Deliverable D7.3

Exploitation plan and business plan preparation - Initial

Project Number	**101189908**
Project Title	AI Engineering Suite to Support Agile Efficient Software Engineering
Project Acronym	AI4SWEng
Title of Deliverable	Exploitation plan and business plan preparation - Initial
Version	V1.0
Due Date of Delivery	M12
Distribution level	PU

Work Package	**7**
Responsible Partner	CEA
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Keywords	AI Engineering Suite, Large Language Models (LLMs), TinyML Test Automation Tool (TAT), Design-by-Contract, Responsible Innovation, Trustworthy AI, Key Exploitable Results (KERs), SWOT Analysis, PESTLEE Analysis

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101189908.

Co-funded by the European Union

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Project funded by

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

Abstract: This document D7.3 presents the exploitation planning framework for the AI4SWEng project, outlining strategies to maximise the impact and commercialisation potential of the targeted innovations in AI for software engineering. After motivating the vision and objectives of the project, it sets out the modular architecture of the resulting AI4SWEng Suite, its unique differentiators, analysis of the target market segments, the five use-cases and contextual factors through SWOT and PESTLEE frameworks, market needs, emerging trends, competitive positioning,

Key Exploitable Results (KERs)are mapped across Consortium Partners, addressing pathways for adoption and value-add in diverse domains, strategic alliances and partnerships, including academic collaborations on trustworthy machine learning and responsible innovation, industrial engagements with technology integrators, and community-driven initiatives through open-source dissemination and standards, Collectively, the plan establishes a roadmap for sustainable exploitation, ensuring that AI4SWEng delivers high-assurance, transformative solutions with measurable societal and industrial benefits.

Document Revision History

Version	Date	Authors	Revision
0.1	05 Sep 2025	Sébastien Bois	Document creation
0.2	15 Oct 2025	Sébastien Bois, Marteyn van Gasteren, Alper Kanak, Marco Tiemann, Pablo Gallegos Jimenez, Alain Duc, Ömer Öztin, Vasilis Pezoulas, Atta Badii, Naga Sai Dasari, Ali Egemen Ener	Document updated by the contributors
0.3	12 Nov 2025	Sébastien Bois	Document refactoring
0.4	24 Nov 2025	Atta Badii, Candela Jordano Bustos	Internal review by AI4SWEng Consortium
0.5	26 Nov 2025	Sébastien Bois	Document updates

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AI4SWEng Innovation Mission

AI4SWEng : AI Engineering Suite to Support Agile, Efficient Software Engineering	*AI4SWEng comprises an excellent chemistry of 15 Partners including experts and practitioners in Model-Driven Software Engineering and AI Engineering (particularly LLMs) from across Europe with five Use-Cases from Software Development, Healthcare, Cyber-Physical Systems involving multi-architectural and resource-constrained systems and Next Generation Battery Management in EVs. The AI4SWEng mission is to significantly contribute to the transformation of agile software development in a sector turbocharged for design-by-contact, high efficiency, reliability, and security-privacy compliant delivery. This is to exploit advanced AI-powered software development support to deliver high-quality reliable fast time-to-market solutions that are socially responsible, scalable, sustainable and lend themselves to audible ethical and regulatory compliance. AI4SWEng aims to deliver AI-powered support to software developers to reduce worker stress through the pain-points in agile SW development pipelines and higher productivity thus enhanced job satisfaction and creativity. Accordingly, using five Use-Cases the project will develop, deliver and validate a platform comprising a set of tools including the AISysDev and Test Automation Tool to support the software lifecycle end-to-end for both functional and non-functional deliverables. A host of tasks will be supported such as code generation, cross-compilation, advanced debugging and dynamic slicing, security-privacy-by-design, model optimisation for reliability, energy efficiency as well as model adaptation and maintenance. This also includes software quality support through data-driven insights for informed design decision-making and strategic software development planning. Additionally, with a commitment to user-centred design, AI4SWEng will provide structured design in advanced prompt engineering to support software developer teams to best exploit the capabilities of the platform.*

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Terms and Abbreviations

Acronym	Meaning
AI	Artificial Intelligence
ASIC	Application-Specific Integrated Circuit
AutoML	Automated Machine Learning
BMS	Battery Management System
BOM	Bill Of Material
CI/CD	Continuous Integration/Continuous Delivery
CPS	Cyber-Physical System
ECSS	European Cooperation for Space Standardisation
EHR	Electronic Health Record
EV	Electric Vehicle
FPGA	Field-Programmable Gate Array
GDPR	General Data Protection Regulation
GIS	Geographical Information System
IDE	Integrated Development Environment
IEC	International Electrotechnical Commission
IoT	Internet of Things
IP	Intellectual Property
ISO	International Organisation for Standardisation
IT	Information Technology
KER	Key Exploitable Result
KIO	Key Innovative Output
LLM	Large Language Model
MCU	Micro Controller Unit
ML	Machine Learning
NDA	Non-Disclosure Agreement
NIDS	Network Intrusion Detection System
NL	Natural Language
NN	Neural Network
NRE	System Reliability Engineering
OEM	Original Equipment Manufacturer
PaaS	Platform as a Service
ROI	Return On Investment
RTO	Research and Technology Organisation
RUL	Remaining Useful Life
SaaS	Software-as-a-Service
SDK	Software Development Kit
SDLC	Software Development Life Cycle
SE	Software Engineering

SLA	Service Level Agreement
SME	Small and Medium-sized Enterprise
SOC	Security Operation Centre
TAT	Test Automation Tool
TRL	Technology Readiness Level
XAI	Explainable Artificial Intelligence

AI4SWEng Partners

Partner	Country
AI4SEC OU	EE
EURECOM GIE	FR
COMMISARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES	FR
LIBERA UNIVERSITA DI BOLZANO	IT
FUNDACION INSTITUTO TECNOLOGICO DE CASTILLA Y LEON	ES
IDRYMA TECHNOLOGIAS KAI EREVNAS	EL
IDENER RESEARCH & DEVELOPMENT AGRUPACION DE INTERES ECONOMICO	ES
THE UNIVERSITY OF READING	UK
BITNET BILISIM HIZMETLERI LIMITED SIRKETI	TR
INNOVA	UK
ATPHARMA	TR
ERG	TR
HAUTE ECOLE SPECIALISEE DE SUISSE OCCIDENTALE	CH
ERGTECH	CH
UNIVERSITY OF GENEVA	CH

Executive Summary

Development approaches struggle to cope with the rising scope, quality, and legal requirements of the next generation of software systems, characterised by ever-increasing maturity levels, distributions, and distributed properties, as well as energy efficiency. The AI4SWEng project is an engineering suite that seeks to improve the agility and efficiency of software development. It strives to revolutionise European software engineering by introducing artificial intelligence and data-driven approaches, and by integrating a Responsible Research and Innovation (RRI) attitude throughout the entire software development process.

The operational strategies for transforming research results into a market-oriented solution adapted to the industry are defined in D7.3 Exploitation plan and Business plan – Initial. The deliverable D7.3 includes project vision and description, exploitation objectives, key differentiators, market analysis, Key Exploitation Results (KERs) for each use-case and possible strategic alliances. These strategies focus on ensuring AI4SWEng sustainability after the project period.

1. Introduction

1.1. Purpose of the document

The purpose of this document is to provide a comprehensive plan for AI4SWEng exploitation and business. There are several high-level strategies put forward with an aim to guide how to translate the results from research and development towards market-oriented and industry solutions. From those strategies, this document transforms the academic and innovative outcomes of the AI4SWEng project into commercially viable products and services with measurable impacts on industry.

In particular, the document develops a structured framework for the identification of exploitable results, the analysis of the competitive and regulatory environment, as well as the definition of strategies for product positioning and market entry. It also details an action plan to deal with the whole innovation pathway, from early identification of user needs and market trends up to the design of sustainable business models and long-term funding strategies. Finally, it provides tools to analyse feasibility through market and competition analysis, SWOT (Strengths, Weaknesses, Opportunities and Threats) [1] and PESTLE (Political, Economic, Sociological, Technological, Legal and Environmental) [2] assessments, and financial projections that support informed decision-making by all Partners.

Beyond its analytical function, this paper serves as a guide for action. Concrete actions are identified to enhance the collaboration between academic, industrial, and policy stakeholders. The document also defines the lines of communication with open-source communities and the ecosystem of developers. It provides guidance on the formation of strategic alliances that will be critical for scaling up the adoption and ensuring interoperability across domains such as healthcare, automotive systems, FPGA (Field Programmable Gate Arrays) design, energy management through to geographical information systems, network intrusion detection, and software engineering.

This exploitation and business plan has thus been conceived to ensure effective commercialisation of the AI4SWEng suite and to guarantee its sustainability beyond the funded period of the project. Accordingly, this plan sets out the framework for our impact mobilisation to contribute to strengthening European competitiveness in AI-driven software engineering as part of broader policy priorities, such as digital transformation [3], the green transition [4], and the responsible deployment of trustworthy AI [5].

The above presets the logically requisite sections to be included across the two exploitation deliverables as a whole; thus, some of the sections will be covered in this deliverable and some will be presented in its sequel as planned.

