The AI Data Robotics Association

Digital Twins: Driving Europe's Twin Transition

Strategy for a Trusted, Sustainable and Sovereign Digital Future

adr-association.eu

Abbreviations

AAS: Asset Administration Shell
ADRA: AI, Data and Robotics Association
AI: Artificial Intellicence
BDOPEM: Big Data for OPen innovation Energy Marketplace
CPS: Cyber-Physical System
DestinE: Destination Earth
DG CNECT: Directorate-General for Communications Networks, Content and Technology
DG GROW: Directorate-Genertment Bank
DG RTD: Directorate-General
al for Internal Market, Industry, Entrepreneurship and SMEs
DPP: Digital Product Passport
DSSC: Data Spaces Support Centre
DT: Digital Twins
DTO: Digital Twin Ocean
EC: European Commission
EDIH: European Digital Innovation Hub
EFFRA:(Made in Europe Partnership
EIB: European Invesfor Research and Innovation
EIC: European Innovation Council
EIT: European Institute of Innovation & Technology
EU: European Union
ESG: Environmental, Social and Governance
IoT: Internet of Things
LDT: Local Digital Twin
LLM: Large Language Models
NIST: National Institute of Standards and Technology
OPC UA: Open Platform Communications Unified Architecture
RAMI 4.0: Reference Architectural Model for Industry 4.0
SDGs: Sustainable Development Goals
SciML: Scientific Machine Learning
TEF: Testing and Experimentation Facilitites

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The AI Data Robotics Association

Executive Summary

This document presents Europe's coordinated vision for the development and deployment of Digital Twins as core enablers of the AI, Data and Robotics ecosystem. It builds on the collective expertise of ADRA's Digital Twin Topic Group and leading European researchers and industry representatives, defining a roadmap for competitiveness, sustainability and sovereignty.

Towards a European Digital Twin Revolution

Europe stands at a defining moment in its digital transformation. The next technological revolution will not be driven by isolated applications of AI, Data, or Robotics, but by their seamless integration through Digital Twins: dynamic, data-rich replicas that connect the physical and digital worlds.

Digital Twins are not a goal in themselves. They are the connective tissue of Europe's data, AI, and robotics ecosystem, the operational layer enabling real-time understanding, prediction, and optimization across all sectors. When deployed at scale, they become the backbone of **Europe's industrial sovereignty, sustainability**, and **competitiveness**.

Europe at a Crossroads

Around the world, nations are racing to operationalize the convergence of data, AI, and simulation:

- **The United States** focuses on industrial scalability, leveraging private capital and data concentration.
- **China** deploys Digital Twin ecosystems across cities and infrastructures through centralized coordination and massive state investment.
- **Europe**, uniquely, is building a trustworthy, interoperable, and human-centric model, one that turns ethical, secure, and sustainable digitalisation into a global competitive advantage.

But this advantage will only materialize if Europe moves decisively now, **from fragmented initiatives to a coherent pan-European Digital Twin strategy**.

Our Vision: Digital Twins as Strategic Infrastructure

We envision a future where **AI-powered Digital Twins** form the invisible infrastructure of a smarter, greener, and more resilient Europe.

Digital Twins will:

- Empower AI with real-world, contextual, and explainable data for simulation, training, and decision-making.
- Fuel Data Spaces with high-quality, interoperable, real-time industrial data.
- Enable robotics and cyber-physical systems to act autonomously and safely through continuous feedback loops.

- Reinforce sovereignty by ensuring that critical data, computation, and decision-making remain under European control.

By 2030, Digital Twins should form the foundation of Europe's Twin Transition, digital and green, supporting measurable progress towards the EU Green Deal, the Industrial Strategy, and the Digital Decade goals.

Europe´s Strategic Differentiators

Europe's leadership will not come from scale or speed but from **trust, standards, and collaboration**. Our ecosystem is already rich in enablers:

- ADRA (AI, Data, and Robotics Association) aligns technology development with ethical and human-centric principles.
- Horizon Europe and Made in Europe partnerships mobilize R&I capacity for trustworthy, interoperable innovation.
- European Digital Innovation Hubs (EDIHs) and Testing and Experimentation Facilities (TEFs) accelerate adoption by SMEs and regions.
- Data Spaces Support Centre (DSSC) and Gaia-X ensure semantic and technical interoperability across domains.
- EuroHPC and AI Factories provide the computing backbone for scalable, sovereign Digital Twin infrastructures.

This collaborative model is Europe's greatest asset and its primary pathway to leadership.

From Fragmentation to a robust Ecosystem

To unlock the full potential of Digital Twins, Europe must overcome its current fragmentation.

This requires:

- **Common architectures and standards** (RAMI 4.0, OPC UA, AAS) to guarantee interoperability.
- **Pan-European governance frameworks** to align investment, policy, and industrial adoption.
- **Targeted support for SMEs** through EDIHs, cascading funding, and cross-border pilots.
- **Investment in hybrid AI–DT skills** and certification programs to retain top talent.
- **Sovereign computing and cybersecurity frameworks** ensuring trust, resilience, and data control.

A Call to Action: Europe's Moment to Lead

Europe has the scientific excellence, industrial base, and ethical compass to lead this new era **if it acts with urgency and unity**.

By repositioning Digital Twins as the **core enabler** of AI, Data Spaces, and Robotics, Europe can create a model of digital transformation that is trusted, interoperable, human-centric, and sustainable.

The next decade must be about execution, building a robust Digital Twin ecosystem that anchors Europe's competitiveness, advances the Green Deal, and safeguards sovereignty in a world defined by data.

The time to act is now. Europe cannot afford to follow. Europe must design the future.

1. Introduction

Europe at a Crossroad: The Drive Towards Digital Twins

Europe is entering a new technological era, one where the fusion of **data, AI, and cyber-physical systems** defines industrial competitiveness, societal resilience, and strategic sovereignty. At the centre of this transformation lies the **Digital Twin (DT)**: a dynamic, continuously evolving virtual counterpart of a physical asset, process, or environment.

Digital Twins connect the real and digital worlds, transforming data into actionable intelligence. They allow Europe not only to monitor and predict but also to **simulate, optimise and act**, enabling faster innovation, greener operations, and smarter decision-making across all sectors.

This roadmap explores how Digital Twins can become the **core infrastructure of Europe's Twin Transition**, linking the continent's digital transformation to its green and industrial ambitions.

Closing the Data-AI-Simulation Loop

For decades, digital models were used mainly for design and visualization. Today, they have evolved into **self-updating, AI-powered ecosystems** that synchronize in real time with the physical world.

By merging data from IoT, sensors, and connected systems with AI-driven analytics, Digital Twins create **continuous feedback loops** between design, operation, and improvement. This "data-AI-simulation loop" transforms static industries into learning systems capable of autonomous optimisation and adaptation.

In this loop:

- **Data** provides the foundation, feeding real-time information from machines, environments, and citizens.
- **AI** interprets, predicts, and proposes new scenarios.
- **Simulation** enables safe experimentation before implementation.

The result is a Europe capable of testing policy, production, and infrastructure decisions in a **virtual environment** before acting in the real one—reducing risk, waste, and cost.

Relevance in the European Context

Europe holds a singular position in the global technological landscape. Its legacy of scientific excellence, engineering tradition, and industrial innovation has produced one of the most advanced and diverse economies in the world. Across its regions, research institutions, large industries, and networks of small and medium-sized enterprises form a dense ecosystem capable of transforming data and knowledge into value. This foundation provides **Europe** with the necessary tools to **lead the new wave of Digital Twin technologies**, but it also demands renewed focus, coherence, and urgency.

For decades, Europe's competitive advantage has relied on the strength of its industrial base and its capacity to generate high-quality innovation. In sectors such as manufacturing, energy, mobility, and healthcare, European organisations have pioneered digital solutions that integrate sensors, automation, and data analytics. The same scientific and industrial assets that enabled the first digitalisation wave now position Europe to lead in Digital Twins: virtual systems that connect the physical and digital domains to optimise processes, predict behaviour, and support better decisions. What differentiates Europe is not the speed of its technological race but the vision that guides it. European innovation has always been anchored in principles of safety, trust, and sustainability. In this context, Digital Twins are not only instruments of efficiency but also vectors of social and environmental progress.

The policy framework surrounding these technologies is another source of strength. Europe has built a regulatory model that embodies its core values: fairness, transparency, privacy, and human oversight. Initiatives such as the General Data Protection Regulation, the Data Act, and the AI Act ensure that innovation remains ethical, responsible, and aligned with citizens' rights. Far from being barriers, these frameworks constitute a global benchmark for trustworthy digital transformation. They provide the conditions under which Digital Twins can thrive: environments where data is shared securely, artificial intelligence remains accountable, and human actors retain control over automated systems. This ethical foundation is becoming a competitive advantage in a world that increasingly demands technologies that serve people and the planet alike.

