly, this successful integration underlines the important achievement of turning scientific inputs to validated outputs, prototypes, and solutions, tested in live, actual diverse environments, from finance and mobility to hospitality and retail or manufacturing.

In summary, the deliverable attests that TANGO has achieved most of the intended technical project milestones and offered value to the stakeholders involved. The structured KPI and TRL assessments offer a clear overview of the project's impact, providing valuable input for future exploitation strategies. The lessons learned identify potential barriers and future enhancements necessary to ensure the project's sustainability. Ultimately, the results presented in this deliverable position TANGO as a highly promising platform for wider adoption, offering interoperability, trustworthiness, and energy efficiency in the innovative EU digital spaces.

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1 Introduction

1.1 Purpose of the document

Deliverable 7.2. “Validation Report and Lessons Learnt” provides a consolidated overview of the TANGO Project’s outcomes and impact. It also forms the basis for discussion on how such an innovative framework can be further developed and play a vital role in the EU’s digitalization initiatives. The document’s objective is to provide a structured overview of TANGO’s architecture performance, value creation, and technological maturity.

Aligning with the project’s roadmap and the Description of Action (DoA), the deliverable explores the Technology Readiness Levels (TRLs) of the individual TANGO technological components, it evaluates their performance against the designated per component Key Performance Indicators (KPIs), and ultimately it validates the proposed technical solutions deployed across the seven use cases and pilots. This process ensures that all results are evaluated against predefined benchmarks and technical requirements, guaranteeing that TANGO’s deliverables align with specifications such as interoperability, privacy, trust, energy efficiency, and the responsible use of Artificial Intelligence (AI), including Explainable AI (XAI).

Apart from the technical validation, this document’s objective is also to showcase the regulatory, societal, and business applicability of TANGO’s outcomes. User acceptance, evidence of usability, lessons learned, and proof of the platform’s responsiveness to real-world use cases (i.e., hospitality, manufacturing, retail, automotive, finance) are also highlighted in the document. By incorporating pilot feedback with users’ feedback, the deliverable discusses the ability of the Tango platform to expand to comply with frameworks, such as the upcoming EU AI Act [1] and GDPR and the EU Digital Sovereignty goals.

Finally, the deliverable offers projective insights into how the assessed results could support TANGO’s future development strategy and sustainability roadmap. By bringing together measurable results and market impact with technical achievements, the deliverable positions TANGO as a trusted platform that leverages next-generation digital services and technologies enabling secure, interoperable and energy-efficient data exchange, while contributing to the development of the EU’s innovation ecosystems.

Summing up, the objective of the document is to:

- Examine the technology readiness level (TRL) of the TANGO individual technological components
- Evaluate and validate the TANGO proposed technical solutions against the KPIs and requirements identified in the context of WP2
- Verify that the targeted KPIs have been successfully met
- Present the results of the overall TANGO solution validation and demonstrate its value proposition related to the seven distinct use cases/pilots.
- Present the results of the usability assessment and user acceptance evaluation of the solution.
- Conduct a comprehensive analysis of the overall results, identifying lessons learned and aiming to inform the TANGO exploitation strategy and plan.

1.2 Relation to other project work

Deliverable 7.2. “Validation Report and Lessons Learnt” aligns with the TANGO Project’s roadmap and the Description of Action (DoA), focusing on assessing the project’s results and validating its strategic objectives. The document builds on the architectural specifications and requirements defined in WP2 “System Requirements and Architecture”, as per Deliverable D2.4 [2], which provides the reference framework against which both KPIs and TRLs are assessed. Consequently, the deliverable acts as a connector between the early-stage conceptualization and the final implemented solutions validation, ensuring that the early designed functionalities have not only been deployed but also were verified against quantitative performance criteria.

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Moreover, the document explores the technical offerings and outcomes as defined in WPs 3, 4 and 5, where the TANGO framework's components were designed, expanded, and incorporated. These two WPs offer the material on which input and evidence for the TRL and KPI assessment is presented in this document. Additionally, the user acceptance and technological elements' maturity of the platform are confirmed using as analysis basis the remarks on validation, usability, and feedback found in WP6 (Integration and Testing) and WP7 (Pilots and Validation).

Lastly, apart from the technical references, the deliverable also makes references to the sustainability planning and exploitation as mentioned in WP8, since the TRLs, KPIs, and lessons learned are important aspects of TANGO's market positioning, value proposition, and future strategy. As such, during the project's lifecycle, this deliverable ensures coherence and continuity, and it demonstrates the importance of combining scientific excellence with commercial and market relevance.

1.3 Structure of the document

This Deliverable 7.2 is designed using a structure that helps the reader (reviewer, project managers, industry experts, regulators, and anyone that might want to understand TANGO's effectiveness) move logically from the methodological tools used to the actual results and learned lessons. It ensures alignment with the TANGO Roadmap and the DoA. Specifically, it is separated into distinctive, progressively elaborating, sections. Specifically:

- **Section 1 (Introduction):** It defines the overall deliverable objectives, the document's structure, and relations with other project work.
- **Section 2 (Methodological Framework):** "It presents the selected approach to TRL and KPI assessment, the structured questionnaires used for the analyses, the validation steps, and the core benefits of the process.
- **Section 3 (Technology Readiness Levels (TRLs)):** It provides an overview of the EU projects' TRL assessment along with a detailed, individual TRL evaluation per TANGO technology offering and component. It is enriched with the stakeholders' direct input and validation.
- **Section 4 (Key Performance Indicators (KPIs)):** It provides detailed reporting per KPI identified in the project; it presents their progress and links the achievements to the project's objectives.
- **Section 5 (Validation):** It provides both a qualitative and a quantitative verification of TANGO's framework, exploring the pilot implementations, the platform's operational performance, and the extent to which the proposed solution delivers real value to stakeholders.
- **Section 6 (Lessons Learned):** It presents a synopsis of the pilots' TRLs and KPIs assessment, with summarized insights, and future recommendations for sustainability and exploitation.
- **Section 7 (Annexes):** It provides complementary and detailed material related to the assessments, as well as proof of successful implementation of different components in the pilots, as provided by the partners. In total, the deliverable goes beyond documented results and explores qualitative aspects, such as the user friendliness and developers' barriers, making the assessment process clear, impactful, and evidence based. It serves as a seamless navigation roadmap linking methodology, validation, and results and providing an insightful report for the reviewers and broader audience.

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2 Methodological Framework

2.1 Introduction

As the TANGO Project involves multiple stakeholders and integrated tools and components, a definite challenge occurred: To efficiently collect reliable information across the project's partners that will be then provide a high-quality resource to draw further assumptions and conclusions. Early in the Deliverable's conception, the approach of structured questionnaires [3] was adopted as the optimal methodology to extract accurate and harmonized data, directly from the partners involved. The basic objective of this section is to explain the structured approach adopted in D7.2 for assessing the Technology Readiness Levels (TRLs) and Key Performance Indicators (KPIs) across all TANGO components and technology offerings. Given that the first part of this deliverable is dedicated to the analysis of TRLs and KPIs, this section focuses mostly on describing the methodology behind their collection, validation, and consolidation. The approach followed ensures that the results presented at a later stage are consistent, evidence-based, and comparable across the project's clusters and technical domains.

By adopting a unified methodology, the project ensures that reported KPI achievements and maturity levels can be directly traced to stakeholder feedback, documented evidence, and deployment activities in the pilots. The methodology also provides a clear audit trail for future reference, enabling reviewers and auditors to verify the validity of the results.

2.2 Principles of the Selected Approach

Across multiple EU-funded projects, the KPI measurement and TRL assessment are established practices for tracking their progress and effectiveness. As it will be described in detail in the following chapter "Technology Readiness Level advance per TANGO component", the European Commission's Horizon Europe TRL framework [4] provides a standardised nine-level scale for assessing technology maturity. It spans from basic principles (TRL 1) to full commercial deployment (TRL 9). In parallel, KPIs are used to evaluate the extent to which project-specific objectives, as outlined in the Description of Action (DoA), have been achieved.

Considering that TANGO is a multifaceted project involving and combining different, cutting-edge technologies such as data spaces, AI/ML, blockchain technology, energy optimization and strict regulatory frameworks (e.g., GDPR [5]), the consortium demanded a comparable, uniform, and transparent methodology to collect the KPI and TRL data from all involved stakeholders. The Structured Questionnaires were selected as the basic tool to tackle the task. The methodology offers the necessary:

- **Consistency:** Same criteria are used for all respondents thus reducing misinterpretations and enhancing the incoming data quality.
- **Focus on evidence:** For each claim stated in the responses, partners must support it by referencing it to deliverables, screenshots, test results, or logs.
- **Traceability:** Each TRL/KPI entry is linked to specific work packages, tasks, and pilot activities.
- **Consolidation and Integration Efficiency:** The standard-based questionnaire format allows straightforward aggregation and structured integration to the deliverable, providing clear alignment with the partners' and technologies' objectives.

2.3 Collecting the TRL/KPI Information

This section analyses the approach followed to collect information for D7.2. The methodology, from a broader perspective, includes a 3-step set of activities. The main goal was not only to collect quantitative information, but also to include the qualitative perspective of involved partners. Only by combining these two approaches can the lessons learned be accurate and provide insights into efficiency, barriers,

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and future proposals to further enhance TANGO, and similar frameworks. In brief, the following figure (Figure 1) presents the framework of the selected approach:

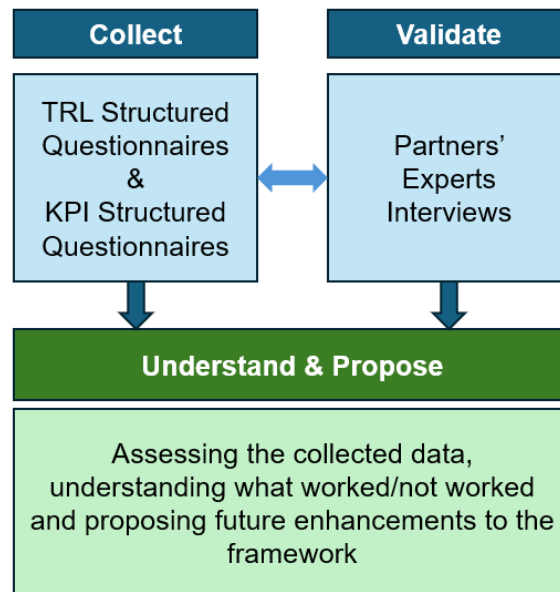


Figure 1: D7.2 selected assessment approach framework.

2.3.1 Technology Readiness Level (TRL) Structured Questionnaire

To assess the TR Level, a structured template was distributed to all component leaders. The questionnaire followed the prerequisites of the EU TRL definition [4] and included the following evaluation criteria:

- **Functionality:** The degree to which the component meets the functional requirements
- **Integration:** How interoperable is the component/technology with other TANGO components.
- **Validation Environment:** Description of the deployment in pilot or simulated conditions.
- **Repeatability** – reproducibility of results across trials.
- **User/Stakeholder Feedback:** The feedback section enables partners to assess and describe what worked/did not work in the developed component.

The partners could provide a weighted score from 1 to 5 (1 being low applicability and 5 being high applicability), together with evidence, such as online repositories, screenshots, deliverable sections, and test logs, showing that the component worked or not. An open-text section allowed for justifications and additional remarks. This approach enabled not only the calculation of the final TRL per component, but also a qualitative understanding of its evolution from the project start to post-pilot validation. The TRL Questionnaire template can be found in the present deliverable's Annex 9.1.

Additionally, to further assist the partners and receive optimal results, a detailed instructions document was also distributed, together with the Questionnaires. The document guided step by step the respondents on what and how to provide their content thus further enhancing the data quality of their responses (and consequently TANGO's lessons learned quality). The questionnaire's guideline can be accessed in the present deliverable's Annex 9.3.

2.3.2 Key Performance Indicators (KPIs) Tracking Structured Questionnaire

The KPI assessment was also performed by using a dedicated structured questionnaire. The questionnaire was sent to the responsible WP leaders or component owners, as described in the DoA for all KPIs defined. The questionnaire captured:

- **KPI identification:** It included the target KPI, the verification means, the responsible WP and relevant objective, the KPI's baseline, and the final status achieved.

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- **Justification:** It enables the respondent to describe how the KPI was achieved, including technical work and validation activities.
- **Comments / remarks:** It allows the respondents to assess the component's KPIs and highlight deviations, lessons learnt, or influencing factors.
- **Evidence:** As with the TRL Structured Questionnaire, the respondents can provide screenshots or other KPI proof, labeled with a unique ID for traceability.

The format ensured consistency, comparability, and evidence-based validation of all KPIs, simplifying consolidation and review. The KPI Questionnaire template can be found in the present deliverable's Annex 9.2.

2.3.3 Benefits of Methodology

Using the layered approach described in Figure 1 which combines structured questionnaire responses with a qualitative validation process, the Deliverable ensures clarity for the TANGO consortium, including partners and reviewers:

- **Harmonization:** Clarity in assessing the progress, the component maturity and the performance across diverse technologies, partner clusters, and pilots.
- **Traceability:** Traceability from reported metrics to documented evidence, highlighting what worked and what did not work, including the users' experience and perspectives on the framework.
- **Standardized Scoring:** Reduced bias in self-assessment scoring criteria as each partner evaluates its component in the same standardized way.
- **Alignment:** Project objectives and reported achievements remain consistent across stakeholders, supporting a clear evaluation of TANGO's effectiveness.

The 3-layer selected methodology not only underlines the credibility of the TRL and KPI analysis in this deliverable, but also provides a replicable model for future large-scale, multi-partner innovation projects.

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3 Technology Readiness Level advance per TANGO component

3.1 Introduction

Developed by the US National Aeronautics and Space Administration (NASA) in the 1970s to assess the preparedness of space innovations, the Technology Readiness Level (TRL) framework [6] has since become a broadly recognized standard in both private and public Research and Development (R&D) clusters for evaluating investment strategies, assessing risks in applied innovation, and measuring performance [6]. Therefore, the TRL framework offers a designed and robust methodology for evaluating and communicating to stakeholders the capabilities of a given technology throughout its lifecycle—from initial concept to design and full operational deployment.

3.2 TRLs and the European context

For projects funded by programs, such as Horizon Europe or Horizon 2020, the European Commission (EC) uses TRLs as the standard tool to assess and compare the technological maturity of systems or components developed within projects. The EC specifies a nine-point TRL scale [4], spanning from TRL1 (status where basic principles are observed) to TRL9 (operationally proven and ready), defining specific criteria for each level [4]. Figure 2 presents the 9-level TRL scale along with definitions per level.

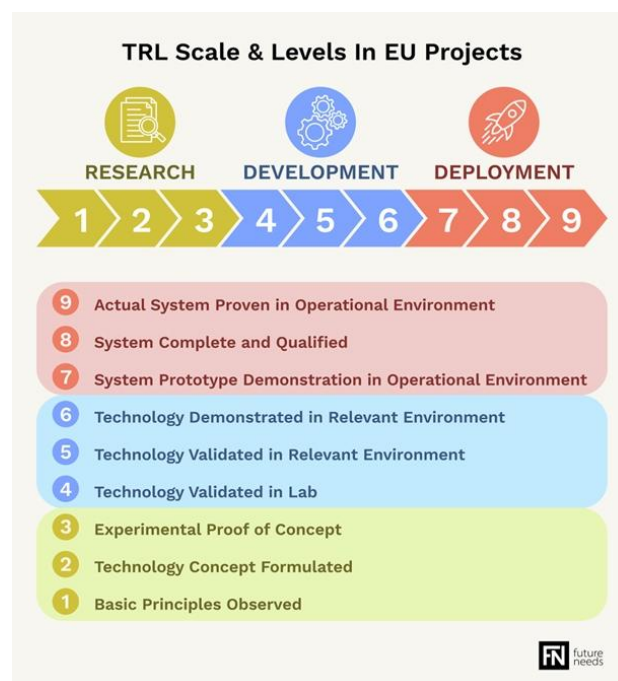


Figure 2: TRL scale in EU projects (Source: [Technology Readiness Level \(TRL\): Your Key to EU Funding](#)).

TRL assessment is a valuable tool for collaborative projects like TANGO, as it captures the effectiveness and readiness of diverse technological components and solutions at different development stages, towards their integration in the TANGO's framework. Using the TRL framework, the external evaluators and consortium stakeholders can:

- Showcase measurable results towards innovation implementation goals.
- Stress out dependencies or barriers among subsystems.

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- Check and record the progress of the pilots within the project's Work Packages.
- Identify and follow up on realistic evolution goals.

In the TANGO project, this is important as different and diverse technologies, such as privacy-enhancing components, self-sovereign identity systems, federated learning, infrastructure orchestration frameworks, and behavioral authentication modules are developed and integrated. These modules are introduced at different stages of the project; therefore, they have varying TRLs during testing, development and validation within the pilots.

3.3 Application of TRLs in TANGO Project

Using TRLs to evaluate TANGO systems readiness assists in multiple ways the project's lessons learned, apart from the technological evaluation:

- It assists all stakeholders, including external ones like the evaluators, policymakers, or industries' representatives, to clarify the maturity gaps between actual implementation and research.
- It coordinates technical progress with actual market strategy and compliance with regulations like GDPR [5] or eIDAS [7].
- It ensures the connection and accountability between different innovations evolving across different Work Packages (e.g., TO13 – Privacy Threat Modeling, TO3 – Confidentiality and Privacy by Design, and TO7 – Behavioral Authentication).
- It provides clarity and transparency when measuring progress across the different technologies developed.

Consequently, for a project like TANGO, which aims to develop trustworthy, high-quality, sovereign, and secure information ecosystems, it is crucial to have a validation mechanism and/or tool to evaluate the adoption readiness, compliance, and scalability of offered technologies. Implementing the TRL methodology supports TANGO, a deployment-focused project contributing to the EU Digital Strategy, IDSA and GAIA-X [8] Data Spaces, and EC policy frameworks.

3.4 Overview of TRL Advances per TANGO technology offering

In this chapter, a structured synopsis of the TRL development across the TANGO technological components is provided. From orchestration frameworks and behavioral authentication to privacy-preserving infrastructures or federated AI, each Technology Offering (TO) is introduced in the project at different TRLs. Throughout the project and by being pilot validated and integrated, it aims to advance to a higher TRL. By charting these advances, we underline TANGO's input in closing the gaps between actual deployment in real-world conditions and state-of-the-art research.

The TRL development is updated by using case testing, experimental acceptance, and, above all, stakeholders' input between the different TANGO's operational pilots. The synopsis also underlines the components' deployment maturity and cross-sector application. The chapter emphasizes verifiable and measurable progress aiming to showcase the project's alignment with Horizon Europe's innovation objectives. It serves as a point of reference for innovation assessors and technical reviewers. Table 1 describes and summarizes the TRL status of the different TOs, supported by results from WP evaluations.

Table 1: TANGO Technology Offerings status overview.

REF	Technology Offering	Starting TRL	Target TRL	Final TRL Achieved
TO1	Blockchain-based Data Storage and Sharing: The Fides ecosystem (TRL4) is governed by a consortium of participants in financial services who can securely exchange documentation via advanced	TRL2	TRL7	TRL7

REF	Technology Offering	Starting TRL	Target TRL	Final TRL Achieved
	distributed technologies, including blockchain. Through TANGO , the Fides ecosystem solution will be leveraged across multiple sectors and not only in banking, reaching TRL 7.			
TO2	Trustworthy Data Sharing: Trustworthiness (TRL 4) will be extended in TANGO . Demonstration of the approach and metrics provide a starting point for extension and generalization of the use case of trustworthiness into distributed privacy-preserving data sharing mechanism reaching TRL6.	TRL 4	TRL 5-6	TRL 5
TO3	Confidentiality and Privacy by Design: From TRL4, this work will leverage the algorithms in the state of the art to enable high level data usage control privacy policies. TANGO will utilize them to realize a set of concrete data usage control policies and integrate the privacy preserving technologies reaching TRL6.	<ul style="list-style-type: none"> • PEP/PDP: TRL4 • CP-ABE: TRL3 	<ul style="list-style-type: none"> • PEP/PDP: TRL6 • CP-ABE: TRL6 	<ul style="list-style-type: none"> • PEP/PDP: TRL6 • CP-ABE: TRL6
TO4	Self-encryption and Decryption Techniques with Multi-Factor Information Recovery Mechanisms: Currently the module is at TRL 3. TANGO will enhance self-encryption with recoverability. Through TANGO , the technology will be deployed in relevant environment given the four pilots in WP7, allowing the technology to reach TRL6.	TRL3	TRL3	TRL3
TO5	Self-sovereign Identity Management: The Module is currently at TRL3 and it will advance to TRL6 through incorporating additional trust-based attributes and compatibility with other identity mechanisms (eIDAS, OpenID, etc.)	<ul style="list-style-type: none"> • SSI-ZKP: TRL3 • SSI Agent: TRL3 • SSI Wallet: TRL6 	<ul style="list-style-type: none"> • SSI-ZKP: TRL6 • SSI Agent: TRL3 • SSI Wallet: TRL6 	<ul style="list-style-type: none"> • SSI-ZKP: TRL6 • SSI Agent: TRL3 • SSI Wallet: TRL6
TO6	Seamless Onboarding for Users & Devices: Currently the module is at TRL3 being validated in relevant environment. During TANGO the technology will be demonstrated in relevant environment across 5 use cases reaching TRL6.	TRL3	TRL6	TRL6
TO7	User continuous behavioural authentication: The user continuous behavioural authentication is currently at TRL 5 stage and has already been validated in the retail/manufacturing domains. Within TANGO the technology will be enhanced with dedicated risk scoring APIs	TRL5	TRL7	TRL7

REF	Technology Offering	Starting TRL	Target TRL	Final TRL Achieved
	and SDKs and improved AI models leveraging behavioural patterns such as keystroke dynamics, mouse movements, device holding and touchscreen interactions, and will be demonstrated in an operational environment, aiming to reach TRL7.			
TO8	Device continuous behavioural authentication: In the context of TANGO , the device continuous behavioural authentication solution (TRL 3) will leverage sensor and network traffic to continuously assess the device and detect any potential anomalies in the behaviour of the device, which will be validated in the defined use cases (TRL6).	TRL3	TRL6	TRL6
TO9	Hardening against Side-channel Attacks: The compiler that already supports the code polymorphism countermeasure is currently at TRL 3 for RISCv and ARM v7m. At the end of the project, the compiler should reach a TRL of 6, as one or several of its artifacts will be used in a significative environment.	TRL3	TRL6	TRL6
TO10	Exploratory Data Analysis Engine: The Exploratory Data Analysis engine will start from a TRL4 relying upon other projects, where sensitive data were analysed. The newly developed module is expected to reach a TRL7, within TANGO , and will be demonstrated in an operational environment.	TRL4	TRL7	TRL7
TO11	Energy efficient AI model training: The solution will be based on open-source AutoML solutions, which is already available to be used and validated with real use-cases. During the project, the new functionalities will be implemented and validated by the different use-cases, reaching TRL 6.	<ul style="list-style-type: none"> • AutoML: TRL3 • Federated Learning: TRL2 • MLOps: - 	<ul style="list-style-type: none"> • AutoML: TRL6 • Federated Learning: TRL6 • MLOps: TRL6 	<ul style="list-style-type: none"> • AutoML: TRL4 • Federated Learning: TRL6 • MLOps: TRL6
TO12	Dynamic Intelligent Execution on Heterogeneous Systems: TornadoVM is at TRL 7 with PoCs being developed for commercial applications. The improvements of TornadoVM in the context of TANGO will assist towards complementing the necessary missing features required for commercial offerings.	TRL 3	TRL5	TRL5

REF	Technology Offering	Starting TRL	Target TRL	Final TRL Achieved
TO13	Privacy Threat Modelling and Identification for Trustworthy AI: TANGO aims to develop a TRL6 privacy enhancing tool utilising the NIST Privacy Framework [9] (TRL2) to identify, assess, prioritise, mitigate and convey privacy-related risks associated with the collection, processing, storing and sharing of data.	<ul style="list-style-type: none"> • PAT: TRL1 • PEC: TRL1 	<ul style="list-style-type: none"> • PAT: TRL5 • PEC: TRL6 	<ul style="list-style-type: none"> • PAT: TRL5 • PEC: TRL6
TO14	X-AI for Privacy and Trust Enhancement: The XAI module has been partially implemented for financial institutes targeting the explainability of credit risk scoring. AI methods including Knowledge Graphs will be tested, combined with ML to enhance the decidability process related to the responsibility, validity and trust of AI systems (TRL6).	TRL3	TRL6	TRL6
TO15	Infrastructure Management based on AI: The resource management components (xOpera orchestrator) that can be used are currently at the TRL7. The monitoring framework is based on Wazuh (TRL4). The expected improvements of the approach in terms of its resource use will reach TRL 6. The AIOps approach at TRL3, with several algorithms, approaches already been developed. The research performed should raise the expected combined TRL to TRL6.	Different components with different TRLs: <ul style="list-style-type: none"> • The resource management components (xOpera orchestrator) - TRL7. • The monitoring framework based on Wazuh – TRL4). • The AIOps approach - TRL3. 	TRL6	TRL6

The TRL progress reported for each TO showcases clearly how the components will precisely support the project’s overall capabilities and potential. As each TO matures, the overall TANGO framework is enhanced in all its’ levels like interoperability, functionality, adoption readiness, and deployment to real-world applications capability. Combined, the TOs prove TANGO’s effectiveness to deliver for all pilot clusters a trustworthy, robust, and privacy-preserving framework.

3.5 TRL Evaluation per Technology Offering

In this chapter, the detailed Technology Readiness Level (TRL) assessments for each TANGO Technology Offering (and its components) as provided by the stakeholders, are aggregated. The information derives from the structured TRL questionnaires, as presented in previous chapters, ensuring that the input provided is consistently validated and evidence based. Each subsection within this chapter analyzes the initial, target and final TRL, together with details based on validation, integration,

stakeholder feedback, and functionality. The partners are prompted to offer evidence if available, accepting either direct references to material or a boolean Yes/No response, especially when the material is available in the additional material section of their responding questionnaires (as included in the annex 9.7 of this deliverable). All these detailed records per component offer a clear view of the technological advancements achieved per pilot and how they contribute to TANGO's overall objectives. The accuracy and validity of the information provided is a sole responsibility of the partners providing it. To avoid confusion in the document's structure, the partners' questionnaire responses are incorporated in the deliverable without being captioned since they are repeated for the each different TRL and are associated directly with it.

3.5.1 Blockchain-based Data Storage and Sharing

The following TRL assessment for Blockchain-based Data Storage and Sharing was provided by Norbloc AB (TANGO "NOR"), based on the structured TRL questionnaire. The entry includes the initial TRL at project start, the planned target TRL, and the final TRL achieved after pilot validation, supported by evidence on functionality, integration, validation environment, repeatability, and user or stakeholder feedback. Further details and evidence can be found in Section 9.7.1 of Annex 9.7 in this deliverable.

3.5.1.1 Component Identification for Blockchain-based Data Storage and Sharing

Component Identification	Component details
Component Name	Fides v3 (Blockchain-based Data Storage and Legally Compliant Data Sharing)
WP / Task	3 / 3.1
Lead Partner(s)	Norbloc AB (NOR)
TRL Contact Person (Name, Organization)	Vitalii Demianets, Chief Architect & Co-founder at Norbloc AB

3.5.1.2 TRL Assessment Table for Blockchain-based Data Storage and Sharing

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	Tango Pilot Manual - Fides Journey (PDF)	5	Fides satisfies all functional requirements as per pilot scope (data submission, validation, approval).
Integration	Has it been integrated with at least one other TANGO component?	No	1	No integration
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	<ul style="list-style-type: none"> - Tango Pilot Manual - Fides Journey (PDF) - https://tango-c.norbloc.com/sancus-mgmt - https://tango-a.norbloc.com/sancus-mgmt 	5	Deployed and tested in a realistic pilot environment. Note: All onboarding data used were 100% synthetic (fake data).

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
		- https://tango-b.norbloc.com/sancus-mgmt		
Repeatability	Were the results reproducible across multiple trials/tests?	Tango Pilot Manual - Fides Journey (PDF)	5	Repeated tests with multiple actors and data with stable and consistent outputs.
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	Evaluation Report	5	VISARIGHT and the responsible TANGO partners provided feedback after the live pilot testing. Also, they followed the standard evaluation process of TANGO.

3.5.1.3 TRL Level Summary for Blockchain-based Data Storage and Sharing

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	2
Target TRL (as planned in DoA)	7
Final TRL reached after pilot testing	7

3.5.1.4 TRL Justification for Blockchain-based Data Storage and Sharing

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	<p>At the start of the TANGO project Fides v3 was at TRL 2 - a formulated technology concept, with analytical studies and speculation but no experimental proof yet</p> <p>Fides v2, in contrast, was already a mature, commercialized platform in production (TRL 9) - fully operational in the financial services sector and actively used by major financial institutions in the United Arab Emirates for regulatory compliant KYC data sharing.</p> <p>In the duration of TANGO, that theoretical concept of Fides v3 system was implemented and deployed in a pilot scenario involving VISARIGHT and migration authorities, effectively serving as a standalone use case.</p> <p>By the end of the TANGO project, Fides v3 had advanced to TRL 7 (a system prototype demonstrated in an operational environment). Justification of TRL 7 criteria: a high-fidelity prototype that was deployed across multiple operational pilot sites (tango-c/a/b), repeatedly tested by different users with consistent, reliable results, and refined through several iterative cycles informed by</p>

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Task Description	Input provided
	VISARIGHT and migration authority feedback. All core functional requirements (data submission, validation, and approval) were satisfied in a real-world environment, demonstrating repeatable performance and effective risk mitigation. The pilot user feedback fully confirmed promised functionality of Fides v3.

3.5.1.5 Additional Comments / Remarks for Blockchain-based Data Storage and Sharing

Task Description	Input provided
Provide additional comments regarding the components' successful or unsuccessful TRL level, remarks and lessons learned from the process, if any	The pilot confirmed the applicability of Fides v3 beyond the financial sector, highlighting the importance of modular design and flexible data schemas.
Provide comments regarding the component's societal/organizational/ legal readiness level	The Fides v3 platform demonstrates a high level of organizational and legal readiness, being already deployed in regulated environments. It is GDPR-compliant by design [5] and supports full data subject control. The TANGO pilot further validated its adaptability to public-sector workflows, reinforcing its societal relevance for citizen-centric, cross-border use cases.

Summing up, during deployment in a TANGO Pilot involving VISARIGHT and migration authorities, the Fides v3 platform, developed under WP3 T3.1 by Norbloc AB, progressed from TRL 2 at project start to TRL 7. Building on the commercial maturity of Fides v2, Fides v3 was deployed as a high-profile prototype suited for legally compliant, cross-border information sharing, satisfying all operational requirements for validation, submission, and approval. The system was implemented, tested repeatedly with synthetic data and refined through feedback from pilot stakeholders. Even if no integration with other TANGO components was implemented, the pilot confirmed the solution's GDPR-compliant design [5], its adaptability, and its high legal and organizational readiness for citizen-centric use cases.

3.5.2 Trustworthy Data Sharing

The following TRL assessment for Trustworthy Data Sharing was provided by Fujitsu Services GmbH (TANGO "FSDE"), based on the structured TRL questionnaire. The entry includes the initial TRL at project start, the planned target TRL, and the final TRL achieved after pilot validation, supported by evidence on functionality, integration, validation environment, repeatability, and user or stakeholder feedback. Further details and evidence can be found in the respective Section 9.7.2 of Annex 9.7 in this deliverable.

3.5.2.1 Component Identification for Trustworthy Data Sharing

Component Identification	Component details
Component Name	Trustworthiness Scoring Module (TSM)
WP / Task	3 / 3.2
Lead Partner(s)	FSDE
TRL Contact Person (Name, Organization)	Jürgen Neises, FSDE

3.5.2.2 TRL Assessment Table for Trustworthy Data Sharing

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	D3.2 [10]	4	The module meets the functional requirements of FR-DATA-TDS-001 to FR-DATA-TDS-003. The 1 st one was confirmed using data from a realistic test-drive. Moreover, it is configurable related to the most relevant data to assess the Trustworthiness. Finally, the module has been prepared for further extension using AI.
Integration	Has it been integrated with at least one other TANGO component?	D6.2 [11]	5	The component has been integrated with the PEP
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	Should be part of the IDIADA Pilot description in D7.1 [12]	3	The component was used in a simulated environment based on real case CAN and video data resulting from a test drive. Due to the limited HW capabilities, analysis of the video data as well as the interpretation of the CAN data were performed in an external environment with similar operating system.
Repeatability	Were the results reproducible across multiple trials/tests?	Should be part of the IDIADA Pilot description in D7.1 [12]	4	The results can be used on the relevant CAN data after any extraction.
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	Should be part of the IDIADA Pilot description in D7.1 [12]	5	The demonstration was jointly developed with IDIADA the stakeholder of the Autonomous Vehicle pilot

3.5.2.3 TRL Level Summary for Trustworthy Data Sharing

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	TRL 4
Target TRL (as planned in DoA)	TRL 5-6
Final TRL reached after pilot testing	TRL 5

3.5.2.4 TRL Justification for Trustworthy Data Sharing

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	<p>The Trustworthiness Scoring Model (TSM) was validated in a manufacturing related environment using the fixed model of the IIC. Beyond this application scope we consider the technology in principle validated in lab for generic application. However, for the TANGO approach the technology needed to be extended for general applicability.</p> <p>Furthermore, it was adapted to apply vehicle CAN-data, a privacy risk scoring (provided by FHG) and – first time – integrated in a generic PEP.</p> <p>This way the TSM could be validate in the vehicle area using and interpreting realistic data.</p>

3.5.2.5 Additional Comments / Remarks for Trustworthy Data Sharing

Task Description	Input provided
Provide additional comments regarding the components' successful or unsuccessful TRL level, remarks and lessons learned from the process, if any	<p>The component successfully reached TRL 5 with all core features tested in a test environment. Further TRL development needs more capable in vehicle systems.</p> <p>Due to the system requirements for privacy risk analysis (GPU) and the necessary interpretation of CAN-bus data the implementation in the car's on board unit was not possible.</p> <p>Further iterations will focus on real-world interoperability and use cases as well as the integration of AI for configuration and evaluation.</p>
Provide comments regarding the component's societal/ organizational/ legal readiness level	<p>The component was designed to provide a light-weighted trustworthiness evaluation using flexible configuration and integrated with access management systems.</p> <p>With increasing capabilities of processing engines in vehicles, the system shall contribute to improved safety and privacy measures.</p>

Summing up, the, developed by FSDE, Trustworthiness Scoring Module (TSM) component progressed from TRL 4 to TRL 5 during the project. The module offered preparing for AI-driven extensions and configurable evaluation of trustworthiness, meeting its defined functional requirements. It was integrated with the Policy Enforcement Point (PEP) and validated using realistic CAN and video data from the Autonomous Vehicle pilot at IDIADA in a simulated environment. The component received positive stakeholder involvement. Even though full in-vehicle deployment was limited by hardware constraints, the results were reproducible across trials. Successful validation of core features was confirmed with the TRL achieved, with future work aimed at broader applicability through AI-supported configuration and real-world interoperability.

3.5.3 Confidentiality and Privacy by Design

The following TRL assessment for Confidentiality and Privacy by Design was provided by Universidad de Murcia (University of Murcia) (TANGO “UOG”) for the Policy Enforcement/Decision Point (PEP) and the Sticky Policies, CP-ABE components based on the structured TRL questionnaire. The entry includes the initial TRL at project start, the planned target TRL, and the final TRL achieved after pilot validation, supported by evidence on functionality, integration, validation environment, repeatability, and user or stakeholder feedback. The stakeholder provided two different questionnaires for the two different components, namely PAT and PEC. The component evaluation is presented per subchapter for each one of them. Further details and evidence can be found in Section 9.7.3 of Annex 9.7 in this deliverable.

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3.5.3.1 Component Identification for Confidentiality and Privacy by Design

Policy Enforcement/Decision Point

Component Identification	Component details
Component Name	Policy Enforcement/Decision Point
WP / Task	WP3, T3.3.
Lead Partner(s)	UMU
TRL Contact Person (Name, Organization)	Antonio Skarmeta, skarmeta@um.es , UMU

Sticky Policies, CP-ABE

Component Identification	Component details
Component Name	Sticky Policies, CP-ABE
WP / Task	WP3, T3.3
Lead Partner(s)	UMU
TRL Contact Person (Name, Organization)	Antonio Skarmeta, skarmeta@um.es , UMU

3.5.3.2 TRL Assessment Table for Confidentiality and Privacy by Design

Policy Enforcement/Decision Point

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	D2.3 [2], D3.1 [13], D3.2 [10]	5	The PEP/PDP meets all defined functional requirements, including enforcing access control policies, issuing capability tokens, and integrating Verifiable Credentials (VCs) and Verifiable Presentations (VPs). It applies contextual factors such as trust scores (from TSM) and behavioral scores (from UCBA) during policy evaluation. The component also supports policy creation and registration via the PAP, tested with real pilot scenarios.
Integration	Has it been integrated with at least one other TANGO component?	D2.3 [2], D3.2 [10], D6.1 [14], D6.2 [11]	5	Fully integrated with multiple TANGO components: SSI Module for credential verification, TSM for trust scoring, UCBA for behavioral scoring, Sticky Policies (CP-ABE) for data-level enforcement, and TANGO portal/UI. These integrations were validated in multiple pilot deployments.

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	D7.1 [12], D7.2	5	Deployed across several pilots, including Flanders Make (manufacturing), IDIADA (automotive), Smart Hospitality, METRO (retail), and RIASTONE. Each deployment validated the component in realistic environments with domain-specific requirements.
Repeatability	Were the results reproducible across multiple trials/tests?	D3.2 [10], D7.1 [12], D7.2	5	The component's results were reproducible across pilots and test environments. Automated workflows (capability token issuance, access request validation, policy enforcement) consistently produced identical outcomes under the same policy conditions. Tests across pilots confirmed repeatability despite heterogeneous environments (e.g., different APIs, datasets).
User/Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	D7.1 [12], D7.2	5	Yes, when it was deployed in the pilot.

Sticky Policies, CP-ABE

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	D3.1 [13], D3.2 [10], D6.2 [11]	5	The component encrypts data based on attribute-based policies (CP-ABE). Only users whose SSI-based attributes satisfy the encryption policy can decrypt data. Supports hybrid encryption with SEDSS. Functional requirements have been met — key generation, encryption, and decryption workflows are in place.
Integration	Has it been integrated with at least one other TANGO component?	D3.2 [10], D6.1 [14], D6.2 [11]	5	Main integrations with SSI modules and PEP. Hybrid

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
				encryption demonstrated with SEDSS.
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	D7.1 [12], D7.2	4	Deployed in FMAKE pilot.
Repeatability	Were the results reproducible across multiple trials/tests?	D7.1 [12], D7.2	4	Workflows reproducible and testable, though further pilot iterations will strengthen robustness.
User/Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	D7.1 [12], D7.2	5	Received input through pilot testing.

3.5.3.3 TRL Level Summary for Confidentiality and Privacy by Design

Policy Enforcement/Decision Point

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	4
Target TRL (as planned in DoA)	6
Final TRL reached after pilot testing	6

Sticky Policies, CP-ABE

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	3
Target TRL (as planned in DoA)	6
Final TRL reached after pilot testing	6

3.5.3.4 TRL Justification for Confidentiality and Privacy by Design

Policy Enforcement/Decision Point

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	The PEP/PDP component progressed from TRL 4 (core modules tested with datasets) to TRL 5 (validated in integrated environments with other components), and finally to TRL 6 (demonstrated in relevant pilot environments). Its deployment across multiple heterogeneous pilots confirms its maturity. The integration of SSI-based credentials, dynamic policy management, and collaboration with Sticky Policies and trust modules validates its readiness. Stakeholder feedback ensured alignment with real-world constraints and compliance requirements, supporting the TRL 6 classification.

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Sticky Policies, CP-ABE

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	The Sticky Policies component (CP-ABE) achieved TRL 6 by demonstrating functionality in relevant pilot environments. It integrates SSI credentials, PEP/PDP access control, and policy enforcement mechanisms to provide end-to-end confidentiality. Integration with SEDSS hybrid encryption enhances robustness. Validation in pilots with reproducible workflows and stakeholder input confirms operational maturity.

3.5.3.5 Additional Comments / Remarks for Confidentiality and Privacy by Design

No additional remarks provided for Policy Enforcement/Decision Point and Sticky Policies, CP-ABE components.

Summing up based on the feedback received, the PEP/PDP Component progressed from TRL 4 to TRL 6, proving its maturity after being implemented in multiple heterogeneous pilots and validated about its' readiness by the SSI-based credentials, dynamic policy management, and collaboration with Sticky Policies.

The Sticky Policies component (CP-ABE) progressed from TRL 3 to TRL 6 integrating SSI credentials, PEP/PDP access control, and policy enforcement mechanisms to provide end-to-end confidentiality. It confirmed its' operational maturity through validation in pilots with reproducible workflows and stakeholder input.

Together, PEP/PDP and CP-ABE components form a complementary privacy management and enforcement framework within TANGO, enabled GDPR-compliant [5], and privacy-by-design operations across multiple pilots. Their integration strengthens the platform's trust layer by providing organisations with the ability to both assess and act on privacy risks in real-world data sharing and AI environments.

3.5.4 Self-encryption and Decryption Techniques with Multi-Factor Information Recovery Mechanisms

The following TRL assessment for Self-encryption and Decryption Techniques with Multi-Factor Information Recovery Mechanisms was provided by Technische Universiteit DELFT (TANGO "DUT"), based on the structured TRL questionnaire. The entry includes the initial TRL at project start, the planned target TRL, and the final TRL achieved after pilot validation, supported by evidence on functionality, integration, validation environment, repeatability, and user or stakeholder feedback. Further details and evidence can be found in Section 9.7.4 of Annex 9.7 in this deliverable.

3.5.4.1 Component Identification for Self-encryption and Decryption Techniques with Multi-Factor Information Recovery Mechanisms

Component Identification	Component details
Component Name	SEDSS
WP / Task	3 / 3.4
Lead Partner(s)	Kaitai Liang
TRL Contact Person (Name, Organization)	Kaitai Liang (DUT)

3.5.4.2 TRL Assessment Table for Self-encryption and Decryption Techniques with Multi-Factor Information Recovery Mechanisms

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	Yes	5	The functional testing has been executed, all the planned functions has been implemented and work properly.
Integration	Has it been integrated with at least one other TANGO component?	Yes	5	Integrated into CP-ABE workflow, thus provide the data and key simultaneously.
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	Yes	5	The component is integrated into FMAKE manufacturing pilot.
Repeatability	Were the results reproducible across multiple trials/tests?	Yes	4	We tested the performance for multiples and the results is similar (the variance of time cost, memory cost and other resource usage on the same file is less than 5%).
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	Yes	3	Feedback based on our encryption demo has been collected from pilot owners. The deployment is still ongoing, more feedback will be collected once the deployment is done and pilot owners can test the functionality in person.

3.5.4.3 TRL Level Summary for Self-encryption and Decryption Techniques with Multi-Factor Information Recovery Mechanisms

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	TRL3
Target TRL (as planned in DoA)	TRL3
Final TRL reached after pilot testing	TRL3

3.5.4.4 TRL Justification for Self-encryption and Decryption Techniques with Multi-Factor Information Recovery Mechanisms

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and	The TRL achieved (TRL. 3 – Self-encryption and decryption techniques with multi-factor information recovery mechanism) is consistent with the testing and validation performed against the offline version and online deployment in TANGO platform on various data formats.

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Task Description	Input provided
any user or pilot feedback received	

3.5.4.5 Additional Comments / Remarks for Self-encryption and Decryption Techniques with Multi-Factor Information Recovery Mechanisms

Task Description	Input provided
Provide additional comments regarding the components' successful or unsuccessful TRL level, remarks and lessons learned from the process, if any	The validation in the pilots is enough to achieve TRL 3. More work will be done in the future to integrate this component to FMAKE pilots with compatible APIs regarding encryption, data storage and key storage.
Provide comments regarding the component's societal/organizational/ legal readiness level	The tool is following the legal and ethical guidelines of the EC. Note that the tool itself only process data but doesn't store data. Moreover, the software can be deployed to user's private server, making the component confidential to users' privacy.

Summing up, the SEDSS component, developed under WP3(T3.4) and led by DUT, maintained Technology Readiness Level 3 (TRL 3) from project start through pilot testing, as initially defined in the DoA. Functional testing confirmed that all planned capabilities operate correctly, with full implementation of the required features. The component achieved integration by embedding into the CP-ABE workflow, enabling simultaneous data and key provision, and was deployed in the FMAKE manufacturing pilot. Performance testing demonstrated reproducibility with less than 5% variance in key metrics such as time, memory, and resource usage across multiple trials. Pilot stakeholder feedback was collected through encryption demos, with additional feedback expected as deployment progresses. While the TRL remains at 3 due to the current validation scope, future work will focus on full integration into the FMAKE pilot with compatible APIs for encryption, data storage, and key management. The component adheres to EC legal and ethical guidelines and supports deployment on private servers, preserving confidentiality and user privacy.

3.5.5 Self-sovereign Identity Management

The following TRL assessment for Self-Sovereign Identity Management (SSID) was provided by ATOS IT Solutions and Services Iberia SL (TANGO "ATOS") and Teknologian Tutkimuskeskus VTT OY (TANGO "VTT"), based on the structured TRL questionnaire. The entry includes the initial TRL at project start, the planned target TRL, and the final TRL achieved after pilot validation, supported by evidence on functionality, integration, validation environment, repeatability, and user or stakeholder feedback. Further details and evidence can be found in the respective Section 9.7.5 of Annex 9.7 in this deliverable.

3.5.5.1 Component Identification for Self-sovereign Identity Management

SSI – ZKP

Component Identification	Component details
Component Name	SSI - ZKP
WP / Task	WP4, T4.1.
Lead Partner(s)	UMU
TRL Contact Person (Name, Organization)	Antonio Skarmeta, skarmeta@um.es, UMU

SSI Agent

Component Identification	Component details
Component Name	SSI Agent

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Component Identification	Component details
WP / Task	4 / 4.1
Lead Partner(s)	ATOS
TRL Contact Person (Name, Organization)	Ross Little, ATOS

SSI Wallet

Component Identification	Component details
Component Name	SSI Wallet
WP / Task	4 / 4.1
Lead Partner(s)	VTT
TRL Contact Person (Name, Organization)	Anni Karinsalo, WP lead, VTT Valtteri Lipiäinen, Researcher, VTT

3.5.5.2 TRL Assessment Table for Self-sovereign Identity Management

SSI - ZKP

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	D2.3 [2], D4.1 [15], D4.2 [16]	5	Fully functional with support for JSON-LD, OID4VC and OIDC4VP, ZKP presentations, and M2M credential flows
Integration	Has it been integrated with at least one other TANGO component?	D6.1 [14], D6.2 [11]	5	Demonstrated interoperability across multiple TANGO components and pilots. The component has been integrated with the FIWARE Data Space Connector (DSC). It also interworks with the Policy Enforcement Point (PEP) for access control decisions and with the ePassport App for seamless onboarding.
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	D7.1 [12], D7.2	5	Successfully deployed in both real pilot settings (FMAKE, IDIADA) and controlled simulations.
Repeatability	Were the results reproducible across multiple trials/tests?	D7.1 [12], D7.2	5	The component's results have been reproducible across multiple tests and pilots. Automated workflows for credential issuance, selective disclosure, and ZKP verification consistently produced expected outcomes under identical conditions. Multiple deployments in different pilots confirmed reliability.

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Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	D7.1 [12], D7.2	5	

SSI Agent

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	Yes	5	Issues JWT VCs in all cases.
Integration	Has it been integrated with at least one other TANGO component?	Yes	5	It is integrated with the SSI Wallet (VTT) and the Onboarding App (QBE).
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	Yes	5	It was deployed in: Smart-Hospitality, Smart Manufacturing and the Retail pilots.
Repeatability	Were the results reproducible across multiple trials/tests?	Yes	5	See previous comment above.
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	No	-	No comments to the SSI Agent are directly observed as it is a component that supports the frontend apps and therefore not visible to the end users.

SSI Wallet

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	Yes	5	All the relevant functional requirements (FR-TRUST-SSIM-010, FR-TRUST-SSIM-011, FR-TRUST-SSIM-012) fulfilled.
Integration	Has it been integrated with at least one other TANGO component?	D4.2 [16]	5	ATOS SSI Agent, frontend (through the FIWARE verifier), epassport application onboarding.
Validation Environment	Has it been deployed in a pilot or relevant	Yes	5	

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
	simulated environment?			
Repeatability	Were the results reproducible across multiple trials/tests?	No	4	Some need for manual setup for each separate pilot.
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	Yes	5	The component was used successfully in several pilots (e.g., Smart Hospitality and Retail), and it has received positive feedback. Evaluation Results: Overall satisfaction of users (3.88) D7.1 [12]

3.5.5.3 TRL Level Summary for Self-sovereign Identity Management

SSI – ZKP

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	3
Target TRL (as planned in DoA)	6
Final TRL reached after pilot testing	6

SSI Agent

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	3
Target TRL (as planned in DoA)	6
Final TRL reached after pilot testing	6

SSI Wallet

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	TRL3
Target TRL (as planned in DoA)	TRL6
Final TRL reached after pilot testing	TRL6

3.5.5.4 TRL Justification for Self-sovereign Identity Management

SSI – ZKP

Task Description	Input provided
Explain how the above scores and evidence justify your	The SSI-ZKP component advanced from TRL 3 (concept validation with cryptographic proofs) to TRL 6 (demonstrated in relevant pilot)

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Task Description	Input provided
proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	environments). It was first implemented in dockerized environments, then integrated with the FIWARE DSC and other relevant components. Through pilots in Flanders Make (Manufacturing) and IDIADA Autonomous vehicles, it proved operational maturity. Demonstrations confirmed that ZKP-based selective disclosure works across heterogeneous use cases. Stakeholder feedback confirmed its added value for GDPR-compliant [5] identity verification and user-centric privacy, justifying the TRL 6 rating.

SSI Agent

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	The SSI Agent was validated to Technology Readiness Level 6 (TRL 6), demonstrating its functionality in the relevant environment of the three pilots it took part in.

SSI Wallet

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	The SSI wallet core functionality (authentication using verifiable credentials) as well as interoperability (with issuer, verifier, and ePassport onboarding application) was demonstrated. The demonstration was carried out in three different pilots, which provided real-world environments for using authentication technology. The SSI subsystem and its wallet component were successfully deployed in pilot environments, where they were used for their intended purpose: onboarding and authenticating using a digital identity. This is reflected in the high scores in the TRL Assessment Table.

3.5.5.5 Additional Comments / Remarks for Self-sovereign Identity Management

SSI - ZKP

Task Description	Input provided
Provide additional comments regarding the components' successful or unsuccessful TRL level, remarks and lessons learned from the process, if any	The SSI-ZKP solution represents a major privacy-preserving enhancement to SSI in TANGO, enabling compliance with EU data protection requirements. Legal readiness is supported through GDPR-aligned [5] selective disclosure, minimizing exposure of personal data.
Provide comments regarding the component's societal/ organizational/ legal readiness level	Lessons learned include the complexity of integrating ZKP algorithms into existing SSI frameworks and the need for extensive interoperability testing across wallets and connectors.

Summing up based on the feedback received, the SSI-ZKP component developed by UMU progressed from TRL 3 to TRL 6, implemented in FMAKE and IDIADA pilots, proving as well operational maturity and confirmed its' added value for GDPR-compliant [5] identity verification and user-centric privacy.

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The Self-Sovereign Identity (SSI) Agent, developed by ATOS and lead by VTT, after pilot validation advanced from TRL 3 at project start to TRL 6. All functional requirements were successfully met, issuing JWT-based Verifiable Credentials and integrating with the SSI Wallet (VTT) and the Onboarding App (QBE). The component was deployed across three pilots (Smart Manufacturing, Smart Hospitality, and Retail), where it consistently achieved reproducibility and reliable performance. Even if not directly visible to end users, the SSI Agent proved essential as a backend enabler for secure and privacy-preserving onboarding, achieving its planned TRL target.

3.5.6 Seamless Onboarding for Users & Devices

The following TRL assessment for Seamless Onboarding for Users and Devices (SOUD) was provided by Quadible Greece I.K.E. (TANGO “QBE”), based on the structured TRL questionnaire. The entry includes the initial TRL at project start, the planned target TRL, and the final TRL achieved after pilot validation, supported by evidence on functionality, integration, validation environment, repeatability, and user or stakeholder feedback. Further details and evidence can be found in Section 9.7.6 of Annex 9.7 in this deliverable.

3.5.6.1 Component Identification for Seamless Onboarding for Users & Devices

Component Identification	Component details
Component Name	Seamless onboarding for Users and Devices
WP / Task	4 / 4.2
Lead Partner(s)	Quadible (QBE)
TRL Contact Person (Name, Organization)	Stefanos Heikki Panagiotou

3.5.6.2 TRL Assessment Table for Seamless Onboarding for Users & Devices

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	Yes	5	Yes, all the functionalities were developed considering the requirements for real-word usage, as for example in the pilots of the project.
Integration	Has it been integrated with at least one other TANGO component?	Yes	5	It has been integrated with the SSI Issuers/Verifier and Wallet components (T4.1).
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	Yes	5	This component was used successfully in several pilots (Smart Hospitality, Retail, Manufacturing, 3D Printing, Automotive) in the project, as a critical initial step for enrollment, validating its robustness and accuracy.
Repeatability	Were the results reproducible across multiple trials/tests?	Yes	5	The onboarding steps are deterministic and reproducible, allowing for consistent outcomes—specifically, the issuance of the ePassport credential—across multiple trials

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Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
				when following the well-defined instructions.
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	Yes	5	The component was used successfully in several pilots (e.g., Smart Hospitality, Retail, 3D Printing), and it has received positive feedback.

3.5.6.3 TRL Level Summary for Seamless Onboarding for Users & Devices

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	3
Target TRL (as planned in DoA)	6
Final TRL reached after pilot testing	6

3.5.6.4 TRL Justification for Seamless Onboarding for Users & Devices

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	The TRL achieved is justified by a combination of lab testing and more importantly pilot deployments. The TRL 6 (Technology demonstrated in a relevant environment) is aligned with the integration and consistent results from the different pilot environments the component was used (Smart Hospitality, Retail, Manufacturing, 3D Printing, Automotive). Examples of the SOUD usage is provided in the Annex of this deliverable (Section 9.7.6)

3.5.6.5 Additional Comments / Remarks for Seamless Onboarding for Users & Devices

Task Description	Input provided
Provide additional comments regarding the components' successful or unsuccessful TRL level, remarks and lessons learned from the process, if any	During the process of developing the SOUD component, the team put focus to design and implement user interfaces (ePassportApp) that facilitate user experience. However, the main effort was put on the functionality and integration testing aspects. In the future, extensive testing and feedback from certified User Experience (UI/UX) experts can be received to further improve the interfaces, towards easier integration and exploitation of the component from the end-users/organizations.
Provide comments regarding the component's societal/ organizational/ legal readiness level	The SOUD component demonstrates strong organizational and societal readiness, offering secure, remote user onboarding without the need for human verification. Its privacy-preserving, local-only processing design aligns with modern data protection expectations and supports scalable deployment across organizations. Legally, it is well-positioned for compliance with major privacy regulations like GDPR [5].

Summing up, the Seamless Onboarding for Users & Devices (SOUD) component, developed by Quadible, progressed from TRL 3 to TRL 6 during the project. The component fully met functional requirements, it was integrated with SSI Issuers/Verifiers and Wallet components while enabling remote, secure onboarding through the ePassportApp. It was successfully deployed across multiple pilots (Manufacturing, Retail, Smart Hospitality, and Autonomous Vehicles). The component showed consistency in terms of reproducibility, robustness, and positive user feedback. Through its privacy-preserving and GDPR-compliant design [5], SOUD proved ready for real-world application as a critical entry point for user and device enrollment, achieving its planned TRL target.

3.5.7 User continuous behavioural authentication

The following TRL assessment for User Continuous Behavioural Authentication (UCBA) was provided by Quadible Greece I.K.E. (TANGO “QBE”), based on the structured TRL questionnaire. The entry includes the initial TRL at project start, the planned target TRL, and the final TRL achieved after pilot validation, supported by evidence on functionality, integration, validation environment, repeatability, and user or stakeholder feedback. Further details and evidence can be found in the respective Section 9.7.7 of Annex 9.7 in this deliverable.

3.5.7.1 Component Identification for User continuous behavioural authentication

Component Identification	Component details
Component Name	User Continuous Behavioural Authentication (UCBA)
WP / Task	4 / 4.3
Lead Partner(s)	Quadible (QBE)
TRL Contact Person (Name, Organization)	Stefanos Heikki Panagiotou

3.5.7.2 TRL Assessment Table for User continuous behavioural authentication

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	Yes	5	The component has been developed taking into account functional and non-functional requirements from internal environments and also the Retail pilot.
Integration	Has it been integrated with at least one other TANGO component?	Yes	5	The component was integrated with the PEP and PDP components, as described in deliverable D3.1 [13] and D3.2 [10].
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	Yes	5	Yes, the component was used during the Retail pilot (METRO partner).
Repeatability	Were the results reproducible across multiple trials/tests?	Yes	5	The component's outputs are dynamic based on the user and its behaviour (mouse usage patterns, keystroke dynamics), meaning

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Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
				that different users generate different data. For the task at hand, i.e., to authenticate users throughout multiple sessions, the component exhibits reproducible outputs amongst the same set of users and sessions, and the overall authentication accuracy reaches > 95% in most cases.
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	Yes	5	Yes, the component was used during the Retail pilot (METRO partner). Initially, the pilot provided positive feedback on the usefulness of the tool to be able to authenticate users and identify fraud cases based on their typing and mouse patterns, while interacting with a website/web application.

3.5.7.3 TRL Level Summary for User continuous behavioural authentication

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	5
Target TRL (as planned in DoA)	7
Final TRL reached after pilot testing	7

3.5.7.4 TRL Justification for User continuous behavioural authentication

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	The component was used during the Retail pilot (METRO partner) and the UCBA's indicative results are demonstrated in the Annex of this deliverable (Section 10.7.7). Given the successful integration and testing, the deployment to this pilot (industrial environment with real-world operation) justifies, TLR 7 - System prototype demonstration in an operational environment.

3.5.7.5 Additional Comments / Remarks for User continuous behavioural authentication

Task Description	Input provided
Provide additional comments regarding the components' successful or unsuccessful TRL level, remarks and lessons	The validation and demonstration in the Retail pilot is enough to achieve TRL 7. Future work includes adding more authenticator mechanisms (e.g. based on the location of the user sessions, the

Task Description	Input provided
learned from the process, if any	device fingerprints, etc) to provide further robustness and accuracy across edge cases.
Provide comments regarding the component's societal/ organizational/ legal readiness level	The UCBA component provides dual value at both the citizen and the organization level, since it enables the continuous authentication of the former while interacting with services and interfaces for the former. Therefore, UCBA enhances security and trust in the society, helping reduce fraudulent behaviors and their consequences. The component's legal readiness level is also on track, with clear definitions for the data processing, storage and maintenance of the collected data, under GDPR context [5].

Summing up, the UCBA component, developed under WP4 T4.3 and led by Quadible (QBE), progressed from an initial TRL of 5 at project start to TRL 7 after being successfully integrated and deployed in the pilot. Designed to provide continuous user authentication based on behavioural biometrics such as mouse usage patterns and keystroke dynamics, the component achieved perfect scores (5/5) across all TRL evaluation criteria. It was fully integrated with the Policy Enforcement Point (PEP) and Policy Decision Point (PDP) components, as detailed in D3.1 [13] and D3.2 [13], and deployed in the Retail pilot (METRO partner) to operate in a real-world environment. Testing demonstrated high reproducibility, with authentication accuracy exceeding 95% for the same user/session scenarios. The operational deployment in a production-like setting and stakeholders' feedback justifies its TRL 7 status. Future enhancements include incorporating additional authentication factors—such as session location and device fingerprinting—to further improve robustness. The component strengthens both organisational and societal trust by reducing fraudulent activity risks, and its data handling processes are GDPR-compliant [5], ensuring legal readiness.

3.5.8 Device continuous behavioural authentication

The following TRL assessment for Device continuous behavioural authentication was provided by Panepistimio Thessalias (University of Thessaly) (TANGO “UTH”), based on the structured TRL questionnaire. The entry includes the initial TRL at project start, the planned target TRL, and the final TRL achieved after pilot validation, supported by evidence on functionality, integration, validation environment, repeatability, and user or stakeholder feedback. Further details and evidence can be found in Section 9.7.8 of Annex 9.7 in this deliverable.

3.5.8.1 Component Identification for Device continuous behavioural authentication

Component Identification	Component details
Component Name	Device Continuous Behavioural Authentication (DCBA)
WP / Task	4 / 4.4
Lead Partner(s)	University of Thessaly (UTH)
TRL Contact Person (Name, Organization)	Ilias Syrigos (UTH)

3.5.8.2 TRL Assessment Table for Device continuous behavioural authentication

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	Annex 9.7, Section 9.7.8 (Screenshots DCBA_150925_1, DCBA_150925_4,	5	The Device Continuous Behavioural Authentication (DCBA) component meets all the defined functional

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Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
		DCBA_150925_5)		requirements (FR-TRUST-DCBA-001 to FR-TRUST-DCBA-006). As Demonstrated by the provided screenshots and videos.
Integration	Has it been integrated with at least one other TANGO component?	Annex 9.7, Section 9.7.8 (Screenshots DCBA_150925_2, DCBA_150925_4, DCBA_150925_5)	5	DCBA has been successfully integrated with the SSI Verifier, the SSI Wallet and the PEP/PDP.
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	Annex 9.7, Section 9.7.8 (Screenshot DCBA_150925_3)	5	DCBA has been deployed in the Smart Manufacturing Pilot (RIASTONE).
Repeatability	Were the results reproducible across multiple trials/tests?		5	Several tests were performed in our premises during development and integration. The component showed consistent results in terms of accuracy of the localization feature with a 95% accuracy of detecting the correct area that a device is located. More tests to be carried at the pilot premises during the execution of the validation activities.
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	Smart manufacturing pilot tested the solution and provided feedback.	5	Pilot validation activities have been conducted in Riastone premises.

3.5.8.3 TRL Level Summary for Device continuous behavioural authentication

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	TRL 3
Target TRL (as planned in DoA)	TRL 6
Final TRL reached after pilot testing	TRL 6

3.5.8.4 TRL Justification for Device continuous behavioural authentication

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation	The Device Continuous Behavioural Authentication component has advanced beyond theoretical design and isolated lab validation, reaching a stage of integration, deployment, and operational testing in a relevant environment in the Smart Manufacturing case. Multiple

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Task Description	Input provided
activities, number of deployments or iterations, and any user or pilot feedback received	testing iterations were conducted at both module and system level to ensure robustness, interoperability, and performance (classification accuracy, F1-score, and detection latency). The deployment validated the feasibility of using behavioural authentication for access control, confirming correct functioning of data extraction/log collection, anomaly detection, localization and alerting mechanisms. Feedback from pilot is pending.

3.5.8.5 Additional Comments / Remarks for Device continuous behavioural authentication

Task Description	Input provided
Provide additional comments regarding the components' successful or unsuccessful TRL level, remarks and lessons learned from the process, if any	The DCBA component successfully achieved the targeted TRL 6 level, as it was validated in a relevant environment beyond controlled laboratory conditions. The deployment at a manufacturer's site, particularly for localization-based physical access authorization, confirmed that the technology works as intended under real-world constraints. To move towards TRL 7–8, additional multi-site pilots, sustained real-world usage, and systematic collection of KPIs (uptime, detection accuracy, false positive/negative rates) will be necessary.
Provide comments regarding the component's societal/ organizational/ legal readiness level	Early pilot results show that the component is generally accepted by end-users, particularly because it is non-intrusive and operates seamlessly in the background. In addition, the deployment at a manufacturer's site demonstrated that the component can be integrated into existing physical access control workflows without major disruption. However, the collection and processing of device, network, and location data falls under the scope of GDPR [5] and similar data protection regulations. As such, the component must ensure: 1) Purpose limitation and data minimisation, 2) explicit user consent for behavioural monitoring, and 3) strong safeguards for storage, transfer, and processing of personal data.

Summing up, the led by UTH Device Continuous Behavioural Authentication (DCBA) component, was designed to enhance security and trust using localization and behavioral patterns to continuously verifying devices. Starting the project, the component was at TRL 3. Following successful deployment, testing, and integration, it advanced to TRL 6. The component was fully aligned with the defined functional requirements (FR-TRUST-DCBA-001 to FR-TRUST-DCBA-006) and validated through multiple trials. It showed a notable 95% accuracy in detecting device location. The component was integrated with the PEP/PDP, SSI Wallet, and SSI Verifier and it was implemented in the Smart Manufacturing pilot (RIASTONE). Within this pilot's scope, it confirmed robust localization features in a relevant environment and detected successfully anomalies. Extensive integration and lab tests confirmed stability and repeatability of results, despite pilot feedback is still pending. From an organizational aspect, the component fits effortlessly within existing access control workflows, while from a societal perspective, it is positively received due to its non-intrusive operation. Nevertheless, GDPR [5] implications require strong safeguards around consent, behavioural data collection, and processing.