1.2. Project overview and vision

AI4SWEng is envisioned as a collaborative effort at the juncture of artificial intelligence, software engineering, and applied industrial innovation. It addresses an ever-increasing demand for more efficient, reliable, and ethically aligned processes in software development when faced with raising challenges such as system heterogeneity, accelerated release cycles, regulatory compliance, and pressing sustainability issues [6].

The project unites the skills and expertise of 15 academic, industrial, and research Partners from Europe in model-driven software engineering, AI engineering, healthcare IT, automotive systems, cybersecurity, and high-performance computing. This diverse Consortium provides the technical capability and market insight for successful innovation and exploitation.

The vision of AI4SWEng is to establish itself as the reference AI-enabled software engineering suite in Europe and beyond. To achieve this, the project seeks to integrate large language models (LLMs) and TinyML into agile software engineering workflows, while enabling design-by-contract, trustworthy-by-design, and energy-efficient development practices. Its holistic approach ensures cross-domain applicability, which is demonstrated and validated through use-cases in software lifecycle optimisation, automated medical report generation, FPGA programming, and battery management for electric vehicles. Its compatibility is also illustrated by a use case in smart energy management through Geographical Information Systems (GIS). By taking advantage of those technologies, AI4SWEng seizes the opportunity to increase developer's productivity by reducing repetitive workload and abnormally long development processes. More than being a technological enabler, AI4SWEng positions itself as a catalyst for European digital and green transition [6].

1.3. Objectives of exploitation and commercialisation

AI4SWEng objectives regarding commercialisation and results exploitation are defined to ensure that the produced outputs will extend beyond the funded lifetime of the project and generate a sustainable impact for industrial and academic worlds. To achieve this ambition of transforming the research output into a market-ready solution that could be adopted by SMEs, industrial partners and public organisations from Europe, the project should target a global technology readiness level (TRL) of 4 to 5 for its modules during the project period. Further developments will be necessary to commercialise the product and are described in the Key Exploitable Results (KER) section of this document. AI4SWEng should also ensure that requirements such as interoperability and scalability can be adapted to the operational context, maturity and transparency of individual companies for trust purposes in real-world applications. Moreover, to consider sustainability, robust business models must be established, encompassing Software as a Service (SaaS) offerings, enterprise licensing, consultancy and training modules. It will also enable AI4SWEng to evolve through open innovation and community engagement.

In the academic context, AI4SWEng can secure the long-term growth of the resulting AI-empowered software development suite through additional investments, especially coming from European funds for the digital and green transition. Indeed, the strong emphasis on ethical and regulatory compliance, including responsible AI principles, alignment with GDPR [7] and the EU AI Act [8] and specific regulations related to the healthcare and automotive sectors makes it a strong candidate for future funding. Through all those characteristics, seeks to establish itself as a competitive and reliable solution for AI-driven software engineering in Europe.

Part I – Exploitation Plan

2. Product Identification

2.1. Overview of AI4SWEng Engineering Suite

AI4SWEng is an AI engineering suite conceived as a modular platform bringing together a set of comprehensive AI-driven tools, referred to as KIOs (Key Innovations and Outputs), to support the end-to-end software development lifecycle. Compared to other AI solutions specialising in specific tasks from the SDLC (Software Development Lifecycle) [32], AI4SWEng is designed as a holistic framework interconnecting requirement engineering, software design and implementation, debugging/testing, deployment and maintenance by considering a data management plan. This approach addresses the inherent complexity of modern software systems caused by heterogeneous environments by considering the whole SDLC instead of specialising in parts of it. It is also designed to meet reliability, security and energy efficiency standards.

The core of AI4SWEng brings together intelligence, automation and adaptability into all phases of software engineering through LLMs and TinyML models. The modular architecture of the suite makes it flexible and interoperable, enabling it to be available either as a cloud-based SaaS platform for SMEs and academic institutions, or as an on-premises enterprise solutions for sectors requiring confidentiality and privacy over the data. This dual deployment makes the suite even more adaptable to a wide variety of operational contexts and suitable for further development to support exploitation.

AI4SWEng ensures that the produced solutions are not only efficient but also trustworthy and aligned with European standards for sustainable and ethical AI. This embodiment is possible thanks to mechanisms such as design-by-contract, compliance checking and energy-aware optimisations. It positions the suite as a perfect balance between productivity and considerations for societal and environmental stakes.

The modular architecture of the framework enables it to be an evolving ecosystem capable of integrating emerging new technologies through open-science principles and DevOps. It safeguards the long-term relevance of this project by keeping pace with the rapid advances in AI and software engineering.

2.2. Description of Modules

As presented in the product overview, the AI4SWEng suite is composed of a rich portfolio of modules addressing critical steps in the SDLC and interoperability of the framework.

As a main component, an orchestrator is responsible for connecting all modules, ensuring the smooth running of the development process. This module presents a User Interface, enabling the different stakeholders to interact with the framework and providing the inputs required by each SDLC task. The orchestrator can even involve users when reviews or information complements are required by other KIOs.

As a starting point, KIO3, which is the "natural language processing to formal requirements" module responsible for the translation between human dialect and machine interpretation. Its goal is to capture the user's needs with precision, transforming a provided natural language description into formal requirements. After obtaining the requirements, KIO4, "formal requirements to code architectural planning" pushes the translation further by transforming the specifications into structured software architectures capable of ensuring those requirements.

At the centre of the framework, the "AI-SysDev tool" (KIO7) provides code assistance and completion capabilities by combining LLM fine-tuning and inferencing to support a wide range of development tasks. This module acts as an intelligent collaborator enhancing human expertise in tasks from code generation to proactive coding suggestions.

The combination of KIO2 "bug locate and fix" and KIO11 "AI-powered test automation tool" enables error fixing and test execution to prevent code malformations and to cover a test battery, including edge cases, as a guarantee of software quality. These modules improve productivity by addressing debugging tasks which are time-consuming and test generation which is often non-exhaustive and requires several iterations. Ultimately, these are responsible for the solution reliability by reducing the likelihood of undetected errors.

Alongside these definitive and contextual bug detection and mitigation components, KIO12, "AI-assisted cybersecurity and multi-level security by design", acts as a proactive safeguard for the security of the solution by identifying vulnerabilities and embedding resilience into the product from the earliest stage of development.

As a deployment facilitator, KIO8, "AI cross-compilation and reconfiguration", enables the configuration of the build environments and the compilation of the produced software within them. It provides flexibility by simplifying the compilation across multiple platforms and hardware architectures.

Recognising the need for trustworthy and sustainable software development, KIO9, "responsible innovation and design-by-contract code generation", ensures that compliance and contractual

constraints are embedded directly into the generated code. This guarantees not only functional correctness but also alignment with ethical principles and regulatory frameworks.

As a complementary module depending on the target solution, KIO10, “energy-efficient TinyML and LLM integration”, addresses the challenge of deploying AI at the edge of low-power and resource-efficiency for IoT and embedded applications in domains such as electric mobility. KIO5 “synthetic data generation” and KIO6 a “data preparation and validation tool” offer data-centric capabilities. In domains where the real-world data is scarce and subject to privacy constraints, AI4SWEng tends to provide the ability to generate high-quality synthetic datasets which should replace the initial dataset or complete it. Alongside this capability, AI4SWEng also aims for a consistent data preparation and validation process to guarantee the data usability in ML/DL models and enabling their clean and robust integration in AI pipelines.

Lastly, to provide guidance to the practitioners and encourage the suite acceptance, KIO13 “developer training module” offers a support for learning about AI4SWEng tools and capabilities. This module does not only facilitate the integration of the whole framework into existing workflows but also contributes to the wider diffusion of knowledge in a longer term.

Beyond their innovative nature, the combination of all KIOs, each specialising in specific tasks, represents an important step towards a comprehensive framework for addressing the challenges of AI-based SDLC. New modules such as KIO9 and KIO13 will support other tasks by offering compliance checks and tutorials throughout the SDLC workflow.

2.3. Key Differentiators & Unique Selling Points

AI4SWEng distinguishes itself in a competitive landscape through its unique combination of modules addressing the SDLC. Whereas existing AI-driven tools specialise in narrow tasks such as code completion or bug detection, the proposed solution aims to provide a fully integrated ecosystem that spans the entire spectrum of software engineering tasks. This coverage ensures that AI4SWEng functions as a unified framework capable of supporting diverse contexts and not as a fragmented set of utilities.

A significant distinguishing feature of AI4SWEng lies in its commitment to responsible and trustworthy AI. By embedding mechanisms such as design-by-contract, compliance verification and ethical safeguards in its modules, it guarantees efficiency and alignments with regulatory frameworks and standards such as the GDPR [7] and EU AI Act [8]. For the healthcare sector and automotive industries, this strong emphasis on transparency and accountability positions the framework as a trustworthy candidate.

Another important selling point is the capability of combining state-of-the-art solutions based on LLMs and energy-efficient TinyML deployment. It makes the solution relevant in both cloud-based environments and resource-constrained systems by addressing a balance between high-performance computing and low-power edge scenarios that only few competitors can offer.