However, structural weaknesses still limit Europe's capacity to scale. The Draghi Report on Competitiveness [1] highlighted that Europe's productivity and innovation potential are hindered by fragmentation, slow decision-making, and insufficient investment in key digital infrastructures. Despite world-class research and technological excellence, too many initiatives remain isolated within national or sectoral boundaries. Many regions lack access to high-performance computing, interoperable data infrastructures, and specialised skills. Small and medium-sized enterprises, which make up the backbone of the European economy, often face barriers to digital adoption due to costs, complexity, and lack of awareness. Without decisive action, this gap between potential and deployment risks widening, leaving Europe technologically advanced but strategically constrained.

To unlock its full potential, Europe must accelerate. It must convert its excellence in research into industrial impact, and its ethical and regulatory leadership into a global model for sustainable digitalisation. This requires a concerted effort to align national strategies, mobilise public and private investment, and strengthen coordination among Member States. Initiatives **such as Horizon Europe, the Digital Europe Programme, and partnerships**

1. Draghi's Report: https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en

like ADRA and EFFRA provide the structural foundation for this transformation. The task ahead is to use them not as isolated funding instruments, but as elements of a common European mission that positions Digital Twins as the connective infrastructure of the continent's digital economy.

If Europe succeeds in this mission, Digital Twins will become more than technological artefacts: they will represent a new model of competitiveness based on trust, sovereignty, and shared value. They will allow industries to innovate responsibly, governments to design evidence-based policies, and citizens to benefit from transparent, efficient, and sustainable systems. The challenge, as the Draghi Report emphasised, is not only to innovate but to deliver, to translate Europe's intellectual and ethical capital into concrete outcomes that strengthen its global role. Acceleration, coherence, and ambition will determine whether Europe becomes a leader in the Digital Twin era or remains a follower in a world increasingly defined by data and intelligent infrastructure.

From Visualisation to Infrastructure

Digital Twins are no longer simple visual representations. They are **strategic enablers** of real-time, data-driven collaboration between people, machines, and systems.

In manufacturing, they synchronise shopfloors with AI; in cities, they enable participatory urban planning; in healthcare, they support predictive and personalised medicine; and in energy, they optimise grids and renewable integration.

Europe's opportunity lies in treating Digital Twins as **public–private infrastructure**, not isolated tools. They must be built on open standards, ethical principles, and secure computing backbones that reflect European values: transparency, human oversight, and sustainability.

By integrating Digital Twins across sectors, Europe can deliver on its **Green Deal**[2], achieve the **Digital Decade**[3] goals, and reinforce **industrial sovereignty** through control of data, computation, and standards.

Objectives and Structure of the Document

This roadmap sets out a shared European vision for the development and deployment of Digital Twin technologies as key enablers of Europe's digital and green transformation. It aligns research, policy and industry under a single goal: to position Digital Twins as the operational backbone of a trustworthy, sustainable and sovereign digital Europe.

Its objectives are:

- **Define a common European vision for Digital Twins**. It positions Europe within the global landscape, outlining how Digital Twins can strengthen competitiveness, resilience and sovereignty while reflecting European values of trust and human-centric innovation.
- **Identify high-impact sectors and applications**. It highlights the role of Digital Twins in

2. The European Green Deal: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
3. Europe's Digital Deacade: Europe's digital decade: 2030 targets | European Commission

manufacturing, healthcare, logistics, mobility, energy and urban environments, linking them directly to the EU Green Deal, Digital Decade and Industrial Strategy.

- **Recommend strategic actions and governance**. It proposes concrete measures to accelerate adoption, promote interoperability, support SMEs and align investment and policy across Member States.
- **Define a clear technology roadmap**. It sets short-, medium- and long-term milestones for Europe's leadership, integrating Horizon Europe, the Digital Europe Programme and the Competitiveness Compass.

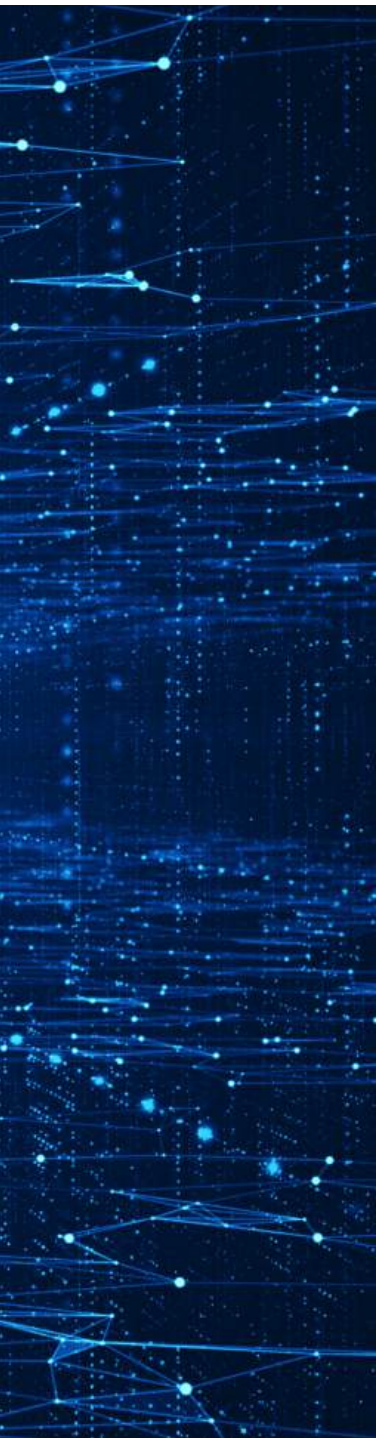
This roadmap is both a policy guide and a call to action. It invites all European stakeholders to work together to turn Digital Twins into a cornerstone of Europe's competitive, ethical and sustainable digital future.

2. State-of-the-Art

From Technological Concept to Strategic Infrastructure

Digital Twin technology has evolved from an emerging concept into a cornerstone of Europe's digital transformation. What began as a tool for simulation and visualisation is now recognised as a strategic enabler that connects data, artificial intelligence, and cyber-physical systems across sectors. By integrating real-time information, analytics and predictive modelling, Digital Twins allow Europe to monitor, optimise and transform complex systems, from factories and hospitals to cities and energy networks.

In recent years, the maturity of this technology has accelerated thanks to advances in computing power, cloud and edge architectures, and AI-driven analytics. As a result, Digital Twins have moved beyond industrial pilots to become an operational layer supporting decision-making and automation at scale. Their adoption is expanding rapidly across manufacturing, logistics, healthcare, energy, construction, and public administration.



At the global level, the United States and China have already made Digital Twins central to their industrial strategies, focusing on standardisation, data-driven innovation, and national sovereignty. Europe has taken a different path: one built on trust, ethics and interoperability. Guided by Horizon Europe, ADRA and the Made in Europe Partnership, Europe's approach ensures that Digital Twins evolve within a regulatory and technological framework aligned with the principles of transparency, safety and sustainability.

Digital Twins are becoming the **connective layer of Europe's data, AI and robotics ecosystem**. Their capacity to create continuous feedback loops between the digital and physical worlds provides the foundation for a new generation of intelligent, resilient and environmentally conscious systems.

The purpose of this chapter is to:

- Outline the **conceptual and technological foundations** of Digital Twin systems.
- Assess their adoption and impact across key European sectors.
- Compare Europe's position within the global Digital Twin landscape.
- Identify the strengths, weaknesses, opportunities and threats shaping Europe's leadership potential.

This state-of-the-art analysis sets the stage for the strategic roadmap that follows, highlighting where Europe already excels, where action is needed, and how coordinated investment, governance and innovation can turn technological progress into lasting competitive advantage.

2.1 Definitions and Conceptual Framework

Digital Twin technology operates at the intersection of **physical systems**, **digital models**, and **data intelligence**. They are not stand-alone models, but part of **cyber-physical infrastructures** that enable closed feedback loops across industrial and societal systems.

Digital Twin (DT) is a dynamic, data-driven virtual representation of a physical system, process, or asset. It is continuously updated with real-time data collected from sensors, IoT devices, and other inputs to reflect the current state of its physical counterpart. Digital Twins enable simulation, analysis, and optimization of operations, bridging the gap between the physical and digital worlds.

Key components include:

- **Physical Entity**: real-world object, system, or environment being mirrored.
- **Digital Model**: The virtual counterpart designed to mimic the physical entity.
- **Data Connectivity:** Real-time integration of data streams from the physical entity to the digital model
- **Feedback Loop**: The capability to influence the physical system through insights generated by the Digital Twin.
- **Closed Loop Control**: a system where data is continuously collected, analyzed, and used to automatically control or influence the physical environment without human intervention. In a closed-loop system, the feedback generated by the digital twin or AI model is directly used to autonomously adjust operations in real time, creating a self-regulating process.

The following image shows the split between, digital model, digital shadow and digital twin depending on information flow between real world and digital world and their main characteristics.