3.5.9 Hardening against Side-channel Attacks

The following TRL assessment for Hardening against Side-channel Attacks was provided by Commissariat A L Energie Atomique Et Aux Energies Alternatives (TANGO "CEA") and Teknologian Tutkimuskeskus Vtt Oyvtt (TANGO "VTT"), based on the structured TRL questionnaire. The entry includes the initial TRL at project start, the planned target TRL, and the final TRL achieved after pilot validation, supported by evidence on functionality, integration, validation environment, repeatability,

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and user or stakeholder feedback. Further details and evidence can be found in Section 9.7.9 of Annex 9.7 in this deliverable.

3.5.9.1 Component Identification for Hardening against Side-channel Attacks

Component Identification	Component details
Component Name	Hardening against side-channel attacks
WP / Task	4 / 4.5
Lead Partner(s)	CEA, VTT
TRL Contact Person (Name, Organization)	Nicolas Belleville, CEA

3.5.9.2 TRL Assessment Table for Hardening against Side-channel Attacks

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	https://link.springer.com/chapter/10.1007/978-3-031-57543-3_14 https://ieeexplore.ieee.org/abstract/document/10798512	5	Cryptographic function work as intended, and security is largely improved.
Integration	Has it been integrated with at least one other TANGO component?	Section 9.7.9 of Annex 9.7 (Screenshot KER10_Hardened_AES_081224)	5	Integrated in smart hospitality pilot
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	Section 9.7.9 of Annex 9.7 (Screenshot KER10_Hardened_AES_081224)	5	Deployed in smart hospitality pilot. (as the component is transparent, it is hard to provide different evidence for integration and validation: no errors means that it is working)
Repeatability	Were the results reproducible across multiple trials/tests?		3	Functional both at CEA and at AnySolution
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	Section 9.7.9 of Annex 9.7 (Screenshot KER10_Hardened_AES_081224)	1	The component replaces a library: as such its use required very little work (see Screenshot 1, just copy-pasting library files was enough to integrate it). Its use is transparent; thus no particular feedback was expected in the absence of bugs.

3.5.9.3 TRL Level Summary for Hardening against Side-channel Attacks

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	3
Target TRL (as planned in DoA)	6
Final TRL reached after pilot testing	6

3.5.9.4 TRL Justification for Hardening against Side-channel Attacks

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	The component was integrated and used in the smart hospitality pilot without issue.

3.5.9.5 Additional Comments / Remarks for Hardening against Side-channel Attacks

Task Description	Input provided
Provide additional comments regarding the components' successful or unsuccessful TRL level, remarks and lessons learned from the process, if any	One of the lessons learned is that replacing an open-source library by a modified version of the same library is efficient from an integration point of view, as it results in a straightforward integration requiring minimal work on the pilot side.
Provide comments regarding the component's societal/organizational/ legal readiness level	As the component do not interact with humans, it is ready from a societal point of view. It does not change the data proceeded by a device, the input and output remain identical as without our component, as such it should be also ready from a legal point of view.

Summing up, the Hardening against Side-channel Attacks component, developed by VTT and CEA, was designed to offer cryptography-based resilience through the integration of a hardened AES library. The component was successfully and seamlessly validated and deployed in the Smart Hospitality pilot, with minimal changes required from the pilot partner. Improved security and consistent functionality was affirmed through testing at AnySolution and CEA but with limited direct stakeholder feedback due to its' transparent nature. In terms of the component's progress, it developed from TRL 3 to TRL 6, achieving its' target. The component demonstrated preparedness from both legal and societal perspectives, since it perpetuates information integrity and conforms to regulatory requirements.

3.5.10 Exploratory Data Analysis Engine

The following TRL assessment for Exploratory Data Analysis Engine (EDAE) was provided by EXUS Software Monoprosopi Etairia Periorismenis Evthinis (TANGO "EXUS"), based on the structured TRL questionnaire. The entry includes the initial TRL at project start, the planned target TRL, and the final TRL achieved after pilot validation, supported by evidence on functionality, integration, validation environment, repeatability, and user or stakeholder feedback. Further details and evidence can be found in Section 9.7.10 of Annex 9.7 in this deliverable.

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3.5.10.1 Component Identification for Exploratory Data Analysis Engine

Component Identification	Component details
Component Name	Exploratory Data Analysis Engine
WP / Task	5 / 5.1
Lead Partner(s)	EXUS
TRL Contact Person (Name, Organization)	Anaxagoras Fotopoulos, EXUS

3.5.10.2 TRL Assessment Table for Exploratory Data Analysis Engine

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	Yes [D2.4 [17]]	4	Only a couple of requirements were decided to be dropped to focus on satisfying the feedback received for enhancing the components quality to end user needs.
Integration	Has it been integrated with at least one other TANGO component?	Yes [D6.2 [11], D5.2 [18]]	5	EDAE was integrated with the TANGO UI/Visualisation component and PEP/PDP.
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	Yes [D6.2 [11], D5.2 [18]]	5	EDAE was deployed locally in Spain and Greece for Smart Hospitality and Retail pilot respectively.
Repeatability	Were the results reproducible across multiple trials/tests?	Yes [D6.2 [11], D5.2 [18]]	5	EDAE participated successfully in two different pilots in Smart Hospitality and Retail pilot.
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	Yes [D6.2 [11], D5.2 [18]]	4	Before the finalisation of each pilot version the co-designed changes were introduced in an iterative manner until the satisfaction of end users is met.

3.5.10.3 TRL Level Summary for Exploratory Data Analysis Engine

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	4
Target TRL (as planned in DoA)	7
Final TRL reached after pilot testing	7

3.5.10.4 TRL Justification for X-AI for Exploratory Data Analysis Engine

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention	During the first years of the project, EDAE was demonstrated by EXUS to end user partners, gathering their feedback (Lab Environment Testing). Based on the received feedback the co-

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Task Description	Input provided
the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	designed updates were incorporated to the final version and EDAE was tested solely from the end user without any intervention from EXUS (Technical Partner) in two major TANGO pilots (Smart Hospitality and Retail) at their premises being deployed locally in an integrated manner along with other TANGO components such as the TANGO UI.

3.5.10.5 Additional Comments / Remarks for Exploratory Data Analysis Engine

Task Description	Input provided
Provide additional comments regarding the components' successful or unsuccessful TRL level, remarks and lessons learned from the process, if any	Although there were difficulties in obtaining timely responses on certain aspects from end users that delayed part of the development, all feedback requests from end users were satisfied. Our component due its interdependency with some other TANGO components (as a back-end service) endangered the successful reach to its TRL target, since a delay was observed in the finalisation of the retail pilot. However, the TANGO platform as a whole solved any pending issues and we successfully reached our TRL target.
Provide comments regarding the component's societal/ organizational/ legal readiness level	N/A for EDAE since it's a back-end service that is not involved in direct interaction with end user operations. EDAE indirectly analysed privacy-preserved data offered through the overall secure-by-design TANGO environment. EXUS as an ISO:27001 certified company ensured that its component was 100% GDPR compliant [5] and its services were secure.

Summing up, TRL7 was achieved for the Exploratory Data Analysis Engine (EDAE) after being successfully deployed in the Smart Hospitality and Retail pilots, starting initially at a TRL 4 when the project started. Most refinements and requirements, based on co-designed feedback to improve user experience, were implemented demonstrating strong functionality (score: 4). Integration (score 5) was achieved with the PEP/PDP and TANGO UI/Visualization components, ensuring seamless operation within the platform. The local deployments in Greece and Spain, confirmed reliability across diverse pilot environments (Validation score: 5), with repeatable results (score: 5). Pilot stakeholders provided feedback iteratively (score: 4), supporting any final improvement. The interdependencies with other components caused initial delays, but EDAE met its TRL target, proving GDPR [5] and compliance operational readiness as a backend analytical service.

3.5.11 Energy efficient AI model training

The following TRL assessment for Energy efficient AI model training was provided by ATOS IT Solutions and Services Iberia SL (TANGO "ATOS"), based on the structured TRL questionnaire. The entry includes the initial TRL at project start, the planned target TRL, and the final TRL achieved after pilot validation, supported by evidence on functionality, integration, validation environment, repeatability, and user or stakeholder feedback. The stakeholder provided three different questionnaires for the three different components, namely AutoML, MLOps, and Federating Learning (FL). The component evaluation is presented per subchapter for each one of them. Further details and evidence can be found in Section 9.7.11 of Annex 9.7 in this deliverable.

3.5.11.1 Component Identification for Energy efficient AI model training

AutoML

Component Identification	Component details
Component Name	Energy efficient AI model training-Support for AutoML
WP / Task	5 / 5.2
Lead Partner(s)	ATOS

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Component Identification	Component details
TRL Contact Person (Name, Organization)	Tomás Pariente, ATOS

MLOps

Component Identification	Component details
Component Name	Energy efficient AI model training-Support for MLOps
WP / Task	5 / 5.2
Lead Partner(s)	ATOS
TRL Contact Person (Name, Organization)	Tomás Pariente, ATOS

Federated Learning

Component Identification	Component details
Component Name	Energy efficient AI model training-Support for Federated Learning
WP / Task	5 / 5.2
Lead Partner(s)	ATOS
TRL Contact Person (Name, Organization)	Tomás Pariente, ATOS

3.5.11.2 TRL Assessment Table for Energy efficient AI model training

AutoML

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	Yes	3	The component is based in the open-source tool MLJAR, which provides functionality for AutoML.
Integration	Has it been integrated with at least one other TANGO component?	No	2	It has been used standalone by data scientists.
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	Yes	3	Checked by members of the banking pilot but not deployed in any pilot's scenario.
Repeatability	Were the results reproducible across multiple trials/tests?	Yes	4	Depending on the training data the results might be different, but this is what ML does.
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	No	3	Finally, it was not required by any scenarios. The two pilots with data scientists used Federated Learning instead.

MLOps

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Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	Yes	4	The component is based in the open-source tools MLFlow and provides rich functionality for MLOps.
Integration	Has it been integrated with at least one other TANGO component?	Yes, with RENOPS, XAI and FL Support. Description available in D6.2 [11] section 6.4.	5	It can work together with other tools. Tested in collaboration with FL Support (T5.2), RENOPS (T5.6) and XAI (T5.5).
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	Yes	4	Deployed in the Banking pilot and especially tested in the Smart Manufacturing (FMAKE) pilot.
Repeatability	Were the results reproducible across multiple trials/tests?	Yes	5	MLOps can be used in any project or pilot which requires tracking the ML life cycle, experimentation, etc.
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	Yes	4	The 2 pilots provided positive feedback from data scientists.

Federated Learning

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	Yes	5	The component has been developed taking into account requirements from the pilots, such as the usage of hdf5 files, support for pyTorch, etc.
Integration	Has it been integrated with at least one other TANGO component?	Yes, MLOps Support. Description available in D6.2 [11] Annex B.7	4	FLEVIDEN stores metrics of the training in MLOps.
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	Yes	5	Deployed in the Banking and Smart Manufacturing (FMAKE) pilots.
Repeatability	Were the results reproducible across multiple trials/tests?	Yes	5	Federated training of ML models can be done in multiple local nodes and averaged in a central node.

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	Yes	5	The pilots provided positive feedback for the data scientists.

3.5.11.3 TRL Level Summary for Energy efficient AI model training

AutoML

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	3
Target TRL (as planned in DoA)	6
Final TRL reached after pilot testing	4

MLOps

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	-
Target TRL (as planned in DoA)	6
Final TRL reached after pilot testing	6

Federated Learning

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	2 (new tool, PoC under preparation)
Target TRL (as planned in DoA)	6
Final TRL reached after pilot testing	6

3.5.11.4 TRL Justification for Energy efficient AI model training

AutoML

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	As the pilots did not require the usage of AutoML, the component was tested in a simulated environment, not really in the pilot infrastructure. It was tested by the developers in local environments with open datasets giving good results, as well as by the banking pilot in a first iteration, but only for testing purposes (no real data involved). The TRL achieved (TRL 4 – technology validated in lab) is consistent with this type of testing. Nevertheless, it should be noticed that the underlying AutoML library used (MLJAR), has been used by multiple organisations in the past, so although the TRL

Task Description	Input provided
	claimed is low, the reliability of the component is bigger than what could be expected by a TRL4 tool.

MLOps

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	The TRL achieved (TRL 6 - Technology demonstrated in a relevant environment) is consistent with the testing and validation performed in the relevant environment of the pilots. Especially in the case of FMAKE, where validation experiments were carried out in combination with other tools, such as RENOPS. In FMAKE a couple of main deployments and several interactions with the pilot's data scientists were done: one with the initial version after M18, and a final one after the delivery of the final version in M30. The feedback was used to include tests with other tools (RENOPS) in collaboration with MLOps.

Federated Learning

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	The TRL achieved (TRL 6 - Technology demonstrated in a relevant environment) is consistent with the testing and validation performed in the relevant environment of the pilots. Both FMAKE and Banking tested the tool with different datasets and requirements in 2 iterations (after M18 and the final version around M30). The feedback was positive.

3.5.11.5 Additional Comments / Remarks for Energy efficient AI model training

AutoML

Task Description	Input provided
Provide additional comments regarding the components' successful or unsuccessful TRL level, remarks and lessons learned from the process, if any	Initially the aim was to achieve a TRL 6, but the lack of interest of the pilots in the AutoML functionality, combined with the requirements for tools such as support for Federated Learning and MLOps instead, shifted the focus of T5.2 towards the latter. Therefore, the support for AutoML was left at a minimum simply using a simple, but efficient library (MLJAR), plus the support for naïve users of a notebook-like user interface based on the MERCURY framework. This was deemed enough to cope with potential last-minute requirements from pilots, requirements that never materialised.
Provide comments regarding the component's societal/ organizational/ legal readiness level	The component, based on an OS tool (MLJAR) is state-of-the-art technology on AutoML. Note that the tool itself is not responsible of the training data or compliance with the regulations, which is part of the work to be performed by the users.

MLOps

Task Description	Input provided
Provide additional comments regarding the components' successful or unsuccessful TRL	The final release provided local deployment, which was in line with the requirements of the pilots. The validation in the pilots is enough to achieve TRL 6. In the future, if required, the component may

Task Description	Input provided
level, remarks and lessons learned from the process, if any	evolve to add authentication and authorisation mechanisms based on the TANGO approach, but it was not deemed necessary for this version.
Provide comments regarding the component's societal/ organizational/ legal readiness level	The component, based on an OS tool (MLFlow) is state-of-the-art technology on MLOps, therefore taking into account the major organisational and legal aspects. Note that the tool itself is not responsible of the training data or compliance with the regulations, which is part of the work to be performed by the users. Papers such as this one (https://ijsra.net/sites/default/files/IJSRA-2024-1798.pdf), provides information on how MLOps could help on scaling up AI.

Federated Learning

Task Description	Input provided
Provide additional comments regarding the components' successful or unsuccessful TRL level, remarks and lessons learned from the process, if any	The validation in the pilots is enough to achieve TRL 6. More work has to be done in the future to extend the tool with a control plane enabling advanced functionalities for monitoring and handling bigger datasets, as well as providing better data privacy control.
Provide comments regarding the component's societal/ organizational/ legal readiness level	The tool is following the legal and ethical guidelines of the EC. Note that the tool itself is not responsible of the training data or compliance with the regulations, which is part of the work to be performed by the users.

Summarizing the three components performance, the AutoML component, based on the open-source MLJAR tool, progressed from TRL 3 to TRL 4. While it met its functional requirements and demonstrated reproducibility in lab testing, it was not deployed in any pilot scenario, being used only in simulated environments by developers and briefly tested by the Banking pilot without real data. Lack of pilot demand shifted focus toward MLOps and Federated Learning, leaving AutoML as a minimal, notebook-based capability for potential use.

The MLOps component, built on the open-source MLFlow platform, achieved TRL 6 following successful integration with RENOPS, XAI, and Federated Learning Support, and deployment in the Banking and Smart Manufacturing (FMAKE) pilots. It received positive feedback from pilot data scientists, with validation in relevant environments confirming its readiness for operational contexts.

The Federated Learning component advanced significantly from TRL 2 to TRL 6, being developed with pilot requirements in mind (e.g., PyTorch and HDF5 support) and integrated with MLOps for metric tracking. It was deployed and tested in both the Banking and FMAKE pilots in two major iterations (M18 and M30), demonstrating stable federated training across multiple nodes and receiving strong stakeholder feedback.

Together, MLOps and Federated Learning achieved full pilot deployment and validation, aligning with TANGO's privacy-preserving and distributed AI objectives, while AutoML remained at a lower TRL due to limited pilot applicability.

3.5.12 Dynamic Intelligent Execution on Heterogeneous Systems (TornadoVM)

The following TRL assessment for Dynamic Intelligent Execution on Heterogeneous Systems (TornadoVM) was provided by the University of Manchester (TANGO "UOM"), based on the structured TRL questionnaire. The entry includes the initial TRL at project start, the planned target TRL, and the final TRL achieved after pilot validation, supported by evidence on functionality, integration, validation environment, repeatability, and user or stakeholder feedback. Further details and evidence can be found in the respective Section 9.7.12 of Annex 9.7 in this deliverable.

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3.5.12.1 Component Identification for Dynamic Intelligent Execution on Heterogeneous Systems (TornadoVM)

Component Identification	Component details
Component Name	Dynamic Intelligent Execution on Heterogeneous Systems
WP / Task	5 / 5.3
Lead Partner(s)	UOM
TRL Contact Person (Name, Organization)	Athanasios Stratikopoulos, University of Manchester

3.5.12.2 TRL Assessment Table for Dynamic Intelligent Execution on Heterogeneous Systems (TornadoVM)

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	Yes	5	<p>The component has been successfully validated through a case study that involves the offloading of a histogram processing computation from a Python program to a heterogeneous hardware accelerator. The runtime used to orchestrate the computation, and compile the accelerated code is JVM with the extension of TornadoVM. The target device is automatically selected by T5.3 technology, leveraging a trained ML model developed within TANGO to determine the optimal hardware for execution.</p> <p>Score 5 is assigned, because the functionality of the component at this stage satisfies what has been previously described in D6.2 [11] (see Figure 3).</p>
Integration	Has it been integrated with at least one other TANGO component?	No	1	<p>No. The component has been deployed in a relevant simulated environment. It has been tested with a Python program that simulates code from EDAE that performs a histogram computation over some data coming from a use case. In our case study, the use case is Retail (METRO) and the data are synthetic data that have the same data type (“float”) but random values. The evaluated computation of this experiment is characterized across various dataset sizes, ranging from 8,000 rows up to 1,048,575 rows (representing the maximum data size observed in the Retail (METRO)) and reaching up to 64 million rows.</p>
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	Yes	3	<p>The component has been deployed on a relevant simulated environment on the premises of the University of Manchester. The testbed is a server with a CPU, integrated GPU (i.e., iGPU, GPU integrated with the CPU) and discrete GPU (i.e., GPU attached via PCIe to the CPU) that represents a platform that could be installed in the Retail (METRO) premises to</p>

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
				run the histogram computations offered via the EDAE tool (T5.1) on the most energy-efficient device.
Repeatability	Were the results reproducible across multiple trials/tests?	Yes	5	<p>Yes, we conducted the experiment for performance and energy measurements at least 2000 times and analyzed the output logs from the running program. The plots you will see in Screenshot ID DYNAMIC_INTELLIGENT_SCHEDULER_010825_01 (Section 9.7.12) reflect the relative performance (blue) and energy efficiency (green) that is achieved by running the computation on a heterogeneous device (CPU, iGPU, GPU) versus vanilla Java execution.</p> <p>EXPERIMENTAL METHODOLOGY: We evaluated 4 implementations: 1) a parallel implementation running on an NVIDIA 4090 GPU, 2) a parallel implementation running on an integrated Intel 770 Graphics Card, 3) a parallel implementation running on an Intel i9-13900k CPU and compared those three against a Java implementation with GraalVM JDK 21. All implementations were executed on the same machine in the premises of the University of Manchester, with Ubuntu 22.04, 32 CPU threads and 64 GB RAM.</p> <p>All metrics used in this plot are the mean measurement of the last 10 executions, ensuring that the Java code is warmed up.</p> <p>The power metrics were recorded using an EATON 5PX 1500i UPS, with power measurements captured at a frequency of 100 ms.</p> <p>EXPERIMENTAL ANALYSIS: Our analysis showed that across all data sizes the GPU shows higher energy efficiency than the Java baseline implementation, ranging from 1.6x (for 8 thousand rows) to 9x for 64 million rows elements.</p> <p>Additionally, the prediction for the target device (NVIDIA 4090 GPU) was consistent. For all those data sizes, the recommended device to run energy efficiently by the model has been the NVIDIA GPU,</p>

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
				<p>and the execution is automatically handled as shown in Section 9.7.12 Screenshots ID: (DYNAMIC_INTELLIGENT_SCHEDULER_010825_03 and DYNAMIC_INTELLIGENT_SCHEDULER_010825_04).</p> <p>To validate that different devices can be selected from the T5.3 technology, we run for very small data sizes (i.e., 16 rows), where the CPU is more suitable than GPUs (See Section 9.7.12 Screenshot ID: DYNAMIC_INTELLIGENT_SCHEDULER_010825_02). And the results showed that for 30 trials, the prediction for the target device (CPU) is consistent.</p>
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	n/a	1	<p>No, this particular experiment requires users to have at least two hardware accelerators available in their system, along with the respective drivers.</p> <p>The technology has been tested in two classes of computers (laptop PC and server).</p>

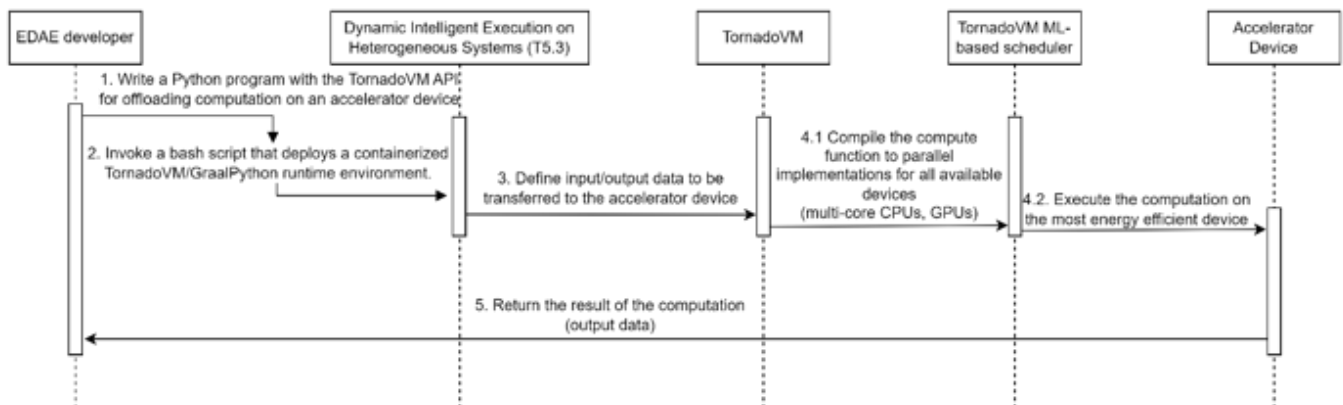


Figure 3: D6.2 Dynamic Intelligent Execution on Heterogeneous Systems component functionality description.

3.5.12.3 TRL Level Summary for Dynamic Intelligent Execution on Heterogeneous Systems (TornadoVM)

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	TRL 3, in DOA it is described that TornadoVM is in TRL 7. But the TRL of the Dynamic Intelligent Execution on Heterogeneous Systems has not been defined.
Target TRL (as planned in DoA)	TRL 5 (it has not been defined in DoA).

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TRL Level	Achieved TRL Result
Final TRL reached after pilot testing	TRL 5

3.5.12.4 TRL Justification for Dynamic Intelligent Execution on Heterogeneous Systems (TornadoVM)

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	<p>The initial version of the T5.3, was a prototype version that had been validated only to schedule the execution of programs based on performance.</p> <p>At this stage, the technology has been transformed into a software that can automatically consume a trained ML model that is fed with power and energy metrics for 30 TornadoVM benchmarks (i.e., compute operations from various applications domains implemented in Java and TornadoVM). Link: https://github.com/TANGO-EU-PROJECT/TornadoVM/blob/feat/benchmarks/training/tornado-assembly/src/bin/tornado-benchmarks-training.py</p> <p>The justification for the final TRL is that it has been tested for 12 Java applications implemented with TornadoVM, as well as the TANGO relevant simulated environment where it has been deployed as a Dockerized container. The container contains the Java parallel implementation of computations (e.g., histogram) along with the integrated GraalPython implementation that enables the computation to be launched by a Python program. The execution is taking place through the dynamic-intelligent-execution runner script (See here https://github.com/TANGO-EU-PROJECT/docker-tornadovm/blob/tango-v1.1.1/final/RUN_DYNAMIC_INTELLIGENT_TASK.md#5-run-a-python-program-and-accelerate-a-computation-using-the-tornadovm-api-automatically-on-the-most-energy-efficient-device).</p>

3.5.12.5 Additional Comments / Remarks for Dynamic Intelligent Execution on Heterogeneous Systems (TornadoVM)

Task Description	Input provided
Provide additional comments regarding the components' successful or unsuccessful TRL level, remarks and lessons learned from the process, if any	<p>To launch the dynamic-intelligent-scheduler software and run our TANGO experiment you need to do the following from a Linux computer with at least two OpenCL devices (CPU/GPU):</p> <pre>git clone https://github.com/TANGO-EU-PROJECT/docker-tornadovm cd docker-tornadovm git checkout tango-v1.1.1/final export TORNADO_DOCKER_SCRIPT="<path>/docker-tornadovm"</pre> <p><code>\${TORNADO_DOCKER_SCRIPT}/dynamic_intelligent_execution.sh</code> <code>example/polyglot-examples/histogram.py</code></p>

Task Description	Input provided
Provide comments regarding the component's societal/ organizational/ legal readiness level	<p>The T5.3 component shows promising societal readiness by enabling more efficient use of heterogeneous hardware resources, improving performance and energy efficiency while making advanced computation more accessible to developers.</p> <p>Organizationally, the technology demonstrates initial compatibility with existing Python-based workflows, but broader deployment and scalability testing are needed before it can be adopted in large-scale production environments.</p> <p>From a legal perspective, the component currently poses no significant risks, operating within established software frameworks and standards. Overall, its legal readiness poses no immediate barriers but potential obligations regarding the ML-driven decision making may be presented in future, as regulatory landscapes evolve.</p> <p>As lesson learnt, we can mention that it has been confirmed that running compute tasks for small data sizes on heterogeneous hardware (GPUs, iGPUs) is not efficient. For small data sizes staying on the CPU side is much faster and energy efficient, because data are not being moved through PCIe across the system. In our case, we observed that for the data sizes that match the requirement of the METRO use case, the NVIDIA GPUs showcase significant performance and energy efficiency for running histogram computations. If discrete GPUs are not available in the server, the integrated GPUs (iGPUs) are also good alternatives performing significant performance improvement ranging from 1.8x (for 32 thousand rows) to 5.5x (for 64 million rows), along with energy efficient which outperforms the Java baseline implementation for data sizes bigger than 16 million rows, resulting in 2x energy efficiency for 64 million rows.</p> <p>On the other hand, the OpenCL CPU implementation of histogram has been slower than the Java implementation. The generated OpenCL kernel for Intel CPUs seems to pose some inefficiencies that do not scale performance as long as the number of rows increases. As a result, the efficiency of the OpenCL CPU code is lower than the Java baseline implementation across all data sizes.</p> <p>Finally, our work in T5.3 of the TANGO project has shown that ML models can be trained and utilized to predict the most suitable devices to run. Additionally, it proved that the programming language ecosystem can be unified by utilizing polyglot runtime implementations (such as GraalPython) and integrating them with TornadoVM to unlock hardware acceleration not only for Java but also for Python, Ruby, NodeJS etc.</p>

Summing up, the Dynamic Intelligent Execution on Heterogeneous Systems component (WP5/T5.3, led by UOM) after being validated in a relevant simulated environment, reached a TRL5. The component enables the automatic selection of the most energy-efficient hardware device (integrated GPU, CPU, or discrete GPU) for computation by leveraging a trained ML model integrated with TornadoVM. The component was successfully tested using a histogram processing case study for the Retail (METRO) use case, with experiments repeated over 2,000 times to ensure reproducibility. Results showed significant performance and energy efficiency gains, with GPUs achieving up to 9 times higher efficiency compared to Java baseline execution, and intelligent switching to CPUs for small datasets. A sincere societal impact through energy-efficient computing and compatibility with Python-based workflows potential is shown for the technology despite not still integrated with other TANGO components, charting the path for greater adoption in heterogeneous computing environments.

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3.5.13 Privacy Threat Modelling and Identification for Trustworthy AI

The following TRL assessment for Privacy Threat Modelling and Identification for Trustworthy AI was provided by Fujitsu Technology Solutions (Luxembourg) SA (TANGO “FUJ_LU”) for the Privacy Assurance Tool (PAT) component, and the University of Greenwich (TANGO “UOG”) for the Privacy Enhancing Component (PEC), based on the structured TRL questionnaire. The entry includes the initial TRL at project start, the planned target TRL, and the final TRL achieved after pilot validation, supported by evidence on functionality, integration, validation environment, repeatability, and user or stakeholder feedback. Further details and evidence can be found in Section 9.7.13 of Annex 9.7 in this deliverable.

3.5.13.1 Component Identification for Privacy Threat Modelling and Identification for Trustworthy AI

Privacy Assurance Tool (PAT)

Component Identification	Component details
Component Name	Privacy Assurance Tool (PAT)
WP / Task	5 / 5.4
Lead Partner(s)	FUJITSU Luxembourg
TRL Contact Person (Name, Organization)	Sofiane Lagraa, Ibrahim Mecirdi Fujitsu Luxembourg

Privacy Enhancing Component (PEC)

Component Identification	Component details
Component Name	Privacy Enhancing Component (PEC)
WP / Task	5/ 5.4
Lead Partner(s)	UoG
TRL Contact Person (Name, Organization)	Sakshyam Panda, Manos Panaousis University of Greenwich

3.5.13.2 TRL Assessment Table for Privacy Threat Modelling and Identification for Trustworthy AI

Privacy Assurance Tool (PAT)

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	Yes	5	The component has been developed taking into account functional and non-functional requirements from the smart hospitality pilot.
Integration	Has it been integrated with at least one other TANGO component?	Yes	5	Integrated with TANGO Dashboard UI, PEP/PDP, and PEC. Description available in D6.2 [11].
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	Yes	5	Deployed in the Smart Hospitality and automotive vehicle pilots.
Repeatability	Were the results reproducible across multiple trials/tests?	Yes	5	PAT can be adapted for any type of data and consent models.

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Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	Yes	5	Smart hospitality pilot and partners have been successfully tested PAT, providing positive feedback.

Privacy Enhancing Component (PEC)

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	Yes	5	The component has been developed considering functional and non-functional requirements from cybersecurity and privacy perspective, covering multiple TANGO pilots.
Integration	Has it been integrated with at least one other TANGO component?	Yes	5	Integrated with TANGO Dashboard UI and PAT. Description available in D6.2 [11].
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	Yes	5	Tested with Public Administration (VISARIGHT), Autonomous Vehicle (IDIADA) and Retail (METRO) pilots.
Repeatability	Were the results reproducible across multiple trials/tests?	Yes	5	PEC can be used to support privacy risk assessment across sectors.
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	Yes	5	All three pilots provided positive feedback on PEC and its usability.

3.5.13.3 TRL Level Summary for Privacy Threat Modelling and Identification for Trustworthy AI

Privacy Assurance Tool (PAT)

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	1
Target TRL (as planned in DoA)	5
Final TRL reached after pilot testing	5

Privacy Enhancing Component (PEC)

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	1

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TRL Level	Achieved TRL Result
Target TRL (as planned in DoA)	6
Final TRL reached after pilot testing	6

3.5.13.4 TRL Justification for Privacy Threat Modelling and Identification for Trustworthy AI Privacy Assurance Tool (PAT)

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	The TRL achieved is justified by a combination of lab testing and pilot deployment testing. Initial validation in the context of the Smart Hospitality pilot. Core functionalities, such as consent management, role-based access control, and automated data deletion, were tested in a test environment across several iterations.

Privacy Enhancing Component (PEC)

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	The TRL achieved (TRL 6 - Technology demonstrated in a relevant environment) is consistent with the testing and validation performed in the relevant environment of the pilots. The tool has been validated across three different pilots. The initial feedback received from the Public Administration pilot has been considered to enhance the component. The PEC tool has received feedback from all three pilots it has been validated with.

3.5.13.5 Additional Comments / Remarks for Privacy Threat Modelling and Identification for Trustworthy AI

Privacy Assurance Tool (PAT)

Task Description	Input provided
Provide additional comments regarding the components' successful or unsuccessful TRL level, remarks and lessons learned from the process, if any	The component successfully reached TRL 5 with all core features tested in a test environment. Further iterations will focus on real-world interoperability and use cases.
Provide comments regarding the component's societal/ organizational/ legal readiness level	The component is designed with GDPR [5] principles in mind, including purpose limitation, data minimization, consent management, and automated data deletion. Organizational roles and access rights are clearly defined. Further deployment in real-world settings will help validate compliance at scale.

Privacy Enhancing Component (PEC)

Task Description	Input provided
Provide additional comments regarding the components' successful or unsuccessful TRL level, remarks and lessons	The component successfully reached TRL 6 with all core features tested in a test environment. In the future, if required, the component may evolve to add components that help manage compliance with evolving regulations.

Task Description	Input provided
learned from the process, if any	
Provide comments regarding the component's societal/ organizational/ legal readiness level	The PEC tool is designed considering the state-of-the-art guidelines and principles (such as NIST PRAM, GDPR and AI Act) to identify and manage privacy risks. It also covers identification of privacy threats from the use of AI. This tool helps organisation identify, plan and mitigate possible privacy threats from their data handling processes and services.

Summing up based on the feedback received, the Privacy Assurance Tool (PAT), led under the Confidentiality and Privacy by Design offering, advanced from TRL 1 to TRL 5 through successful lab validation and deployment in the Smart Hospitality and Automotive Vehicle pilots. It met all functional requirements, integrating with the TANGO Dashboard UI, PEP/PDP, and PEC, and demonstrated adaptability to multiple consent and data management models. Core features such as consent management, role-based access control, and automated data deletion were tested iteratively, with positive feedback from pilot partners confirming its readiness for relevant environments.

The Privacy Enhancing Component (PEC) developed by University of Greenwich progressed from TRL 1 to TRL 6, being developed in line with EU and NIST privacy guidelines [9] and integrated with PAT to support end-to-end privacy risk assessment and enforcement. It was tested in the Public Administration and Autonomous Vehicle pilots, showing high repeatability and positive stakeholder feedback on its utility for identifying and managing privacy risks. Minor UI improvement suggestions were noted, and future development will consider alignment with the EU AI Act [19].

3.5.14 X-AI for Privacy and Trust Enhancement

The following TRL assessment for X-AI for Privacy and Trust Enhancement was provided by SQUAREDEV (TANGO “SQD”), based on the structured TRL questionnaire. The entry includes the initial TRL at project start, the planned target TRL, and the final TRL achieved after pilot validation, supported by evidence on functionality, integration, validation environment, repeatability, and user or stakeholder feedback. Further details and evidence can be found in Section 9.7.14 of Annex 9.7 in this deliverable.

3.5.14.1 Component Identification for X-AI for Privacy and Trust Enhancement

Component Identification	Component details
Component Name	X-AI for Privacy and Trust Enhancement
WP / Task	5 / 5.5
Lead Partner(s)	SQD
TRL Contact Person (Name, Organization)	John Zaras (SQD)

3.5.14.2 TRL Assessment Table for X-AI for Privacy and Trust Enhancement

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	Yes	5	The component has been developed taking into account requirements from the pilots, such as the desired usage and support for different model

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
				architects like ONNX, pyTorch, etc.
Integration	Has it been integrated with at least one other TANGO component?	No	3	It has been used by data scientists and APIs were developed for seamless integration with other components.
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	Yes	4	Deployed in the Banking and Smart Manufacturing (FMAKE) pilots.
Repeatability	Were the results reproducible across multiple trials/tests?	Yes	5	The XAI module was tested multiple times and the algorithms can be performed on multiple models that share the same architecture.
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	Yes	4	The FMAKE pilot provided positive feedback from the data scientists.

3.5.14.3 TRL Level Summary for X-AI for Privacy and Trust Enhancement

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	3
Target TRL (as planned in DoA)	6
Final TRL reached after pilot testing	6

3.5.14.4 TRL Justification for X-AI for Privacy and Trust Enhancement

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	The TRL achieved (TRL 6 - Technology demonstrated in a relevant environment) is consistent with the testing and validation performed in the relevant environment of the pilots. FMAKE tested the module with different models and requirements. Positive feedback was received.

3.5.14.5 Additional Comments / Remarks for X-AI for Privacy and Trust Enhancement

Task Description	Input provided
Provide additional comments regarding the components' successful or unsuccessful TRL level, remarks and lessons	The validation in the pilots is enough to achieve TRL 6.

Task Description	Input provided
learned from the process, if any	
Provide comments regarding the component's societal/ organizational/ legal readiness level	The module is following the legal and ethical guidelines of the EC. Note that the module itself is not responsible of the training data or compliance with the regulations, which is part of the work to be performed by the users, but rather explains the outcomes.

Summing up, the X-AI component, developed by SQUAREDEV (SQD) under WP5 T5.5, progressed from TRL 3 to TRL 6 through deployment and testing in the Banking and Smart Manufacturing (FMAKE) pilots. It met all functional requirements, supported multiple model architectures (e.g., ONNX, PyTorch), and demonstrated high repeatability across tests. While not fully integrated with other TANGO components, APIs were developed to support seamless integration, and data scientists in the FMAKE pilot provided positive feedback. The component's ability to explain model outcomes enhances trust and accountability without directly handling training data, aligning with ethical and legal guidelines. Based on its validation in relevant environments and stakeholder usage, the component was assessed at TRL 6.

3.5.15 Infrastructure Management based on AI

The following TRL assessment for Infrastructure Management based on AI was provided by TANGO partner XLAB Razvoj Programske Opreme in Svetovanje DOO (TANGO "XLAB"), based on the structured TRL questionnaire. The entry includes the initial TRL at project start, the planned target TRL, and the final TRL achieved after pilot validation, supported by evidence on functionality, integration, validation environment, repeatability, and user or stakeholder feedback.

3.5.15.1 Component Identification for Infrastructure Management based on AI

Component Identification	Component details
Component Name	Infrastructure Management based on AI (RENOPS)
WP / Task	5 / 5.6
Lead Partner(s)	XLAB
TRL Contact Person (Name, Organization)	Nejc Bat, XLAB

3.5.15.2 TRL Assessment Table for Infrastructure Management based on AI

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?	Deliverables: <ul style="list-style-type: none"> - D5.2 [18], section 3.6 - D6.2 [11], section 4.1.23 	5	<ul style="list-style-type: none"> - Provides an accurate forecast of renewable energy availability - Provides the model prediction via API - Utilizes information from the forecasting service and schedules energy intensive tasks in time - Utilizes information from the forecasting service to

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Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
				geographically schedule the workload
Integration	Has it been integrated with at least one other TANGO component?	Deliverable D6.2 [11], section 6.4	5	Integrated and tested with MLOps component.
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?	Deliverables: - D5.2 [18], section 3.6 - D7.1 [12]	5	Deployed and tested in Manufacturing pilot (FMAKE).
Repeatability	Were the results reproducible across multiple trials/tests?	Yes	5	RENOPS can be used in different trials and tests, results depend on the current forecast.
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?	Yes	5	The Manufacturing pilot provided positive feedback.

3.5.15.3 TRL Level Summary for Infrastructure Management based on AI

TRL Level	Achieved TRL Result
Initial TRL at project start (as defined in DoA)	Different components with different TRLs: - The resource management components (xOpera orchestrator) - TRL7. - The monitoring framework based on Wazuh. - The AIOps approach - TRL3.
Target TRL (as planned in DoA)	6
Final TRL reached after pilot testing	6

3.5.15.4 TRL Justification for X-AI for Infrastructure Management based on AI

Task Description	Input provided
Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	The component was tested and validated in the relevant environment of the Manufacturing pilot which demonstrates the consistency to the TRL achieved (TRL 6 - Technology demonstrated in a relevant environment).

3.5.15.5 Additional Comments / Remarks for Infrastructure Management based on AI

Task Description	Input provided
Provide additional comments regarding the components' successful or unsuccessful TRL level, remarks and lessons	The testing and validation in the Manufacturing pilot is enough to achieve TRL6.

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Task Description	Input provided
learned from the process, if any	
Provide comments regarding the component's societal/ organizational/ legal readiness level	The tool is following the legal and ethical guidelines of the EC. Note that the tool itself is not responsible of the training data or compliance with the regulations, which is part of the work to be performed by the users.

Summing up, the RENOPS component, developed under WP5 T5.6 and led by XLAB, reached TRL 6 after successful deployment and validation in the Manufacturing (FMAKE) pilot. Building on several underlying technologies—including the xOpera orchestrator (TRL 7), the Wazuh-based monitoring framework, and an AIOps approach (TRL 3 at start)—RENOPS integrates AI-based forecasting to optimise infrastructure usage. It accurately predicts renewable energy availability, schedules energy-intensive tasks in time and location according to forecast data and exposes model predictions via an API. Full integration with the MLOps component was achieved and tested, confirming interoperability within the TANGO ecosystem. The component demonstrated high repeatability across trials, with positive feedback from pilot stakeholders validating its utility in operational environments. RENOPS complies with EC legal and ethical guidelines, providing sustainable infrastructure management capabilities without processing personal data, and is ready for broader deployment in relevant sectors.

4 KPIs

4.1 Introduction

To assess TANGO's technical and broader strategic objectives, this chapter presents the Key Performance Indicators (KPIs) are presented, which serve as the project's measurable benchmarks. The KPIs examine various parameters in the project like privacy and security improvements, technological integration, sustainability impacts, technological integration, and stakeholders' degree of engagement. They offer the necessary traceability factor for TANGO's Specific Objectives (SOs) and relevant Work Packages (WPs).

The KPI framework covers both qualitative indicators (e.g., diversity of supported policy descriptions etc.) and quantitative metrics (e.g., reduction percentages in energy consumption or privacy violations, number of integrated technologies, etc.). The dual assessment offers a holistic analysis and evaluation of TANGO's performance in terms of user trust, innovation impact, societal relevance, and technical maturity.

In this chapter, each KPI will be reported against its relevance to project objectives, status, and target value, underlying the status and progress (e.g., KPI achieved, KPI exceeded, or KPI remains in progress). As with the TRLs monitored in previous chapters, the structured monitoring process tracking offers the basis for identifying areas requiring additional effort during the remaining project lifecycle and permits transparent performance for all stakeholders and pilots.

4.2 Overview of KPIs per Strategic Objective

A synopsis of the KPIs per Strategic Objective (SO) is presented in the following table:

Table 2: KPI Targets and Status Synopsis.

REF	Target Measurable KPIs	WP	Relevant SO	Target	Status
KPI1	Number of trustworthy digital technologies integrated into TANGO platform > 10	WP2	1	>10	Achieved
KPI2	Number of existing reference architectures that TANGO will be aligned with > 3	WP3	1	3	Achieved
KPI3	Number of proposed and integrated data sharing models > 10	WP7	5	>10	Not Achieved
KPI4	Number of TANGO components/assets to be integrated in the GAIA-X catalogue > 10	WP2,3,4,5	1	>10	Not Achieved
KPI5	Reduction in energy consumption for blockchain solution > 30%	WP3	4	30% reduction in energy consumption	Achieved
KPI6	Reduction of privacy violation incidents in data sharing > 50%	WP3	2	>50%	Not Achieved
KPI7	Recoverability of data > 99.9%	WP3,4	2	>99.9%	Achieved
KPI8	Number of different security & privacy policy descriptions to be supported > 5	WP3	2	>5	Achieved

REF	Target Measurable KPIs	WP	Relevant SO	Target	Status
KPI9	Number of external identities supported by SSI > 3	WP4	3	> 3	Achieved
KPI10	Accuracy of user verification and authentication > 99.6%	WP4	3	>99.6%	Achieved
KPI11	Accuracy of device verification and authentication > 90%	WP4	3	>90%	Achieved
KPI12	Number of recommendation & decision making models to be developed > 6	WP5 (and others)	4	>6	Achieved
KPI13	Reduction in energy consumption for an ML model training > 60%	WP5	4	> 60%	Partially Achieved
KPI14	Reduction in energy consumption in application execution for a single node > 30%	WP5	4	> 30%	Achieved
KPI15	Number of AutoML tools > 2	WP5	4	>2	Achieved
KPI16	Number of privacy assessment tools to be developed > 2	WP5 (and others)	4	>2	Achieved
KPI17	Number of XAI models to be developed > 8	WP5	4	>8	Achieved
KPI18	Reduction in energy consumption for a datacentre > 30%	WP5	4	>30%	Partially Achieved
KPI19	Number of pilot validation campaigns > 6	WP7	5	>6	Achieved
KPI20	Number of external stakeholders participating in the validation campaigns > 4,000	WP7	5	> 4,000	Not Achieved
KPI21	Number of usage scenarios integrated > 18	WP7	5	>18	Achieved
KPI22	Number of datasets uploaded on the proposed data spaces > 20	WP7	5	>20	Not Achieved

4.3 Detailed KPIs reporting

This chapter provides a clear account of TANGO's development in relation to its Key Performance Indicators (KPIs), defined in the project's Description of Action (DoA). The KPIs serve as measurable indicators of the project's progress, helping the consortium, stakeholders, and reviewers to evaluate the efficiency, effectiveness, and impact of all the methodologies, technologies, and pilots involved in TANGO's framework.

Through systematic reporting on every KPI, considering their baseline, target value, achieved results, and justification, the chapter provides traceability and clarity about the project's technical activities, objectives, barriers, and measurable outcomes. The methodology based on detailed reporting underlines not only which KPI targets have been exceeded or basically met but also provides supporting evidence from pilot operations, component validation, and stakeholder feedback.

The chapter supports the overall goal of offering clear, evidence-based performance monitoring, while also assisting with the project's general objectives of showcasing compliance, trustworthiness, and technical excellence in privacy-based information distribution. The results drawn here will help identify strengths that prove the framework's effectiveness, as well as opportunities to maximize TANGO's impact. The accuracy and validity of the information provided is a sole responsibility of the partners

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providing it. To avoid confusion in the document's structure, the partners' questionnaire responses are incorporated in the deliverable without being captioned since they are repeated for the each different KPI and are associated directly with it.

4.3.1 Number of trustworthy digital technologies integrated into TANGO platform

The following KPI assessment for 'Number of trustworthy digital technologies integrated into TANGO platform' was provided by Netcompany-Intrasoft SA (TANGO "INTRA"), based on the standard template they received and the relevant KPI monitoring framework. The entry includes the KPI's target value, the relevant work package and specific objective, as well as the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in Section 9.8.1 of Annex 9.8 in this deliverable.

4.3.1.1 KPI identification for Number of trustworthy digital technologies integrated into TANGO platform

KPI Status	KPI Information
Target Measurable KPI	Number of trustworthy digital technologies integrated into TANGO platform
Verification Means (as stated in the DoA / xls file)	Report submitted at the early stages of the project listing the digital technologies upon which TANGO platform will be developed, along with a common architecture that integrates them into a single platform.
WP	2
Relevant objective	1
Target	> 10
Baseline value	N/A
Achieved (YES/NO)	YES

4.3.1.2 KPI Justification for Number of trustworthy digital technologies integrated into TANGO platform

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	<p>The following list groups the main technologies used in the TANGO project into broader, well-established categories. Similar tools and methods have been combined to offer a quick overview of the leveraged technologies, while still showing the important functionalities offered by the TANGO platform. Each technology category is linked to specific implementation tasks, illustrating how these technologies are applied within the project.</p> <p>Based on the information reported in deliverables D2.3 [2] and D2.4 [17], below is the list of trustworthy digital technologies integrated into TANGO platform:</p> <ol style="list-style-type: none"> 1. Data Spaces Technology (T2.5) 2. Distributed Ledger Technology (T3.1) 3. Trust & Privacy Risk Management (T3.2, T5.4) 4. Secure & Privacy-preserving Technologies (T3.3, T3.4) 5. Self-Sovereign Identity (SSI) & Digital Identity Management (T4.1) 6. Digital Identity Verification & Behavioural Biometric Authentication (T4.2, T4.3)

Task	Justification
	7. Device Behavioural Authentication & AI-based Anomaly Detection (T4.4) 8. Cryptographic Security & Side-Channel Attack Mitigation (T4.5) 9. Data Analytics (T5.1) 10. AI/ML-driven Energy & Resource Optimization (T5.2, T5.3, T5.6) 11. Explainable & Trustworthy AI (XAI) (T5.5)

4.3.1.3 Additional Comments / Remarks for Number of trustworthy digital technologies integrated into TANGO platform

No additional comments/remarks provided by the partner.

Summing up, the KPI has been successfully achieved. Based on the architecture and technical developments described in Deliverables D2.3 [2] and D2.4 [17], TANGO framework has integrated at least 11 core digital technologies covering areas like distributed ledgers, data spaces, privacy risk management, cryptographic security, self-sovereign identity, AI-based analytics, and explainable AI. These technologies have been integrated into well identified categories and tested with specific implementation tasks across the platform. This diverse technological integration ensures a robust, secure, and trustworthy foundation for TANGO, fully aligned with Objective 1 and the platform's vision for privacy-preserving, interoperable, and scalable data sharing.

4.3.2 Number of existing reference architectures that TANGO will be aligned with

The following KPI assessment for 'Number of existing reference architectures that TANGO will be aligned with' was provided by the University of Thessaly (Panepistimio Thessalias) (TANGO "UTH"), based on the standard template they received and the relevant KPI monitoring framework. The entry includes the KPI's target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in the respective Section 9.8.2 of Annex 9.8 in this deliverable.

4.3.2.1 KPI identification for Number of existing reference architectures that TANGO will be aligned with

KPI Status	KPI Information
Target Measurable KPI	Number of existing reference architectures that TANGO will be aligned with
Verification Means (as stated in the DoA / xls file)	Before the release of the architectural design, the consortium will identify existing reference architectures that enhance trust, privacy-preservation and accountability such as the reference architecture of IDSA, EOSC and EGI Open Data Architecture.
WP	2
Relevant objective	1
Target	3
Baseline value	0
Achieved (YES/NO)	Yes

4.3.2.2 KPI Justification for Number of existing reference architectures that TANGO will be aligned with

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	The KPI was achieved by aligning TANGO with the reference architectures promoted by the Data Space Business Alliance (DSBA), which brings together BDVA, FIWARE, GAIA-X [8], and IDSA. Through the evaluation and selection of the FIWARE Data Space Connector, which implements the DSBA Technical Convergence recommendations, TANGO ensures interoperability and portability across data spaces. In this way, TANGO is aligned with more than three established reference architectures.

4.3.2.3 Additional Comments / Remarks for Number of existing reference architectures that TANGO will be aligned with

No additional comments/remarks provided by the partner.

Summing up, the KPI “Number of existing reference architectures that TANGO will be aligned with” targeted alignment with at least three existing reference architectures to enhance privacy, trust, and accountability. The KPI was successfully achieved by aligning TANGO with the Data Space Business Alliance (DSBA) [20], which integrates the efforts of BDVA, FIWARE, GAIA-X [8], and IDSA. Specifically, TANGO adopted the FIWARE Data Space Connector, implementing the DSBA Technical Convergence recommendations [20] to ensure interoperability and portability across data spaces. This alignment ensures compliance with more than three established reference architectures. As such, it surpasses the original target and reinforces TANGO’s commitment to interoperable and trusted digital ecosystems.

4.3.3 Number of proposed and integrated data sharing models

The assessment of the “Number of proposed and integrated data sharing models” was provided by the University of Piraeus Research Center (TANGO “UPRC”), based on the standard template. The entry includes the KPI’s target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in the respective Section 9.8.3 of Annex 9.8 in this deliverable.

4.3.3.1 KPI identification for Number of proposed and integrated data sharing models

KPI Status	KPI Information
Target Measurable KPI	Number of proposed and integrated data sharing models
Verification Means (as stated in the DoA / xls file)	Documentation and reporting of validation activities across all TANGO pilots, including test plans, execution reports, and results.
WP	2
Relevant objective	1
Target	>10
Baseline value	0
Achieved (YES/NO)	NO

4.3.3.2 KPI Justification for Number of proposed and integrated data sharing models

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	The KPI aimed for the development and integration of more than ten distinct data sharing models. Based on the TANGO pilots data sharing activities, nine models were proposed and validated across different pilots. FMAKE delivered two models: one for exchanging printing information with customers and one supporting the machine learning scenario. IDIADA provided a model for sharing map information with clients, while METRO implemented a cross-border model for data exchange between Greece and Cyprus. RIAS developed a location breach incidents data model, and VISAR established a data exchange model between VISARIGHT, employers, and public authorities. ANYS contributed two models, including a customer information data model integrated with hotel management systems and the NADIA platform for data sharing. Finally, NTT defined a dummy transaction data sharing model for banking institutions.

4.3.3.3 Additional Comments / Remarks for Number of proposed and integrated data sharing models

Task	Comment(s)
Provide additional comments regarding the KPI's successful or unsuccessful achievement.	In total, nine models were achieved, marginally not reaching the KPI target (>10). Nevertheless, the variety and applicability of these models demonstrate significant progress towards interoperability and practical deployment across heterogeneous domains, providing a strong foundation for further expansion.

Summing up, the KPI required the development of more than ten data sharing models. Within TANGO, a total of nine models were proposed and integrated, addressing different application domains and pilot needs. While this represents substantial progress in creating interoperable and reusable data sharing approaches, the KPI target was not fully achieved. Nevertheless, the outcome demonstrates TANGO's capacity to define and operationalize diverse models, providing a solid basis for further scaling.

4.3.4 Number of TANGO components/assets to be integrated in the GAIA-X catalogue

The assessment of the "Number of TANGO components/assets to be integrated in the GAIA-X catalogue" was provided by TANGO partner ATOS IT Solutions and Services Iberia SL (TANGO "ATOS"), based on the standard template they received and the relevant KPI monitoring framework. The entry includes the KPI's target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in the respective Section 9.8.4 of Annex 9.8 in this deliverable.

4.3.4.1 KPI identification for Number of TANGO components/assets to be integrated in the GAIA-X catalogue

KPI Status	KPI Information
Target Measurable KPI	Number of TANGO components/assets to be integrated in the GAIA-X catalogue
Verification Means (as stated in the DoA / xls file)	DoA: TANGO components will appear at the GAIA-X catalogue portal enabling developers to browse, select and integrate services on trustworthy, fair, accountable data management, storage and sharing.

KPI Status	KPI Information
WP	2/3/4/5
Relevant objective	1
Target	>10
Baseline value	0
Achieved (YES/NO)	NO

4.3.4.2 KPI Justification for Number of TANGO components/assets to be integrated in the GAIA-X catalogue

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	This KPI was introduced at the proposal time following the premise that TANGO will actively engage with GAIA-X to produce some technical results that could be included or branded as “GAIA-X-compliant”. However, we followed a different path towards a more practical IDS or DSBA compliance.

4.3.4.3 Additional Comments / Remarks for Number of TANGO components/assets to be integrated in the GAIA-X catalogue

Task	Comment(s)
Provide additional comments regarding the KPI’s successful or unsuccessful achievement.	We didn’t pursue this in favour of compliance with IDS and DSBA, complementing functionalities for trustworthiness and privacy to the Data Spaces interoperability efforts. Instead, we did the architectural choice of using an IDS Connector and did a study of some candidates before deciding on the FIWARE DS Connector and technologies for identity management compliant with those.

Summing up, in the context of the KPI “Number of TANGO components/assets to be integrated in the GAIA-X catalogue”, more than 10 TANGO components were targeted for integration into the GAIA-X [8] catalogue. Unfortunately, this goal was not achieved. The initial expectation during the proposal phase, was that TANGO would deliver technical results marked as GAIA-X-compliant [8]. However, the project prioritized privacy-preserving functionalities and interoperability aligned with broader Data Spaces initiatives, therefore it strategically shifted its focus toward IDS and DSBA compliance [20]. Even though the specific GAIA-X [8] catalogue target was not pursued, this was the reason for an architectural decision to adopt the FIWARE Data Space Connector and identity management technologies compatible with DSBA standards [20], ensuring practical alignment and impact with evolving European data space ecosystems.

4.3.5 Reduction in energy consumption for blockchain solution

The following KPI assessment for “Reduction in energy consumption for blockchain solution” was provided by NORBLOC AB (TANGO “NOR”), based on the standard template they received and the relevant KPI monitoring framework. The entry includes the KPI’s target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in the respective Section 9.8.5 of Annex 9.8 in this deliverable.

4.3.5.1 KPI identification for Reduction in energy consumption for blockchain solution

KPI Status	KPI Information
Target Measurable KPI	Reduction in energy consumption for blockchain solution

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KPI Status	KPI Information
Verification Means (as stated in the DoA / xls file)	Report describing the performance improvement in terms of efficiency/energy consumption between existing blockchain solutions and the TANGO mechanisms.
WP	3
Relevant objective	4
Target	30% reduction in energy consumption
Baseline value	Current energy consumption level (as measured for Ethereum-like blockchain consumption per node. Estimated by required amount of CPU cycles per block)
Achieved (YES/NO)	YES

4.3.5.2 KPI Justification for Reduction in energy consumption for blockchain solution

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	<p>Energy usage was estimated based on CPU cycles per block during pilot operations. Internal benchmarks showed that the Fides nodes deployed in the TANGO pilot consumed significantly fewer computational resources per transaction compared to similar public blockchain implementations, thereby supporting the KPI target of a 30% reduction.</p> <p>The primary strategy for reducing CPU cycles per block was to decouple block creation/validation from block propagation by assigning distinct roles to different blockchain peers. Specifically, the design adopted the approach used in Hyperledger Fabric, which introduces specialized nodes known as ordering peers (orderers). Typically, only a small number of orderer peers is required. Usually, 3 to 5 orderers can support a network comprising several hundred “worker” peers. This architectural separation results in a notable decrease in CPU cycles consumed during block creation and validation, leading to a corresponding reduction in overall energy consumption.</p> <p>Validation of this approach was conducted in a pilot cloud environment. The evaluation methodology involved two sets of measurements under an identical workload pattern to assess CPU cycle usage on cloud nodes in the following scenarios:</p> <ol style="list-style-type: none"> 1. Scenario 1: Both the orderer peer and a “worker” peer run on the same node. 2. Scenario 2: Only the “worker” peer runs on the node.

4.3.5.3 Additional Comments / Remarks for KPI Reduction in energy consumption for blockchain solution

Task	Comment(s)
Provide additional comments regarding the KPI’s successful or unsuccessful achievement.	<p>The selected validation scenarios offer the advantage of simplicity: since both the environment and the workload remain identical across tests, a straightforward measurement of the percentage of CPU cycles consumed is sufficient to compare the two scenarios. This approach eliminates the need to account for additional technical variables such as the number of CPUs, threads, CPU models, RAM types, or external storage configurations.</p> <p>In the screenshots found in annex 9.8.5, the first scenario shows</p>

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Task	Comment(s)
	59.1% of consumed CPU resource, while the second scenario yields the result of 36.4% of consumed CPU resource. While it is virtually impossible to specify the exact number of CPU cycles per block, the numerical KPI metric (advantage of the chosen scenario over the baseline scenario) can be estimated quite reliably, as $\text{KPI metric} = (59.1\% - 36.4\%) / 59.1\% = \mathbf{38.4\%}$

Summing up, the KPI targeted an energy consumption reduction by 30% for blockchain operations. The KPI was achieved with an 8.4% decrease in CPU resource usage compared to the baseline. The improvement was achieved by using a Hyperledger Fabric-inspired design which separated block propagation from block creation/validation applying a small set of specialized ordering peers alongside worker peers. Additionally, efficiency gains were confirmed by validating in a controlled pilot cloud environment under identical workloads. This demonstrated very satisfying progress and operational performance for TANGO's blockchain architecture energy reduction target.

4.3.6 Reduction of privacy violation incidents in data sharing

The following KPI assessment for Reduction of privacy violation incidents in data sharing was provided by the University of Piraeus Research Center (TANGO "UPRC"), based on the standard template they filled in and the relevant KPI monitoring framework. The entry includes the KPI's target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in the respective Section 9.8.6 of Annex 9.8 in this deliverable.

4.3.6.1 KPI identification for Number of proposed and integrated data sharing models

KPI Status	KPI Information
Target Measurable KPI	Reduction of privacy violation incidents in data sharing
Verification Means (as stated in the DoA / xls file)	Documentation and reporting of validation activities across all TANGO pilots, including test plans, execution reports, and results.
WP	2
Relevant objective	1
Target	>50%
Baseline value	0
Achieved (YES/NO)	NO

4.3.6.2 KPI Justification for Number of proposed and integrated data sharing models

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	A qualitative justification has been performed for this KPI. No direct measurement of privacy violations was performed. Instead, policy enforcement (PEP/PDP), GDPR-compliant [5] mechanisms (PAT, PEC, CP-ABE), and SSI onboarding were successfully deployed and assessed. Evidence from questionnaires and focus groups confirmed that these features reduce risks in data sharing and strengthen compliance. The KPI is therefore considered achieved through demonstrated privacy-by-design functionality.

4.3.6.3 Additional Comments / Remarks for Number of proposed and integrated data sharing models

Task	Comment(s)
Provide additional comments regarding the KPI's successful or unsuccessful achievement.	<p>To address this KPI, evidence-based validation of the following privacy-preserving mechanisms was considered:</p> <p>Privacy-enhancing components (PEC, PAT, CP-ABE) that protect sensitive attributes and enforce encrypted access control.</p> <ul style="list-style-type: none"> Trustworthiness Scoring Module (TSM), which increases transparency and accountability of data exchange. GDPR-compliant [5] data handling ensured by the Policy Enforcement Point (PEP) and Policy Decision Point (PDP). Self-Sovereign Identity (SSI) onboarding, reducing risks linked to identity misuse. <p>The evidence collected via questionnaires and focus groups confirmed that these features are perceived by pilot partners as effective measures to mitigate privacy violation risks. Several partners explicitly reported improved confidence in GDPR compliance [5] and secure data sharing as a result of TANGO adoption. Concrete testing in real-world scenarios for quantitative results is recommended based on the feedback with a high success potential.</p>

Summing up, the KPI required a demonstrated performance against privacy violation incidents. Since no quantitative data was tracked within the project, it was decided to be addressed through the validation of privacy-preserving and GDPR-compliant [5] mechanisms, including PAT, PEC, CP-ABE, PEP/PDP, and SSI onboarding. Pilots and focus groups confirmed these features reduce risks in data sharing by ensuring compliance and secure access control. No direct measurement of privacy violation incidents was performed, but the evidence supports that TANGO lowers the likelihood of such events. Acknowledging the need for quantitative result for the KPI, it is considered as not achieved.

4.3.7 Recoverability of data

The following KPI assessment for Reduction in energy consumption for blockchain solution was provided by TANGO partner Technische Universiteit DELFT (TANGO “DUT”), based on the standard template they received and the relevant KPI monitoring framework. The entry includes the KPI's target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in the respective Section 9.8.7 of Annex 9.8 in this deliverable.

4.3.7.1 KPI identification for Recoverability of data

KPI Status	KPI Information
Target Measurable KPI	Recoverability of data
Verification Means (as stated in the DoA / xls file)	Test the SEDSS component against various data formats and verify whether the encrypted files can be successfully decrypted.
WP	3,4
Relevant objective	2
Target	>99.9%
Baseline value	0
Achieved (YES/NO)	YES

4.3.7.2 KPI Justification for Recoverability of data

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	We designed and implemented a robust encryption and decryption component to ensure secure data transmission. To validate its functionality, we conducted extensive testing across diverse datasets and input conditions. For each encrypted output, we verified that the corresponding decryption accurately reconstructed the original data without loss or corruption. Our experiments demonstrated >99.99% accuracy, confirming the reliability and correctness of both processes. We also verified the system's performance under various edge cases and stress conditions. These results affirm that our encryption-decryption pipeline is both secure and precise, meeting the intended cryptographic and functional requirements with complete fidelity.

4.3.7.3 Additional Comments / Remarks for Recoverability of data

Task	Comment(s)
Provide additional comments regarding the KPI's successful or unsuccessful achievement.	We have tested the performance of our component offline. Since the integration of our component and pilots are still ongoing, we don't manage to collect feedback from pilot users. We will do that once the integration is done.

Summing up, the KPI demonstrated a >99.99% accuracy in reconstructing primary information across different datasets and input conditions thus being evaluated as successful. After severe validation processes it was confirmed that the encrypted files could be satisfactorily decrypted, reliably and with no corruption or losses, even under edge stress tests and cases. The results verify the security, robustness, and precision of the encryption-decryption mechanism. It meets both functional and cryptographic requirements.

4.3.8 Number of different security & privacy policy descriptions to be supported

The following KPI assessment for Number of external identities supported by SSI was provided by TANGO partner Universidad de Murcia (University of Murcia) (TANGO "UMU"), based on the standard template they received and the relevant KPI monitoring framework. The entry includes the KPI's target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in the respective Section 9.8.8 of Annex 9.8 in this deliverable.