Furthermore, the modular and extensible architecture of the suite ensures adaptability to emerging technologies and evolving industrial needs. Depending on the use-case, modules are involved and orchestrated to fulfil the different tasks. The modular architecture makes this orchestration adaptable to the maturity level,and coupled with dual deployment modes enhances its attractiveness across multiple sectors. This adaptability will be demonstrated in a concrete way through the five representative project use-cases:

- Use-case 1 – Optimising Software Development Lifecycle Using Large Language Models: The goal is to accelerate CI/CD pipelines, improve code quality and enable intelligent documentation to support enterprise-level DevOps adoption.
- Use-case 2 – Automating Medical Report Generation Using Large Language Models: The goal is to deliver secure, explainable document automation for hospitals and digital-health providers within strict regulatory environments.
- Use-case 3 – Advanced Software Generation for FPGAs in C++ and HLS: The goal is to assist semiconductor and telecom industries by translating high-level code into hardware logic, reducing reliance on scarce expertise.
- Use-case 4 – Next-Generation Battery Management in EVs with AI-Driven TinyML: The aim is to support OEMs and fleet operators with edge-deployed AI for safe, efficient and regulation-compliant battery optimisation.

- Use-case 5 – AI-Powered GIS Integration for Smart Energy Management: The goal is to enable cities and energy operators to integrate distributed renewable assets and enhance grid intelligence.

Finally, beyond providing tools, the AI4SWEng focuses on developer empowerment and capability to integrate dedicated training resources and adoption programs, and to provide practitioners with the skills and confidence to leverage AI effectively. It does not only accelerate adoption but also ensures that the productivity and creativity gains brought by AI are accessible to a wide range of users, from SMEs to large industrial actors.

3. Market Analysis

3.1. Target Market Segments

AI is shaping several sectors by creating opportunities for intelligent software engineering solutions in Europe. The investment for AI in the software development market is projected to grow from $674 million in 2024 to over $15,7 billion by 2033, reflecting a 42% compound annual growth rate (Figure 1). This trend is mirrored across other segments such as healthcare, automotive, energy and smart infrastructure. This trend is driven by the escalating demand for automation, digital transformation pressure, skill shortages and complex regulatory landscapes.

System integrators, software vendors, industry solution providers and public sector stakeholders represent the core market of AI4SWEng. Companies of all sizes seek end-to-end automation, explainable AI and toolsets meeting security, privacy and auditability demand. Additionally, specific groups such as digital health innovators, automotives OEMs and research institutions also seek to harness the trustworthiness and high performances of AI to drive competitiveness and sustainability.

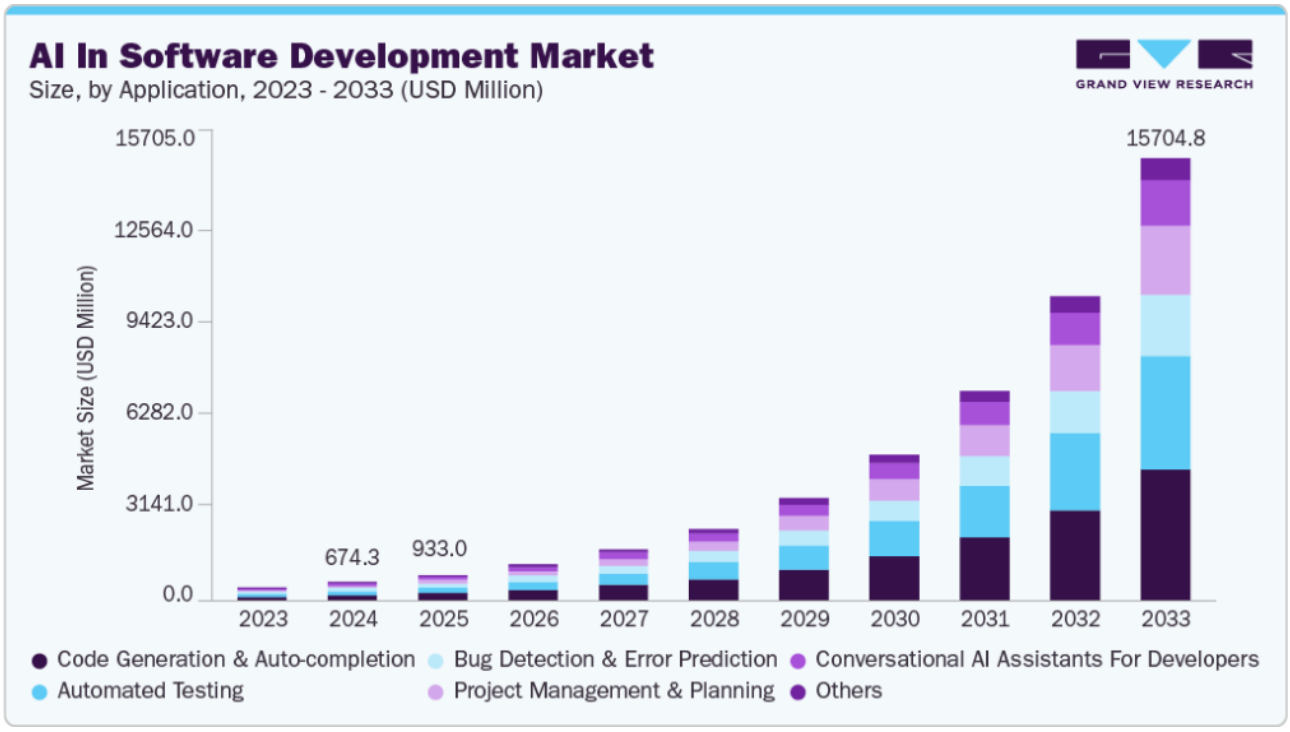

Figure 1 AI in Software Development Market Analysis [9]

Use-case 1: Optimising Software Development Lifecycle Using Large Language Models

Software development and DevOps markets are evolving rapidly, fuelled by the mainstreaming of generative AI and the increasing adoption of AI tools for code assistance, code review and intelligent documentation generation. The market stakeholders in this segment require an adaptable and scalable solution integrating AI as a release accelerator. Its benefits also include the improvement of the software quality and an easier integration with modern CI/CD pipelines. Nearly every enterprise IT function stands to benefit as nearly half of all AI deployments now focus on IT automation and code lifecycle tasks.

Use-case 2: Automating Medical Report Generation Using Large Language Models

Stakeholders such as healthcare providers, hospitals and digital health start-ups represent an important segment requiring secure and explainable automation for medical records. Europe and health authorities exert pressure on them to digitise and harmonise data infrastructure, reduce clinician workload and eliminate documentation errors. Those requirements empower AI-driven solutions because they can achieve them. According to *Precedence Research* (2024), the global healthcare IT market is projected to grow at a CAGR of 15.83% from 2025 to 2034 [10].

Use-case 3: Advanced Software Generation for FPGAs in C++ and HLS

Industries focused on hardware acceleration, edge computing, and telecom, especially those deploying FPGAs, are experiencing an urgent need for tools that bridge software engineering and hardware logic. Semiconductor vendors, digital twin developers, and R&D organisations stand to gain from an AI-based translation of high-level code into efficient, error-resistant hardware logic, reducing reliance on scarce hybrid talent and compressing time-to-market.

Use-case 4: Next-Generation Battery Management in EVs with AI-Driven TinyML

Because of its central position toward energy transition and climate neutrality, the global EV sector represents an important market segment for AI-powered solutions boosting battery safety and efficiency. OEMs, fleet managers and BMS developer also could benefit analytic capabilities to support their compliance with strict EU data and sustainability mandates. TinyML-powered models that perform on the edge without compromising security or privacy are of critical commercial interest.

Use-case 5: AI-Powered GIS Integration for Smart Energy Management

GIS software companies and city energy managers contribute to energy transition by seeking digital solutions which can manage the distributed energy assets. They also work for the integration of renewables and build climate resilience. As part of this effort, AI-augmented GIS emerges as a key

enabler for grid modernisation and operational intelligence in a market already valued at over $30 billion worldwide [11].

3.2. Market Needs & Trends

The landscape of AI-driven software engineering is undergoing rapid transformation driven by regulatory shifts and an escalating demand for efficiency, reliability and compliance. Across all domains organisations seek an innovation accelerator addressing skill shortages and responding to ethical and legal imperatives such as the EU AI Act [7], Data Act [30], GDPR [8] and several other local regulatory bodies.

First, the global market undergoes a profound transformation driven by the increasing demands for automation and digital transformation across sectors such as software development, healthcare, mobility and energy. Moreover, organisations are under pressure, seeking competitive enhancement, and reduction of operational costs and time-to-market. Beyond efficiency gains, enterprises also request more adaptive and optimised tools enabling integration across distributed and hybrid architectures.

In addition, a new market trend emerged, highlighting an imperative need for regulatory compliance, trust and explainable AI. It induces AI-specific requirements for transparent, auditable and interpretable models, upholding accountability and fairness. This is supported by Europe by way of evolving certification protocols, standardisation initiatives and liability frameworks. As a result, compliance with ethical and regulatory standards has become a competitive differentiator for stakeholders from healthcare, transport and energy sectors.

Another key aspect in Europe is the emergence of new pillars for innovation and policy alignment such as sustainability and green technology. The aim is to achieve energy usage optimisation, emission reduction and a minimisation of the environmental impact in line with the European Green Deal and the global decarbonisation objectives. Those new pillars are especially important for sectors like mobility, energy and manufacturing for which AI represents an important driver to achieve the target objectives.

