AI for real-world network operation

WP5 – Dissemination, communication, and exploitation of results

D5.4 – Exploitation plan and strategy phase 2

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SUMMARY

The present document presents the exploitation plan and strategy (phase 2) of the AI4REALNET project, developed in the framework of Task 5.4 – "Exploitation strategy and plan", as part of Work Package 5 – "Dissemination, Communication, and Exploitation".

Phase 2 of the Exploitation Plan outlines how AI4REALNET's results will be brought to market, ensuring widespread adoption, long-term sustainability, and maximising the potential for project perpetuation. The plan refines and expands the project's Key Exploitable Results (KERs) – AI-based decision systems designed to enhance real-world network operations. AI4REALNET's unique selling points lie in combining reinforcement learning with explainability and human-in-the-loop design, addressing the limitations of traditional optimisation and black-box AI methods. Unlike domain-specific or opaque systems, it offers a scalable, transparent framework adaptable to diverse infrastructures and sequential decision-making problems. It manages uncertainty, partial observability, and dynamic environments while reducing operators' cognitive load. Its open-source strategy, cross-sector applicability, and integration of prior knowledge position AI4REALNET as a future-ready solution for complex, safety-critical decision-making and ensures replicability and impact beyond energy and mobility, benefiting sectors like water, telecommunications, and emergency services.

As a result of three workshops, the project went from the original eight KERs to eleven. The following Table provides the revised list of KERs, outlining the problem addressed, the unique selling points, and its description. This overview helps identify their potential applications across different domains.

KER Name	Problem Addressed	Unique Selling Points	Description	IPR	TRL M18→End
KER 1: Conceptual AI framework for decision-making in critical infrastructures	Lack of a unified AI framework for decision-making in critical infrastructures	It bridges the gap between human control and AI automation by encouraging a symbiotic relationship where AI enhances, rather than replaces, human decision-making.	Conceptual framework that describes how a human-AI system as a hybrid intelligence interacts with the environment	Creative Commons: CC-BY[1] and CC-BY-NC-ND[2]	n.a.
KER 2.1: Knowledge-assisted AI building blocks	Real-time decision-making in large-scale infrastructure systems is challenging due to their inflexible nature, poor scalability, and long computational times.	Accelerates and scales AI-driven decision-making by seamlessly integrating advanced algorithms with existing human expertise	An advanced, fully implemented algorithm designed to optimise data handling and learning efficiency by integrating prior knowledge into the AI training process.	Open source software (OSS) with EUPL license	2 → 4/5
KER 2.2: Distributed and hierarchical AI building blocks	Reinforcement learning frequently shows scalability problems in high-dimensional real-world systems.	Increases AI scalability, minimises computational requirements by breaking complex tasks into simpler subproblems, enhances efficiency in real-time operations, and improves adaptability to dynamic environments.	The algorithm breaks down complex problems into simple subproblems and allows the avoidance of unfavourable dependencies between problem complexity and learning performance.	OSS with EUPL and MPL2.0 licenses	3 → 4/5
KER 3.1: Software XAI functions for transparent,	AI lacks transparency in critical decision-making scenarios where humans also play an important role, posing challenges to	Advances explainable AI by enhancing the transparency of complex AI systems and aligning their decision-making with human	Explainable AI enhances operators' understanding of AI behaviour, including policy clarity, decision and action explanation, and	OSS with EUPL and MPL2.0 licenses	3 → 4

KER Name	Problem Addressed	Unique Selling Points	Description	IPR	TRL M18→End
safe, and trustworthy AI	their adoption into mission-critical applications.	cognitive processes. Integrating methodologies from the Social Sciences and Humanities, particularly psychology, improves the clarity of AI-supported policies, decisions, and actions	early fault detection in extreme scenarios. Promote AI transparency and ensure alignment (between AI systems, interfaces, and human needs).		
KER 3.2: Software HMI functions for transparent, safe, and trustworthy AI	Difficulty in delivering AI outputs in a contextually relevant manner, ensuring operators can effectively interpret AI-generated insights.	Facilitates AI understanding for operators through intuitive interfaces, accelerates response times by streamlining decision-making processes, reduces cognitive load by presenting actionable insights, and ensures better human-AI interaction.	HMI is based on the hypervision concept, cross-cutting to any domain, using cognitive engineering to enhance AI transparency, with ecological interfaces tailored to user context for improved understanding of XAI outputs.	OSS with EUPL and MPL2.0 licenses	2 → 4
KER 4: Domain-agnostic dynamic AI-assistant	In critical infrastructures aligned with the EU AI Act risk-based approach, AI assistants can play an important role in supporting human operators in analysing and deciding complex and dynamic operating scenarios. However, the AI assistant should be able to handle uncertainty and variability in the system operation.	The AI assistant provides real-time, domain-agnostic decision support, adapting to operator preferences, cognitive load, and uncertainties. Unlike domain-specific tools, integrating human-in-the-loop feedback enhances trust, accuracy, and efficiency while significantly reducing cognitive stress and workload across critical sectors.	The AI assistance system supports operators with real-time alerts and recommendations across various domains. It integrates an RL agent, risk estimator, alarm system, and a user interface to assess situations, simulate outcomes, and guide decision-making.	OSS with EUPL license	2/3 → 4
KER 5: Human-AI co-learning and adjustable autonomy functions	AI systems face the "ironies of automation," either over-controlling or over-relying on humans. This lack of balanced teamwork and dynamic control sharing leads to rigid systems and hinders performance in critical operations.	The co-learning technology unlocks human-AI collaboration potential through a partnership where humans and AI learn from each other in real-time, enhancing decision-making. Human operators maintain control, enriching the AI with expertise and gaining new knowledge for improved outcomes.	AI solution using advanced RL with human input, inverse RL, XAI, and adjustable autonomy based on operator state. Supports real-time, multi-objective decision-making while reducing workload and improving transparency and resilience.	OSS, EUPL	2 → 4
KER 6: Integrated autonomous AI-driven decision system	Critical infrastructures often operate in dynamic environments where full human control is not feasible. Existing solutions rely on static algorithms that lack adaptability and expert knowledge only in the design phase, not in the AI's training process.	Through a user-friendly interface, it empowers human operators with actionable insights, boosting their effectiveness. By continuously learning and evolving without manual updates, this future-proof solution enhances decision-making and optimises operations across critical systems, ensuring adaptability to evolving demands and complexities.	Autonomous AI that learns from human behaviour to operate safely in complex environments, with explainability, continuous learning, and a user-friendly interface to enhance decision-making and adaptability.	OSS, EUPL	2 → 4
KER 7: Evaluation protocol for AI	Lack of comprehensive AI evaluation in critical infrastructures, including performance, safety, and societal impact. A dedicated protocol is	It follows a socio-technical approach, which, in addition to the technical components of an AI system, also considers human and systemic factors. For	Performance metrics and calculation routines (code) are linked to specific business/task objectives. They are intended to capture the technical,	OSS, EUPL	2 → 4/5

KER Name	Problem Addressed	Unique Selling Points	Description	IPR	TRL M18→End
	needed to assess performance indicators like robustness, resilience, user experience, and trust, ensuring equitable and effective deployment.	instance, it considers the context and interaction with the human operator.	economic, social, and human dimensions—functionalities embedded within existing AI-friendly digital environments.		
KER 8: Digital Environments	There is a lack of accessible (open-source) and standardised digital environments for AI development and benchmarking in critical networks. Moreover, access to data in critical infrastructure is challenging, which hinders the development of data-driven methods.	Offers an AI-friendly environment that emulates realistic operating scenarios and generates synthetic data, enabling the development and benchmarking of different AI-based approaches.	Open-source digital environments for power grid, railway, and ATM networks with baseline models, APIs and HMI (KER 3.2) for AI-environment-human interaction, different use cases and operating scenarios.	BlueSky: OSS with GPL 3.0 license Flatland: OSS with MIT license. Grid2Op: OSS with MPL-2.0 license	4 → 5
KER 9: Human-machine symbiosis	Human error in critical infrastructure is often linked to stress or misjudged well-being. Current systems rely on self-reporting, which can be inaccurate or uncomfortable, leading to poor data and risky decisions.	The solution enables real-time, non-intrusive cognitive stress assessment, allowing AI to adapt interactions without user input. It reduces mental burden, improves comfort, and enhances decision-making in high-stress situations for seamless human-AI collaboration.	It uses wearable sensors and AI to assess stress and cognitive state in real-time, enabling non-intrusive, adaptive human-AI interaction. It improves safety, efficiency, and decision-making by aligning AI responses with the operator's condition.	OSS with MIT license	3 → 5
[1] Creative Commons by attribution (CC-BY); [2] Creative Commons non-commercial no derivatives (CC-BY-NC-ND)					

A dual exploitation strategy is at the essence of AI4REALNET's roadmap. First, an open-source software model will make AI4REALNET's KERs widely accessible, fostering collaboration through platforms like GitHub, AI-on-Demand, and the Linux Foundation Association. This ensures continuous development and scalability, enabling AI communities to build upon the project's results. Second, a targeted commercialisation approach will promote industry adoption through strategic partnerships, results transfer to Associations, and the possibility of creating a partner working group dedicated to further developing and applying AI4REALNET outcomes.

The following table summarises the list of targeted associations, their description, justification, and sustainability strategy by KER.

KER	Host (beyond project duration)	Description and Justification	Exploitation Strategy
KER 2-7, 9 AI Building Blocks, AI-Based Decision Systems, Evaluation	Transfer as a single project where three options (Associations) are under consideration: Linux Foundation (LF) AI&Data, LF Energy, and LF Europe.	- Fair and neutral governance by the Association. - Legal and intellectual property protection. - LF could be a hub to attract funding and research grants from corporate sponsors. - There is the possibility of enhancing cross-industry collaborations. - Promote standardisation.	- Integrate AI4REALNET's results with existing LF projects to enhance visibility and adoption. - Clear contribution guidelines will be created to facilitate third-party involvement, ensuring a structured and transparent process for collaboration and continuous improvement. - Actively pursue opportunities through European funding programmes to ensure long-term sustainability and impact.
KER 8	LF for Energy	- Decoupling the project from the RTE brand and positioning it within	- Development of new proof-of-concept initiatives—such as

KER	Host (beyond project duration)	Description and Justification	Exploitation Strategy
Grid2Op digital environment (power grid)		a neutral and recognised open-source governance structure is essential. - Benefit from increased visibility, interoperability opportunities, and alignment with other energy sector open-source initiatives. - Integration with other LF Energy projects and working groups will create synergies, enabling joint exploration of common challenges and solutions in power system simulation and AI-based grid operation.	simulations on hardware accelerators or the integration of commercial solvers—that were previously limited. - This collaborative methodology will continue to be explored and expanded within the LF ecosystem, supporting ongoing innovation and wider adoption.
KER 8 Flatland digital environment (railway network)	Will remain with Flatland Association, which is an AI4REALNET project partner	- Neutral governance by the Association. - Legal and IP protection. - Provides open peer review and an open community in AI for the railway.	- Further research and development activities are supported by ongoing engagement with new partners and sponsors, many of whom are end-users who have already expressed interest in funding and supporting future work. - Actively pursue opportunities through European funding programmes to ensure long-term sustainability and impact.
KER 8 BlueSky digital environment (air traffic management)	Will remain with TU Delft, which is an AI4REALNET project partner	Exploit the opportunity to maintain a community that already exists. - Industry already uses it for prototyping (e.g., LVNL, ENAIRE) - Keep it close to an ecosystem of open-source tools such as OpenAP - Capacity to attract additional funding	- Further research and development activities are supported by ongoing engagement with new partners and sponsors, many of whom are end-users who have already expressed interest in funding and supporting future work. - Actively pursue opportunities through European funding programmes to ensure long-term sustainability and impact.

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ABBREVIATIONS AND ACRONYMS

AAM	Advanced air mobility
ADRA	AI, Data and Robotics Association
ADRA-e	Adra-ecosystem
AI	Artificial Intelligence
AIoD	AI-on-demand
ALTAI	Assessment list for trustworthy artificial intelligence
ANSP	Air navigation service providers
ATM	Air traffic management
BMC	Business Model Canvas
CAGR	Compound annual growth rate
DB	Deutsche Bahn
EOSC	European Open Science Cloud
EU	European Union
FAIR	Findability, Accessibility, Interoperability and Reusability
FHG	The Fraunhofer-Gesellschaft
FHNW	University of Applied Sciences and Arts Northwestern Switzerland
HAM	The Human Assessment Module
HMI	Human-Machine Interface
HR	Human Resources
ICT	Information and Communication Technology
IFATCA	International Federation of Air Traffic Controllers' Associations
IPR	Intellectual property rights
IRTSX	Institute for Technological Research SystemX
IT	Information Technology
KER	Key Exploitable Result
LACC	Levels of Autonomy Cognitive Control
LF	Linux Foundation for Energy
LiU	Linköping University
LOA	Levels of Automation
ML	Machine Learning
NAV	Navegação Aérea de Portugal
OSS	Open-source software
POLIMI	Politecnico di Milano
R&D	Research and Development
RL	Reinforcement Learning
RTE	Reseau de transport d'electricite

SBB	Swiss Federal Railways
SSH	Social Sciences and Humanities
TRL	Technology Readiness Level
TU DELFT	Technische Universiteit Delft
UKASSEL	University of Kassel
USP	Unique Selling Points
UTM	Unified Threat Management
UvA	University of Amsterdam
UVP	Unique Value Proposition
VUCA	Volatility, Uncertainty, Complexity, Ambiguity
WP	Working package
XAI	Explainable Artificial Intelligence
ZHAW	Zurich University of Applied Sciences

1. INTRODUCTION

The present document presents the second version of the Exploitation Plan of the AI4REALNET project. The AI4REALNET project stands at the forefront of integrating Artificial Intelligence (AI) into the operation of critical infrastructures, such as power grids, railway networks, and air traffic space. The project lies in a novel and multidisciplinary framework designed to augment decision-making in critical infrastructures through human-AI interaction and autonomous AI systems.

This phase aims to refine and expand the strategies for leveraging AI4REALNET's Key Exploitable Results (KERs), ensuring sustainability, adoption, and market readiness. It provides an updated analysis of market trends, unique selling points (USPs) of AI4REALNET outcomes, and potential exploitation pathways through open-source software (OSS) development, industry collaborations, and commercialisation opportunities.

The Exploitation Plan and Strategy – Phase 2 – is structured as follows:

- Section 2, "Market analysis overview," studies the market landscape for AI applications in critical infrastructure operations, presenting trends, challenges, and opportunities. It outlines the rapid growth of the AI market, with a particular emphasis on the increasing adoption of OSS AI solutions.
- Section 3, "Project's exploitation and sustainability plan," defines the roadmap for ensuring AI4REALNET's long-term impact. The exploitation plan presents an updated list of KERs. The unique selling points of AI4REALNET's AI-driven decision-making frameworks are outlined, emphasising their competitive advantages in the market. The OSS strategy focuses on AI4REALNET's commitment to open science, with plans to release KERs on GitHub and AI-on-Demand (AIoD). The sustainability plan explores other exploitation pathways, namely transferring project results to international associations that support OSS and AI development and can support the creation of a community that will continue research and industrialisation efforts and open the possibility to explore other commercialisation opportunities.
- Section 4, "Next activities,", dedicated to presenting a plan to identify the steps and activities that will be performed until the end of the project and that will be incorporated in the final exploitation plan.
- Section 5, "Conclusions," which summarises the key messages from the exploitation and sustainability plan.

2. MARKET ANALYSIS OVERVIEW

Organisations and industries are facing a significant transformation due to the rapid advances in AI. These advancements revolutionise decision-making processes, especially in critical sectors like railway management, air traffic control, and electricity, by improving efficiency, safety, and sustainability.