4.3.8.1 KPI identification for Number of different security & privacy policy descriptions to be supported

KPI Status	KPI Information
Target Measurable KPI	Number of different security & privacy policy descriptions to be supported
Verification Means (as stated in the DoA / xls file)	Contribution of TANGO to the definition of the GAIA-X Policy Rules for infrastructure and for data and software.
WP	3
Relevant objective	2
Target	>5
Baseline value	0
Achieved (YES/NO)	YES

4.3.8.2 KPI Justification for Number of different security & privacy policy descriptions to be supported

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	<p>The TANGO system implements a variety of distinct security and privacy policy descriptions.</p> <p>At the infrastructure level, policy enforcement is carried out using PEP/PDP components that follow the XACML reference model, enabling attribute-based rules for access control, privacy, and usage.</p> <p>At the data level, beyond PEP/PDP mechanisms, sticky policies expressed through CP-ABE access structures embed privacy and security requirements directly into encrypted data.</p> <p>Together, these cover more than five distinct policy description types (PEP/PDP access, PEP/PDP privacy, PEP/PDP usage, CP-ABE access, CP-ABE privacy, CP-ABE security), thereby exceeding the KPI threshold.</p> <p>The Privacy Assurance Tool (PAT, T5.4) further complements this by providing privacy policies that are passed to the PEP for enforcement.</p> <p>This demonstrates TANGO's ability to enforce both service-level and data-level policies across multiple representation paradigms, in full alignment with GAIA-X Policy Rules.</p>

4.3.8.3 Additional Comments / Remarks for Number of different security & privacy policy descriptions to be supported

No additional comments/remarks provided by the partner.

Summing up, by implementing a wide range of policy description types across both infrastructure and data levels within the TANGO platform the KPI was successfully achieved. The PDP/PEP components following the XACML reference model ensured attribute-based rules for usage, privacy, and access control. At the data level, sticky policies expressed through CP-ABE access structures embedded security and privacy requirements directly into encrypted data. In addition, the Privacy Assurance Tool (PAT, T5.4) complemented these mechanisms by providing enforceable privacy policies. Combined together, these approaches covered more than five distinct policy types, fully meeting the KPI target and aligning with the GAIA-X [8] Policy Rules.

4.3.9 Number of external identities supported by SSI

The following KPI assessment for Number of external identities supported by SSI was provided by TANGO partners ATOS IT Solutions and Services Iberia SL (TANGO "ATOS") and Teknologian Tutkimuskeskus VTT OY (TANGO "VTT"), based on the standard template they received and the relevant KPI monitoring framework. The entry includes the KPI's target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in the respective Section 9.8.9 of Annex 9.8 in this deliverable.

4.3.9.1 KPI identification for Number of external identities supported by SSI

Partner ATOS contributed as follows:

KPI Status	KPI Information
Target Measurable KPI	Demonstration of the ability to integrate the identity providers (such OpenID, eIDAS, FIDO, OAuth 2.0 compatibility) including sample code, documentation etc.

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KPI Status	KPI Information
Verification Means (as stated in the DoA / xls file)	Demonstration & Logs
WP	4
Relevant objective	3
Target	> 3
Baseline value	0
Achieved (YES/NO)	YES

Partner VTT contributed as follows:

KPI Status	KPI Information
Target Measurable KPI	Number of external identities supported by SSI
Verification Means (as stated in the DoA / xls file)	Demonstration & Logs
WP	4
Relevant objective	3
Target	>3
Baseline value	0
Achieved (YES/NO)	YES

4.3.9.2 KPI Justification for Number of external identities supported by SSI

Partner ATOS responded as follows:

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	<p>The ATOS SSI Agent was updated to implement the OpenId OID4VP & OID4VCI protocols following EBSI Guidelines for issuing Verifiable Credentials following a certain integration profile i.e. to narrow down the W3C Decentralized Identifiers used (DID:KEY, DID:JWK) and W3C Verifiable Credentials verification method (JWT_VC). It further implemented OAuth2 protocols for supporting the issuing of credentials from Organizations and also with mobile ePassport onboarding app.</p> <p>External identities supported:</p> <ol style="list-style-type: none"> 1. OpenID (OID4VP & OID4VCI) 2. EBSI Guidelines 3. W3C Decentralized Identifiers 4. W3C Verifiable Credentials 5. OAuth2 6. ePassport App for onboarding natural persons satisfying EIDAS quality controls

Partner VTT complimented as follows:

Task	Comment(s)
Explain how the KPI was achieved. Mention any related technical development or validation activities.	<p>SSI wallet is in conformity with EBSI.</p> <p>SSI wallet has been integrated successfully with passport scanner application.</p> <p>SSI wallet is implemented according to standard OpenID & OAuth flows.</p>

4.3.9.3 Additional Comments / Remarks for Number of external identities supported by SSI

No additional comments/remarks were provided by the partners.

Summing up, the SSI Agent was updated to support the integration with multiple external protocols and identity providers. The KPI was successfully achieved. The implementation included OpenID (OID4VP & OID4VCI) following EBSI Guidelines, W3C Decentralized Identifiers (DID:KEY, DID:JWK), W3C Verifiable Credentials (JWT_VC), OAuth2 for credential issuing by organizations, and integration with the mobile ePassport onboarding app meeting eIDAS quality controls. Totally, six external identity mechanisms were supported which exceeded the KPI target and demonstrated the SSI framework's interoperability and flexibility.

4.3.10 Accuracy of user verification and authentication

The following KPI assessment for Accuracy of user verification and authentication was provided by TANGO partner QUADIBLE Greece I.K.E. (TANGO "QBE"), based on the standard template they received and the relevant KPI monitoring framework. The entry includes the KPI's target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in the respective Section 9.8.10 of Annex 9.8 in this deliverable.

4.3.10.1 KPI identification for Accuracy of user verification and authentication

KPI Status	KPI Information
Target Measurable KPI	Accuracy of user verification and authentication
Verification Means (as stated in the DoA / xls file)	Performance evaluation throughout the pilots considering metrics such as false acceptance rate, false rejection rate and failure to enrol.
WP	4
Relevant objective	3
Target	99.6
Baseline value	0
Achieved (YES/NO)	YES

4.3.10.2 KPI Justification for Accuracy of user verification and authentication

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	<p>We designed and implemented a robust component (SOUND) that onboards users to the TANGO ecosystem and integrates with SSI mechanisms. To validate its functionality, we conducted testing in the public LFW dataset, a well-known large database in the face recognition field (13233 images). Our internal evaluation demonstrated 99.68 % accuracy for our face matching algorithm.</p> <p>Furthermore, an Android application (ePassportApp) was developed that incorporates the SOUND SDK and enables the end-to-end onboarding process for the users. This application was used successfully in several pilots (e.g., Smart Hospitality, Retail, 3D Printing) in the project, as a critical initial step for enrollment, validating its robustness and accuracy.</p>

4.3.10.3 Additional Comments / Remarks for Accuracy of user verification and authentication

Task	Comment(s)
Provide additional comments regarding the KPI's successful or unsuccessful achievement.	The interaction with a variance of partners (pilot cases) and users, with different characteristics, has enabled real-world testing of the performance and accuracy of the component, under various edge cases. The fact that dozens of users with different characteristics have enrolled (onboarded) during the pilots, further validates the high percentage of accuracy.

Summing up, KPI's target of 99.6% was achieved by deploying the SOUD component. The SOUD component is responsible for users onboarding to the TANGO ecosystem and integrates SSI mechanisms. An accuracy of 99.68% was achieved during the internal evaluation on the public LFW dataset (13,233 images). The "ePassportApp", an Android devices application, incorporating the SOUD SDK was developed to help users in end-to-end onboarding. The application was used in multiple pilots (e.g., Retail, Manufacturing, Smart Hospitality, and Autonomous Vehicles). Lastly, the system's robustness and accuracy in real-world condition was validated by pilot deployments involving diverse users.

4.3.11 Accuracy of device verification and authentication

The following KPI assessment for Accuracy of device verification and authentication was provided by TANGO partner Panepistimio Thessalias (University of Thessaly) (TANGO "UTH"), based on the standard template they received and the relevant KPI monitoring framework. The entry includes the KPI's target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in the respective Section 9.8.11 of Annex 9.8 in this deliverable.

4.3.11.1 KPI identification for Accuracy of device verification and authentication

KPI Status	KPI Information
Target Measurable KPI	Accuracy of device verification and authentication
Verification Means (as stated in the DoA / xls file)	Performance evaluation throughout the pilots considering metrics such as false acceptance rate, false rejection rate and failure to enrol.
WP	4
Relevant objective	3
Target	90%
Baseline value	0
Achieved (YES/NO)	Yes

4.3.11.2 KPI Justification for Accuracy of device verification and authentication

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	The KPI on the accuracy of device verification and authentication was addressed through the development and validation of the localization sub-component within the Device Continuous Behavioural Authentication pipeline. The localization functionality leverages device-based data (e.g., network identifiers, nearby RF signals such as Wi-Fi and Bluetooth) to determine whether a device is operating in a familiar or authorised area. Through iterative technical development and validation activities focused on the localization functionality, the component achieved a 95% accuracy rate in verifying and authenticating device presence in the correct

Task	Justification
	area. This result demonstrates that the KPI has been successfully met under relevant deployment conditions.

4.3.11.3 Additional Comments / Remarks for Accuracy of device verification and authentication

Task	Comment(s)
Provide additional comments regarding the KPI's successful or unsuccessful achievement.	We expect similar results when the verification at the pilot's premises takes place.

Summing up, the initial target of the KPI on device verification and authentication was 90% accuracy rate, assessed through pilot performance metrics such as false rejection, enrolment failures, and false acceptance. This goal materialized using the localization sub-component of the Device Continuous Behavioural Authentication (DCBA) pipeline. The component analyzes device-based data (e.g., Wi-Fi, network identifiers, and Bluetooth signals) as a verification process that the device is in an authorised area. The technical development and validation activities, performed in iterations, achieved a 95% accuracy rate. The result surpassed the initial target and demonstrated concrete reliability under relevant deployment conditions. Similar performance is expected during the pilot site verifications, confirming successful achievement of this KPI.

4.3.12 Number of recommendation & decision making models to be developed

The following KPI assessment for Number of recommendation & decision making models to be developed was provided by TANGO partner ATOS IT Solutions and Services Iberia SL (TANGO "ATOS"), based on the standard template they received and the relevant KPI monitoring framework. The entry includes the KPI's target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in the respective Section 9.8.12 of Annex 9.8 in this deliverable.

4.3.12.1 KPI identification for Number of recommendation & decision-making models to be developed

KPI Status	KPI Information
Target Measurable KPI	Number of recommendation & decision-making models to be developed
Verification Means (as stated in the DoA / xls file)	Report that details the information about the recommendation and decision-making models that were developed through the TANGO project.
WP	5 (and others)
Relevant objective	4
Target	> 6
Baseline value	0
Achieved (YES/NO)	YES

4.3.12.2 KPI Justification for Number of recommendation & decision-making models to be developed

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	<p>The TANGO project was active on AI, both in the scope of the technical developments of the platform, but also at the pilot execution. In this sense, WP5 tackled most of the work on AI, although other WPs also contributed with some realisations.</p> <p>WP5 developed a few models that are part of the TANGO technical results (D5.2 [18] offers more details on WP5 work):</p> <ul style="list-style-type: none"> • Within TornadoVM, a ML model was developed that can automatically select a hardware device to run parallel workloads based on performance and the energy consumption. • The PEC component developed a model on privacy risks that integrates LLM to support countermeasure recommendations for the identified threats. This way PEC ensures that better explanations can be provided to the users on the choice of controls against a risk. • PAT allows for possible LLM-based AI-assistants. The integration readiness for AI-assistants has been implemented for data subjects and it is hosted in the supervisory authority environment. • RENOPS developed 2 ML models: 1) The renewable potential predictor is an ensemble model that predicts the accuracy of solar irradiation forecasts in combination with other weather models to produce an accurate prediction. 2) The Energy price predictor model uses energy prices to predict renewable energy availability in the grid, considering various factors such as holidays and energy prices. <p>Other WPs offered also ML tools:</p> <ul style="list-style-type: none"> • The UPCV (Recommender) from WP3, provides recommendations to users (e.g., tourists of the Smart Hospitality pilot). D3.2 [10] section 3.2.3 offers more details. • The Device behavioral authentication from WP4 includes a ML model (Risk Assessment Engine), which performs anomaly detection over user logs of their interaction of the system to improve authentication. D4.2 [16] section 3.4.1.2 offers more details. <p>Pilots also developed ML models in the scope of the use cases:</p> <ul style="list-style-type: none"> • The Banking pilot used the Federated Learning component from WP5 to develop a fraud detection model. • The Smart Manufacturing pilot (FMAKE) used the Federated Learning component as well to improve their ML model on quality prediction of the 3D printing. <p>Other non-exhaustive list of WP5 models helping pilot-related activities (reports can be seen in D7.1 [12]) from EADAE using AI is the following:</p> <ul style="list-style-type: none"> • Optimal Cleaning hours for Hotel Managers.

Task	Justification
	<ul style="list-style-type: none"> • Energy Usage informed decisions for Travelers. • Energy Usage informed decisions for Hotel Managers. • Room usage informed decisions (e.g., HVAC settings). • Retail Product Performance Decisions. • Retail Customer Behavioral patterns decisions. • Retail Store Performance decisions.

4.3.12.3 Additional Comments / Remarks for Number of recommendations & decision-making models to be developed

Task	Comment(s)
Provide additional comments regarding the KPI's successful or unsuccessful achievement.	The KPI was successfully achieved. More than 10 models, some of them required by pilots and others inherent to the implementation of the technical components have been delivered.

Summing up, the KPI targeting the development of more than six recommendation and decision-making models was achieved. Many AI models were created across TANGO's pilots and WPs. Within WP5, several core models including PEC's privacy-risk model integrating LLM-based countermeasure recommendations, TornadoVM's hardware selection model, PAT's AI-assistant integration readiness, and the two RENOPS models for price prediction and renewable energy forecasting. WP3 contributed as well with UPCV recommender for Smart Hospitality, and WP4's Device Behavioural Authentication risk assessment engine. Within the pilots, using the Federated Learning component more models were created for manufacturing quality prediction and for banking fraud detection. Lastly, pilot-specific AI tools were used to support operational strategies in retail, energy management, and hospitality. The outputs' breadth showcases TANGO's KPI target exceeding performance.

4.3.13 Reduction in energy consumption for ML model training

The following KPI assessment Reduction in energy consumption for ML model training was provided by TANGO partners ATOS IT Solutions and Services Iberia SL (TANGO "ATOS") and XLAB Razvoj Programske Opreme in Svetovanje DOO (TANGO "XLAB"), based on the standard template they received and the relevant KPI monitoring framework. The entry includes the KPI's target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. As referred by the partners, this KPI was simultaneously processes with KPI "Reduction in energy consumption for a datacentre (Goal: > 30%)" (see subchapter 4.13.18) since they are related and therefore tackled together. Further details and evidence can be found in the respective Section 9.8.13 of Annex 9.8 in this deliverable.

4.3.13.1 KPI identification for Reduction in energy consumption for ML model training

KPI Status	KPI Information
Target Measurable KPI	Reduction in energy consumption for a datacentre > 30% & Reduction in energy consumption for ML model training > 60%
Verification Means (as stated in the DoA / xls file)	Report describing the performance improvement in terms of energy consumption comparing existing datacentres with the TANGO infrastructure & training of ML models.
WP	5
Relevant objective	4
Target	>30% & >60%
Baseline value	Not clear

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KPI Status	KPI Information
Achieved (YES/NO)	Partially. Change of approach to measure improvements not only in energy consumption (not the focus of the tools), but rather in other metrics, such as price reduction, or carbon footprint).

4.3.13.2 KPI Justification for Reduction in energy consumption for ML model training

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	<p>These 2 KPIs are related and therefore tackle together. After several discussions it was apparent that most of the tools developed in WP5 were not designed to lower the energy consumption in ML model training or managing datacentre infrastructure. The focus was on carbon footprint and price reduction of running long-lasting jobs, such as ML model training. In order to achieve that, several approaches were taken:</p> <ol style="list-style-type: none"> 1. Schedule jobs to specific time or place where the cost of energy and availability of renewable energy helps to reduce carbon footprint and price using RENOPS from T5.6. 2. Develop or reuse lightweight and efficient tools to achieve enough functionality for the use cases at hand, rather than going for more complex solutions. <ol style="list-style-type: none"> a. T5.2 decided to base the solution on a MLOps approach using MLflow as baseline instead of other tools such as Kubeflow, much more heavyweight in terms of deployment. Papers such as this one (https://ijsra.net/sites/default/files/IJSRA-2024-1798.pdf), provide information on how MLOps principles, in collaboration with other tools such as RENOPS, hardware accelerators and other techniques, helps on scaling up AI and reduce costs. b. T5.2 also promoted the usage of Federated Learning techniques, by reducing the energy cost of training the model via distributed training and minimising the movement of data to a centralised environment. 3. T5.3 implemented hardware acceleration techniques to reduce the energy required to train models or run jobs in GPUs. <p>A specific validation has been done by XLAB to measure potential of reduction of carbon footprint and price (see details below) using RENOPS.</p>

4.3.13.3 Additional Comments / Remarks for Reduction in energy consumption for ML model training

Task	Comment(s)
Provide additional comments regarding the KPI's successful or unsuccessful achievement.	<p>Key observations of running the validation with RENOPS:</p> <ul style="list-style-type: none"> • Carbon Impact: <ul style="list-style-type: none"> ○ Carbon emissions per run remained stable, due to Slovenia's strong low-carbon energy mix. ○ Minimal use of high-carbon sources like fossil gas and biomass. Thus, effectively lowering carbon emissions per run. • Energy Use Consistency:

Task	Comment(s)
	<ul style="list-style-type: none"> ○ Similar jobs consume similar amounts of energy (*this is why the energy for model training cannot be lowered) • Cost Savings: <ul style="list-style-type: none"> ○ Scheduled training consistently achieved lower EUR/MWh. ○ Clear financial benefit from avoiding high-price periods. • Correlations: <ul style="list-style-type: none"> ○ Training costs strongly correlate with energy source availability and timing. ○ Aligning training with favorable grid conditions reduces costs. • Energy Source vs. Cost: <ul style="list-style-type: none"> ○ Optimized runs show clear cost advantages during periods of higher renewable availability. <p>Conclusion</p> <ul style="list-style-type: none"> • The RENOPS Scheduler effectively: <ul style="list-style-type: none"> ○ Reduces training costs. ○ Aligns energy use with low-carbon sources. ○ Demonstrates predictable energy demand across similar jobs.

Summing up, the KPI targeted a reduction of >60% in energy consumption for ML model training (and >30% for datacentres). The results show that this objective was partially achieved by shifting focus from direct energy consumption reduction to measurable gains in cost efficiency and carbon footprint. RENOPS, a tool from WP5, showed significant improvements by renewable-rich energy availability and scheduling training jobs during low-cost periods thus aligning energy usage with sustainable sources and reducing operational costs. Additional approaches included federated learning to minimize data movement, lightweight MLOps solutions (MLflow), and hardware acceleration via GPUs for improving training efficiency. A consistent energy use was confirmed after being validated by XLAB. It also demonstrated cost savings and reduced carbon impact, especially in low-carbon grid contexts. Conclusively, despite not meeting the strict energy reduction target, the KPI outcomes underline notable environmental and financial benefits, fortifying TANGO's contribution to efficient and sustainable AI operations.

4.3.14 Reduction in energy consumption in application execution for a single node

The following KPI assessment for Reduction in energy consumption in application execution for a single node was provided by TANGO partner University of Manchester (TANGO "UOM"), based on the standard template they received and the relevant KPI monitoring framework. The entry includes the KPI's target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in the respective Section 9.8.14 of Annex 9.8 in this deliverable.

4.3.14.1 KPI identification for Reduction in energy consumption in application execution for a single node

KPI Status	KPI Information
Target Measurable KPI	Reduction in energy consumption in application execution for a single node

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KPI Status	KPI Information
Verification Means (as stated in the DoA / xls file)	Report describing the performance improvement during the execution of an application in terms of efficiency and energy consumption comparing existing with the TANGO way of application execution.
WP	5
Relevant objective	4
Target	>30%
Baseline value	The baseline is the default execution of the application using polyglot runtimes to invoke the Java computation method from Python.
Achieved (YES/NO)	Yes

The partner reported that this was written in DoA assuming that TANGO applications can be written in Java. However, UoM have pivoted to utilize the technology of T5.3 from Python. Hence, the functionally equivalent baseline will be the Java sequential function invoked by Python.

4.3.14.2 KPI Justification for Reduction in energy consumption in application execution for a single node

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	<p>The execution of the baseline relies on a Java method being executed on one CPU thread. As long as the data size passed in the compute method increases, the execution time and power spent to compute increases.</p> <p>Consequently, by employing hardware acceleration (e.g., GPU, multi-core CPU) the execution time is significantly reduced. The fact that power is not increased significantly when GPU is employed for acceleration, results in more than 50% energy efficiency for executing an application on a single compute node that has CPUs, integrated GPUs and discrete GPUs (e.g., NVIDIA GPUs).</p>

4.3.14.3 Additional Comments / Remarks for Reduction in energy consumption in application execution for a single node

Task	Comment(s)
Provide additional comments regarding the KPI's successful or unsuccessful achievement.	For all data sizes the GPU shows higher energy efficiency than the Java baseline implementation, ranging from 1.6x (for 8 thousand rows) to 9x for 64 million rows elements. Our results show >1.30x relative energy efficiency, which means that >30% improvement is achieved.

Summing up, the KPI's >30% reduction in energy consumption for single node application execution, was achieved. The efficiency gains exceeded 50%. By replacing the baseline execution (where on a CPU thread a JAVA compute method ran) with GPUs and multi-core CPUs (hardware accelerated execution) improvement was evident. This approach vastly kept power usage almost constant and reduced execution time. It delivered important energy savings for nodes equipped with CPUs, integrated GPUs, and discrete GPUs (e.g., NVIDIA). Lastly, the partner reported that this was written in DoA assuming that TANGO applications can be written in Java. However, the partner pivoted to utilize the technology of T5.3 from Python. Hence, the functionally equivalent baseline will be the Java sequential function invoked by Python.

4.3.15 Number of AutoML tools

The following KPI assessment for Number of AutoML tools was provided by TANGO partner ATOS IT Solutions and Services Iberia SL (TANGO “ATOS”), based on the standard template they received and the relevant KPI monitoring framework. The entry includes the KPI’s target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in Section 9.8.15 of Annex 9.8 in this deliverable.

4.3.15.1 KPI identification for Number of AutoML tools

KPI Status	KPI Information
Target Measurable KPI	Number of AutoML tools
Verification Means (as stated in the DoA / xls file)	AutoML tools will be uploaded at a repository on GitHub.
WP	5
Relevant objective	4
Target	>2
Baseline value	0
Achieved (YES/NO)	YES

4.3.15.2 KPI Justification for Number of AutoML tools

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	The initial goal was to offer a couple of AutoML tools to the pilots to be able to bootstrap the initial steps of ML model training. The requirements of the pilots showed little interest in ML model training, though, only mentioned by the Smart Manufacturing (FMAKE) and Banking pilots. In both cases they opted for a federated learning approach. Therefore, the shift towards federated learning and MLOps gained traction in the project in detriment of AutoML. The decision was then to offer a couple of means to perform AutoML based on an open-source library (MLJAR), targeting data scientists. The tool was delivered in two versions: API-based, for more advanced users, and GUI-based, for more naïve usage. The validation was done internally by technical partners in the banking pilot with synthetic data, as the pilots did not require the tool.

4.3.15.3 Additional Comments / Remarks for KPI Number of AutoML tools

Task	Comment(s)
Provide additional comments regarding the KPI’s successful or unsuccessful achievement.	The minimal threshold of the KPI was achieved. As commented above, the initial expectations of the tool aimed higher in terms of application of the solution to pilots, although the final use cases did not require AutoML. Therefore, although the KPI has been achieved, its evaluation lacks feedback from real users.

Summing up, the target of more than two AutoML tools was achieved. Two versions were delivered, a GUI-based tool for non-technical basic users and an API-based tool for advanced users. Both were developed based on the open-source MLJAR library. Despite initially being of interest for wider pilot adoption, AutoML was limited to Smart manufacturing and Banking pilots as the other pilots opted for Federated Learning. Technical partners, using synthetic information, carried out the validation, meeting the KPI’s minimum prerequisite without feedback from real pilot users.

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4.3.16 Number of privacy assessment tools to be developed

The following KPI assessment for Number of privacy assessment tools to be developed was provided by TANGO partners FUJITSU Technology Solutions (Luxembourg) SA (TANGO “FUJ_LU”) and University of Greenwich (TANGO “UOG”), based on the standard template they received and the relevant KPI monitoring framework. The entry includes the KPI’s target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in the respective Section 9.8.16 of Annex 9.8 in this deliverable.

4.3.16.1 KPI identification for Number of privacy assessment tools to be developed

KPI Status	KPI Information
Target Measurable KPI	Number of privacy assessment tools to be developed
Verification Means (as stated in the DoA / xls file)	Report that details the information about the recommendation and decision-making models that were developed through the TANGO project.
WP	5 (and others)
Relevant objective	4
Target	>2
Baseline value	0
Achieved (YES/NO)	YES

4.3.16.2 KPI Justification for Number of privacy assessment tools to be developed

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	<p>Two of the three privacy assessment tools were developed in WP5, and the third tool was developed in WP3. These tools have been presented in detail as part of TANGO technical results in D5.2 [18] and D3.2 [10].</p> <p>List of privacy assessment tools developed in TANGO:</p> <ol style="list-style-type: none"> 1. The PEC component (T5.4) developed a tool to assess the privacy risk of generic data handling processes and AI process. The tool achieves this through a privacy risk identification and assessment process leading to privacy risk scores and associated privacy harm. It also recommends countermeasures to address the privacy risks. 2. The PAT component (T5.4) developed a tool to bridge gap between data subject and data controller by reducing complexities in data sharing and increasing awareness before consent. In addition, it supports data controllers remain GDPR compliant [5] by guiding them to create data sharing request and enforcing access-control mechanisms. 3. The TSM component (T3.2) developed a tool that evaluates privacy score of anonymised images within a timeframe. It serves as a platform for experimenting with different anonymised methods and evaluating their effectiveness under various privacy setting and locations.

4.3.16.3 Additional Comments / Remarks for Number of privacy assessment tools to be developed

Task	Comment(s)
Provide additional comments regarding the KPI's successful or unsuccessful achievement.	The KPI was successfully achieved. The developed privacy tools were implemented, improved and validated across the pilot use cases.

Summing up, three distinct tools were developed for the Number of privacy assessment tools KPI, exceeding the benchmark, across WP3 and WP5. The PEC component was developed in WP5, assessing privacy risks in data handling and AI processes, recommending countermeasures, and assigning risk scores. Additionally, the PAT component was design to support consent management through access-control enforcement, and GDPR-compliant [5] data sharing. The TSM component was developed within WP3. It allows experimentation with anonymization methods under various conditions and evaluates the privacy score of anonymized images. The three tools were implemented, validated, and improved across pilot use cases, with an overall result of exceeding the KPI target.

4.3.17 Number of XAI models to be developed

The following KPI assessment for Number of XAI models to be developed was provided by TANGO partner SQUAREDEV (TANGO “SQD”), based on the standard template they received and the relevant KPI monitoring framework. The entry includes the KPI's target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in Section 9.8.17 of Annex 9.8 in this deliverable..

4.3.17.1 KPI identification for Number of XAI models to be developed

KPI Status	KPI Information
Target Measurable KPI	Number of XAI models to be developed
Verification Means (as stated in the DoA / xls file)	XAI model algorithms will be uploaded at a repository on GitHub.
WP	5
Relevant objective	4
Target	> 8
Baseline value	0
Achieved (YES/NO)	YES

4.3.17.2 KPI Justification for Number of XAI models to be developed

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	<p>The goal was to perform XAI on 8 different models that were provided by the pilots, in the scope of this project. Although the availability of models developed by the pilots with the initial pilot mapping was limited, the Smart Manufacturing pilot FMAKE that was mapped later, applied XAI on around 10 models with 5 different structures. The banking pilot applied XAI on at least one model. On top of that, in FMAKE's case 3 different algorithms were used on each model (SHAP, LIME, DeepLift and LRP) and in banking pilot's case two algorithms (SHAP and LIME).</p> <p>To sum up, XAI was performed in around 11 models, offering 2-4 different algorithms on each.</p>

4.3.17.3 Additional Comments / Remarks for KPI Number of XAI models to be developed

Task	Comment(s)
Provide additional comments regarding the KPI's successful or unsuccessful achievement.	The KPI not only met but exceeded the minimum threshold in this case. Although the initial pilot mapping with this technology was not accurate, the number of models offered by FMAKE exceeded expectations.

Summing up, the KPI's goal to develop more than eight XAI models was exceeded. The Smart Manufacturing pilot (FMAKE) applied XAI to around ten models with five different structures, using three to four algorithms per model (e.g., SHAP, LRP, DeepLift, LIME). The Banking pilot also applied XAI in at least one model using LIME and SHAP. Overall, XAI was performed on approximately eleven models, surpassing the KPI target and demonstrating broad applicability across multiple pilot contexts and algorithms.

4.3.18 Reduction in energy consumption for a datacentre

This KPI assessment Reduction in energy consumption for a datacentre was provided by TANGO partners ATOS IT Solutions and Services Iberia SL (TANGO "ATOS") and XLAB Razvoj Programske Opreme in Svetovanje DOO (TANGO "XLAB"), based on the standard template they received and the relevant KPI monitoring framework. The entry includes the KPI's target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. As referred by the partners, this KPI was simultaneously processed with KPI "Reduction in energy consumption for ML model training (Goal: > 60%)" (see subchapter 4.3.13) since they are related and therefore tackled together. Details and results on the KPI achievements can be found in the previous chapter. Further details and evidence can be found in Section 9.8.18 of Annex 9.8 in this deliverable.

4.3.19 Number of pilot validation campaigns

The following KPI assessment for Number of pilot validation campaigns was provided by TANGO partner University of Piraeus Research Center (TANGO "UPRC"), based on the standard template they filled in and the relevant KPI monitoring framework. The entry includes the KPI's target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in Section 9.8.19 of Annex 9.8 in this deliverable..

4.3.19.1 KPI identification for Number of pilot validation campaigns

KPI Status	KPI Information
Target Measurable KPI	Number of pilot validation campaigns
Verification Means (as stated in the DoA / xls file)	Documentation and reporting of validation activities across all TANGO pilots, including test plans, execution reports, and results.
WP	7
Relevant objective	5
Target	>6
Baseline value	0
Achieved (YES/NO)	YES

4.3.19.2 KPI Justification for Number of pilot validation campaigns

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	<p>The KPI was successfully achieved through the implementation and evaluation of:</p> <ul style="list-style-type: none"> Seven (7) pilot campaigns across the different TANGO use cases/pilots so the applicability of the platform could be validated. Each pilot demonstrated their respective TANGO technologies in the pilots' domain and provided valuable operational feedback. A dedicated (1) focus group involving pilot representatives was conducted to assess the overall performance and validation of the TANGO platform, ensuring cross-pilot insights and alignment.

4.3.19.3 Additional Comments / Remarks for KPI Number of pilot validation campaigns

Task	Comment(s)
Provide additional comments regarding the KPI's successful or unsuccessful achievement.	Together, these activities exceeded the original KPI target (8 campaigns over targeted 6) and provided robust evidence of the platform's effectiveness in real-world conditions.

Summing up, the KPI's goal to proceed to more than six pilot validation campaigns was exceeded. Eight campaigns were successfully conducted across TANGO's different domains, including not only the actual implementation of the seven pilots, but also a dedicated focus group of pilot representatives, where valuable lessons and perspectives were discussed about the project, its' effectiveness and further real-world applications in future phases.

4.3.20 Number of external stakeholders participating in the validation campaigns

The following KPI assessment for Number of external stakeholders participating in the validation campaigns was provided by TANGO partner The Lisbon Council for Economic Competitiveness ASBL (TANGO "LIC"), based on the standard template they filled in and the relevant KPI monitoring framework. The entry includes the KPI's target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in Section 9.8.20 of Annex 9.8 in this deliverable.

4.3.20.1 KPI identification for Number of external stakeholders participating in the validation campaigns

KPI Status	KPI Information
Target Measurable KPI	Number of external stakeholders participating in the validation campaigns
Verification Means (as stated in the DoA / xls file)	Validation campaign: defined as a presentation or demonstration of the TANGO Platform, in general, or in relation to a pilot, during which we interacted with stakeholders and received feedback.
WP	7
Relevant objective	5
Target	>4000
Baseline value	0
Achieved (YES/NO)	NO

4.3.20.2 KPI Justification for Number of external stakeholders participating in the validation campaigns

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	<ul style="list-style-type: none"> • YouTube views: total number of views for all videos: 15 videos have been viewed by 1.141 in total • Social media and website: more than 1.000 reached stakeholders (impressions), for content related to the platform (not general news, etc.) (see Figure 4) • Pilot-focused pages on the TANGO website <ul style="list-style-type: none"> - 1490 visits (https://tango-project.eu/pilots) - 211 visits (https://tango-project.eu/pilots/smart-hospitality) - 119 visits (https://tango-project.eu/pilots/autonomous-vehicles) - 82 visits (https://tango-project.eu/pilots/smart-manufacturing) - 206 visits (https://tango-project.eu/pilots/banking) - 65 visits (https://tango-project.eu/pilots/public-administration) - 70 visits (https://tango-project.eu/pilots/retail) • Deliverable downloads from TANGO website (see Figures 5, 6, 7, 8): All related to users and technology. 849 Visits 661 visits (https://tango-project.eu/materials/public-deliverables) 168 visits (https://tango-project.eu/materials/scientific-publications) • Website article downloads – 1088 Visits (https://tango-project.eu/articles) (see Figure 9) • Publication most downloaded: Find link here (see Figure 10) • Webinars: by ECO/LIC – more than 100 participants attended • Stakeholders from pilots: 1490 visits • Business validation workshops with the Horizon Results Booster service: 7 participants • Advisory Board members: 3 stakeholders • Dissemination events / conferences where the platform / pilots were presented: An average number of audiences has been counted which is 220 people

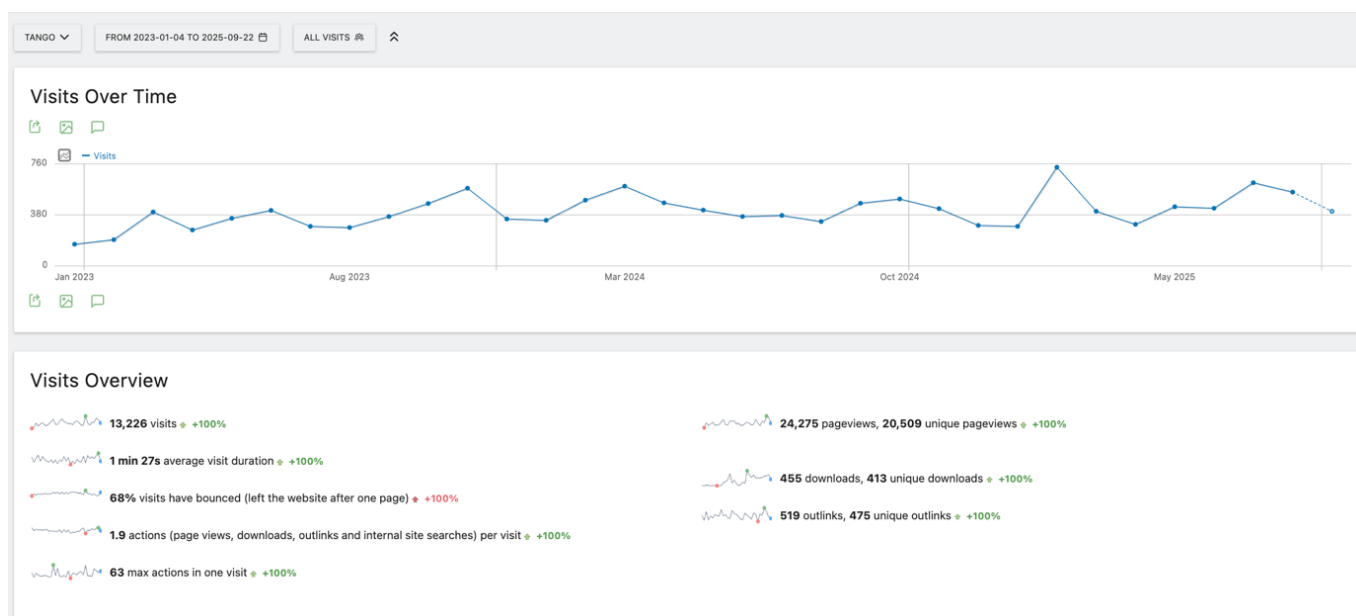


Figure 4: Number of external stakeholders participating in the validation campaigns KPI website visits and key engagement metrics for the TANGO project, from January 2023 to September 2025.

The Figure's 4 chart above displays the evolution of visit volume over time, while the overview panel summarises main indicators, including total visits (13,226), average visit duration (1 min 27 sec), bounce rate (68%), average actions per visit (1.9), total pageviews (24,275), downloads (455), and external link clicks (519). These metrics reflect user interest and interaction with TANGO's website.

Pages

public

PAGE URL	PAGEVIEWS	UNIQUE PAGEVIEWS	BOUNCE RATE	AVG. TIME ON PAGE	EXIT RATE	AVG. PAGE LOAD TIME
materials	849	722	52%	00:01:27	59%	0.71s
/public-deliverables	661	560	47%	00:01:35	61%	-
/scientific-publications	168	142	63%	00:01:09	44%	-

Figure 5: Number of external stakeholders participating in the validation campaigns KPI page-level engagement statistics for the "Materials" section of the TANGO website.

The table displayed in Figure 5 above shows traffic for the main materials landing page and two sub-pages: Public Deliverables and Scientific Publications. In total, the materials section received 849 pageviews (722 unique), with an average time on page of 1 minute 27 seconds.

- The /public-deliverables page received 661 views (560 unique), with a bounce rate of 47% and an average time on page of 1 minute 35 seconds, indicating strong engagement with project outputs.
- The /scientific-publications page recorded 168 views (142 unique) and a slightly higher bounce rate of 63% but still reflects solid interest in TANGO's academic contributions.

Downloads



DOWNLOAD URL	UNIQUE DOWNLOADS	DOWNLOADS
tango-project.eu	379	412
/sites/default/files/materials/TANGO_D1.1_Project Management Handbook_v1.0.pdf	38	41
/sites/default/files/materials/TANGO_D4.1_Distributed_Trust_Management_Framework_v1.0.pdf	32	35
/sites/default/files/materials/TANGO_D3.1_Distributed Privacy-preserving Data Management and Storage_v1.0.pdf	31	35
/sites/default/files/materials/TANGO_D8.1_Dissemination-Communication-Exploitation-and-Stakeholders-Engagement-Plan_v1.0.pdf	29	32
/sites/default/files/materials/TANGO_D5.1_AI-based Framework for Green Trustworthy Operations Intermediate Version_v1.0.pdf	28	29
/sites/default/files/uploads/A First TANGO White Paper - T8-6 - FINAL (1).pdf	28	32
/sites/default/files/materials/A First TANGO White Paper - T8-6 - FINAL.pdf	27	28
/sites/default/files/materials/D2.2_UserNeeds_Reqs_UseCases.zip	27	27
/sites/default/files/materials/TANGO_D2.1_SotA in Distributed Data Management_v1.0.pdf	27	30
/sitemap.xml	26	28
/sites/default/files/materials/TANGO_D1.2_Data Management Plan and Research Ethics_version 1_v1.0.pdf	24	25
/sites/default/files/materials/TANGO_D8.2_Diss-Comm-Expl-and-Stakeholders-Engag-Inter-version_v1.0 (2).pdf	21	26
/sites/default/files/uploads/TANGO Second White Paper - T8-6 - FINAL version.pdf	12	12
/sites/default/files/dissemination/brochure.zip	9	11
/sites/default/files/dissemination/Tango_Rollup_004.pdf	7	8
/sites/default/files/dissemination/TANGO_Template_presentation.pptx	5	5
/sites/default/files/dissemination/icons_PPT.zip	3	3
/sites/default/files/dissemination/LOGO-20240220T110716Z-001.zip	2	2
/sites/default/files/dissemination/TANGO_Deliverable template_v2.0.docx	2	2
/sites/default/files/dissemination/fonts.zip	1	1

Figure 6: Number of external stakeholders participating in the validation campaigns KPI downloads of TANGO deliverables and materials from the project website.

The most downloaded file, as shown in Figure 6 above, is the Project Management Handbook (412 total downloads), followed by key technical deliverables such as D4.1, D3.1, and D5.1. The data reflects strong stakeholder interest in TANGO's core architecture and privacy-preserving solutions.

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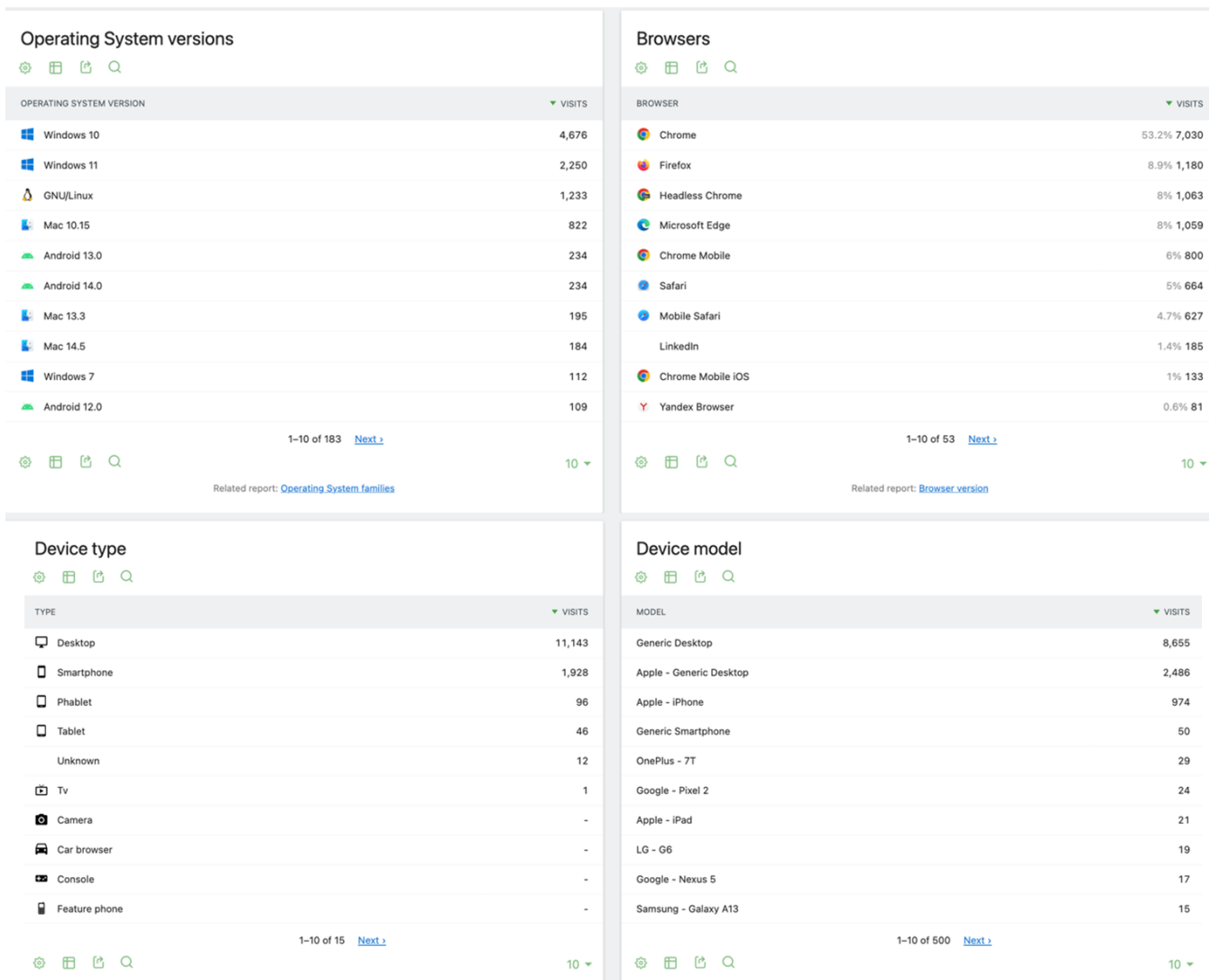


Figure 7: Number of external stakeholders participating in the validation campaigns KPI technical profile of TANGO website visitors: operating systems, browsers, and devices.

Most users, as seen above in Figure 7, accessed the website via desktop devices (11,143 visits), primarily using Windows OS and Google Chrome. Mobile access was also significant, with visits from Android, iOS, and a variety of smartphone models. These insights help contextualise user behaviour and guide optimisation for accessibility across platforms.

COUNTRY	VISITS
 Germany	2,178
 United States	1,694
 Italy	1,616
 Greece	1,039
 Spain	831
 United Kingdom	602
 Netherlands	550
 Belgium	388
 India	342
 Finland	334
 France	289
 China	225
 Austria	204
 Russia	204
 Ireland	183
 Japan	123
 Portugal	114
 Canada	103
 Sweden	103
 South Korea	89
 Poland	83
 Türkiye	83
 Slovenia	77
 Singapore	76
 Vietnam	70

Figure 8: Number of external stakeholders participating in the validation campaigns KPI geographic origin of TANGO website visitors.

As seen in Figure 8, the highest number of visits came from Germany (2,178), followed by the United States (1,694), Italy (1,616), and Greece (1,039). Traffic was recorded from across Europe, Asia, and North America, reflecting the project's broad international reach and relevance.

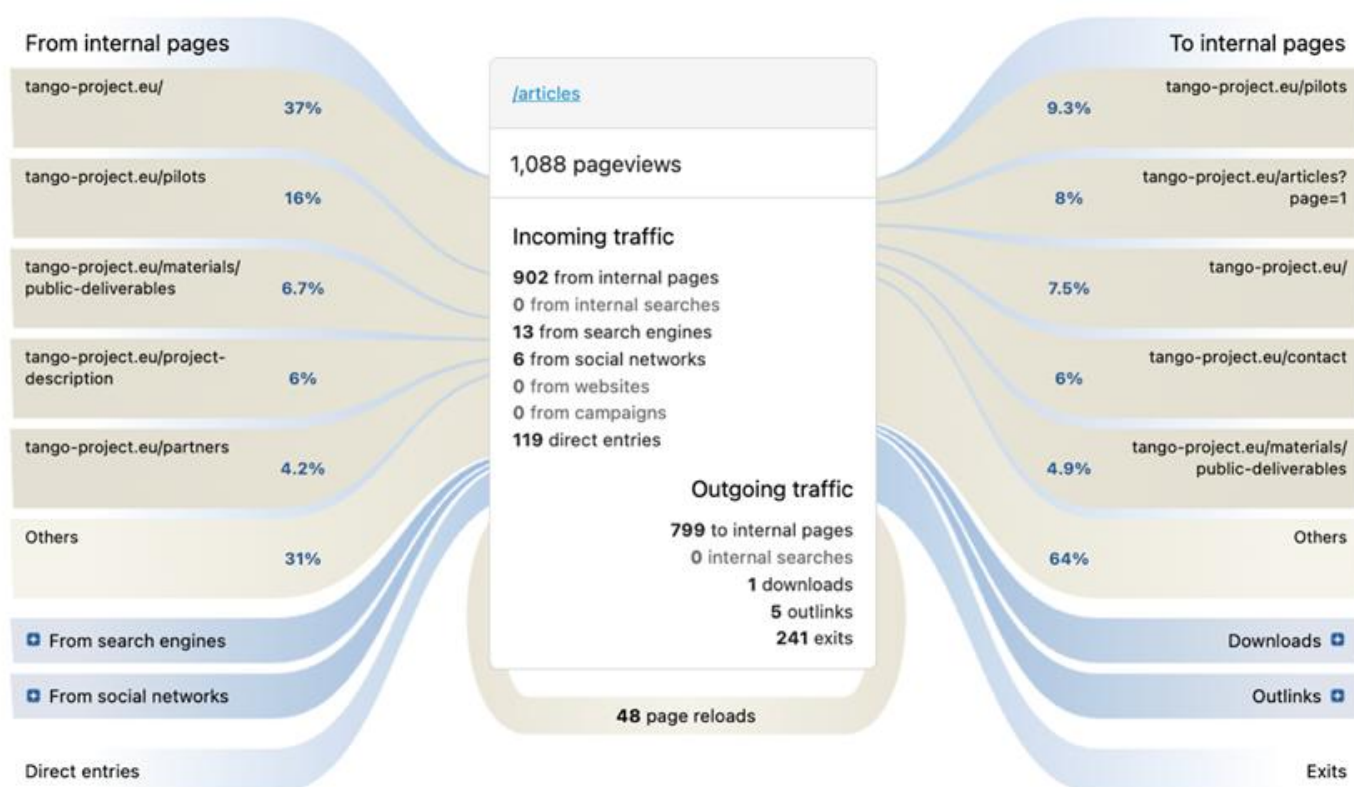


Figure 9: Number of external stakeholders participating in the validation campaigns KPI user navigation for the “Articles” section on the TANGO website.

As seen above in Figure 9, the page received 1,088 views, mostly from internal navigation (83%), with top entry points including the homepage and the pilot’s section. A total of 241 users exited, while 799 continued to other internal pages, confirming that the articles supported further engagement across the site.

Downloads

publication

DOWNLOAD URL	UNIQUE DOWNLOADS	DOWNLOADS
hummedia.manchester.ac.uk	3	4
/institutes/gdi/publications/workingpapers/di/di_wp68.pdf	3	4

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100

Figure 10: Number of external stakeholders participating in the validation campaigns KPI most downloaded scientific publication linked to the TANGO project.

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Pages



PAGE URL	PAGEVIEWS	UNIQUE PAGEVIEWS	BOUNCE RATE	AVG. TIME ON PAGE	EXIT RATE	AVG. PAGE LOAD TIME
/index	10,000	8,570	64%	00:00:35	72%	2.3s
articles	3,228	2,761	81%	00:01:01	77%	3.57s
/project-description	2,016	1,654	74%	00:01:06	62%	2.02s
/partners	1,578	1,412	74%	00:01:01	63%	2.88s
/pilots	1,490	1,177	61%	00:00:44	36%	0.64s

Figure 11: Number of external stakeholders participating in the validation campaigns KPI most viewed pages on the TANGO website

The Figure 11 above indicates that the homepage (/index) recorded the highest traffic with 10,000 pageviews, followed by articles (3,228) and the project description (2,016) pages.

pilots	780	695	79%	00:01:06	59%	1.81s
/smart-hospitality	211	190	82%	00:01:38	63%	2.09s
/banking	206	182	77%	00:00:48	67%	1.33s
/autonomous-vehicles	119	101	70%	00:01:09	48%	0.9s
/smart-manufacturing	82	72	69%	00:01:04	50%	0.95s
/retail	70	62	70%	00:01:21	48%	1.86s
/public-administration	65	61	82%	00:00:34	49%	0.64s

Figure 12: Number of external stakeholders participating in the validation campaigns KPI most viewed pilot pages on the TANGO website.

As seen in Figure 12 above, the Smart Hospitality and Banking pilots received the highest number of views (211 and 206 respectively), followed by Autonomous Vehicles (119). All pilot pages show strong average time on page and relatively low exit rates, indicating user interest in TANGO's real-world applications.

4.3.20.3 Additional Comments / Remarks for Number of external stakeholders participating in the validation campaigns

Task	Comment(s)
Provide additional comments regarding the KPI's successful or unsuccessful achievement.	The nature/objective of the pilots changed since the proposal phase (details) therefore, the initially foreseen number of external stakeholders was not able to be reached, given the different nature and target users of the pilots (e.g., in banking instead of actual bank customers the anti-fraud manager was counted). Nevertheless, a large number of external stakeholders has had access to the platform through the pilots or through dissemination, communication and exploitation activities. Given the new nature of the pilots, as well as of the development timing, we believe that the number of users that validated hands-on the TANGO platform is adequate to capture the opinion of external stakeholders

Summing up, the KPI set a target of more than 4,000 external stakeholders, but this was not achieved. Validation activities nonetheless engaged a substantial number of stakeholders through multiple channels. Website analytics registered over 13,000 visits and 24,000 pageviews, with notable engagement on pilot pages, articles, and public deliverables. Dissemination extended further via 15 YouTube videos (1,141 views), social media impressions (>1,000), deliverable and publication downloads (455), and webinars with over 100 participants. Pilot-specific dissemination also attracted traffic, such as 1,490 visits to pilot pages. Additional engagement included 7 participants in Horizon Results Booster workshops, 3 Advisory Board members, and audiences at conferences averaging 90 people per event. While the originally foreseen number of external stakeholders was not met due to the

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evolving nature of the pilots and their narrower target groups (e.g., anti-fraud managers instead of retail customers), the wide range of activities demonstrates that the TANGO platform reached and engaged a significant, international external audience. These efforts provided sufficient external feedback to validate the platform from both technical and application perspectives.

4.3.21 Number of usage scenarios integrated

The following KPI assessment for Number of usage scenarios integrated was provided by TANGO partner University of Piraeus Research Center (TANGO “UPRC”), based on the standard template they filled in and the relevant KPI monitoring framework. The entry includes the KPI’s target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in Section 9.8.21 of Annex 9.8 in this deliverable.

4.3.21.1 KPI identification for Number of usage scenarios integrated

KPI Status	KPI Information
Target Measurable KPI	Number of usage scenarios integrated
Verification Means (as stated in the DoA / xls file)	Report describing the different usage scenarios that have been successfully implemented and validated within the TANGO pilots.
WP	7
Relevant objective	5
Target	>18
Baseline value	0
Achieved (YES/NO)	YES

4.3.21.2 KPI Justification for Number of usage scenarios integrated

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	The KPI was successfully achieved by mapping and validating all active roles across the different pilots as individual usage scenarios. Specifically, the Hospitality pilot contributed 2 scenarios (Tourist, Manager), the Public Organization pilot 5 scenarios (VISARIGHT Employee, Public Authority, VISA Applicant, Applicant Employer, PEC Evaluation), the Retail pilot 5 scenarios (IT Manager, Sales, Marketing, Product Manager, Recommender Proof-of-Concept), the Smart Manufacturing pilot (FMAKE) 3 scenarios (Customer, Employee, Data Scientist), the Banking pilot 1 scenario (Anti-fraud Operator), the RIAS pilot 2 scenarios (Worker, Manager/Supervisor), and the IDIADA pilot 3 scenarios (Passenger, Client – map access, TSM Proof-of-Concept).

4.3.21.3 Additional Comments / Remarks for KPI Number of usage scenarios integrated

Task	Comment(s)
Provide additional comments regarding the KPI’s successful or unsuccessful achievement.	In total, 21 scenarios were integrated, exceeding the initial target of 18.

Summing up, the KPI’s goal to integrate more than eighteen scenarios was exceeded. Assuming that each active role is an integrated scenario, each different pilot contributed accordingly during the live demonstration, with users performing their role as designed to check the components’ applicability and functionality.

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4.3.22 Number of datasets uploaded on the proposed data spaces

The following KPI assessment for Number of datasets uploaded on the proposed data spaces was provided by TANGO partner University of Piraeus Research Center (TANGO “UPRC”), based on the standard template they filled in and the relevant KPI monitoring framework. The entry includes the KPI’s target value, the relevant work package and specific objective, and the status based on pilot validation and measurable evidence, including integration achievements, technical results, stakeholder feedback, and operational performance. Further details and evidence can be found in the respective Section 9.8.22 of Annex 9.8 in this deliverable.

4.3.22.1 KPI identification for Number of datasets uploaded on the proposed data spaces

KPI Status	KPI Information
Target Measurable KPI	Number of datasets uploaded on the proposed data spaces
Verification Means (as stated in the DoA / xls file)	Report documenting the datasets contributed by each pilot and their successful integration into the TANGO-enabled data spaces.
WP	7
Relevant objective	5
Target	>20
Baseline value	0
Achieved (YES/NO)	NO

4.3.22.2 KPI Justification for Number of datasets uploaded on the proposed data spaces

Task	Justification
Explain how the KPI was achieved. Mention any related technical development or validation activities.	The KPI was not successfully achieved after integrating 12 datasets across pilots and the platform. Contributions included three datasets from the Smart Hospitality pilot (NADIA platform, hotel evaluation by tourists, and check-in dataset), one from the Public Organization pilot (applicant data), three from the Retail pilot (sales data from Greece and Cyprus, and behavioural data), two from the FMAKE pilot (printing job reports and customer printing files), one from the Banking pilot (transactions data), one from RIAS (worker location incidents), one from IDIADA (maps), and the TANGO users dataset covering all onboarded users.

4.3.22.3 Additional Comments / Remarks for KPI Number of datasets uploaded on the proposed data spaces

Task	Comment(s)
Provide additional comments regarding the KPI’s successful or unsuccessful achievement.	While the target of 20 was not fully met (12 datasets identified), the achieved results showcase interesting multi-domain engagement with the data spaces and validate the feasibility of privacy-preserving data sharing across heterogeneous pilots, offering a strong foundation for further extension beyond the project.

Summing up, the KPI Number of datasets uploaded on the proposed data spaces was not successfully achieved. Twelve datasets were identified and loaded in TANGO’s modelling ecosystem for further decision-making. Despite not achieving the KPI goal, the results are significant from both a technical and business perspectives, as they show that in a complicated platform of technologies and data spaces there is a feasible potential of sharing data across heterogeneous domains, which could serve as a foundation for further extension beyond the project.

5 Validation

The cornerstone of the TANGO Project is to evaluate if the selected architecture and developed platform meets its defined objectives, including scalability, security, privacy preservation, and usability across the different pilot ecosystems. Therefore, the final step of the evaluation is the platform's Validation. In alignment with the Project's Grant Agreement, the validation assesses at what degree the integrated innovations and technical components offer actual value to the stakeholders involved. The selected validation framework captures both qualitative insights and performance metrics, by combining structured focus group discussions with carefully selected questions through a structured questionnaire. This approach results in a holistic evaluation of the TANGO platform's commercial and operational potential, its alignment with end-user and regulatory expectations and it aims to identify, if so, what did not work and why.

5.1 Validation Methodology

The selected TANGO Platform validation methodology is founded on two complementary approaches which will be analyzed briefly below.

5.1.1 Validation Structured Questionnaire

As explained earlier in this Deliverable (Chapter 2, "Methodological Framework"), the questionnaire is a tool to collect quantitative responses, in a standardized format, from all pilot leaders and technical partners on the platform's integration, usability, and functionality. The structured layout can be used to compare the alignment, user experience, and technical performance against the defined measurable project objectives and the overall performance across pilots. In this context, and to collect responses from multiple project stakeholders, a digital questionnaire was designed in the "Survey Monkey" tool and a dedicated link was disseminated to the TANGO's mailing list. The questionnaire as sent can be found in this deliverable's annex 9.4. "TANGO Platform Validation Questionnaire".

5.1.2 Focus Groups

Since the questionnaire provides quantitative data based on predefined questions, a complete evaluation should be supported by the opinions of users and other stakeholders involved in the TANGO's platform design, development and deployment. To achieve that, discussion and open-ended interviews were selected as suitable data acquisition techniques for the focus groups. Especially for platforms like TANGO, which deploy a variety of technological components developed by multiple stakeholders, group discussions can reveal actual adoption barriers, user perspectives, and practical deployment issues, which surveys, using a standardized format, may not be able to capture. During group discussions, human spontaneity is prominent and may provide reach insights and valuable feedback [21]. The focus groups approach encourages a collaborative spirit among partners, incorporates their interactive feedback and concerns, and captures their perspectives on integration, usability, transparency, and interoperability within TANGO.

In the validation context, aligned with the Deliverable 2.4 [17] requirements, two focus groups were designed and conducted to capture the above insights and opinions. Each group included key stakeholders like component developers, integrators, pilot leaders and end-user representatives, ensuring that all perspectives across operational and technical domains were freely and objectively captured.

- **Pilot Representatives Focus Group:** The pilot representatives group aimed to offer insights on accessibility, usability, and efficiency. Stakeholders evaluated workflow impact, user interface quality, and perceived value, providing insights beyond KPI measurements and assessing TANGO's potential for future adoption, with the ability to deliver value both within the pilot's sector and beyond its current scope.
- **Technical Teams Focus Group:** The technical team's focus group aimed to offer practical insights specifically into the innovation and technologies used in the various components. The participants assessed the requirements on security, data integrity, and interoperability. The

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discussions identified integration challenges, explored how effectively the components met these requirements and validated operational readiness in pilot environments. Lastly, the participants offered their insight into what additional functionalities and/or technologies could be integrated into TANGO to strengthen its relevance and commercial/market potential, judging from the real-world TANGO demonstrations.

To be more efficient in the focus groups discussion flow, two sets of open questions were created for each of the groups. The set of questions asked are available in Annexes 9.5 “Pilot Representatives Focus Group Questions” and 9.6 “Technical Partners Focus Group Questions”.

The benefits from using focus groups are prominent and they can be summarized [21] [22] below:

- **Actions proposals:** The discussions’ output include informed recommendations for future exploitation, system improvements, additional technologies inclusion that can lead to further scalability and value.
- **Collaborative Validation:** The real-time dialogue captured nuanced performance insights and experts’ opinions on what worked and what could be improved.

5.2 Validation Questionnaire

The validation questionnaire provided a structured way for all the partners to validate the platform’s efficiency, functionality, and applicability. Each question progresses thematically, exploring different TANGO aspects and considering additional comments provided by the participating partners. In this sub-chapter, each question will be presented separately reflecting the details of the responses.

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5.2.1 Validation Questionnaire Results - Meeting Stakeholder Needs and Requirements

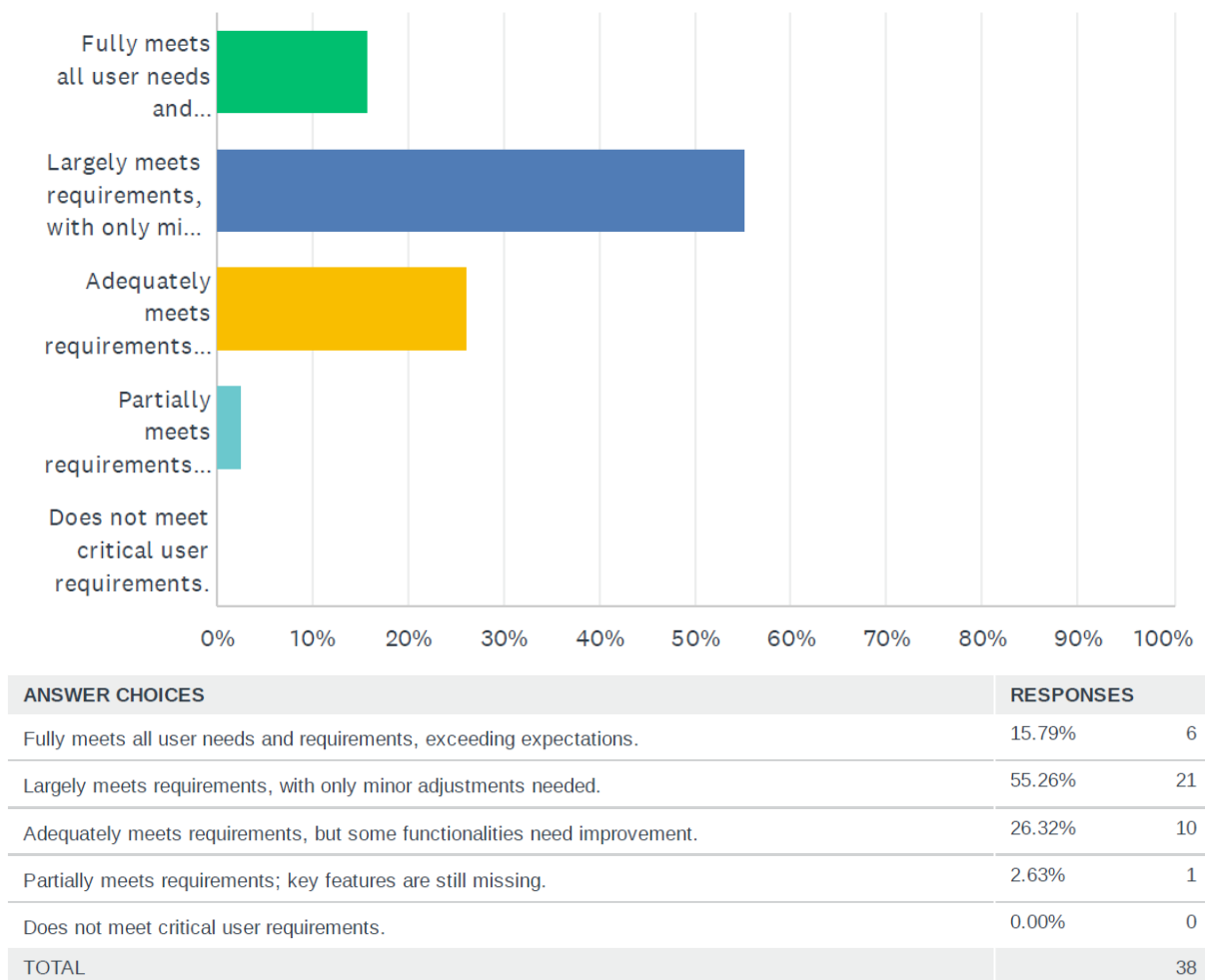


Figure 13: Validation Questionnaire Results Meeting Stakeholder Needs and Requirements.