Lastly, the market is seeking rapid growth for interdisciplinary integration through unified platforms as organisations strive for accessible AI, software engineering, IoT and domain expertise. The complexity induced by those domains, coupled with the scarcity of hybrid technical skills, led to the adoption of low-code and modular SaaS solutions, empowering organisations to embed AI capabilities rapidly and securely.

To go further, market analyses have also been conducted for the five use cases illustrating the impact of the AI4SWEng project.

Use-case 1: Optimising Software Development Lifecycle Using Large Language Models

Over the last decade, the strategic target for software professionals and IT vendors has increasingly shifted toward enabling SDLC time reduction, improved of code quality and regulatory compliance while reducing the technical debt. They also aim for an increase of the productivity and product quality by addressing pain points such as the requirements translation, error-prone manual testing and the inconsistency of the documentation. LLMs position themself as an interesting tool for addressing those points while supporting explainability, traceability and integration within existing DevOps and CI/CD environments. There is increased demand for those tools to meet growing need to adhere to coding standards, manage rising system complexity, and ensure energy efficiency (for Green Software). Wider adoption of LLMs is also inhibited by the scarcity of training resources and the complexity of integrating with secure, privacy-aware data pipelines, underlining the value proposition of end-to-end solutions such as those developed in AI4SWEng.

Use-case 2: Automating Medical Report Generation Using Large Language Models

Healthcare systems are under continual pressure to deliver more with less, against the backdrop of increasing regulation and the moral imperative to ensure patient safety. The generation of accurate, timely, and compliant medical documentation is a critical pain point for clinicians. Manual reporting increases the risk of errors, non-compliance, and burnout. AI-powered report automation offers substantial time savings, accuracy, and consistency, but must also meet stringent requirements for data privacy, explainability, and human oversight. The need to integrate with complex health IT infrastructure and address sectoral regulations (GDPR, MDR [33], national health standards) shapes purchase decisions. Increasingly, there is also demand for structured interoperability and anonymisation as digital health data is shared across providers and jurisdictions. AI4SWEng responds to these needs by enabling LLM-based, human-in-the-loop documentation that is explainable, audit-ready, and adaptable to regional policy contexts.

Use-case 3: Large Language Models for Advanced Software Generation for FPGAs in C++ and HLS

Markets leveraging FPGAs, including telecom, industrial automation, and secure digital infrastructure, face a critical bottleneck in the time-intensive process of code translation, verification, and optimisation for custom hardware. Users need reliable methods to convert high-level programming specifications (e.g. C++, HLS) into efficient and error-free hardware architectures. Manual approaches are slow and susceptible to costly errors, especially as systems demand higher performance and security. The lack of hybrid hardware/software engineering talent further compounds these challenges, making AI-powered code synthesis, iterative prompt engineering, and automated project validation highly desirable. The need for traceable, repeatable

workflows, where designs can be iteratively refined and verified in closed feedback loops directs attention to advanced LLM-driven systems with integrated simulation and debug support. IP protection, hardware compatibility, and standards compliance (e.g., ISO 26262) are mandatory requirements.

Use-case 4: Next-Generation Battery Management in EVs with AI-Driven TinyML Solutions

During recent years, the electric vehicle field has rapidly expanded and put a priority on the improvements in battery lifetime, safety and real-time diagnostics. Fleet managers and EV manufacturers seek AI-powered BMS solutions that deliver accurate RUL predictions and anomaly detection directly at the edge. Their objective is to support predictive maintenance without exposing private data. Growing legislative focus on data privacy (e.g., federated learning mandates), robust over-the-air update paths, and energy efficiency on microcontroller-scale hardware drive demand for innovative solutions. AI models must balance explainability, accuracy, and minimal computational footprint, while supporting reliability evidence for certification. The emergence of "green" supply chains and the need to reduce total cost of ownership further reinforce the value of privacy-preserving, resource-efficient, and trustworthy battery analytics platforms such as those developed in AI4SWEng.

Use-case 5: AI-Powered GIS Integration for Smart Energy Management

Energy and utility sectors, driven by smart grid demands, renewables integration, and grid decentralisation challenges, are among the most rapidly changing sectors. Operators seek AI-powered platforms offering actionable insights into geospatial, operational, and meteorological data. Complex issues demand resilient, explainable, and scalable solutions across national boundaries and regulatory domains: demand forecasting, renewable supply prediction, and network optimisation. System interoperability, secure data integration, and the ability to provide support for real-time and predictive analytics are key to this. In addition, the current shift toward distributed energy resource management and the need to support sustainability and resilience targets, particularly under the European Green Deal, open wide avenues for customisable, modular AI-GIS solutions.

3.3. Competitive Landscape and Exploitation Strategy

Market Position: The Shift to High-Assurance AI Engineering

The current market for AI-assisted software development tools remains highly fragmented. The developers must often combine fragmented, standalone tooling themselves, each addressing only a single, isolated step of the SDLC. This fragmentation increases the total cost of ownership and reduces end-to-end traceability. AI4SWEng addresses this critical market gap by delivering an integrated AI Engineering suite that provides a closed-circle, transparent development environment spanning requirements capture, code generation, testing and validation.

Direct Competitive Analysis

AI4SWEng is primarily differentiated by its commitment to an explainable, integrated, and EU-compliant approach. While many competitors offer excellent single-functionality tools, they fail to provide the end-to-end lifecycle governance necessary for complex enterprise and regulated environments. Table 1 below provides a comparative analysis of AI4SWEng against major incumbents and research-grade solutions across key functional areas, highlighting how the project overcomes the limitations of existing solutions.

Table 1 Gap Analysis: Key Weaknesses of Current AI Point Solutions Compared to the AI4SWEng Suite.

Competitor / solution	Description	Strengths	Weaknesses	AI4SWEng advantage
GitHub Copilot [12]	AI-assisted code completion and generation tool integrated into IDEs (e.g., VS Code, JetBrains).	Mature product, wide user base, strong NLP-code mapping, seamless IDE integration.	Limited explainability, data privacy concerns, lacks domain-specific adaptation.	AI4SWEng offers explainable, trustworthy, and customisable AI with GDPR compliance and ethical design.
DeepCode [13] / Snyk Code [14]	AI-powered code review tool identifying vulnerabilities and code quality issues.	Strong on security and bug detection, real-time feedback, integration with CI/CD.	Focused mainly on static analysis, limited multi-level reasoning.	AI4SWEng integrates predictive debugging, reverse execution, and dynamic slicing (Bug Locate & Fix component).
CodeBERT [15] / CodeT5 [16] / PolyCoder [17]	Foundation LLMs for code understanding and generation.	Excellent open-source benchmarks, flexible pre-training.	Not production-ready, high computational cost, lacks lifecycle integration cost, lacks lifecycle integration	Production-ready suite with low-energy optimisation and integrated training, offering practical deployment into the

				full software lifecycle
UiPath [18]	Automation of repetitive software tasks and testing using AI models.	Robust enterprise adoption, good orchestration capabilities.	Limited applicability for agile software engineering pipelines.	AI4SWEng includes AI-driven DevOps (cross-compilation & reconfiguration) and TinyML energy-efficient optimisation for embedded and edge contexts.
Balsamiq [19] / AdobeXD [20]	Tools for UI/UX design and requirements management with partial automation.	Mature, easy-to-use, established ecosystems.	Mostly manual or rule-based automation, not AI-driven.	AI4SWEng's NLP-to-specification requirements-to-code component enables automatic transition from natural language to architectural design.
Codacy [21] / SonarQube [22]	Continuous code quality and static analysis tools.	Integration in CI/CD pipelines, quality metrics dashboards.	Reactive rather than proactive, no natural language understanding.	AI4SWEng's proactive and deeper coding suggestions and LLM-driven quality checks surpass reactive rule-based systems.
OpenAI ChatGPT Enterprise [23] / Anthropic Claude [24]	General-purpose LLMs used for documentation, testing, and code generation.	Large-scale model capacity, versatile conversational interface.	Black-box models, limited compliance with EU AI Act, privacy risk.	AI4SWEng's LLMs are explainable and EU AI Act-aligned for trustworthy AI-based software engineering.
Katalon [25] / Testim.io [26]	AI-driven test generation and maintenance tools.	Automated test case generation, visual test builder.	Limited interpretability, vendor lock-in, lacks integration with AI-based architecture design.	AI4SWEng's Test Automation Tool (TAT) integrates seamlessly into a complete AI-driven SDLC ecosystem.

AI4SWEng Competitive Advantage

The analysis confirms that the primary technical advantage of AI4SWEng lies in its architectural unity and end-to-end coverage of the software development lifecycle. Unlike competitors that offer black-box, single-layer solutions, AI4SWEng transforms the landscape by integrating its independent modules into a single, traceable platform. This integration enables proactive capabilities, such as automatic transition from natural language requirements to formal specifications and code and includes state-of-the-art features such as predictive debugging and TinyML optimisation for edge deployment. Furthermore, the suite incorporates dedicated advanced developer training to maximise the utility of the AI tools. Critically, this holistic approach guarantees explainability, data privacy and mandatory alignment with EU regulatory demands, positioning the project as a high-assurance solution and the main market differentiator.