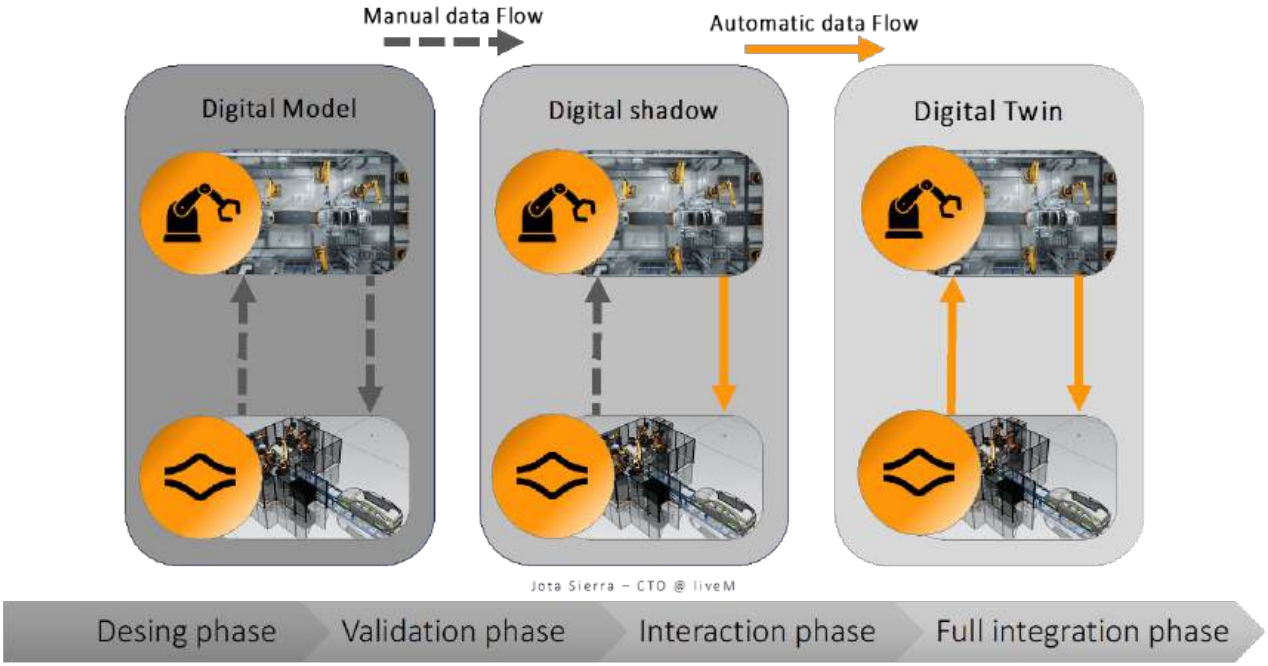


Figure 1. Digital model, digital Shadow and digital twin (source: Jota Sierra)

Enabling Technologies:

The functionality of Digital Twins depends on several technological pillars that are advancing simultaneously across Europe:

- **AI and GenAI**: Provide predictive intelligence and scenario generation.
- **IoT and Edge Computing**: Supply continuous, low-latency data for synchronisation.
- **Cyber-Physical Systems (CPS)**: Embed computation directly in physical processes.
- **Scientific Machine Learning (SciML)**: Integrates physics-based models with ML to improve fidelity and reduce data needs.

Key Associated Terms

- **Predictive Maintenance:** The use of Digital Twins to anticipate failures and schedule maintenance activities before issues occur, minimizing downtime and costs.
- **Prescriptive maintenance**: goes a step further by not only predicting failures but also **recommending or automatically executing the best course of action** to prevent or resolve the issue.
- **Simulation**: The process of using a Digital Twin to test scenarios, optimize designs, and predict outcomes without affecting the physical counterpart.
- **Interoperability**: The ability of Digital Twins to integrate seamlessly with other systems, platforms, or devices across various industries.
- **Data Governance**: Policies and processes that ensure the security, integrity, and ethical use of data in Digital Twin systems.

2.2 Societal and Sectoral Adoption

Digital Twins are no longer confined to research laboratories or isolated industrial pilots. Across Europe, they are becoming an operational reality, transforming the way societies design, produce, manage and interact with their environments. Their growing adoption reflects a broader digital transition in which data, AI and connectivity are merging into real-time decision infrastructures.

The expansion of Digital Twins across sectors marks a profound societal shift. They enable industries to move from reactive maintenance to predictive intelligence, governments to design evidence-based policies, and citizens to participate in shaping their urban and environmental surroundings. Europe's strength lies in the diversity of its applications, which collectively form an integrated ecosystem that links industrial competitiveness with social and environmental responsibility.

Smart Cities and Urban Planning: Across European cities, from Helsinki and Amsterdam to Madrid and Rotterdam, Local Digital Twins (LDTs) are redefining how urban environments are managed. They simulate mobility patterns, energy consumption and climate impacts, enabling city administrations to test scenarios before making policy decisions. This participatory use of data promotes citizen engagement and transparency, aligning with the principles of the *New European Bauhaus*[4] and the *Digital Europe Programme*[5].

Healthcare: Digital Twins are enhancing personalised medicine, clinical planning and hospital efficiency. By creating patient-specific models, doctors can simulate treatment responses, predict disease evolution and optimise resource allocation. European projects under *Horizon Europe* and *AI4Health*[6] are developing secure and ethical frameworks for health data integration, ensuring that Digital Twins in medicine respect privacy while enabling innovation in diagnostics and prevention.

Agriculture and Environment: Digital Twins are transforming Europe's agri-food sector by linking satellite observation, IoT sensors and AI analytics. Digital Twin allows farmers to monitor crop growth and optimize resource usage. Real-time data collection helps farmers create DT of their fields to track soil conditions, water use, and plant health, making farming more efficient and sustainable. By simulating different scenarios, farmers can better prepare for unpredictable weather and market fluctuations. Environmental DTs (e.g. *DTO*[7], *DestinE*[8]) simulate planetary systems to inform climate resilience and the Green Deal. Integrated with *Agri-Food Data Spaces*[9], these technologies support the *Farm to Fork Strategy*[10] and promote resilience in the face of climate and market volatility.

Manufacturing and Industry 5.0: Europe's manufacturing sector is at the forefront of Digital Twin adoption. Industries are increasingly using Digital Twins as enabling infrastructures to optimize production lines, improve product quality, and reduce waste and environmental footprint. Beyond process optimization, DTs also bridge the technological diversity within factories, enabling interoperability and seamless data exchange between machines, systems, and software through standardized frameworks such as OPC UA, AAS, and RAMI 4.0, laying the foundation for smarter, more connected, and sustainable European manufacturing. By integrating Digital Twins with AI, robotics and data spaces, European manufacturing is evolving toward the Industry 5.0 paradigm: human-centric, resilient and sustainable production.

Public Administration and Security: Governments and public agencies are using Digital Twins to improve crisis response, public safety and infrastructure management. From modelling floods and wildfires to simulating emergency

4. https://neweuropeanbauhaus.es/
5. https://digital-strategy.ec.europa.eu/en/activities/digital-programme
6. AI4Health – UKRI Centre for Doctoral Training in AI for Healthcare
7. https://digitaltwinocean.mercator-ocean.eu/
8. https://destination-earth.eu/
9. Gianluca Brunori et al. "Agri-food data spaces: Highlighting the need for a farm-centerd strategy", Data in Brief, Vol. 59, April 2025, 111388, https://doi.org/10.1016/j.dib.2025.111388
10. https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en

logistics, these tools enhance foresight and preparedness. In defence and security, they enable safe training environments and support the EU's *Readiness 2030* goals[11] by linking cyber-physical systems and AI-driven situational awareness.

Across all these domains, the adoption of Digital Twins is accelerating thanks to the growing network of **European Digital Innovation Hubs (EDIHs)**[12] and **Testing and Experimentation Facilities (TEFs)**[13]. These structures act as catalysts, connecting SMEs, researchers and public institutions with digital infrastructures, funding and expertise. Through this distributed model, Europe ensures that innovation reaches every region, bridging the gap between technology excellence and real-world application.

The societal impact of this transformation extends beyond efficiency or cost reduction. By embedding data and intelligence into physical systems, Europe is building a new generation of infrastructures that are more transparent, sustainable and participatory. Digital Twins are not simply technological tools, they are instruments for rethinking how Europe designs, manages and governs its collective future.

2.3 European Digital Innovation Hubs (EDIHs) and TEFs: Catalysts for Adoption

The European Digital Innovation Hubs (EDIHs) and Testing and Experimentation Facilities (TEFs) are two of the European Union's most powerful instruments for accelerating the adoption of Digital Twin technologies. Together, they form the operational backbone of the **Digital Europe Programme** and the **Competitiveness Compass**[14]. Their shared mission is to close the gap between research and deployment. While **EDIHs** act as regional accelerators that support businesses and public administrations in testing and integrating digital solutions, **TEFs** provide large-scale, high-fidelity environments to validate advanced technologies such as AI-driven Digital Twins, robotics and cyber-physical systems under real-world conditions.

By combining proximity with scale, the EDIH–TEF ecosystem turns Europe's distributed innovation landscape into a connected, interoperable and trustworthy network capable of transforming knowledge into impact.