According to the responses (Figure 13) provided, most of the participants (>70% accumulatively) agreed that TANGO met the stakeholders' requirements, though many of them commented that simplifications were necessary. One of the respondents emphasized that "the original requirements and use cases of the pilots had to be simplified to be handled by TANGO" while some requirements could not be fulfilled with the available technologies. In the banking pilot, enforcing HTTPS over HTTP as stricter security was requested, though the Federated Learning component still complied with core needs. Others stressed that most requirements documented in D2.4 [17] were retained as, with only a few not being achieved. Issues with limited OBU power in the autonomous vehicle pilot and usability problems during ePassport testing (e.g., failed face recognition) were also highlighted.

5.2.2 Validation Questionnaire Results - Meeting Technical and Functional Requirements

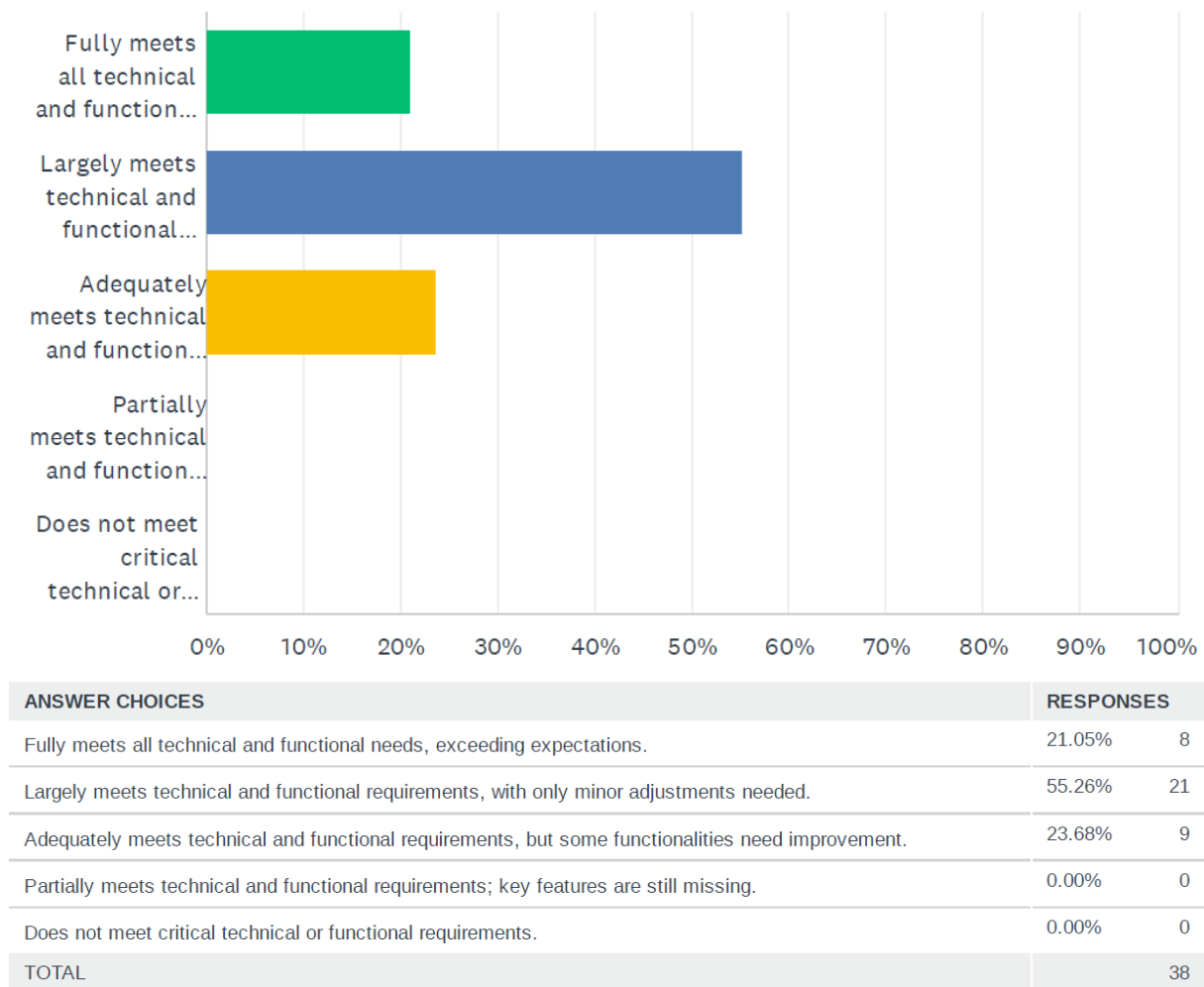
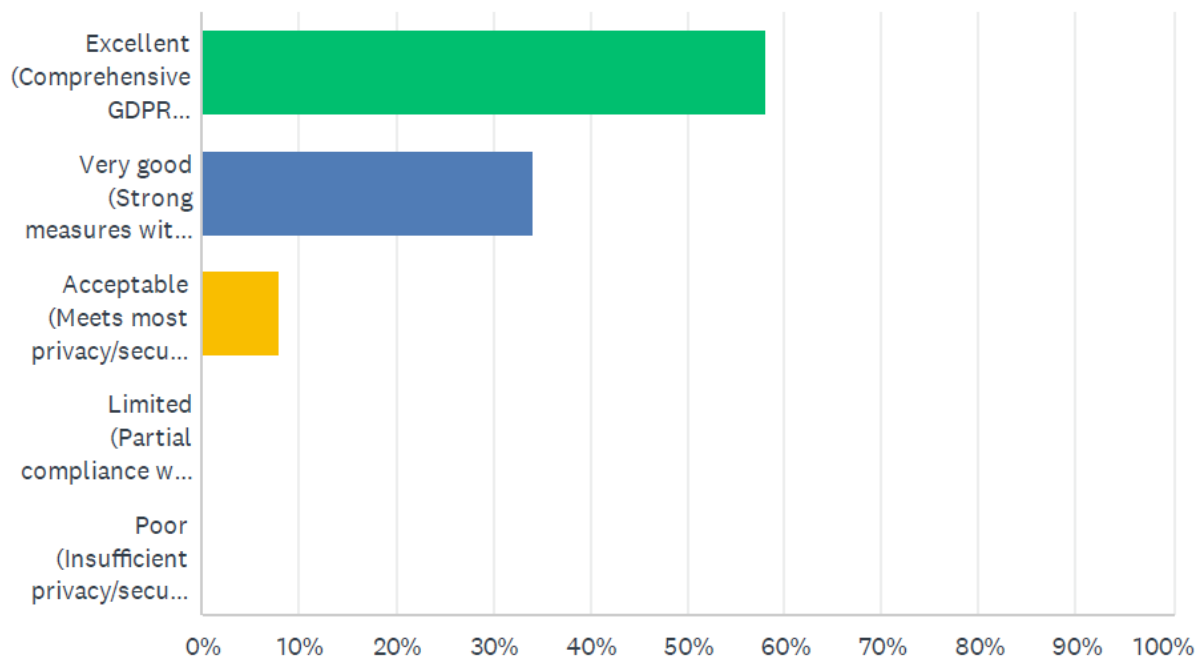


Figure 14: Validation Questionnaire Results Meeting Technical and Functional Requirements.

The technical alignment received generally high acceptance (almost 75% accumulatively) by the partners (Figure 14). They underlined that: “the large majority of initial functional and non-functional requirements have been retained/updated and implemented” (as described analytically in TANGO Deliverable D2.4 [17]). It was mentioned that the Trustworthiness Scoring Module (TSM) was integrated successfully with the PEP component but required additional effort for deployment in real environments. Some onboarding processes still required refinement. Overall, the platform largely met technical and functional needs.

5.2.3 Validation Questionnaire Results - GDPR and Privacy Compliance

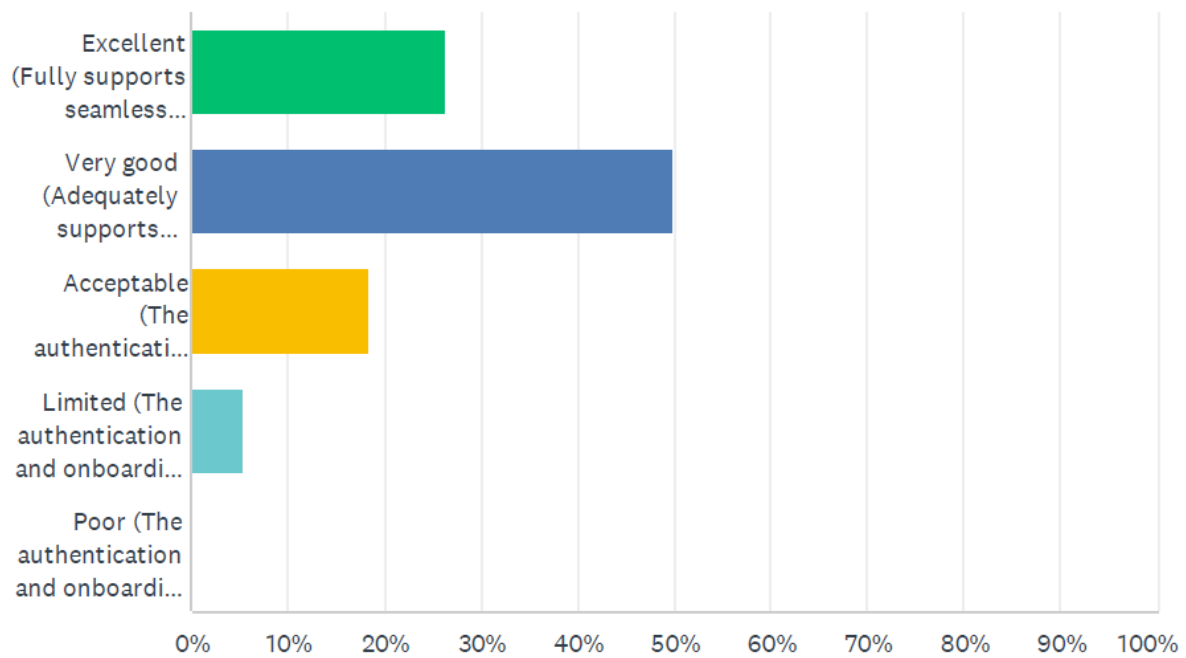


ANSWER CHOICES		RESPONSES	
Excellent (Comprehensive GDPR compliance, strong security, and privacy-by-design).		57.89%	22
Very good (Strong measures with minor improvements required).		34.21%	13
Acceptable (Meets most privacy/security requirements but needs enhancements).		7.89%	3
Limited (Partial compliance with gaps in privacy/security controls).		0.00%	0
Poor (Insufficient privacy/security and non-compliance risks identified).		0.00%	0
TOTAL			38

Figure 15: Validation Questionnaire Results GDPR and Privacy Compliance.

High acceptance derived in terms of the GDPR [5] and privacy compliance (>90% accumulatively), confirming that privacy features such as the PAT and PEC were considered robust (Figure 15). One partner noted: “Both PAT and PEC components comply with GDPR [5] and provide useful services to the end users.”. Attribute-based encryption (CP-ABE) was also recognized as enabling strong confidentiality by restricting access to those with the right attributes.

5.2.4 Validation Questionnaire Results - User Authentication and Onboarding

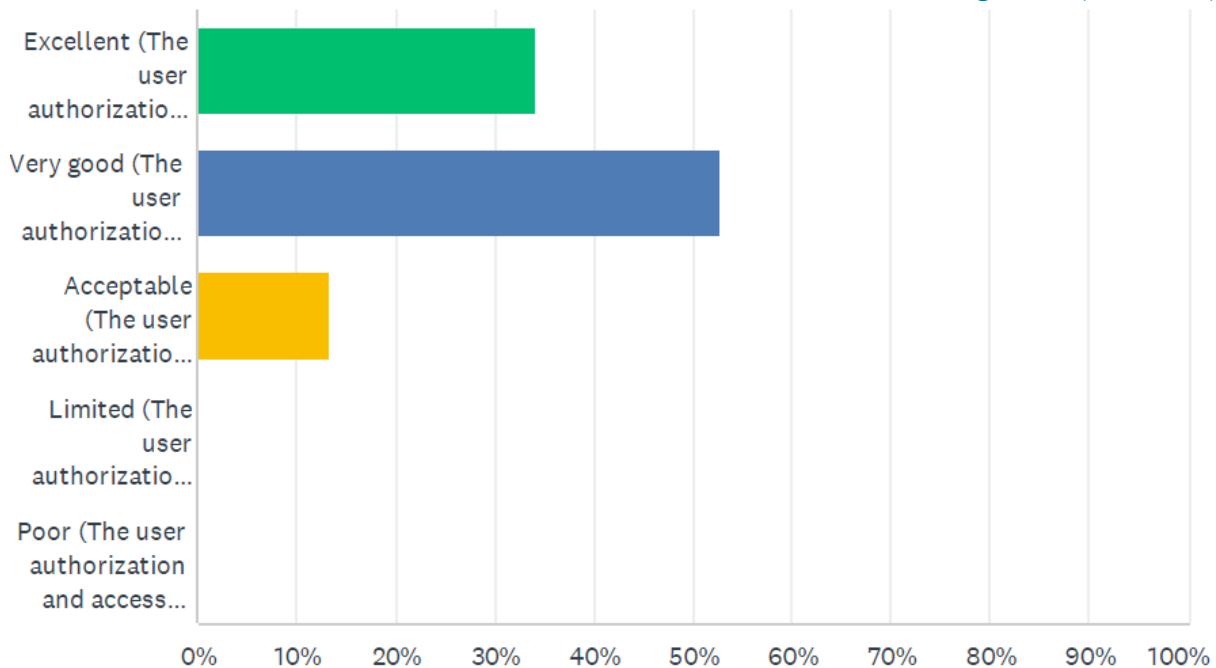


ANSWER CHOICES	RESPONSES	
Excellent (Fully supports seamless authentication and user-friendly onboarding).	26.32%	10
Very good (Adequately supports seamless authentication and user-friendly onboarding).	50.00%	19
Acceptable (The authentication and onboarding process is unclear or complex).	18.42%	7
Limited (The authentication and onboarding process needs technical support).	5.26%	2
Poor (The authentication and onboarding process is an unreliable service).	0.00%	0
TOTAL		38

Figure 16: Validation Questionnaire Results User Authentication and Onboarding.

High acceptance among partners was noted (see Figure 16) for the user authentication and onboarding mechanisms (>75% accumulatively), including the, validated across pilots, SSI wallet, ePassport, and continuous authentication modules. Comments provided acknowledged effectiveness but emphasized usability issues. For example, partners mentioned that “improvements are needed to simplify the process and enhance usability”, especially for ePassport, which should support iOS and more passport types. A partner added: “The ePassport app works very well functionally but can still have some usability improvements.”.

5.2.5 Validation Questionnaire Results - Authorization and Access Management (PEP/PDP)



ANSWER CHOICES	RESPONSES	
Excellent (The user authorization and access management process is highly reliable).	34.21%	13
Very good (The user authorization and access management process demonstrates strong access control).	52.63%	20
Acceptable (The user authorization and access management process works most of the time).	13.16%	5
Limited (The user authorization and access management process is inconsistent).	0.00%	0
Poor (The user authorization and access management process is unreliable).	0.00%	0
TOTAL		38

Figure 17: Validation Questionnaire Results Authorization and Access Management (PEP/PDP).

Most of the partners acknowledged the high impact of PEP/PDP component as a strong element of TANGO (>85% accumulatively) (Figure 17). One of the partners stated that: “The PEP/PDP environment is fundamental for attribute-based access control facilitating fine-grained access management leveraging the other TANGO components.”.

5.2.6 Validation Questionnaire Results - Data Ownership through the Lifecycle (CP-ABE)

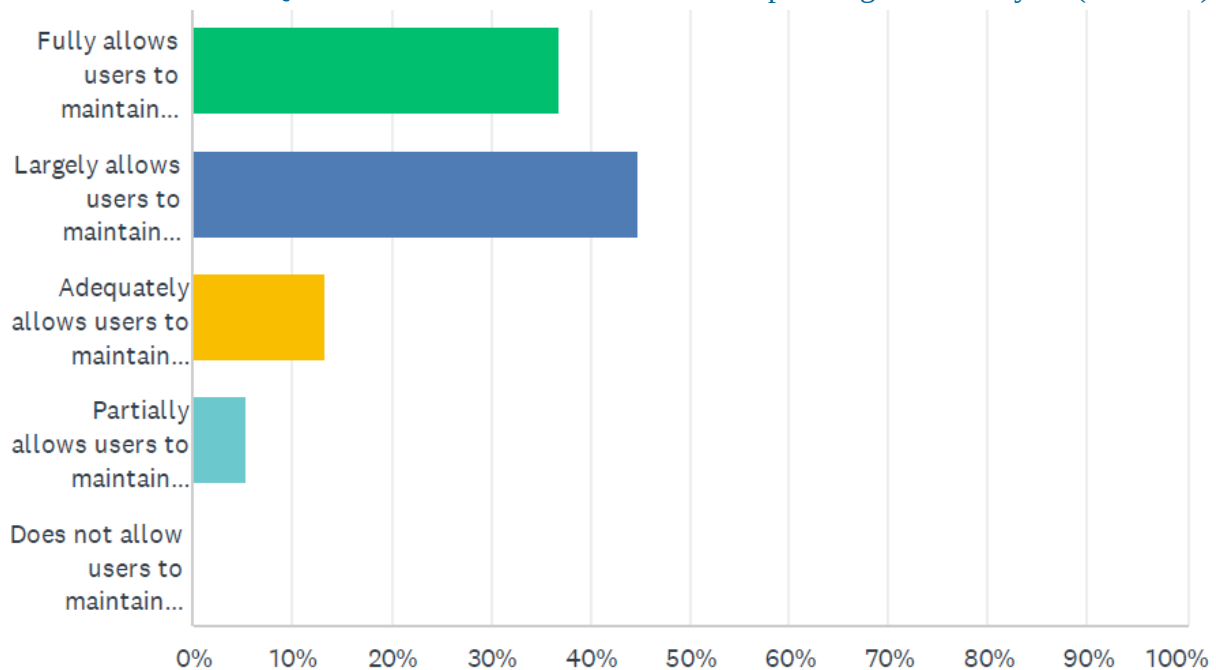


Figure 18: Validation Questionnaire Results Data Ownership through the Lifecycle (CP-ABE).

The partners assessed the TANGO framework as largely successful in maintaining user control over data (accumulatively >80%) (Figure 18). One of the partners stressed that “attribute-based encryption supports keeping encrypted data sets private to those that have the necessary identity attributes even if encrypted data set was maliciously obtained.”. This proves a strong alignment with TANGO’s objective of trust-preserving data sharing.

5.2.7 Validation Questionnaire Results - Data Integrity

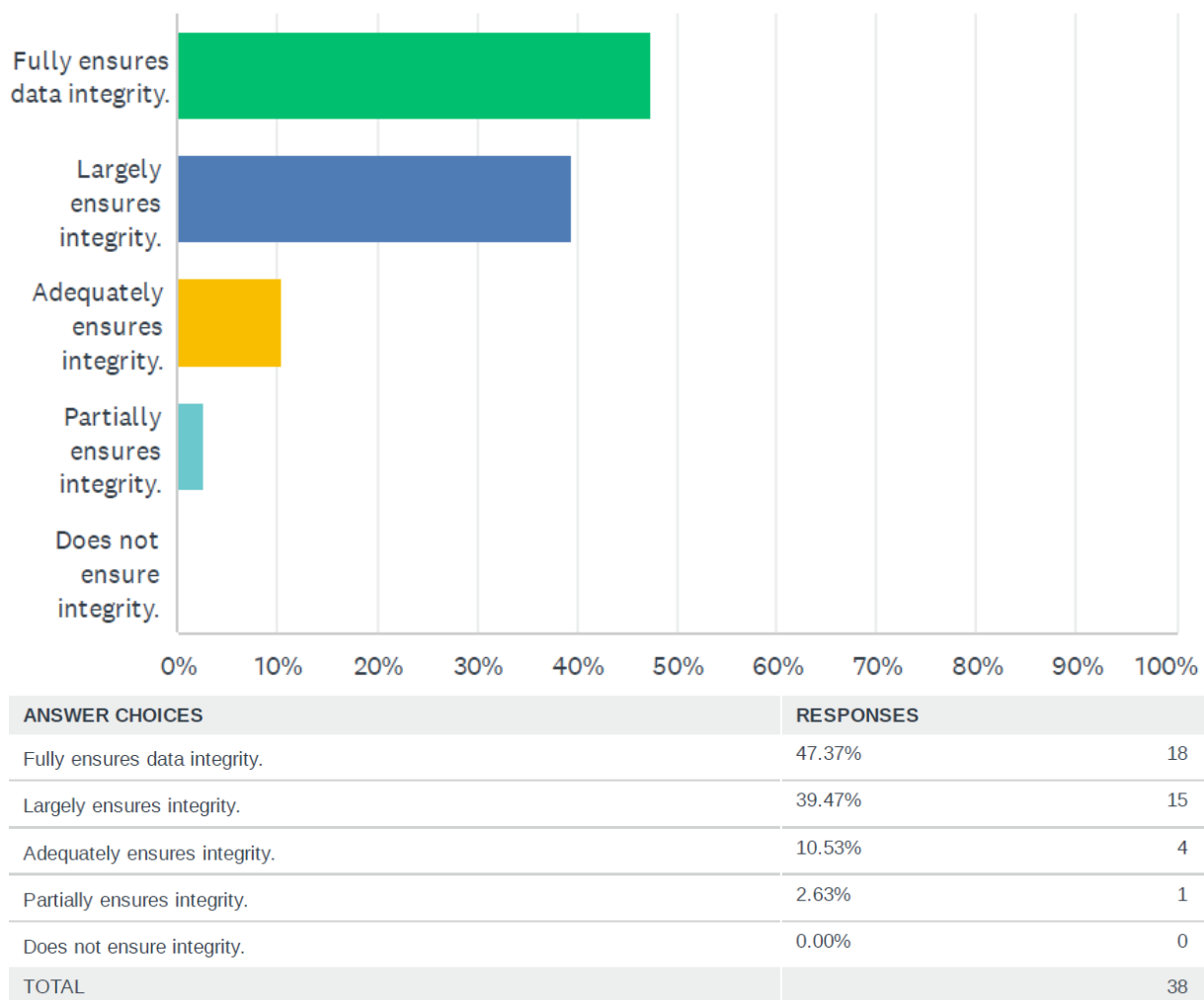


Figure 19: Validation Questionnaire Results Data Integrity.

The partners' responses underlined that TANGO largely (39.5%) or fully (47.4%) ensures data integrity, primarily through encryption/decryption (see Figure 19). One of the comments clarified that the assessment was based on "...what we know from the project meetings..." showing less direct pilot testing but consistent confidence in the cryptographic foundation.

5.2.8 Validation Questionnaire Results - Overall Security Features

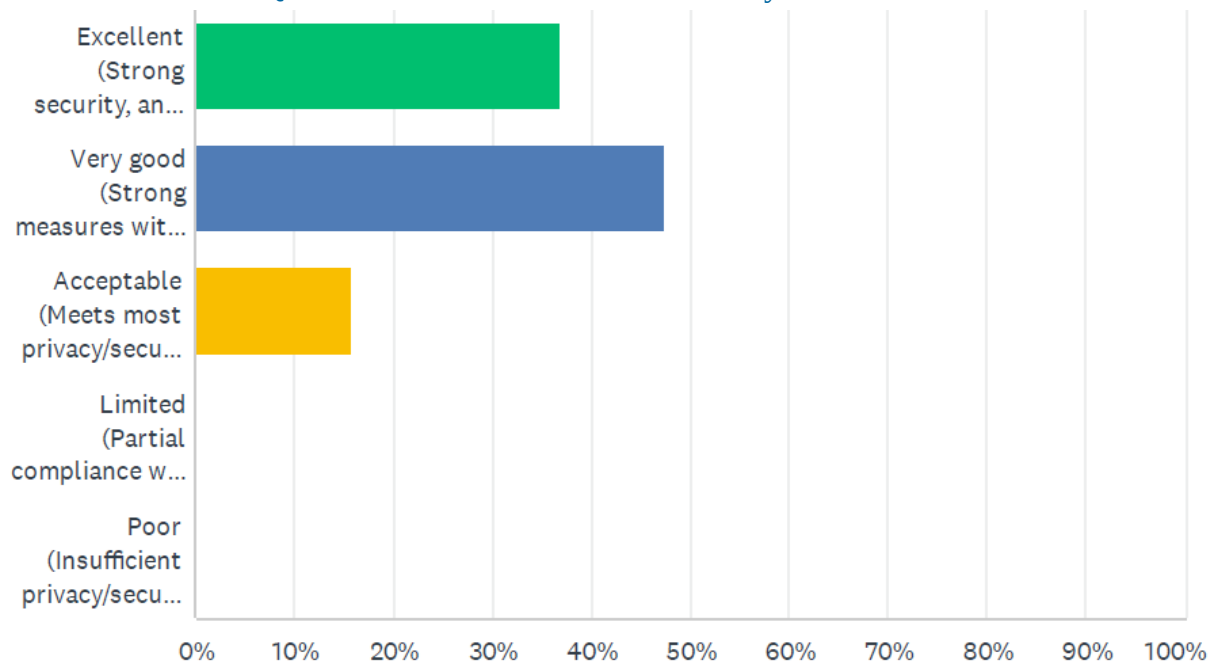


Figure 20: Validation Questionnaire Results Overall Security Features.

As shown in Figure 20, the overall TANGO security was recognized as one of platform's strongest assets (37% of the participants acknowledged an excellent performance and 47.4% very good performance). One of the partners commented that: "the security features of TANGO constitute some of its main assets, as they are aligned with privacy-preserving data sharing principles and based on the use and integration of TANGO components with open-source Data Space Connector solutions/services (FIWARE)". Areas for improvement included expanding recognition of national IDs and incorporating eIDAS-compliant eIDs.

5.2.9 Validation Questionnaire Results - Data Analysis and Modelling (EDAE)

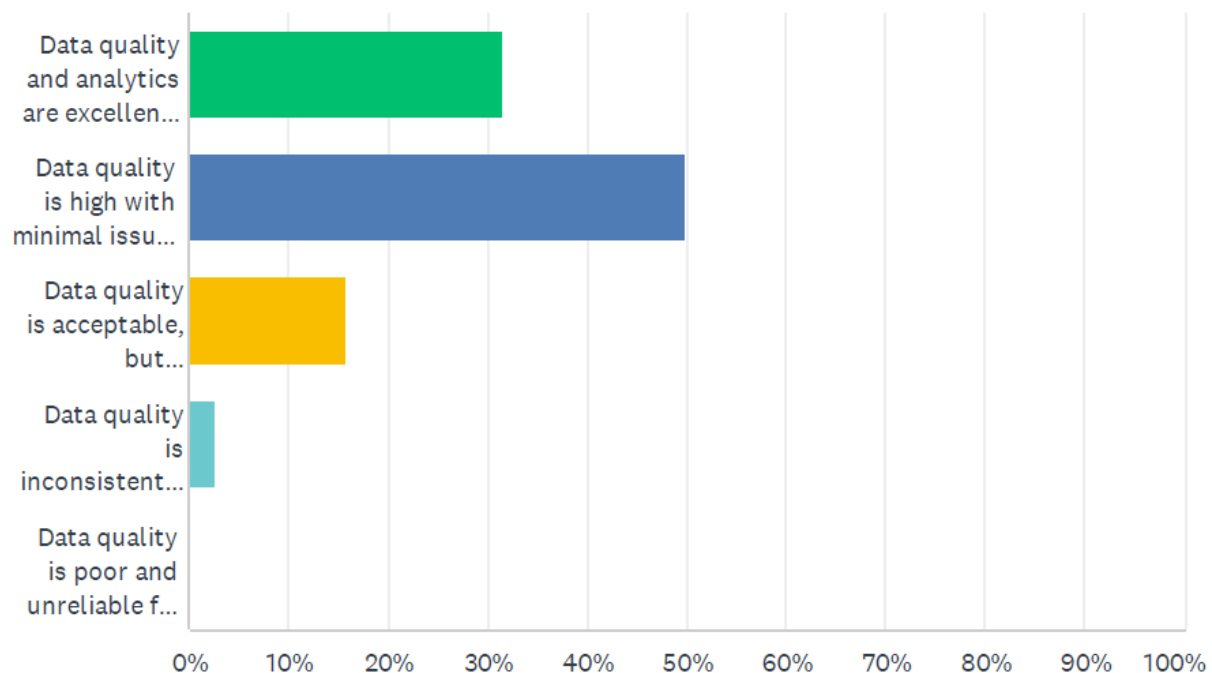
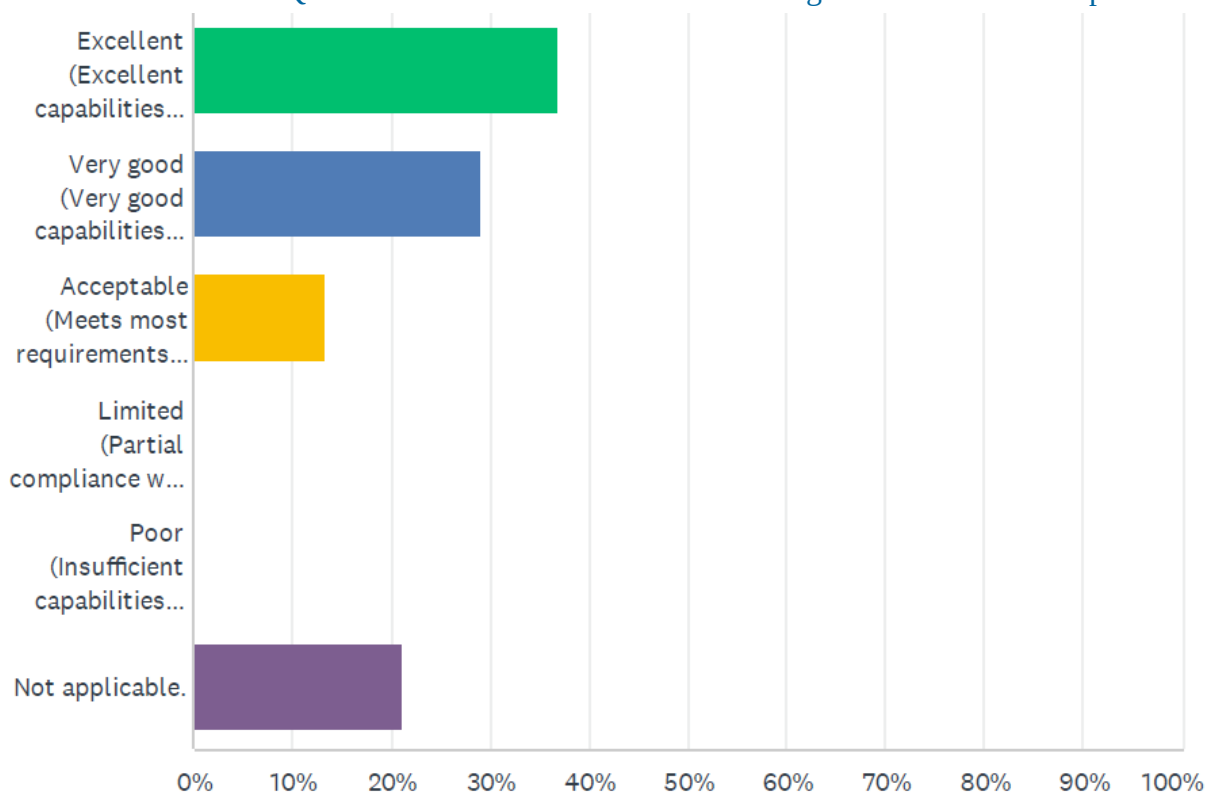


Figure 21: Validation Questionnaire Results Data Analysis and Modelling (EDAE).

The EDAE tool was rated as providing excellent or high data quality and analytics (accumulatively >81%) (Figure 21). However, one partner from Smart Hospitality noted “a few analytics results from the pilot execution were maybe not fully accurate”. Additionally, one partner stated: “EDAE is a very good tool to provide visualization of data analytics for data owners.”. Overall, the framework supports data modelling, but accuracy can be further improved.

5.2.10 Validation Questionnaire Results - Machine Learning and Decentralized Operations



ANSWER CHOICES		RESPONSES	
Excellent (Excellent capabilities to train and track the life cycle of ML models).		36.84%	14
Very good (Very good capabilities to train and track the life cycle of ML models with minor improvements required).		28.95%	11
Acceptable (Meets most requirements for ML training but needs enhancements).		13.16%	5
Limited (Partial compliance with gaps in the requirements).		0.00%	0
Poor (Insufficient capabilities to train and track the life cycle of ML models).		0.00%	0
Not applicable.		21.05%	8
TOTAL			38

Figure 22: Validation Questionnaire Results Machine Learning and Decentralized Operations.

The ratings concerning the ML and decentralized operations were mostly high (>66% accumulatively, see Figure 22). Specifically, in the banking pilot, federated learning demonstrated concrete value, with one partner reporting “a substantial improvement (+21% fraud detection compared to local models)”. MLOps and AutoML were also praised for tracking model training effectively. Nevertheless, some partners had no direct contribution in ML pilots, resulting in limited input from their side.

5.2.11 Validation Questionnaire Results - Sustainability and Green Operations

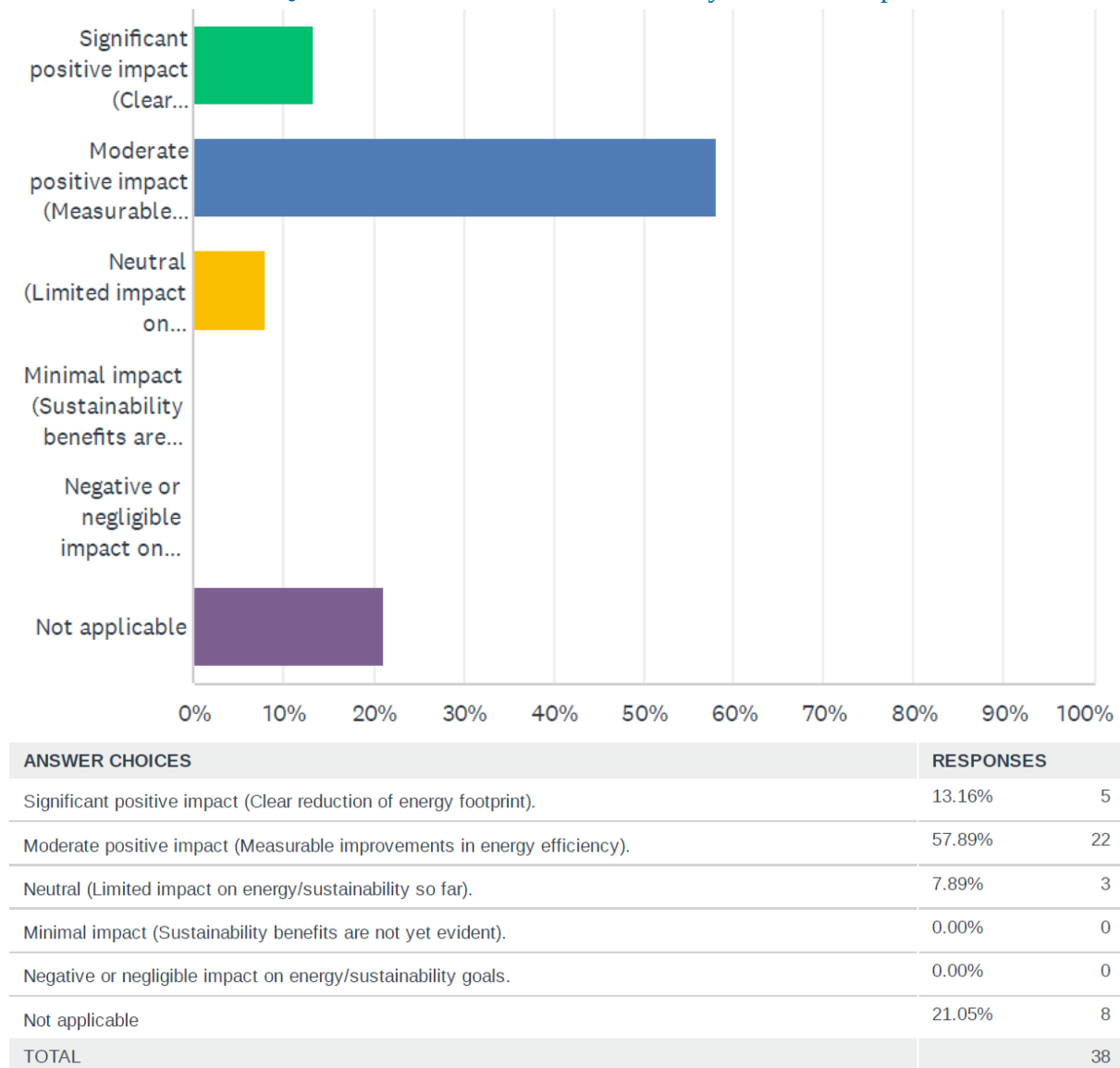


Figure 23: Validation Questionnaire Results Sustainability and Green Operations.

In terms of TANGO's platform sustainability and green operations, the RENOPS and TornadoVM were viewed as promising contributions to energy efficiency (>71% accumulatively) (Figure 23). As per the partners inputs, "RENOPS has the ability to schedule tasks to be executed when renewable energy sources are available, thereby resulting in greener solution and lower electricity cost.". Another comment highlighted TANGO's contribution to lowering carbon emissions by deploying renewable sources' energy. Expectations of measurable improvements were also linked to upcoming evaluations (Deliverable D5.2 [18], section 3.6.5).

5.2.12 Validation Questionnaire Results - Adoption Beyond the Pilot Phase

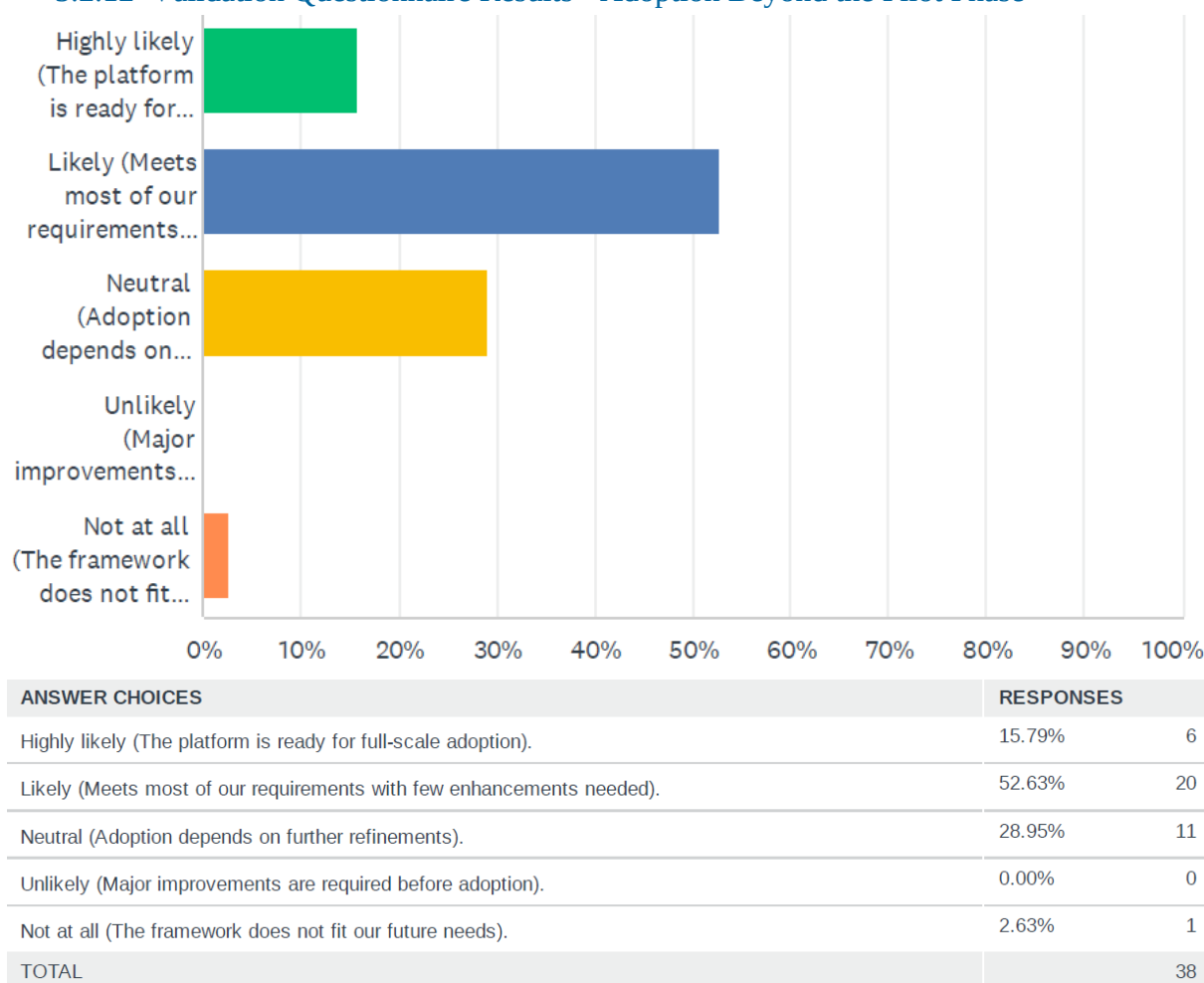


Figure 24: Validation Questionnaire Results Adoption Beyond the Pilot Phase.

In one of the most challenging questions, this of the technologies' adoption beyond the pilot phase, as seen in Figure 24 many of the partners indicated readiness for adoption (>52% are likely to adopt while 15.7% will do it), though ambiguity was identified with refinements being necessary (29% responded neutrally). Some partners stated that "further adoption depends on the specific needs of potential users and the platform's ability to cater for these needs". Others confirmed that "the platform is ready, although adjustments/configuration have to be done to specific pilots' environments". It is important to mention that several highlighted that TANGO's outcomes exceeded initial expectations, with components reaching sufficiently high TRLs for real-world use.

5.2.13 Validation Questionnaire Results - Lessons Learned and Recommendations

The final question provided a significant number of responses, with almost all partners commenting on their opinions and suggestions on what worked and what did not work and needs further assessment. Several interesting themes came up, which can be clustered as follows:

5.2.13.1 Security, Privacy, and Compliance

Concerning the technical recommendations, some partners highlighted that to expand the platform, there is a need of integration with recognized identity schemes, such as national IDs and eIDAS-compliant solutions. The partners identified that future versions should support more ID documents and ensure smoother compliance with GDPR [5] and banking regulations.

5.2.13.2 Pilot Demonstrations and Validation

Pilot demonstrations were a recurring concern for many of the partners. Specifically, they commented that pilot demonstrations should happen earlier and should be iteratively exploited. This would have provided the technical partners with effective time to incorporate real-world feedback. Another suggestion was to replicate pilots across multiple sites to strengthen validation under diverse conditions.

5.2.13.3 Time and Resource Management

Better resource allocation and scheduling were another lesson highlighted by the partners. Delays occurred in obtaining timely responses from end users which slowed down development. Other partners noted that multiple pilot's alignment, each with different constraints, required significant coordination effort. From the recommendations made, building more buffer time into project planning and adopting more flexible resource allocation to respond to unexpected delays were two of the proposed ones.

5.2.13.4 Stakeholder Alignment and Engagement

Closer alignment between the pilot stakeholders and technical teams was noted by several partners. Early and regular engagement with pilot stakeholders is crucial, especially in sensitive domains such as public authorities and banking authorities. Additionally, stakeholders should be more involved in design decisions to ensure smoother adoption. These observations emphasize the value of co-design and continuous communication with end users throughout the project lifecycle.

5.2.13.5 Improved Onboarding and Usability

One of the most important aspects of flawless deployment in the pilots was the onboarding process. Specifically, the identity management and the ePassport app, was remarked as a topic where enhancements are necessary. For some partners, the onboarding process was too complex at first and should be simplified in the future. Additionally, more support for usability testing and user experience expertise would improve onboarding. Better focus on end-user experience in TANGO's future iterations is underlined in general.

5.2.13.6 Faster and Earlier Integration Cycles

Earlier integration between pilots and technical partners was an extension of alignment and engagement. One partner emphasized that: "smaller iteration cycles for each pilot starting early on" was needed, pointing out that if so, resources were needed and delays in integration limited the time available for full validation in real-world situations. Moreover, another noted that: "a more agile process could have been followed" which could bring pilots and components together sooner. Early joint testing to avoid barriers in later project stages, as it occurred, was highly noted by the partners.

To keep clarity and visibility in everyone's opinion Table 3, presents all responses anonymously and with respect to the partners involved.

Table 3: Validation Questionnaire Results - Lessons Learned and Recommendations Partner's Responses.

Response #	Partner Validation Response/Comment
1	Technical development and pilot deployment to keep them on schedule to not have the delays that appeared.
2	I would try to simplify the onboarding and login process to enhance user experience. The focus of development was on security rather than usability.
3	We would design smaller iteration cycles for each pilot starting early on. Diversify the scenarios on the tool usage. Tools that had demonstrated their integration with other tools, no need to repeat the entire structure in another pilot because it required adequate resources. Overall, a more agile process could have been followed.
4	Stricter technical coordination of the project with better adherence to deadlines. Architectural and integration decisions should have taken into consideration the

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Response #	Partner Validation Response/Comment
	different deployment set-ups of pilots (esp. regarding network access and security) and proactively handle these issues by design.
5	Include more pilots, better handling of technical deployment in all project phases.
6	Technical development was slow because dev. data was hard to obtain. A better understanding about the available resources from the beginning might increase the efficiency.
7	Based on my experience, I would have engaged the various banking IT stakeholders earlier in the technical requirements definition phase, in order to mitigate the risk of technical in compatibility between the FL module and the two banking environments.
8	In TANGO we would do technical development even faster.
9	One possible area for improvement could be an early start of pilot demonstrations that would allow adequate time to consider all the suggested improvements.
10	Pilot deployment.
11	In the banking pilot: involvement of the banks' IT department from the initial requirements-gathering phase.
12	In the banking pilot, we can improve integration with the IT department of the stakeholder to find a deployment solution more quickly
13	Pilot.
14	Not much. Maybe better/sooner integration of the secure onboarding process to be available sooner to the pilots.
15	Extend our component, SEDSS, to more pilots and eventually produce a general, privacy-preserving framework for a variety of application scenarios.
16	Define a general architecture as well as specific architecture for each pilot, showing all components and their interactions. Create explicit scenarios for each use case to guide development and integration.
17	While individual components matured well, earlier integration across the full TANGO platform could have helped uncover interoperability challenges sooner. Moreover, although the pilots validated the technology effectively, involving end-users more in iterative feedback cycles during the development phase could have improved usability and accelerated the respective pilot deployment phase.
18	Ideally the SSI Wallet instances based on walt.id developed in the project for integration with Atos Issuer and FIWARE DSC and including different cryptos including ZKP and VTypes (ldp & jwt) could have been integrated into the one wallet. Also, when integrating into a 3rd party system which itself is in continuous development like the FIWARE DSC or EDCconnector it would be recommended to have a meeting with them to decide on level of cooperation available before the decision was made. We were lucky with FIWARE that they agreed to implement some issues we observed on their DSC in the timeline of our project, but this did contribute to the overall delay in SSI Authentication becoming available.
19	It would have been nice to try an agile methodology for deployment in pilot, e.g. to start deployment of early prototypes very early in the project.

Response #	Partner Validation Response/Comment
20	As in TANGO we have a large number of pilots and consequently separate pilot execution environments and scenarios, it would have been better to have more time dedicated to deployments and testing of the TANGO components comprising the TANGO solution at the different pilot environments.
21	Earlier assessment of the data flow and the personal data risks that come with.
22	I would have involved more communities in the testing and validation phase to promote awareness of the project's final product and its future adoption.
23	The development of architecture may be more transparent. However, considering the complexity of the project, it has been adequate. Some pilots seem to have been a bit reluctant in data sharing.
24	I believe the TANGO project was overall very well managed, particularly in terms of communication, technical development, and pilot deployment. That said, if I had the opportunity to approach it differently, I would focus on optimizing the use of time throughout the project. In some cases, tasks took longer to communicate and coordinate across partners than to actually complete. Setting stricter internal deadlines, streamlining communication, and introducing clearer checkpoints could have improved efficiency and ensured smoother progress.
25	Provide support for IOS, get more Pilots tested by the consortia (like SH Pilot).
26	I would be more involved at the early stages of the project to influence project management policies, as from my perspective project management as a whole was a bit chaotic and stressful to me as a participant.
27	Perhaps better communications between Pilots and Technical developers in the early stages of the project.
28	Better feedback of the components by the pilots before the final evaluation starts.
29	It would be better if we had a pilot that has computation expressed in Java, because in this case we would spend more resources on integrating with the TANGO platform and the pilot instead of integrating with a software library (GraalPython) that enables the TornadoVM technology to be used from Python. The vast majority of TANGO pilots brought use cases relevant to data sharing with no requirement for heavy data processing, hence the offering to run efficiently on hardware accelerators had a limited scope.
30	Allow more time for the pilot deployment.
31	Closer collaboration and more proactive action from the pilot cases.
32	Time management (pilot deployment).
33	The integration and deployment proved to be a difficult process. I would suggest to advance integration activities and test the deployment at pilot sites in advance, to avoid last-minute issues.
34	Integration of Nadia Platform within Tango platform.

5.3 Validation Focus Groups

Promoting open dialogue offers deeper insight into adoption readiness, operational challenges, and the actual value of cutting-edge technologies. This was exactly the rationale of the selected focus groups approach within the TANGO validation phase. On the one hand, the partners were able to collectively reflect on barriers encountered, assess the platform's actual impact, and propose improvements. On the

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other hand, cross-pilot perspectives were captured, as stakeholders from different sectors (hospitality, banking, retail, public administration, manufacturing) brought to light common issues, differences, and successes that could be mutually confirmed.

The analysis of the two focus groups' outcomes is presented in this chapter. The sessions were semi-structured, designed to foster open dialogue and brainstorming, allowing spontaneity and active interaction. The focus groups' discussions were transcribed, analyzed thematically, and core outcomes were consolidated in the deliverable. The following analysis includes the participants' statements without attributions to specific participants, preserving confidentiality and richness of insights. The sets of questions for the two different focus group can be found in Annexes 9.5 and 9.6.

5.3.1 Focus Group Results - Pilot representatives

Valuable insights were captured from the pilot representatives' focus group about the end-user and operational effectiveness of the TANGO platform. The participants' statements are aligned with the requirements and objectives as mentioned in Deliverable D2.4 [17], while underlining practical considerations for integration, adoption, and scalability. The analysis comprises thematic areas, as followed during the discussion, complimented by anonymized direct quotes from participants.

5.3.1.1 Focus Group Results - Pilot representatives - TANGO platform operational efficiency evaluation

The pilots' representatives reported noticeable learning and operational outcomes deriving from the TANGO platform, while highlighting user-facing steps that need simplification. Some pilot representatives claimed that they could conduct model training more efficiently and reliably, with enhanced traceability and faster operations (e.g., hospitality pilot), allowing them to save time and resources and spend time on more meaningful processes. As such, a participant underlined the increased Machine Learning efficiency and traceability: ("I think with at least parts of the Tango platform, we were able to do model training more efficient and also more reliable."). Usability of the interface was noted by another participant claiming that: ("it makes it more usable both internally as well."). Tango also provided additional ways for sharing documents in a fast secure effective way, which saves time and resources for employees. This could be the future for many companies for sharing documents in their operations. The pilot compared the previous situation before TANGO where in terms of data exchange, ("...the existing approach was sending emails basically."), something that clearly showcases an operational update occurring from a managed platform. In Retail pilot, TANGO facilitated collaboration across diverse datasets on products, customers, margins, and shops, helping business users analyze information and identify buying patterns. This supported more targeted promotional activities tailored to consumer needs and habits. Additionally, the use of the SSI Wallet enhanced data security and ensured only authorized users could access sensitive information. Within the hospitality pilot the participants reported robust benefits: ("TANGO helped improve the efficiency of operations overcoming existing legal barriers."). What was identified as critical was the onboarding: ("... the onboarding is critical."). Moreover, the collaboration with technical partners helped them get an idea about new technologies. Especially in the banking pilot, the objective was to do experiments, not deliver a final product. TANGO accelerated innovation in this respect. It allowed the banking pilot partners to test something new. TANGO improved cultural awareness in the banking sector. They managed to understand how federated learning works. Lastly, the pilots' participants agreed that to fully unlock user-level benefits, onboarding simplification and improved efficiency (especially for ML traceability and document exchange) is required.

5.3.1.2 Focus Group Results - Pilot representatives - TANGO platform barriers to implementation

The main barriers highlighted by the pilots' participants were heterogeneous security policies and regulatory bureaucracy. Individually per pilot, plenty of comments were discussed. In the experimental, as described, banking pilot context, constraints were also mentioned: ("banks have different security policies. And so, it's very difficult to find a middle way to architect, to define the architecture of the learning, because in some cases, the policies, the security policies are stricter..."). A recommendation to mitigate this issue was the early engagement of the banks' security teams: ("it could be important that

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the security teams, the cybersecurity teams of the final user are involved since the beginning in the requirements identification...). In the Retail pilot, major barriers arose from the strict security architecture needed to protect sensitive information, which made testing and validation of the platform time-consuming. Initial challenges in resolving system requirements highlighted the need for clearer security policies and guidelines. Nonetheless, the use of passports for credential verification proved innovative, giving customers greater control over sharing their data. In the hospitality pilot, regulatory barriers for use of passport were raised. The participants stressed that the customer must be present for check-in. The hotel facilitated the pilot deployment, all went well, nothing significant was encountered. In terms of the public organizations pilot, many of the participants underlined the barriers faced when engaging public authorities: (“they did not agree to participate, and we expected this collaboration so much because it was incredibly important for us to involve them.”). It was obvious that the public authorities were reluctant to participate in the pilot. Bureaucracy was a challenge. The partners underlined that it is a complex process to involve the public authority and discussed that they could have been waiting for years for a positive answer. Authorities were worried about privacy. One of the participants referred to the German context that is characterized by long decision cycles. Their participation would have led to a deeper, more meaningful pilot. Nevertheless, representatives saw the pilot video in the end and provided feedback. Regarding the manufacturing pilot, mandatory use of passport data in TANGO was an issue that was not required in their previous operation. The partners commented that if they could avoid this for GDPR [5] purposes, it would be better from a user involvement perspective (customers may be reluctant to provide their data). They did not encounter any significant technology barriers. The containerized approach was easy to implement, but overall, the platform requires a lot of configurations. Discussing the platform’s future in terms of potential barriers, they agreed that the present as-is architecture is fine for a research project, but for production it should be simpler (less external services to manage). Overall, for the most significant barriers identified—related to regulatory engagement and alignment with each platform partner’s security policy—the most recommended solution to reduce delays was the early inclusion of security or authority stakeholders.

5.3.1.3 Focus Group Results - Pilot representatives - TANGO platform level of trust & security

The pilot representatives assessed the platform as trustworthy and secure, despite them not having a direct overview of the security mechanisms. A pilot participant commented that: (“... I have any idea how the platform works internally, so I'll have to trust them that it is secure.”), providing the technical partners with an opportunity to analyze this statement. The same participant added that: (“It gives a feeling of proper security, but I'm not a security expert.”), indicating that the project’s components helped into confidence building. Another participant’s comment supported that: (“It all looks very, very secure.”). For instance, the wallet approach gives a feeling of security to the non-technical expert. Highlighting some random examples from the pilots, in the hospitality pilot, the customers (tourists) would feel more secure because they would not need to have their passport copied at the reception. In the public organization pilot, customers (visa applicants) could be confident that their documents would be transferred in a secure way. A participant added that the application looks and feels very secure and could be applied in real-world operations. The retail pilot added that the platform strengthens security and compliance by requiring e-passport or employee credential verification before granting access, thereby enhancing trustworthiness. Beyond security, it enables advanced data analytics for customer segmentation, targeted advertising, and improved business decision-making. From a business perspective, distributed tokenization ensures privacy-preserving data exchange while GDPR [5] consent forms support policy-based access control. Nevertheless, some participants noted the lack of involvement of end-user security experts in the security specifications: (“some requirements were defined on top without involving some security expert of the end users.”). Summing up, TANGO platform is considered safe and trustworthy by stakeholders. However, to further build operational real-world confidence an earlier engagement of end-user security experts and security specifications transparency is required.

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5.3.1.4 Focus Group Results - Pilot representatives - TANGO platform overall adoption readiness & user experience

The pilot partners requested User Experience simplifications (for specific workflows) while highlighting the eminent value in TANGO platform's modularity and Machine Learning modules. One of the participants when commented on the banking pilot claimed that: ("the learning and probably also the explainability were, of course, valuable."), while adding that: ("the modularity of the platform... the platform is modular and it's possible to grab and pick something that maybe can be useful to your use case."). As such, the FL and XAI components were assessed as valuable. Regarding the public organizations pilot, according to the participants, the privacy and assessment components can lower manual processes: ("both components, they are advanced components, which could enhance a lot of processes and a lot of, like, add more value and efficiency to a lot of processes."). Therefore, both Fides and PEC add value and efficiency to their processes. They were surprised by how effectively they could apply them to existing operations, significantly reducing the time required. They assessed both components as ready to use and underlined their efficiency. For the retail pilot, the TANGO platform's modularity enables tailored data use while ensuring trustworthy, privacy-preserving exchange of sensitive information. Security and confidentiality are reinforced through e-privacy protocols and continuous behavioral authentication, supporting GDPR compliance [5] and building user trust. Additionally, the Exploratory Data Analysis Engine provides dynamic modeling and visualization, revealing patterns in customer and product segmentation to deliver valuable business insights and enhanced user experience. For the hospitality pilot, the participants added that modularity is very important. VIS added value to the NADIA platform by making use of the data. The recommended service was not very clear, and the activities should be more focused on the customer. They did not get the feeling that suggestions were personalised. They acknowledged that the check-in adds value to customers, since it prevents queueing at receptions and saves time. Finally, in the manufacturing pilot, FL, RENOPS, and XAI components were a positive experience. The participants claimed that it is easy to integrate and is relevant to their needs. They proposed that having a platform for file exchange will add value to customer experience and make company operations more reliable and secure, more robust (currently they exchange emails). Overall, the participants evaluated that simplification during onboarding and streamlined workflows can enhance adoption of the TANGO platform and they acknowledge the high technical value of TANGO's components (e.g., XAI, federated learning).

5.3.1.5 Focus Group Results - Pilot representatives - TANGO platform future vision & impact

The pilots' representatives agreed that the platform was a foundation to expand beyond research and an enabler for experimentation. They identified regulatory customizations needed, especially for cases where multiple critical information is exchanged, like the banking sector. The TANGO's core benefit was summarized like: ("the great value of TANGO was that it demonstrates that the solution works."). For the public organizations pilot, the participants commented that only small comments are needed for improvement for the two components, both worked well. For example, about PEC some questions were overwhelming, but this was the only disadvantage. Fides component worked perfectly and close to being market ready. Main barrier is towards the adoption by public authorities – how to convince them to use the platform. The participants feel that customers would be very positive about using Fides. To get ready for the Banking market several improvements are needed. Security adjustments for data exchange protocols are required – some banks require a more secure protocol for data exchange. Banks face more complex regulatory environments than other industries. The platform should be customized for banking environment to accelerate the adoption of the solution. One of the participants underlined the novelty for banking: ("we never had the possibility to test this approach on a real banking scenario."), while the rest of the participants agreed that ("probably banks are really complex companies.") and recommended specified adaptations: ("a customization of the platform for the banking environment that handles different compliance roles could be something useful to accelerate the adoption or the readiness of the solution in the banking environment."). Commenting on the hospitality pilot impact, the participants acknowledged a future possibility to support hotel services through TANGO. The hotel could have access to customer data, especially for customers coming from tour operators. Collecting customer information during check-in could help the hotel provide additional services based on user preferences.

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Now they do not have this information. Enhancing the PAT form for check-in could provide this service to the hotel. Furthermore, one of the impacts that surprised the participants was data sharing efficiency. They claimed that while existing software solutions are available, TANGO offers an additional layer of security. TANGO should be compatible with and integrated with existing solutions (e.g. Google, etc.), mostly for managing folder structure, labelling data, etc. They believe that a further market study for positioning against existing tools would be necessary. TANGO could integrate with existing platforms to provide authentication services. Additionally, the retail pilot offered a business value perspective commenting that to be ready for the market, the TANGO platform needs adjustments in SSI wallet onboarding, large dataset storage, and more effective graphical representations of sales data. Its strong security and innovative authentication mechanisms provide a solid foundation for commercial adoption. By enabling customer segmentation and smooth data transfer across countries and systems, the platform reduces time and effort while enhancing business decision-making. Moreover, TANGO was acknowledged for permitting research pilots that otherwise would not be feasible: (“TANGO platform allowed us to test and experiment something new that doesn't exist now in banking.”). Summing up, the TANGO partners pinpointed a strong scaling potential in the platform, if it secures regulatory conformance and specific security features, especially for challenging sectors like the banking one.

5.3.1.6 Focus Group Results - Pilot representatives - Lessons learned

Interesting insights into the lessons learned were discussed by the TANGO pilot representatives reflecting on project management but also operational processes. Initially, they agreed that at the beginning of the project, everything was very confusing. For instance, the onboarding process was identified as such. They feel this should have been explained in more detail or made simpler. It is difficult for a customer to complete these processes on their own. Overall, they believe that the user experience should be simpler, and clearer, especially in the onboarding phase. Furthermore, one participant commented that: “I’ve learned in this project that it’s very important to get the user aware on what’s new in the technology.”. The participants discussed that due to the plethora of new technologies applied it was important to make the user aware of what technology can do. Specifically, to explain what is new, what the value will be, and what are the technology’s opportunities. They firmly believe that it was important to organize sessions to disseminate what is new to the end users, and to give evidence about what is innovative in the project. Moreover, project management was raised multiple times by the participants. In this perspective, they added that it was important to follow up on tasks as they arrived and not wait. Tasks were communicated in a structured manner in advance, and this was helpful. But deadlines sometimes were postponed, causing delays. Some partners suffered because other partners did not complete their tasks on time. As a participant commented: “I could share that the lesson I learned do not postpone the tasks because they are becoming a snowball”. Finally, the partners agreed that it was helpful to have a bridge / interface between technical team and pilots. It streamlined the process and facilitated the work. This is a must-have, especially in large consortia like TANGO. The partners acknowledged UPRC team, which had this “bridging” role, as very efficient since it “filtered” and explained to pilots what needed to be done after technical meetings. Also, overall project management worked efficiently. They believe they should have a more agile way of working between technical team and pilot team. They would have liked to see more versions of the platform, also intermediary, to understand how the technology works (like it happened with WP5 components). This may have helped avoid deployment issues as well. Despite these suggested improvements, their overall experience on the project was positive.

5.3.2 Focus Group Results – Technical partners

The discussion between the technical partners provided important points regarding TANGO’s technological performance, barriers faced, the innovation level reached, potential scalability, and future potential. The analysis comprises thematic areas, as followed during the discussion, complemented by anonymized direct quotes from participants.

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5.3.2.1 Focus Group Results – Technical partners – TANGO technological strengths

The technical partners consistently referred to the identity/authentication stack and related middleware as the most valuable elements for cross-pilot integration. In terms of usefulness, the components relevant to authentication (SSI wallet, connector, PDP/PEP authorization) were the main novelties and have been used extensively across the various pilots. As stated by a partner: “I think interoperability on the self-sovereign identity stack really enabled that”. Additionally, they highlighted as big assets to the project the cross-app transferability by the FIWARE connector, interoperability on the SSI stack, and the work by UMU to integrate the PEP/PDP and the VC verifier. PAT was also widely used in various pilot cases. A partner commented that: “PAT was also widely used and tailored for different use cases that couldn't be implemented otherwise”. The smart analysis engine for reporting and Federated Learning (FL) was the main driver of the pilots. Furthermore, developing, demonstrating and piloting a distributed mobile implementation of a collaborative and privacy-preserving recommendation technology UPCV turned out to be a success. Moreover, components that enhanced system performance and energy efficiency overall were TornadoVM, RENOPS and others. The platform achieved high components compliance with the guidelines for interoperability with Data Spaces of DSBA [20] and DSSC. Within the context of this discussion topic, the pilot leaders' insight provided in TANGO Project's official website¹²³ was mentioned as additional input to the question since they cover the topic in depth. The pilot leaders, within the articles, confirmed the technological strengths of the platform. Specifically:

In the article (1) about Distributed Privacy-preserving Data Management and Storage, the systems that provide important advantages highlighted are self-encryption and multi-factor recovery which enhance privacy, data security, and user control.

In the article (2) about Distributed Trust Management Framework, enriched services can be achieved using the User Continuous Behavioral Authentication and Device Continuous Behavioral Authentication tools which combine technologies such as machine learning and biometrics.

Lastly, in the article (3) about AI-based Framework for Green & Trustworthy Operations, energy efficiency lies in adopting different perspectives, such as thinking in lighter models, reducing the footprint of the training phase, and moving computation to more environmentally friendly settings or times. For this purpose, the TornadoVM, PAT, and Federated Learning technologies were addressed as impressive in their support to the efficiency goals.