3.4. SWOT Analysis

The analysis under Task T2.2 identified the interrelations between current scientific advances, market dynamics, and practical challenges relevant to the integration of AI into software engineering. These interrelations and findings on State-of-X (X=Art, Practice or Market) form the basis of the SWOT Analysis.

From a state-of-the-art perspective, AI4SWEng builds upon strong foundations in Large Language Models (LLMs), Explainable AI (XAI), and AI-assisted software lifecycle automation (e.g. AutoML, as in Model-driven automated AI Engineering (AutoML), Moin et al). These research-driven capabilities position the project at the forefront of AI-enabled software engineering. However, challenges remain in achieving robust explainability, scalability, and seamless integration of AI reasoning mechanisms into existing software engineering pipelines.

Regarding the state-of-the-market, there is a clear opportunity for AI4SWEng to address growing industrial demand for intelligent software development tools. The regulatory push under the EU AI Act [8] and ISO/IEC 42001 [27] fosters a favourable environment for transparent, auditable, and human-centric AI applications. Nonetheless, the dominance of major technology providers (e.g., Microsoft, Google, Amazon) poses a competitive threat, emphasising the need for European alternatives that ensure digital sovereignty and compliance with trustworthy AI principles.

In terms of the state-of-the-practice, adoption challenges persist due to limited access to high-quality engineering datasets, lack of standardised methodologies for AI-based verification and certification, and the scarcity of hybrid-skilled professionals combining AI and software engineering expertise. Despite these barriers, AI4SWEng demonstrates the potential to bridge the gap between research innovation and industrial application through demonstrators and co-creation with industrial Partners.

The mapping presented in Table 2 confirms that AI4SWEng is strategically positioned to advance the integration of AI into the software engineering domain by linking research excellence (state-of-the-art), market relevance (state-of-the-market), and operational feasibility (state-of-the-practice). This tri-layered understanding directly supports the definition of key requirements, architecture design, and validation scenarios in subsequent work packages (WP3, 4, 5).

Table 2 State-of-X mapping with SWOT highlights

Dimension	Highlights in SWOT
State-of-the-Art	Strengths in LLM, explainability, self-adaptive SE pipelines; Weakness in integration & explainability maturity
State-of-the-Market	Opportunities from industrial AI adoption & regulatory compliance; Threats from BigTech competition & rapid tech shifts

State-of-the-Practice	Weaknesses in data, tools, and skill alignment; Threats from practitioner resistance and security risks

Based on this mapping, the overall SWOT analysis of the current competitors of AI4SWEng solution portfolio is as follows:

Strengths (State-of-the-Art & Objectives)	**Weaknesses (State-of-the-Practice)**
• Integration of AI and SE across the full software lifecycle (requirements → maintenance). • Cutting-edge research in LLMs, explainability, verification, and trustworthy AI. • Strong Consortium expertise combining RTOs, universities, and industry leaders. • Human-centric, AI-assisted SDLC toolchain improving quality and productivity. • Alignment with EU AI Act [8] and Horizon Europe priorities (trustworthy, sustainable AI). • Cross-domain adaptability (automotive, healthcare, CPS).	• Integration complexity between AI components and legacy / safety-critical SE pipelines. • Data scarcity and inconsistent quality of SE datasets for AI training. • Explainability gap in AI recommendations for software design and testing. • Dependence on hybrid skill sets (AI + SE) that are costly and rare. • Lack of standardised certification frameworks for AI-driven SE processes. • High computational/energy costs challenge sustainability goals.
Opportunities (State-of-the-Market)	**Threats (External Environment)**
• Growing industrial demand for AI-powered coding, testing, and DevOps tools. • Regulatory momentum (EU AI Act [8], ISO 42001 [27]) favouring transparent, auditable AI tools. • Push for European digital sovereignty and open-source AI frameworks. • Emergence of green and sustainable software engineering supported by AI. • Expansion into CPS, cybersecurity, and digital twin domains. • Upskilling through AI-driven SE education and workforce training.	• Big Tech dominance (Copilot [12], Gemini [28], CodeWhisperer [29]) limits EU market share. • Ethical/legal uncertainty on data usage, licensing, and AI accountability. • Rapid technological obsolescence before commercialisation. • Cybersecurity/IP leakage risks in AI-assisted coding environments. • Practitioner resistance and mistrust toward AI recommendations. • Fragmented industry adoption across sectors and maturity levels.

3.5. PESTLEE Analysis

The PESTLEE framework is a comprehensive macro-environmental analysis methodology designed to identify and evaluate external factors that can influence the strategic direction, success, and sustainability of research and innovation projects. It systematically examines the political, economic, social, technological, legal, environmental and ethical dimensions shaping the broader landscape in which AI4SWEng operates. It extends the traditional PESTEL model by including ethical dimensions, a particular aspect relevant to AI4SWEng, which operates at the intersection of AI, SE, and human-centric technology development.

While the SWOT analysis focuses on internal strengths and weaknesses, the PESTLEE analysis assesses external drivers, constraints, and opportunities arising from the political, economic, social, technological, legal, environmental, ethical, and educational context in which the project evolves. For AI4SWEng, this perspective provides essential foresight for aligning its scientific and technical outputs with EU digital policy, regulatory frameworks, societal expectations and skills development objectives.

This following PESTLEE analysis supports the project's risk management, innovation exploitation and strategic alignment with European priorities under Horizon Europe, the AI Act and the Digital Europe Programme.

Political

- The EU AI Act and Digital Europe policies prioritise trustworthy, explainable, and human-centric AI, directly reinforcing the design principles of AI4SWEng.
- Horizon Europe and the Digital Europe Programme frameworks promote European sovereignty in AI technologies, supporting funding continuity and policy relevance.
- Ongoing standardisation activities (ISO/IEC 42001, ETSI, CEN/CENELEC) define new compliance pathways for AI quality management and certification.
- Public procurement in digital transformation and cybersecurity provides opportunities for deploying the tools of AI4SWEng in public-sector SE environments.
- Geopolitical dependencies on non-EU AI infrastructure underline the strategic need for trustworthy, open, European AI solutions, an area where AI4SWEng can lead.

Economic

- The AI-assisted software development market is expanding rapidly, representing a significant opportunity for European innovation.
- AI4SWEng technologies can deliver high efficiency and productivity gains, reducing lifecycle costs across industries.
- Economic barriers such as computational cost, infrastructure requirements, and data acquisition challenges may limit short-term scalability.
- Market competition from Big Tech companies validates demand but necessitates differentiation through openness, transparency, and EU compliance.
- Recovery and resilience funds, and digital transformation initiatives can facilitate technology transfer and industrial adoption at higher TRLs.

Social

- A focus on human-centric AI enhances acceptance among developers and engineering teams by ensuring transparency and user control.
- Upskilling opportunities emerge from the capacity of AI4SWEng to train a new generation of AI-literate software engineers.
- Potential resistance to automation may persist if AI is perceived as a threat to jobs or professional autonomy.
- Co-creation and participatory design approaches are key to ensuring trust and usability in industrial demonstrators.
- By fostering open collaboration and knowledge sharing, AI4SWEng contributes to inclusive digital transformation across Europe.

Technological

- Advancements in LLMs, explainable AI (XAI), trustworthy AI, cyber security, Generative AI (GenAI) and AutoML are key enablers for the AI4SWEng intelligent software engineering framework.
- Integration complexity between AI modules and established SE practice (e.g., DevSecOps, Model-Based Systems Engineering) remains a major challenge.
- The need for cybersecure, privacy-preserving data pipelines demands built-in trust mechanisms.
- Emerging paradigms such as self-healing systems and AI-driven verification complement AI4SWEng's technological roadmap.

Legal

- The AI Act mandates risk-based classification, human oversight, and transparency, principles already embedded in research objectives of AI4SWEng.
- GDPR compliance requires rigorous handling of training data, ensuring consent, anonymisation, and data minimisation.
- Intellectual property risks from AI-generated code necessitate licensing-aware and traceable development workflows.
- Evolving standardisation frameworks (ISO/IEC 42001, ISO/IEC 23894, ECSS standards) will influence the validation and certification approaches of AI4SWEng.
- Accountability and liability remain complex and evolving; proactive governance mechanisms will be essential for trust and adoption.

Environmental

- Sustainable AI practices are increasingly expected. AI4SWEng must balance model performance with energy efficiency.
- AI4SWEng can indirectly contribute to reduced energy consumption via optimised code, predictive maintenance, and adaptive deployment strategies.
- Alignment with the European Green Deal and sustainable digitalisation goals adds policy relevance and strengthens impact potential.
- Promoting eco-efficient AI training and edge deployment supports environmentally responsible innovation.

Ethical

- Trust, transparency, and human oversight are fundamental ethical imperatives embedded within the AI4SWEng approach.
- Ensuring fairness and bias mitigation in AI-driven software recommendations is critical for inclusivity and credibility.
- Establishing ethical governance frameworks aligned with the EU Guidelines for Trustworthy AI will maintain accountability and integrity.
- Explainability and interpretability empower users to understand and challenge AI recommendations, increasing trust.
- The project commitment to open science and reproducibility reinforces ethical excellence and societal benefit.