2.1.1 AI MARKET TRENDS AND OPEN SOURCE

According to Market Research Future (2025), the AI market is expected to grow from USD 406.3 billion in 2025 to USD 3819.2 billion by 2034, with a compound annual growth rate (CAGR) of 28.3%. The market is divided into Hardware, Software, and Services segments. In 2021, the software solutions category led the market with over 38% revenue share, thanks to significant advancements in storage capacity, powerful computing, and parallel processing capabilities.

AI technology's ability to analyse large amounts of data and predict future actions using sophisticated algorithms boosts productivity and transforms company management. Many startups and tech companies are adopting open-source AI platforms to enhance their value chains' efficiency.

A recent survey by McKinsey (2024) involving over 700 tech leaders and developers from 41 countries highlights key trends in adopting OSSAI. Key findings include:

- AI as a competitive advantage: Organizations that view AI as critical to their competitiveness are over 40% more likely to use OSS AI models and tools.
- Industry adoption: The technology sector leads this trend, with 72% of respondents' organisations using open-source AI models, compared to 63% across all industries.
- Benefits of OSSAI:
    - Cost Savings: 60% of decision-makers report lower implementation costs with open-source AI versus proprietary tools.
    - Developer Community Value: 81% of developers highly value experience with OSS tools.

2.1.2 RAILWAY NETWORK

According to the European Rail Industry Market Study (2024), which analyses 66 countries that account for 99% of global rail traffic and the entire rail supply value chain, the global market is expected to grow by 3% annually in real terms. Straits Research (2023) expects global IT spending in railways to increase at a 9.8% CAGR through 2026. Increasing investments in smart transportation infrastructure and the push for decarbonised public transport systems drive the adoption of AI technologies.

McKinsey (2024) also highlights that AI technologies are transforming railway companies by improving planning and operational efficiency. Decreasing data storage and processing costs and increasing data availability drive AI adoption. The report highlights that greater AI adoption could unlock significant financial impact, estimated between $13 billion to $22 billion annually. However, challenges such as data quality, regulatory considerations, and standardisation must be addressed for successful implementation.

InterTech Rail (2025) states that AI and machine learning (ML) applications in railway management can enhance operations, boosting efficiency and cost-effectiveness. The following benefits have been appointed:

- *Optimization of train routing and scheduling:* By analysing a vast amount of data, AI can determine the most efficient routes for trains. This feature can reduce delays and improve the flow of trains through the yard, leading to increased productivity and lower operating costs.
- *Improve safety and environmental sustainability in rail yard management:* Algorithms can detect potential safety hazards, such as trains or railcars in unsafe positions, and alert yard workers to take corrective action. Additionally, AI can monitor the behaviour of yard workers, ensuring they follow safe operating procedures and identifying areas where additional training may be required.
- *Improved communication and collaboration in rail yard management:* AI algorithms can provide real-time updates on train and railcar movements, enabling yard workers to respond quickly to changing conditions and make informed decisions.

2.1.3 AIR TRAFFIC MANAGEMENT

According to Grandview Research (2023), the global ATM market was estimated at $8.64 billion in 2023 and is projected to grow by 8.6% from 2024 to 2030. The growth is attributed to the integration of advanced technologies like AI and ML. While specific data on its applications remains limited, AI is being explored to optimise flight routes, enhance air traffic control systems, and enable predictive aircraft maintenance. These innovations could help manage rising air traffic volumes while boosting operational efficiency. Figure 1 presents the growth market by component hardware and software solutions.

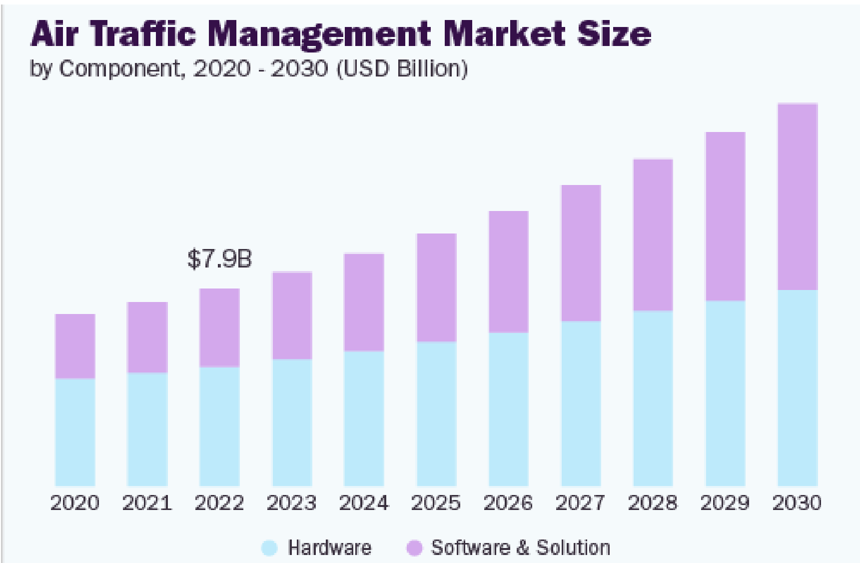

FIGURE 1 – AIR TRAFFIC MANAGEMENT MARKET SIZE BY COMPONENT. SOURCE: GRAND VIEW RESEARCH (2023)

Eurocontrol (2024) discusses how digitalisation and AI are transforming air traffic control, focusing on the need to balance technological innovation with the human element to ensure safety, efficiency, and reliability in the future of air traffic management. The report emphasises that, although AI offers significant benefits, the human element has deep expertise and enables traffic controllers to handle complex and unforeseen situations. Helena Sjöström Falk, President and Chief Executive Officer of the International Federation of Air Traffic Controllers Associations (IFATCA), emphasised the importance of a balanced approach between humans and technology: "*To maximise the benefits of digitalisation and AI while preserving the core role of air traffic controllers, IFATCA advocates for a balanced and integrative approach. AI and digital systems should serve as collaborative tools, providing controllers with valuable insights and support. Controllers should retain ultimate authority over decisions, with AI augmenting rather than replacing them*" (Eurocontrol, 2024).

In conclusion, AI is transforming air traffic control, presenting unparalleled opportunities to enhance safety, efficiency, and capacity. However, the human element – the skilled and experienced air traffic controllers – remains central to the system. By adopting a user-centred development approach that prioritises the needs and expertise of the user and by combining technological innovation with human knowledge, the aviation industry can effectively harness the benefits of both. As the technological landscape continues to evolve, ensuring that controllers remain at the heart of air traffic control, as advocated by IFATCA, will be essential for a safer and more efficient future in aviation (Eurocontrol, 2024).

2.1.4 POWER GRID

According to Allied Market Research (2024), the global AI in energy market was valued at USD 5.4 billion in 2023 and is projected to reach USD 14.0 billion by 2029, growing at a CAGR of 17.2% from 2024 to 2029. AI has over 50 applications in the energy sector, potentially making the market worth up to USD 13 billion. By processing large datasets, including historical climate patterns, energy production data, and real-time sensor data, AI helps improve supply and demand predictions. Understanding when renewable power is available and needed is crucial for next-generation power systems.

The Department of Energy CESER (2024) reinforced the significant potential of AI in transforming critical energy infrastructure. According to the study, AI offers numerous benefits, particularly in enhancing security, reliability, and resilience across the sector. However, to fully realise these benefits, the report stresses the need for regularly updated, risk-aware best practice guidelines that facilitate the safe and effective deployment of AI in critical energy infrastructure.

2.1.5 CONCLUDING REMARKS

In conclusion, we highlight the following points:

- AI is transforming Europe's critical infrastructures across various sectors. Its adoption in essential systems, including but not limited to energy, transportation, and telecommunications, is accelerating due to the growing demand for efficiency, sustainability, and safety.
- Despite the benefits, integrating AI into critical network infrastructures in Europe presents challenges, including data privacy concerns, cybersecurity risks, and the need for substantial investments in infrastructure and training.

- While the market for AI infrastructure is poised for significant growth, addressing the associated challenges is crucial for sustainable and effective integration.
- Open-source AI solutions hold the potential for rapid innovation and collaboration, making them an attractive option for stakeholders in these sectors. By addressing key pain and aligning with regulatory requirements, open-source AI software can carve a niche in this evolving market.

Furthermore, considering the context of AI4REALNET in terms of the full release of all results in OSS, it is important to mention that, unlike proprietary systems, open-source AI allows network operators to customise and scale solutions to their specific operational needs. Open-source AI also enhances security by enabling continuous peer review and reducing reliance on closed, opaque algorithms. Additionally, it facilitates compliance with regulatory standards by promoting transparency in AI decision-making processes. As industries increasingly adopt AI-driven solutions, OSS platforms can help lower implementation costs and reduce high dependency on vendor development efforts.

3. EXPLOITATION AND SUSTAINABILITY PLAN

3.1 EXPLOITATION PLAN

3.1.1 GLOBAL VALUE PROPOSITION AND UNIQUE SELLING POINTS OF AI4REALNET

The AI4REALNET project KERs are significant outcomes that deliver unique advantages, forming the **Unique Selling Points (USPs) and Unique Value Proposition (UVP)** that distinguish AI4REALNET in the market.

A **USP** highlights a product or service's unique features and benefits compared to its competitors, providing a clear message to potential customers and addressing their pains. The **UVP** is the overall value it provides its customers, showcasing the gains compared to alternatives. While a USP is a part of a UVP, a UVP encompasses a broader range of values.

The unique value of AI4REALNET lies in its alignment of core expertise with real industry needs. Through direct engagement with stakeholders—such as network operators within the consortium and public webinars held as part of WP1 activities (see Deliverable D1.1, Bessa et al., 2024)—AI4REALNET has identified key market demands and tailored its AI-driven solutions to address practical, real-world challenges.

Looking at the USP of the project results, AI4REALNET uses reinforcement learning (RL) as a core AI technology for decision-making across different time horizons, ranging from long-term planning to real-time operations. This approach is combined with explainability and cognitive transparency in human-AI interaction, suitable for operational scenarios that are typically characterised by multiple features that make the decision-making process particularly challenging. AI4REALNET solutions are designed for systems characterised by interconnected subsystems, time-sensitive decisions (regularly made by humans), stochastic behaviour, dynamic changes over time, and the need to manage cascading events and extreme cases.

While initially focused on power grids, railway networks, and air traffic management, AI4REALNET provides a decision-making framework that extends beyond these specific domains. Many industries, including water and wastewater management, telecommunications, emergency services, and defence, face similar challenges in balancing real-time decision-making, multi-operator coordination, and uncertainty management. The adaptability of AI4REALNET ensures that its methodologies can be applied across diverse infrastructure sectors, making it a valuable solution for complex, safety-critical environments. In fact, infrastructures such as power grids and railways are becoming central and impacting other infrastructures, with known examples such as energy-water nexus, electrical mobility, and intermodal transportation.

A cross-sector analysis of decision-making processes conducted with industry within the project highlighted strong similarities across different infrastructure domains (Bessa et al., 2024). Despite differences in context, common characteristics were identified, including the interaction between human operators and AI systems, the involvement of multiple stakeholders, time resolution, action type and space complexity, the need for trade-offs on conflicting objectives, and the handling of disruptions caused by emergencies or external events. The RL-based solution developed in AI4REALNET is designed to be generalisable to decision-making processes characterised by the framework from Figure 2. All these scenarios share fundamental requirements that must be met, emphasising the necessity of human involvement beyond simply validating AI-driven decisions.

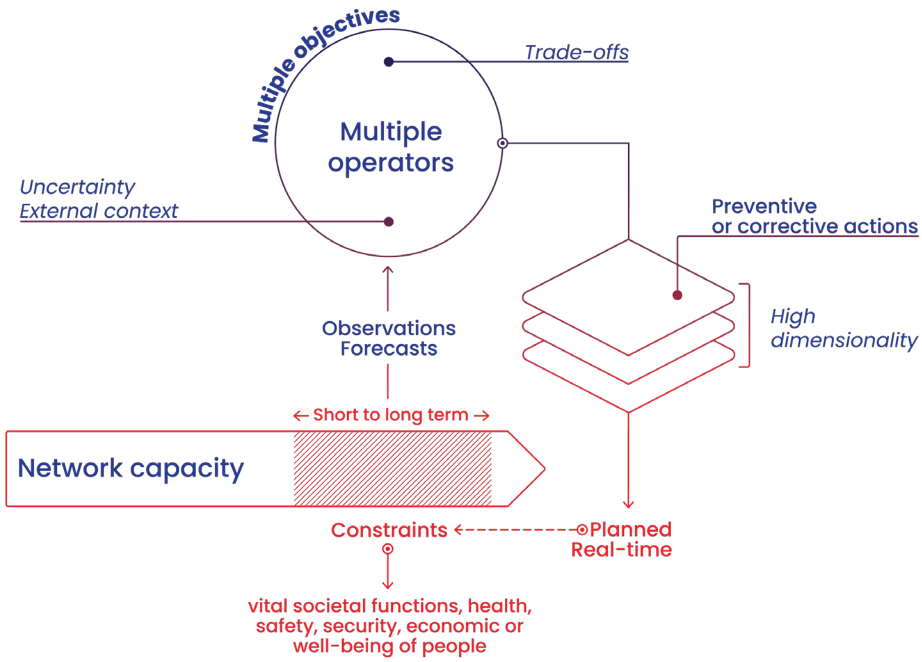

FIGURE 2 – GENERIC DECISION-MAKING FRAMEWORK FOR WHERE AI4REALNET'S KERS FIT

AI4REALNET presents several advantages **over traditional model-driven and mathematical optimisation approaches**. AI enables real-time insights and decision recommendations that human operators can manually execute or integrate into automated human-in-the-loop workflows. Moreover, it effectively addresses challenges such as partial observability, complex modelling of physical equations, non-stationarity (i.e., adaptability to changing conditions in real-world environments), multi-step planning, and uncertainty quantification, making it more robust to real-world applications.

Beyond conventional supervised and reinforcement learning techniques, AI4REALNET introduces knowledge-assisted, distributed, and hierarchical learning paradigms. These innovations reduce computational costs and enhance scalability in large-scale systems. Moreover, the explainability and transparency components enable AI models to recognise their limitations, facilitating deferral to human operators when needed. This co-learning mechanism ensures that AI remains a support tool rather than an unclear decision-maker, fostering trust and operational resilience.

For human operators managing critical infrastructures, AI4REALNET alleviates cognitive load by simplifying information processing, reducing the number of interfaces and tools required for monitoring, and providing actionable insights without overwhelming users. The system enhances situational awareness while preserving transparency and human oversight, ensuring that operators remain fully engaged in decision-making without undue complexity.

The flexibility and scalability of AI4REALNET position it as a transformative AI framework that is not confined to specific use cases. By demonstrating its applicability across multiple infrastructures, the project establishes a foundation for AI-driven decision support that is adaptable, explainable, and aligned with the operational needs of diverse infrastructure industries.

After presenting the project's USP, the focus shifts to the USPs of each KER. The following section introduces KER Management, outlining the project's results along with the problems they address, their USP, existing market solutions, targeted market segments, and go-to-market strategies.

3.1.2 KER MANAGEMENT

The Exploitation Plan required the identification and effective management of the KERs. A KER is defined as:

> *"A Key Exploitable Result is an identified main interesting result which has been selected and prioritised due to its high potential to be "exploited" – meaning to make use and derive benefits- downstream the value chain of a product, process or solution, or act as an important input to policy, further research, or education. The criteria that make a result Key Exploitable are (a) the degree of innovation, (b) their exploitability and (c) their impact".*
>
> European IP Helpdesk (2021)

During Phase 2 (M7-M18), the project refines existing KERs and explores the potential for new ones through a deeper analysis of project results. Building on Phase 1, where KERs were initially characterised and a general go-to-market strategy was outlined, this phase expands on the initial identification process, ensuring that each KER is well-defined and considers the ongoing developments, results, and market challenges and needs. During Phase 3 (M19-M42), the most promising KERs will be refined through cost analysis, risk assessment, and scalability evaluations. A detailed SWOT analysis will assess market conditions, intellectual property considerations, and strategic feasibility, ensuring successful exploitation and long-term impact.