A EDIHs: Regional Gateways to Digital Transformation

EDIHs operate as one-stop access points for digital innovation. They offer local actors, particularly small and medium-sized enterprises (SMEs) and public administrations, the resources needed to assess their digital maturity, identify opportunities, and experiment with new technologies before committing to large-scale investment.

Their work focuses on four main areas:

- **Awareness and Skills Development**: EDIHs raise awareness about the potential of

11. https://defence-industry-space.ec.europa.eu/eu-defence-industry/white-paper-european-defence-readiness-2030_en
12. https://european-digital-innovation-hubs.ec.europa.eu/home
13. https://digital-strategy.ec.europa.eu/en/policies/testing-and-experimentation-facilities
14. A Competitiveness Compass for the EU, COM(2025) 30 final; https://commission.europa.eu/topics/eu-competitiveness/competitiveness-compass_en

Digital Twins and provide training on AI, data governance, and simulation tools. Through workshops, microcredentials and hands-on support, they help organisations acquire the skills needed to design and manage Digital Twin systems.

- **Testing and Experimentation**: In collaboration with TEFs, EDIHs give companies access to testbeds, virtual environments and physical infrastructures where Digital Twin solutions can be validated safely and efficiently.
- **Access to Finance and Networks:** EDIHs connect innovators with European funding mechanisms, such as Horizon Europe, InvestEU and Cohesion Funds , and with private investors and venture capital networks. They also facilitate participation in cross-border initiatives like ADRA, EFFRA and Gaia-X[15].
- **Support for SMEs and Public Administrations**: EDIHs play a crucial role in democratising access to digital technologies. They act as intermediaries that reduce entry barriers for SMEs, helping them adopt interoperable and standardised Digital Twin platforms aligned with European data and AI regulations.

TEFs: Large-Scale Validation for Trustworthy Technologies

Testing and Experimentation Facilities (TEFs) complement the regional work of EDIHs by providing **pan-European test environments** for advanced technologies at scale. Designed under the Digital Europe Programme, TEFs are sector-specific infrastructures where companies, research centres and regulators can evaluate the safety, reliability and interoperability of complex AI and Digital Twin systems before they enter the market.

TEFs13 operate across strategic domains (manufacturing, healthcare, agri-food, and smart cities) and are instrumental in building trust and accelerating adoption. They simulate realistic operating conditions, ensuring that new solutions comply with European standards and regulations such as the *AI Act*[16] and *Data Act*[17].

Their role is particularly relevant for **AI-powered Digital Twins**, which require validation not only of technical performance but also of ethical and cybersecurity dimensions. By providing access to shared datasets, physical labs and high-performance computing resources, TEFs reduce development costs and shorten the time between research and deployment.

Together, EDIHs and TEFs form a **distributed test and innovation ecosystem** that reflects Europe's federated approach to digital sovereignty. EDIHs anchor innovation locally, helping SMEs and regions develop tailored Digital Twin solutions, while TEFs ensure that those solutions meet pan-European requirements for safety, interoperability and trustworthiness.

Examples of Impact

Across Europe, this dual structure is already producing tangible results.

In Hungary, *Innomine DIH* has helped more than 300 SMEs deploy AI-enhanced Digital Twin pilots in collaboration with TEFs focused on manufacturing and predictive maintenance. In

15. https://gaia-x.eu/
16. https://digital-strategy.ec.europa.eu/en/policies/regulatory-framework-ai
17. https://digital-strategy.ec.europa.eu/en/policies/data-act

Spain, *DIH4GaI* and the *TEF for Smart Cities and Communities* are enabling urban Digital Twins for mobility optimisation and climate adaptation. In Finland, the *Agri-Food TEF* is testing Digital Twins that integrate satellite data and AI for precision farming, supporting the Farm to Fork strategy and the Green Deal.

A Foundation for Europe's Digital Sovereignty

By linking local experimentation with European-scale validation, the EDIH and TEF ecosystem embodies Europe's distinctive model of digital transformation: collaborative, human-centric and regionally balanced. It ensures that innovation is not concentrated in a few hubs but distributed across all Member States, reducing the digital divide and fostering cohesion.

This structure directly supports the priorities outlined in the Draghi Report1, reinforcing Europe's competitiveness through productivity, investment and innovation. It also advances the objectives of the **Apply AI Strategy**[18] and the **GenAI4EU Initiative**[19], which call for large-scale testing and deployment of trustworthy AI and Digital Twin technologies through networks of EDIHs and TEFs.

EDIHs and TEFs together represent more than instruments of innovation. They are the practical manifestation of Europe's strategic vision: a continent capable of transforming its scientific excellence and regulatory strength into concrete technological leadership, ensuring that the Digital Twin revolution benefits every region and every citizen.

2.4 Benefits and Strategic Value for Europe

Digital Twin technology is emerging as one of the most strategic assets for Europe's digital transformation. Its capacity to merge real-world data with AI-driven intelligence allows industries, governments and societies to move from reactive management to predictive and prescriptive decision-making. This transformation directly supports Europe's overarching policy goals: **competitiveness, sustainability and digital sovereignty**.

Across sectors, Digital Twins are delivering measurable benefits that strengthen the resilience and performance of European systems.

Boosting Competitiveness and Productivity

By creating real-time feedback loops between design, operation and optimisation, Digital Twins enable continuous improvement and efficiency gains across manufacturing, logistics, energy and services. They reduce downtime, improve quality control and optimise resource allocation. This leads to higher productivity and faster innovation cycles, contributing directly to the objectives set out in the *Draghi Report* and the *Competitiveness Compass*.

For Europe's industrial base, this means producing more with fewer resources, energy, materials and time, while maintaining quality, safety and traceability throughout the value chain.

18. Apply AI Strategy; COMM(2025) 723 final; https://digital-trategy.ec.europa.eu/en/policies/apply-ai
19. https://digital-strategy.ec.europa.eu/en/policies/genai4eu

Accelerating the Green and Digital Transitions

Digital Twins are instrumental in achieving the EU's Twin Transition, the simultaneous digitalisation and decarbonisation of Europe's economy. Through real-time monitoring, simulation and optimisation, they reduce waste, energy consumption and emissions at every stage of production and operation.

Projects such as Destination Earth (DestinE)and the Digital Twin of the Ocean (DTO) exemplify how these tools help Europe understand and manage complex environmental systems, translating the ambitions of the European Green Deal into tangible, data-driven action.

By integrating life-cycle analysis, circular design and energy efficiency into industrial processes, Digital Twins contribute to the *Sustainable Development Goals (SDGs)*[20] and reinforce Europe's global leadership in sustainability.

Enhancing Trust, Interoperability and Collaboration

Europe's approach to Digital Twins is defined by trust, openness and interoperability. Through frameworks such as Gaia-X, the Data Spaces Support Centre (DSSC), RAMI 4.0 and the Asset Administration Shell (AAS), Digital Twins can exchange data securely across domains and borders.

The ADRA Strategic Research, Innovation and Deployment Agenda (SRIDA) further reinforces this ecosystem by coordinating research, innovation and policy alignment across AI, Data and Robotics communities. Together, these initiatives create a unified European framework for Digital Twin deployment — one that values collaboration, transparency and shared standards.

This interoperability ensures that value is created collectively rather than in isolation, fostering synergy between Member States, industries and research ecosystems while avoiding technological lock-in and dependence on external infrastructures.

Empowering AI with Real-World Context

Digital Twins provide the structured, contextualised and traceable data that artificial intelligence systems need to operate responsibly. They allow AI to train and validate in realistic conditions, improving reliability and explainability.

The *Apply AI Strategy*, the *GenAI4EU Initiative* and the *ADRA SRIDA*[21] identify Digital Twins as critical enablers for "world models", safe environments where AI can learn from simulation before deployment. This synergy between AI and Digital Twins strengthens Europe's position in developing ethical, trustworthy and human-centric AI systems that align with the *AI Act* and *Data Act*.

Strengthening Technological Sovereignty

Digital Twins also advance Europe's strategic autonomy by reducing dependence on non-European cloud, hardware and software providers. As they integrate with European data spaces, edge computing and high-performance computing infrastructures such as

20. https://sdgs.un.org/goals
21. https://www.eurohpc-ju.europa.eu/index_en

EuroHPC[22], they ensure that critical data, computation and decision-making remain under European control.

This federated and standards-based approach supports the vision of a sovereign European digital ecosystem, one that safeguards privacy, fosters innovation and preserves strategic independence in an increasingly competitive global landscape.

Social and Policy Impact

Beyond industry, Digital Twins enhance the quality of public decision-making and citizen engagement. Governments use them to simulate the effects of policies, optimise public services and manage critical infrastructure. Cities employ Local Digital Twins to plan mobility, energy and urban resilience in collaboration with citizens. This promotes transparency, inclusiveness and better governance, reinforcing citizens' trust in the digital transformation process.