4. Key Exploitable Results

4.1. Use-case 1: Optimising Software Development Lifecycle Using LLMs

The main goal of use-case 1 is to improve the SDLC by leveraging LLMs' capabilities integrated within the AI4SWEng framework. It aims to improve the efficiency across all phases of software engineering, from the requirements elicitation to the debugging and deployment while improving the overall code quality.

It tends to address issues such as long debugging times, inconsistent documentations, limited automation in testing and reviewing processes, and the lack of connections between the requirements and the code implementation. The use-case leverages several KIOs integrated in the AI4SWEng suite to address those challenges. Among them, key components are "bug locate & fix", "NLP to formal requirements", "requirements to code planning", "AI-SysDev with fine-tuned LLMs for code generation" and "AI-powered Test Automation Tool (TAT)". The integration of these modules enables a smooth and intelligent workflow that transforms natural language inputs into reliable and maintainable software artefacts.

AI-assisted software development is a rapidly evolving field. For example, GitHub Copilot is a paid tool that can help automate some parts of code generation. In contrast, AI4SWEng integrates all stages of the software development lifecycle into a unified framework. It enables full traceability from requirements written in plain language to formally validated code. Its design includes ideas such as responsible innovation, explainability, and ethical compliance.

The immediate-term purpose of this use case is to turn AI4SWEng into a tool that improves internal development processes within IDENER, making them more efficient and delivering higher quality outcomes. The first planned post-project milestone is to test the integrated suite in a real pilot to evaluate its impact on code quality, development speed, and maintainability. If successful, the suite will be adopted in current and future R&D projects. This use case has two main purposes: improving internal workflows at IDENER and demonstrating tangible improvements in efficiency and robustness to support future exploitation of the AI4SWEng modules.

To assess the effectiveness of the AI4SWEng suite, both quantitative and qualitative measures will be used. These include shorter development times, fewer coding and debugging errors, better code quality as shown by static analysis and maintainability indices, and increased developer satisfaction and perceived productivity, measured through structured feedback surveys. IDENER aims to demonstrate the real benefits of LLM-driven software engineering by systematically evaluating these indicators. The insights gained from this use case will support the broader adoption of AI4SWEng and its modules in future innovation-driven software projects.

4.2. Use-case 2: Automating Medical Report Generation Using LLMs

Use-case 2 focuses on automating the generation of medical reports using the AI4SWEng LLMs for enhancing efficiency, consistency, and the quality of clinical documentation. It should also implement prescription drug checks to ensure compliance with healthcare regulations and ethical standards. The technical implementation begins with the definition of the requirements and the analysis of clinical workflows to identify automation opportunities. Curated, anonymised datasets and medical ontologies are prepared to ensure interoperability, privacy, and GDPR compliance. An LLM-driven system is then designed to generate accurate, coherent medical reports from structured and unstructured clinical data, supported by human-in-the-loop validation for reliability and knowledge graphs for explainability. Integration with AI4SWEng tools such as AI-SysDev enables continuous improvement, testing, and performance monitoring. Explainability, auditability, and compliance mechanisms ensure clinicians can trace outputs to source data, fostering transparency and trust. In the long-term, the system would be ultimately deployed as a scalable service integrated into hospital information systems, pharmacy software, and patient portals, with commercialisation potential under a SaaS model.

The exploitation strategy targets three user groups within the healthcare ecosystem. For clinicians and hospitals, the fine-tuned LLM would be embedded within EHR systems to detect drug inconsistencies, enhance report accuracy, and support compliance with pharmacovigilance standards while providing explainable guidance for prescription assignment.

In addition, the EHR system would generate clinically accurate health records and reports in compliance with international standardised Logical Observation Identifiers, Names and Codes. Both patient histories and health reports would be generated. The patient history (anamnesis) consolidates the patient's vital data and medical background, while the health report (epicrisis) would bring together clinical tests, examinations, diagnoses, and procedures, providing a complete view of the patient's clinical journey.

For pharmacies, the system would verify prescriptions at the dispensing stage, flagging risky combinations, and would be delivered via API or cloud service to support independent pharmacies and chains. It would also enable anonymised analytics on prescribing trends for regulators, insurers, and manufacturers. Patients would benefit indirectly through safer treatments and clearer communication, with future consumer apps enabling cross-checking of medications against official safety databases, supporting adherence and health literacy while maintaining KVKK (Law on the Protection of Personal Data)-compliant data protection. Together, these streams would create a self-reinforcing ecosystem: clinicians drive adoption, pharmacies ensure safety, and patients gain trust in treatments, while aggregated anonymised data supports national pharmacovigilance.

For patients, consolidated health reports and records would help to provide access to their information from health maintenance services used by the patient without unnecessary repetition of clinical procedures through global access to the patient's data.

BitNet and ATPHARMA leverage a multi-tier licensing approach to maximise adoption and revenue. OEM SDK licenses would target Electronic Health Record (EHR) and Hospital Information Management System (HIMS) vendors with setup and per-patient royalties. Additionally, on-premises enterprise licenses would serve large hospital groups with annual site fees and maintenance. The solution would also be accessible through SaaS API subscriptions, catering to smaller clinics and pharmacies with per-check or monthly fees. Lastly, a regulatory white-label agreement with Ministries of Health or the Turkish Medicines and Medical Devices Agency (TITCK) would provide custom framework support. Intellectual property is protected across key assets: the Drug Interaction Knowledge Graph is safeguarded via copyright and database rights; the AI reasoning and prompt pipeline is patentable; the LLM fine-tuning dataset and prompt library are maintained as trade secrets; and the front-end UI and APIs are protected via copyright and SDK licensing. Compliance and regulatory strategy include MDR EU 2017/745 Class IIa SaMD alignment, TİTCK approval, ISO 13485 QMS [34] and ISO 27001 ISMS certification [35], AI Act compliance with human-in-the-loop oversight and event logging, and strict KVKK [36]/GDPR adherence with on-premises EHR processing and no cloud storage of Personally Identifiable Information (PII).

4.3. Use-case 3: LLMs for Advanced Software Generation for FPGAs in C++ and HLS

As an immediate-term impact, ITCL aims at strengthening its position as an FPGA implementor. In a wide variety of applications, the larger number of clients and publicly funded innovation initiatives lie in dedicated video signal processing and computing devices such as post-quantum cryptography cores and spiking neural network acceleration. Typical advantages of FPGA implementation include very low latency and the ability to deal with high intensities of computation.

However, FPGA designs can be very complex, composed of many submodules, each with its own specific requirements. The AI4SWEng solution is expected to accelerate the entire design, development and testing pipeline significantly, and also reduce errors and reduce resources needed, while increasing the quality.

In line with the general exploitation plans of the AI4SWEng results, and depending on them, in the short-term ITCL can consider the possibilities of licencing the FPGA solution as a development kit. Partnerships with the industry can also leverage the benefits of AI4SWEng for FPGA to wider applications.

Finally, in the mid to long-term, the project results could lead to solid cryptography, NN acceleration or signal processing solutions that can be marketed.

In the follow-up deliverables, when the AI4SWEng solution will have been shaped further, these exploitation options will be detailed, giving more information about immediate-term, short-term and long-term exploitation.

4.4. Use-case 4: Next-Generation Battery Management in EVs with AI-Driven TinyML

Use case 4 is owned by two Partners (AI4SEC & UREAD), each of whom defined their exploitation plan.

AI4SEC exploitation of results

AI4SEC innovation roadmap turns next-generation EV battery management into a deployable, market-ready stack that runs lightweight TinyML models on existing vehicle controllers to forecast RUL, to identify anomalies early, and to recommend BMS actions; while keeping raw data on-vehicle (via federated learning) to protect privacy. The Key Exploitable Results (KERs) remain a portable TinyML model library and code-generation tooling for fast integration, an edge orchestration loop for safe over-the-air updates and a diagnostics assistant that makes alerts explainable for technicians. The delivery follows a pragmatic TRL path from lab baselining to pilots and then OEM hardening with clear KPIs (better RUL error vs. baseline, lower false positives, small on-device footprint/latency, and demonstrated operational ROI).

Commercialisation prioritises revenue and licensing with explicit energy-efficiency and resource-constraint advantages. As a first model, AI4SEC would sell secured licenses/white-labels to OEM Tier-1 for an embedded TinyML RUL module and an integration SDK (licensed per vehicle/platform). It should achieve a higher Inferences Per Watt (IPW) on MCU-class hardware, enabling lower BOM and certifiable energy budgets. Additionally, they would propose an offer combining SaaS and Edge-Twin for fleets (monthly per vehicle) to pair on-device inference with aggregated cloud insights for cutting cellular telemetry and cloud compute costs, directly lowering the operator's bottom line. Moreover, an on-premises OEM toolchain/PaaS for R&D (with synthetic-data support) would permit the tuning of models within strict memory/CPU envelopes, trading cloud spend for deterministic, resource-aware builds. The solution would also be presented as an aftermarket telemetry package (retrofit device + app) priced as fixed fee plus analytics subscription where the business case is driven by fewer uploads, fewer truck rolls, and extended pack life. To improve the customer's confidence, professional services and certification (integration, validation, ISO 26262-aligned evidence using T5 artefacts) will be created, shortening time-to-revenue. Lastly, AI4SEC would make available an open/freemium developer tier (small open models and datasets) to seed adoption from the market.