From M7 to M18, the AI4REALNET project has carried out several key activities to refine and expand the KERs. These efforts have included an in-depth analysis of project outcomes, exploring opportunities for new KERs, and assessing their relevance and potential impact. Additionally, the project has evaluated market challenges, identified existing solutions, and defined each KER's USP and UVP. This refinement process also involved identifying target markets, early adopters, and suitable business models to maximise the real-world application and adoption of AI4REALNET's innovations. Namely:

1. **KER WORKSHOPS AND REVIEW:** Three online workshops were conducted to enhance the characterisation of KERs, bringing together **41 participants and five facilitators** in interactive exercises. A detailed description of the workshop objectives and framework can be found in Annex 1. As a result of these workshops, new KERs were identified, including **KER 2.1, KER 2.2, KER 3.1, KER 3.2, and KER 9**. A refined version of the KER characterisation was then shared with all project partners, allowing them to provide comments and feedback. Additionally, interviews were conducted with select KER owners, including those responsible for KER 8 (Digital Environments). These interviews aimed to deepen the understanding of specific results

and explore potential exploitation pathways in collaboration with the involved partners. The complete characterisation is available from Table 1 to Table 11.

2. **HORIZON RESULTS BOOSTER:** In July 2024, the AI4REALNET team applied to the Horizon Results Booster services and the application was approved. The services started in October of the same year; nevertheless, in collaboration with the experts' team, it was decided to postpone the services to fall under the new updated Horizon Results Booster. This programme aims to help beneficiaries of Horizon Europe, the EU research and innovation programme, bring their research or innovations to concrete use and maximise their impact (Directorate-General for Research and Innovation, 2024). So far, we have had the kick-off, established the service roadmap, and received the Entry Level Consultation Report with the identification of other opportunities for Dissemination and Exploitation support. Under the new programme, the roadmap defined is:
    - Go-to-market: Module A: Kick-off – March 2025 (M18)
    - Go-to-market: Module B: Unique Value Proposition & Key Exploitable Results – March 2025 (M18)
    - Go-to-market: Module C: Exploitation Strategy – April 2025 (M19)
    - Go-to-market: Module D: Business Plan – June 2025 (M21)
    - Go-to-market: Module F: Reporting – July 2025 (M22)
    - Networking – To be defined
    - Intellectual Management Assets – To be defined

3.1.3 AI4REALNET CURRENT KERS

KER 1: Conceptual AI framework for decision-making in critical infrastructures	
Problem	There is a lack of conceptual frameworks supporting socio-technical systems' design, development, and testing, such as cooperation between humans and AI. This is particularly relevant for critical infrastructures that rely on humans to make high-stakes decisions. In this way, a critical need exists for a specialised tool tailored to AI systems designed for critical infrastructure. This tool is essential for ensuring that functional and non-functional requirements, including appropriate trustworthiness and human-AI interaction, are met and assessed.
Current solutions	Current solutions offer insights into integrating AI for decision-making in critical infrastructures but tend to focus on specific sectors or challenges. There is a growing demand for a unified conceptual framework encompassing the diverse requirements of critical infrastructures that balance technical, ethical, and human considerations.
Description	A conceptual framework that describes how a human-AI system as a hybrid intelligence interacts with the environment. It encapsulates the operator's point of view and its synergies with other components and stakeholders integrated within a more extensive system. It also includes a method to assess trustworthiness and derive functional and non-functional requirements aligned with the EU framework for trustworthy AI, i.e., Assessment List for Trustworthy Artificial Intelligence (ALTAI) adapted to the context of safety-critical systems considering the ethical and epistemological analysis of risk, uncertainty, and trustworthiness.
USP	The AI4REALNET framework interconnects human control and AI automation by creating a reciprocal relationship where AI enhances, rather than replaces human decision-making. It advances the development of human-AI systems that are not only technically robust but

	also ethically and contextually aware, ensuring adaptability to dynamic operational conditions. Additionally, as it integrates transparency, trust, and accountability, the framework will enhance social and technical performance, leading to safer and more effective decision-making.
UVP	For network operators, AI developers, and control system providers, the multi-disciplinary conceptual framework enables the co-design of the social-technical system considering the organisation, AI developer, and user (e.g., a human operator). It offers a structured approach to designing, evaluating, and validating human-AI interactions, ensuring compliance for trustworthy AI integration.
Market: Target markets	AI and automated systems; human-machine interfaces. *Customer Segments*: Network operators (of critical infrastructures); ICT/Control system providers; AI service providers.
Market: Early adopters	Network operators (of critical infrastructures). They will be the ones to set the fundamental requirements for AI systems and how they should be integrated with the existing ecosystem.
Go-to-Market: Use Model	AI4REALNET will generate examples of framework applications and, combined with the algorithms from WPs 2-3 (KER 2.1 to KER 6), will offer proof of concept for industry and academia. It will use Creative Commons by attribution (CC-BY) and Creative Commons non-commercial no derivatives (CC-BY-NC-ND) for a scientific paper (under review in Cell Press iScience journal) and an Adra-e book chapter. Based on this KER, several potential products and services can be generated, such as: a) consulting in designing and assessing collaborative AI systems in critical infrastructure sectors, b) training for designers or regulatory staff on design considerations and performance indicators, and c) publishing the framework and uses cases in a widely accessible manner.
TRL (current) and TRL (at the end of the project)	Not applicable.

TABLE 1 – KER 1. CONCEPTUAL AI FRAMEWORK FOR DECISION-MAKING IN CRITICAL INFRASTRUCTURES

KER 2.1: Knowledge-assisted AI building blocks	
Problem	Real-time decision-making in large-scale infrastructure systems is challenging due to their inflexible nature, poor scalability, and long computational times. Solvers struggle with scalability, efficiency, and adaptability, often failing to integrate human expertise, which provides important insights into environmental dynamics and significantly improves solution quality and overall system flexibility. Existing methods rely on a) rigid manual strategies or b) abstraction-based heuristics that omit critical details, leading to suboptimal solutions. In either case, there might be a significant gap in quality with the optimal solution.
Current solutions	Companies currently rely on human expertise to monitor and interact with critical infrastructure, using forecasts and simple models for environmental interaction. However, manually designed strategies often fall short, particularly with unfamiliar problem types. Traditional machine learning methods require extensive training time and struggle with the complexity seen in real-world network domains. Existing algorithms and heuristics designed for specific domains lack the flexibility to integrate with human operators effectively. In scenarios where these methods fail to produce viable solutions, humans are forced to take over despite often lacking the capability to understand or solve these complex problems independently.

Description	An advanced algorithm with a fully implemented source code designed to optimise data handling and learning efficiency by leveraging existing knowledge. The interface specifies the expected form of the prior knowledge and a comprehensive algorithm description. With the integration of this prior knowledge base into the learning process, there is a significant increment in performance when compared to conventional methods lacking the input by accelerating and scaling the learning process, enabling high-quality results on larger-scale tasks with smaller datasets, offering faster and more efficient solutions for complex problems. To guarantee ease of use, the AI building blocks are complemented with detailed documentation to support their integration.
USP	The solution accelerates and scales AI-driven decision-making by seamlessly integrating advanced algorithms with existing human expertise. Unlike traditional systems, it combines data-driven and knowledge-driven approaches, significantly improving performance even with smaller datasets and complex scenarios. This capability enables faster adaptation, uncovering critical insights often overlooked in infrastructure networks, thus optimising real-time decision-making, reducing operational costs, and improving overall service quality.
UVP	For infrastructure network operators and AI developers seeking robust, flexible, and scalable decision-making solutions, our solution delivers superior performance by effectively leveraging prior domain knowledge. Unlike conventional machine learning, this algorithm excels in scenarios with limited datasets and computational constraints. Accelerating learning, enhancing adaptability, and integrating human insights ensure consistent optimisation outcomes, operational efficiency, significant cost savings, and greater reliability in managing complex infrastructure systems.
Market: Target markets	*Target Market:* AI-based decision systems for large networks where scalability is a key challenge for AI adoption, along with knowledge databases with heuristics rules and mathematical models for decision-making. *Customer Segments*: Network operators (of critical infrastructures); AI service providers; ICT and Control system providers.
Market: Early adopters	Network operators (of critical infrastructures); AI community (researchers, developers, practitioners, corporate R&D); *Integrators:* AI and service providers, ICT and control systems providers.
Go-to-Market: Use Model	The Go-to-Market strategy for the AI building blocks centres on releasing them as OSS on platforms like GitHub and the AIoD platform, encouraging community development and positioning the project as a leader in AI innovation. This will also be one of the models used in all the software-based KERs, from KER 2.1 to KER 8. The project partners can offer training and consultancy to network operators and AI service providers, generating new revenue streams while building industry leadership. The building blocks will serve as a foundation for future R&D, enabling the development of digital assistants for network operations and creating opportunities for collaboration, commercialisation, and securing funding for new projects. We aim to use this KER as a foundation for further research on digital assistants. By focusing on more specific questions, we can enhance the basic functionality of digital assistants. This will, in turn, provide value through new projects that use this framework. This KER has the following potential applications: a) Promoting results through open-access scientific publication, b) establishing public-private collaborations in follow-up projects, and c) offering consultancy services to infrastructure network operators, control system providers, and AI developers, helping integrate AI building blocks into their solutions.
TRL (current) and TRL (at the end of the project)	TRL 2 -> TRL 4/5

TABLE 2 – KER 2.1. KNOWLEDGE-ASSISTED AI BUILDING BLOCKS

KER 2.2: Distributed and Hierarchical AI building blocks	
Problem	Existing solutions typically rely on a single controller to manage the environment. However, using a single controller for high-dimensional problems becomes increasingly inefficient as dimensionality grows. The learning process requires a data volume that scales exponentially with the problem's complexity. Moreover, treating the environment as a monolithic system means that any internal change can invalidate previously acquired knowledge and datasets, ultimately rendering traditional approaches ineffective.
Current solutions	Current solutions struggle with scalability in high-dimensional control problems, as they must manage exponentially increasing data as problem dimensions grow. Although optimization-based approaches exist, they typically rely on prior knowledge of the underlying model, preventing their applicability in scenarios where this information is unavailable or incomplete. Moreover, a key bottleneck in applying optimisation-based methods is their poor scalability and the prolonged time required for decision-making, which severely restricts their practical applicability.
Description	The algorithm processes data to enable the learning and execution of control tasks. Its core capability lies in breaking down complex problems into simpler subproblems, ensuring efficient handling. A unique feature of this approach is its ability to avoid unfavourable dependencies between problem complexity and learning performance, ensuring scalability and efficiency even as problem dimensions increase.
USP	The advanced algorithm addresses scalability issues inherent in high-dimensional control problems by decomposing complex tasks into simpler subproblems. Unlike traditional centralised solutions, this approach mitigates the exponential growth in data requirements with increasing problem dimensions, achieving superior scalability, minimised computational effort, and reduced dependency on extensive datasets.
UVP	For researchers and developers dissatisfied with traditional centralised control solutions, these distributed and hierarchical AI building blocks ensure efficient scalability and minimal data dependency. Unlike conventional methods that require significant computational resources and struggle in real-time contexts, this approach simplifies complex control tasks into manageable subtasks. It ensures robust performance with limited datasets, significantly reduces computational overhead, and effectively addresses real-time decision-making challenges in large-scale scenarios.
Market: Target markets	Target Market: AI-based decision-making systems require a hierarchical or distributed approach incorporating human domain expertise. *Customer Segments*: Network operators (of critical infrastructures); AI service providers; ICT and Control system providers.
Market: Early adopters	Network operators (of critical infrastructures). AI community (researchers, developers, practitioners, corporate R&D). Integrators: AI and service providers, ICT and control systems providers.
Go-to-Market: Use Model	Consistent with the established Go-to-Market: Use Model strategy, this result relies on open-source release and community-driven growth (GitHub and AIoD). The project partners can offer training and consultancy to network operators and AI service providers, generating new revenue streams while building industry leadership. The building blocks will serve as a foundation for future R&D, enabling the development of digital assistants for network operations and creating opportunities for collaboration, commercialisation, and securing funding for new projects. The value we would like to get from this KER: The basis for further research on digital assistants, with more focused questions. (that then uses this for base functionality) will get value through new projects that use the framework. This KER has the following potential applications: a) promoting results through open-access scientific publications, b) establishment of public-private collaborations in follow-up projects, and c) offering consultancy services to infrastructure network operators, control system providers, and AI developers, helping integrate AI building blocks into their solutions.

TRL (current) and TRL (at the end of the project)	TRL 3 -> TRL 4/5

TABLE 3 – KER 2.2. DISTRIBUTED AND HIERARCHICAL AI BUILDING BLOCKS

KER 3.1: Software XAI functions for transparent, safe, and trustworthy AI	
Problem	State-of-the-art AI systems often lack transparency and explainability, posing challenges for their adoption to critical applications. These models do not try to facilitate understanding the reasoning behind AI decisions by operators and other stakeholders, limiting accountability. In critical infrastructure, the lack of clarity behind them can pose risks since it does not allow operators to validate and adjust quickly. Due to the critical nature of these high-stakes domains that need high levels of transparency and reliability, the absence of explainability is perilous.
Current solutions	Critical infrastructure management primarily relies on human expertise due to a mistrust of AI solutions, mainly stemming from their lack of explainability. The complexity of these domains and the growing solution space challenge human capabilities, highlighting the need for AI integration. Efforts are being made to develop explainable and trustworthy AI tools, but their validation in safety-critical infrastructures remains incomplete, keeping AI's implementation limited in these areas.
Description	The KER involves: a) applying Social Sciences and Humanities methodologies to inform the design of AI decision support systems, incorporating psychological insights into human cognition. b) developing explainable AI (XAI) to enhance operator understanding of AI behaviour, including policy clarity, decision and action explanation, and early fault detection in extreme scenarios. c) exploring cognitive engineering to promote AI transparency and ensure alignment between AI systems, interfaces, and human needs.
USP	It advances XAI by enhancing the transparency of complex AI systems and supporting their decision-making with human cognitive processes. Integrating methodologies from the Social Sciences and Humanities, particularly psychology, improves the clarity of AI-supported policies, decisions, and actions. Improving situational awareness and decision-making quality leads to faster, more accurate decisions, minimising delays. The open-source nature of the solution provides incremental scientific value, ensuring future development and continuous innovation. This XAI solution supports and empowers operators by reducing training time, boosting motivation, and improving work satisfaction, all while delivering superior, AI-enhanced performance.
UVP	This solution delivers value for network operators in critical infrastructure domains by providing transparent and trustworthy AI-driven decision-making capabilities. It enhances operator trust and confidence through advanced explainability features, including decision-path visualisation, feature importance rankings, and clear, scenario-based explanations. Designed specifically for operators who find it challenging to interpret AI-generated insights in real-time, this solution presents a comprehensive interface that streamlines interaction between humans and machines, reducing cognitive load, minimising training effort, and improving job satisfaction. Accelerating critical decision-making and reducing validation time ensures safer, more efficient operations while maintaining high accountability and operator confidence.
Market Target markets	Target Market: Operators and decision-makers across various industries, including but not limited to defence, healthcare, finance, and logistics, starting in critical infrastructures. These professionals seek advanced AI systems that enhance decision-making processes while ensuring transparency and reliability. They value solutions that integrate SSH methodologies to support human cognition, providing clear explanations and early fault detection in critical scenarios. *Customer segments:* Network operators (of critical

	infrastructures); AI service providers; ICT and Control system providers. AI community: researchers, developers, and practitioners, corporate R&D).
Market: Early adopters	In the energy sector, smart grid operators, renewable energy companies, and energy management software providers are leading the adoption of XAI functionalities to enhance decision-making transparency in demand-response management, energy forecasting, and efficiency recommendations. TSOs that incur high costs due to dispatching and system outages can also be considered. Similarly, in the railway industry, urban transit authorities, freight rail operators, and rail infrastructure maintenance firms could embrace these technologies to improve overall operational efficiency. In ATM, ANSPs and their operators (strategic and tactical ATCOs) can benefit from the solution.
Go-to-Market: Use Model	This result adopts a model-based strategy and leverages open-source release and community-driven growth through platforms like GitHub and the AIoD ecosystem. Project partners can offer training and consultancy services to network operators and AI service providers, creating new revenue streams while strengthening their position as industry leaders. The XAI software functions will form the foundation for future R&D efforts, supporting the development of digital assistants for network operations and opening pathways for collaboration, commercialisation, and funding of new initiatives. This Key Exploitable Result (KER) will also serve as a basis for further research into more specialised digital assistant applications. The software will continue to evolve, with new features added through subsequent projects that adopt and extend the framework. This KER has the following potential applications: a) promoting results through open-access scientific publications, b) establishment of public-private collaborations in follow-up projects, and c) offering consultancy services to infrastructure network operators, control system providers, and AI developers, helping integrate Software XAI functions into their solutions.
TRL (current) and TRL (at the end of the project)	TRL 3 -> TRL 4