In summary, Digital Twins embody Europe's ambition to lead a model of digitalisation that is competitive yet ethical, innovative yet sustainable. They are not merely instruments of efficiency but **foundations of strategic renewal**, connecting data, intelligence and purpose across the continent.

By embedding Digital Twins within the *Apply AI Strategy*, the *GenAI4EU Initiative*, the A*DRA SRIDA* and the *Green Deal*, Europe can consolidate its leadership in building a digital ecosystem that is trustworthy, interoperable, human-centric and globally competitive.

2.5 Global Landscape and Comparative Positioning

Digital Twin technology has become a key element of global competition in innovation, industrial policy and digital sovereignty. Around the world, governments are integrating Digital Twins into their national strategies for artificial intelligence, advanced manufacturing and climate resilience. The race to define international standards and dominate value chains is accelerating. In this context, Europe must consolidate its unique position, one that combines scientific excellence, ethical leadership and a collaborative industrial base.

United States: Market-Driven Innovation and Scale

The United States leads in the commercialisation and standardisation of Digital Twin technologies through strong private sector alliances. Organisations such as the *Digital Twin Consortium and Manufacturing USA* drive interoperability initiatives across industries, often guided by market demand rather than public regulation.

American leadership is characterised by rapid deployment, venture capital investment and close collaboration between large technology firms and industrial corporations. The focus lies in scalability and monetisation, using Digital Twins to optimise operations, reduce costs and create new data-driven business models.

While this approach enables fast innovation and global market dominance, it also creates

22. https://www.eurohpc-ju.europa.eu/index_en

fragmented standards and raises questions about data sovereignty and transparency. The U.S. ecosystem remains primarily industry-led, with limited public coordination in areas such as ethics, sustainability or interoperability.

Asia: State-Led Integration and Large-Scale Deployment

Asia, and particularly China, has placed Digital Twins at the centre of its state-led industrial transformation. National strategies such as *Made in China 2025*[23] and *Smart City 2030*[24] integrate Digital Twins into large-scale urban, infrastructure and energy projects.

China's model prioritises centralised coordination and massive investment, linking Digital Twins with 5G, IoT and AI to manage cities, factories and logistics networks. This has resulted in rapid deployment and the emergence of national standards driven by governmental agencies and large state-owned enterprises.

Japan, under its *Society 5.0* vision[25], adopts a more human-centric approach. It integrates Digital Twins into healthcare, mobility and industrial automation to balance technological progress with social wellbeing. South Korea follows a similar trajectory, focusing on smart cities and resilient infrastructures through coordinated public-private initiatives.

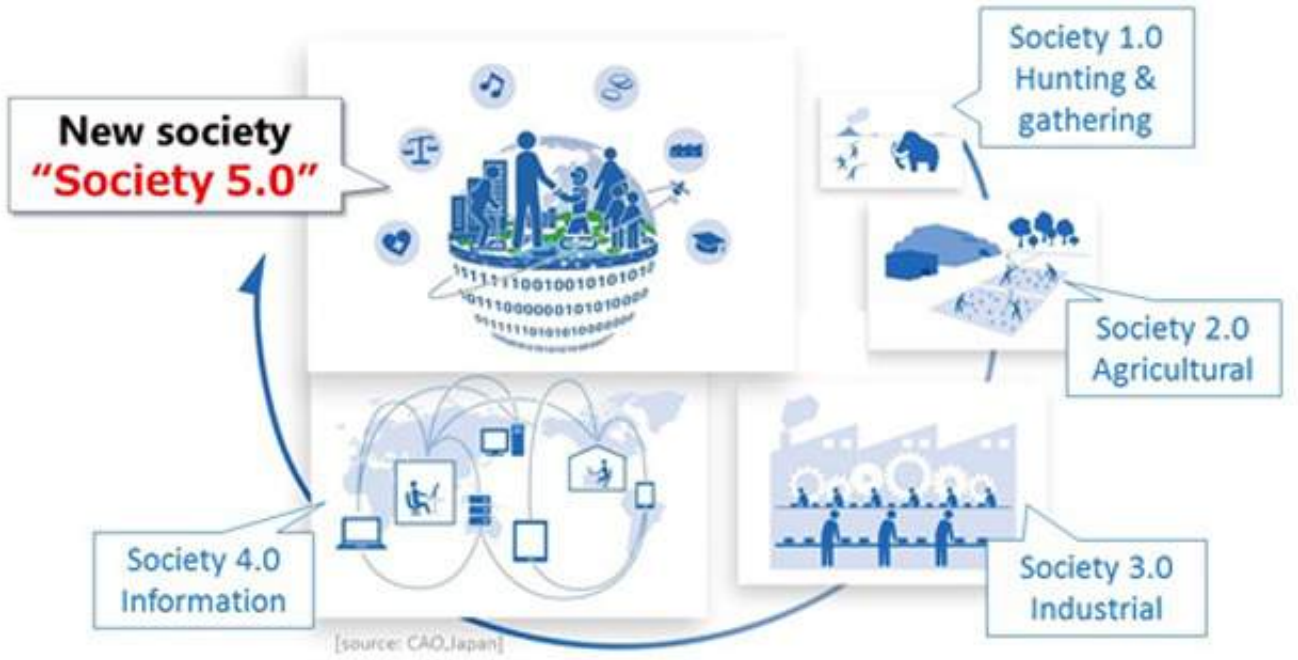


Figure 2. Society 5.0

These models demonstrate Asia's capacity to achieve speed and scale. However, they rely heavily on centralised governance and vast capital mobilisation, often with limited transparency in data management and ethical oversight.

23. https://www.isdp.eu/wp-content/uploads/2018/06/Made-in-China-Backgrounder.pdf
24. https://www.drc.gov.cn/tmpuploadfiles/china2030.pdf
25. https://www8.cao.go.jp/cstp/english/society5_0/index.html

Europe: Trust, Interoperability and Human-Centric Innovation

Europe's approach to Digital Twins is distinct. It combines technological excellence with ethical, social and environmental responsibility. Guided by frameworks such as *Horizon Europe, ADRA SRIDA, Apply AI Strategy* and the *GenAI4EU Initiative*, the European model prioritises interoperability, trust and sustainability over short-term gains.

Europe's strength lies in its **federated innovation ecosystem**. Initiatives like the *Made in Europe Partnership, Data Spaces Support Centre (DSSC), Gaia-X, EDIHs and TEFs* create a coherent infrastructure that connects regions, industries and research communities. This distributed approach ensures that innovation is inclusive and that technological benefits are shared across all Member States.

Europe is also shaping global standards. Through *CEN, CENELEC and ETSI*, it contributes to defining interoperability frameworks such as *RAMI 4.0, OPC UA and the c (AAS)*. These efforts ensure that Digital Twins developed in Europe can interconnect seamlessly, safely and transparently, aligning with the *AI Act* and the *Data Act*.

In contrast with the U.S. model's focus on market dynamics and Asia's emphasis on state control, Europe positions itself as a **trusted global reference** for ethical and sustainable digitalisation. Its model proves that competitiveness and responsibility are not mutually exclusive but mutually reinforcing.

Region	Model	Strengths	Weaknesses	Strategic Focus
United States	Market-driven, innovation through scale	Rapid deployment, strong private investment, global platforms	Fragmented standards, limited regulation, data sovereignty risks	Industrial scalability, commercial leadership
China / Asia	State-led, centralised coordination	Fast implementation, large-scale integration, infrastructure development	Limited transparency, weak ethical oversight, dependency on state funding	National integration, infrastructure optimisation
Europe	Federated and value-driven	Ethical governance, interoperability, regional balance, sustainability	Slower execution, fragmented funding, complex regulation	Trust, sovereignty, human-centric competitiveness

Europe's Strategic Position

Europe's challenge is not technological inferiority but strategic coherence. It already possesses world-class research, industrial capacity and regulatory foresight. The key lies in executing at scale, aligning public policy, private investment and regional ecosystems to accelerate deployment.

By leveraging Digital Twins as infrastructure for AI, Data Spaces and Robotics, Europe can redefine competitiveness on its own terms. Rather than competing on speed or capital intensity, it can lead through **standards, ethics and system-level integration**, domains that are increasingly decisive in the digital economy.

The European model thus represents more than an alternative; it offers a blueprint for **responsible technological sovereignty**. By transforming its principles of openness, collaboration and trust into economic advantage, Europe can set the global benchmark for how Digital Twins serve not only industry but society at large.

2.6 European SWOT in Digital Twin Leadership

Europe stands at a decisive juncture in the global Digital Twin landscape. The continent combines deep scientific excellence, a strong industrial base and a robust regulatory environment. However, to convert these assets into sustainable leadership, Europe must overcome structural fragmentation, accelerate standardisation and mobilise private investment at scale.

This section summarises Europe's position through a SWOT analysis, identifying the **Strengths**, **Weaknesses**, **Opportunities** and **Threats** that shape its competitiveness in the emerging Digital Twin economy.