5.3.2.2 Focus Group Results – Technical partners – TANGO major integration challenges

The technical partners clarified the concrete configuration blockers and infrastructure issues encountered during multi-site integration. The integration effort of relevant components with the FIWARE connector was quite high and challenging, but once achieved, it could be easily replicated across the different pilot sites. Achieving that was considered by the partners as a large project asset. Overall, this facilitated the integration with each pilot. Moreover, the partners highlighted many integration issues with project tasks T4.1 and T4.2 due to implementation of new protocols and innovative onboarding with the ePassport app. Many of the integration issues were due to lack of clarity about the protocols that were followed. As a participant mentioned: “...many of the integration issues were due to lack of clarity, and the standards were following. For example, what to do with the signature types and how you send VP tokens”. Having automated tests early in the process would have helped, even with dummy information. One recommendation expressed was moving target in the data spaces community. For example, two different versions of the FIWARE DS Connector led to two different versions for SSI agents/wallets. Another challenging aspect mentioned by the partners was the large

¹ TANGO WP Leaders Interview Series – WP3 Distributed Privacy-preserving Data Management and Storage (accessed 09/2025): <https://tango-project.eu/articles/tango-wp-leaders-interview-series-wp3-distributed-privacy-preserving-data-management-and>

² TANGO WP Leaders Interview Series – WP4 Distributed Trust Management Framework (accessed 09/2025): <https://tango-project.eu/articles/tango-wp-leaders-interview-series-wp4-distributed-trust-management-framework>

³ TANGO WP Leaders Interview Series – WP5 AI-based Framework for Green & Trustworthy Operations (accessed 09/2025): <https://tango-project.eu/articles/tango-wp-leaders-interview-series-wp5-ai-based-framework-green-trustworthy-operations>

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number of components to be integrated from different partners, creating practical frictions (meeting times, etc.). As a partner mentioned: "...I think it has to be highlighted that in this project, we were many partners working on many components that had to be integrated together. And this is also challenging from the point of view, for instance, how to meet together all the time, agendas of everyone. So, it's not only technical aspect, but also logistical aspects". A comment made by a partner stressed that: "...some bits and pieces were missing", identifying as helpful more formal documentation from all components. Regarding the integration with pilots, an issue that kept popping up was the NGINX / API-GWs. There were limitations in the headers size for HTTP requests. The partners had issues with configuration to support large headers (e.g., Bearer token > 7Kb). This was an issue also during deployments with the pilots that was not originally identified in the testing environment. Additionally, it was mentioned that for the distributed model of collaborative recommendations technology UPCV, each user has an instance on their single mobile device. For the future, implementations where a user could have a plurality of mobile devices, sharing the same recommendations, might be in order. Lastly, from the environment preparation perspective there were many issues (internet access, networking restrictions, type of cloud environment, etc.), which are not specific to TANGO, but affected deployment efforts. Finally, the large number of components and different component deployment per pilot required large preparation. Overall, the platform scale and complexity were identified as a challenge.

5.3.2.3 Focus Group Results – Technical partners – Assessing the level of innovation

The technical partners singled out several components as novel contributions to trustworthiness, privacy and secure analytics tools. Firstly, they mentioned privacy preservation. The encryption/decryption approach was an innovation, since it relies on the data and not only on a password. The encryption workflow provides a security level that helps users protect their encrypted data. SEDSS divides the data into multiple blocks and applies self-encryption, a technique that leverages intrinsic features of the data itself for encryption. This not only enhances confidentiality and strengthens the protection of users' private information but also facilitates efficient data transfer in complex network environments and storage systems. As a partner commented: "...we have reached the feature from each data block, enhance the security level of the encryption process, which helps the users to better protect their privacy in the encrypted data.". Additionally, the partners mentioned the PEC component which shows high innovation because it is the first tool that provides in-depth analysis of privacy risk assessment focusing on the user privacy part. As a partner stressed: "...I haven't found any other tool or methodology that actually considers security risks and then translates those effects towards privacy breach and privacy cost and help with not just security risk assessment, but more on the privacy side...it would be more on identifying the privacy impacts from security breaches. It identifies the privacy impacts from security breaches focusing on both data flows and AI applications...", while being characterized by another partner: "...one of the highly innovative outcomes of the project". Technical feasibility of the distributed model of collaborative recommendations technology, shifting computational load from a data center to a mobile device address both privacy-preserving and green AI issues. Furthermore, another innovative element of the TANGO ecosystem mentioned was the onboarding process using the ePassport. It follows the eIDAS (electronic Identification, Authentication and Trust Services) recommendation from the European Commission. During onboarding and credentials issuance, the use of zero-knowledge proof is also innovative. It is used to prove a claim without revealing the information. The DCBA (Device Continuous Behavioral Authentication) component was also commented by a partner as innovative concluding that: "...the innovative aspect is that we managed to integrate with authentication mechanisms, so as to use this both localization and the AI component, as an additional layer of authentication.". Lastly, the technical experts acknowledged Fides component since it employs an innovative approach on data privacy in distributed environments, respecting customer consent in all stages of the data sharing process.

5.3.2.4 Focus Group Results – Technical partners – Evaluating scalability & maintainability

In general, the partners reported that technical choices supporting scalability, though maintainability and automation require further work. They firstly discussed the encryption/decryption operations where they experimentally confirmed that the component can work with different data formats. It is scalable to different data size in terms of computational/time costs and complexity and ready for most scenarios

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beyond TANGO pilots. Furthermore, as a research and innovation project, the platform has been tested in seven different pilots, so it can be deployed in very different environments. This ensured that it can go beyond these fixed scenarios. An important fact underlined was that not all components are required to be deployed in a future scenario. Some key components are used in most cases. The partners acknowledged that there is a need to improve the components and evolve them beyond project funding. Further EU funding and investment would be required for this. As a partner commented: “At the end of the day, you finish the project, you have a set of components, a framework, but the evolution happens besides the project...there is a disorganizational and market problem that requires a further investment, further responsibility of the platform and things like that, that it's difficult to achieve...”. Additionally, the partners agreed that they managed to integrate with the FIWARE connector, but the components need to be included in an open catalogue to be used in other projects in the future. For a research and innovation project this was understood as a very good result. On top of that, the partners mutually agreed that the fact that most deployments were done in the Kubernetes cluster promotes easy scalability and replicability in other environments. Anyone can replicate the deployments easily across different environments and as a partner mentioned: “...it is quite straightforward to replicate as soon as you follow this road of microservices based on Kubernetes, etc.”. One partner added also that as the computation in the distributed model of collaborative recommendations technology takes place on the user device, the approach is indefinitely scalable. As a final remark on this topic, the partners claimed that many components require extensive configuration to be deployed in a new environment, so this could be improved for future pilots. Also, more documentation would be helpful (e.g., defining the roles in databases is an issue). More automatic configuration has been suggested as a solution.

5.3.2.5 Focus Group Results – Technical partners – Future vision & impact (exploitation / packaging recommendations)

The technical participants recommended packaging and simple deployables to support uptake beyond the project. They briefly mentioned that it would be ideal to have a Kubernetes package that new stakeholders/customers would have to download and install and configure themselves following guidelines.

5.3.2.6 Focus Group Results – Technical partners – Lessons learned

In this last question, the technical partners reflected on planning and coordination lessons for multi-partner, multi-pilot research projects. Their main concerns were project management and dissemination of related information. Initially, they commented that data availability at the pilots is always an issue. They always run into difficulties with pilot cases. This is a common issue for all projects. Resources availability always causes a problem. People leaving or coming to the project cause delays or difficulties. Specifically for TANGO Project, the size of the project, number of partners, and solutions made things difficult in implementation. It took a long time to find an architecture that was appropriate to the project. Also, the connector had the complexity to understand how to apply it in the project. As a participant commented: “...it took a while to elicit what this Connector really shall do and how we shall integrate into it”. Replicability of the solution in five to seven pilots validated in a better way the project outcomes but posed great challenges for a 3-year project. The partners elaborated that they had completely different environments for each pilot, without a central common environment for actual implementation. They had significant time limits and needed strong integration effort that took a lot of time. In the project plan the effort/time required to deploy and test the defined use case scenarios in seven different pilots was underestimated, especially given the architectural decisions made during the project. They claimed that they made changes in the time plan, but the architecture was still in design, so they could not plan properly. However, the time was still not enough for pilot sequential integration, especially since the same technical partners were involved in all. Moreover, although pilots were involved from the beginning, still it took them a while to understand the technical offerings. It was difficult to align requirements with technologies. The matching between technical implementations and pilot expectations was difficult to achieve. The partners claimed that this requires more frequent and short iterations of the technology to share with pilots rather than longer versions of the platform. Another lesson they identified was that the integration guidelines were very helpful, but still integration was challenging due to the high number of pilots. Shorter time between iterations would have been helpful.

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This also depends on the size of the project and the number of technical elements. As a participant commented: "...shorter releases with shorter validation time would help avoid gaps between the technical and the pilots." A big lesson and issue noted as well was the huge evolution of all technologies during the project duration. A participant commented for example that: "There was a mismatch between one of the main non-functional objectives, which is this energy efficiency and the actual components that were proposed in the Grant Agreement. So, most of the components were not related to energy efficiency at all...". The partners agreed that they needed to stay closer to the original project objectives. Moreover, from a project management perspective, the partners at this point agreed that when planning a project on a real calendar, August or December as final months should be avoided, especially for such innovative projects with lots of components and integrations. They added on this topic that the high number of different components and different objectives, was not possible integrate in a single architecture/platform that could fit them all. This was not foreseen in the proposal phase. They had to find a way to have a middleware, but there was no effort assigned to this, as it was not foreseen. So, they had to find a solution to find an architecture where all partners could contribute. As a lesson learned, they proposed ideally, after finalizing the architecture, the time plan should be revised to reflect the new needs of the project and if possible, resources need to be adjusted.

Summing up, the technical partners' perspective was that TANGO's strongest immediate value came from the identity/authentication stack and privacy tooling, while integration friction (configuration, versioning, etc.) and limited automation were the main barriers to fast uptake.

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6 Lessons learned

In this chapter, the main outcomes and insights gathered during the exploitation and validation phases of TANGO Project are captured. A reflection of both the organizational and technical experiences is made, barriers and strengths captured across the pilots are highlighted, and lessons learned of strategic value are noted. The chapter is structured so that the reader can understandably identify what worked well and where challenges emerged. It also proposes how the lessons learned can be exploited for future integration, research or commercialization of this or similar platforms. All conclusions presented in this chapter are based on the TRL/KPI questionnaires, validation results, and focus group feedback which are documented in chapters 3 to 5 and Annex 9 of this deliverable. The annexes materials (screenshots, evidence submissions, logs) provide full traceability and prove the observations analyzed here.

6.1 Executive summary

The TANGO Project has been characterized as an innovative conception, integrating multiple technologies and cutting-edge components, and requiring a thorough collaboration of different partners not only during the design but also during the roll-out in the different pilots' domains. The project successfully developed multiple technical components from early conceptualized prototypes to ready-to-use technologies, as multiple proposed Technological Offerings (TOs) achieved TRL 6 to 7. The evidence-based, structured methodology, used for TRL and KPI achievements' capturing, offered a harmonized methodology of cross-pilot validation for the different use cases and pilots. Meanwhile, recurrent objections were observed, especially in areas of multi-pilot technologies configurability, integration, and deployment efficiency. Overall, from a market readiness, technological maturity, and compliance alignment perspective, the TANGO Project established clear progress. The lessons learned consolidated here intend to provide a roadmap for enhancing packaging and reproducibility, reducing integration overhead, and developing more focused strategies in potential future phases of development. Finally, TANGO's lessons learned could serve as a strategic foundation for identifying what to consider and what to avoid in future similar projects within the EU innovative projects data spaces and ecosystems.

6.2 TANGO Project key successes

Considering the in-depth analysis performed using the insights of the project's partners involved, TANGO's key successes could be summarized in the following domains.

- ▶ **Stakeholder Engagement:** Valuable feedback has been generated from the pilot focus groups and questionnaires on performance, usability, and user's perceived trust. The input gathered, validated user acceptance across the different project domains and shaped directly technical improvements. Both are a crucial step for future acceptance.
- ▶ **TRL progress and pilot validation:** Many technological offerings progressed from lab prototypes to validated tools in real-world settings. For instance, self-sovereign identity (SSI), trust management mechanisms, and privacy-preserving modules were integrated successfully into pilot workflows and demonstrated their efficiency and applicability in, hospitality, retail, finance, and manufacturing contexts.
- ▶ **Interoperability:** Complicated access-control and data-sharing scenarios were demonstrated during TANGO successfully. Examples were the interaction between policy decision points (PDP), the policy enforcement points (PEP), the privacy analysis, and the SSI credentials. These complicated cross-integrations verified that TANGO's architectural approach was feasible.
- ▶ **Evidence-based validation approach:** By adopting a questionnaire-based methodology complemented with evidence provided directly by the project's partners (logs, screenshots, deliverables), traceability and transparency were ensured while objectivity of both KPIs and TRLs has been maintained. This made the results auditable, which boosted trust among partners and reviewers.

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6.3 TANGO Project main challenges

As described earlier in this chapter, the project's magnitude and complexity would unavoidably create reasonable frictions and barriers which are summarized below.

- ▶ **Non-functional goals alignment:** Partial misalignment with TANGO's objectives was noticed since some of the deployed components were not initially designed with energy efficiency taken into account. As such, during evaluation, additional effort was required by the partners to ensure that all KPIs could be monitored.
- ▶ **Deployment and configurability constraints:** Pilot setups became complicated because of different deployment environments, role/schema ambiguities, and manual configuration requirements. Reproducibility was affected due to the absence of automated deployment packages which stalled pilot partners' onboarding.
- ▶ **Iterations time limitation:** During the components' pilot deployment, the sequential integration dependencies resulted in limited time for their iterative refinement. This resulted in less opportunities for fine-tuning the components' features, and these were based on only early feedback.
- ▶ **Hardware and resources constraints:** In some pilots, limits of deploying resource-intensive components in internal environments or directly on embedded devices were reached.
- ▶ **Integration difficulties across heterogeneous pilots:** The parallel, five to seven, multiple pilots' deployment resulted in important integration complexities. The different data models, environments, and APIs needed serious customization to work which often surpassed the available technical resources. The effort required was not comprehended sufficiently during the project's planning.

6.4 TANGO Project technical lessons

TANGO platform is comprised of multiple different technologies and innovations which when deployed interesting lessons occurred. These are summarized below.

- ▶ **Synthetic vs real data trade-offs:** Future validation and testing could be significantly improved provided a tailored library of synthetic data which should reflect the domain-specific pilot scenarios were provided. The synthetic datasets were efficient to run the pilots when real data could not be available but often proved to be experimental and lacked realism.
- ▶ **Automation needed for reproducibility:** To reduce reporting burdens and increase repeatability, even if the evidence-based collection method worked successfully (e.g., screenshots and logs), automated continuous integration pipelines, test harnesses, and reusable synthetic datasets are considered essential for a consistent validation across pilots.
- ▶ **Importance of modularity and packaging:** Smoother integration was captured where containerization and microservice-based deployment happened. Nevertheless, the pilots were affected in terms of deployment velocity because of the lack of consistent packaging across all components. Standardized packaging is highly recommended for future projects of this calibre.
- ▶ **Clear integration contracts value:** Developers and pilot partners would have reduced significantly the negotiation cycles, if early definitions of lightweight API and data-schema contracts were identified and provided at early stages.

6.5 TANGO Project management and organisational lessons

As mentioned in the validation chapter, several partners reported their perspectives on the project's management performance which is reviewed below.

- ▶ **Need for detailed documentation:** Of the most noted gaps from the partner's side was the one of setup guides. Understandable, clearer, detailed step-by-step instructions with configuration templates could have countered for important troubleshooting delays.
- ▶ **Release cycles in iterations are preferable:** More frequent and shorter releases between pilots and pilot partners would have improved responsiveness and alignment.

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- ▶ **Centralized integration environments:** Reproducibility of deployments and reduced environment-specific issues could have been avoided if a common reference sandbox had been used for all pilots.
- ▶ **Need for dedicated resource allocation:** Stretching the resources across multiple different pilots became a barrier in the project's development several times. Deployment acceleration would have been achieved by assigning dedicated technical resources to each cluster or pilot.

6.6 TANGO Project regulatory, exploitation and business lessons

One of the concerns, for the majority of the project's partners, is the future steps of TANGO platform. A commercial and business future could be realized and a connection with the current market needs should be made before strategic decisions. As such, considering the pilots' insights, any business future could be based on the following possible business factors.

- ▶ **Market considerations:** In case go-to-market decisions need to be taken, the models with which the platform and/or components are positioned should take into account the pilots (and their respective industries) need and offer full support in terms of training, how-to-start guidelines and service-level agreements with potential users.
- ▶ **Transforming the technical components to end-user product offerings:** To take advantage of the many different but working technical components, TANGO's outputs need to be addressed as end-user bundled product offerings (e.g., "Privacy Preserving Suite", "Decision Making System", etc.) instead of isolated working modules. This could assist in pinpointing a clear value proposition and create a foundation for adoption at a commercial level for external stakeholders.
- ▶ **Energy efficiency proposition:** Energy efficiency was one more differentiator in the platform, beyond technical compliance. If a future exploitation strategy would be selected, sustainability and energy-efficient design could be a core value proposition. This would align with the required energy efficiency compliance needs of potential users.
- ▶ **Compliance as a market facilitator:** An added value that differentiates the developed platform in the broader data spaces market was the alignment with GDPR [5], eIDAS [7], and GAIA-X [8]. Compliance demonstrates users' trust and intensifies possible commercial adoption.

6.7 TANGO Project recommendations and next steps

Many different proposals have been made from partners regarding the project's and platform's past and future efficiency. Many of them are focused on the operational level and are easy to deploy in shorter terms, while others need strategic decisions for efficient outcomes. In this sub-chapter a segregation based on time follows.

6.7.1 Short term recommendations and next steps

As short term could be proposed an implementation duration of zero to 6 months. It could include short-term automations and focus on operational efficiency like:

- ▶ Development of ready-to-install deployment packages (e.g., container registries, configuration templates, etc.).
- ▶ Automation of the TRL/KPI evidence collection so manual reporting is reduced for the partners and digital analysis is provided at any time within the project.

6.7.2 Medium term recommendations and next steps

As medium-term recommendations could be identified those needing six to eighteen months to implement, thus affecting in a broader strategic direction the project's progress and market exploitation:

- ▶ Identify clear and bundled product offerings to realize a potential commercialisation roadmap.
- ▶ Make cross-pilot integration more efficient by establishing a reference sandbox environment.

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6.7.3 Long term recommendations and next steps

These recommendations are core strategic decisions proposed to be made to proceed with TANGO's next steps.

- ▶ Broaden the ecosystem of adapters and connectors to external platforms (GAIA-X [8], FIWARE, sector-specific standards).
- ▶ Add a layer of trust in data sharing by exploring available global or UN/EU data standards, and data elements per different sectors.
- ▶ Expand the lessons learned and components functionality to other sectors where secure, interoperable data sharing is critical, beyond the pilots, as case studies.
- ▶ Use training, documentation, and open collaboration to continue building a community of adopters around TANGO.
- ▶ Exploit and expand TANGO's platform and partners' ecosystem possibly to other global communities that are examining similar data spaces.

Wrapping up, TANGO Project's lessons learned verify both the challenges of large-scale integration in heterogeneous environments and the strength of the technological approach followed. By addressing the technical and integration challenges, and selecting a robust exploitation strategy, the project has the potential to evolve from research and innovation pilot implementations into an initiative that delivers sustainable impact within the European digital ecosystem.

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7 Conclusions

This deliverable included a thorough validation analysis of the TANGO platform, and its technology offerings while monitoring the extent these offerings achieved predefined KPIs. Due to the complexity and heterogeneity of the partners, systems, and platforms, a structured approach through questionnaires, focus groups, and evidence-based reporting was followed engaging all technical partners and pilot representatives. The validation confirms that TANGO has progressed its core components to higher TRLs, addressed core challenges related to trust, privacy, and secure data sharing while demonstrating interoperability across multiple different domains.

7.1 Main conclusions and challenges addressed report

Measurable progress has been achieved in the project. As defined in TANGO Project's Grant Agreement, the progress reflects energy-efficient execution, GDPR-compliant [5] data sharing, secure-by-design tools for developers, and advanced authentication and authorization mechanisms. Multiple components reached TRL 6-7 and were successfully deployed in real-world scenarios within the project's pilots. Strong assets of the platform have been proved to be privacy-preserving computation (PAT, PEC, CP-ABE components), SSI-based onboarding, and GDPR compliance [5]. However, some limitations persisted since five to seven pilots required higher effort than planned during integration. For example, the energy efficiency objective was not consistently covered across all components requiring further alignment.

7.2 Main results report

The main results synopsis of the validation analysis is as follows:

- ▶ TRL progress to TRL 6 – TRL 7 was demonstrated for several technology offerings across the different domains (hospitality, retail, finance, mobility, manufacturing).
- ▶ The majority of Deliverable's D2.4 [17] functional and non-functional requirements defined were implemented and validated.
- ▶ More than 70% of pilot representatives confirmed strong acceptance agreeing that TANGO met their requirements.
- ▶ Focus groups of different background stakeholders confirmed positive perceptions of trustworthiness, GDPR compliance [5], and user/device authentication.
- ▶ TornadoVM and RENOPS contributed to sustainability goals while Federated Learning demonstrated measurable improvements in fraud detection.
- ▶ Although further configuration and usability refinements are needed, adoption beyond pilots was considered feasible.

7.3 Deliverable objectives report

Assessing the deliverable's scope, the outcomes are reported in Table 4.

Table 4: Deliverable D7.2 objectives report.

Deliverable Objective	Status	Comments
Objective 1: Prepare an extensive plan to evaluate and validate the TANGO technical solutions against KPIs and requirements identified in WP2	Achieved	Structured TRL and KPI questionnaires were defined and applied as a detailed evaluation methodology, making use of evidence-based reporting directly from the pilots (screenshots, logs, deliverables), and cross-validation with requirements identified in WP2.

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Deliverable Objective	Status	Comments
		Both functional and non-functional requirements were addressed: authentication, GDPR compliance [5], authorisation, usability, interoperability, and energy efficiency.
Objective 2: Recruit highly representative end-users to participate in the TANGO pilot demonstrators, train them and support them during pilot execution	Achieved	Key end-users were recruited from all six pilot domains (hospitality, finance, mobility, manufacturing, retail). Technical support and training were provided during onboarding and pilot execution. User perceptions and experiences were captured through focus groups and questionnaires, verifying high levels of acceptance in most cases and issues were reported where occurred.
Objective 3: Evaluate TANGO individual technological components, their interoperability and the overall system	Mostly achieved	TRL 6–7 was validated for individual technological offerings (TOs), and evidence has been submitted for functional and non-functional KPIs. Interoperability was demonstrated through the integration of multiple components (e.g., attribute-based encryption (CP-ABE), privacy-preserving computation (PAT, PEC), policy enforcement, trust scoring, and SSI credentials). However, integration across five to seven pilots required more effort and time than anticipated.
Objective 4: Validate the overall TANGO solution and demonstrate its value proposition by testing it in six distinct use cases/pilots	Partially to fully achieved	The TANGO platform's value proposition has been successfully demonstrated across the six pilots in their respective domains confirming its' architecture's generalized approach. Simplifications and adaptations were required for some pilots, identifying areas for further optimisation.
Objective 5: Conduct a comprehensive analysis and assessment of test and pilot results to identify improvements	Achieved	A detailed analysis of TRL/KPI results, pilot evidence, and user feedback has been performed. The lessons learned underlined TANGO platform's strengths (SSI onboarding, GDPR

Deliverable Objective	Status	Comments
and inform the exploitation strategy		compliance [5], federated learning, sustainability contributions, interoperability) but also challenges (integration complexity, partial alignment with energy efficiency objectives, usability gaps, and limited support for constrained devices).

7.4 Possible next steps

Deriving from the information provided by the project's partners and its' analysis, possible next steps in TANGO Project's roadmap could be the following:

- ▶ Consolidation of the validated results into concrete product offerings to support commercial leverage beyond the research and innovation project's scope.
- ▶ Onboarding usability and extend support improvement for more platforms and ID documents.
- ▶ Expansion and connection to other platforms within the data spaces EU ecosystem.
- ▶ Deployment and reproducibility simplification by strengthening packaging and automation.
- ▶ Making energy efficiency as a systematic KPI by integrating it across all components.

In conclusion, the analysis performed in this deliverable proves that TANGO has achieved extensive progress in technological validation and maturity, while pinpointing specific improvements for future exploitation. TANGO can be considered as a high-impact ecosystem within the EU data spaces and its innovations could be exploited towards commercial end-user products. The heritage of innovations, expertise, and research experiences could be further developed and probably scaled to more similar ecosystems within EU.

8 References

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9 Annex

9.1 TRL Structured Questionnaire Template Version 1.0

For instructions on why, what and how to fill in the questionnaire, please refer to the document
“TRL_Questionnaire_Fill_Instructions”

Questionnaire completed by (Name, Role, Organization)	
Date	

1. Component identification

Component Identification	
Component Name	
WP / Task	
Lead Partner(s)	
TRL Contact Person (Name, Organization)	

2. TRL Assessment Table

Please fill in the following fields with **evidence-backed responses**. Kindly attach or link to any relevant documentation (e.g., test logs, screenshots, demo videos, performance charts).

Evaluation Criteria	Description	Evidence Provided (Document Name / Link / Screenshot ID)	Score (1: Low Applicability to 5: High Applicability)	Comments / Clarification
Functionality	Does the component meet the defined functional requirements (FRs)?			
Integration	Has it been integrated with at least one other TANGO component?			
Validation Environment	Has it been deployed in a pilot or relevant simulated environment?			
Repeatability	Were the results reproducible across multiple trials/tests?			
User/ Stakeholder Input	Did any pilot stakeholder test and provide feedback on the component?			

3. TRL Level Summary

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Initial TRL at project start (as defined in DoA)	
Target TRL (as planned in DoA)	
Final TRL reached after pilot testing	

4. TRL Justification

Explain how the above scores and evidence justify your proposed TRL level. Mention the nature of the validation activities, number of deployments or iterations, and any user or pilot feedback received	
---	--

5. Additional Comments / Remarks

Provide additional comments regarding the components' successful or unsuccessful TRL level, remarks and lessons learned from the process, if any	
Provide comments regarding the component's societal/ organizational/ legal readiness level	

6. Additional Material / Screenshots

Please post below screenshots, if available or needed, as one form of evidence for your “Evidence Provided” response in ‘2. TRL Assessment Table’. Provide the screenshot and a relevant ID based on the Component and the technology used (e.g., “ComponentID_Technology_Date[DDMMYY]”). Repeat the table rows as many times needed depending on the material you need to provide.

Screenshot ID	Screenshot

Screenshot ID	Screenshot

9.2 KPI Structured Questionnaire Template Version 1.0

Questionnaire completed by (Name, Role, Organization)	
Date	

1. KPI identification

Please use information either from the KPIs xls, or from the DoA to complete the table.

Target Measurable KPI	
Verification Means (as stated in the DoA / xls file)	
WP	
Relevant objective	
Target	
Baseline value	
Achieved (YES/NO)	

2. KPI Justification

--	--

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Explain how the KPI was achieved. Mention any related technical development or validation activities.	
--	--

3. Additional Comments / Remarks

Provide additional comments regarding the KPI's successful or unsuccessful achievement.	
--	--

4. Additional Material / Screenshots

Please post below screenshots, if available or needed, as form of evidence. Provide the screenshot and a relevant ID based on the Component and the technology used (e.g., "ComponentID_Technology_Date [DDMMYY]"). Repeat the table rows as many times needed depending on the material you need to provide.

Screenshot ID	Screenshot

Screenshot ID	Screenshot

9.3 TRL (& KPI) Questionnaire Completion Guide

TRL Questionnaire Completion Guide

This 1-pager explains how to complete the Component TRL Evaluation Questionnaire for TANGO Deliverable D7.2. The questionnaire ensures evidence-based and comparable TRL assessments across all technologies. Your evidence-based response is highly appreciated and will support a holistic approach on the lessons learned and the project's components and technologies maturity level.

1. Who Should Fill This Questionnaire In?

The questionnaire must be completed by the technical leads or designated TRL (Technology Readiness Level) champions responsible for each TANGO platform component. Their technical insight, development history, and integration knowledge is required to provide accurate, evidence-based responses. They can judge the functionality and maturity of their assigned component and supply the supporting material necessary for a valid, evidence-based TRL evaluation. Note that one submission per TANGO component (see D6.1 [14] for full list) is requested.

2. How to Fill In the Questionnaire?

Questionnaire Section 1: Component Identification

In this section, as a TRL Lead or Champion, please ensure that it accurately reflects the component's name, its related work package (WP) and task, the lead partner responsible, and your contact details. These details ensure traceability, accountability, and link your evaluation to the correct part of the TANGO platform.

Questionnaire Section 2: TRL Assessment Table

Fill out the five criteria using:

- Evidence: Please provide a document name which you may attach in your response, a screenshot (see questionnaire section '6'), or test log.
- Score: Please provide a response from 1 to 5, 1 being the lowest applicability in the question and 5
- Comments: Please clarify or justify briefly, if needed, your response

The criteria, we request your response on, try to evaluate as follows:

- ✓ Functionality: Is it working per its specifications?
- ✓ Integration: Was it actually integrated in a test/pilot?
- ✓ Validation Environment: Was it used in a simulated or real pilot?
- ✓ Repeatability: Were the results stable when repeated in multiple runs?
- ✓ User Input: Was any actual feedback from users collected?

Score scale: 1=Very low applicability; 2=Low applicability; 3=Applies in some cases; 4=Applies in most cases; 5=Applies in all cases

Questionnaire Section 3: TRL Level Summary

Please enter initial, target, and proposed final TRL (1–9 scale). For TRL scaling please refer here:

<https://horizoneuropencpportal.eu/sites/default/files/2022-12/trl-assessment-tool-guide-final.pdf>

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Questionnaire Section 4: Justification

In one, brief, paragraph please describe you evidence and TRL score

Questionnaire Section 5: Additional Comments / Remarks

In this section, please share any detail that cannot be associated directly to the scoring table but is vital for understanding the component's status. Highlight pending updates, known limitations, constraints during deployment, useful lessons learned, technical inefficacies or challenges you faced during collaboration.

Questionnaire Section 6: Additional Material / Screenshots

In this section, please provide screenshots or other material associated to the evidence requested to the scoring table. This could be an API log or application's UI as used in the TANGO project during the pilots' live applications with or without actual data.

3. What should I do if I have any additional material or I cannot provide it directly in the questionnaire?

If you do have additional material which you cannot include directly in the questionnaire, like test logs, huge number of screenshots, validation reports, demo links or pilot KPI charts, you can send them as attachments in your e-mail when sending back the filled-in questionnaire.

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1.1.2 TANGO positioning and TRL advances

Technology Offerings, Target TRL Level & Means to Reach It

Blockchain-based Data Storage and Sharing: The Fides ecosystem (TRL4) is governed by a consortium of participants in financial services who can securely exchange documentation via advanced distributed technologies, including blockchain. Through TANGO, the Fides ecosystem solution will be leveraged across multiple sectors and not only in banking, reaching TRL 7.
Trustworthy Data Sharing: Trustworthiness (TRL 4) will be extended in TANGO. Demonstration of the approach and metrics provide a starting point for extension and generalization of the use case of trustworthiness into distributed privacy-preserving data sharing mechanism reaching TRL6.
Confidentiality and Privacy by Design: From TRL4, this work will leverage the algorithms in the state of the art to enable high level data usage control privacy policies. TANGO will utilize them to realize a set of concrete data usage control policies and integrate the privacy preserving technologies reaching TRL6.
Self-encryption and Decryption Techniques with Multi-Factor Information Recovery Mechanisms: Currently the module is at TRL 3. TANGO will enhance self-encryption with recoverability. Through TANGO, the technology will be deployed in relevant environment given the four pilots in WP7, allowing the technology to reach TRL6.
Self-sovereign Identity Management: The Module is currently at TRL3 and it will advance to TRL6 through incorporating additional trust-based attributes and compatibility with other identity mechanisms (eIDAS, OpenID, etc.)
Seamless Onboarding for Users & Devices: Currently the module is at TRL3 being validated in relevant environment. During TANGO the technology will be demonstrated in relevant environment across 6 use cases reaching TRL6.
User continuous behavioural authentication: The user continuous behavioural authentication is currently at TRL 5 stage and it has been already validated in retail/manufacturing domain. Through TANGO the technology will be enhanced with additional behavioural patterns including gait and fraud detection based on transactions, reaching TRL7.
Device continuous behavioural authentication: In the context of TANGO, the device continuous behavioural authentication solution (TRL 3) will leverage sensor and network traffic to continuously assess the device and detect any potential anomalies in the behaviour of the device, which will be validated in the defined use cases (TRL6).
Hardening against Side-channel Attacks: The compiler that already supports the code polymorphism countermeasure is currently at TRL 3 for RISCv and ARM v7m. At the end of the project, the compiler should reach a TRL of 6, as one or several of its artifacts will be used in a significative environment.
Exploratory Data Analysis Engine: The Exploratory Data Analysis engine will start from a TRL4 relying upon other projects, where sensitive data were analysed. The newly developed module is expected to reach a TRL7, within TANGO, and will be demonstrated in an operational environment.
Energy efficient AI model training: The solution will be based on open-source AutoML solutions, which is already available to be used and validated with real use-cases. During the project, the new functionalities will be implemented and validated by the different use-cases, reaching TRL 6.
Dynamic Intelligent Execution on Heterogeneous Systems: TornadoVM is at TRL 7 with PoCs being developed for commercial applications. The improvements of TornadoVM in the context of TANGO will assist towards complementing the necessary missing features required for commercial offerings.
Privacy Threat Modelling and Identification for Trustworthy AI: TANGO aims to develop a TRL6 privacy enhancing tool utilising the NIST Privacy Framework (TRL2) to identify, assess, prioritise, mitigate and convey privacy-related risks associated with the collection, processing, storing and sharing of data.
X-AI for Privacy and Trust Enhancement: The XAI module has been partially implemented for financial institutes targeting the explainability of credit risk scoring. AI methods including Knowledge Graphs will be tested, combined with ML to enhance the decidability process related to the responsibility, validity and trust of AI systems (TRL6).
Infrastructure Management based on AI: The resource management components (xOpera orchestrator) that can be used are currently at the TRL7. The monitoring framework is based on Wazuh (TRL4). The expected improvements of the approach in terms of its resource use will reach TRL 6. The AIOps approach at TRL3, with several algorithms, approaches already been developed. The research performed should raise the expected combined TRL to TRL6.

9.4 TANGO Platform Validation Questionnaire

The following is the questionnaire submitted to the partners to be completed via link using the responses' capture tool "Survey Monkey":

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TANGO Platform Validation

A. Validation overview

* A.1. Partner performing the validation

(e.g. VISAR, IDIADA, etc.)

* A.2. Validation date

(Enter specific date)

Date



TANGO Platform Validation

B. Validation

* 1: How effectively does the TANGO framework meet the needs and requirements of the various actors and stakeholders?

- ☐ Fully meets all user needs and requirements, exceeding expectations.
- ☐ Largely meets requirements, with only minor adjustments needed.
- ☐ Adequately meets requirements, but some functionalities need improvement.
- ☐ Partially meets requirements; key features are still missing.
- ☐ Does not meet critical user requirements.

Add comment (optional):

Figure 25: Validation Questionnaire (part 1 from 5).

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*** 2: How effectively does the TANGO framework meet the technical and functional requirements?**

- ☐ Fully meets all technical and functional needs, exceeding expectations.
- ☐ Largely meets technical and functional requirements, with only minor adjustments needed.
- ☐ Adequately meets technical and functional requirements, but some functionalities need improvement.
- ☐ Partially meets technical and functional requirements; key features are still missing.
- ☐ Does not meet critical technical or functional requirements.

Add comment (optional):

*** 3: How do you rate the privacy and GDPR compliance features of the TANGO platform (e.g., Privacy Assurance Tool (PAT), Privacy Enhancing Component (PEC))?**

- ☐ Excellent (Comprehensive GDPR compliance, strong security, and privacy-by-design).
- ☐ Very good (Strong measures with minor improvements required).
- ☐ Acceptable (Meets most privacy/security requirements but needs enhancements).
- ☐ Limited (Partial compliance with gaps in privacy/security controls).
- ☐ Poor (Insufficient privacy/security and non-compliance risks identified).

Add comment (optional):

*** 4: How effectively does the TANGO framework support user authentication and onboarding mechanisms (e.g. SSI wallet, ePassport, User Continuous Behavioral Authentication, Device Continuous Behavioral Authentication)?**

- ☐ Excellent (Fully supports seamless authentication and user-friendly onboarding).
- ☐ Very good (Adequately supports seamless authentication and user-friendly onboarding).
- ☐ Acceptable (The authentication and onboarding process is unclear or complex).
- ☐ Limited (The authentication and onboarding process needs technical support).
- ☐ Poor (The authentication and onboarding process is an unreliable service).

Add comment (optional):

Figure 26: Validation Questionnaire (part 2 from 5).

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*** 5: How effectively does the TANGO framework support the user authorization and access management process (e.g. PEP/PDP)?**

- ☐ Excellent (The user authorization and access management process is highly reliable).
- ☐ Very good (The user authorization and access management process demonstrates strong access control).
- ☐ Acceptable (The user authorization and access management process works most of the time).
- ☐ Limited (The user authorization and access management process is inconsistent).
- ☐ Poor (The user authorization and access management process is unreliable).

Add comment (optional):

*** 6: How effectively does the TANGO framework allow users to maintain ownership throughout the whole lifecycle of the data sharing process (e.g. CP-ABE)?**

- ☐ Fully allows users to maintain ownership.
- ☐ Largely allows users to maintain ownership.
- ☐ Adequately allows users to maintain ownership.
- ☐ Partially allows users to maintain ownership.
- ☐ Does not allow users to maintain ownership.

Add comment (optional):

*** 7: How effectively does the TANGO framework ensure data integrity (e.g. data encryption/decryption)?**

- ☐ Fully ensures data integrity.
- ☐ Largely ensures integrity.
- ☐ Adequately ensures integrity.
- ☐ Partially ensures integrity.
- ☐ Does not ensure integrity.

Add comment (optional):

Figure 27: Validation Questionnaire (part 3 from 5).

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*** 8: How would you rate the overall security features of the TANGO platform?**

- ☐ Excellent (Strong security, and privacy-by-design).
- ☐ Very good (Strong measures with minor improvements required).
- ☐ Acceptable (Meets most privacy/security requirements but needs enhancements).
- ☐ Limited (Partial compliance with gaps in privacy/security controls).
- ☐ Poor (Insufficient privacy/security and non-compliance risks identified).

Add comment (optional):

*** 9: How well does TANGO enable the comprehensive analysis and modelling of data (e.g., EDAA)?**

- ☐ Data quality and analytics are excellent, enabling robust decision-making.
- ☐ Data quality is high with minimal issues affecting operations.
- ☐ Data quality is acceptable, but improvements are needed in accuracy or visualisation.
- ☐ Data quality is inconsistent, limiting usability.
- ☐ Data quality is poor and unreliable for operational needs.

Add comment (optional):

*** 10: How do you value the capabilities of TANGO to deal with Machine Learning operations in a decentralized environment (e.g., Federated Learning, MLOps, AutoML, XAI)?**

- ☐ Excellent (Excellent capabilities to train and track the life cycle of ML models).
- ☐ Very good (Very good capabilities to train and track the life cycle of ML models with minor improvements required).
- ☐ Acceptable (Meets most requirements for ML training but needs enhancements).
- ☐ Limited (Partial compliance with gaps in the requirements).
- ☐ Poor (Insufficient capabilities to train and track the life cycle of ML models).
- ☐ Not applicable.

Add comment (optional):

Figure 28: Validation Questionnaire (part 4 from 5).

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*** 11: How do you assess TANGO's contribution to sustainability and green operations (e.g., energy-efficient AI via RENOPS, hardware optimization via TornadoVM)?**

- ☐ Significant positive impact (Clear reduction of energy footprint).
- ☐ Moderate positive impact (Measurable improvements in energy efficiency).
- ☐ Neutral (Limited impact on energy/sustainability so far).
- ☐ Minimal impact (Sustainability benefits are not yet evident).
- ☐ Negative or negligible impact on energy/sustainability goals.
- ☐ Not applicable

Add comment (optional):

*** 12: How likely are you to adopt or recommend the TANGO framework beyond the pilot phase?**

- ☐ Highly likely (The platform is ready for full-scale adoption).
- ☐ Likely (Meets most of our requirements with few enhancements needed).
- ☐ Neutral (Adoption depends on further refinements).
- ☐ Unlikely (Major improvements are required before adoption).
- ☐ Not at all (The framework does not fit our future needs).

Add comment (optional):

*** 13: Given the opportunity and based on your experience and role in the project, what would you do differently in the TANGO project (e.g. technical development, integration, pilot deployment)?**

Figure 29: Validation Questionnaire (part 5 from 5).

9.5 Pilot Representatives Focus Group Questions

Group A – Pilot Representatives Questions

1. Evaluating the TANGO Platform operational efficiency:

How has the TANGO ecosystem and platform impacted your pilot operations in terms of innovation, efficiency, and usability?

2. Identifying the barriers to implementation:

What were the main barriers (regulatory, technical, organizational) encountered during deploying your pilot in the TANGO platform, and how were they resolved or mitigated?

3. Identifying the level of trust & security:

How confident are you in the platform's ability to ensure security, trustworthiness, and compliance in real-world, live operations?

4. Evaluating the overall adoption readiness & user experience:

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Which TANGO components or features provide the greatest value to users, and what enhancements would make the platform more attractive for long-term adoption?

5. Discussing the future vision & impact:

In your view, how can TANGO evolve as a platform for further adoption in the EU digital ecosystem and provide even greater value to your sector or beyond its current pilot scope?

6. Lessons learnt:

Which do you believe are the most important lessons from your overall experience as a pilot partner?

9.6 Technical Partners Focus Group Questions

Group B – Technical Teams Questions

1. Assessing the TANGO Platform Technological Strengths:

Which components (e.g., CP-ABE, XAI, RENOPS, FL, PAT, PEC, etc.) demonstrated the most effective performance during testing and development?

2. Identifying the major integration challenges:

Which do you identify as the key technical barriers during platform integration, and how do you believe that they could be addressed in future iterations?

3. Assessing the level of innovation:

Which innovative elements of TANGO stand out for you as significant contributions to the field of privacy-preserving, trustworthy, and green AI systems?

4. Assessing the platform's scalability & maintainability:

In your opinion, how ready is the TANGO platform for scaling beyond the pilot environment, and what technical improvements would you suggest to ensure long-term maintainability and reliability?

5. Discussing the platform's future potential:

In your opinion, from your experience, and judging from the real-world TANGO demonstrations, what additional functionalities and/or technologies could be integrated into TANGO to strengthen its relevance and commercial/market potential?

6. Lessons learnt:

Which do you believe are the most important lessons from your overall experience as a member of the TANGO technical team?

9.7 TRL Additional Material and Screenshots per Technology Offering

9.7.1 Additional Material / Screenshots for Blockchain-based Data Storage and Sharing

As provided by the partner, below is material proving the component's progress.

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NORBLOC

TANGO Pilot 5 (T7.6 - Public Organizations) utilizes Fides, Norbloc's decentralized infrastructure designed for secure regulated data sharing, ensuring seamless and compliant information exchange.

As shown in the diagram below, the setup consists of three main nodes: one for the Employer (Node C), one for VisaRight (Node A), and one for the Immigration Authority (Node B). All nodes are connected together in a single p2p flat network that ensures privacy, transparency, and traceability.

This setup incorporates Norbloc's DRILL for secure data redundancy, DnAMS for decentralized access control and encryption, and the blockchain (Hyperledger Fabric) for maintaining a full audit trail of all ecosystem activity.

Together, these components ensure verified data can be exchanged safely, with full user consent and real-time compliance enforcement.

Figure 30: Blockchain-based Data Storage and Sharing TRL pilot journey (part 1 of 3) (Screenshot ID: FIDES_TANGO_PilotJourney_150725).

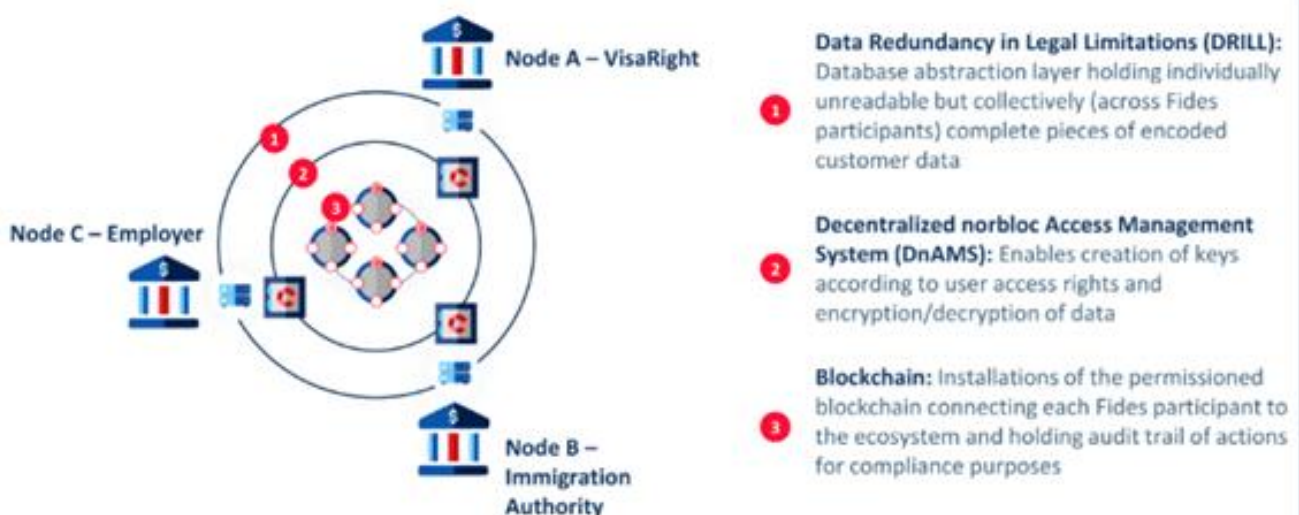


Figure 31: Blockchain-based Data Storage and Sharing TRL pilot journey (part 2 of 3) (Screenshot ID: FIDES_TANGO_PilotJourney_150725).

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TANGO Pilot 5 (Public Organizations) Manual - Step-by-Step Journey (via Fides)

This guide was created to walk you through the full process of creating and managing a visa application using the Fides platform. Whether you are an employer, a VisaRight officer, or a reviewer at the Immigration Authority, this checklist shows exactly what happens and what you need to do at each step - clearly and simply.

Credentials for all nodes:

Username: demo

Password: Demo123\$

Actors:

- ✓ **Applicant** - natural person that is a potential employee of the Employer and needs visa to Germany to start the employment.
- ✓ **Employer** - a company that wants to hire the Applicant. Employer uses Fides multi-tenancy Tango node for employers (tango-c.norbloc.com).
- ✓ **VisaRight** - a company that facilitates visa application process. Has its own dedicated Fides node (tango-a.norbloc.com).
- ✓ **Immigration Authority** - a government entity that makes visa decisions. Has its own dedicated Fides node (tango-b.norbloc.com).

Figure 32: Blockchain-based Data Storage and Sharing TRL pilot journey (part 3 of 3) (Screenshot ID: FIDES_TANGO_PilotJourney_150725).

The above material can be accessed as well using the following, provided the partner, link: https://drive.google.com/drive/folders/1gyZLGM_qhLtBx9PQdXEzA4dryJ4B04FI

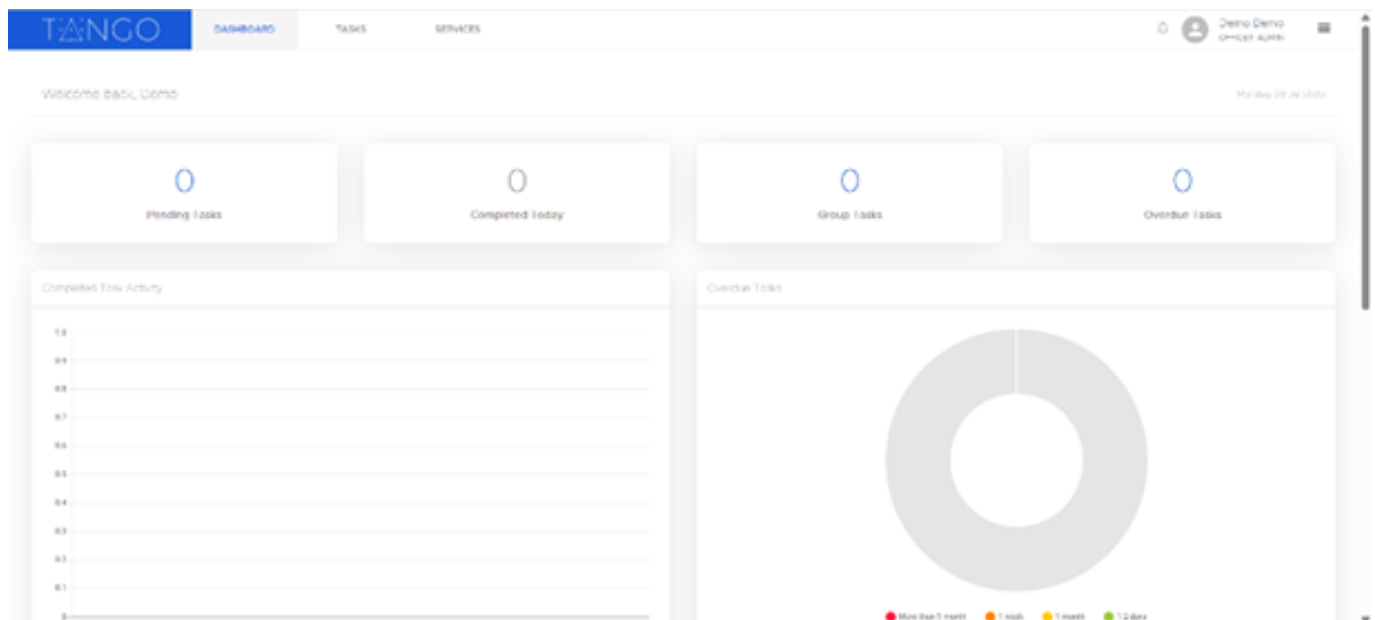


Figure 33: Blockchain-based Data Storage and Sharing TRL TANGO Employer Portal (Screenshot ID: Tango_Employer_Portal).

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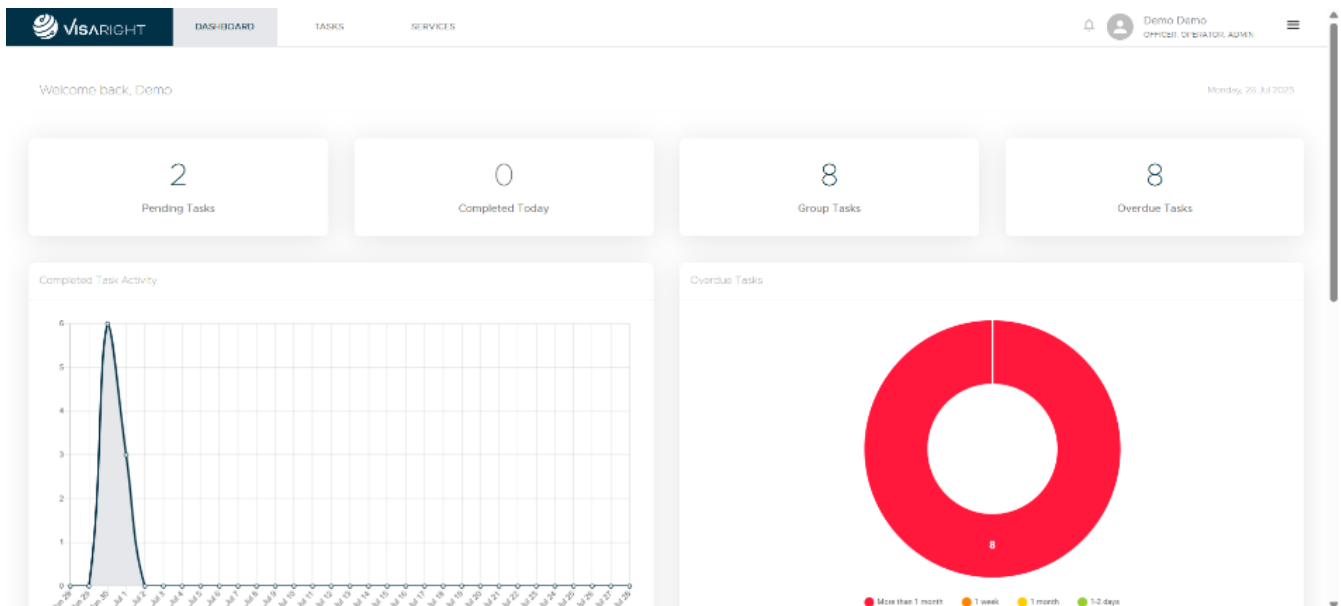


Figure 34: Blockchain-based Data Storage and Sharing TRL TANGO VISAR Portal (Screenshot ID: Tango_VISAR_Portal).

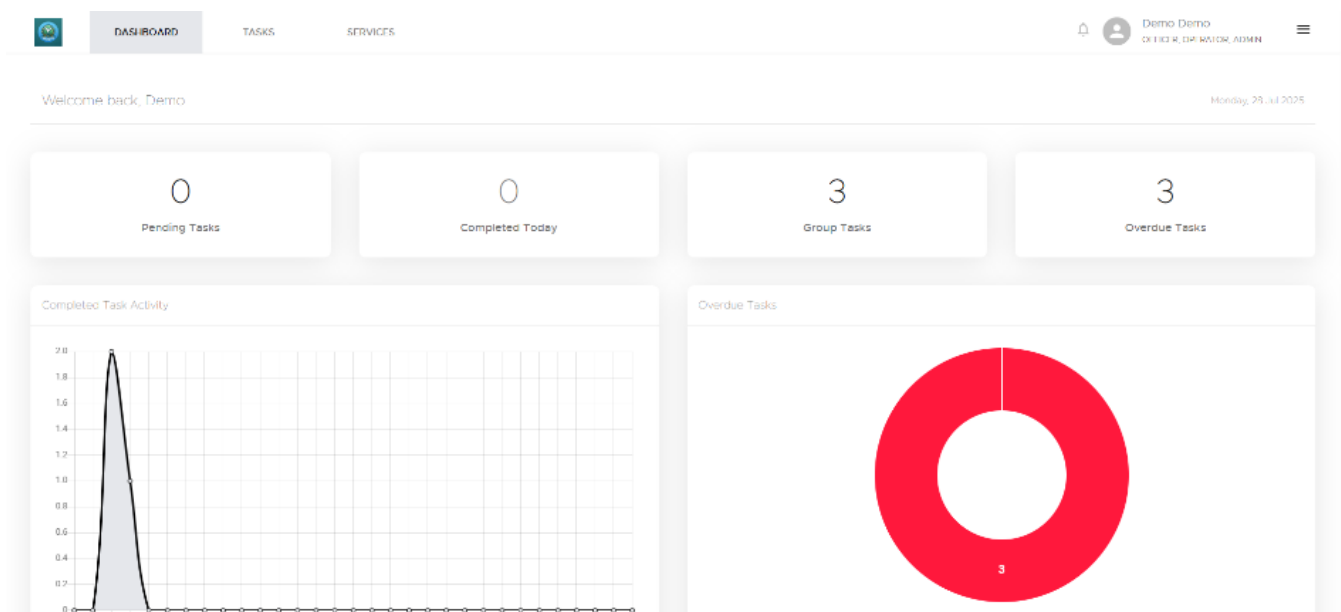


Figure 35: Blockchain-based Data Storage and Sharing TRL TANGO Authority Portal (Screenshot ID: Tango_Migration Authority Portal).

9.7.2 Additional Material / Screenshots for Trustworthy Data Sharing

As provided by the partner, below is material proving the component's progress.

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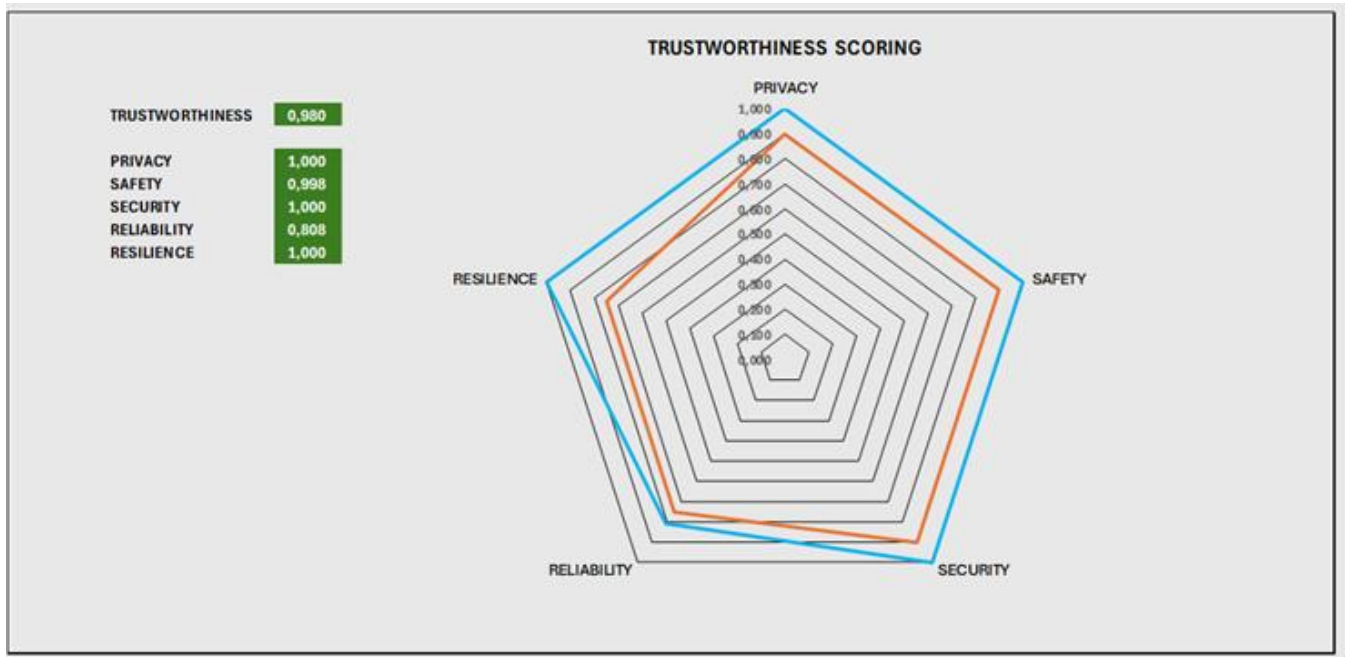


Figure 36: Trustworthy Data Sharing TRL Trustworthiness scoring test 1 (Screenshot ID: TSM_score_0001).

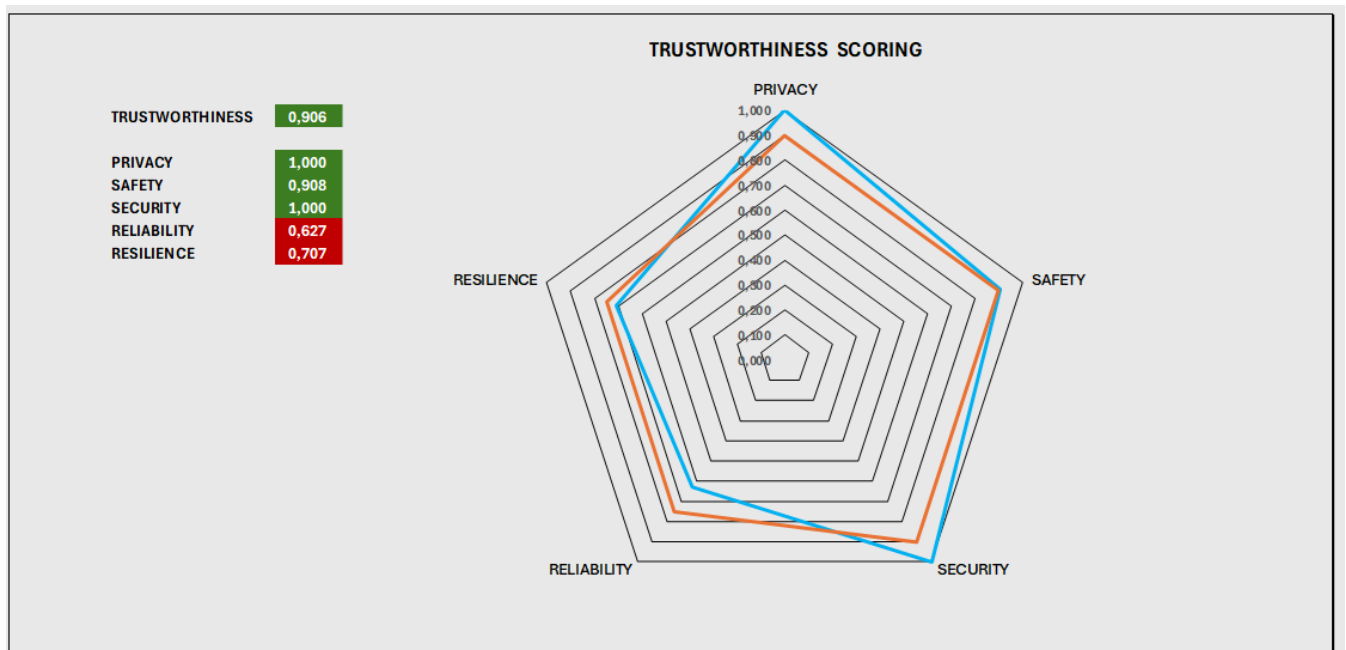


Figure 37: Trustworthy Data Sharing TRL Trustworthiness scoring test 2 (Screenshot ID: TSM_score_0007).

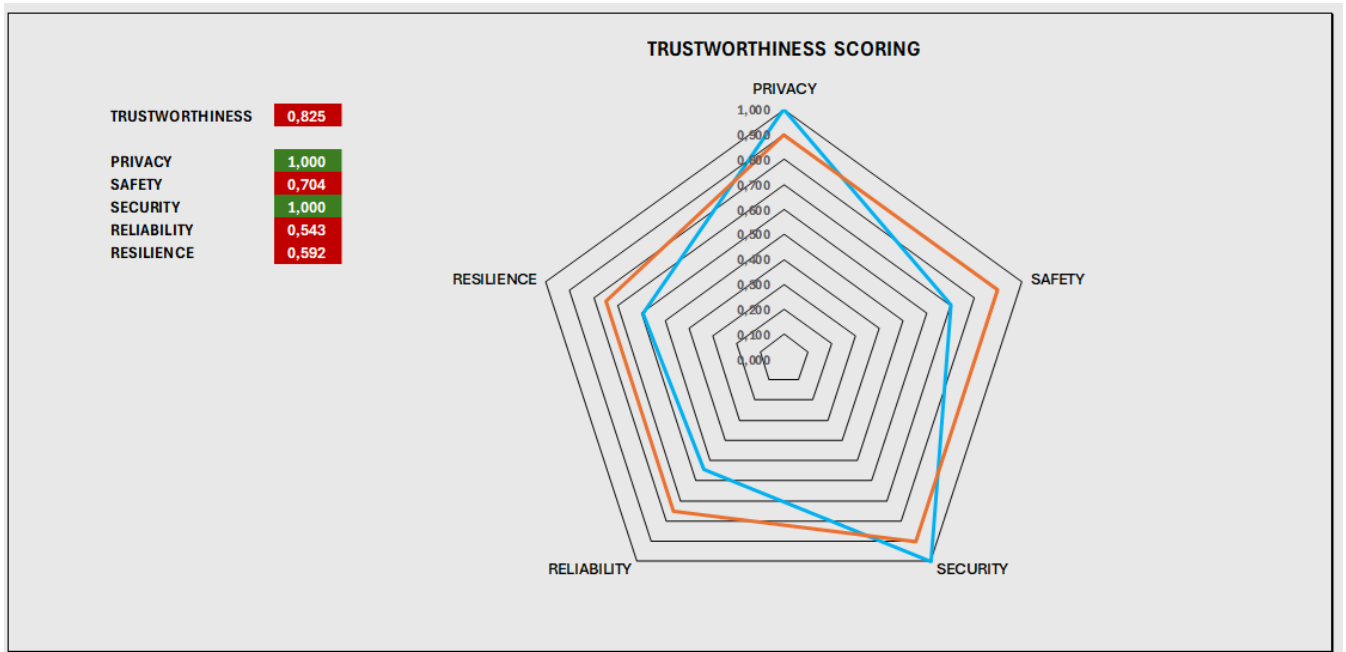


Figure 38: Trustworthy Data Sharing TRL Trustworthiness scoring test 3 (Screenshot ID: TSM_score).

9.7.3 Additional Material / Screenshots for Confidentiality and Privacy by Design

No additional material/screenshots provided by the partner.

9.7.4 Additional Material / Screenshots for Self-encryption and Decryption Techniques with Multi-Factor Information Recovery Mechanisms

As provided by the partner, below is material proving the component's progress.