TABLE 4 – KER 3.1. SOFTWARE XAI FUNCTIONS FOR TRANSPARENT, SAFE, AND TRUSTWORTHY AI

KER 3.2: Software HMI functions for transparent, safe, and trustworthy AI	
Problem	The core problem is the difficulty of delivering AI outputs in a contextually relevant manner, ensuring operators can effectively interpret AI-generated insights. Without these tailored approaches to contexts, XAI outputs are essentially less actionable.
Current solutions	Existing HMI solutions often lack intuitive visualisations or precise mechanisms for operators to interpret AI-generated decisions quickly. Most available HMIs do not sufficiently integrate explainability methods, leaving operators reliant on manual interpretation, thus potentially delaying critical operational responses.
Description	Based on the hypervision concept, human-machine interface modules serve as operators in understanding the outputs of XAI methods and are cross-cutting to different domains. These interfaces are designed to translate complex AI reasoning into accessible, actionable insights for end users. The approach involves investigating principles from cognitive engineering to enhance AI transparency, ensuring that both the AI systems and their interfaces are line up with human cognitive processes and operational needs. A key aspect is the design of ecological HMI solutions, interfaces that are intuitively tailored to the specific context and tasks of the user, to support the interpretation and usability of XAI algorithms effectively.
USP	The solution changes operators' interaction with complex automated systems by seamlessly integrating with XAI algorithms. It enables faster decision-making and higher-quality outcomes, reduces workload and training time, and empowers operators to engage more efficiently with the system, resulting in higher job satisfaction. The HMI not only lowers

	operating costs through efficient decision-making strategies but also enables a proactive approach to managing complex systems in a user-friendly way.
UVP	Directed to operators in critical infrastructure who find it challenging to interpret AI-generated insights and recommendations in real-time, this solution presents a comprehensive interface that streamlines interaction between humans and machines. Reducing cognitive load, decreasing training effort, and improving job satisfaction are achieved while enhancing critical decision-making in a shorter timeframe.
Market Target markets	Target Market: Operators and decision-makers across various industries, including but not limited to defence, healthcare, finance, and logistics, starting in critical infrastructures. These professionals seek advanced AI systems that enhance decision-making processes while ensuring transparency and reliability. They value solutions that integrate SSH methodologies to align with human cognition, providing clear explanations and early fault detection in critical scenarios. *Customer segments:* Network operators (of critical infrastructures); AI service providers; ICT and Control system providers. AI community: researchers, developers, and practitioners, corporate R&D).
Market: Early adopters	In the energy sector, smart grid operators, renewable energy companies, and energy management software providers are leading the adoption of XAI/HMI functionalities to enhance decision-making transparency in demand-response management, energy forecasting, and efficiency recommendations. TSOs that incur high costs due to dispatching and system outages can also be considered. Similarly, in the railway industry, urban transit authorities, freight rail operators, and rail infrastructure maintenance firms could embrace these technologies to improve overall operational efficiency. In ATM, ANSPs and their operators (strategic and tactical ATCOs) can benefit from the solution.
Go-to-Market: Use Model	Consistent with the established Go-to-Market: Use Model strategy, this result also relies on open-source release and community-driven growth (GitHub and AIoD). The project partners can offer training and consultancy to network operators and AI service providers, generating new revenue streams while building industry leadership. The Software HMI functions will serve as a foundation for future R&D, enabling the development of digital assistants for network operations and creating opportunities for collaboration, commercialisation, and securing funding for new projects. This KER would be used as a basis for further research on digital assistants with more focused applications. The software functionality will be enhanced via additional features from new projects that use the framework. This KER has the following potential applications: a) promoting results through open-access scientific publications, b) establishment of public-private collaborations in follow-up projects, and c) offering consultancy services to infrastructure network operators, control system providers, and AI developers, helping integrate software HMI functions into their own solutions.
TRL (current) and TRL (at the end of the project)	TRL 2 -> TRL 4

TABLE 5 – KER 3.2. SOFTWARE HMI FUNCTIONS FOR TRANSPARENT, SAFE, AND TRUSTWORTHY AI

KER 4: Domain-agnostic dynamic AI-assistant	
Problem	In critical infrastructures aligned with the EU AI Act risk-based approach, AI assistants can play an important role in supporting human operators in analysing and deciding complex and dynamic operating scenarios. However, the AI assistant should be able to handle uncertainty and variability in the system (network) operation, including the impact of natural hazards, but also communicate with humans. The potential risks and confidence of recommendations made by the AI system to human operators. This gap hinders operators' ability to select the most trustworthy AI solutions based on past performance and to appropriately adjust their risk thresholds in accordance with the criticality of the decisions

	at hand, ultimately affecting the decision-making process and trust in AI-assisted operations. An important question is whether the uncertainty aspect of an AI assistant can be made in a domain-agnostic way or whether the types of uncertainty are too domain-specific for a unified approach.
Current solutions	Currently, real-time decisions regarding the operation of critical infrastructures heavily rely on the cognitive abilities of human operators, who draw upon their mental models and experience. AI assistants in critical infrastructure systems are typically at the lab level or implemented in control rooms only as rudimentary recommendation systems.
Description	The AI assistance system supports operators with real-time alerts and recommendations across various domains. It integrates an RL agent, risk estimator, alarm system, and a user interface to assess situations, simulate outcomes, and guide decision-making. The system dynamically adjusts the level of automation based on context and operator cognitive load, enhancing trust and reducing workload. It includes human-in-the-loop feedback and links recommendations to key performance indicators while also estimating and communicating uncertainty and risk. This makes it adaptable, reliable, and suitable for critical sectors like emergency response and network management.
USP	The AI assistant offers real-time, domain-agnostic decision support, instantly evaluating complex scenarios and generating precise recommendations that adapt dynamically to operator preferences, cognitive load, and real-time uncertainties. Unlike current solutions limited to specific domains or reliant entirely on operator experience, this software incorporates human-in-the-loop feedback to enhance trust and accuracy, significantly reducing cognitive stress and workload across diverse critical sectors such as transportation, emergency response, and network management, where reliability and efficiency are critical.
UVP	This software provides an innovative domain-agnostic dynamic AI assistant for IT network operators, AI service providers, and ICT and control system providers, aiming to surpass human cognitive abilities and enhance operational reliability. The domain-agnostic dynamic AI-assistant delivers substantial value through adaptive real-time support tailored explicitly to operators' cognitive and stress levels, ensuring improved performance, minimised risk of service interruption, and enhanced decision-making confidence. Unlike existing solutions, it employs advanced RL for situational assessment, explicit uncertainty estimation, and a customisable graphical interface. It provides operators with actionable, trust-enhancing insights and ensures consistent operational effectiveness even under uncertainty and variability.
Market Target markets	Target Market: Industry where operators and decision-makers seek advanced technologies that optimise KPIs while ensuring trust and reliability in decision-making processes. This means industries where operational efficiency and risk management are critical, such as manufacturing, transportation, energy, and emergency services. *Customer Segments:* Network operators (of critical infrastructures); AI service providers; ICT and Control system providers. AI community: researchers, developers, and practitioners, corporate R&D).
Market: Early adopters	Partners of the project: The early adopters are the critical infrastructure operators in the project: RTE and TENNET for the power grid, SBB and DB for the railway, and NAV for air traffic management. These companies already have AI in their roadmap and are conducting proof of concepts with academia and AI providers. Therefore, they offer an adequate environment for proof of concept and early construction of business cases for AI assistants.
Go-to-Market: Use Model	Consistent with the established Go-to-Market: Use Model strategy, this result also relies on open-source release and community-driven growth (GitHub and AIoD). The project partners can offer training and consultancy to network operators and AI service providers, generating new revenue streams while building industry leadership. The system will serve as a foundation for future R&D, enabling the development of digital assistants for network operations and creating opportunities for collaboration, commercialisation, and securing funding for new projects. This KER would be used as a basis for further research on digital assistants.

	Based on this KER, several potential products and services can be generated, such as a) developing digital assistants for any network operation or real-time operation application, and b) offering consultancy services to infrastructure network operators, control system providers, and AI developers, helping integrate the domain-agnostic AI assistant into their own solutions.
TRL (current) and TRL (at the end of the project)	TRL 2/3 -> TRL 4

TABLE 6 – KER4. DOMAIN-AGNOSTIC DYNAMIC AI-ASSISTANT

KER 5: Human-AI co-learning and adjustable autonomy functions	
Problem	The problem revolves around the persistent "ironies of automation", where AI systems either take excessive control or demand too much human input, causing inefficiencies and frustration. Current AI systems struggle to balance human-AI teamwork, dynamically sharing control while allowing humans and AI to leverage each other's strengths. This imbalance results in rigid systems that fail to engage humans in the control loop, ultimately hindering optimal performance and collaborative decision-making in critical operations. To address these issues, AI must evolve into adaptive, human-in-the-loop systems that balance autonomy and human input, improving performance, trust, and decision-making in critical operations.
Current solutions	Co-learning AI systems and adjustable autonomy often rely on structured optimisations, heuristic methods, or AI-based approaches. However, these solutions remain largely unused in the industry, with much research focused on developing theoretical concepts and frameworks rather than practical implementations. Alternative methods involve observing human experts during training to replicate or optimise behaviour in line with human goals. A significant issue not yet addressed is the tendency for users to fully trust AI systems until a failure occurs, after which trust in the AI is abandoned, highlighting the lack of robust, adaptable solutions in real-world scenarios.
Description	AI4REALNET solution leverages advanced RL techniques to create a human-centred AI framework that supports high-stakes, real-time decision-making through adaptive autonomy and transparent collaboration. It integrates multiple AI components designed to operate effectively in dynamic, multi-objective environments. Key technologies include: a) order-agnostic network architectures for RL that incorporate human data in their training or mimic human perturbations for decision-making with human input; b) inverse RL to deduce an optimal reward function incorporating to some degree human behaviour while still exploring new solutions; c) deep RL with XAI to clarify AI decisions to humans; d) adjustable autonomy in RL, using preference, stress or fatigue levels to decide when to transfer control between AI and human operators. This approach not only reduces operator workload and cognitive burden but also encourages active, efficient, and resilient decision-making in demanding environments.
USP	The co-learning technology unlocks human-AI collaboration potential; it brings up a partnership where humans and AI learn from each other in real-time, enhancing decision-making. The platform, built on trust and adaptation, ensures AI responds to queries and anticipates needs. Human operators maintain control, enriching the AI with their expertise and gaining new knowledge for improved outcomes. Experience decision-making where human intuition and AI intelligence converge.
UVP	Human-AI co-learning context-sensitive collaboration is an AI technology that provides higher performance despite more complex environments; unlike other solutions, our system offers continuous learning of context-aware dynamic autonomy allocation, operationalising meaningful human control.
Market Target markets	Target Market: Spans across industries where human-machine collaboration is paramount, such as autonomous vehicles, healthcare, robotics, and critical infrastructures. Operators

	and decision-makers in these sectors are seeking advanced AI solutions that seamlessly integrate human input while optimising decision-making processes. *Customer Segments:* Network operators (of critical infrastructures); AI service providers; ICT and Control system providers.
Market: Early adopters	Network operators in the consortium will be "lighthouses" through their effort and commitment to learning with AI, tailoring human and machine roles dynamically, and sharing with policymakers and "followers" new organisational architectures, processes, behaviours, and attitudes. The novel co-learning and dynamic autonomy systems are of interest to researchers in AI and psychology, who can utilise the methods developed as building blocks in their own research.
Go-to-Market: Use Model	Consistent with the established Go-to-Market: Use Model strategy, this result also relies on open-source release and community-driven growth (GitHub and AIoD). Based on this KER, several potential products and services can be generated, such as: a) promoting results through open-access scientific publications, and b) offering consultancy and training services to help industries in Volatility, Uncertainty, Complexity, Ambiguity (VUCA) contexts integrate and benefit from the technology.
TRL (current) and TRL (at the end of the project)	TRL 2 -> TRL 4

TABLE 7 – KER 5. HUMAN-AI CO-LEARNING AND ADJUSTABLE AUTONOMY FUNCTIONS

KER 6: Integrated autonomous AI-driven decision system	
Problem	Many critical infrastructures are not suitable for full human control, nor is it always feasible to have a human agent collaborating with an AI agent. Current automation systems (complex algorithms and heuristics) are static and unable to adapt to dynamic environments. While expert knowledge is often considered in their development, this is limited to the design process and does not extend into the training process.
Current solutions	Trust in autonomous AI solutions remains low due to several factors: lack of transparency and interpretability, human aversion to algorithmic decision-making, and inadequate supervision and maintenance. Consequently, adoption in critical infrastructures is minimal. Most systems rely on rule-based expert systems due to their perceived transparency. Addressing these challenges requires improving transparency, user interfaces, and governance frameworks to promote trust and wider adoption of autonomous AI solutions.
Description	The autonomous AI-driven decision system is designed to enhance decision-making processes in critical infrastructure management while ensuring humans remain in control, in contrast to fully autonomous, human-out-of-the-loop systems. This approach prioritises collaborative decision-making, where AI and human operators dynamically interact to achieve optimal outcomes. The system comprises an RL engine, supervised learning models, a decision-support HMI, monitoring and feedback mechanisms. This solution encourages continuous collaboration by enabling operators to validate, adjust, or override AI-generated decisions through an intuitive, user-friendly interface. A key differentiator is the system's ability to adapt its autonomy level in real-time based on human feedback. AI does not replace human judgment but rather augments and refines it, learning from operator inputs to improve decision recommendations over time. To further enhance this human-AI interaction, we propose prioritising the development of adaptive user interfaces that guide operators in integrating RL engines at varying levels of automation.
USP	An autonomous AI system that learns from and builds on human behaviour to operate safely in complex, high-risk environments. It combines explainability and transparency, enabling it to act in and safely navigate human-dominated systems. Through a user-friendly interface, it empowers human operators with actionable insights, boosting their effectiveness. By continuously learning and evolving without manual updates, this future-proof solution

	enhances decision-making and optimises operations across critical systems, ensuring adaptability to evolving demands and complexities.
UVP	For critical infrastructure operators facing limitations with semi-autonomous systems, this solution delivers enhanced responsiveness, greater operational efficiency, and a streamlined workflow that dynamically adapts to evolving conditions.
Market Target markets	Target Market: Industries requiring complex coordination and decision-making, such as logistics, cybersecurity, smart infrastructure, and autonomous systems. In these industries, accountability to a human overseer is paramount, ensuring transparency and performance assessment in AI-driven decision-making processes. *Customer segments:* Network operators (of critical infrastructures); AI service providers; ICT and Control system providers.
Market: Early adopters	Operators of critical infrastructure: Critical infrastructure is highly regulated and subject to safety and security considerations which hinder automation. For these reasons, explainable and transparent autonomation provides significant value potential. AI researchers / R&D: The autonomous decision systems developed can be adapted for implementation in other areas or serve as a basis for continued development.
Go-to-Market: Use Model	Consistent with the established Go-to-Market: Use Model strategy, this result also relies on open-source release and community-driven growth (GitHub and AIoD). Based on this KER, several potential products and services can be generated, such as a) promoting results through open-access scientific publications, b) hardware and software packages that enable autonomous control of infrastructure components, and c) offering consultancy services to infrastructure network operators, control system providers, and AI developers, helping integrate Software HMI functions in their own solutions.
TRL (current) and TRL (at the end of the project)	TRL 2 -> TRL 4