STRENGTHS +	WEAKNESSES –
▶ Robust Research and Innovation Ecosystem (ADRA; EFFRA, HORIZON EUROPE) ▶ Regulatory Framework and Ethical Standards ▶ Industrial Excellence ▶ Sustainability leadership aligned with the Green Deal ▶ Skills Gap and limited private investment. ▶ Limited Private Investment ▶ Slow pace of standardisation and interoperability. ▶ Dependence on non-EU hardware/cloud providers.	▶ State-led, centralised coordination ▶ Federated and value-driven ▶ Fragmented regulation and uneven maturity among Member States.
OPPORTUNITIES +	**THREATS –**
▶ Leadership in Ethical, Human-centric AI & Digital Twins. ▶ -Digital Twins as safe training grounds for AI (synthetic data, world models). ▶ -Integration of GenIA, Robotics and Scientific ML. ▶ -Expansion into new sectors (healthcare, mobility, energy). ▶ -Green Transition and Climate Adaptation. ▶ -Collaboration.	▶ Global Competition (USA, China, etc) ▶ -Cybersecurity and trust vulnerabilities ▶ -Economic Uncertainty, fragmented investment. ▶ -Technological Dependency and IP leakage. ▶ -Resistance to Change in traditional industries ▶ -Weak IP protection in global collaborations.

STRENGTHS

1. **Robust Research and Innovation Ecosystem**:
   - Europe hosts leading research institutions, universities, and innovation clusters driving advancements in DTs, AI, and robotics.
   - Strong public-private partnerships foster collaborative development, exemplified by initiatives like Horizon Europe and ADRA.
2. **Regulatory Framework and Ethical Standards:**
   - Europe is a global leader in establishing regulations for data security, privacy (e.g., GDPR), and AI ethics, ensuring trusted adoption of DTs.
   - Initiatives like Gaia-X promote data sovereignty and interoperability across industries.
3. **Industrial Strength:** Europe's manufacturing and engineering sectors, particularly in Germany, France, Spain and Italy, are integrating DT technology to optimize processes and improve competitiveness.
4. **Focus on Sustainability**: European strategies emphasize using DTs for climate resilience, sustainable urban planning, and green energy transitions

WEAKNESSES

1. **Fragmentation Across Member States**: Diverse regulatory environments and technological disparities between EU countries hinder the unified adoption of DT technologies.
2. **Skills Gap**: A shortage of skilled professionals in AI, robotics, and data analytics limits the pace of DT adoption and innovation.
3. **Limited Private Investment**: Compared to the U.S. and China, Europe faces a funding gap, particularly in scaling startups and SMEs specializing in DT technology.
4. **Slow Pace of Standardization**: Despite progress, Europe lags in establishing universal technical standards for DT implementation, creating barriers to interoperability.

OPPORTUNITIES

1. **Global Leadership in Ethical AI and DTs**: Europe can leverage its ethical frameworks and focus on safety to become a global standard-bearer for trustworthy DT applications.
2. **DTs as AI models for training**: By simulating real-world conditions with high precision, DTs enable the generation of high-quality synthetic data, which can be used to train AI systems. This allows AI to learn and adapt in safe, controlled settings, accelerating development while reducing the risks associated with deploying AI in real-life environments.
3. **Integration of AI using LLMs (Large Language Models)**: These tools can simplify how users interact with complex systems, allowing them to ask questions or explore data in plain language. LLMs also help process unstructured information and support faster, smarter decision-making. This makes DTs more accessible and useful across different sectors, not just for technical experts.
4. **Expansion of Use Cases**: Emerging sectors such as personalized healthcare, autonomous systems, and smart cities provide vast opportunities for DT deployment.
5. **Green Transition and Climate Adaptation**: DTs are pivotal in advancing Europe's Green Deal goals by optimizing energy systems, infrastructure, and resource management.
6. **Strategic Alliances and International Collaboration**: Strengthening partnerships with global leaders and developing alliances in underserved regions can expand market reach and influence.
7. **Integration of Generative AI and Robotics**: Combining DTs with GenAI and advanced robotics opens pathways for innovation in manufacturing, logistics, and autonomous systems.
8. **Optimizing natural resources through DT and AI**: DTs combined with AI offer a powerful way to manage natural resources more efficiently. By creating accurate, real-time models of ecosystems, energy grids, or water systems, it becomes easier to predict demand, reduce waste, and plan sustainable use.

THREATS

1. **Competition from Global Players**: The U.S. and China are heavily investing in DT ecosystems, supported by significant funding and rapid technological advancements.
2. **Cybersecurity and Data Risks**: As DTs rely on vast amounts of real-time data, vulnerabilities to cyberattacks and breaches could undermine trust and adoption.
3. **Economic Uncertainty**: Fluctuating economic conditions and limited resources in some EU member states may delay investments in DT infrastructure.
4. **Technological Dependency**: Heavy reliance on non-European technologies (e.g., cloud services, semiconductors) threatens Europe's digital sovereignty and resilience.
5. **Resistance to Change**: Industries with entrenched practices may resist adopting disruptive technologies like DTs, slowing the transformation process.

Strategic Outlook

Europe's leadership potential in Digital Twins rests on its ability to act collectively. The continent's unique combination of ethics, industrial strength and regulatory foresight positions it as a **global reference for trustworthy digitalisation**. However, leadership will depend on executing with speed and coherence, turning policies and pilot projects into scalable infrastructures and competitive markets.

By consolidating the efforts of *ADRA SRIDA, Apply AI Strategy, GenAI4EU and the Digital Europe Programme*, Europe can move from coordination to acceleration. This means investing in people, harmonising standards, and aligning industrial policy with digital sovereignty goals.

If achieved, this transformation will not only secure Europe's technological independence but also define a new paradigm of innovation, one that combines trust, interoperability and sustainability as pillars of global competitiveness.

2.7 Conclusions and Strategic Directions

Europe stands at a decisive point. Its leadership in research, ethics, and industrial

Europe is uniquely positioned to lead the next technological wave driven by Digital Twins. The continent already possesses world-class research capabilities, a solid industrial base and a regulatory framework built on ethics, transparency and human-centric innovation. What remains is to transform this potential into coordinated execution, to move from excellence in research to excellence in implementation.

Digital Twins have evolved from conceptual tools into **strategic infrastructures** that connect data, artificial intelligence and physical systems. They represent a decisive step in Europe's Twin Transition, linking digitalisation with sustainability and competitiveness. When deployed at scale, they can reduce industrial emissions, enhance resilience, and improve productivity across sectors while reinforcing Europe's technological sovereignty.

However, as the Draghi Report (2024) underlined, Europe must accelerate its capacity to deliver. Fragmentation, uneven investment and skills shortages continue to slow down large-scale deployment. The key challenge is no longer invention but **integration**, turning fragmented initiatives into a federated European ecosystem governed by shared standards, trusted data and common infrastructures.

Strategically, Europe must:

- **Unify governance and policy alignment**. Coordinate efforts across Member States, ensuring that Horizon Europe, the Digital Europe Programme, ADRA SRIDA [12] and national strategies converge under a single European Digital Twin framework.
- **Invest in scalability and SME adoption**. Leverage EDIHs and TEFs to accelerate deployment, particularly among small and medium-sized enterprises, where most of Europe's industrial base resides.
- **Strengthen education and hybrid skills**. Expand training programmes that combine AI, data science and physics-based modelling, aligning with the Apply AI Strategy (2024) and the GenAI4EU Initiative [11] to ensure talent retention and mobility across Europe.

- **Advance interoperability and standardisation**. Accelerate implementation of frameworks such as *RAMI 4.0, OPC UA, the Asset Administration Shell (AAS) and Gaia-X*, transforming Europe's commitment to openness into a global standard for trustworthy digital infrastructures.
- **Reinforce data sovereignty and cybersecurity**. Ensure that critical data, computation and decision-making processes remain within European jurisdiction through federated cloud and edge infrastructures supported by *EuroHPC* and AI .

If executed coherently, these actions will consolidate Europe's position as the world's leading region for ethical, interoperable and sustainable Digital Twin ecosystems. By combining scientific excellence with industrial pragmatism, Europe can deliver measurable progress on the Green Deal, strengthen its industrial competitiveness and establish a model of innovation that others will follow.

Digital Twins are not just technological instruments; they are **Europe's strategic bridge between vision and reality**, the infrastructure through which data, AI and robotics converge to create intelligent, adaptive and resilient systems. The challenge ahead is clear: to turn leadership in principles into leadership in performance.

The following chapter explores how this vision materialises across key sectors, from manufacturing and logistics to energy, healthcare and cities, illustrating how Digital Twins are already shaping Europe's industrial and societal transformation.

3. Use Cases

Digital Twins as Cross-Sector Enablers for Europe's Twin Transition

Digital Twins are no longer experimental technologies confined to research projects or isolated industrial applications. Across Europe, they are becoming operational infrastructures that support the continent's digital and green transformation. By merging real-world data with artificial intelligence, simulation and advanced analytics, Digital Twins provide the intelligence layer needed to optimise processes, anticipate disruptions and accelerate innovation across all sectors of society.