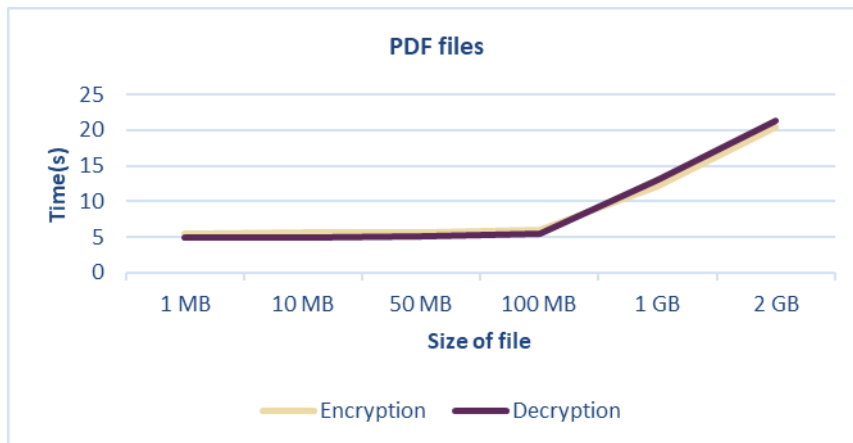


Figure 39: Self-encryption and Decryption Techniques with Multi-Factor Information Recovery Mechanisms TRL PDF Time Cost (Screenshot ID: SEDSS_PDFTimeCost_15112024).

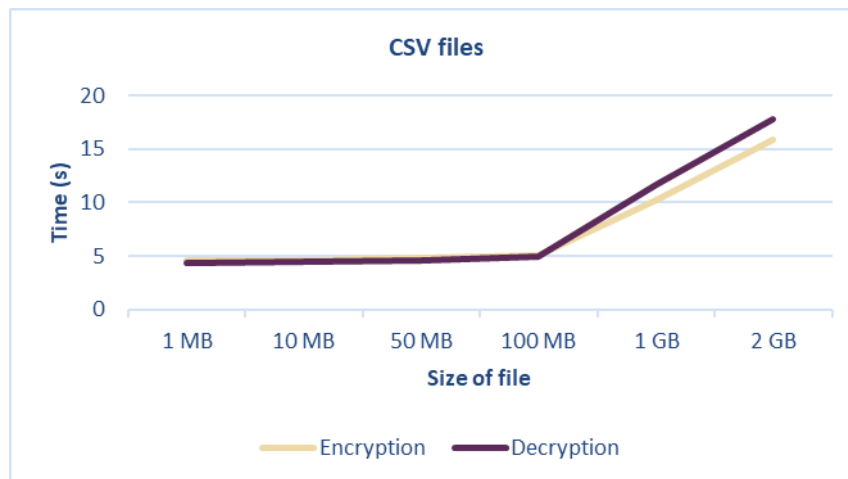


Figure 40: Self-encryption and Decryption Techniques with Multi-Factor Information Recovery Mechanisms TRL CSV Time Cost (Screenshot ID: SEDSS_CSVTimeCost_15112024).

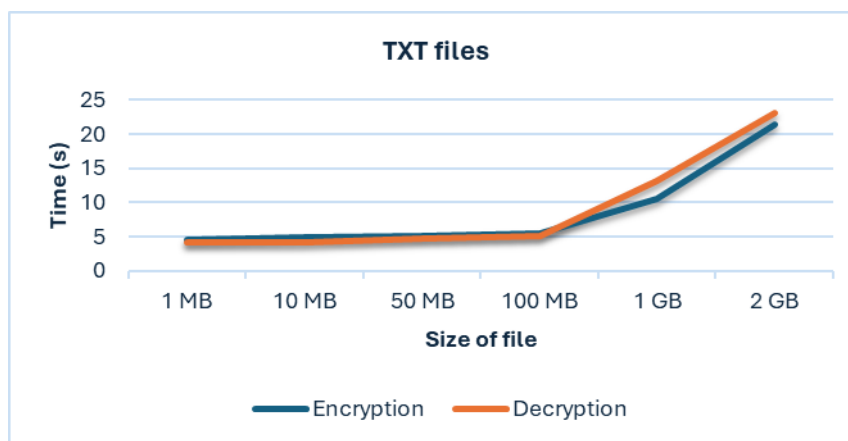


Figure 41: Self-encryption and Decryption Techniques with Multi-Factor Information Recovery Mechanisms TRL TXT Time Cost (Screenshot ID: SEDSS_TXTTimeCost_15112024).

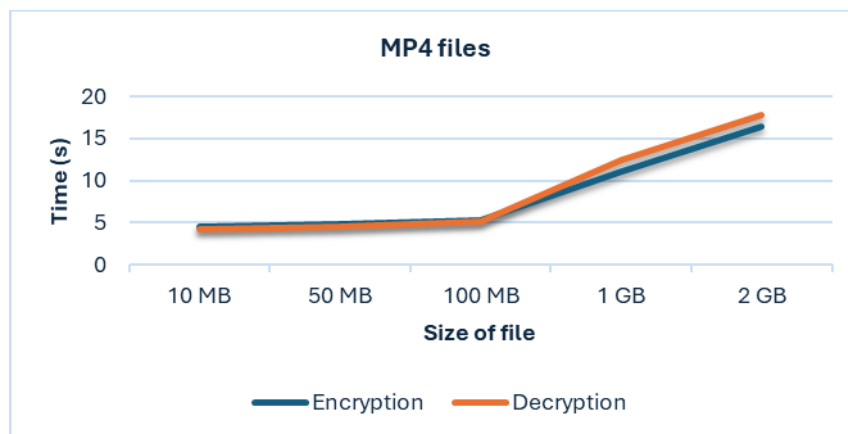


Figure 42: Self-encryption and Decryption Techniques with Multi-Factor Information Recovery Mechanisms TRL MP4 Time Cost (Screenshot ID: SEDSS_MP4TimeCost_15112024).

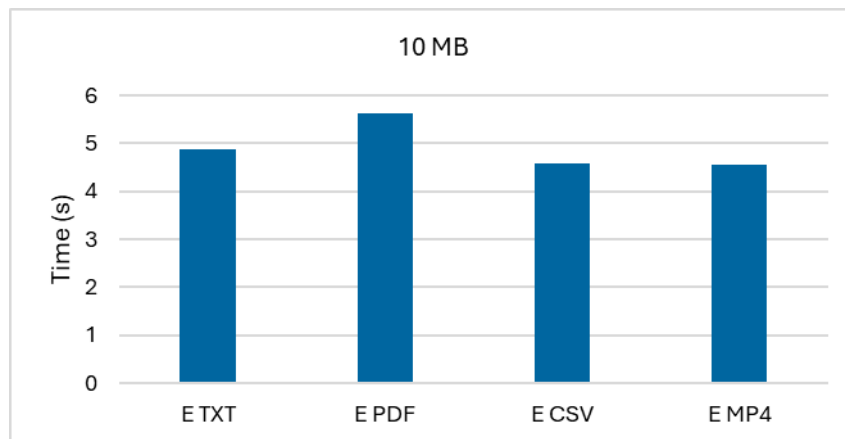


Figure 43: Self-encryption and Decryption Techniques with Multi-Factor Information Recovery Mechanisms TRL file complexity 10MB (Screenshot ID: SEDSS_FILECOMPLEXITY10MB_15112024).

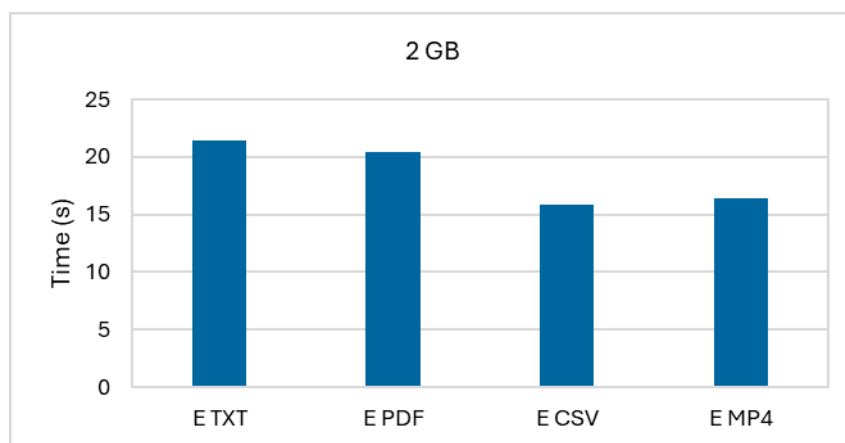


Figure 44: Self-encryption and Decryption Techniques with Multi-Factor Information Recovery Mechanisms TRL file complexity 2GB (Screenshot ID: SEDSS_FILECOMPLEXITY2GB_15112024).

9.7.5 Additional Material / Screenshots for Self-sovereign Identity Management

As provided by the partner, below is material proving the component's progress.

Table 5: SSI Agent Additional Material / Screenshots.

Log ID	Log
ssi-uself-agent_IDM_03-03-25	<p>ePassport issuer SSI Agent log:</p> <p>https://github.com/TANGO-EU-PROJECT/ssi-agent-specs/tree/main?tab=readme-ov-file#5-issuer-integration-logs</p>

ssi-uself-agent_IDM_22-05-25	Employee issuer SSI Agent log: https://github.com/TANGO-EU-PROJECT/ssi-agent-specs/tree/main?tab=readme-ov-file#5-issuer-integration-logs
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9.7.6 Additional Material / Screenshots for Seamless Onboarding for Users & Devices

As provided by the partner, below is material proving the component's progress.

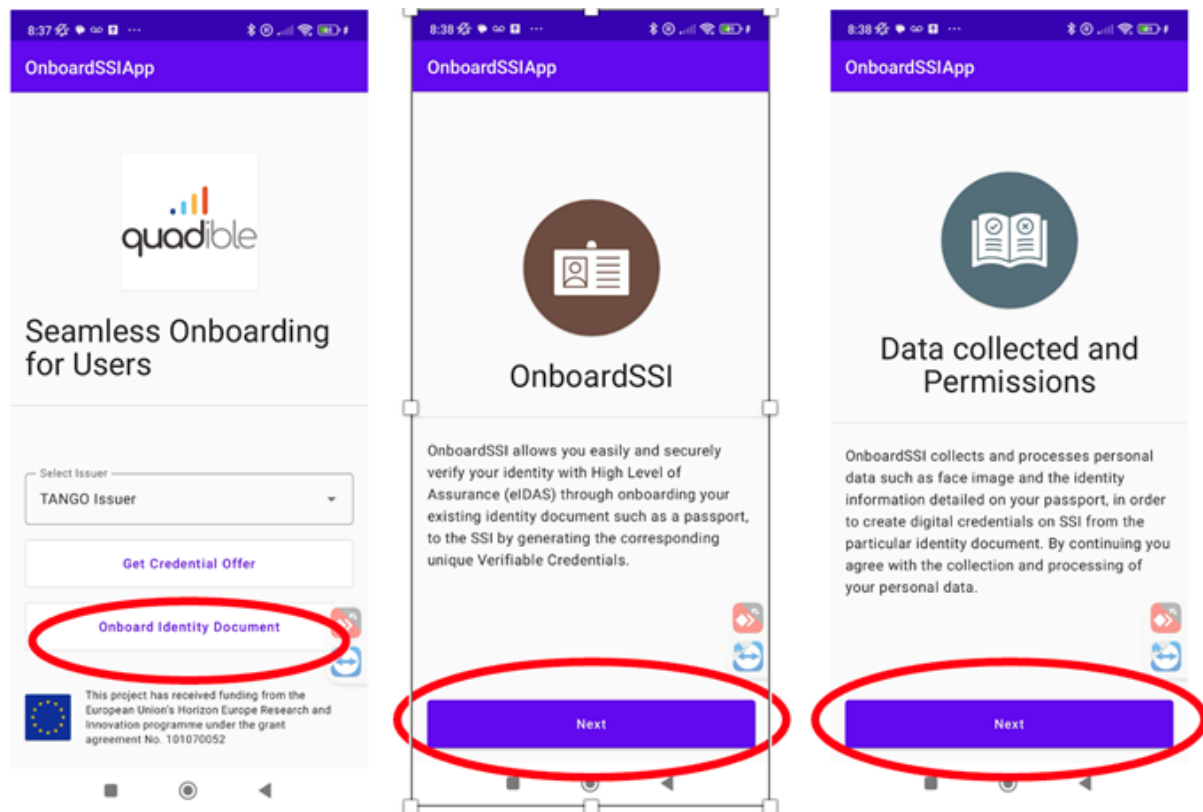


Figure 45: Seamless Onboarding for Users & Devices TRL onboarding steps 1-3 (Screenshot ID: SOUD_150725_1).

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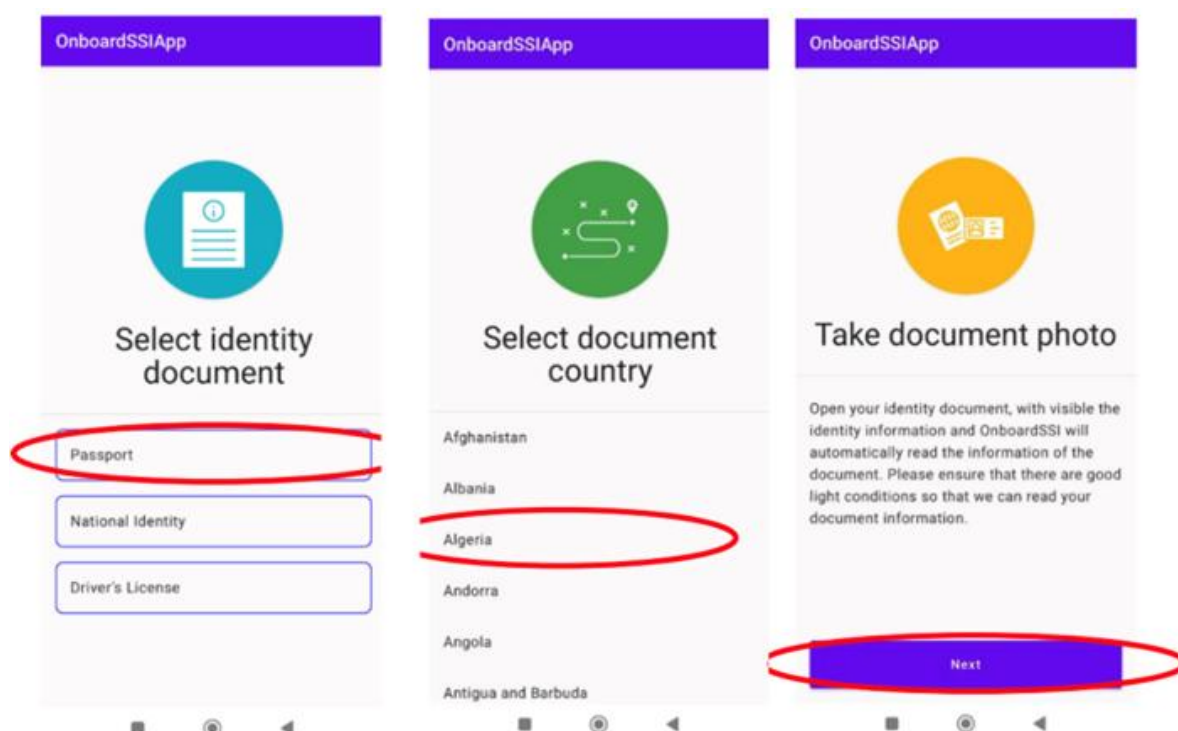


Figure 46: Seamless Onboarding for Users & Devices TRL onboarding steps 3-6 (Screenshot ID: SOUD_150725_2).

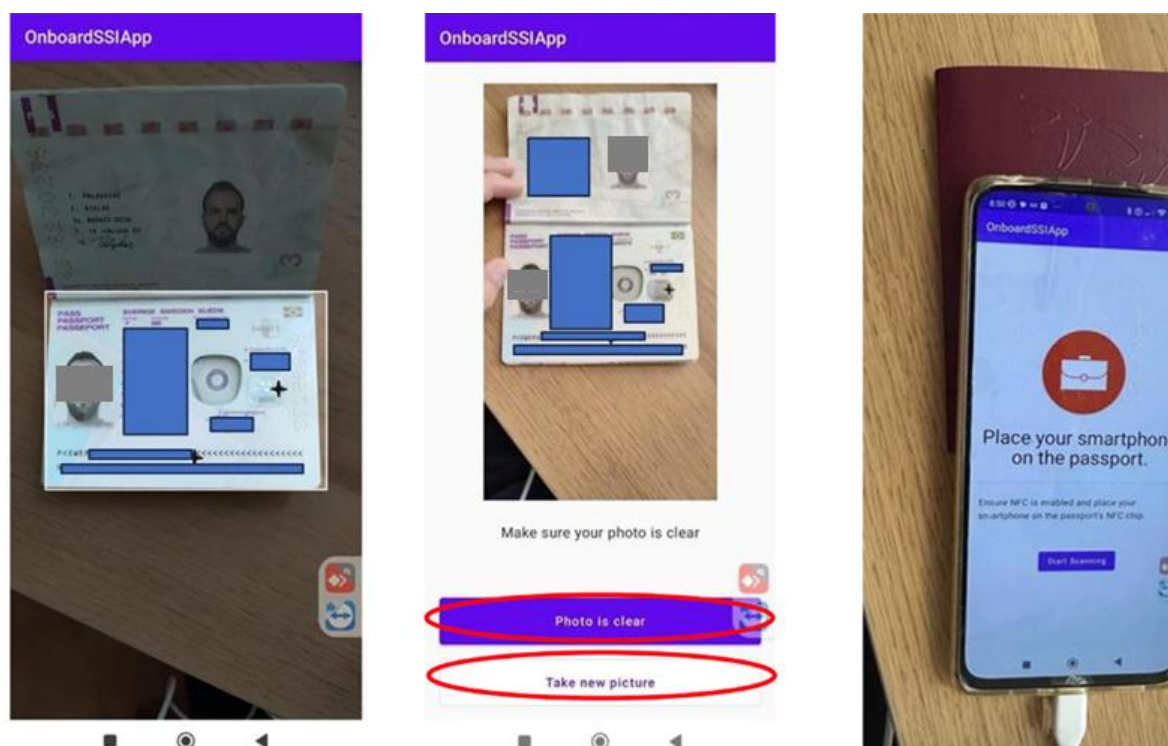


Figure 47: Seamless Onboarding for Users & Devices TRL onboarding steps 7-9 (Screenshot ID: SOUD_150725_3).

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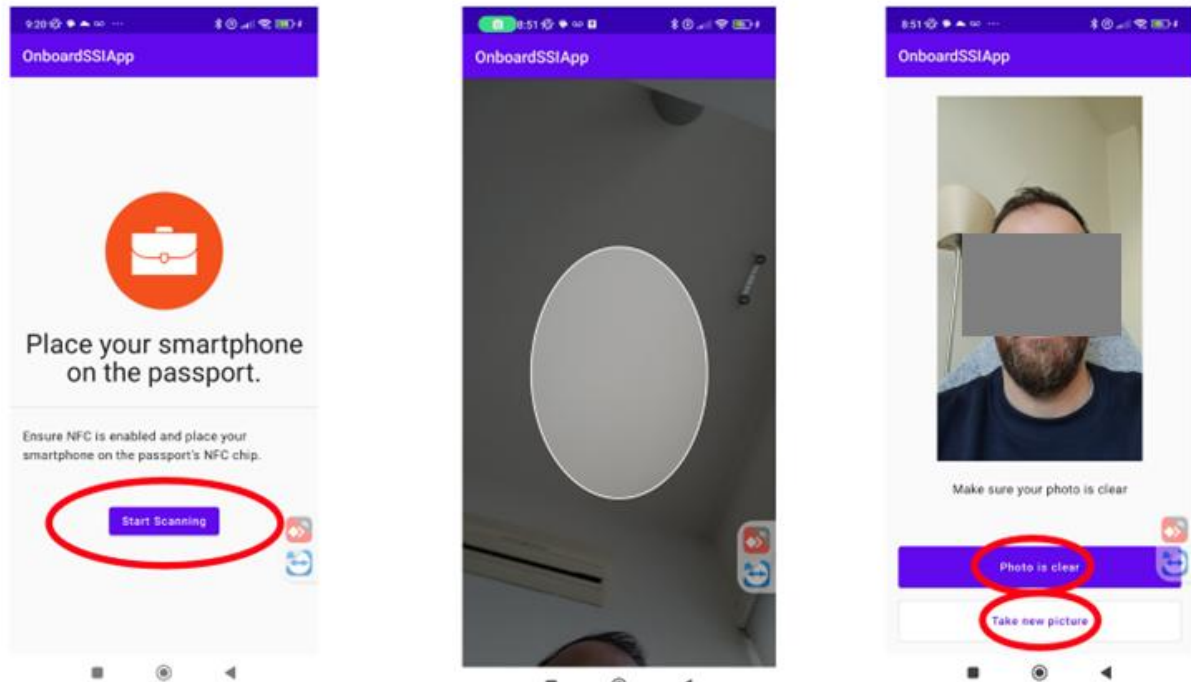


Figure 48: Seamless Onboarding for Users & Devices TRL onboarding steps 10-12 (Screenshot ID: SOUD_150725_4).

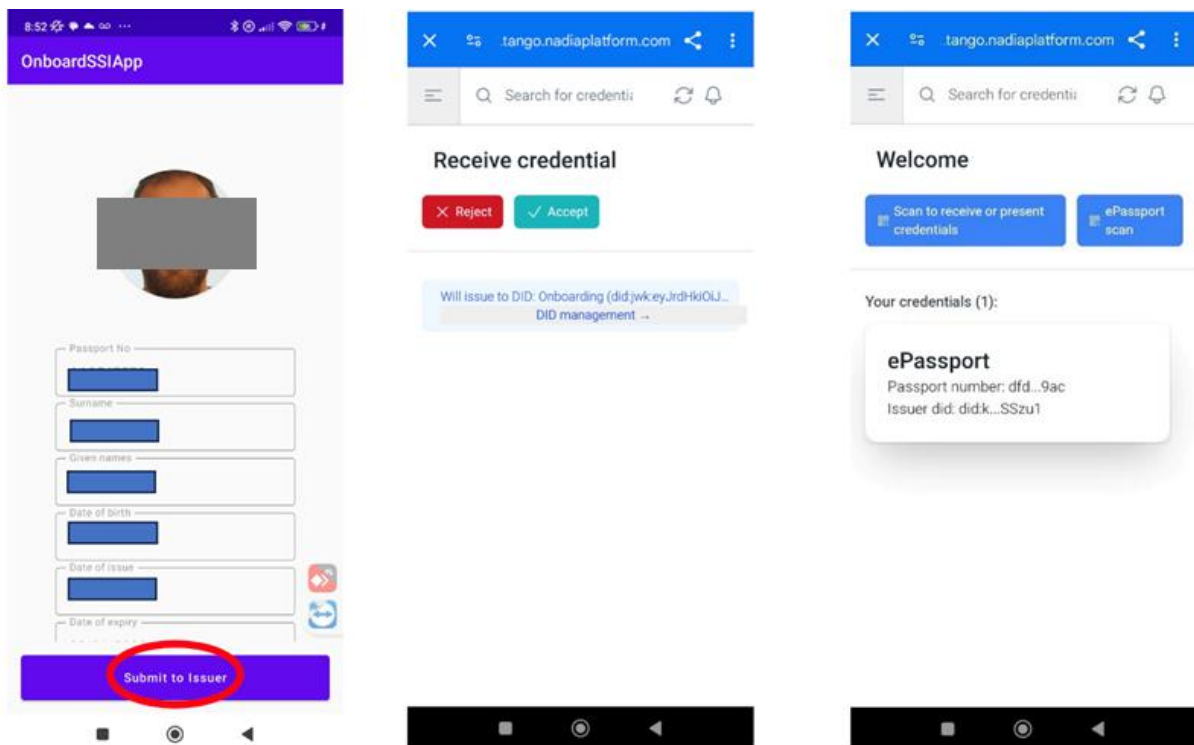


Figure 49: Seamless Onboarding for Users & Devices TRL onboarding steps 13-15 (final) (Screenshot ID: SOUD_150725_5).

9.7.7 Additional Material / Screenshots for User continuous behavioural authentication

As provided by the partner, below is material proving the component's progress.

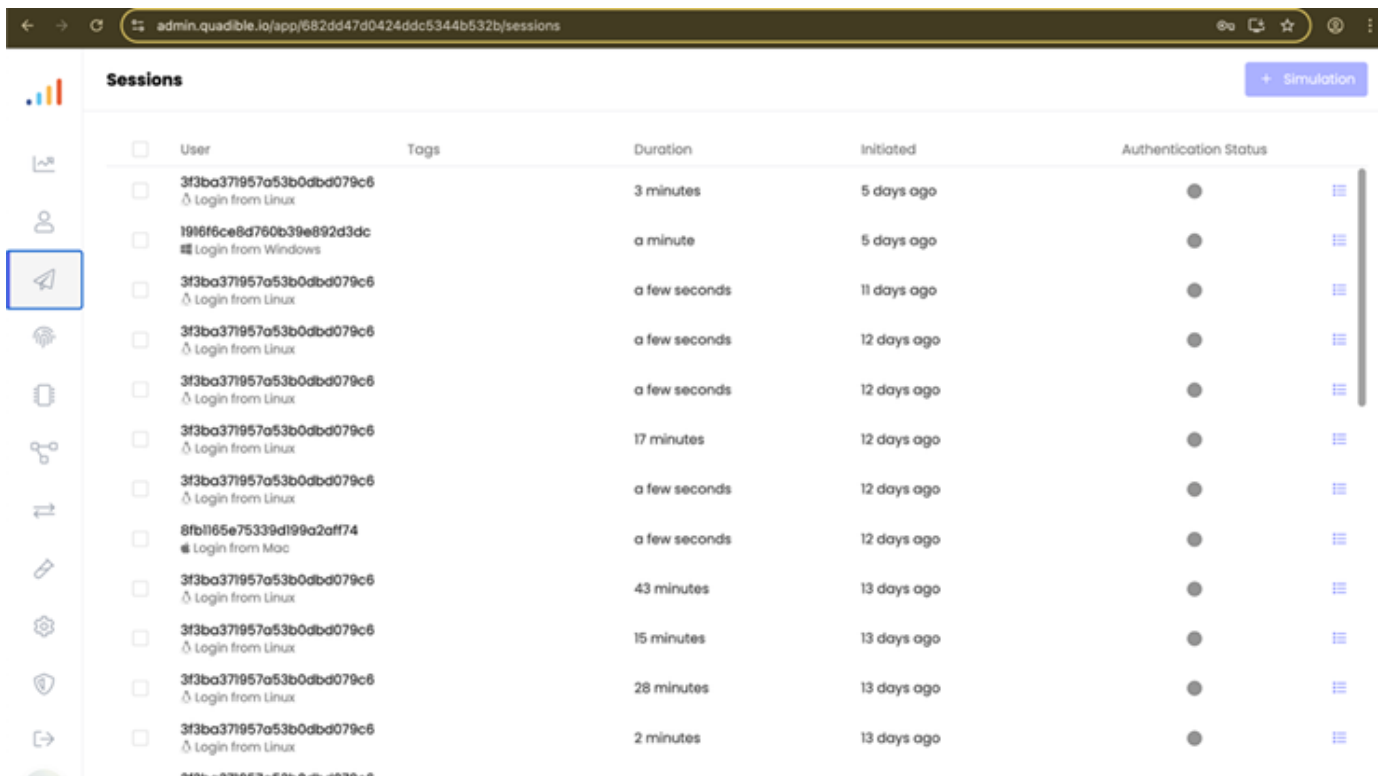
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Below is the typing form integrated in the TANGO UI (New Data Processing Job page), where users are filling in the form fields and UCBA records typing and mouse data in the background to analyze the behavioural patterns of the user and perform the continuous authentication.

Figure 50: User continuous behavioural authentication TRL new data processing job page (Screenshot ID: UCBA_170925_1).

Furthermore, below is an example from the internal admin panel of the UCBA component, showing the different sessions of a user logged from the web application.

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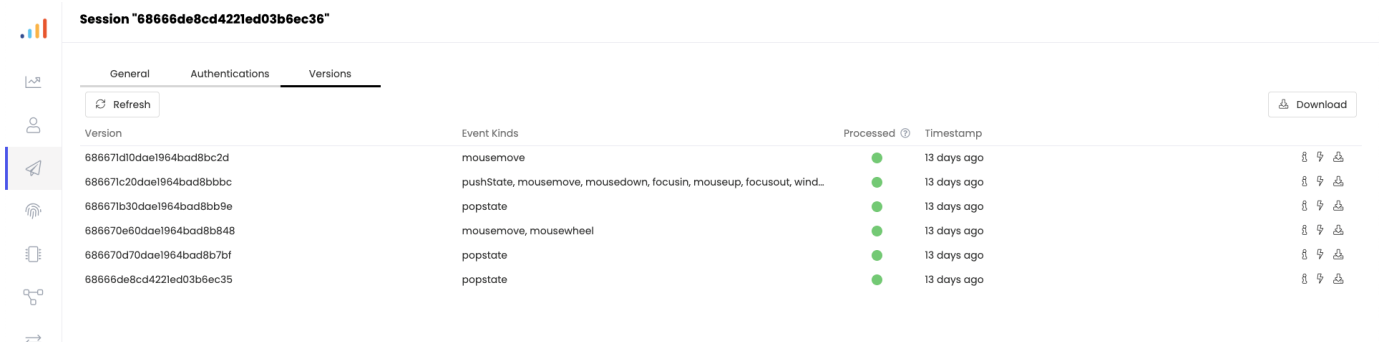


The screenshot shows a web application interface for 'Sessions'. The browser address bar displays 'admin.quadible.io/app/682dd47d0424ddc6344b532b/sessions'. The page has a sidebar with various icons, and a main content area titled 'Sessions' with a '+ Simulation' button. The table lists sessions with columns: User, Tags, Duration, Initiated, and Authentication Status. Each row includes a checkbox, a user ID, a login source, duration, time initiated, and a status indicator.

	User	Tags	Duration	Initiated	Authentication Status
☐	3f3ba371957a53b0dbd079c6 Login from Linux		3 minutes	5 days ago	●
☐	1916f6ce8d760b39e892d3dc Login from Windows		a minute	5 days ago	●
☐	3f3ba371957a53b0dbd079c6 Login from Linux		a few seconds	11 days ago	●
☐	3f3ba371957a53b0dbd079c6 Login from Linux		a few seconds	12 days ago	●
☐	3f3ba371957a53b0dbd079c6 Login from Linux		a few seconds	12 days ago	●
☐	3f3ba371957a53b0dbd079c6 Login from Linux		17 minutes	12 days ago	●
☐	3f3ba371957a53b0dbd079c6 Login from Linux		a few seconds	12 days ago	●
☐	8fb1165e75339d199a2aff74 Login from Mac		a few seconds	12 days ago	●
☐	3f3ba371957a53b0dbd079c6 Login from Linux		43 minutes	13 days ago	●
☐	3f3ba371957a53b0dbd079c6 Login from Linux		15 minutes	13 days ago	●
☐	3f3ba371957a53b0dbd079c6 Login from Linux		28 minutes	13 days ago	●
☐	3f3ba371957a53b0dbd079c6 Login from Linux		2 minutes	13 days ago	●

Figure 51: User continuous behavioural authentication TRL user different sessions log (Screenshot ID: UCBA_170925_2).

In addition, below the partner provided an example from the internal admin panel of the UCBA component, showing the different data versions that are analyzed in the background from the component to perform the continuous authentication.



The screenshot shows a web application interface for a specific session. The browser address bar displays 'admin.quadible.io/app/6866de8cd4221ed03b6ec36'. The page has a sidebar with various icons, and a main content area titled 'Session "6866de8cd4221ed03b6ec36"'. The 'Versions' tab is selected, showing a table of data versions with columns: Version, Event Kinds, Processed, and Timestamp. Each row includes a version ID, event kinds, a processed status indicator, and the timestamp.

Version	Event Kinds	Processed	Timestamp
686671d10dae1964bad8bc2d	mousemove	●	13 days ago
686671c20dae1964bad8bbbc	pushState, mousemove, mousedown, focusin, mouseup, focusout, wind...	●	13 days ago
686671b30dae1964bad8bb9e	popstate	●	13 days ago
686670e50dae1964bad8b848	mousemove, mousewheel	●	13 days ago
686670d70dae1964bad8b7bf	popstate	●	13 days ago
68666de8cd4221ed03b6ec35	popstate	●	13 days ago

Figure 52: User continuous behavioural authentication TRL different data versions background analysis (Screenshot ID: UCBA_170925_3).

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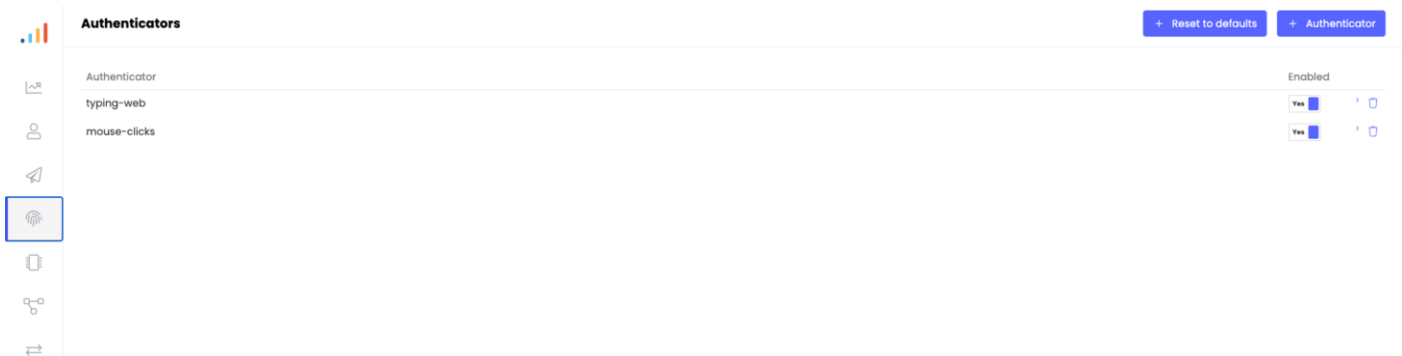


Figure 53: User continuous behavioural authentication TRL specific user authentication results (part 1 of 2) (Screenshot ID: UCBA_170925_4).

Moreover, below is an example from the internal admin panel of the UCBA component for one specific user session, showing the authentication results for each modality, typing and mouse respectively. Each node marker in the timeline represents a specific data version (time window) during the session. When a user logs in for the first time, UCBA enrolls him by creating a unique behavioural profile (large numerical vector representation). Thus, no authentications can be provided (node markers with grey color). This profile is then used (and updated) in the subsequent sessions of the user to perform the continuous authentication by comparing with the current session data representation. If there is a high similarity, the user is authenticated (consecutive node markers with green color) or flagged as an imposter (consecutive node markers with red color).



Figure 54: User continuous behavioural authentication TRL specific user authentication results (part 2 of 2) (Screenshot ID: UCBA_170925_4).

Lastly, the partner provided one more example (with legitimate user logged in) from the internal admin panel of the UCBA component for one specific user session, showing the authentication results for each modality, typing and mouse respectively. Node markers with grey color indicate that there is not enough data for authentication, either because the user enrolls for the first time or he has not performed enough typing and mouse actions at that moment (data version). Consecutive node markers with green color indicate legit user session, i.e., user is authenticated successfully. Occasional node markers with red color indicate few data and instantaneous abnormal user actions, and are not indicating an actual imposter/fraudulent session (which is indicated by many consecutive red node markers).

9.7.8 Additional Material / Screenshots for Device continuous behavioural authentication (DCBA)

As provided by the partner, below is material proving the component's progress.

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SORTING_LINES_1_TO_3

```
05-21 15:39:20.896 19811 19811 D WifiNetworkScannerN: SSID: VAGuest,
BSSID: e8:6d:e9:0f:d5:f2, Level: -85, SSID: VisaCorp, BSSID:
e8:6d:e9:0f:d5:f0, Level: -85, SSID: MiR_6, BSSID: b8:69:f4:b1:4f:a3,
Level: -49, SSID: awb_5274b4, BSSID: 00:30:11:52:74:b5, Level: -72,
SSID: VisaPrivate, BSSID: e8:6d:e9:0f:d5:f1, Level: -85, SSID: MiR_2,
BSSID: b8:69:f4:b1:62:3f, Level: -53, SSID: MiR_5, BSSID:
cc:2d:e0:32:ce:a5, Level: -71, SSID: MiR_2, BSSID: b8:69:f4:b1:62:3e,
Level: -64, SSID: VAGuest, BSSID: e8:6d:e9:0f:fb:72, Level: -89, SSID:
MIR_WIFI3, BSSID: 02:50:7f:c1:dc:fa, Level: -66, SSID: VisaPrivate,
BSSID: e8:6d:e9:0f:fb:71, Level: -89, SSID: MiR_3, BSSID:
08:55:31:43:87:36, Level: -73, SSID: VisaCorp, BSSID:
e8:6d:e9:0f:fb:70, Level: -89, SSID: MiR_1, BSSID: cc:2d:e0:3f:cc:ca,
Level: -57, SSID: MIR_WIFI3, BSSID: 00:50:7f:f1:dc:b9, Level: -73
```

Figure 55: Device continuous behavioural authentication (DCBA) TRL Sorting lines (Screenshot ID: DCBA_150925_1).



Figure 56: Device continuous behavioural authentication (DCBA) TRL E-Passport login (Screenshot ID: DCBA_150925_2)

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TENGO

DIGITAL TECHNOLOGIES ACTING
AS A GATEKEEPER TO INFORMATION
AND DATA FLOWS

Smart Manufacturing Pilot Dashboard

LIVE ALERTSALERTS HISTORYDEVICESSTATISTICS

Device ID	Location	First Seen ↓	Last Seen	Duration (s)
effaa817534276ac	PACKAGING_LINES	2025-07-02 14:14:57	2025-07-02 14:14:57	0
effaa817534276ac	SORTING_LINES_6_TO_8	2025-07-02 14:14:21	2025-07-02 14:14:57	36
effaa817534276ac	WAREHOUSE	2025-07-02 14:11:49	2025-07-02 14:14:21	152
effaa817534276ac	PACKAGING_LINES	2025-06-17 14:53:05	2025-07-02 14:11:49	0
effaa817534276ac	SORTING_LINES_6_TO_8	2025-06-17 14:52:34	2025-06-17 14:53:05	31
effaa817534276ac	SORTING_LINES_1_TO_3	2025-06-17 14:52:02	2025-06-17 14:52:34	31

Additionally, the partner provided a video as a proof of concept of the component's functionality which can be accessed online through the following link (ID: DCBA_150925_5): https://uthnoc-my.sharepoint.com/:v:/g/personal/lstergios_o365_uth_gr/Ed0W0nkZ0W9LleelyXl7TYoBZ5BctTpDA6Aa_A06xixQJw?e=XSVPM7&nav=evJvZWZlcnJhbEluZm8iOnsicmVmZXJvYWxBcHAiOiJtdHJl

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YW1XZWJBcHAIJCJyZWZlcnJhbFZpZXciOiJTaGFyZURpYWxvZy1MaW5rIiwicmVmZXJyYWxBcHBQbGF0Zm9ybSI6IldlYiIsInJlZmVycmFsTW9kZSI6InZpZXcifX0%3D

9.7.9 Additional Material / Screenshots for Hardening against side-channel attacks

As provided by the partner, below is material proving the component's progress.

[TANGO] library with hardened AES

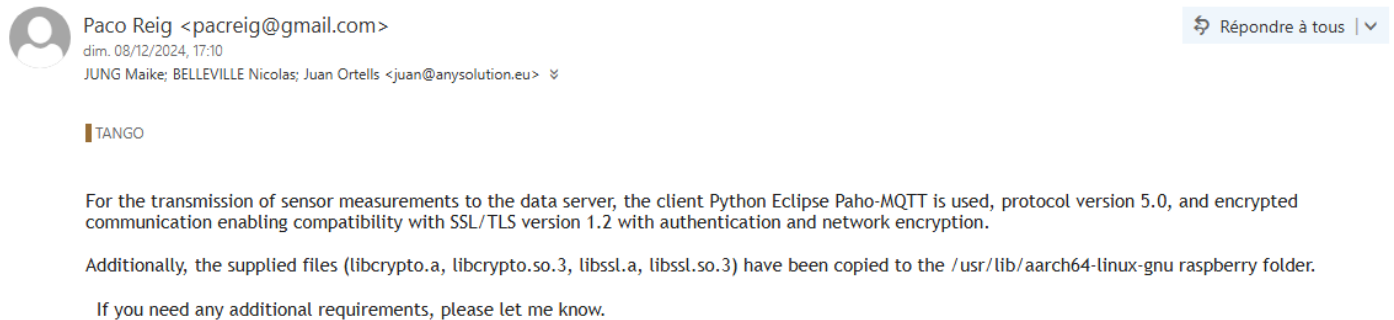


Figure 59: Hardening against side-channel attacks TRL TANGO library with hardened AES (Screenshot ID: KER10_Hardened_AES_081224).

9.7.10 Additional Material / Screenshots for Exploratory Data Analysis Engine

As provided by the partner, below is material proving the component's progress.



Figure 60: Exploratory Data Analysis Engine TRL Smart Hospitality pilot manager reports dashboard (Screenshot ID: EDAE_SmartHospitaliy_02052025).

[Retail] Managers: They can select to produce either a “Satisfaction Report” or a “Sensor Report”. They can use the filters to query for specific hotels, countries and date range. If all filters are blank, a general report for all hotels using data from all available dates will be generated. Then, click “Generate report” to get the report. The screenshot shows the integrated version with VT component.

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Smart Hospitality Pilot Traveller Report Dashboard

Room Number
1

Date From
01/05/2025

Date To
02/05/2025

GENERATE REPORT

Traveller Report

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1. Your Personalized Insights
2. Average Power Consumption
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Figure 61: Exploratory Data Analysis Engine TRL Smart Hospitality pilot traveller reports dashboard (Screenshot ID: EDAE_SmartHospitaliy_02052025).

[Retail] Travellers: They will have to select the room number and the dates during which they performed their stay. If their room number is not listed, they can select “Other” or leave the field blank. Then click on “Generate report” and the traveller report will be generated. The screenshot shows the integrated version with VT component.

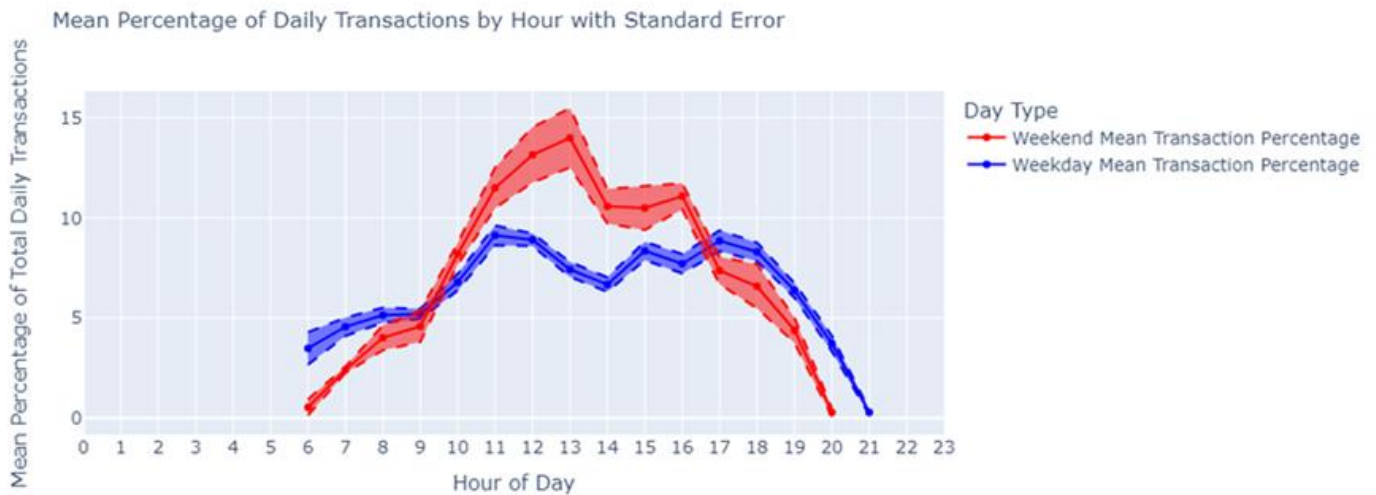


Figure 62: Exploratory Data Analysis Engine TRL Smart Hospitality pilot mean percentage of daily transactions by hour with standard error (Screenshot ID: EDAE_SmartHospitaliy_07112024).

The data is visualized using a line plot with two lines — one representing the mean hourly transactions volume on weekdays and the other on weekends. The areas around the lines, defined by the standard error, help in understanding the consistency of the pattern across different days. This analysis provides insights into customer purchasing patterns and behaviour at different times of the day, and how these patterns differ between weekdays and weekends. Understanding the mean hourly transactions volume helps in making informed decisions about staffing and resource allocation. More staff or resources can be allocated during hours with higher volumes of transactions to ensure optimal customer service and

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efficiency. Identifying hours with higher average transactions volume helps in recognizing peak business hours, which is crucial for planning promotions, marketing strategies, and store operations. Over a longer term, these insights can be instrumental in shaping broader business strategies, including store hours adjustment, targeted marketing during peak hours, and even pricing strategies.

9.7.11 Additional Material / Screenshots for Energy efficient AI model training

As provided by the partner, below is material proving the component's progress.

AutoML



Train AutoML

Upload CSV with training data

dataset-sin-missings.csv
541 KB

Upload complete
tap to undo

Input features

first × last × age × phone ×

street × zip ×

Target

state

AutoML Mode

Explain

Algorithms

Baseline × Linear ×

Decision Tree × Random Forest ×

Xgboost × Neural Network ×

Time limit (seconds)

60

Start training

Train Machine Learning Pipeline with MLJAR AutoML

Please follow the steps:

1. Upload CSV file with data. Data should have column names in the first line.
2. Select input features and target column.
3. Select AutoML training mode, algorithms and training time limit.
4. Directory with all ML models will be zipped and available to download.

Training data

	first	last	age	phone	street	zip	state
0	Thomas	Hill	24	(402) 439-2485	Orkur Path	48910	WA
1	Adam	Carpenter	46	(826) 829-9699	Ervu Manor	1050	WA
2	Clifford	Walton	39	(465) 886-7895	Bisaw Highway	55511	OR
3	Dean	Vasquez	33	(773) 295-1239	Pumnor Extension	99499	NE
4	Louisa	Hamilton	60	(677) 721-2283	Hujbih View	60176	OK
...	...	...	...	...	...	...	...
9995	Chad	Russell	41	(624) 441-9229	Ahmop Path	99156	IN
9996	Christine	Holland	31	(417) 931-5669	Deptuw Mill	54762	MO
9997	Francis	Leonard	56	(585) 291-1160	Wini Highway	20769	IL
9998	Rose	Hart	37	(531) 867-3720	Havvoj Avenue	29751	SC
9999	Fannie	Simmons	56	(322) 491-1279	Nuuso Avenue	95717	TX

10000 rows × 7 columns

StopExecution

Figure 63: Energy efficient AI model training TRL Training ML Pipeline with AutoML (Screenshot ID: AutoML_MLJAR_24062025_1).

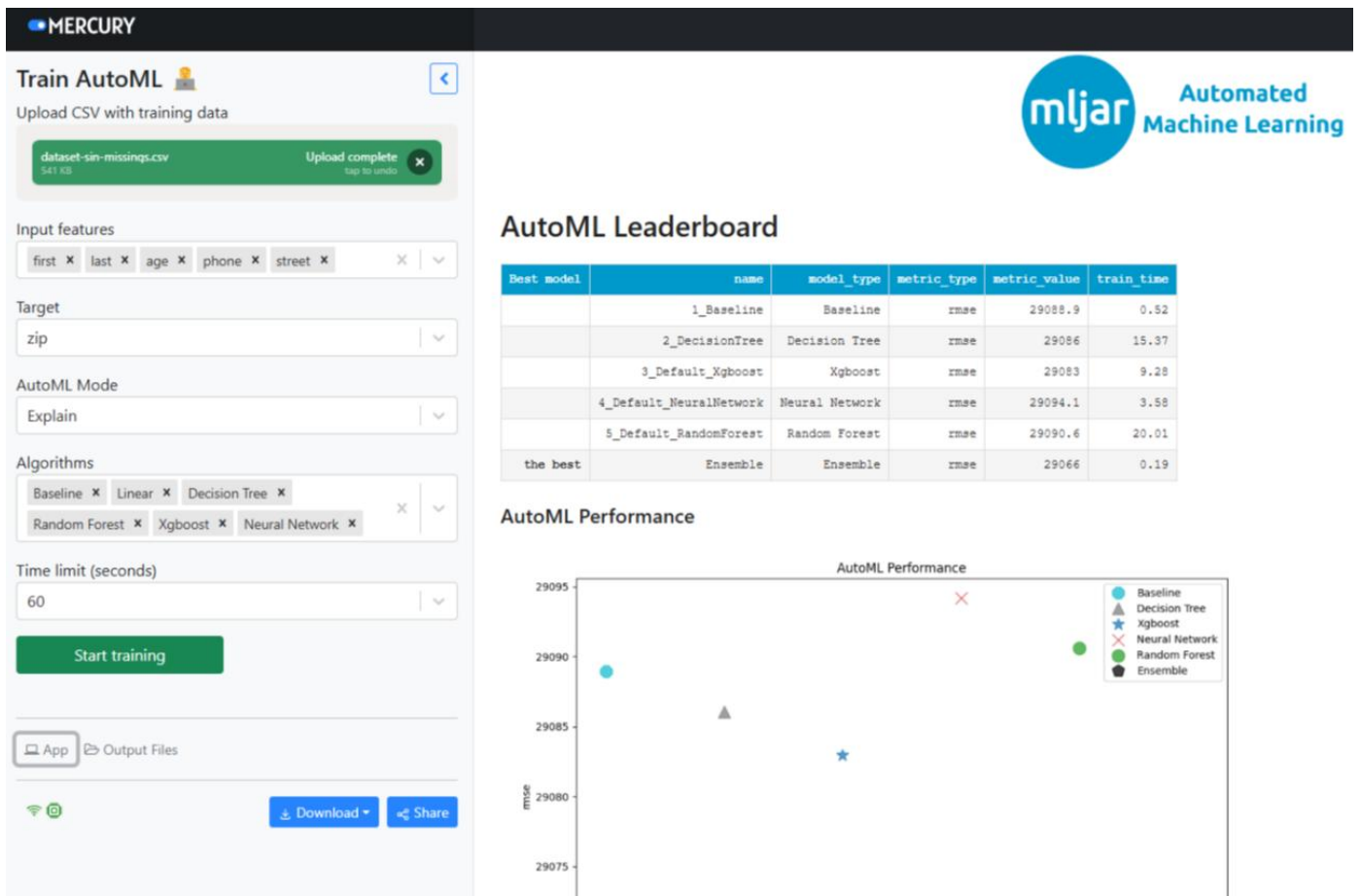


Figure 64: Energy efficient AI model training TRL AutoML Leaderboard (Screenshot ID: AutoML_MLJAR_24062025_2).

MLOps

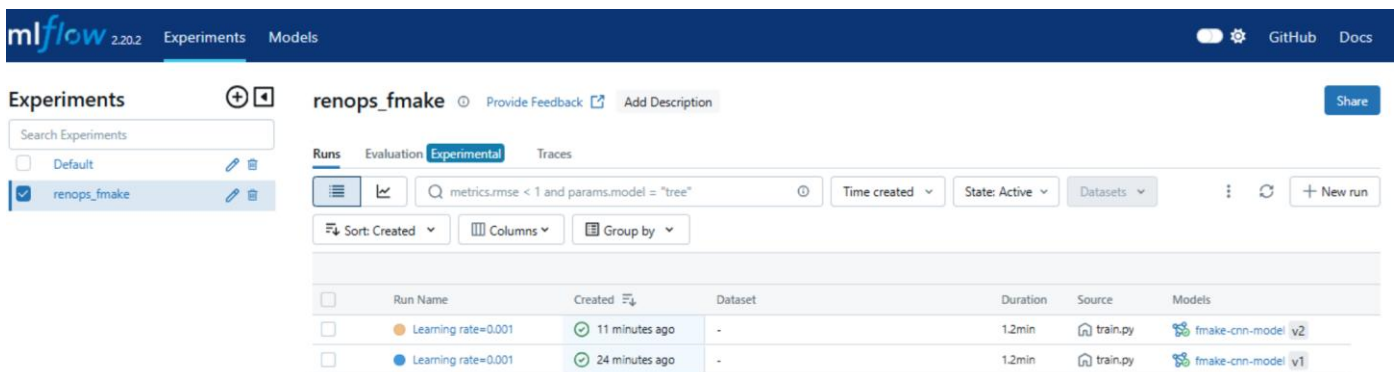


Figure 65: Energy efficient AI model training TRL MLOps flow (Screenshot ID: MLOPS_MLflow_24062025_1).

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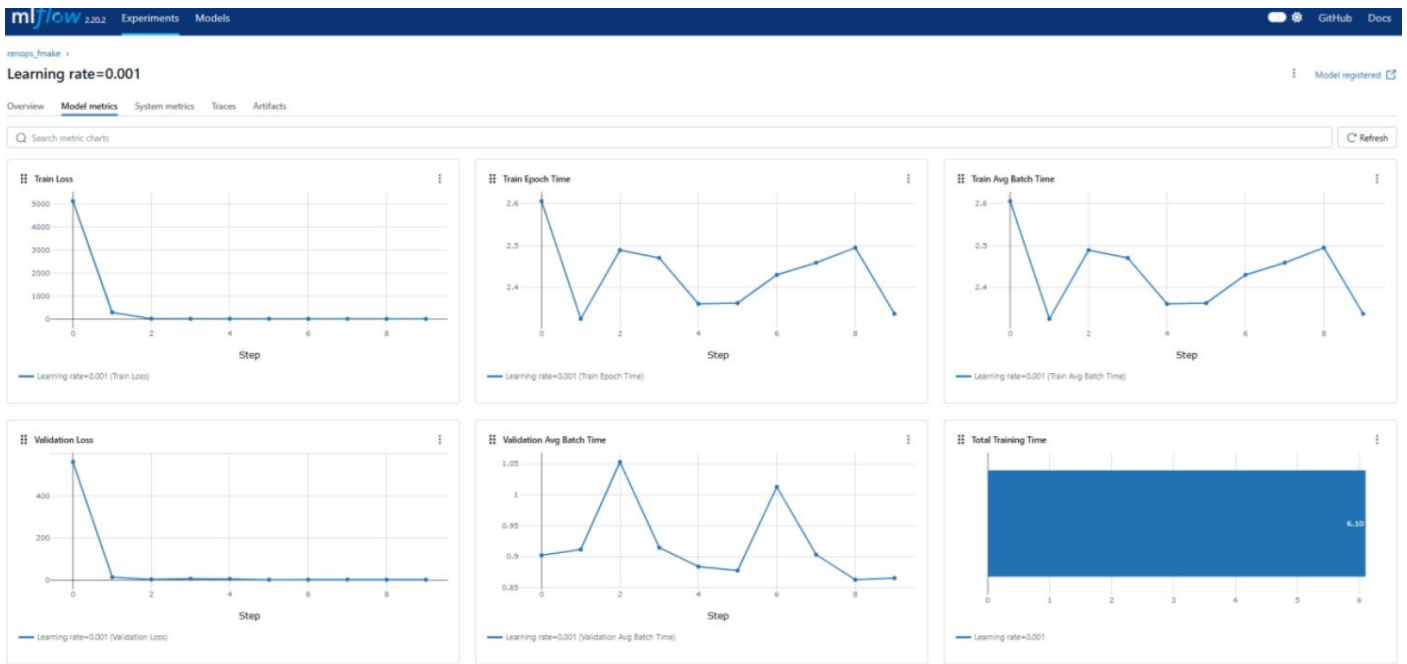


Figure 66: Energy efficient AI model training TRL MLOps flow training results (Screenshot ID: MLOPS_MLflow_24062025_2).

9.7.12 Additional Material / Screenshots for Dynamic Intelligent Execution on Heterogeneous Systems (TornadoVM)

As provided by the partner, below is material proving the component's progress.

Relative Performance and Energy Efficiency per Device against Java

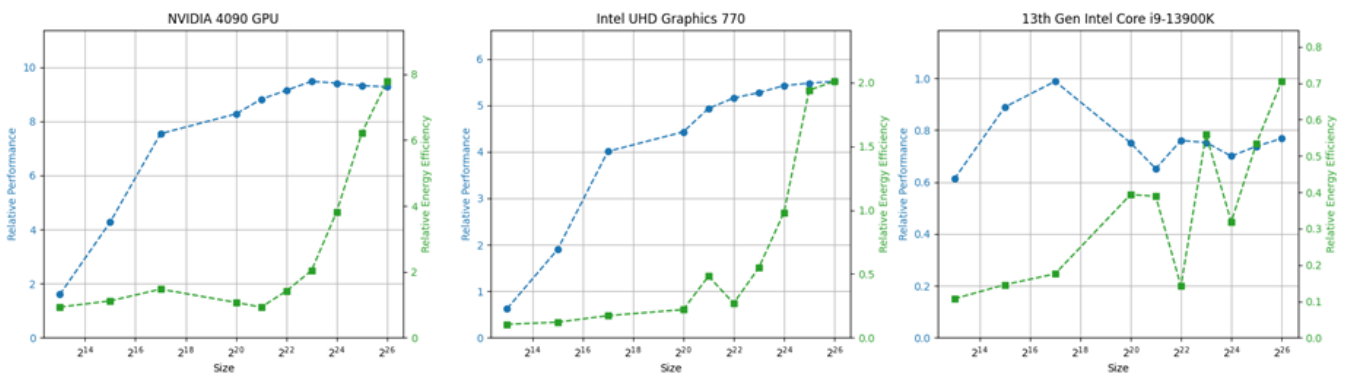


Figure 67: Dynamic Intelligent Execution on Heterogeneous Systems TRL Plot for energy and performance for histogram running on multiple devices across data sizes (Screenshot ID: DYNAMIC_INTELLIGENT_SCHEDULER_010825_01).

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```
~/repositories/docker-tornadovm$ $TORNADO_DOCKER_SCRIPT/dynamic_intelligent_execution.sh example/polyglot-examples/histogram.py
Running the TANGO Dynamic Intelligent Execution...
=====
TornadoVM FEATURE EXTRACTION AND DYNAMIC INTELLIGENT EXECUTION
=====

👉 Step 1: Extract code features of selected class with TornadoVM...
✅ TornadoVM feature extraction completed successfully
🧠 Inferred total threads from Global work size: [16, 1, 1] → 16

👉 Step 2: Detecting available devices...
=== Detected 1 device(s) of CPU type ===
-----
Tornado device=0:2
OPENCL -- [Intel(R) OpenCL] -- 13th Gen Intel(R) Core(TM) i9-13900K
Global Memory Size: 62.5 GB
Local Memory Size: 256.0 KB
Workgroup Dimensions: 3
Total Number of Block Threads: [8192]
Max WorkGroup Configuration: [8192, 8192, 8192]
Device OpenCL C version: OpenCL C 3.0
-----
=== Detected 1 device(s) of GPU type ===
-----
Tornado device=0:0 (DEFAULT)
OPENCL -- [NVIDIA CUDA] -- NVIDIA GeForce RTX 4090
Global Memory Size: 23.5 GB
Local Memory Size: 48.0 KB
Workgroup Dimensions: 3
Total Number of Block Threads: [1024]
Max WorkGroup Configuration: [1024, 1024, 64]
Device OpenCL C version: OpenCL C 1.2
-----
=== Detected 1 device(s) of iGPU type ===
-----
Tornado device=0:1
OPENCL -- [Intel(R) OpenCL Graphics] -- Intel(R) UHD Graphics 770
Global Memory Size: 58.3 GB
Local Memory Size: 64.0 KB
Workgroup Dimensions: 3
Total Number of Block Threads: [512]
Max WorkGroup Configuration: [512, 512, 512]
Device OpenCL C version: OpenCL C 1.2
-----

👉 Step 3: Loading features from JSON...
✅ Features loaded successfully
Input size: 16
Number of features: 29

👉 Step 4: Predicting optimal device type...
✅ Predicted optimal device type: CPU

👉 Step 5: Running workload on predicted device...
Executing: tornado --threadInfo --jvm="-Ds0.t0.device=0:2" --truffle python example/polyglot-examples/histogram.py

✅ Final execution completed successfully
=====
ANALYSIS SUMMARY
=====
Criterion to automatically select device: ENERGY
Input size: None
Truffle is used for language: python
Running program: example/polyglot-examples/histogram.py
Predicted device: CPU
Available devices: ['CPU', 'GPU', 'iGPU']
Prediction matches available: Yes

✅ Analysis completed successfully
```

Figure 68: Dynamic Intelligent Execution on Heterogeneous Systems TRL DIS for small size (16 rows): predicting CPU (Screenshot ID: DYNAMIC_INTELLIGENT_SCHEDULER_010825_02).

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```
~/repositories/docker-tornadovm$ $TORNADO_DOCKER_SCRIPT/dynamic_intelligent_execution.sh example/polyglot-examples/histogram.py
Running the TANGO Dynamic Intelligent Execution...
=====
TornadoVM FEATURE EXTRACTION AND DYNAMIC INTELLIGENT EXECUTION
=====

👉 Step 1: Extract code features of selected class with TornadoVM...
✅ TornadoVM feature extraction completed successfully
🧠 Inferred total threads from Global work size: [67108864, 1, 1] → 67108864

👉 Step 2: Detecting available devices...
=== Detected 1 device(s) of CPU type ===
-----
Tornado device=0:2
OPENCL -- [Intel(R) OpenCL] -- 13th Gen Intel(R) Core(TM) i9-13900K
Global Memory Size: 62.5 GB
Local Memory Size: 256.0 KB
Workgroup Dimensions: 3
Total Number of Block Threads: [8192]
Max WorkGroup Configuration: [8192, 8192, 8192]
Device OpenCL C version: OpenCL C 3.0
-----
=== Detected 1 device(s) of GPU type ===
-----
Tornado device=0:0 (DEFAULT)
OPENCL -- [NVIDIA CUDA] -- NVIDIA GeForce RTX 4090
Global Memory Size: 23.5 GB
Local Memory Size: 48.0 KB
Workgroup Dimensions: 3
Total Number of Block Threads: [1024]
Max WorkGroup Configuration: [1024, 1024, 64]
Device OpenCL C version: OpenCL C 1.2
-----
=== Detected 1 device(s) of iGPU type ===
-----
Tornado device=0:1
OPENCL -- [Intel(R) OpenCL Graphics] -- Intel(R) UHD Graphics 770
Global Memory Size: 58.3 GB
Local Memory Size: 64.0 KB
Workgroup Dimensions: 3
Total Number of Block Threads: [512]
Max WorkGroup Configuration: [512, 512, 512]
Device OpenCL C version: OpenCL C 1.2
-----

👉 Step 3: Loading features from JSON...
✅ Features loaded successfully
Input size: 67108864
Number of features: 29

👉 Step 4: Predicting optimal device type...
✅ Predicted optimal device type: GPU

👉 Step 5: Running workload on predicted device...
Executing: tornado --threadInfo --jvm="-Ds0.t0.device=0:0" --truffle python example/polyglot-examples/histogram.py

✅ Final execution completed successfully
=====
ANALYSIS SUMMARY
=====
Criterion to automatically select device: ENERGY
Input size: None
Truffle is used for language: python
Running program: example/polyglot-examples/histogram.py
Predicted device: GPU
Available devices: ['CPU', 'GPU', 'iGPU']
Prediction matches available: Yes

✅ Analysis completed successfully
```

Figure 69: Dynamic Intelligent Execution on Heterogeneous Systems TRL DIS for large size (64m): predicting GPU (Screenshot ID: DYNAMIC_INTELLIGENT_SCHEDULER_010825_03).