TABLE 8 – KER 6. INTEGRATED AUTONOMOUS AI-DRIVEN DECISION SYSTEM

KER7. Evaluation Protocol for AI	
Problem	Need to comprehensively evaluate AI's performance, safety, and overall impact on stakeholders and communities to maximise benefits and minimise harm. There is a need to comprehensively evaluate AI's technical performance, safety, and overall impact on the social-technical systems, stakeholders (including citizens), and communities to maximise benefits and minimise the risks. This involves assessing the current ecosystem of AI usage and understanding to ensure technology advances are equitable and beneficial across all affected groups. In addition to quantitative and qualitative key performance indicators, an evaluation protocol for critical infrastructures is needed so that AI developers and end-users can test different dimensions, in particular robustness, resilience, safety, user experience and acceptability, and trustworthiness, along different dimensions and identify required organisational changes.
Current solutions	AI-based solutions adopted by the industry are being mainly tested following best practices in software development and testing. However, classical software and AI testing are different in many aspects, namely: i) software testing detects bugs in the code, while AI testing seeks to correct bugs in input data, learning process and structure, and model's hyper-parameters; ii) the behaviour of AI can change with input data and historical data update, while the behaviour of a software code is, in general, fixed; iii) test inputs may have different forms in AI, e.g., input data (for training and operation), model's functions; iv) AI tends to give more false positives in detected bugs; v) in AI bugs may be present in data, code, mathematical algorithm, which requires the active involvement of the AI engineer in the testing phase. Presently, new AI-based recommenders or automation systems are being researched without a structured framework and evaluated without a structured protocol,

	therefore incurring the risk of not being comprehensive, impacting their performance and safety.
Description	The Evaluation Protocol for AI addresses the need to comprehensively evaluate AI's performance, safety, and impact on stakeholders and communities. The protocol includes quantitative and qualitative metrics for functional and non-functional requirements, allowing AI developers and end-users to test dimensions such as robustness, resilience, safety, user experience, and organisational changes. It is complemented by tailored approaches to assess risks regarding safety and robustness, socio-technical aspects, and decision quality of the AI solution. AI evaluation is highly relevant in key decision-making processes, especially in critical infrastructure scenarios. This protocol consists of guidelines with qualitative and quantitative criteria. It will have an algorithm for automated deployment of the protocol. It allows for a more accurate assessment of AI, a higher level of assessment automation, joint human-AI assessment, dynamic system usage performance assessment, and assess the level of automation. The system's uniqueness is that the assessment of humans and AI in joint operations increases human-AI joint performance. It focuses beyond accuracy on the way the human leverages the AI.
USP	Ability to assess and optimise human-AI collaboration, focusing on accuracy and how humans effectively leverage AI in joint operations. This multidisciplinary approach improves human-AI systems' overall performance and understanding by providing deeper insights into interaction, collaboration, and teaming coherence. By offering a transparent, standardised protocol for measuring and comparing joint performance, this solution empowers users to enhance the quality of human-AI teamwork, making it highly attractive for industries seeking to boost real-world system efficiency and effectiveness.
UVP	This protocol distinguishes itself by evaluating AI in isolation and considering the ecosystem in which AI operates, aiming for equitable and positive outcomes for all affected parties. It provides a comprehensive and rigorous framework to evaluate AI in critical network infrastructures, considering both quantitative and qualitative aspects, as well as human user experience and acceptability. This protocol will be associated with three digital environments (Grid2Op, Flatland, BlueSky), which offer AI developers a complete package for evaluating their AI algorithms between TRL 4 and 5, and that can be further upgraded to higher TRL.
Market Target markets	Target Market: Organisations that are investing in the responsible deployment of AI technologies recognise the critical importance of assessing AI performance, safety, and impact to ensure beneficial outcomes for all involved parties and communities. *Customer segments:* Network operators (of critical infrastructures); AI service providers; ICT and Control system providers.
Market: Early adopters	Critical infrastructure operators in the project: RTE and TENNET for the power grid, SBB and DB for the railway, and NAV for air traffic management. The early adopters will be industries which fall under the high-risk category of the AI Act.
Go-to-Market: Use Model	Consistent with the established Go-to-Market: Use Model strategy, this result also relies on open-source release and community-driven growth (GitHub and AIoD). Based on this technology, several applications can be developed: a) quality control, support, and benchmarking for AI-human systems, b) complying with AI-human systems certifications, and c) offering consultancy services to infrastructure network operators, control system providers and AI developers, helping integrate evaluation protocol functions into their own solutions.
TRL (current) and TRL (at the end of the project)	TRL 2 -> TRL 4/5

TABLE 9 – KER 7. EVALUATION PROTOCOL FOR AI

KER8: Digital Environments	
Problem	The problem addressed is the lack of accessible, specialised digital environments for AI development and benchmarking in critical infrastructure sectors such as electricity, railway, and ATM networks. This gap hinders innovation, collaboration, and the iterative improvement of AI applications, leading to the underutilisation of AI's potential to enhance the efficiency and reliability of these essential services. Moreover, it becomes a cause of slower AI adoption and, as a result, missed opportunities for process optimisation.
Current solutions	Currently, there are no open-source digital environments available to comprehensively test AI algorithms. Previous research attempts, such as the Advanced Air Mobility (AAM)-Gym intended for ATM, have not become publicly available beyond initial conference publication. Apart from that specific attempt, no other open-source AI API currently exists for ATM, Unified Threat Management (UTM), or Advanced Air Mobility (AAM). In the area of Power Grids, the l2rpn-baselines repository can potentially serve as an alternative solution. However, significant effort remains needed to maintain its base dependencies, and further additional development is required. For Railway applications, developments have been with narrow scopes. The Flatland framework focused on the algorithmic part without HMI (Flatland Challenges) with narrow problem formulation in the past. The absence of combined, open-source digital environments forces the community into isolated, disjointed developments across different research institutions and industry players. Consequently, benchmarking AI algorithms becomes challenging, as substantial effort is necessary to adapt the software to multiple, incompatible frameworks for accurate and fair comparisons. Moreover, the fragmented approach limits progress by compelling individual groups to spend considerable resources on environment development rather than leveraging a shared, community-supported foundation and focusing directly on AI innovations and agent development.
Description	Open-source digital environments allow AI development and benchmarking for electricity, railway, and ATM networks. The digital environments support established APIs like the Gym API and, through that, empower AI research and applications in these specific domains. Further, the standardisation of training and application allows the exploitation of algorithms for various domains. This solution establishes benchmarks for state-of-the-art solutions for the different use cases and consists of open-source nature and open data (sensitive and quality data that is needed to support simulation). The digital environments consist of a unique dataset that is hard to recreate and a realistic problem formulation that is addressed with AI.
USP	The open-source digital environments offer realism and standardisation for power grids, railway, and ATM networks, enabling seamless AI development and benchmarking. With built-in support for the Gym API and standardised problem formulations, researchers can easily compare algorithm performance across domains, ensuring state-of-the-art solutions. By leveraging high-quality datasets, the platform empowers the research community and industry to accelerate AI innovation in critical infrastructure, driving impactful, AI-driven applications with repeatable and verifiable results.
UVP	For the researchers and organisations within the electricity, railway, and air traffic management sectors, as well as the broader AI development community, who are dissatisfied with the availability of mature tools and frameworks for experimentation with AI for network operations for their domains, the Digital environment is a simulation framework that allows to develop and compare solutions to business problems modelled in the digital environment. The digital environments enable and support the research community and related industry partners, such as consultants and network operators, to develop concrete AI applications.
Market Target markets	Target Market: Developers, researchers, and organisations within the electricity, railway, and air traffic management (ATM) sectors, as well as the broader AI development community. By providing open-source digital environments tailored for specific sectors, we empower developers and researchers to experiment, innovate, and benchmark AI solutions effectively. The availability of open code on platforms like GitHub facilitates collaboration

	and knowledge-sharing, accelerating the pace of AI development and refinement. Moreover, the reusability of open-source code promotes cost-effectiveness and scalability, allowing organisations to leverage existing frameworks for future projects and adaptations. *Customer Segments:* AI service providers, / ICT and control system providers. AI community, corporate R&D (network service providers), researchers, developers, and practitioners.
Market: Early adopters	AI Community researchers, academic researchers, and employees of R&D organisations. AI developers from R&D Departments of network operators.
Go-to-Market: Use Model	This result follows a use-model strategy supported by open-source release and community-driven growth through platforms such as GitHub and the AIoD ecosystem. In addition, KER 8, the Digital Environment, is structured for targeted transfer to relevant communities: • **Grid2Op** will be transferred to the **Linux Foundation for Energy**, • **Flatland** to the **Flatland Association**, and • **Bluesky** to **TU Delft**. These transfers ensure long-term sustainability, community engagement, and continued development beyond the project's lifetime. Based on this KER, several potential products and services can be generated, such as: a) services benchmarking (+ AI competitions), and b) services to help formulate problems for industry partners, concrete applications, and ML in similar domains.
TRL (current) and TRL (at the end of the project)	TRL 4 -> TRL 5

TABLE 10 – KER 8. DIGITAL ENVIRONMENTS

KER9. Human-Machine Symbiosis	
Problem	One of the causes of accidents on critical infrastructure networks is human error. Increased stress levels or misdiagnosis of well-being significantly increase this risk. Monitoring and controlling the operator's level of wellness usually requires asking the person how they feel, obligating the operator to answer. This can cause discomfort for operators. Also, sometimes, the answer might not represent reality, and it can be caused by collecting wrong information and making decisions based on it.
Current solutions	Current solutions for assessing stress and cognitive capability primarily rely on self-report surveys, questionnaires, and direct user input, which can be subjective, time-consuming, and disruptive to workflows. Some approaches use computer-based cognitive tests, which require active participation and cannot provide continuous monitoring. Other methods involve wearable biosensors but often focus on isolated physiological signals (e.g., heart rate variability) without integrating AI-driven real-time adaptation.
Description	It leverages a human assessment model (HAM) to enable implicit human-system interaction by analysing physiological data in near real-time through wearable devices and AI-powered signal processing. It estimates an operator's stress level and cognitive capability without requiring direct input, allowing AI agents to adapt their interactions dynamically. This effortless real-time assessment enhances safety, efficiency, and user experience across various industries, from industrial automation to healthcare. HAM's unique strength lies in its ability to instantly assess cognitive load and stress levels, enabling AI systems to optimise decision-making based on the user's real-time state.
USP	Offers real-time cognitive stress assessment, enabling AI to adapt interactions dynamically and enhance human-machine empathy. Unlike traditional surveys, HAM provides continuous and implicit monitoring, eliminating the need for active user input. This results in better working conditions, reducing the mental burden of using AI systems and making interactions more natural and comfortable. Additionally, HAM improves critical event

	detection, allowing AI to recognise high-stress situations faster and support better decision-making. HAM sets a new standard for seamless and effective human-AI collaboration by offering non-intrusive, AI-driven stress and cognitive analysis.
UVP	The HAM is a seamless companion system for operators with AI-based decision systems that enhances AI interactions by adding real-time sensibility and empathy. Unlike traditional biofeedback systems that only provide status updates and recommendations, HAM integrates effortlessly into AI management systems, enabling them to understand better and adapt to the operator's cognitive state and stress levels—continuously and implicitly. This creates a more natural, responsive, and user-friendly human-AI collaboration, reducing friction and improving efficiency.
Market Target markets	Human resources services companies**.** Companies that aim to evaluate better, to know, to understand their operator's health and status during their work. ICT service providers outside the project's domains. Insurance companies.
Market: Early adopters	Power grid and railway network operators.
Go-to-Market: Use Model	Based on this KER, several potential products and services can be generated, such as: a) a program for occupational health support, b) enhanced human-machine interaction systems, and c) integration in the worker's management system.
TRL (current) and TRL (at the end of the project)	TRL 3 -> TRL 5

TABLE 11 – KER 9. HUMAN-MACHINE SYMBIOSIS

3.1.4 OPEN-SOURCE STRATEGY

The European Commission aims to establish an effective, efficient, and secure digital landscape by increasing the use of OSS. OSS is software whose source code is openly shared and can be freely accessed, used, modified, and redistributed within specific copyright guidelines (European Commission, 2022). The principles of open-science and OSS are at the core of the AI4REALNET project. The activities and project plan are built around sharing knowledge, data, and tools as early and openly as possible, enabling reproducible research whenever this does not violate the project results' Intellectual Property Rights (IPR). A detailed description of the project's OSS strategy can be found in Deliverable 5.2 (Neves et al., 2024), namely in Section 2.3, "Open-source strategy".

The OSS strategy in AI4REALNET brings multiple benefits, enhancing innovation capacity among consortium partners and external stakeholders while adopting collaborative AI development. It promotes transparency and accountability, and economically, it stimulates sectoral growth. It supports the evolution of critical infrastructure business models towards more dynamic and interconnected networks. Additionally, it encourages data sharing and the creation of open digital environments for AI testing and deployment. Finally, the strategy ensures regulatory compliance by addressing legal challenges related to liability and ethics, aligning with the AI Act's requirements for high-risk infrastructure sectors. In particular, the AI4REALNET project will:

- Make available three open-source digital environments to the AI community
- Promote AI open innovation competitions to boost further development and testing by external stakeholders.
- Make research results available via an open repository and publish results on the project website for public, quick, and free access.
- Publish all project's key exploitable results under the OSS licence, which will be made available as a GitHub repository and in the AI-on-Demand platform.

The project believes that openness will facilitate the continuous evolution of the AI4REALNET results beyond the project's end. This approach promotes knowledge sharing, mitigates the risk of becoming obsolescence and promotes the replication and expansion of AI4REALNET's results. Moreover, the project aims to create a new mindset towards community building of digital environments for AI development and testing, evolving towards a more dynamic network joining technological platforms, mobility and energy providers, and customers. The platforms that will be used are presented in Table 12.