To deepen the efficiency story and offer a clear silicon migration path, the roadmap adds a FPGA to chiplet-ASIC integration, consisting of optional acceleration blocks for anomaly/RUL kernels that can be delivered first as FPGA/bitstream IP for rapid prototyping and field pilots, then licensed as chiplet-ready IP for integration into Partner SoCs, yielding higher Inference Per Watt and lower unit cost at scale. The commercialisation includes IP licensing (bitstreams/chiplets), NRE for tape-out,

and bundled validation assets. It ties efficiency to value with offerings that include efficiency-linked SLAs (mJ per inference, % telemetry reduction, uptime gains), shared-savings or RoI-backed pricing for fleets, and efficiency badges for OEM sustainability reporting. The solution would deliver higher Inference Per Watt, lower data/compute bills, and measurable reductions in the total cost of ownership, aligned with the actual purchase modes of Tier-1s, OEMs, and fleet operators.

UREAD exploitation of results

In the UREAD exploitation plan, use-case 4 advances the state of the art in the electric vehicle battery management through a privacy-preserving TinyML platform that leverages advanced AI methodologies for precise real-time RUL predictions, engaging EV software engineers, TinyML developers, and data privacy specialists to foster efficiency and sustainability in EV ecosystems. The innovation roadmap commences with core development in the project phase, establishing a secure collaborative framework that prioritises data integrity.

In the immediate term covering M1-M12 post-project, UREAD and AI4SEC aim to build on the results developed by UREAD and AI4SEC to further scientific, technical innovation and contributions for the advancement of Edge AI as for innovations on TinyML, extending the research base and doctoral student training in emerging technologies while collaborating with Partners as the scientific leader to offer trusted-system-by-design consultancy and co-innovation services to industry focused on system security-privacy-integrity protection. This phase facilitates entering into licensing agreements for any exploitation of the KERs that will be delivered in this project, and its background, exclusively subject to terms and condition to be agreed on a case-by-case basis, with acknowledgment and references made to originators in any publications.

Transitioning to the short-term M12-M24 post-project, efforts will be focused on driving value from our innovation to contribute to its social and economic impact and in particular sectoral applications through various channels including commissioned research, consultancy and partnerships to be agreed subject to specific terms and conditions on a case-by-case basis. This plan is centred on UREAD and AI4SEC, KERs for TinyML innovations whereby, exploitable outcomes are safeguarded by Non-Disclosure Agreement (NDA), Copyright and Know-How. Collaboration shall be based on appropriate terms and NDA for scientific and/or commercial exploitation as may be agreed on a case-by case basis, alongside public-licensing or partnerships subject to terms and conditions for scientific and/or commercial exploitation as may also be agreed on a case-by-case basis. Key elements include the federated TinyML platform for commercial licensing in automotive domains, model optimisation strategies enabling public-licensing or partnership integrations with tools such as TensorFlow Lite, and self-adaptive algorithms supporting co-innovation services, collectively yielding enhanced prediction accuracy, computational efficiency, and societal advancements in green mobility through new economic opportunities.

4.5. Use-case 5: AI-Powered GIS Integration for Smart Energy Management

The platform developed at HES-SO Valais serves as a digital twin for territorial communities such as the Canton of Valais. This platform integrates a variety of geospatial and operational data sources (photovoltaic potential, geothermal potential, population, heating and cooling demand, electricity load curves, energy production, grid topology) in a single unified interface to support energy management and predict analytics for photovoltaics, hydropower, and grid performance.

The main challenge is the variety of open-data sources and the external code contributions introduced without proper validation during calculation module development, potentially leading to bugs occurring in the platform. The development, testing, and maintenance of specialised calculation modules are time-consuming and prone to human errors. New requirements from energy analysts often require a manual translation into technical specifications, before becoming production-ready code.

The market for smart energy management platforms is dominated by large players and specialised software vendors. Enterprise GIS and Digital Twin solutions are provided by Esri ArcGIS [37], GE Vernova or Siemens through comprehensive platforms with strong GIS and network management, but custom code generation/testing is manual. AI often focuses on pre-trained models or feature extraction. Other energy and IT/OT utilities also exist and are provided by Schneider Electric, ABB, or Honeywell, but focus on asset management, operational technology integration, and business intelligence. AI is primarily used for optimisation or forecasting, not for automated development. Finally, solutions such as Dagster [38], MLflow [39], and Open Data Cube [40] are excellent for managing data lineage and models but requires the underlying geospatial code to be written manually.

Today, no single digital twin platform fully integrates physics-aware ML, Earth Observation standards, GIS interoperability, and automated compliance testing. The AI4SWEng core innovation lies in the AI-driven automation of the software development lifecycle for geospatial energy solutions. Unlike traditional GIS platforms that offer GeoAI tools or low-code environments, AI4SWEng uses an LLM to ingest high-level NL requirements and generate the corresponding production-ready code, including pipelines and compliance tests. The solution is designed to proactively generate user stories and acceptance criteria and User Acceptance Tests, and then automatically create the necessary unit tests, integration tests, and end-to-end tests. This embeds compliance and data integrity validation into the development process from the start. AI4SWEng accelerates and validates the development of the calculation modules that build the digital twin.

Our exploitation strategy focuses on a phased rollout, prioritising internal validation on the current citiwatts.eu [31] platform before scaling to external Partners and industrial applications:

In the immediate term, covering M1 to M6 post-project, HES-SO aims to focus on the technical foundation, including LLM fine-tuning and prompting, and on improving code generation accuracy. At the end of this phase, a Geospatial Code Generation Engine MVP is expected. Its purpose is to transform high-level NL requirements from energy analysts into production-ready, highly compliant code modules for the citiwatts.eu platform. As a second phase in the immediate term, covering M6 to M12 post-project, the citiwatts.eu platform would integrate the engine. It will also pass through automated testing and compliance documentation phases, leading to a compliant automation framework for GIS. Lastly, as a transition to short-term exploitation during M12 to M18, the focus would be set on scaling and industrialising the product by optimising its performance and developing collaborative engagements with external Partners. At the end of these three phases plan, a complete, optimised, production-ready solution should be available.

The success of AI4SWEng will be measured by following indicators tracking the development productivity induced using LLMs. This productivity is measured through the time-to-deployment, measuring the time elapsed between the NL requirement submission by the analyst and the calculation module being successfully deployed and passing all compliance tests. To be successful, the solution should help reduce time-to-deployment by at least 50%. Another relevant metric is the code correctness rate, which measures the proportion of generated code blocks passing the automated unit and integration tests without human correction. Achieving a score of at least 80% would significantly contribute to the development productivity. Lastly, the test coverage ratio, measuring the proportion of the generated code that is covered by the automatically created unit and functional tests, ensure robust compliance from inception if a minimum score of 80% is obtained.

5. Strategic Alliances & Partnerships

5.1. Potential Academic Collaboration

A sustained and systemic collaboration with Universities and RTOs is a main component of the AI4SWEng exploitation strategy, aligning precisely with the project long-term goals. This engagement model ensures the continuous scientific validation and peer review required to transition core innovations from the targeted project state (TRL 5) towards TRL 7, guaranteeing both technical excellence and future market acceptance. Academic engagement focuses on four critical areas requiring scientific rigor and peer-reviewed validation, complementing the industrial exploitation efforts outlined in WP7 (Exploitation and Business Planning).

Trustworthy ML Validation

A core purpose of AI4SWEng is to address the critical need for trustworthy AI validation in safety-critical software engineering applications. The primary objective of this collaboration is to develop and scientifically validate robust, interpretable reasoning layers for LLMs used in core software engineering tasks (such as code generation, debugging, and testing). This academic challenge directly aims to generate the peer-reviewed evidence and methodologies required to satisfy the strict transparency and explainability mandates of the emerging EU AI Act. This validation ensures that our industrial solutions achieve immediate regulatory compliance, establishing a competitive advantage in European markets.

Responsible Innovation and Formal Assurance

Cooperation with specialised institutes is essential to transition the high-assurance outputs of the Responsible Innovation and Design-by-Contract Compliant Coding component. The joint work will concentrate on the scientific validation of the automated proof generation and symbolic verification systems developed within the project. This critical academic rigour is necessary to confirm the soundness and reliability of the generated proofs, which is a prerequisite for pursuing formal certification in regulated and high-integrity systems markets (for instance, automotive and health). This ensures that the LLM-generated code respects security, ethical, and legal standards.

Advanced Modelling and Requirements Ontology

The effort, which focuses on advanced modelling and a requirements ontology will establish strategic partnerships with academic leaders in software language engineering. This collaboration aims to refine and expand the ontological models initially developed under the Natural Language Processing to Formal Requirements Component, which is a key part of the requirement Engineering and planning phase. The primary focus is on formalising a rigorous, AI-enabled representation for complex functional and non-functional requirements, including key qualities such as energy consumption, real-time performance, and resilience. This formalisation is essential for automating the validation and assurance of these requirements, ensuring the model can handle the diversity and complexity of next-generation, ML-intensive systems.