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```
~/repositories/docker-tornadovm$ $TORNADO_DOCKER_SCRIPT/dynamic_intelligent_execution.sh example/polyglot-examples/histogram.py
Running the TANGO Dynamic Intelligent Execution...
=====
TornadoVM FEATURE EXTRACTION AND DYNAMIC INTELLIGENT EXECUTION
=====

👉 Step 1: Extract code features of selected class with TornadoVM...
✅ TornadoVM feature extraction completed successfully
🧠 Inferred total threads from Global work size: [8192, 1, 1] → 8192

👉 Step 2: Detecting available devices...
=== Detected 1 device(s) of CPU type ===
-----
Tornado device=0:2
OPENCL -- [Intel(R) OpenCL] -- 13th Gen Intel(R) Core(TM) i9-13900K
Global Memory Size: 62.5 GB
Local Memory Size: 256.0 KB
Workgroup Dimensions: 3
Total Number of Block Threads: [8192]
Max WorkGroup Configuration: [8192, 8192, 8192]
Device OpenCL C version: OpenCL C 3.0
-----
=== Detected 1 device(s) of GPU type ===
-----
Tornado device=0:0 (DEFAULT)
OPENCL -- [NVIDIA CUDA] -- NVIDIA GeForce RTX 4090
Global Memory Size: 23.5 GB
Local Memory Size: 48.0 KB
Workgroup Dimensions: 3
Total Number of Block Threads: [1024]
Max WorkGroup Configuration: [1024, 1024, 64]
Device OpenCL C version: OpenCL C 1.2
-----
=== Detected 1 device(s) of iGPU type ===
-----
Tornado device=0:1
OPENCL -- [Intel(R) OpenCL Graphics] -- Intel(R) UHD Graphics 770
Global Memory Size: 58.3 GB
Local Memory Size: 64.0 KB
Workgroup Dimensions: 3
Total Number of Block Threads: [512]
Max WorkGroup Configuration: [512, 512, 512]
Device OpenCL C version: OpenCL C 1.2
-----

👉 Step 3: Loading features from JSON...
✅ Features loaded successfully
Input size: 8192
Number of features: 29

👉 Step 4: Predicting optimal device type...
✅ Predicted optimal device type: GPU

👉 Step 5: Running workload on predicted device...
Executing: tornado --threadInfo --jvm="-Ds0.t0.device=0:0" --truffle python example/polyglot-examples/histogram.py

✅ Final execution completed successfully
=====
ANALYSIS SUMMARY
=====
Criterion to automatically select device: ENERGY
Input size: None
Truffle is used for language: python
Running program: example/polyglot-examples/histogram.py
Predicted device: GPU
Available devices: ['CPU', 'GPU', 'iGPU']
Prediction matches available: Yes

✅ Analysis completed successfully
```

Figure 70: Dynamic Intelligent Execution on Heterogeneous Systems TRL DIS for large size (8k): predicting GPU (Screenshot ID: DYNAMIC_INTELLIGENT_SCHEDULER_010825_04).

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```

Task info: __GENERATED_TASK_GRAPH__4.reduce
  Backend      : OPENCL
  Device       : NVIDIA RTX A2000 8GB Laptop GPU CL_DEVICE_TYPE_GPU (available)
  Dims         : 1
  Global work offset: [0]
  Global work size  : [1024]
  Local work size   : [256, 1, 1]
  Number of workgroups : [4]

Task info: __GENERATED_TASK_GRAPH__4.reduce_seq4
  Backend      : OPENCL
  Device       : NVIDIA RTX A2000 8GB Laptop GPU CL_DEVICE_TYPE_GPU (available)
  Dims         : 0
  Global work offset: [0]
  Global work size  : [1]
  Local work size   : [1, 1, 1]
  Number of workgroups : [1]

Test: class uk.ac.manchester.tornado.unittests.profiler.TestProfiler
  Running test: testProfilerFromExecutionPlan ..... [PASS]
  Running test: testProfilerReductionOnAndOff ..... [PASS]
  Running test: testProfilerEnabled ..... [PASS]
  Running test: testProfilerDisabled ..... [PASS]
  Running test: testProfilerOnAndOff ..... [PASS]
  Running test: testProfilerReduction ..... [PASS]
  Running test: testProfilerReductionOffAndOn ..... [PASS]
  Running test: testKernelOnAndOff ..... [PASS]
  Running test: testThreadInfoOnAndOff ..... [PASS]
Test ran: 9, Failed: 0, Unsupported: 0

Total Time (s): 3.2221789360046387

```

Figure 71: Dynamic Intelligent Execution on Heterogeneous Systems TRL TornadoVM unit-tests assessing the profiler functionality (part 1 of 3) (Screenshot ID: DYNAMIC_INTELLIGENT_SCHEDULER_010825_05).

```

Enable the profiler with: -Dtornado.profiler=True
#pragma OPENCL EXTENSION cl_khr_fp64 : enable
#pragma OPENCL EXTENSION cl_khr_fp16 : enable
#pragma OPENCL EXTENSION cl_khr_int64_base_atomics : enable
__kernel void reduction(__global long *kernel_context, __constant uchar *_constant_region, __local uchar *_local_region, __global int *_atomics, __global uchar *input, __global uchar *output)
{
    bool b_18, b_25;
    float f_19, f_12, f_26, f_21, f_22;
    long l_10, l_29, l_9, l_8, l_31, l_30;
    int i_33, i_28, i_27, i_6, i_7, i_4, i_5, i_3, i_16, i_17, i_14, i_15, i_13, i_24, i_23, i_20;
    ulong ul_0, ul_32, ul_1, ul_11;

    // BLOCK 0
    ul_0 = (ulong) input;
    ul_1 = (ulong) output;
    __local float adf_2[256];
    i_3 = get_global_size(0);
    i_4 = get_global_id(0);
    // BLOCK 1 MERGES [0 11 ]
    i_5 = i_4;
    for(;i_5 < 1024;)
    {
        // BLOCK 2
        i_6 = get_local_id(0);
        i_7 = get_local_size(0);
        i_8 = (long) i_5;
        l_9 = l_8 << 2;
        l_10 = l_9 + 24L;
        ul_11 = ul_0 + l_10;
        f_12 = *((__global float *) ul_11);
        adf_2[i_6] = f_12;
        i_13 = i_7 >> 31;
        i_14 = i_13 + i_7;
        i_15 = i_14 >> 1;
        // BLOCK 3 MERGES [2 7 ]
        i_16 = i_15;
        for(;i_16 >= 1;)
        {
            // BLOCK 4
            barrier(CLK_LOCAL_MEM_FENCE);
            i_17 = i_16 >> 1;
            b_18 = i_6 < i_16;
            if(b_18)
            {
                // BLOCK 5
                f_19 = adf_2[i_6];
                i_20 = i_16 + i_6;
                f_21 = adf_2[i_20];
                f_22 = f_19 + f_21;
                adf_2[i_6] = f_22;
            } // B5
            else
            {
                // BLOCK 6
            } // B6
            // BLOCK 7 MERGES [6 5 ]
            i_23 = i_17;
            i_16 = i_23;
        } // B7
        // BLOCK 8
        barrier(CLK_GLOBAL_MEM_FENCE);
        i_24 = i_3 + i_5;
        b_25 = i_6 == 0;
        if(b_25)
        {
            // BLOCK 9
            f_26 = adf_2[0];
            i_27 = get_group_id(0);
            i_28 = i_27 + 1;
            l_29 = (long) i_28;
            l_30 = l_29 << 2;
            l_31 = l_30 + 24L;
            ul_32 = ul_1 + l_31;
            *((__global float *) ul_32) = f_26;
        } // B9
        else
        {
            // BLOCK 10
        } // B10
        // BLOCK 11 MERGES [10 9 ]
        i_33 = i_24;
        i_5 = i_33;
    } // B11
    // BLOCK 12
    return;
} // kernel

```

Figure 72: Dynamic Intelligent Execution on Heterogeneous Systems TRL TornadoVM unit-tests assessing the profiler functionality (part 2 of 3) (Screenshot ID: DYNAMIC_INTELLIGENT_SCHEDULER_010825_05).

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```
#pragma OPENCL EXTENSION cl_khr_fp64 : enable
#pragma OPENCL EXTENSION cl_khr_fp16 : enable
#pragma OPENCL EXTENSION cl_khr_int64_base_atomics : enable
__kernel void rAdd(__global long *kernel_context, __constant uchar *constant_region, __local uchar *local_region, __global int *atomics, __global uchar *array, __private int size)
{
    float f_4, f_2, f_13, f_14, f_11, f_12, f_10, f_8, f_6;
    ulong ul_0, ul_1, ul_3, ul_5, ul_7, ul_9;

    // BLOCK 0
    ul_0 = (ulong) array;
    ul_1 = ul_0 + 24L;
    f_2 = *((__global float *) ul_1);
    ul_3 = ul_0 + 28L;
    f_4 = *((__global float *) ul_3);
    ul_5 = ul_0 + 32L;
    f_6 = *((__global float *) ul_5);
    ul_7 = ul_0 + 36L;
    f_8 = *((__global float *) ul_7);
    ul_9 = ul_0 + 40L;
    f_10 = *((__global float *) ul_9);
    f_11 = f_2 + f_4;
    f_12 = f_11 + f_6;
    f_13 = f_12 + f_8;
    f_14 = f_13 + f_10;
    *((__global float *) ul_1) = f_14;
    return;
} // kernel

Task info: __GENERATED_TASK_GRAPH_4.reduce
Backend      : OPENCL
Device       : NVIDIA RTX A2000 8GB Laptop GPU CL_DEVICE_TYPE_GPU (available)
Dims        : 1
Global work offset: [0]
Global work size : [1024]
Local work size : [256, 1, 1]
Number of workgroups : [4]

Task info: __GENERATED_TASK_GRAPH_4.reduce_seq4
Backend      : OPENCL
Device       : NVIDIA RTX A2000 8GB Laptop GPU CL_DEVICE_TYPE_GPU (available)
Dims        : 0
Global work offset: [0]
Global work size : [1]
Local work size : [1, 1, 1]
Number of workgroups : [1]

Test: class uk.ac.manchester.tornado.unittests.profiler.TestProfiler
Running test: testProfilerFromExecutionPlan ..... [PASS]
Running test: testProfilerReductionOnAndOff ..... [PASS]
Running test: testProfilerEnabled ..... [PASS]
Running test: testProfilerDisabled ..... [PASS]
Running test: testProfilerOnAndOff ..... [PASS]
Running test: testProfilerReduction ..... [PASS]
Running test: testProfilerReductionOffAndOn ..... [PASS]
Running test: testKernelOnAndOff ..... [PASS]
Running test: testThreadInfoOnAndOff ..... [PASS]
Test ran: 9, Failed: 0, Unsupported: 0
```

Figure 73: Dynamic Intelligent Execution on Heterogeneous Systems TRL TornadoVM unit-tests assessing the profiler functionality (part 3 of 3) (Screenshot ID: DYNAMIC_INTELLIGENT_SCHEDULER_010825_05).

The source code of the above tests can be accessed in the following provided by the partner link: <https://github.com/TANGO-EU-PROJECT/TornadoVM/blob/tango-v1.1.1/final/tornado-unittests/src/main/java/uk/ac/manchester/tornado/unittests/profiler/TestProfiler.java>

The above three-part figures (Figures 67, 68, and 69) can be accessed through the link provided by the partner: <https://newrepository.atosresearch.eu/index.php/f/1415269>

```
Testing the integration of Java/Python for GPUs...
WARNING: Using incubator modules: jdk.incubator.vector
Hello World from Python!
Total time of Java execution: 1064013643 (nanoseconds)
Total time of TornadoVM execution: 167783473 (nanoseconds)
[TornadoVM_EDAE_I001]..... [PASS]: Matrices are identical
```

Figure 74: Dynamic Intelligent Execution on Heterogeneous Systems TRL test for the integration between TornadoVM and GraalPython (Screenshot ID: DYNAMIC_INTELLIGENT_SCHEDULER_010825_06).

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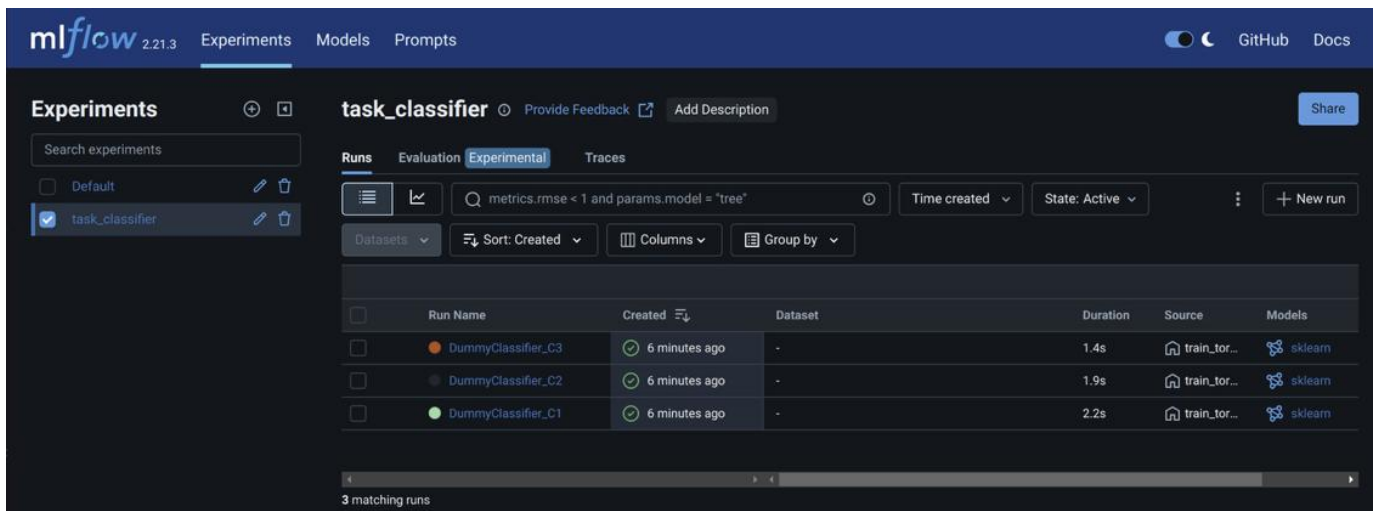


Figure 75: Dynamic Intelligent Execution on Heterogeneous Systems TRL integration of the training of TornadoVM ML Model by using MLFlow and RENOPS (part 1 of 2) (Screenshot ID: DYNAMIC_INTELLIGENT_SCHEDULER_010825_07).

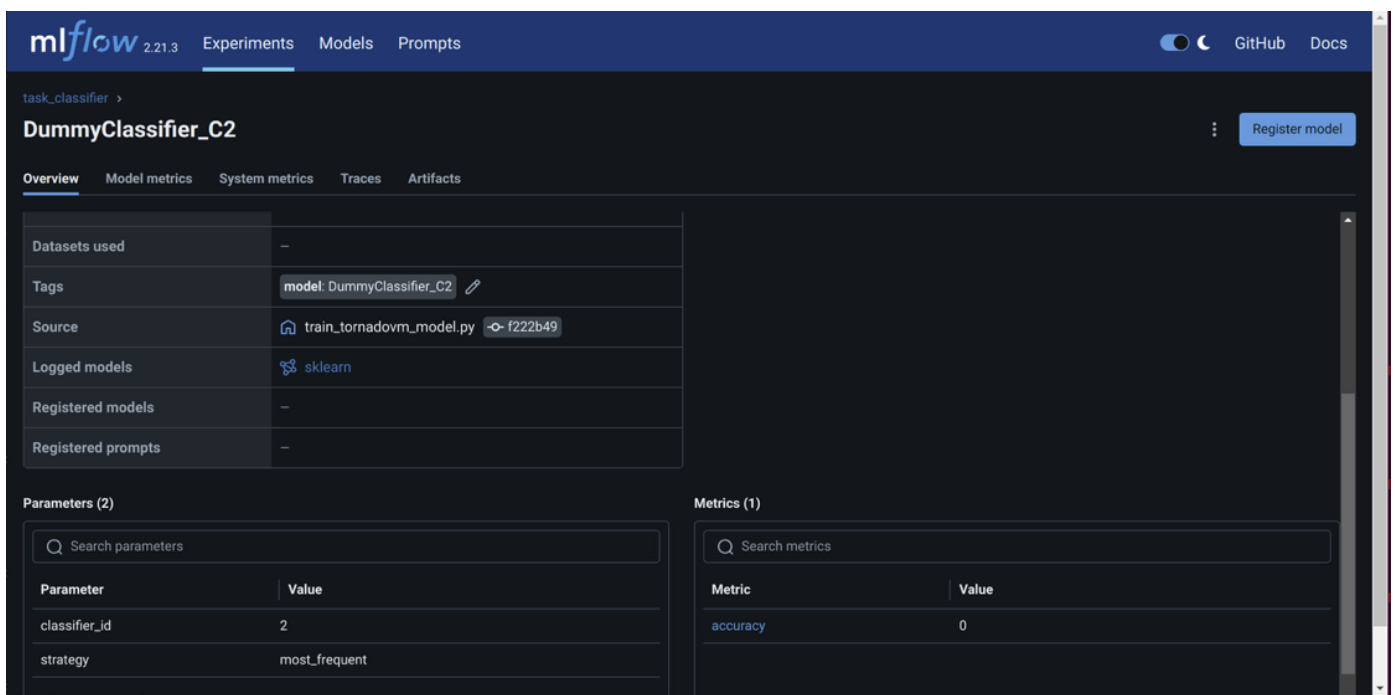


Figure 76: Dynamic Intelligent Execution on Heterogeneous Systems TRL integration of the training of TornadoVM ML Model by using MLFlow and RENOPS (part 2 of 2) (Screenshot ID: DYNAMIC_INTELLIGENT_SCHEDULER_010825_07).

It is mentioned that this is a proof-of-concept that UOM did as synergy between T5.2, T5.3, T5.6. Further information can be accessed in the following repository: <https://github.com/TANGO-EU-PROJECT/tornadovm-mlops-renops>

9.7.13 Additional Material / Screenshots for Privacy Threat Modelling and Identification for Trustworthy AI

As provided by the partner, below is material proving the component's progress.

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Create A Consent Request



Below you may create your own custom consent request. The consent request is divided into two parts. The first part (left) is the mandatory data that you will require from your data subjects. This can be seen as the minimal data required by you to process the data subject correctly. The preferences section (right) is any additional information you wish to collect from the data subject, that is not strictly for you two process the data subject accordingly. These are nice-to-have information, which a data subject may not need to fill-in unless they wish to.

1

Mandatory Data - Information

First name

String

Last name

String

Email

String

Arrival Date

Date

Departure Date

Date

Add Field

Mandatory Data - Data Processing Clarifications

Please state which roles within your organisation can process the data above.

Select role

If you share any of the above data with third parties, please list them below.

Select third party

Please select for how many months the data will be stored and processed:

9 months

Please select within which country the data will be stored and accessed:

Spain

Spain

Preferences Data - Information

Food restrictions

String

Room preferences

String

Add Field

Preferences Data - Data Processing Clarifications

Please state which roles within your organisation can process the data above.

EXPERIENCE PROVIDER

EXPERIENCE PROVIDER

The purposes for processing the data above are:

recommendations

service personalization

The following actions will be performed on the data above:

read

If you share any of the above data with third parties, please list them below.

Submit

Figure 77: Confidentiality and Privacy by Design TRL PAT Consent Creation Request (Screenshot ID: PAT_consentRequestCreation_100725).

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14:40:11

Enter Your Details

Mandatory Data - Information

First name

Last name

Email

Arrival Date

Departure Date

Mandatory Data - Processing Clarification

Your data listed above will be available to the following staff members of the hotel:

MANAGER

RECEPTIONIST

The purposes for which the hotel staff members would like to access your data above:

Preferences Data - Information

Room preferences

Food preferences

Preferences Data - Processing Clarification

Your data listed above will be available to the following staff members of the hotel:

EXPERIENCE PROVIDER

MANAGER

The purposes for which the hotel staff members would like to access your data above:

recommendations

security

check-in

check out

The actions that the hotel staff will be able to perform on your above:

Submit

Figure 78: Confidentiality and Privacy by Design TRL PAT Consent Form (Screenshot ID: PAT_consentForm_100725).

Consent Preferences

Below you may set your default data sharing preferences. By setting these preference you may speed up your data sharing consent and you may double check if a consent request suits your preferences or not. Do not worry, none of these preferences are final! You may change them at any time. Whenever you see a consent request, your preferences will be used to guide you on whether or not the consent request is aligned with your preferences.

Information

Controller

Third Parties

First Name

☒

☒

Last Name

☒

☒

Credit Card

☒

☒

Nationality

☒

☒

Phone

☒

☒

Email

☒

☒

Figure 79: Confidentiality and Privacy by Design TRL PAT Consent Form (Screenshot ID: PAT_consentPreferences_100725).

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The screenshot shows a web form titled "Enter Your Details" with two main sections: "Mandatory Data - Information" and "Preferences Data - Information". A white chat window titled "Chat with LLM" is overlaid in the center. The form includes fields for First name, Last name, Email, Arrival Date, and Departure Date. Below these are sections for "Mandatory Data - Processing Clarification" and "Preferences Data - Processing Clarification", which contain checkboxes for various data processing options like "MANAGER", "RECEPTIONIST", "check in", "check out", "delete", "read", "Your personal data will only be accessible from the within the following areas:", and "Your data listed above will be available to the following staff members of the hotel:". At the bottom right, there are "Submit" and "Cancel" buttons.

Figure 80: Confidentiality and Privacy by Design TRL PAT llm chat (Screenshot ID: PAT_llmChat_100725).

The screenshot shows the TANGO Privacy Enhancing Component (PEC) AI Assessment form. The left sidebar contains navigation links: "Dashboard", "App Assessment", "AI Assessment" (highlighted), "Need for DPIA", "Navigate to PAT", and "Logout". The main form area includes fields for "Project Name*" (Autonomous Car Ride), "Date of Assessment*" (11/08/2025), and "Use case*" (Autonomous Vehicles). Below these are two text areas: "Describe the scenario where you plan to use AI*" and "Briefly describe the primary purpose of the AI system*". The "Implementation*" section has checkboxes for "Predictive" (checked) and "Generative". The "What types of data does the AI system process to achieve its purpose?*" section has checkboxes for "Personally Identifiable Information" (checked), "Financial Data", "Special Categories of Personal Data" (checked), and "Non-Sensitive Data" (checked).

Figure 81: Privacy Threat Modelling and Identification for Trustworthy AI TRL PEC AI Assessment (Screenshot ID: PEC_01).

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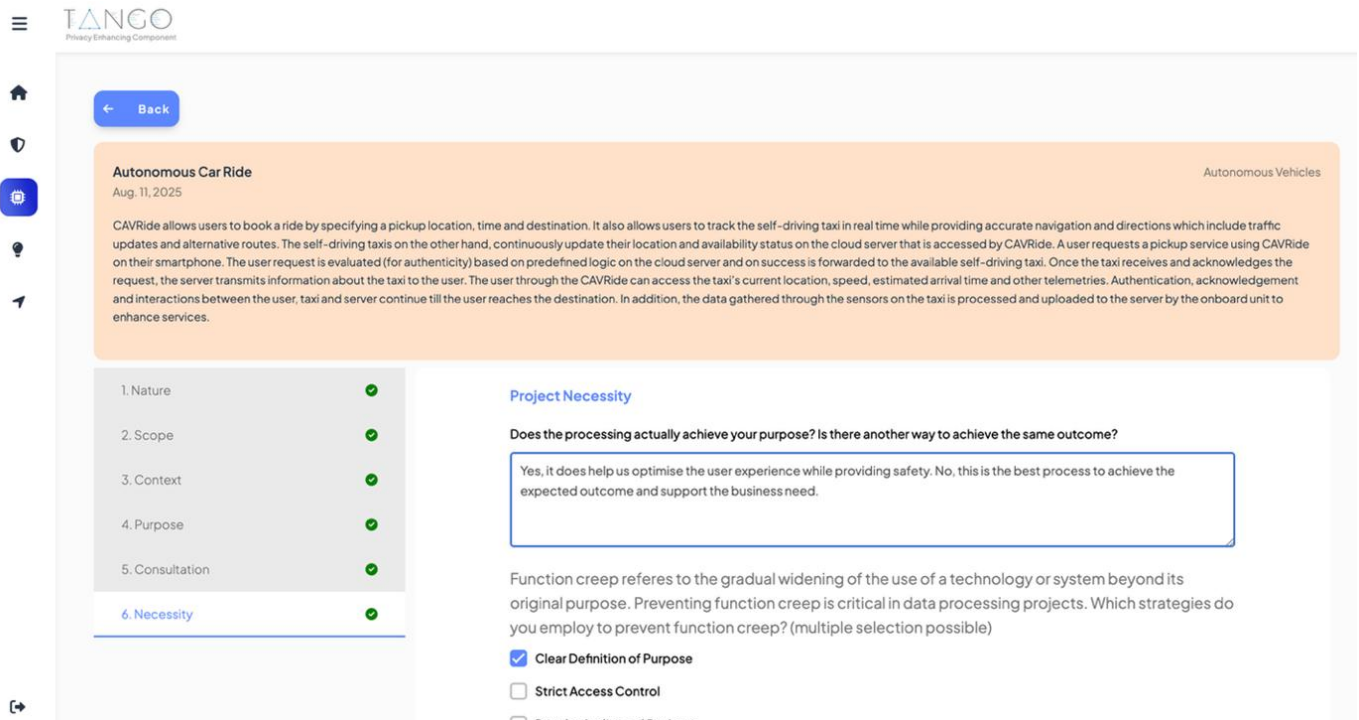


Figure 82: Privacy Threat Modelling and Identification for Trustworthy AI TRL PEC AI necessity evaluation (Screenshot ID: PEC_02).

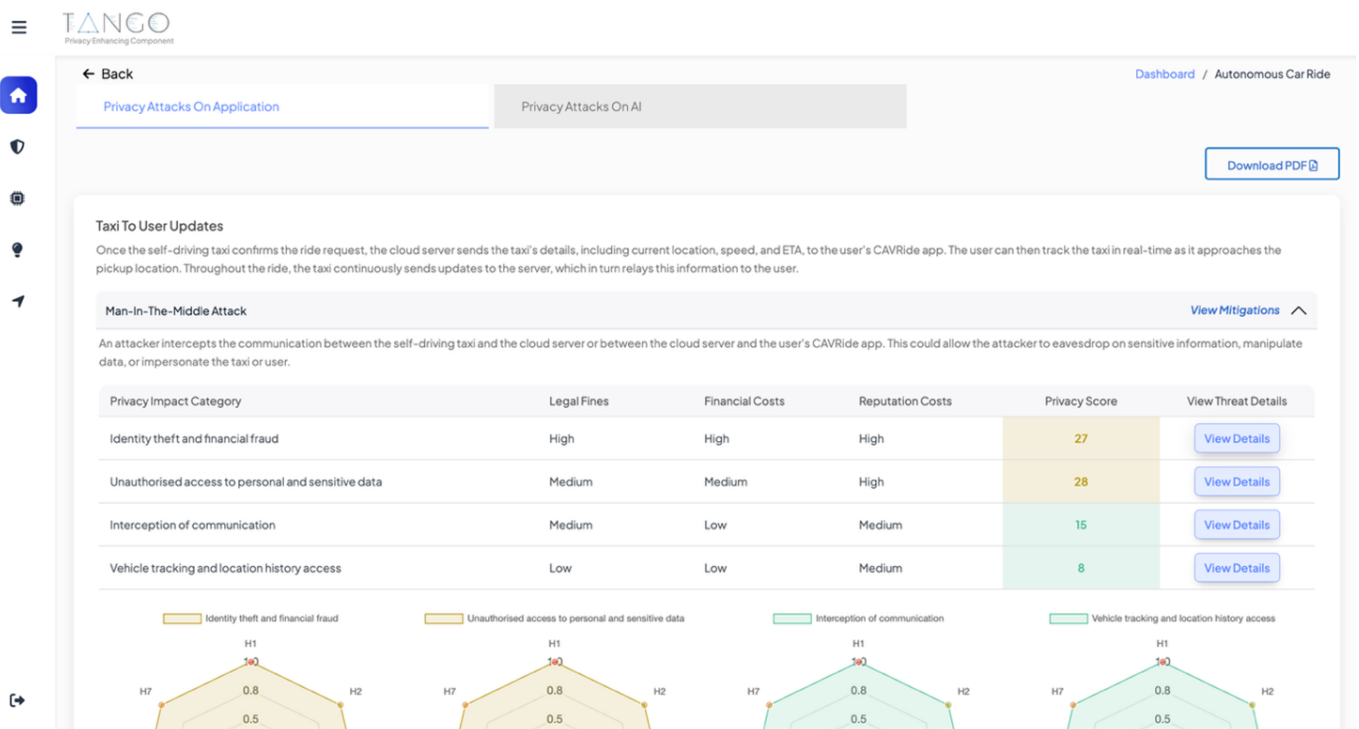


Figure 83: Privacy Threat Modelling and Identification for Trustworthy AI TRLPEC Privacy impact evaluation (Screenshot ID: PEC_03).

9.7.14 Additional Material / Screenshots for X-AI for Privacy and Trust Enhancement

As provided by the partner, below is material proving the component's progress.

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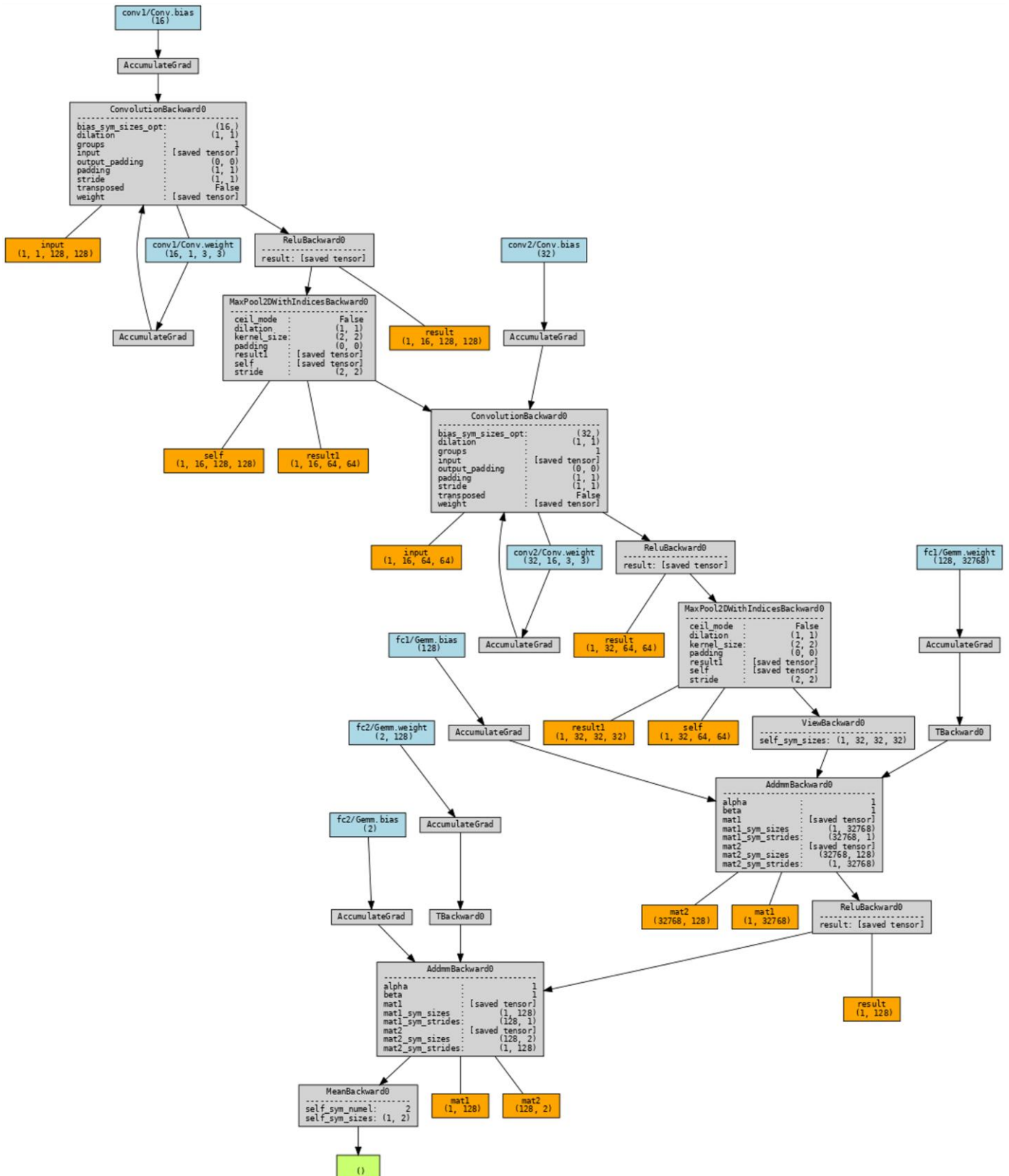


Figure 84: X-AI for Privacy and Trust Enhancement TRL FMAKE's initial model's architecture (Screenshot ID: XAI_15072025_1).

The above model can be accessed for detailed review in the following, provided by the partner, online repository link:

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	Version:	1.0	Status: Final

https://drive.google.com/file/d/1QnoDBCnmrEubWLMCxRxhEV17VT5vGhwB/view?usp=drive_link

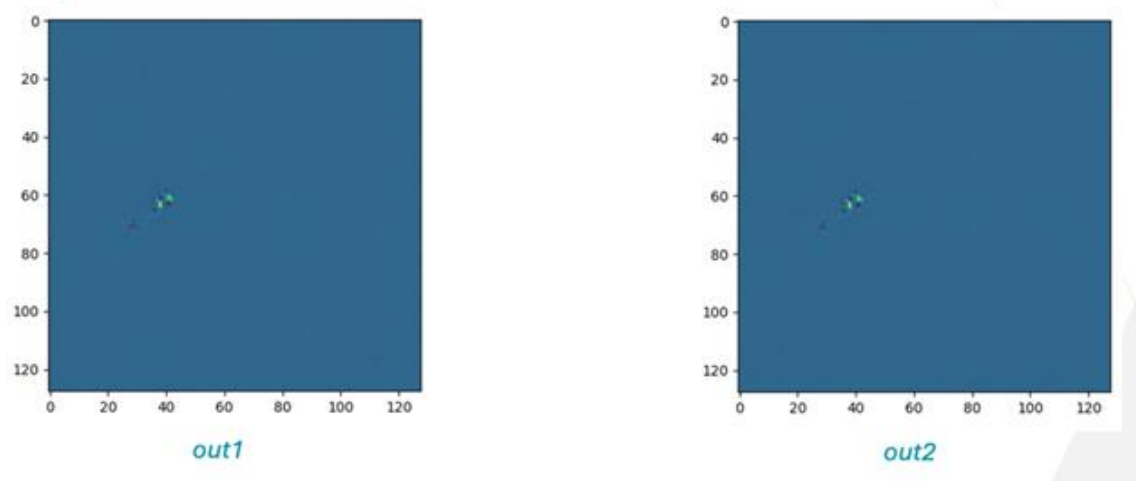


Figure 85: X-AI for Privacy and Trust Enhancement TRL FMAKE's initial model Deeplift outputs (Screenshot ID: XAI_15072025_2).

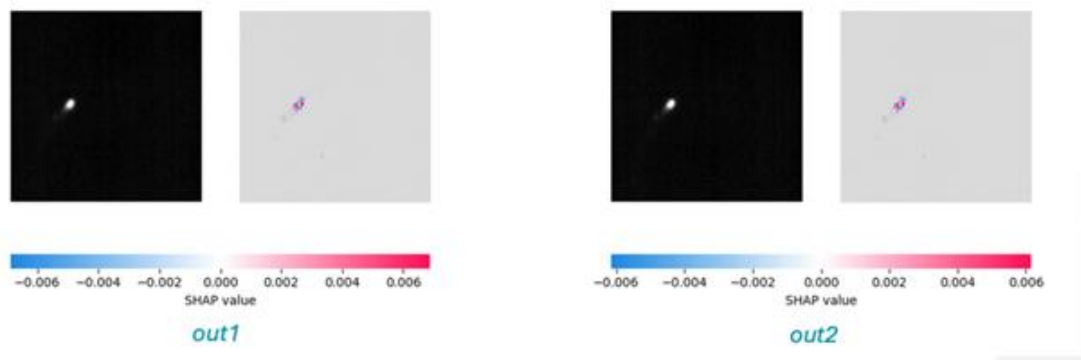


Figure 86: X-AI for Privacy and Trust Enhancement TRL FMAKE's initial model SHAP value outputs (Screenshot ID: XAI_15072025_3).

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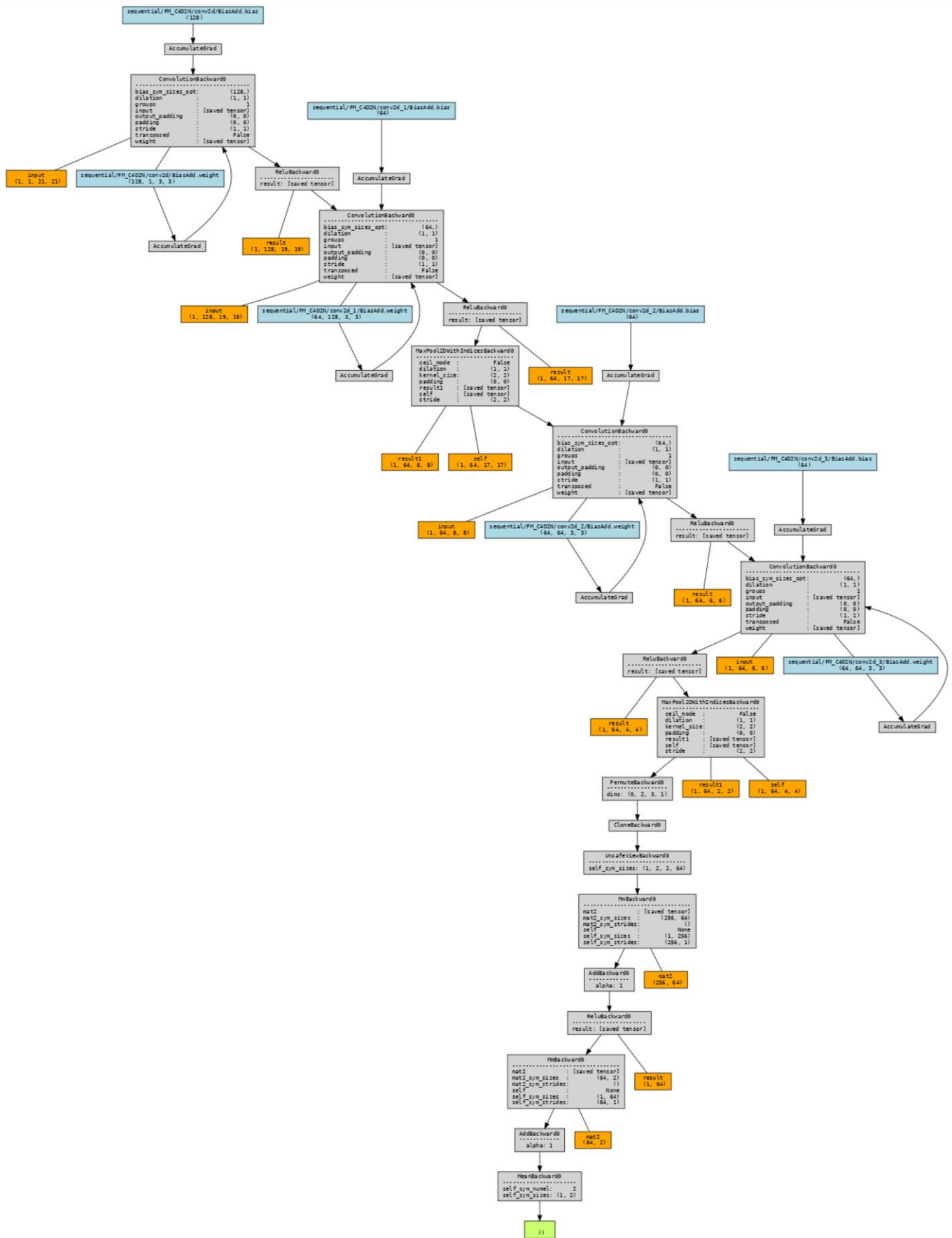


Figure 87: X-AI for Privacy and Trust Enhancement TRL FMAKE's recent model's structure (Screenshot ID: XAI_15072025_4).

The above model can be accessed for detailed review in the following, provided by the partner, online repository link:

https://drive.google.com/file/d/1iQb4H6jZCto0n3uOl0Rp5A-0hBIOer-J/view?usp=drive_link

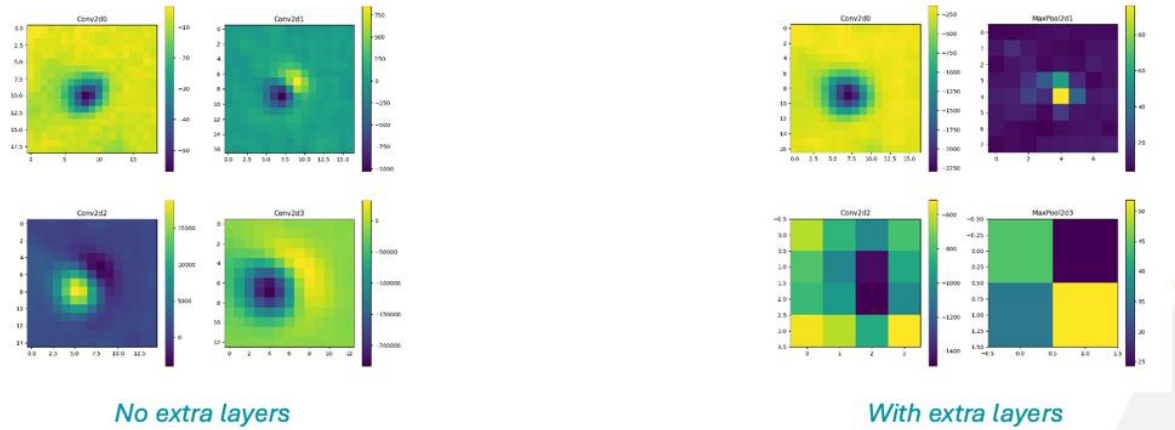


Figure 88: X-AI for Privacy and Trust Enhancement TRL FMAKE's recent model's activation without (left) and with extra layers (right) (Screenshot ID: XAI_15072025_5).

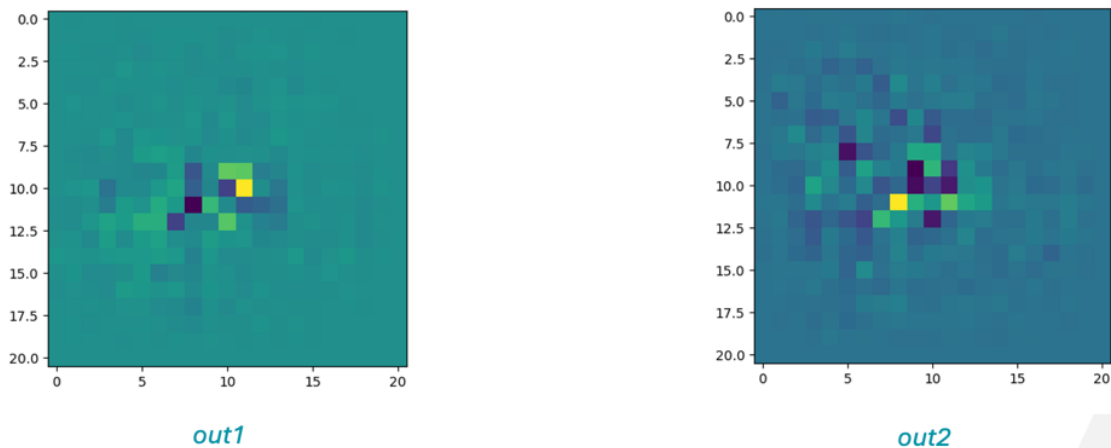


Figure 89: X-AI for Privacy and Trust Enhancement TRL FMAKE's recent model Deeplift outputs (Screenshot ID: XAI_15072025_6).

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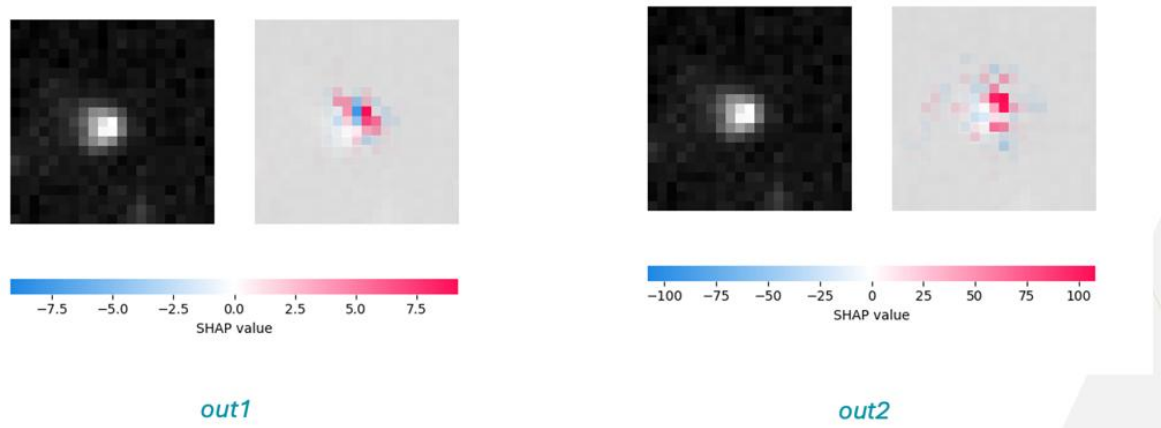


Figure 90: X-AI for Privacy and Trust Enhancement TRL FMAKE's recent model SHAP value outputs (XAI_15072025_7).

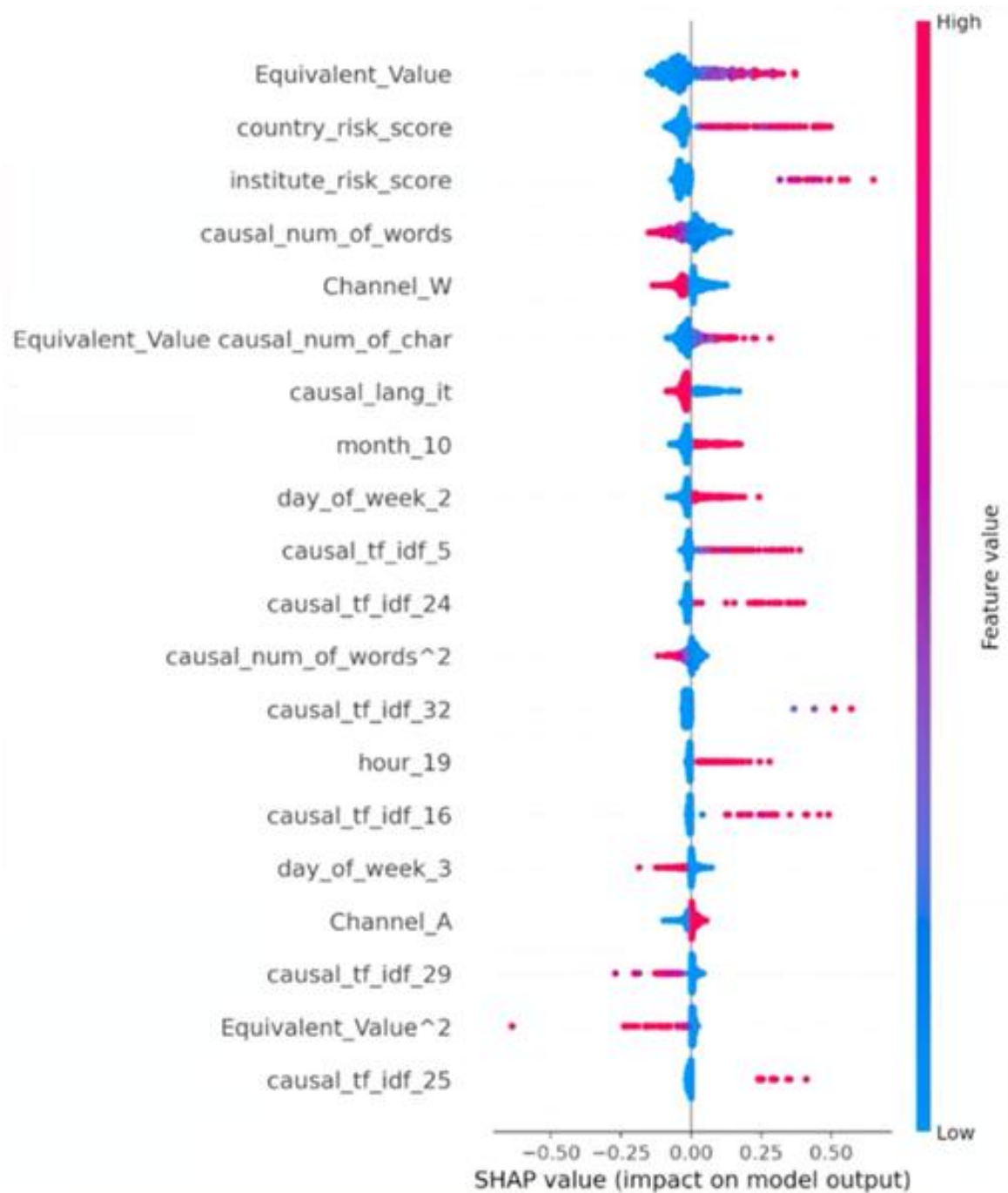


Figure 91: Banking pilot SHAP summary plot (XAI_15092025_1).

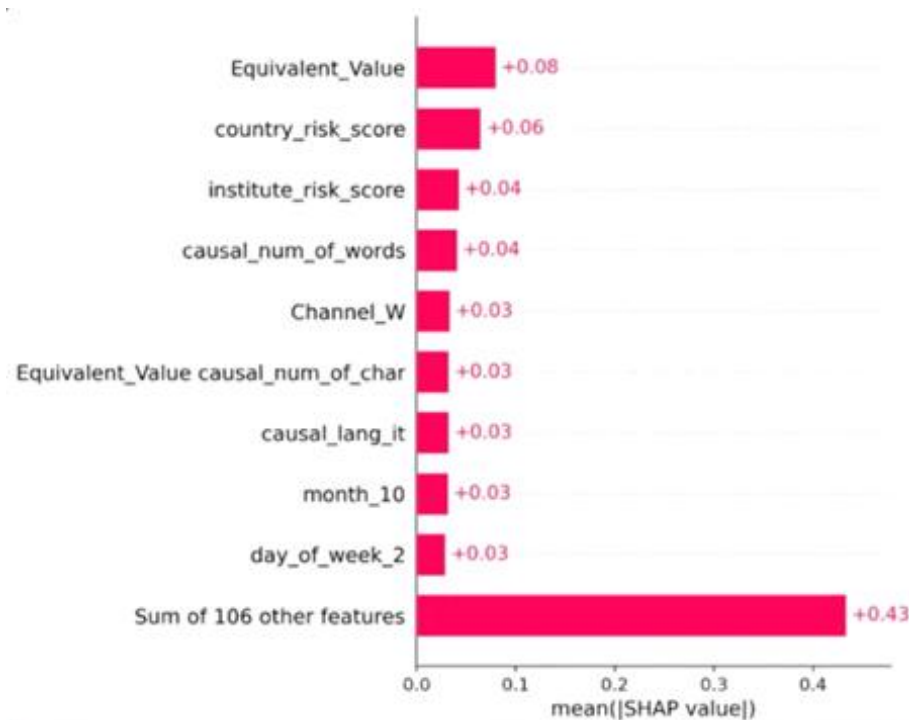


Figure 92: Banking pilot SHAP bar plot (XAI_15092025_2).

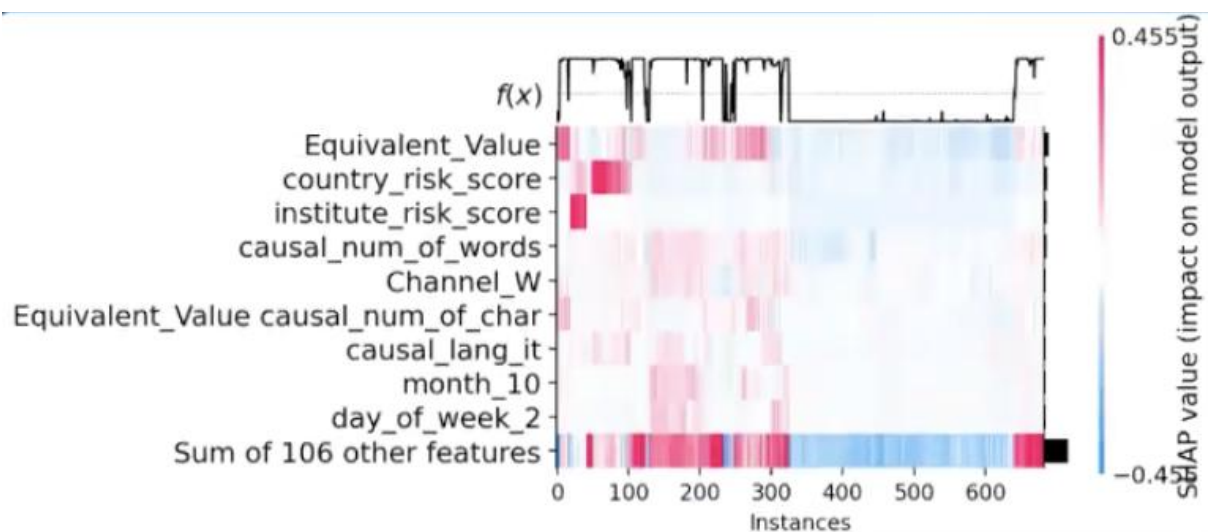


Figure 93: Banking pilot SHAP heatmap plot (Screenshot ID: XAI_15092025_3).

9.7.15 Additional Material / Screenshots for X-AI for Infrastructure Management based on AI

No additional material/screenshots provided by the partner.

9.8 KPI Additional Material and Screenshots

9.8.1 Additional Material / Screenshots for Number of trustworthy digital technologies integrated into TANGO platform

No additional material/screenshots provided by the partner.

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9.8.2 Additional Material / Screenshots for Number of existing reference architectures that TANGO will be aligned with

No additional material/screenshots provided by the partner.

9.8.3 Additional Material / Screenshots for Number of proposed and integrated data sharing models

No additional material/screenshots provided by the partner.

9.8.4 Additional Material / Screenshots for Number of TANGO components/assets to be integrated in the GAIA-X catalogue

No additional material/screenshots provided by the partner.

9.8.5 Additional Material / Screenshots for Reduction in energy consumption for blockchain solution

As provided by the partner, below is material proving the KPI's achievement.

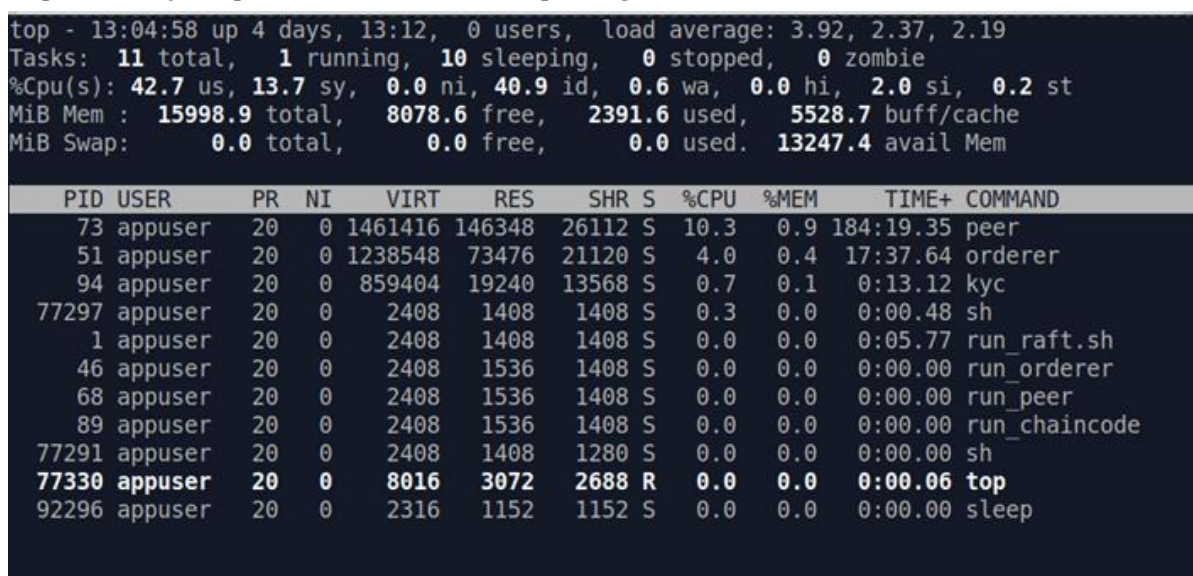


Figure 94: Reduction in energy consumption for blockchain solution KPI measurement of the Ethereum-like approach.

In Figure 94, the measurement of the Ethereum-like approach (orderer and “worker” peer on the same node). The grand total number of CPU percentage is 100% - %idle = 100% - 40.9% = **59.1%**.

```
top - 12:59:26 up 4 days, 13:07, 0 user, load average: 0.78, 1.87, 2.16
Tasks: 10 total, 2 running, 8 sleeping, 0 stopped, 0 zombie
%Cpu(s): 24.0 us, 9.8 sy, 0.0 ni, 63.6 id, 0.3 wa, 0.0 hi, 2.4 si, 0.0 st
MiB Mem : 15998.9 total, 8092.2 free, 2760.8 used, 5507.2 buff/cache
MiB Swap: 0.0 total, 0.0 free, 0.0 used. 13238.0 avail Mem
```

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
51	appuser	20	0	884428	176932	27136	S	10.3	1.1	89:32.28	peer
66	appuser	20	0	720820	15012	8192	S	1.0	0.1	0:37.76	kyc
19634	appuser	20	0	1712	1024	896	S	0.7	0.0	0:04.85	sh
122059	appuser	20	0	745916	20096	15104	R	0.3	0.1	0:00.01	peer
61	appuser	20	0	1620	896	896	S	0.0	0.0	0:00.00	run_chaincode
46	appuser	20	0	1620	768	768	S	0.0	0.0	0:00.00	run_peer
19640	appuser	20	0	1684	1024	896	S	0.0	0.0	0:00.00	sh
80488	appuser	20	0	3632	2816	1024	R	0.0	0.0	0:00.24	top
1	appuser	20	0	1624	1024	1024	S	0.0	0.0	0:04.62	docker_start_pe
121524	appuser	20	0	1592	768	768	S	0.0	0.0	0:00.00	sleep

Figure 95: Reduction in energy consumption for blockchain solution KPI measurement of the Hyperledger Fabric approach.

In Figure 95, the measurement of the Hyperledger Fabric approach (orderers are running sperartely). The grand total number of CPU percentage is 100% - %idle = 100% - 63.6% = **36.4%**.

9.8.6 Additional Material / Screenshots for Reduction of privacy violation incidents in data sharing

No additional material/screenshots provided by the partner.

9.8.7 Additional Material / Screenshots for Recoverability of data

As provided by the partner, below is material proving the KPI's achievement.

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```

> testing loop ... ..
> testing case [1]:
> plain_file_name: testcase1.txt
> ...doing encryption...
> generated_encrypted_file: testcase1_enc.enc
> ...doing decryption...
> decrypted_file: testcase1_enc.enc.dec.dec
> verify HASH value
> consistent!
> testing case [2]:
> plain_file_name: testcase2.PDF
> ...doing encryption...
> generated_encrypted_file: testcase2_enc.enc
> ...doing decryption...
> decrypted_file: testcase2_enc.enc.dec.dec
> verify HASH value
> consistent!
> testing case [3]:
> plain_file_name: testcase3.MP4
> ...doing encryption...
> generated_encrypted_file: testcase3_enc.enc
> ...doing decryption...
> decrypted_file: testcase3_enc.enc.dec.dec
> verify HASH value
> consistent!
> testing case [4]:
> plain_file_name: testcase4.CSV
> ...doing encryption...
> generated_encrypted_file: testcase4_enc.enc
> ...doing decryption...
> decrypted_file: testcase4_enc.enc.dec.dec
> verify HASH value
> consistent!
> testing case [5]:
> plain_file_name: testcase5.DB
> ...doing encryption...
> generated_encrypted_file: testcase5_enc.enc
> ...doing decryption...
> decrypted_file: testcase5_enc.enc.dec.dec
> verify HASH value
> consistent!
> testing case [6]:
> plain_file_name: testcase6.ZIP
> ...doing encryption...
> generated_encrypted_file: testcase5_enc.enc
> ...doing decryption...
> decrypted_file: testcases_enc.enc.dec.dec
> verify HASH value
> consistent!

```

Figure 96, Recoverability of data KPI FMAKE manufacturing pilot decryption Success Rate (Screenshot ID: FMAKE_decryptionSuccRate_15112024).

9.8.8 Additional Material / Screenshots for Number of different security & privacy policy descriptions to be supported

No additional material/screenshots provided by the partner.

9.8.9 Additional Material / Screenshots for Number of external identities supported by SSI

As provided by the partner, below is material proving the KPI's achievement.

Table 6: Number of external identities supported by SSI KPI SSI Agent logs.

Log ID	Log
ssi-uself-agent_IDM_03-03-25	ePassport issuer SSI Agent log: https://github.com/TANGO-EU-PROJECT/ssi-agent-specs/tree/main?tab=readme-ov-file#5-issuer-integration-logs

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ssi-uself-agent_IDM_22-05-25	Employee issuer SSI Agent log: https://github.com/TANGO-EU-PROJECT/ssi-agent-specs/tree/main?tab=readme-ov-file#5-issuer-integration-logs
------------------------------	---

9.8.10 Additional Material / Screenshots for Accuracy of user verification and authentication

As provided by the partner, below is material proving the KPI's achievement.

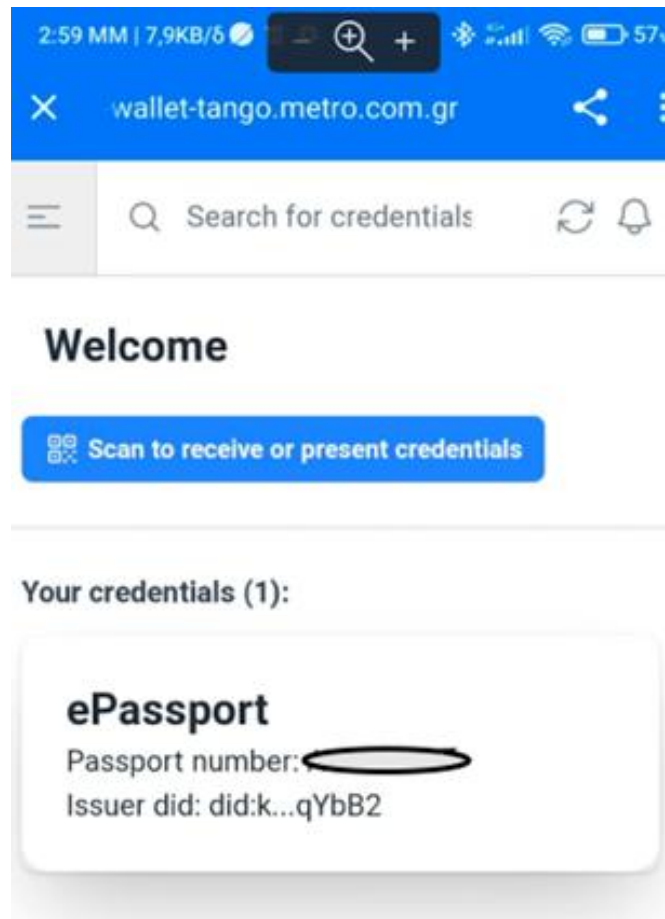


Figure 97: Accuracy of user verification and authentication KPI user ePassport onboarding (Screenshot ID: SOUD_150725_1).

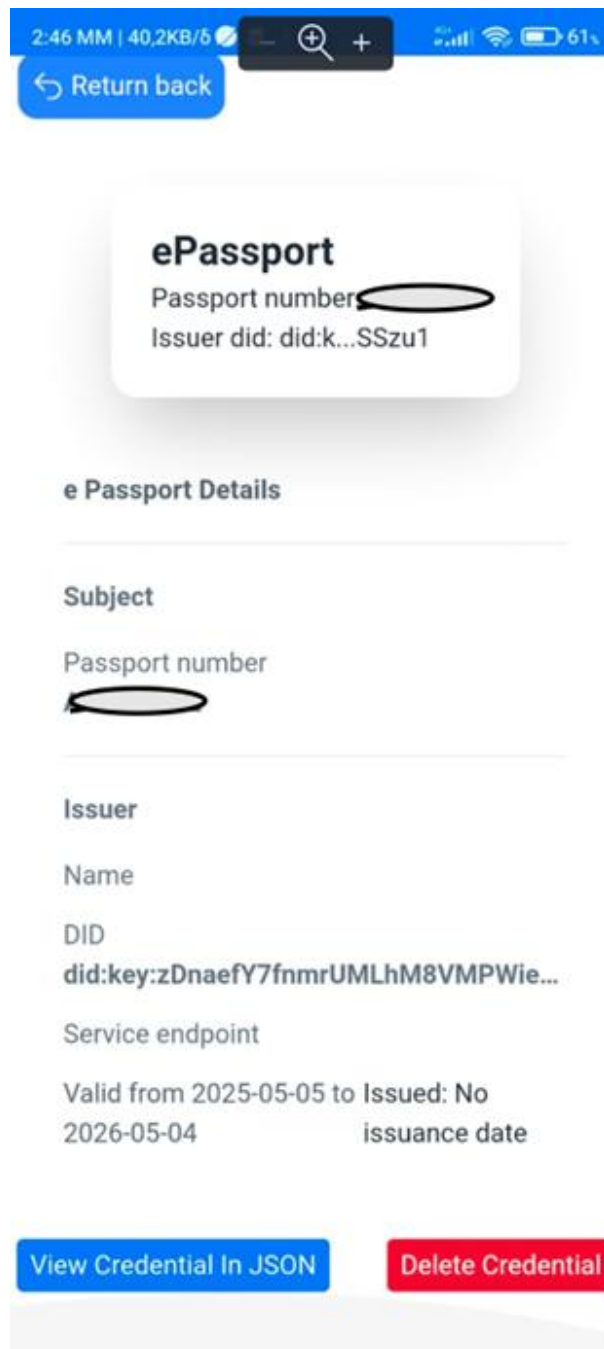


Figure 98: Accuracy of user verification and authentication KPI ePassport credentials enabling (Screenshot ID: SOUD_150725_2).