The true strategic value of Digital Twins lies in their **cross-sector integration**. They act as the connective layer between artificial intelligence, data spaces, robotics and cyber-physical systems, enabling Europe to build resilient, data-driven ecosystems that learn and adapt continuously. Whether in manufacturing, energy, healthcare, logistics or cities, these systems allow decision-makers to experiment, predict and act with unprecedented precision, turning data into a strategic asset for competitiveness and sustainability.

Europe's approach to Digital Twin adoption reflects its broader values: **trust, interoperability and human-centric innovation**. Through initiatives such as *Horizon Europe, ADRA SRIDA, Apply AI Strategy, GenAI4EU and the Digital Europe Programme*, Europe is aligning research and deployment efforts to scale Digital Twin solutions that are ethical, transparent and sustainable. The involvement of EDIHs and TEFs ensures that these innovations reach companies of all sizes and public administrations in all regions, bridging the gap between technological excellence and real-world implementation.

Each of the following sections presents a set of **sectoral use cases** that demonstrate how Digital Twins are reshaping Europe's industrial and societal landscape:

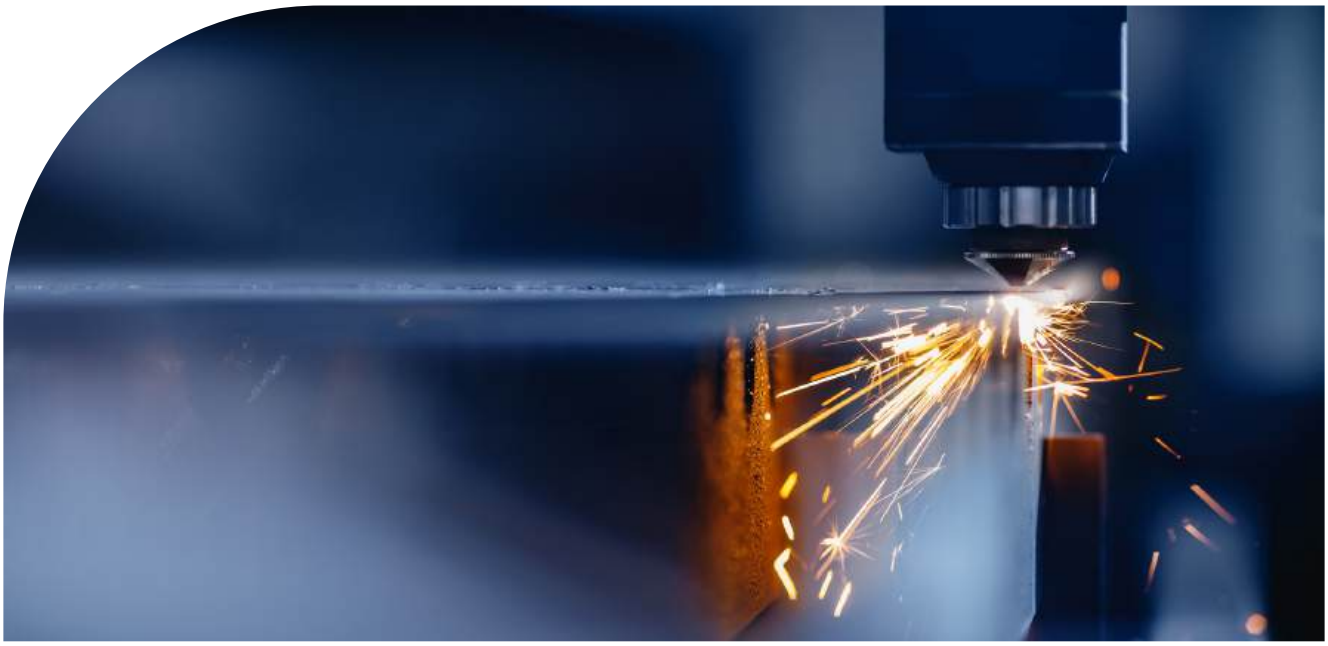
- In **manufacturing**, they enable predictive and prescriptive operations that improve productivity, quality and energy efficiency.
- In **logistics and mobility**, they create real-time visibility and coordination across supply chains and transport networks.
- In **agriculture and agri-food systems**, they optimise production, reduce waste and ensure traceability from farm to fork.
- In **healthcare**, they enable personalised treatments, resource optimisation and safer, more efficient clinical environments.
- In **construction and urban planning**, they guide the development of smart, sustainable and climate-resilient cities.
- In **energy and environment**, they support Europe's Green Deal goals by improving resource management and decarbonisation strategies.
- In **public services, defence and security**, they enhance preparedness, resilience and policy decision-making.

Collectively, these examples illustrate how Digital Twins act as a **strategic enabler of Europe's Twin Transition**, not as standalone tools, but as integrated infrastructures that connect data, intelligence and sustainability.

The following section begins with one of the most mature and impactful domains of application: **manufacturing**, where Digital Twins are already transforming production models, driving competitiveness and enabling the next generation of human-centric, resilient and sustainable industries in Europe.

3.1 Manufacturing

Reinventing European Industry Through AI-Powered Digital Twins



Manufacturing is the sector where Digital Twins have achieved the highest level of maturity and impact. Across Europe, factories are undergoing a profound transformation as data, connectivity and artificial intelligence converge to create intelligent, adaptive and sustainable production systems. Digital Twins serve as the backbone of this evolution, enabling real-time monitoring, simulation and optimisation of manufacturing processes while ensuring efficiency, safety and sustainability.

In a traditional production environment, decision-making has often been reactive, responding to faults or inefficiencies after they occur. Digital Twins reverse this paradigm. By mirroring the physical factory in a virtual environment,

they allow manufacturers to simulate process changes, anticipate failures and test new configurations before implementation. This creates a **closed feedback loop** where production lines learn continuously, guided by data and AI-driven analytics.

Europe's strength lies in its deep industrial expertise and technological foundations. Through the Made in Europe Partnership under Horizon Europe, the continent is aligning research and innovation efforts toward a new model of **Industry 5.0** — one that places people,

sustainability and resilience at the core of production. Within this vision, Digital Twins act as a unifying layer that connects machinery, robotics, and cyber-physical systems, creating flexible and resource-efficient factories capable of adapting to changing market and environmental conditions.

Strategic Benefits for European Manufacturing

- **Predictive and Autonomous Production**: Digital Twins integrate sensor data, machine learning and simulation to predict equipment failures, optimise maintenance schedules and improve uptime. This reduces operational costs and enhances quality consistency.
- **Sustainability and Energy Efficiency**: Real-time tracking of energy consumption and material usage enables factories to minimise waste and carbon emissions, supporting the European Green Deal and the Fit for 55 objectives.
- **Human-Centric and Safe Work Environments**: In the Industry 5.0 paradigm, Digital Twins enhance human-machine collaboration by simulating ergonomic layouts, safety scenarios and operator interactions. This ensures that automation strengthens, rather than replaces, the human role in production.
- **Interoperability and Supply Chain Integration**: Through European standards such as RAMI 4.0, OPC UA and the Asset Administration Shell (AAS), Digital Twins connect machines, suppliers and logistics systems into interoperable value chains. This enhances traceability, resilience and transparency.
- **Innovation and Product Customisation**: By linking design, production and performance data, manufacturers can deliver customised products at industrial scale while shortening innovation cycles.

European Use Cases and Flagship Initiatives

Several large-scale initiatives illustrate Europe's leadership in this field:

- The *Change2Twin*[26] project supports SMEs in adopting Digital Twin technologies through the EDIH network, providing assessment tools and funding for implementation pilots across manufacturing sectors.
- The *DIGITbrain* project[27] introduces the concept of "Digital Product Brains," allowing manufacturers to model and replicate production assets as data-driven services.
- The *AI REGIO* initiative[28] integrates regional innovation ecosystems to connect AI and Digital Twin capabilities, promoting cross-border industrial collaboration.
- In Germany, *Siemens Digital Industries and Fraunhofer IPA* are developing hybrid AI–DT platforms for predictive quality management and circular manufacturing. [29]
- In Finland, *KONE* is using Digital Twins for lifecycle management of elevators and maintenance optimisation, improving efficiency and extending asset lifespan. [30]

26. https://www.change2twin.eu/
27. https://www.digitbrain.eu/
28. https://www.airegio-project.eu/
29. https://press.siemens.com/global/en/pressrelease/siemens-accelerates-path-toward-ai-driven-industries-through-innovation-and
30. https://www.kone.com/en/news-and-insights/stories/from-wrenches-to-wireless.aspx

Strategic Alignment and Policy Integration

The transformation of Europe's manufacturing sector through Digital Twins directly supports the priorities set out in the *Apply AI Strategy, GenAI4EU Initiative and ADRA SRIDA*. These frameworks recognise Digital Twins as foundational enablers for scaling trustworthy, human-centric AI across industrial domains.

By integrating simulation, data and automation within ethical and regulatory frameworks, Europe ensures that innovation strengthens both competitiveness and societal value.