<table>
<tr><th>Platform</th><th>Role in AI4REALNET</th><th>Update (at M18)</th><th>Release Plan (for M18)</th></tr>
<tr><td>GitHub</td><td>Version control is conducted in an internal Gitlab repository. The GitHub is used as a repository to disseminate the public results. https://github.com/AI4REALNET</td><td>-The project has released a dataset containing structured training, validation, and test data in M13.
-Created a Zenodo page where the GitHub repository is linked.</td><td rowspan="3">KER 2.1 and KER 2.2 (deliverable D2.2):
• Distributed reinforcement learning module: a) State and action factorisation, b) distributed Q-learning
• Graph neural solver (power grid)
• Neural prioritised planning
• Maze-Flatland (distributed reinforcement learning)
KER 3.1 and KER 3.2:
• Failure prediction
• Interactive AI: Grid2Op, Flatland and BlueSky (Deliverable D1.2)
KER 8:
• Version 1 release of the digital environments in Deliverable D1.2
KER 9:
• Human assessment module</td></tr>
<tr><td>AI-on-demand (AIoD)</td><td>The OSS assets from AI4REALNET will be available on the AIoD catalogue using the project GitHub.</td><td>-The software assets presented in Deliverables 1.2 and 2.2, available on the projects' GitHub, will be integrated into the AIoD platform by M20.</td></tr>
<tr><td>Linux Foundation (LF)</td><td>It will be considered a potential hub for exploitation beyond the project duration, leveraging the active involvement of RTE in this domain.</td><td>We have started discussions with the Linux Foundation regarding the potential inclusion of the AI4REALNET project results in their OSS ecosystem.
Detailed information can be found in Section 3.1.4</td></tr>
</table>

TABLE 12 – PLATFORMS (ROLE, UPDATE AND SOFTWARE RELEASE PLAN)

In section 2.3 of Deliverable 5.2, we outlined the AI4REALNET roadmap for IPR and OSS management, establishing a structured approach to handling OSS while ensuring sustainable exploitation of key results. The approach identified, still updated, and further strengthened within different work packages includes the following elements: continuous assessment of the project goals and needs; identification of IPR risks and opportunities; holistic IPR approach; critical evaluation of "freedom 0" in OSS; evaluate the type of support to be given to the community; define a governance model with clear policies for code release, external contributions, compliance, and adoption strategies; integration of IPR considerations into the development processes; monitoring and quality control; code of conduct.

The governance model for AI4REALNET's OSS strategy establishes a distributed control framework to manage contributions, decision-making, and software maintenance. Pre-existing OSS projects (i.e., the digital environments of KER 8) continue their independent development while AI4REALNET forks and manages relevant repositories. Key roles include maintainers (led by INESC TEC), contributors (partners such as Fraunhofer, ZHAW, IRTSX, UKASSEL, and POLIMI), and users (stakeholders like SBB, DB, NAV, and FHNW). External contributions are encouraged but must adhere to project quality standards and licensing policies, potentially requiring a Contributor License Agreement or following an inbound=outbound approach. External contributions are welcomed but must comply with project quality standards and licensing policies, possibly requiring a Contributor License Agreement or an inbound=outbound approach.

3.1.5 AI4REALNET SUSTAINABILITY PLAN

The sustainability plan for AI4REALNET includes a series of actions to ensure widespread adoption of the project results and long-term impact. All outcomes are planned for open-source development and release, promoting transparency, accessibility, and community engagement. In parallel, several exploitation pathways have been identified, including the transfer of results to existing associations and the potential creation of dedicated working groups within partner organisations.

Figure 3 presents a visual summary of the project results, exploitation, sustainability strategies, and routes.

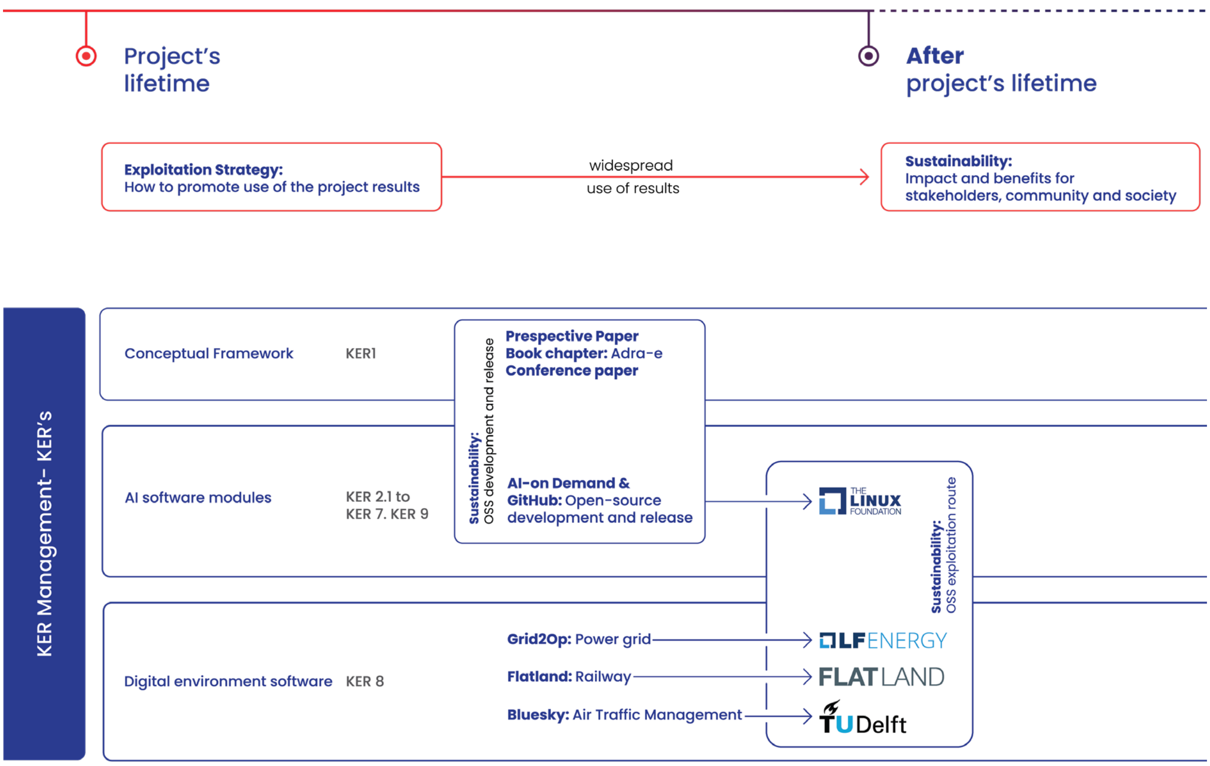

FIGURE 3 – AI4REALNET SUSTAINABILITY PLAN

OSS DEVELOPMENT AND RELEASE

The strategy is guided by the mission to ensure open access to project results through platforms that promote active engagement and collaboration within the AI community. The results will be released on the AIoD platform and GitHub and transferred to an association to support long-term sustainability.

For the AI Building blocks (KERs 2-7 and 9) and the three digital environments (KER 8), the main advantages are:

- AI assets are discoverable for the AI community, where organisations and developers can discover, use and integrate the software into their projects. This also facilitates cross-sector replication, extending the impact beyond the initial target domains.
- There is the potential to engage with additional contributors and promote the co-development and continuous improvement of the AI assets.

- AIoD is connected to the European Funding Programs, simplifying the process of attracting grants and investment for further development.
- By embedding AI4REALNET's results within an established and growing AI ecosystem, the project ensures continued use, adaptation, and expansion beyond its initial lifecycle.

EXPLOITATION ROUTES

The sustainability plan for AI4REALNET is designed to ensure the long-term impact, accessibility, and continuous development of the project's KERs. To achieve this, the AI4REALNET consortium will implement during the project duration two complementary strategies that will extend the project's value beyond its official duration:

1) **Transferring results to an Association**. This approach guarantees long-term accessibility, governance, and the evolution of AI4REALNET's KERs within an established ecosystem, ensuring the project's innovations remain relevant and widely available.

2) **Establishing a Partners Working Group**. This group will focus on further development, research collaboration, and technology transfer mechanisms. It will also explore a service-oriented revenue model to sustain and expand AI4REALNET's impact, promoting new opportunities for commercialisation and industry adoption.

Combining these efforts, AI4REALNET ensures its results remain valuable, adaptable, and continuously enhanced to meet evolving industry needs.

1- TRANSFER THE PROJECT RESULTS TO AN ASSOCIATION

- Transfer KERs 2-7, 9 and KER 8 (Grid2Op) to Linux Foundation (LF), which is already a member of the AI4REALNET Advisory Board.
- The transfer to the LF ensures that the AI4REALNET results remain openly accessible and continuously developed within a vendor-neutral and industry-backed ecosystem. The LF provides a sustainable governance structure that supports ongoing collaborations, enhancements, and following industry standards. Integrating AI4REALNET's KERs into this ecosystem facilitates broad adoption and adaptation across critical infrastructure operators, AI developers, technology providers, and regulatory bodies.
- This strategy decision is supported by some data that highlight the LF's capacity to ensure sustainability and widespread adoption of OSS initiatives:
  - In 2022, the LF OSS community contributed over 3.2 million project builds, with active member contributions increasing by 13% (Linux Foundation, 2022).
  - In 2023, LF hosted approximately 1,000 active projects, reflecting a high commitment to boost innovation and their robust organisation (Linux Foundation, 2023).

Status in month M18: The consortium has initiated discussions with LF.

For the AI Building Blocks, AI-based Decision Systems, AI Evaluation (KERs 2-7, 9):

- Transfer as a single project where three options are under consideration: Linux Foundation AI&Data[1]; Linux Foundation Energy[2] and Linux Foundation Europe[3].
- The justification for this approach lies in its ability to provide fair and neutral governance through the Association, ensuring balanced decision-making and long-term accessibility of AI4REALNET's results. It also offers legal and intellectual property protection, safeguarding the rights of contributors while facilitating controlled access. Additionally, leveraging the Association, mainly through LF, could serve as a hub to attract corporate sponsorships, funding, and research grants, further sustaining development efforts. This model enhances cross-industry collaboration by promoting knowledge exchange and joint innovation across different sectors. Moreover, it is key in promoting standardisation, ensuring that AI-driven solutions remain interoperable, widely adopted, and supported with the industry's best practices.
- Sustainability strategy: The OSS development and release strategy integrates AI4REALNET's results with existing LF projects to enhance visibility and adoption. A well-defined governance model will be established, outlining clear policies for code releases, contribution acceptance from external entities, compliance, and strategies to promote adoption for each type of KER developed. Additionally, clear contribution guidelines will be created to facilitate third-party involvement, ensuring a structured and transparent process for collaboration and continuous improvement.
- Exploitation routes: Building on the governance and sustainability benefits offered by LF, the AI4REALNET project can still pursue a wide range of commercial and exploitation routes for its KERs. As mentioned, LF provides a neutral platform with legal protection and open collaboration models that facilitate innovation and value generation.

For the digital environments (KER 8):

1) **The power grid digital environment Grid2Op** is in the process of being transferred to the **Linux Foundation for Energy**:
    - Justification for this option: driven by the strategic objective of transforming Grid2Op into a fully community-driven project. Originally developed and closely associated with RTE, Grid2Op has gained significant traction within the research and innovation ecosystem. However, to unlock its full potential for broader collaboration, reuse, and industrial adoption, decoupling the project from the RTE brand and positioning it within a neutral and recognised open-source governance structure is essential. By joining LF Energy, Grid2Op will benefit from increased visibility and interoperability opportunities, in accordance with other energy sector open-source initiatives. Moreover, integration with other LF Energy projects and working groups will foster synergies, enabling joint exploration of common challenges and solutions in power system simulation and AI-based grid operation.

[1] https://lfaidata.foundation/projects/
[2] https://lfenergy.org/
[3] https://linuxfoundation.eu/

2) **The Flatland railway** digital environment will remain in the **Flatland Association**. This non-profit organisation is pivotal in advancing research and practical transportation and resource management solutions, leveraging open-source collaboration to drive innovation.
    - Justification for this option: ensures neutral and transparent governance while providing legal and intellectual property protection. The Association also adopts an open-source mission with a peer-reviewed community, creating a collaborative environment for innovation in AI for railway systems. The Flatland framework will create a continuous railway benchmark that allows researchers working on railway (re-) scheduling and (re-)dispatching problems to evaluate their solutions on standardised problem sets defined by domain experts and compare them to other solutions. The framework will regularly run machine learning challenges for the railway domain. In addition, the Flatland framework is already used and planned to be used in other research projects. It is promoted as an enabler for algorithmic and human-AI-interaction research through conferences and workshops like the Flatland workshop. Beyond the research projects and promotion, the Flatland Association will extend the Flatland framework based on inputs from its industrial and academic advisory committees and engage the community through meetups and events, fostering the use of the Flatland framework not only in research but also as a testbed in the early stages of the implementation of novel AI-systems.
3) The air traffic management digital environment **BlueSky** will remain to be managed by the **Delft University of Technology**, which hosts the Aerospace Innovation Hub[4], a community of aerospace-related startups, academics, students, corporates, and industry professionals aiming to support innovations in space.
    - Justification for this option: Leverage the opportunity to sustain an active and established community already engaged with the platform—currently used by industry stakeholders such as LVNL and ENAIRE for prototyping. Keeping the environment aligned with a broader ecosystem of open-source tools, such as OpenAP (Sun, J., Hoekstra, J. M., & Ellerbroek, J., 2020), reinforces its relevance and usability. This positioning also strengthens its potential to attract additional funding and further innovation.

The exploitation strategy for the software digital environment will be further refined and expanded in the coming months of the project. At this stage, the partners involved in KER 8 (Flatland and Bluesky) have confirmed their strong commitment to continuing the exploitation of results beyond the project's duration. Their plans include further research and development activities, supported by ongoing engagement with new partners and sponsors—many of whom are end-users who have already expressed interest in funding and supporting future work. In parallel, the partners aim to actively pursue opportunities through European funding programmes to ensure long-term sustainability and impact. This entire process will follow a structured methodology aimed at identifying concrete exploitation paths and supporting partners in maximising the value of their results. Regarding KER 8 Grid2Op, project partner RTE has recognised the value of building on the LF Energy community. They

[4] https://aerospaceinnovationhub.nl/

are considering the development of new proof-of-concept initiatives—such as simulations on hardware accelerators or the integration of commercial solvers—that were previously limited. This collaborative methodology will continue to be explored and expanded within the LF ecosystem, supporting ongoing innovation and wider adoption.

In summary, to ensure the long-term sustainability, openness, and impact of its key results, the AI4REALNET project is considering transferring its results, including KERs 2–7, 9 and KER 8 (Grid2Op), to an established and neutral association, the Linux Foundation. Meanwhile, the other two KER 8 digital environments will remain under their respective ecosystems. These actions go in line with AI4REALNET's adoption goals through cross-sector collaboration, enhancing standardisation, and promoting the adoption of AI-based solutions in critical infrastructures. Following an open-source strategy, these solutions become highly replicable and adaptable, paving the way for their application in various domains.

2- CREATION OF A PARTNERS WORKING GROUP

The idea behind this strategy is twofold. On the one hand, the project aims to transfer its results as OSS, where the community of researchers, academic institutions, startups, infrastructure operators, and other stakeholders could work and develop further. We recognize that a vast share is crucial as it accelerates its adoption and innovation, as the external developers can use, adapt and even enhance the technology. Beyond its tangible results, the actual value of AI4REALNET lies in its partners' deep expertise and extensive experience.

To ensure the project's long-term impact, AI4REALNET partners will establish a working group to continue collaborating beyond the project's duration. While not a formal legal entity, this group represents a committed network of partners dedicated to advancing and sustaining the project's results. Its mission is to develop a sustainable revenue model that balances open-source development and dissemination with service-oriented offerings. The strategy includes openly sharing the project's outcomes—even in parallel with the previously mentioned option of transferring components to established associations—while offering premium services such as advanced customisation, implementation support, consultancy, and training programmes. The working group will also actively explore external funding opportunities through grants, sponsorships, and collaborations with industry partners. The commercial and research-based activities that are under consideration to be delivered by the working group are presented in Table 13.