9.8.11 Additional Material / Screenshots for Accuracy of device verification and authentication

As provided by the partner, below is material proving the KPI's achievement.

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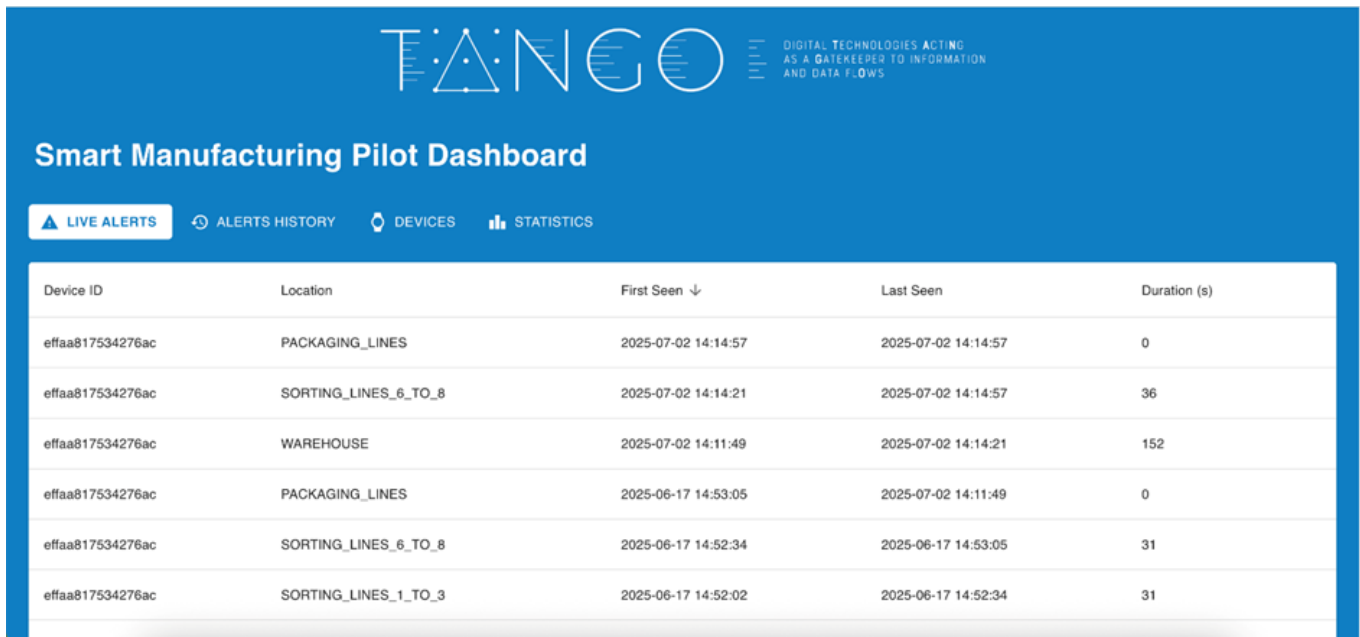


Figure 99: Accuracy of device verification and authentication KPI Smart manufacturing pilot dashboard (Screenshot ID: DCBA_150925_2).

Additionally, the partner provided a link to further material (Screenshot ID: DCBA_150925_1) which can be accessed [here](#).

9.8.12 Additional Material / Screenshots for Number of recommendation & decision-making models to be developed

As provided by the partner, below is material proving the KPI's achievement.

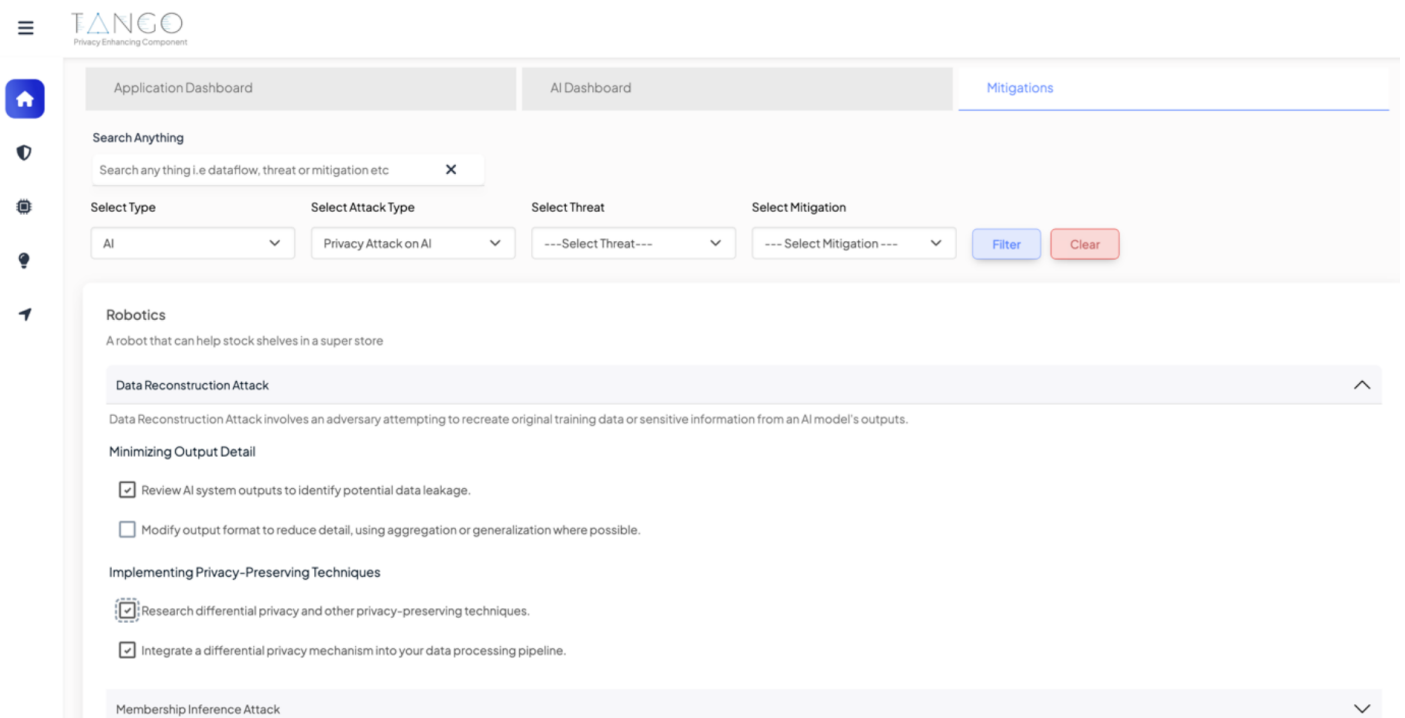


Figure 100: Number of recommendation & decision-making models to be developed KPI LLM recommendations from PEC (Screenshot ID: PEC_250625_1).

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```

1 {
2   > "carbon_emissions": [ ...
27   ],
28   "latitude": 46.5,
29   "longitude": 15.5,
30   > "timestamps_hourly": [ ...
55   ],
56   "timezone": "UTC",
57   "units": {
58     "carbon_emissions": "gCO2eq/kWh",
59     "timestamps_hourly": "s"
60   },
61   "utc_offset_seconds": "0"
62 }

```

Figure 101: Number of recommendation & decision-making models to be developed KPI example of results outcome from /forecast/carbon emissions endpoint from RENOPS (Screenshot ID: RENOPS_250625_2).

Figure 102: Number of recommendation & decision-making models to be developed KPI LLM-based AI assistance from PAT (Screenshot ID: PAT_040701_3).

9.8.13 Additional Material / Screenshots for Reduction in energy consumption for an ML model training

RENOPS: Training Models During Planned Time Ranges

To present the impact of the RENOPS Scheduler, XLAB performed an experiment running LMM model training during unplanned and planned (using the RENOPS scheduler) times and compared the total cost of the trained models.

The experiment consisted in 18 model trainings runs. It was carried out in Slovenia, taking into account the electricity prices and trading volume, as shown below in Figure 103:

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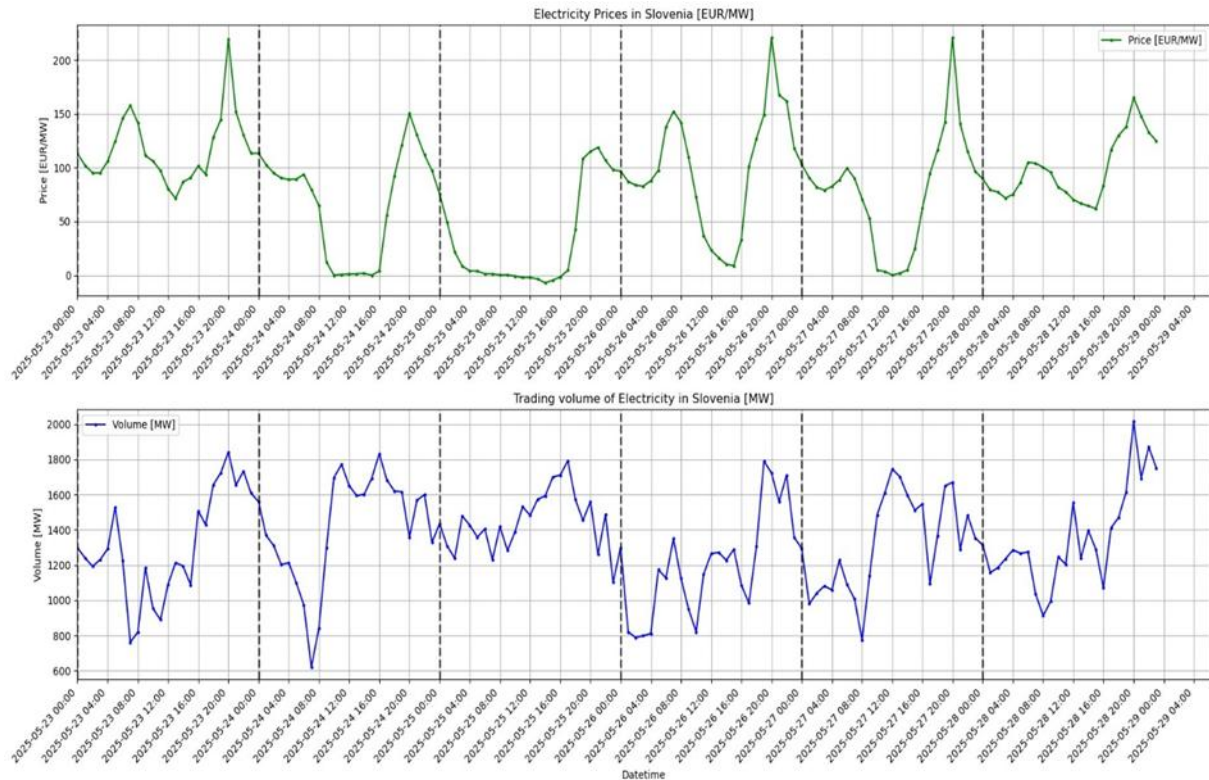


Figure 103: Reduction in energy consumption for an ML model training KPI Visualization of Electricity Prices and Trading Volume in Slovenia.

The Table 7 below shows the types of energy in the network during the period of the experiment (e.g., percentage of renewables vs. traditional energy sources):

Table 7: Reduction in energy consumption for an ML model training KPI types of energy in the network during the period of the experiment.

Time stamp	Biomass	Fossil_Brown_Coal_Lignite	Fossil_Gas	Fossil_Oil	Hydro_Pumped_Storage	Hydro_Run_Of_River_And_Pondage	Nuclear	Solar	Waste	Wind_Onshore
2025-05-23 00:00:00	8.0	5.0	116.0	0.0	0.0	807.0	696.0	0.0	1.0	3.0
2025-05-23 01:00:00	8.0	5.0	118.0	0.0	0.0	720.0	696.0	0.0	1.0	3.0
2025-05-23 02:00:00	8.0	5.0	116.0	0.0	0.0	591.0	696.0	0.0	1.0	2.0
2025-05-23	8.0	5.0	119.0	0.0	0.0	554.0	696.0	0.0	1.0	3.0

Time stamp	Biomass	Fossil_Brown_Coal_Lignite	Fossil_Gas	Fossil_Oil	Hydro_Pumped_Storage	Hydro_Run_Of_River_And_Poundage	Nuclear	Solar	Waste	Wind_Onshore
03:00:00										
2025-05-23 04:00:00	8.0	5.0	121.0	0.0	0.0	755.0	696.0	0.0	0.0	3.0

The total emissions per energy source, to later calculate the carbon footprint of the experiment, is shown in the Table 8 below:

Table 8: Reduction in energy consumption for an ML model training KPI emissions per source in Slovenia [kg/MWh].

	Source	kg_MWh
0	fossil_brown_coal_lignite	937
1	fossil_gas	490
2	fossil_oil	650
3	hydro_pumped_storage	58
4	hydro_run_of_river_and_poundage	24
5	nuclear	12
6	solar	41
7	biomass	230
8	wind_onshore	9
9	waste	360

Visualization of the results of the experiment

Below, the partners show metrics of model training runs and compare them with each other by different attributes and visualizations. We compare model training runs attributes by EUR/MWh:

- **Total EUR:** Total EUR spent on the model training run.
- **EUR per MWh:** Average EUR spent per MWh of GPU power consumed.
- **Hour of Day (Start):** Hour of the day when the model training run started.

The Figure 104 below shows the results of the different runs from the perspectives of these metrics:

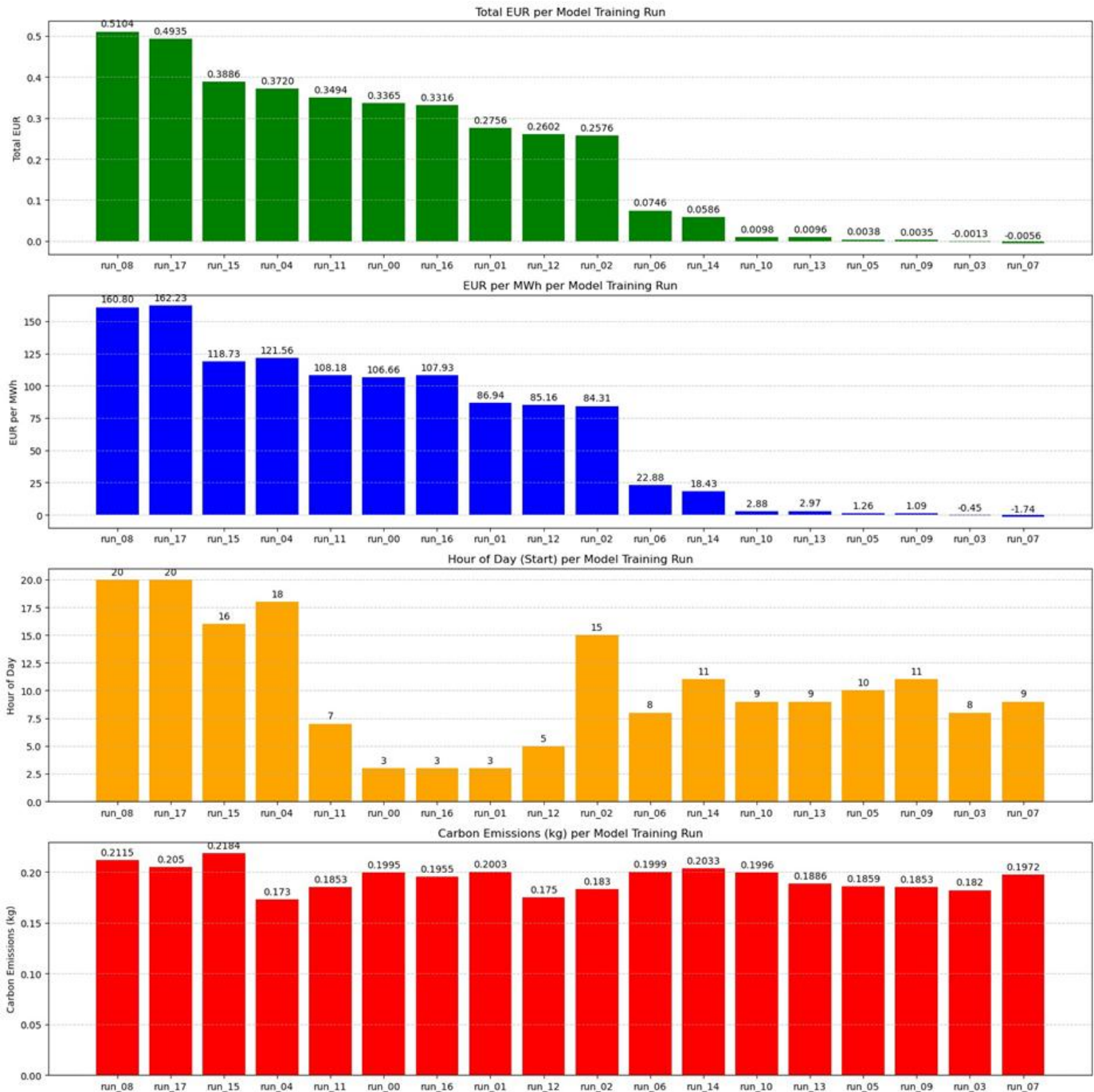


Figure 104: Reduction in energy consumption for an ML model training KPI model training runs attributes by EUR/MWh.

Carbon emissions

As seen on the last subplot, the carbon emissions are quite stable, especially in comparison to the prices. As shown in the Figure 105 below, the amount of energy production from sources with low carbon emissions is quite high, while the amount from sources with high carbon emissions, like fossil gas and biomass, is quite low.

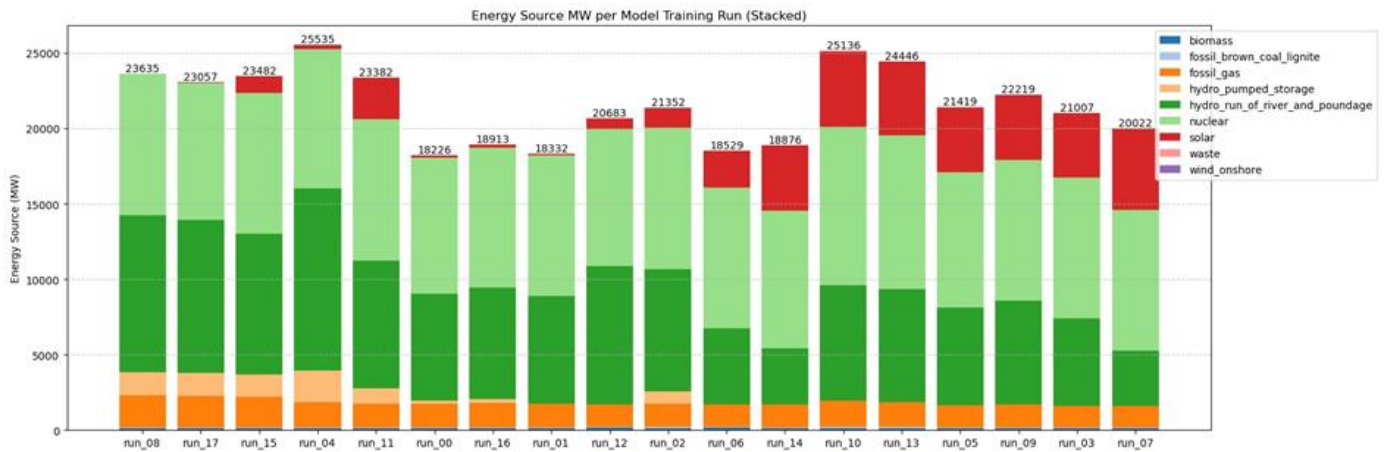


Figure 105: Reduction in energy consumption for an ML model training KPI carbon emissions

Correlation Heatmap of Model Training Metrics

In the Figure 106 below, the partners provided metrics that show a correlation of given attributes. Warmer the colour (red) the stronger the correlation.

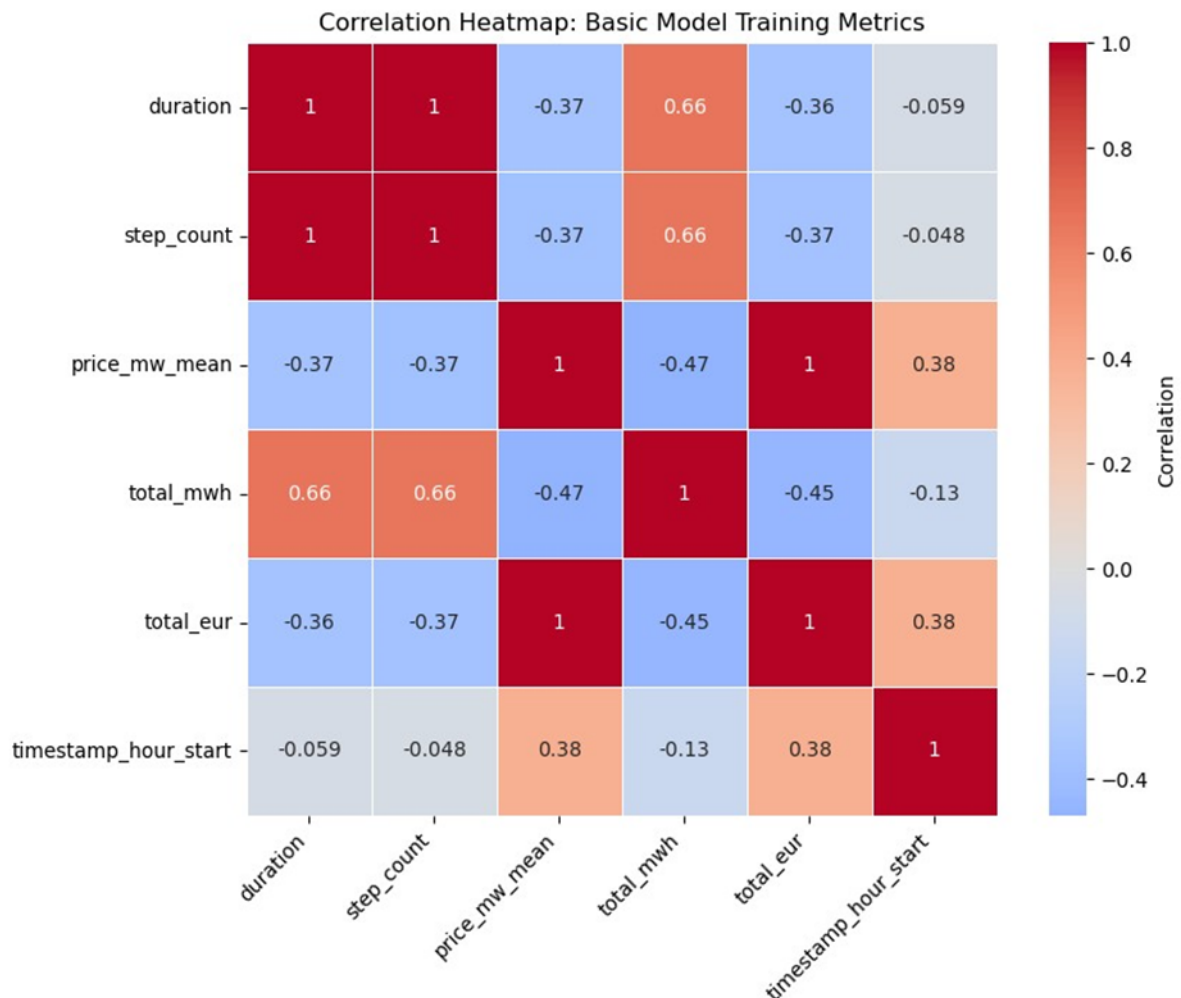


Figure 106: Reduction in energy consumption for an ML model training KPI correlation heatmap basic model training metrics.

The following heatmap (Figure 107) visualizes the correlation between total EUR and the energy source MWh columns for each model training run. The 'total_eur' column and row are highlighted in red to emphasize their relationships with other variables.

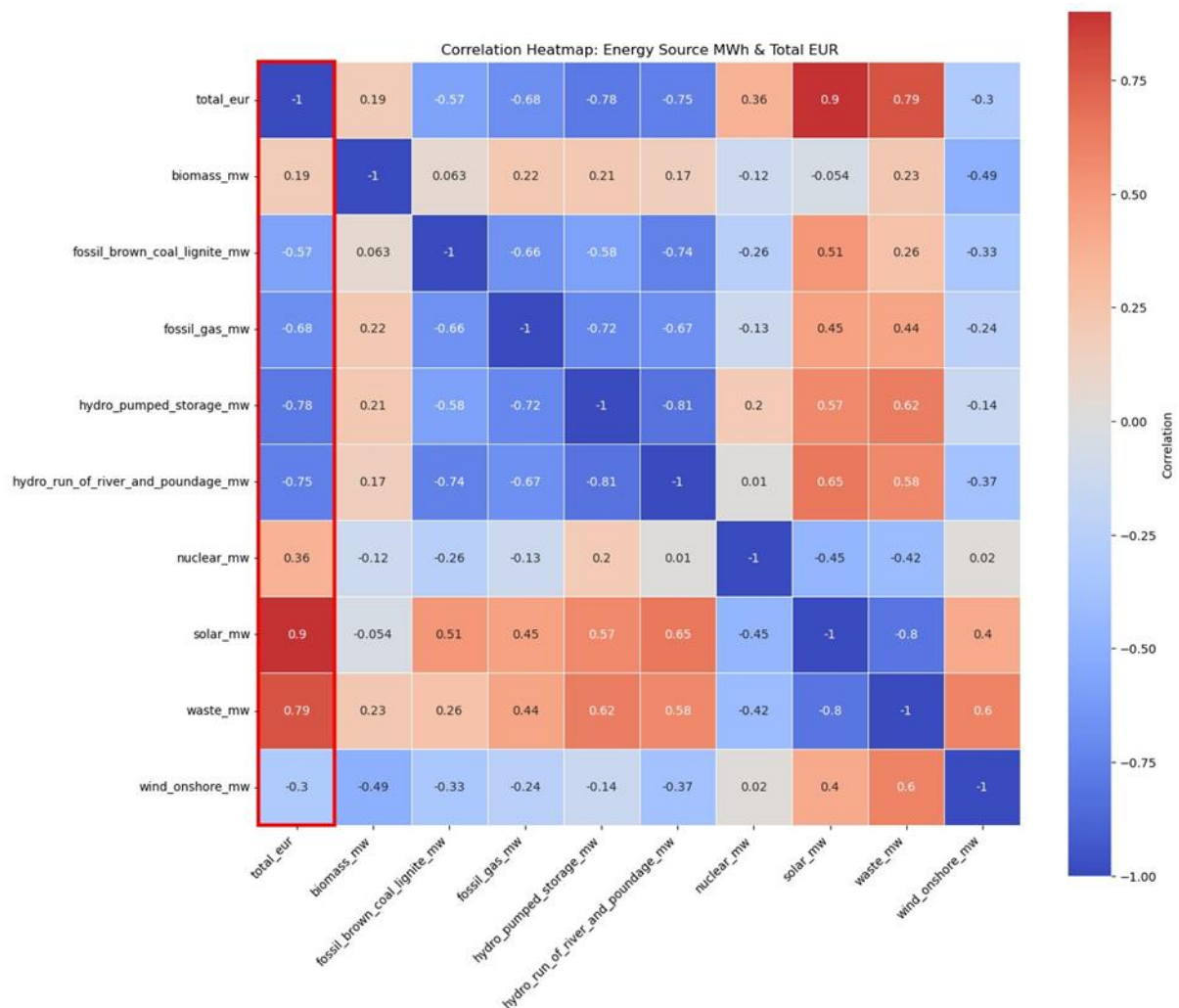


Figure 107: Reduction in energy consumption for an ML model training KPI energy source MWh and Total EUR.

Scatter Plots of Energy Sources vs EUR per MWh

Below (Figure 108) the partners provided scatter plots showing the relationship between each energy source and the average EUR per MWh (price_mw_mean). Each point represents a model training run, coloured by run number.

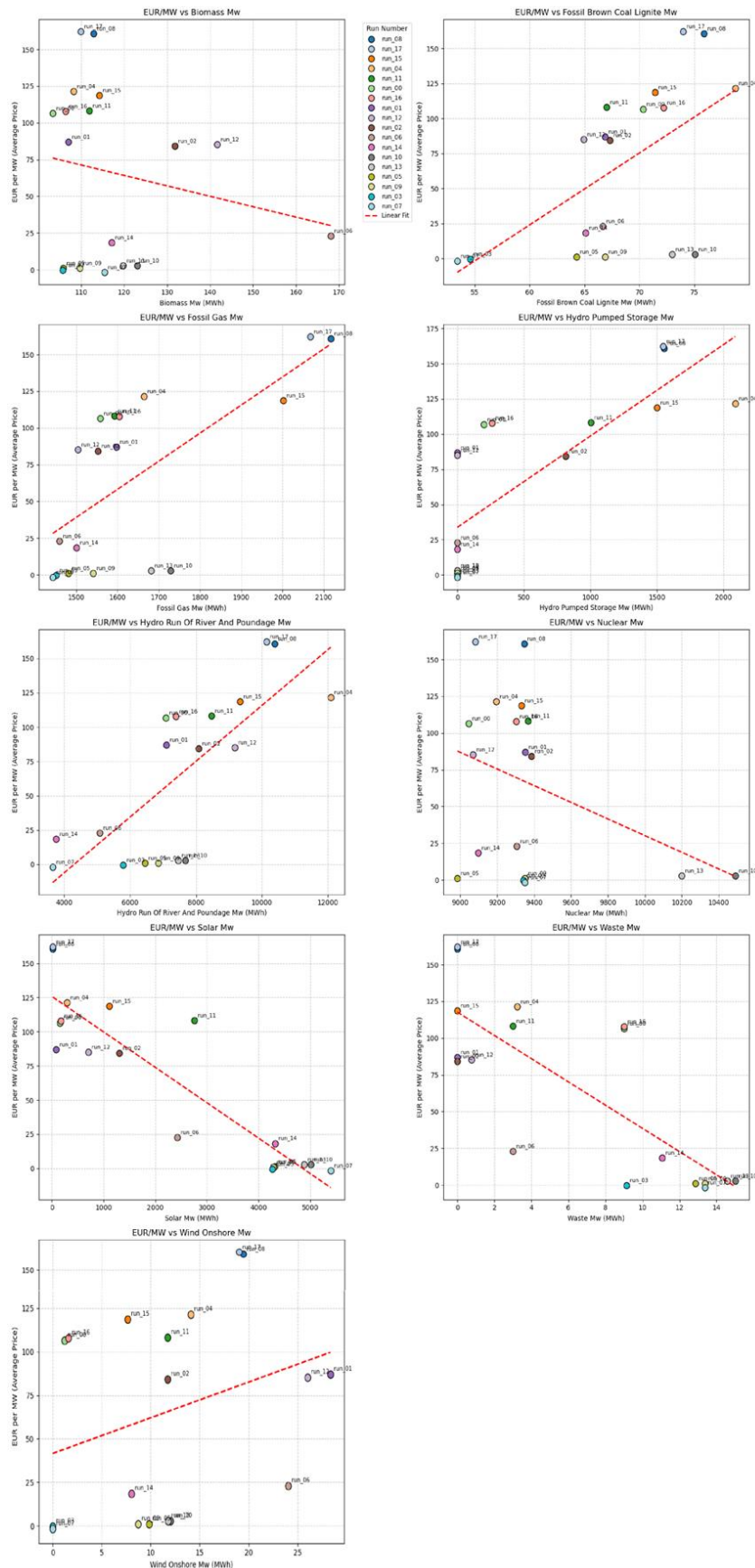


Figure 108: Reduction in energy consumption for an ML model training KPI correlation between total EUR and the energy source MWh.

Run comparison by energy source metrics

The following Table 9 provided by the partners, summarizes the results of multiple model training runs, showing for each run:

- The start and end timestamps of the run (timestamp_start , timestamp_end).
- The total energy consumed by GPUs during the run in megawatt-hours (total_mwh).
- The average electricity price during the run in euros per megawatt-hour price_mw) The total electricity cost for the run in euros (total_eur).

Each row corresponds to a different training run, identified by run_name, and table is sorted by total eur.

Table 9: Reduction in energy consumption for an ML model training KPI Results of multiple model training runs.

	Run_Name	Timestamp_Start	Timestamp_End	Total_Mwh	Price_Mw	Total_Eur
0	run_07	2025-05-25 09:23:55	2025-05-25 13:51:02	0.003264	-1.743657	-0.005611
1	run_03	2025-05-25 07:35:53	2025-05-25 12:02:47	0.003145	-0.454907	-0.001341
2	run_09	2025-05-24 11:05:52	2025-05-24 15:33:21	0.003167	1.085100	0.003516
3	run_05	2025-05-24 09:50:02	2025-05-24 14:07:06	0.003174	1.255511	0.003813
4	run_13	2025-05-24 09:04:13	2025-05-24 13:56:04	0.003232	2.971118	0.009574
5	run_10	2025-05-24 09:05:34	2025-05-24 14:05:42	0.003421	2.884814	0.009795
6	run_14	2025-05-26 11:20:46	2025-05-26 15:41:08	0.003188	18.425691	0.058553
7	run_06	2025-05-27 08:25:39	2025-05-27 12:52:16	0.003220	22.881590	0.074638
8	run_02	2025-05-27 15:05:47	2025-05-27 19:34:53	0.003097	84.312294	0.257594
9	run_12	2025-05-27 04:55:44	2025-05-27 09:15:23	0.003044	85.156035	0.260209
10	run_01	2025-05-27 02:35:57	2025-05-27 07:03:28	0.003176	86.938024	0.275632
11	run_16	2025-05-26 03:05:47	2025-05-26 07:31:39	0.003101	107.930924	0.331573
12	run_00	2025-05-26 03:05:47	2025-05-26 07:24:17	0.003154	106.661522	0.336531
13	run_11	2025-05-26 07:05:51	2025-05-26 11:33:52	0.003192	108.180693	0.349374
14	run_04	2025-05-24 17:55:33	2025-05-24 22:18:39	0.003048	121.558173	0.371972
15	run_15	2025-05-26 16:05:48	2025-05-26 20:32:52	0.003324	118.733213	0.388586

16	run_17	2025-05-26 19:59:38	2025-05-27 00:19:23	0.003048	162.233302	0.493497
17	run_08	2025-05-26 19:58:50	2025-05-27 00:26:07	0.003151	160.797844	0.510395

In conclusion, these results show that the RENOPS Scheduler effectively reduces training costs, aligns energy use with low-carbon sources and demonstrates predictable energy demand across similar jobs. Scheduling jobs, such as ML model training or any other heavy computation in a datacentre, may drastically reduce the price and carbon footprint of the operations. The combination of the Scheduler with MLOps helps AI engineers to gather and monitor all these metrics and the resulting models, giving them unvaluable hints to reduce the carbon footprint and the price of AI model training.

9.8.14 Additional Material / Screenshots for Reduction in energy consumption in application execution for a single node

9.8.15 Additional Material / Screenshots for Number of AutoML tools

As provided by the partner, below is material proving the KPI's achievement.

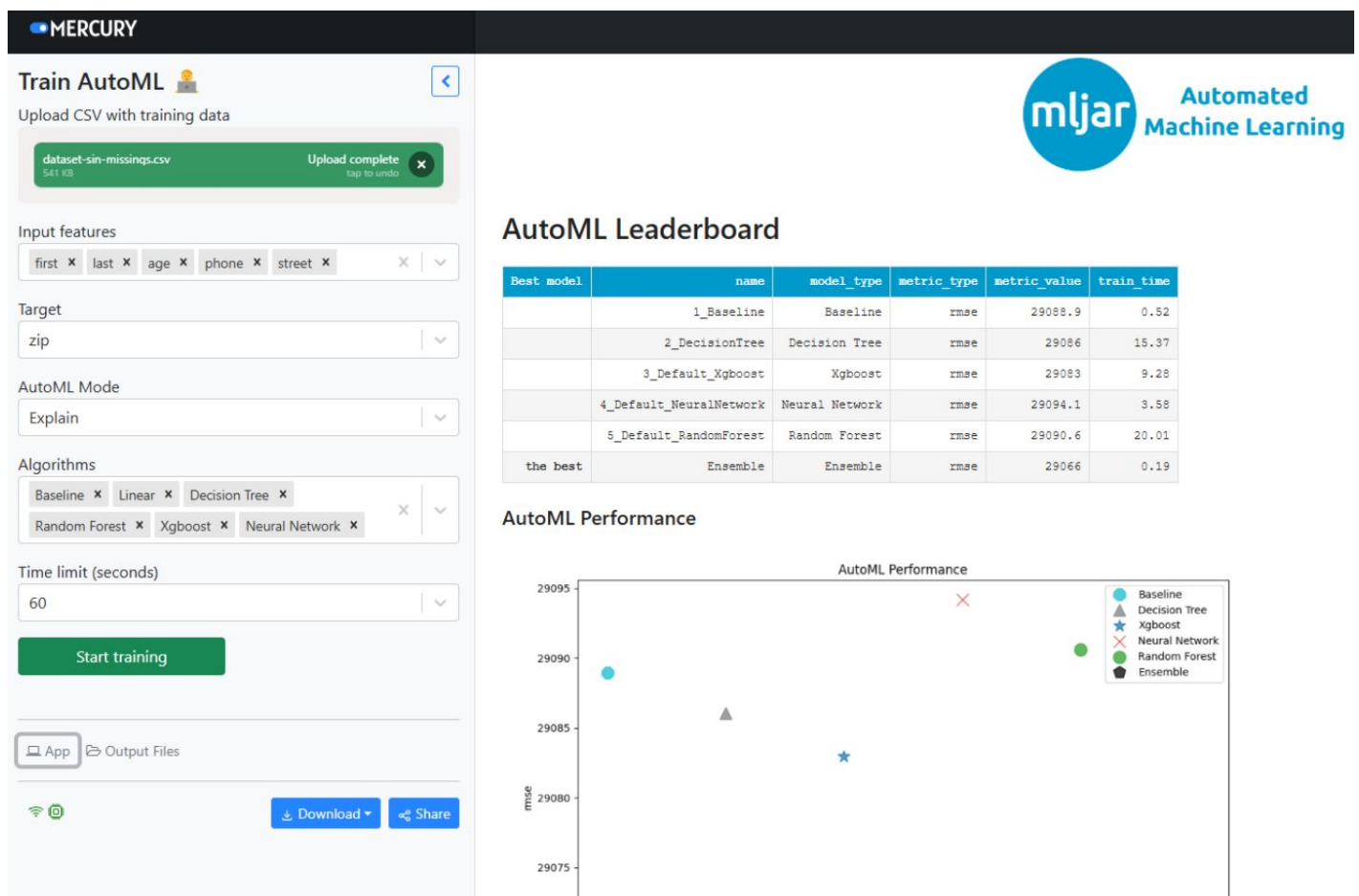


Figure 109: Number of AutoML tools KPI AutoML Leaderboard (Screenshot ID: AutoML_250625_1).

MERCURY

Train AutoML (advanced)

Upload CSV with training data

dataset-sin-missings.csv
541 KB

Upload complete
Tap to undo

Input features

first last age phone street

Target

zip

Prepare data

Construct Golden Features

Features Selection

Algorithms

Algorithms

Decision Tree Linear Random Forest
Extra Trees LightGBM Xgboost CatBoost
Neural Network Nearest Neighbors

Stack Models

Train Ensemble

Validation

Number of Folds

5

Suffle Samples

Stratify Samples

Evaluation Metric

auto

Time Limit (seconds)

60

Start Training

Train Machine Learning Pipeline with MLJAR AutoML

You can control AutoML behavior with more parameters. This notebook is running autoML in the `Compete` mode.

You can choose:

- feature preprocessing parameters: golden features and features selection
- select algorithms, stack, and ensemble them,
- set cross-validation strategy (number of folds, stratify and shuffle),
- choose evaluation metric.

Steps

- Upload CSV file with data. Data should have column names in the first line.
- Select input features and target column.
- Select AutoML training mode, algorithms, and training time limit.
- Directory with all ML models will be zipped and available to download.

Training data

	first	last	age	phone	street	zip	state
0	Thomas	Hill	24	(402) 439-2485	Orkur Path	48910	WA
1	Adam	Carpenter	46	(826) 829-9699	Envu Manor	1050	WA
2	Clifford	Walton	39	(465) 886-7895	Bisaw Highway	55511	OR
3	Dean	Vasquez	33	(773) 295-1239	Pumnor Extension	99499	NE
4	Louisa	Hamilton	60	(677) 721-2283	Hujbih View	60176	OK
...	...	...	...	...	...	...	...
9995	Chad	Russell	41	(624) 441-9229	Ahmop Path	99156	IN
9996	Christine	Holland	31	(417) 931-5669	Deptuw Mill	54762	MO
9997	Francis	Leonard	56	(585) 291-1160	Wini Highway	20769	IL
9998	Rose	Hart	37	(531) 867-3720	Havvoj Avenue	29751	SC
9999	Fannie	Simmons	56	(322) 491-1279	Nuuso Avenue	95717	TX

10000 rows x 7 columns

StopExecution

Figure 110: Number of AutoML tools KPI ML Train Pipeline with AutoML (Screenshot ID: AutoML_250625_2).

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Predict with AutoML

Upload zip with AutoML

AutoML_5.zip
2.4 MB

Upload complete
tap to undo

Upload test data

dataset-para-training.csv
421 KB

Upload complete
tap to undo

App

Output Files

Download

Share

Compute predictions

Please follow the steps:

1. Upload zip file with AutoML.
2. Upload test data as CSV file.
3. Download predictions.

	first	last	age	phone	street	state
0	Thomas	Hill	24	(402) 439-2485	Orkur Path	WA
1	Adam	Carpenter	46	(826) 829-9699	Ervu Manor	WA
2	Clifford	Walton	39	(465) 886-7895	Bisaw Highway	OR
3	Dean	Vasquez	33	(773) 295-1239	Pumnor Extension	NE
4	Louisa	Hamilton	60	(677) 721-2283	Hujboh View	OK
...	...	...	...	...	...	...
9995	Chad	Russell	41	(624) 441-9229	Ahmop Path	IN
9996	Christine	Holland	31	(417) 931-5669	Deptuw Mill	MO
9997	Francis	Leonard	56	(585) 291-1160	Wini Highway	IL
9998	Rose	Hart	37	(531) 867-3720	Havvoj Avenue	SC
9999	Fannie	Simmons	56	(322) 491-1279	Nuuso Avenue	TX

10000 rows × 6 columns

	prediction
0	50528.443501
1	49674.068990
2	49674.068990
3	49674.068990
4	49674.068990
...	...
9995	49674.068990
9996	49674.068990
9997	49674.068990
9998	50528.443501
9999	49674.068990

Figure 111: Number of AutoML tools KPI computer predictions using AutoML (Screenshot ID: AutoML_250625_3).

9.8.16 Additional Material / Screenshots for Number of privacy assessment tools to be developed

As provided by the partner, below is material proving the KPI's achievement.

Document name:	D7.2 Validation Report and Lessons Learnt	Page:	207 of 215
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	Version:	1.0	Status:
			Final

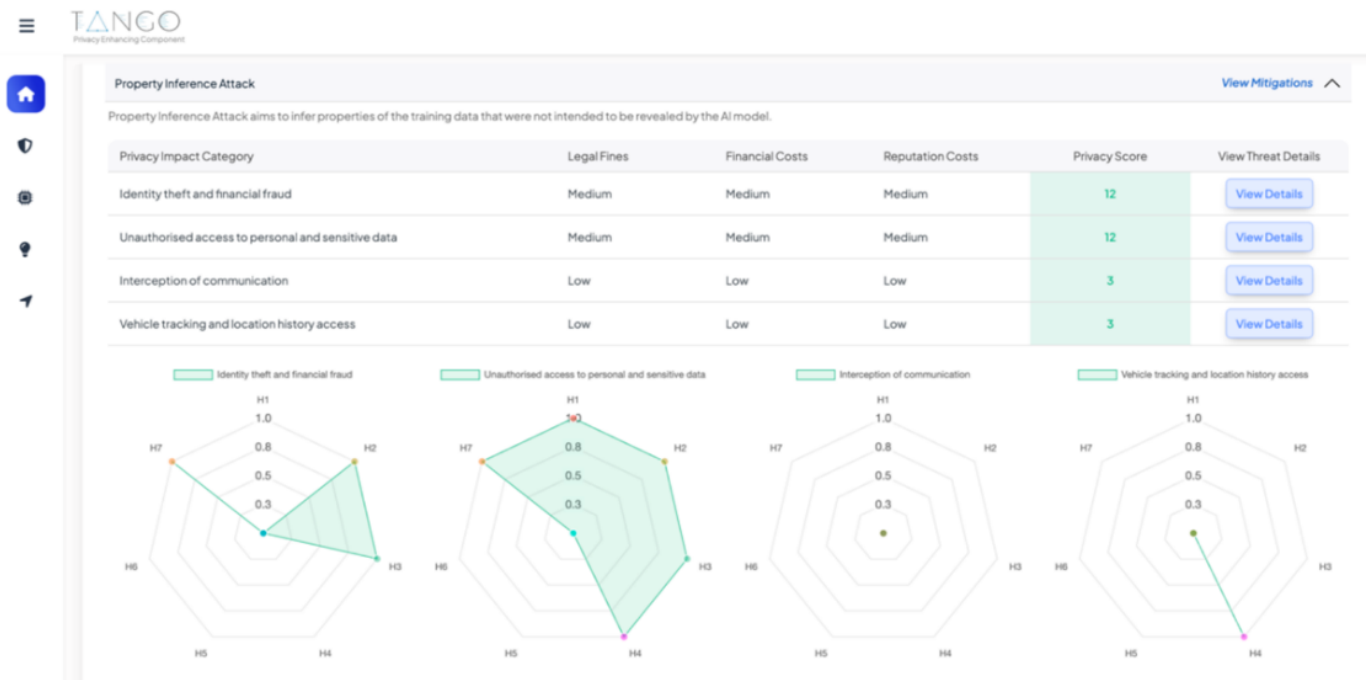


Figure 112: Number of privacy assessment tools to be developed KPI property inference attack report PEC tool (Screenshot ID: KPI5_PEC_040725_1).

Create A Consent Request



Below you may create your own custom consent request. The consent request is divided into two parts. The first part (left) is the mandatory data that you will require from your data subjects. This can be seen as the minimal data required by you to process the data subject correctly. The preferences section (right) is any additional information you wish to collect from the data subject, that is not strictly for you two process the data subject accordingly. These are nice-to-have information, which a data subject may not need to fill-in unless they wish to.

Mandatory Data - Information

First name
String

Last name
String

Email
String

Arrival Date
Date

Departure Date
Date

[Add Field](#)

Mandatory Data - Data Processing Clarifications

Please state which roles within your organisation can process the data above.
Select role

If you share any of the above data with third parties, please list them below.
Select third party

Please select for how many months the data will be stored and processed:
9 months

Please select within which country the data will be stored and accessed:
Spain

Spain

Preferences Data - Information

Food restrictions
String

Room preferences
String

[Add Field](#)

Preferences Data - Data Processing Clarifications

Please state which roles within your organisation can process the data above.
EXPERIENCE PROVIDER

EXPERIENCE PROVIDER

The purposes for processing the data above are :

recommendations

service personalization

The following actions will be performed on the data above :

read

If you share any of the above data with third parties, please list them below:

[Submit](#)

Figure 113: Number of privacy assessment tools to be developed KPI create consent request form PAT tool (Screenshot ID: KPI5_PAT_040725_1).

Document name:	D7.2 Validation Report and Lessons Learnt	Page:	209 of 215
Reference:	D7.2 Dissemination: PU	Version:	1.0
		Status:	Final

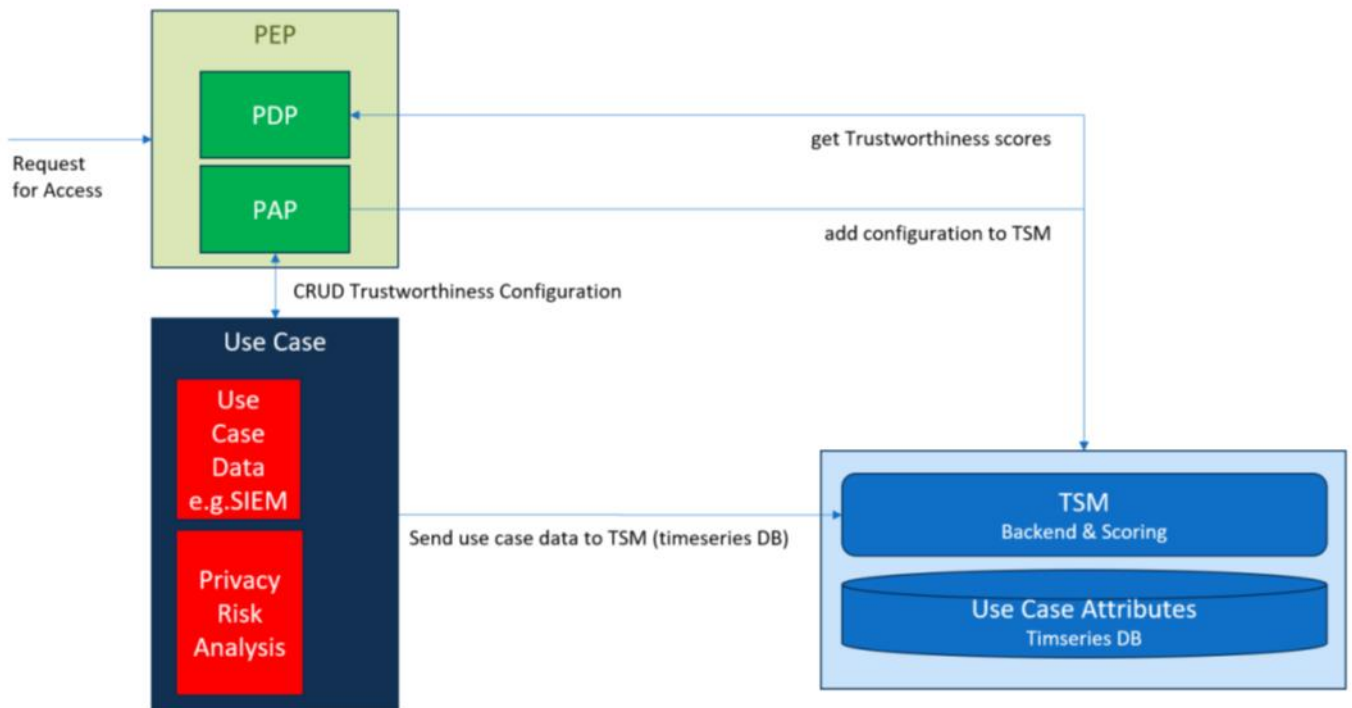


Figure 114: Number of privacy assessment tools to be developed KPI PEP component architecture (Screenshot ID: KPI5_TSM_040725_1).

9.8.17 Additional Material / Screenshots for Number of XAI models to be developed

The material provided by the partner can be accessed in the Deliverable's annex "9.7.14 Additional Material / Screenshots for X-AI for Privacy and Trust Enhancement".

9.8.18 Additional Material / Screenshots for Reduction in energy consumption of a datacentre

As stated by the partner, the input is consolidated in the one found in subchapter "11.8.13 Additional Material/Screenshots for Reduction in energy consumption for an ML model training" of the deliverable.

9.8.19 Additional Material / Screenshots for Number of pilot validation campaigns

No additional material/screenshots provided by the partner.

9.8.20 Additional Material / Screenshots for Number of external stakeholders participating in the validation campaigns

As provided by the partner, below is material proving the KPI's achievement.

Document name:	D7.2 Validation Report and Lessons Learnt	Page:	210 of 215
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			Final

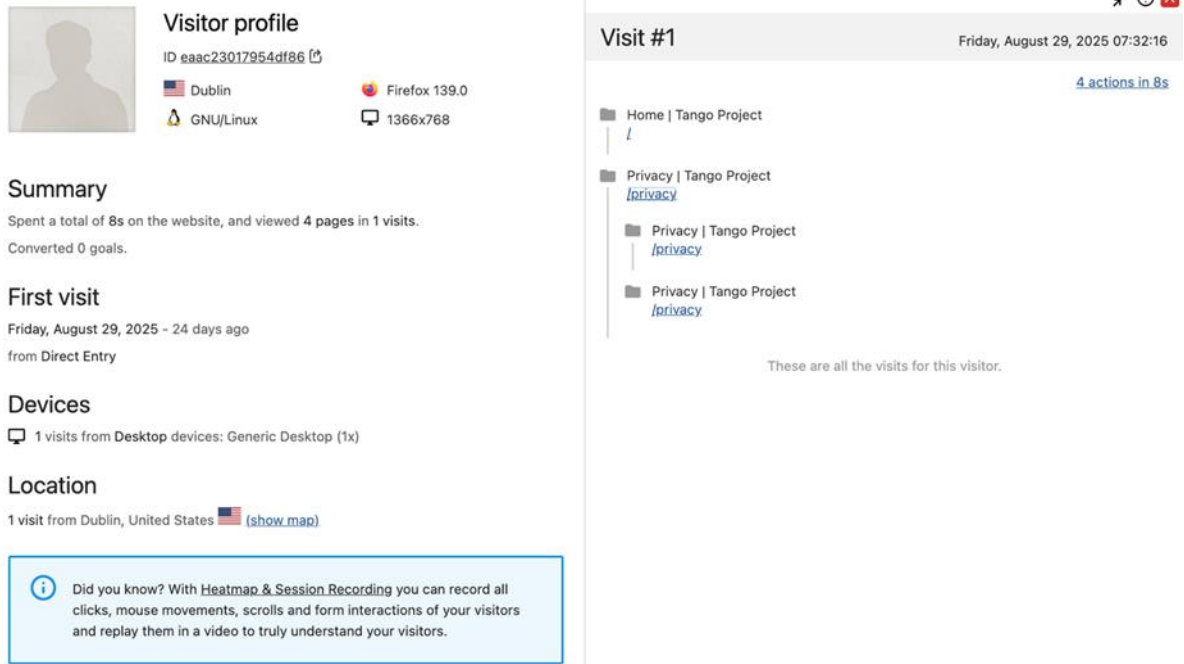


Figure 115: Number of external stakeholders participating in the validation campaigns KPI privacy repeated visits to Privacy page (Screenshot ID: ID-TANGO-PRIVACY-20250829-08).

Document name:	D7.2 Validation Report and Lessons Learnt					Page:	211 of 215
Reference:	D7.2	Dissemination:	PU	Version:	1.0	Status:	Final



Visitor profile

ID 714b31854ae335b6 [🔗](#)

New Delhi (Block A)

Chrome 116.0

GNU/Linux

1080x600

Summary

Spent a total of 1 min 7s on the website, and viewed 15 pages in 1 visits.
Converted 0 goals.

First visit

Wednesday, August 20, 2025 - 33 days ago
from Direct Entry

Devices

1 visits from Desktop devices: Generic Desktop (1x)

Location

1 visit from New Delhi (Block A), India [\(show map\)](#)



Did you know? With [Heatmap & Session Recording](#) you can record all clicks, mouse movements, scrolls and form interactions of your visitors and replay them in a video to truly understand your visitors.

Visit #1

Wednesday, August 20, 2025 08:13:30

[15 actions in 1 min 7s](#)

- Home | Tango Project
[/](#)
- Governance | Tango Project
[/governance](#)
- Cookies | Tango Project
[/cookies](#)
- Upcoming Events | Tango Project
[/events](#)
- Scientific Publications | Tango Project
[/materials/scientific-publications](#)
- Dissemination materials | Tango Project
[/dissemination-materials](#)
- Partners | Tango Project
[/partners](#)
- Public Deliverables
[/materials/public-deliverables](#)
- Pilots | Tango Project
[/pilots](#)
- Description of the project | Tango Project
[/project-description](#)
- Contact | Tango Project
[/contact](#)
- Home | Tango Project
[/](#)
- Accessibility statement | Tango Project
[/accessibility](#)
- Articles | Tango Project
[/articles](#)

These are all the visits for this visitor.

Figure 116: Number of external stakeholders participating in the validation campaigns KPI pages (Governance, Events, Publications, Deliverables, Pilots, Project Description, etc.) (Screenshot ID: ID TANGO-PILOTS-20250820-03).

Document name:	D7.2 Validation Report and Lessons Learnt					Page:	212 of 215
Reference:	D7.2	Dissemination:	PU	Version:	1.0	Status:	Final



Visitor profile

ID [d3d0acd7304726a3](#)

 Singapore (Hougang)  Microsoft Edge 139.0

 Windows 11  1260x840

Summary

Spent a total of 7 min 35s on the website, and viewed 9 pages in 1 visits.
Converted 0 goals.

First visit

Friday, August 22, 2025 - 31 days ago
from Direct Entry

Devices

 1 visits from Desktop devices: Generic Desktop (1x)

Location

1 visit from Singapore (Hougang), Singapore  ([show map](#))

 Did you know? With [Heatmap & Session Recording](#) you can record all clicks, mouse movements, scrolls and form interactions of your visitors and replay them in a video to truly understand your visitors.

Visit #1

Friday, August 22, 2025 03:39:10

[9 actions in 7 min 35s](#)

-  首页 | 探索项目
[/](#)
-  Contact | Tango Project
[/contact](#)
-  Pilots | Tango Project
[/pilots](#)
-  Contact | Tango Project
[/contact](#)
-  Public Deliverables
[/materials/public-deliverables](#)
-  Scientific Publications | Tango Project
[/materials/scientific-publications](#)
-  Description of the project | Tango Project
[/project-description](#)
-  Newsletter registration | Tango Project
[/thankyou-newsletter](#)
-  Contact | Tango Project
[/contact](#)

These are all the visits for this visitor.

Figure 117: Number of external stakeholders participating in the validation campaigns KPI pages: Pilots, Deliverables, Publications, Project Description, Newsletter Registration (Screenshot ID: ID TANGO-PILOTS-20250822-04).



Visitor profile

ID [a3a11f3eb106112](#)

 Des Moines  Chrome 138.0

 Windows 10  1280x960

Summary

Spent a total of 2 min 3s on the website, and viewed 4 pages in 1 visits.
Converted 0 goals.

First visit

Friday, August 22, 2025 - 31 days ago
from Direct Entry

Devices

 1 visits from Desktop devices: Generic Desktop (1x)

Location

1 visit from Des Moines, United States  ([show map](#))

 Did you know? With [Heatmap & Session Recording](#) you can record all clicks, mouse movements, scrolls and form interactions of your visitors and replay them in a video to truly understand your visitors.

Visit #1

Friday, August 22, 2025 12:05:28

[4 actions in 2 min 3s](#)

-  02 Home | Tango Project
[/](#)
-  Description of the project | Tango Project
[/project-description](#)
-  Pilots | Tango Project
[/pilots](#)

These are all the visits for this visitor.

Figure 118: Number of external stakeholders participating in the validation campaigns KPI pages: Project Description, Pilots (Screenshot ID: ID TANGO-PILOTS-20250822-05).

Document name:	D7.2 Validation Report and Lessons Learnt	Page:	213 of 215
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	Version:	1.0	Status:
			Final



Visitor profile

ID 920cec6637267c78

Cologne (Ehrenfeld, Colo... Firefox 143.0

Windows 10 3440x1440

Summary

Spent a total of 4 hours 25 min on the website, and performed 163 actions (160 Pageviews, 2 Downloads, 1 Outlinks) in 31 visits.

Converted 0 goals.

Each page took 0.269s to load for this visitor on average.

First visit

Wednesday, July 23, 2025 - 61 days ago
from Direct Entry

Last visit

Monday, September 22, 2025 - 0 days ago
from Campaign: chatgpt.com -
www.perplexity.ai

Devices

31 visits from Desktop devices: Generic Desktop (31x)

Location

31 visits from different cities, Germany ([show map](#))



Did you know? With [Heatmap & Session Recording](#) you can record all clicks, mouse movements, scrolls and form interactions of your visitors and replay them in a video to truly understand your visitors.



Visit #31

Monday, September 22, 2025 13:11:05

[1 Actions](#)

Description of the project | Tango Project
</project-description>

Visit #30

Monday, September 15, 2025 18:01:52

[4 actions in 32s](#)

Home | Tango Project
[/](#)

Articles | Tango Project
</articles>

Articles | Tango Project
</articles?page=3>

Navigating the Terrain of Data Sovereignty: What about Individual Ri...
</articles/navigating-terrain-data-sovereignty-what-about-individual-...>

Visit #29

Friday, August 29, 2025 12:12:33

[2 actions in 9 min 6s](#)

Home | Tango Project
[/](#)

Visit #28

Friday, August 29, 2025 11:20:52

[3 actions in 9 min 45s](#)

Home | Tango Project
[/](#)

Figure 119: Number of external stakeholders participating in the validation campaigns KPI pages: Articles, Project Description, Navigating Data Sovereignty, etc. (Screenshot ID: ID-TANGO-ARTICLES-20250922-06).

Document name:	D7.2 Validation Report and Lessons Learnt					Page:	214 of 215
Reference:	D7.2	Dissemination:	PU	Version:	1.0	Status:	Final

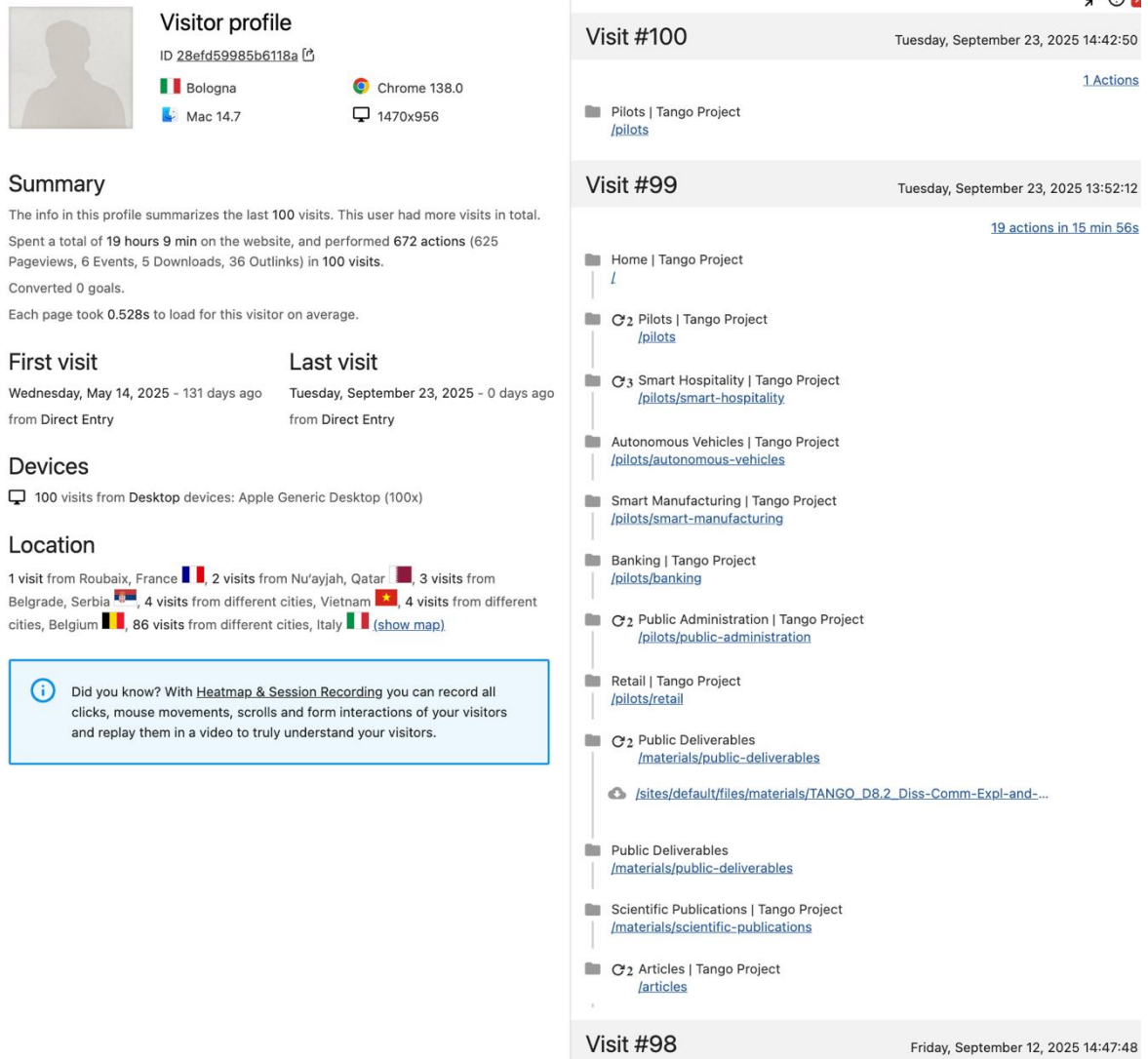


Figure 120: Number of external stakeholders participating in the validation campaigns KPI pages: Pilots (Smart Hospitality, Autonomous Vehicles, Smart Manufacturing, Banking, Public Administration, Retail), Deliverables, Publications, Articles (Screenshot ID: ID -TANGO-PILOTS-20250923-07).

9.8.21 Additional Material / Screenshots for Number of usage scenarios integrated

No additional material/screenshots provided by the partner.

9.8.22 Additional Material / Screenshots for Number of datasets uploaded on the proposed data spaces

No additional material/screenshots provided by the partner.

Document name:	D7.2 Validation Report and Lessons Learnt	Page:	215 of 215
Reference:	D7.2	Dissemination:	PU
	Version:	1.0	Status:
			Final