Knowledge Dissemination and Workforce Development

To establish lasting societal impact and address the acute European AI skills gap, academic Partners will play a core role in knowledge dissemination and workforce development. This includes the strategic integration of the Developer Training Tool into university curricula. AI4SWEng will effectively establish an AI-Software-Engineering Academy, embedding the project's innovations directly into the next generation of engineers by granting discounted SaaS access for research and teaching. This will be further reinforced through structured programs for co-supervised PhDs, Post-Doctoral research, and short-term faculty secondments, ensuring a continuous, bidirectional flow of cutting-edge research into the Consortium industrial exploitation roadmaps.

5.2. Industrial Partners & Technology Integrators

This subsection discusses how the IP created in AI4SWEng can be used in alliances and partnerships with relevant industrial organisations. In the first instance, several groups of potential industrial Partners are considered: AI model developers, software engineering tool developers and software development companies. For each of these groups, we first characterise how they use AI tools in their respective work areas, to what extent key organisations are using AI and how AI4SWEng can position itself for alliances and partnerships. Next steps are briefly outlined at the end of the subsection.

AI Model Developers

AI Model developers working on generative AI models, including both general-purpose models and custom models targeting software development tasks, are natural candidates for alliances and partnerships with AI4SWEng: The project uses several generative AI models as part of the AI4SWEng toolchain and AI model developers can benefit from the functionalities and features developed by this framework. It incorporates and supplements the functionalities of AI models in the software development and DevOps field.

At the time of writing, all the major AI model developers including OpenAI, Google, Anthropic and Meta develop specialised generative AI models that have been tuned for typical generative AI applications in software development such as code generation, code analysis and test case generation. All the aforementioned organisations have a significant footprint in the EU and are competing with EU-based generative AI developers, notably Mistral AI from France.

Engagement with industrial Partners among AI model developers is expected to primarily be achieved through the integration of generative AI models for software development created by AI model developers, as well as potentially via fine-tuning generative AI models that are provided with the relevant information. Commercial partnership options are expected to emerge after the completion of the AI4SWEng project and to potentially involve bundling of AI4SWEng solutions with specific commercial generative AI software engineering model products. Benefits from such collaborations could be realised via technical customisation of the AI4SWEng solution with a specific model family as well as through commercial activities including, for example, cross-promotion and bundled product and service offerings.

Software Engineering Tool Developers

Software engineering tool developers are among the early adopters of generative AI for business applications and have shown a strong interest in integrating AI tools into existing products in order to improve their offerings, differentiate from competitors and avoid being outpaced by competitors that integrate AI software engineering tools. New and completely AI-driven tools are also being developed by established tool developers as well as by start-ups. Both of these groups typically possess good knowledge of the software engineering processes that their tools are being used in, but do not necessarily have strong in-house AI capabilities, which makes them good candidates for collaborating with AI4SWEng.

At the time of writing, both commercial software development IDE developers, including JetBrains and Microsoft, and Continuous Integration service providers such as GitHub (a Microsoft company) and GitLab are already offering generative AI as add-on services for a range of products and services within their toolchains. JetBrains is a notable Europe-based company with leading products in the software IDE field.

Partnerships with software engineering tool developers can be targeted coinciding with the technical implementation work of the project. Generally, all major software and service providers in the software engineering domain offer extension mechanism interfaces and marketplaces that enable third parties to create and market modules with specialised functionalities to customers of the core products, which would be a largely vendor-independent approach for accessing customers of popular products for novel AI4SWEng solutions. Further options for collaboration may be licensing and collaboration on the development of core features for a software or service provider or the development of a novel product in collaboration with established companies, using their existing customer base and marketing reach in order to promote such novel solutions.

Software Developers

Software development organisations are among the key intended end-user communities for AI4SWEng tools. Forming partnerships with software developer organisations may be particularly helpful for the ongoing development of AI4SWEng tools, and it may provide a channel for direct marketing of project outputs to the intended end users of the developed tools.

Uptake of generative AI tools in companies specialising in software development both for product development (e.g. Google, Salesforce, Meta, SAP) and for organisations that offer development and consulting services (e.g. IBM, Accenture, Deloitte, Cognizant). Several larger organisations are also developing proprietary generative AI tools in order to gain a competitive advantage e.g. when pitching to potential customers. Many software development companies and consulting service providers are EU-based companies, including SAP, and all major international organisations named above have significant presence in European Union territories.

Apart from indirect engagement with software developer organisations through open-source and commercial product offerings, AI4SWEng can potentially interact with such organisations by directly licensing pre-commercial and commercial product outcomes for (potentially exclusive) use by consulting-oriented organisations. Advances in processes for structured use of integrated AI toolchains may also be of interest for such organisations, mainly if it includes certification and accreditation opportunities with at least regional reach.

Next Steps

At the time of writing, the areas of concern for AI4SWEng in terms of commercial partnerships and interactions with technology integrators are themselves rapidly evolving the extent to which generative AI is being developed, used and integrated into products, as well as the way they are marketed and sold to customers in the areas described in this subsection. Major actors in the respective areas of concern have generally managed to retain their competitive positions, while new start-up organisations are establishing themselves with novel approaches and attempting to gain market shares.

Given the nature of AI4SWEng and the project's duration, forming strategic alliances or partnerships is best revisited at a later stage of the project. This is necessary firstly in order to safeguard the independence of the research undertaken in the project, including the ability to publish achievements following Open Science principles. Secondly, the positioning of both established and new market participants is expected to change significantly over time with numbers of start-up organisations being reduced to the most promising candidates as offerings are evaluated and are further developed.

Given these factors, the potential for commercial collaborations for the purpose of exploitation will be revisited at the M24 mark of the project.

5.3. Open-Source & Community Engagement

The AI4SWEng project is deeply committed to the open-science practices and open-source ecosystem, leveraging state-of-the-art assets from the community and contributing back to this it. It aims to ensure sustainability, interoperability and a wide-scale adoption through this commitment. This strategy focuses on a bidirectional relationship, accelerating the development of the framework by consuming open-source technologies and sharing the project innovation with the developer community. The foundation of the AI4SWEng suite is built upon robust, open-source components across multiple KIOs. Their integration and refinement are prioritised, with necessary patches and improvements contributed upstream. While the entire AI4SWEng AI Engineering Suite is designed as a marketable framework, strategic components and methodologies will be open-sourced to maximise impact and gain external validation. This contribution is essential for maintaining alignment with industry standards and driving continuous quality improvement.

Releasing Core Components

Modular and high-impact components across the KIOs will be released under permissive open-source licenses to drive adoption, gather external validation, and enable community integration. This includes Data Preparation/Validation methodologies, where we will use open-source tools and wrappers for automated data preprocessing and report generation, enabling the community to operationalise data quality and standardisation checks. Furthermore, the core components of the Formal Requirement Mapping framework, used to map Natural Language Processing outputs to Architectural planning, shall be shared in the future to establish a standard for requirements-to-code traceability. Finally, our commitment extends to Code Quality Enhancements by releasing utility functions and algorithms that support the Bug Locate & Fix mechanism and reverse execution logic, thereby enabling broader community development of advanced debugging tools.

Establishing a Developer Forum and Collaboration Platform

A dedicated online platform will be established to act as the central hub for several critical functions supporting the KIO ecosystem. Primarily, the platform will facilitate beta-testing and feedback by inviting industrial Partners, early adopters, and external developers to rigorously test pre-release KIO versions, providing essential feedback on usability, interoperability, and integration challenges. In addition, it will be the central repository for documentation and training, hosting open documentation for APIs, comprehensive integration guides, and tutorials, which will complement the structured training materials provided by the framework. Finally, the platform will serve as the engine for standardisation advocacy, disseminating the proposed standards of the project, especially those focused on security-by-design, GDPR, and ethical LLM usage, to encourage wider market adoption and gather input on regulatory best practices.

Standards and Regulatory Alignment

Our engagement strategy includes active participation in relevant international standard bodies and working groups. This ensures that the innovations developed within AI4SWEng, especially in areas such as multi-level security, energy-efficient computing, and responsible AI, are correctly aligned with, and influential in shaping, global standards for AI-powered software engineering.

Conclusion

This document, D7.3, has addressed the exploitation planning framework for the AI4SWEng Consortium, having set out its purpose, project vision, and objectives for commercialisation. It has examined the AI4SWEng Engineering Suite, described its constituent modules, and highlighted the differentiators that establish its unique value proposition. The market analysis has been carried out across multiple use-cases, ranging from software lifecycle optimisation with Large Language Models to FPGA programming, medical report automation, AI-enabled battery management, and smart energy GIS integration. Furthermore, market needs, trends, and the competitive landscape have been assessed, supported by SWOT and PESTLEE analyses to provide a structured understanding of external and internal factors.

The document has also presented the Key Exploitable Results, mapped to Consortium Partners, and demonstrated how these outcomes could be mobilised for impact. Strategic alliances and partnerships have been explored, including academic collaborations on trustworthy machine learning and responsible innovation, industrial engagements with technology integrators, and community initiatives through open-source dissemination and standards alignment. Overall, this analysis base has established the foundations for a comprehensive exploitation plan, ensuring that the Consortium innovations in AI for software engineering are positioned for sustainable adoption, measurable industrial relevance, and long-term societal benefit to support European competitive positioning towards excellence in Compliance by Design of Safe-AI.

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