Route	After the project's lifetime
Consulting, Training, and Industry Support Services	Purpose: Integrate AI4REALNET technologies into organisations' operational environments By: -Consultancy and Support Services to develop tailored implementation strategies. -Training programs to help professionals in those organisations to do the integration and overcome challenges. -Workshops within a specific topic to equip the technical teams and decision-makers.
Industry Partnerships	Purpose: Enable industry players to create value-added services based on AI4REALNET's OSS components. Purpose: Jointly develop and implement KERs in new products, services, or processes.

Route	After the project's lifetime
Public-Private Partnerships	Purpose: Enhance AI4REALNET's industry integration by creating collaboration models between governments, regulatory bodies, and private companies. By: Creating formal agreements with government entities and private sector stakeholders to support AI research, deployment, and regulatory compliance.
Funding opportunities and European Funding programs	Purpose: Secure additional financial resources to develop further, scale, and commercialise the project's KERs. By: Pitching project outcomes and KERs to venture capitalists and other funding sources to secure additional financing. Exploring and applying for European funding programs to obtain financial support for continued research and innovation.

TABLE 13 – ROUTES FOR THE PARTNERS WORKING GROUP

This sustainability plan ensures that AI4REALNET's innovations do not remain confined to the project's timeline but instead serve as a lasting contribution to the global AI community.

BUSINESS MODEL CANVAS

Below, we present the Business Model Canvases (BMC) for the AI Software Modules and the Digital environment software (Table 14 to Table 17). They are evolving; they will become more detailed and reach a conclusive stage following the interactions and analyses conducted by the exploitation team. In summary, the AI Software Modules (KER 2 to 7, 9) aim to offer comprehensive AI-driven decision-making solutions for critical infrastructure operators. The key partners include the GitHub community, The LF, AI researchers, infrastructure operators, and standardisation bodies. The value proposition emphasises hierarchical, explainable AI solutions and a standardised framework adaptable to various domains. The customer base includes operators in critical systems, AI developers, and regulatory agencies. Revenue comes from consultancy, training, custom developments, and grants.

Table 15 to Table 17 present the three digital Environment Software. Grid2Op is an open-source tool for simulating and benchmarking AI for power grid reliability. It is supported by RTE, universities, and the LF Energy, promoting collaborative development. Relationships with users are community-driven, with paid consultancy and training sessions available. Revenue streams include sponsorships, grants, consultancy, and training programs. Flatland is a railway-focused toolkit for developing routing and scheduling algorithms using multi-agent reinforcement learning. The toolkit's strength lies in open-source flexibility, community engagement, and neutral governance via the Flatland Association. Collaborative R&D funding, sponsorships, and membership fees support its sustainability. Lastly, BlueSky provides open-source, realistic ATM simulations. Hosted by TU Delft, it collaborates with Air Navigation Service Providers and research consortia like SESAR and NextGen. Core activities include maintaining alignment with aviation standards and active community engagement. Its revenue largely derives from research grants and institutional support.

Business Model Canvas: AI SOFTWARE MODULES KERs 2 to 7 and 9				
Key Partners	**Key Activities**	**Value Propositions**	**Customer Relationships**	**Customer Segments**
-**GitHub and AIoD** developer community, AI research community, and open innovation networks that contribute to and extend the AI4REALNET tools. -**Infrastructure and critical system** operators co-developing and validating AI modules in real-world scenarios -Organisations like the **Linux Foundation** (host, governance, and OSS results dissemination). -**Universities and labs** contributing advanced algorithms, domain expertise, and continuous R&D to improve the AI building blocks -Collaboration with standards organisations and **regulators** to align the evaluation protocol and AI assistant features with industry regulations, facilitating broader acceptance and compliance.	-**Continuous improvement** of knowledge-assisted and hierarchical AI algorithms, XAI/HMI software, and the integrated decision system – including coding, testing, and updating the open-source repositories. -Manage the GitHub project and work on a growing contributor base. -**Adapting** the AI4REALNET building blocks for **various domains** and **integrating** them into existing **critical infrastructure systems**. - Developing **tutorials**, **workshops**, and guides to train operators and developers. **Partners conduct training sessions and offer consultancy to help stakeholders implement the AI4REALNET solutions** - Seeking **new collaborations** or **funded projects** that use the AI4REALNET framework as a foundation for further	- AI components that combine data-driven learning with expert knowledge - Distributed and hierarchical AI building blocks that break down complex network problems into sub-tasks. This improves scalability for high-dimensional, real-world systems and adapts efficiently to dynamic environments. - Built-in explainable AI functions and advanced human-machine interfaces provide clear, context-relevant explanations of AI decisions. -Real-time AI assistant that can adapt to different domains and operator needs. Managing uncertainty and variability in critical scenarios. -Human-AI co-learning enables a stable collaboration between humans and AI. The system continuously learns from human feedback and	- **Peer-support model**. Users can interact with the open-source repository. A knowledge base of tutorials and examples is openly available, and community members help each other and share best practices. - Relationships are built on **collaboration**. Key users might become active contributors. - The consortium partners or a future support organisation offer more personal relationships (consultancy, custom development or on-site training) for critical system operators. This enhances trust with more traditional customers who expect direct support. - Regular webinars or community calls keep users engaged with new updates and allow feedback.	-**Operators of critical networks** in energy (power grids, TSOs), transportation (rail networks, ATM), telecom, water utilities, and other critical infrastructures. These organisations need AI decision support to optimise operations and manage incidents. Early adopters identified include network operators in energy, rail, and ATM as per the project's pilot domains, with the potential to expand to others. - Companies providing control systems or AI solutions to the above operators. This includes **ICT and AI service providers** → They use AI4REALNET blocks to enhance their product offerings for critical systems. Integrating the open-source modules allows them to deliver more advanced, transparent AI features to

AI4REALNET has received funding from European Union's Horizon Europe Research and Innovation programme under the Grant Agreement No 101119527, and from the Swiss State Secretariat for Education, Research and Innovation (SERI).

Business Model Canvas: AI SOFTWARE MODULES KERs 2 to 7 and 9				
	innovation. This includes **public-private R&D partnerships** and **grant applications** to continuously enrich the open-source project.	behaviour, adjusting the level of autonomy accordingly. - Holistic AI-driven decision-making solution that combines all these components into one framework. It can autonomously manage complex operations end-to-end while still supporting, not replacing, human decisions. - A standardised evaluation framework to measure performance, safety, and human factors of AI in critical systems. - A human assessment module monitors the operator's state in real-time. Using implicit signals instead of intrusive allows the AI assistant to adapt its interactions and autonomy level to support the human when stress is high. - The **AI4REALNET solution is domain-agnostic by design**, meaning techniques proven		their clients without building from scratch. - A secondary segment is the **AI community** (researchers and corporate R&D departments) →They benefit from the open platform to experiment, publish, or build new tools. This segment contributes to the sustainability and evolution of the project through collaborations and feedback. - **Regulatory** agencies, certification bodies, or safety auditors form a niche segment using the evaluation protocol.
	Key Resources		**Channels**	
	- OSS building blocks and tools. - Teams' know-how. - Community (developers and user community)		- Release the software through GitHub and AI-on-Demand, reaching a broad audience of industry and research users. - Direct channels to critical infrastructure operators include conferences, trade shows, and workshops. Partners leverage their membership - If hosted under an association like the Linux Foundation, the project gains visibility and acts as a channel - Scientific publications; success stories published on the project's website help potential adopters in different domains of the solution's benefits.	

Business Model Canvas: AI SOFTWARE MODULES KERs 2 to 7 and 9				
		in one sector can transfer to others. Many infrastructure sectors face similar challenges of real-time, multi-actor decision-making under uncertainty. **This broad applicability increases its value proposition, as a single open toolbox can serve multiple industries.** - **Released as open-source**.		

Cost Structure	Revenue Streams
- Continuing effort to update software and incorporate new features. Core contributors (whether at the partner or a foundation) have personnel costs. As an open-source initiative, some costs are shared or reduced through community contributions. - Sustainability investments: To ensure long-term viability, funds might be allocated to join foundations (Linux Foundation) or to seed new R&D projects that enhance the OSS.	- Consulting services generate revenue by supporting critical infrastructure operators and technology providers implementing AI4REALNET solutions in their specific context. The partners' working group offers paid consultancy to customise and integrate it with the customers' systems. This provides value to users and revenue to sustain development. - Training and workshops and paid training programs could be a revenue stream. Organisations would pay for workshops or online courses to upskill their staff. - Companies that heavily rely on the toolkit might sponsor specific feature developments. -Additionally, new R&D grants or public funding can be obtained by building on AI4REALNET. These support continued improvement without charging license fees. - In the long term, revenue can come from value-added offerings, while the core remains OSS.

TABLE 14 – BUSINESS MODEL CANVAS: AI SOFTWARE MODULES

Business Model Canvas: DIGITAL ENVIRONMENT SOFTWARE KER 8 – Grid2Op				
Key Partners	**Key Activities**	**Value Propositions**	**Customer Relationships**	**Customer Segments**
-The transfer to Linux Foundation Energy →access to a network of energy companies and developers, promoting the adoption of cross-project collaborations -RTE (creator and ongoing key partner) and other operators serve as domain partners, providing real-world insight and data. -Universities and institutes like Fraunhofer, University of Kassel, ZHAW, and POLIMI (partners in AI4REALNET) remain contributors. They act as R&D partners, validating Grid2Op in research and contributing advanced features. Moreover, publishing papers using	-Constant improvement of the Grid2Op code is essential. It also included fixing problems raised by the community. -Under LF Energy, Grid2Op's maintainers host regular meetings, design discussions, and code reviews. A significant activity is managing community contributions. - To keep Grid2Op relevant, the team will make efforts to create new use cases and scenarios. - Publishing papers or case studies demonstrating Grid2Op are activities that solidify its value proposition and attract users.	-Provides an AI-friendly environment matching power grid behaviour. -Grid2Op enables the development and benchmarking of AI algorithms for grid reliability under realistic stress conditions. -Offers a comprehensive and powerful experimental platform for developing autonomous grid control agents. -**Open-source tool** (MPL-2.0 license). The value to customers is a no-cost, **evolving toolset backed by a growing community now under neutral governance** (LF Energy) for long-term sustainability.	-Relationships are mainly community-based. -The move to LF Energy: any organisation or individual can join the community on equal terms, strengthening trust. -Grid2Op's roadmap is influenced by its user base (hackathons and LF Energy working groups) -For more involved industry users, project partners provide closer relationships through workshops, training, or custom support. -Regular updates and release notes to keep users engaged.	-AI service providers, ICT and control system providers → They benefit from the open-source nature of integrating Grid2Op into their workflows without licensing barriers. -Developers, researchers, and organisations within the electricity sectors and the broader AI development community. The AI community is interested in critical infrastructure and is a key segment.
	Key Resources		**Channels**	

Business Model Canvas: DIGITAL ENVIRONMENT SOFTWARE KER 8 – Grid2Op				
Grid2Op may expand its credibility. - Grid2Op benefits from partnerships outside the power domain, using AI4REALNET's cross-sector approach. Additionally, partnerships with AI organisations help in promoting standards.	- The core resource is the Grid2Op software platform, a codebase that models power grid operations and supports sequential decision-making by AI. - Grid2Op is released under Mozilla Public License 2.0.	-Through AI4REALNET, Grid2Op was enhanced with APIs and an HMI for human-in-the-loop interaction. This means it produces data for training AI and allows human operators to visualise and interact with simulations.	-Distributed via GitHub and now moving to LF Energy's repositories. - AI Competitions and Challenges: "Learning to Run a Power Network (L2RPN)" competitions are a channel to engage the community. -Grid2Op presented in conferences and forums.	

Cost Structure	**Revenue Streams**
- The continuous improvement of Grid2Op incurs personnel costs. - Marketing and community activities, such as organising competitions and presenting at conferences.	- Grid2Op transitions to LF Energy can attract sponsorships from energy companies and grants from innovation programs. -Partners could offer paid consultancy, custom implementations, and training related to Grid2Op. -As Grid2Op gains adoption, a revenue stream could be professional training courses

TABLE 15 - BUSINESS MODEL CANVAS: DIGITAL ENVIRONMENT GRID2OP

Business Model Canvas: DIGITAL ENVIRONMENT SOFTWARE **KER 8 – Flatland**				
Key Partners	**Key Activities**	**Value Propositions**	**Customer Relationships**	**Customer Segments**
-The Flatland Association itself is a coalition of partners (for example, SBB and Deutsche Bahn, both AI4REALNET partners and SNCF (national rail companies)) as founding members → It ensures that multiple major stakeholders are jointly devoted to Flatland's success. - AIcrowd is a partner for community engagement and competitions. -Railway research initiatives.	-Extending Flatland's simulator to handle more complex or extensive networks and optimising its performance. -Continuously curating a diverse set of scenarios is important. The Flatland team generates and validates new test scenarios -Flatland carries out activities to keep the community active. -Seek collaborations with universities or other EU projects. Writing grant proposals is an activity aimed at securing funding. - As multiple rail companies are involved, coordinating joint development is essential. These partnerships ensure resources for Flatland's sustainability.	-Delivers an open-source toolkit for managing dense train traffic on railway networks. It generates challenging scenarios so users can develop and benchmark algorithms for routing and scheduling in a risk-free environment. - Flatland's value lies in being a flexible, method-agnostic environment for multi-agent reinforcement learning and operations research problems in railways. Flatland helps the rail sector identify robust AI solutions and compare them objectively. - As an MIT-licensed open project, Flatland invites collaboration. It was co-developed by significant rail operators and AIcrowd.	- Flatland's users interact under the umbrella of the Flatland Association, which provides neutral and transparent governance. -Relationships were built during the Flatland challenges; participants formed forums and chat groups. Users are encouraged to share results or ask for help. This peer-to-peer support culture means new users often find quick help from community members. - The rail companies behind Flatland remain closely involved and serve as "lead users".	- -AI service providers, ICT and control system providers. -Rail network companies. They represent end-users who seek resilient scheduling algorithms and can directly fund or support the tool's evolution. - Participants of global AI challenges are a segment of their own. -Developers, researchers, and organisations within the railway sector and the broader AI development community. The AI community is interested in critical infrastructure and is a key segment.
	Key Resources		**Channels**	

Business Model Canvas: DIGITAL ENVIRONMENT SOFTWARE KER 8 – Flatland				
	-Flatland environment code – an open-source toolkit for generating and simulating railway scenarios. - Flatland's MIT license is a strategic resource, as it encourages maximum usage. - The involvement of significant rail companies is an intangible resource.		-Flatland Association's platform (flatland.aicrowd.com) and GitHub- -Developers discover Flatland through its open-source presence, which includes PyPI (pip installable package), documentation sites, and references in research papers. -Community interaction via GitHub issues, Discord/Slack, and by publishing in AI newsletters or railway IT forums.	

Cost Structure	Revenue Streams
-Flatland's open-source nature means no direct revenue, so its costs are mainly human resources. -Flatland's infrastructure cost. Organising challenge events carries costs. These operational costs must be covered either by sponsors or the organising partners.	-The Flatland Association, a non-profit, may sustain itself through memberships or sponsorships. -Collaborative R&D funding. Flatland has expressed intent to seek European programs to finance future enhancements

TABLE 16 - BUSINESS MODEL CANVAS: DIGITAL ENVIRONMENT FLATLAND

Business Model Canvas: DIGITAL ENVIRONMENT SOFTWARE KER 8 – Bluesky				
Key Partners	**Key Activities**	**Value Propositions**	**Customer Relationships**	**Customer Segments**
-TU Delft provides development resources and integration with the Aerospace Innovation Hub. TU Delft's backing ensures BlueSky benefits from long-term vision and alignment with academic goals (education and open science). -Partnerships with Air Navigation Service Providers like LVNL and ENAIRE (already using BlueSky for prototyping) are valuable →provide real end-user feedback -Organisations like Eurocontrol or FAA tech centres can be considered high-value partners; if BlueSky is adopted in any of their research initiatives, their involvement will validate and strengthen the tool's development -Research consortia (SESAR in Europe, NextGen in the US) and industry alliances are potential partners in the aviation domain.	-Ensuring BlueSky stays up to date with aviation standards so that simulations remain credible. -BlueSky's maintainers engage with users by updating the wiki, responding to issues, and incorporating user feedback. - A notable activity is keeping BlueSky aligned with other open-source aviation initiatives. **Key Resources** - BlueSky simulation software. It is distributed under GPL v3.0, ensuring it remains free and open. - BlueSky comes packaged with open datasets and - Being lodged at TU Delft gives BlueSky access to institutional resources: server infrastructure for development, labs for	-Open ATM Simulation: BlueSky's core value is that it "provides everybody who wants to visualise, analyse or simulate air traffic with a tool to do so without any restrictions". -BlueSky includes high-fidelity models and open data to ensure realistic scenarios. The open-data, open-source approach increases result reproducibility and comparability in ATM research. -BlueSky can be extended with new functionalities. -BlueSky is backed by an established community at TU Delft's Aerospace Innovation Hub and beyond. The tool has been sustained for years with continuous improvements and is used in	-BlueSky's user relationships often begin in an academic context - BlueSky connects with industry professionals and startups through the Aerospace Innovation Hub, creating a network relationship. **Channels** -BlueSky is maintained by TU Delft and is shared through academic channels. - GitHub - The Aerospace Innovation Hub workshops and demo days.	-AI service providers, ICT and control system providers. -Air Navigation Service Providers -Developers, researchers, and organisations within the ATM sector and the broader AI development community.

Business Model Canvas: DIGITAL ENVIRONMENT SOFTWARE KER 8 – Bluesky				
	testing, and the research group's expertise. -BlueSky has been cited in research and used by other projects. This academic track is a resource as it drives adoption.	education and prototyping by the industry.		

Cost Structure	**Revenue Streams**
-BlueSky's development is primarily tied to TU Delft researchers and students. -Cost with ensuring documentation, tutorials, and user support has a cost.	-Research grants and institutional support essentially fund BlueSky's continued development at TU Delft.

TABLE 17 - BUSINESS MODEL CANVAS: DIGITAL ENVIRONMENT BLUESKY

4. NEXT ACTIVITIES

This section is dedicated to presenting a plan to identify the steps and activities that will be performed during the next 24 months and that will be incorporated in the final Exploitation Plan (Exploitation Plan and Strategy – Phase 3) in month 42. The development of the plan will include the activities and tasks presented in Table 18.

Topic		Description	Schedule
Exploitation and Sustainability	Horizon Booster services	Participate and work with the HRB experts to perform all the services offered (Go-to-market, Networking, and Intellectual Management Assets).	M18-M21
	Target Customers and stakeholders	Identify external stakeholders, from early adopters' customers to policymakers and even to existing associations, and conduct interviews to capture real-world interest to identify possible barriers and requirements that our results need to meet to be transferred and adopted.	M19-M24
		Define market positioning.	M30
		Value proposition canvas.	M30
	Market readiness assessment	Classify each result by maturity, commercial potential and relevance.	M24-M30
	Cost and risks	Assess the cost profile of each solution, evaluate potential risks, and determine their replicability and scalability.	M31-M34
	Strategic alignment	Examine market conditions, IPR, and consortium agreements to ensure strategic alignment.	M36
	Sustainability workshops	Sustainability beyond the project. Two workshops will be held to identify the partner's interest and involvement in the defined routes.	M37-M39
	Other scenarios and sectors	Analyse the potential for re-using (replicability across different sectors) and upscaling the use cases in future adoptions in different scenarios.	M37-M39
	SWOT Analysis	A detailed SWOT analysis will be developed to evaluate the exploitation potential, incorporating key policy insights to enhance feasibility and impact.	M40
	Business Model Canvas	Development of a detailed Business Model Canvas. The team will follow the Business Model Navigator approach blended with elements of Business Model Canvas and Lean Canvas.	M40
Community	**Workshops**		
	AI for Safety-Critical Infrastructures	The workshop will be organised at the European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases.	M24
	Ethics and regulation (co-organized with CLAIRE)."	Workshop co-organised with our ZHAW. In person.	M24-M30
	AI challenges for energy and mobility networks	The workshop is to be co-organised in person with our partners RTE, DB, and SBB.	M30

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Topic		Description	Schedule
	RL applied to complex networks.	The workshop will be co-organised with our partners Politecnico di Milano and the University of Amsterdam. Online.	M37
	Stakeholders		
	Engagement with Stakeholders	Define a list of activities to be performed to engage with the stakeholders. Set a schedule for those activities. This task will set the agenda to engage with: -Network operators, especially those from critical infrastructure, ICT and control system providers, and AI service providers. To gain insights, ensure solutions meet industry needs, leverage expertise, raise collaboration and innovation, and demonstrate the project results. How: Workshops and demonstrations will have regular interactive sessions to demonstrate KERs and solicit feedback and engagement. Technical Workshops and seminars to share in-depth technical aspects and create an awareness in the field about AI4REALNET expertise and results. Open-source contributions: the project partners should encourage participation in Github and AIoD. - Associations, there is a need to facilitate governance and leverage the ecosystem, so AI4REALNET should participate in working groups, for example, with LF, and be an active member. Create or participate in joint events to enhance visibility and facilitate adoption. -Academy and research institutions. To promote research-based innovation, create credibility and reputation, and contribute to future R&D. How: Participation in academic conferences and publications. -Regulatory agencies and policymakers to ensure compliance with regulatory frameworks. How: Engage in discussions and write policy papers in collaboration with other European-funded projects. -OSS community, the project will need to encourage collaborative development of open-source solutions; there is also a need to enhance visibility. How: Create interactive forums and provide newsletters and blog posts.	M20
	AI Open Competitions		
	Railway	AI Open Competitions - Railway	M24
	Power grid	AI Open Competitions - Power grid	M32
	Air Traffic Management	AI Open Competitions - Air Traffic Management	M37

TABLE 18 - AI4REALNET TIMELINE OF ACTIVITIES

5. CONCLUSIONS

In Phase 2 of the Exploitation Plan and Strategy, we adopted a collaborative approach involving all consortium partners to expand the initial eight KERs into a refined set of eleven. Each KER is clearly defined by the specific problem it addresses, its unique selling points, and detailed exploitation pathways.

The sustainability and exploitation strategies for our digital environments software (KER 8), particularly Grid2Op, Flatland, and BlueSky, highlight our commitment to integrating these results within robust open-source ecosystems such as the Linux Foundation for Energy, the Flatland Association, and TU Delft, respectively. We also plan to support collaboration by establishing a Partners Working Group focused on consulting services, training programs, strategic industry partnerships, and leveraging additional funding opportunities. Similarly, sustainability and exploitation strategies for our AI software Modules (KERs 2 to 7 and 9) emphasise using open-source platforms like GitHub and AI-on-Demand, facilitating broad access, continuous improvement, and widespread adoption across diverse sectors. The potential transfer of these KERs to associations such as the Linux Foundation further reinforces their long-term sustainability by providing neutral governance, legal protection, and opportunities for cross-industry collaboration and standardisation.

Several activities have been outlined as the next steps to ensure successful exploitation in the project's final phase. Participation in the Horizon Results Booster services from month 18 to month 21 will guide the refinement and optimisation of the exploitation strategy. Following this, between months 24 and 30, the project will perform a market readiness assessment, systematically classifying each KER by maturity, commercial potential, and relevance. By month 30, market positioning and a clear value proposition canvas for each KER will be fully established. In months 31 to 34, comprehensive cost and risk evaluations will be conducted to assess the financial viability and replicability of AI4REALNET solutions. By month 34, the project will also perform a strategic alignment exercise, examining market conditions and IP considerations. This will lead to a SWOT analysis. AI4REALNET will continue to engage with the community through workshops and open AI competitions.

With these strategies and clear next steps, the AI4REALNET team is well-positioned to realise the full potential of its project outcomes.

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ANNEX 1 – KER WORKSHOP PROCESS

Hands-on Workshops (M10-M12): Three online workshops to develop a detailed and comprehensive version of the KERs. Partners participated in interactive exercises via Zoom and Miro. The average duration was two hours—a total of 41 participants. In preparation for the workshops, 22 questions were developed, as well as examples of answers to them. The questions' content and sequence underwent several iterations after internal testing. The final version of the workshop template is attached below.

Conducting this workshop helped to articulate the description of each of the KERs more clearly and formulate the UVP, USP, Customer segments, and Go-to-market use model. Also, after the workshops, it was decided to split KER 2 into KER 2.1 and KER 2.2 and KER 3 into KER 3.1 and KER 3.2. In addition, another new KER 9 Human-Machine Symbiosis was formulated by conducting an additional workshop with INESC TEC. Thus, the total number of KERs increased from eight to eleven.

The information received was analysed and formulated into a new KER description based on this. These descriptions were sent to all partners involved in a particular KER for verification and adjustment.

KER description **KER is an identified main interesting project result, which has been selected and prioritised due to its high potential to be "exploited" – meaning to make use and derive benefits- downstream the value chain of a product, process, solution, or act as an important input or to policy, further research or education.**		
Exercise 1 | General Characterisation		
Questions	Example	Answer
1. Name of the KER:	TMBS Power Semiconductors	
2. Describe the KER	A Trench Metal-Oxide Barrier allows greater on-state resistance for power semiconductors. Putting a trench on the surface of a semiconductor requires different process steps in wafer fabrication.	
3. Status of development TRL Initial: Current: Expected at the end:	Initial: TRL 2 Current: TRL 4 Expected at the end: TRL 7	
4. Identify KER components: (KER components - are the distinct, individual parts or subsystems of a technological system that allow specific capabilities for this KER.)	A Trench Metal-Oxide Barrier allows greater on-state resistance for power semiconductors. Putting a trench on the surface of a semiconductor requires different process steps in wafer fabrication.	
5. Identify the main KER capabilities: (KER Capabilities - are conceptual-level elements that capture WHAT KER can do. These often have quite abstract names, but it is important that they do not imply any particular class of technology or product. Example: KER Component: Relational Database Management System - that provides services that give us the	Faster switching time, allows more power to be handled by the device, decreases device size and device yield	

capability to manage structured data KER Capability: "Manage structured data ")		
6. What is the uniqueness of the key capabilities?	Lengthens the time current batteries can run a device.	
Exercise 2 | Potential Value and Applications		
7. What problem does it address and solve?	**Increased On-State Resistance:** Traditional power semiconductors often face limitations in their ability to resist current flow when in the "on" state **Thermal Management:** Power semiconductors generate heat during operation. The trench configuration allows for improved heat dissipation due to a larger surface area for heat transfer **Miniaturization:** The trench structure can facilitate the creation of smaller and more compact semiconductor devices. **Enhanced Breakdown Voltage:** Implementing a trench oxide barrier can also lead to improved breakdown voltage characteristics.	
8. How has this problem been solved so far without this KER? (name some of the solutions, and explain how they resolve the problem)	Solutions to these challenges relied heavily on optimizing material properties, device geometry, cooling solutions, and manufacturing techniques. However, these methods often involve size, efficiency, cost, and complexity trade-offs.	
9. What is its added value compared to existing solutions? (link with question 8)	Trench technologies introduced more efficient solutions to these problems, leading to more compact, reliable, and higher-performing power semiconductor devices. It lengthens the time that current batteries can run a device.	
10. Describe the potential applications for this KER. (List potential products or services based on the technology).	Chip set for efficient power rectification Chip set for down-hole-drilling applications Chips for electric motor control	
Exercise 3 | MARKET and COMPETITION		
11. Who will be the target customers of the KER? (A customer is someone who purchases or pays for products or services. A customer can be a user, but not all users are necessarily customers.)	Clients: Battery manufacturers, manufacturers of electronic devices such as cell phones, tablets, laptops, cameras, electric vehicles, etc.	
12. Enumerate the specific user groups who are expected to benefit from, interact with, or be affected by the KER. (A user is someone who interacts with and uses a product or service)	Cell phone users, laptop computer users, PDA owners. People who need long, dependable battery life of their electronic tools. People who want more efficient and quieter electric motors.	
13. What makes this KER attractive to the potential customers/users? What are the key benefits?	Customers: Lower operating costs, lower costs and higher performance. Users: Longer operating time, lower operating temperature, lighter weight and higher performance.	

14. Who will be early adopters of the KER? (An early adopter is a persons or business that acquires a new product or technology before others)	Cell phone manufacturers	
15. What technology/product or company/research centers do you think will be the major competitors for this KER? Mention any existing technologies/products/research outcomes that are similar or related to the result; Name some companies or organisations that are currently active in the same field.	Semiconductors manufacturers	
16. Explain how this KER (technology, product or etc.) is unique from other. What advantage does it represent before competitors?	It is not a logic or memory device; it is a power management device. Longer operating time, lower operating temperature, lower operating costs, lighter weight, lower costs and higher performance.	
Exercise 4 | Exploitation		
17. What is the value that you would like to get from this KER? (e.g., for scientific, societal, or economic purposes, etc.) Define the types of value you seek to derive from the result;	Can be used for multiple low-and high-power applications ranging from DC battery management to high-voltage, high-amp motor controllers. 1.Chip set for efficient power rectification 2.Chip set for down-hole-drilling applications 3.Chips for electric motor control	
18. How do you plan to get the value? Describe specific objectives related to the value. Outline strategies or approaches you plan to use to get it.	Continue R&D until TRL9 and protect IP. Addressing the need by possible market segment such us: 1.Cell phone users Needs: Longer talk time 2.Companies doing oil exploration Needs: Robust electronics for power circuits 3.Companies producing oil from wells Needs: Installed devises in wells to power telemetry equipment 4.Companies that use electric motors for production Needs: Motor control to reduce costs 5.HVAC equipment manufactures Needs: Higher-efficiency products to be more competitive	
19. What is the time to have a commercial exploitation? (if there's different products and services with different time frames, please differentiate it)	Chip set for efficient power rectification - 1 years Chip set for down-hole-drilling applications - 2 years Chips for electric motor control - 2 years	
Exercise 5 | Compile the KER Value Proposition		
20. Formulate a value proposition for your KER using the following template: For (target customer) ________________	For *Cell phone manufactures* who are dissatisfied with *existing battery solutions and their rapid loss of capacity.*	

Who are dissatisfied with (the current alternative) ___________________ (KER name________________) is a (solution category__________________) That provides (statement of key benefits______________) Unlike (primary competitive alternative_______________) Our solution (solution and primary differentiations____________________)	*TMBS Power Semiconductors* is *a power management device* that provides *longer operating time, lower operating temperature, lower operating costs, lighter weight, higher performance and lower costs.* Unlike existing solutions**,** *our TMBS Power Semiconductors lengthen the time it takes for current batteries to run a device*.	
Identify the degree of innovation for this KER		
LOW	MEDIUM	HIGH
Identify the degree of exploitability for this KER		
LOW	MEDIUM	HIGH
Identify the degree of impact for this KER		
LOW	MEDIUM	HIGH
Homework		
21.What is the IPR Background (type/ partner)? Provide information considering IPR ownership already agreed in the Consortium Agreement.	Look for IP Rights before	
22. What is the IPR Foreground (type/ partner)? Provide information considering IPR ownership, registration and maintenance already agreed in the Consortium Agreement.	Joint venture between company A and company B (company A registers and B has maintenance costs)	