Furthermore, *EDIHs and TEFs for Manufacturing* act as bridges between technology development and industrial deployment. They provide SMEs and mid-sized companies with access to testbeds, training and financial support, ensuring that the benefits of Digital Twins reach all regions and business sizes.

Looking Ahead

The future of European manufacturing will be defined by intelligent systems that are not only efficient but also sustainable, safe and human-oriented. Digital Twins represent the operational foundation for this transformation. They enable Europe to shift from reactive production models to anticipatory, adaptive and resilient factories that embody the principles of the Twin Transition.

By reinforcing the links between research, innovation and industrial, through *Horizon Europe, Digital Europe Programme and Made in Europe Partnership*, Europe can maintain global leadership in advanced manufacturing while ensuring that technological progress serves people, the planet and prosperity alike.

3.2 Energy and Environment

Digital Twins as Enablers of Europe's Green and Sustainable Transformation

Europe's ambition to achieve climate neutrality by 2050 depends on its capacity to manage energy and environmental systems with precision, transparency and foresight. Digital Twin technology is emerging as a decisive enabler of this transition, offering the tools to model, simulate and optimise complex infrastructures, from energy grids and industrial plants to oceans, forests and cities.

By merging real-time data with artificial intelligence and physics-based models, Digital Twins allow decision-makers to monitor performance, anticipate disruptions and implement corrective actions before inefficiencies or failures occur. In the energy and environmental domains, this capability translates into more reliable grids, smarter consumption, and better stewardship of natural resources.

Strategic Benefits for Europe's Energy and Environmental Systems

- **Optimised Energy Management**: Digital Twins enable continuous monitoring and optimisation of generation, distribution and consumption. Energy operators use them to balance supply and demand, integrate renewables and improve grid stability. This supports Europe's Fit for 55 and REPowerEU objectives.
- **Renewable Integration and Storage Efficiency**: By simulating scenarios that combine solar, wind and hydroelectric generation with storage systems, Digital Twins help predict fluctuations, prevent outages and maximise renewable potential.
- **Emission Reduction and Circular Economy**: Environmental Digital Twins track resource flows, emissions and waste across industrial value chains. This supports Europe's shift toward circular production and enables compliance with carbon footprint regulations.
- **Climate Modelling and Resilience**: Large-scale environmental twins, such as Destination

Earth (DestinE) and the Digital Twin of the Ocean (DTO), allow Europe to anticipate extreme weather events, assess climate policies and design mitigation strategies with unprecedented accuracy.

- **Efficient Infrastructure and Smart Grids**: In cities, Digital Twins connect buildings, transport and energy systems to reduce consumption and emissions while enhancing citizen comfort. In industrial zones, they optimise utilities management and environmental performance.

European Flagship Projects and Initiatives

- **Destination Earth (DestinE)**: Led by the European Commission, ESA, EUMETSAT and ECMWF, this initiative is developing a high-precision Digital Twin of the planet to simulate the effects of climate change and human activity. It aims to provide policymakers with actionable data for climate resilience and sustainable planning.
- **Digital Twin of the Ocean (DTO)**: Managed by the European Marine Observation and Data Network (EMODnet) and Copernicus, the DTO provides real-time ocean data and predictive models for biodiversity, pollution and maritime transport.
- **Smart Energy Twin Projects**: Initiatives like *BD4OPEM*[31] use Digital Twins to optimise energy generation, grid operation and distributed storage, enhancing efficiency in renewable energy systems.
- **Urban and Environmental Twins**: Cities such as Madrid[32] or Aachen[33] are deploying Digital Twins to integrate mobility, energy and environmental data for sustainable urban planning and climate adaptation.

Strategic Alignment with EU Policies

Digital Twins in energy and environmental systems embody the principles of the European Green Deal, translating high-level policy goals into operational reality. Their ability to integrate data, simulation and AI aligns directly with the Apply AI Strategy and the GenAI4EU Initiative, which promote AI applications that are explainable, trustworthy and oriented toward the common good.

Moreover, the ADRA SRIDA identifies energy and environment as priority domains for cross-technology integration. By aligning the development of Digital Twins with robotics, edge computing and data spaces, Europe can achieve smarter, safer and more sustainable infrastructures that operate under shared ethical and interoperability standards.

A Foundation for Sustainable Sovereignty

The deployment of Digital Twins in the energy and environmental sectors strengthens Europe's strategic autonomy. By managing resources through European data spaces, cloud infrastructures (Gaia-X, EuroHPC) and edge computing, Europe ensures that critical environmental and energy data remain under its jurisdiction.

This approach also enhances resilience to global shocks, from energy crises to climate

31. https://cordis.europa.eu/project/id/872525
32. https://gemelo.madrid.es/en/
33. https://urban-mobility-observatory.transport.ec.europa.eu/resources/case-studies/digital-twins-lessons-learned-city-aachen_en

disasters, by enabling predictive management and cross-border coordination. Through Digital Twins, Europe is building not just greener systems, but smarter governance, capable of linking sustainability objectives with technological sovereignty.

Looking Ahead

In the coming decade, Digital Twins will become indispensable for Europe's green transformation. They will underpin renewable integration, guide decarbonisation and inform policies for biodiversity, agriculture and circular economy.

By embedding these technologies within Horizon Europe, the Digital Europe Programme and the Green Deal Industrial Plan, Europe can turn sustainability into a source of competitiveness, proving that leadership in clean technology and responsible digitalisation can advance together.

3.3 Smart Cities and Urban Planning

Designing Sustainable and Resilient Urban Futures through Digital Twins

Europe's cities are the frontlines of the digital and green transformation. As population density, energy demand and environmental pressures increase, cities need smarter tools to plan, manage and adapt their infrastructures. Digital Twins are becoming essential instruments in this evolution, enabling cities to connect data from multiple systems: energy, mobility, construction, waste, and public services into unified digital environments that support informed decision-making, citizen participation and sustainable growth.

A **City Digital Twin** integrates real-time data from sensors, IoT devices, public databases and citizen inputs into a single virtual model. This model mirrors the dynamics of the physical city, allowing planners and policymakers to simulate interventions, assess environmental and social impacts, and optimise urban operations before decisions are implemented.

Through this continuous data loop, Digital Twins transform cities into living systems.

Strategic Benefits for Europe's Urban Transformation

- **Integrated Urban Planning**: Digital Twins allow planners to visualise and test complex interactions between transport, buildings, utilities and the environment. They help anticipate the consequences of zoning changes, infrastructure projects and climate adaptation strategies.
- **Decarbonisation and Energy Efficiency**: By monitoring energy flows, building performance and mobility patterns, cities can identify emissions hotspots, optimise public transport routes and design low-carbon districts aligned with *Fit for 55*[34] and *REPowerEU*[35] targets.
- **Citizen Engagement and Participatory Governance**: Local Digital Twins (LDTs) make urban data accessible to citizens, fostering transparency and inclusion. Interactive visualisations allow communities to understand and contribute to policy choices, reflecting the principles of the *New European Bauhaus*[36].
- **Crisis Management and Resilience**: Digital Twins support emergency response by simulating floods, heatwaves or traffic disruptions in real time. This predictive capability strengthens cities' preparedness and resilience to climate and infrastructural challenges.
- U**rban Innovation and Data Economy**: By connecting public and private stakeholders through interoperable data spaces, Digital Twins stimulate local innovation ecosystems, new business models and services in areas such as energy management, waste reduction and smart mobility.

European Flagship Initiatives and Examples

- **Local Digital Twins (LDTs)**: Supported by the *Digital Europe Programme*, the European Commission is developing a network of LDTs that help municipalities integrate AI and data analytics for planning, climate adaptation and participatory decision-making.
- **Helsinki Energy and Mobility Twin**[37]: Helsinki's city-wide Digital Twin integrates transport, building and environmental data to plan low-emission districts and improve energy efficiency.
- **Rotterdam Climate Twin**[38]: Rotterdam's Digital Twin simulates flooding and sea-level scenarios, guiding investments in climate-resilient infrastructure.
- **Barcelona Urban Data Platform**[39]: Barcelona uses a comprehensive Digital Twin framework for energy, waste and mobility management, aligned with open data and citizen participation policies.

34. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal/fit-55-delivering-proposals_en
35. https://commission.europa.eu/topics/energy/repowereu_en
36. https://new-european-bauhaus.europa.eu/about/about-initiative_en
37. https://testbed.hel.fi/wp-content/uploads/2025/01/digital-twin-for-mobilty-working-paper-v2-1124.pdf
38. https://data.europa.eu/sites/default/files/course/Slides%20webinar%20smart%20cities.pdf
39. https://ajuntament.barcelona.cat/digital/en/technology-accessible-everyone/accessible-and-participatory/accessible-and-participatory-6

- **Smart City TEFs and EDIHs**: The *TEF for Smart Cities and Communities* and regional *EDIHs* provide cities and SMEs with testbeds to trial interoperable Digital Twin solutions, ensuring scalability and adherence to European data and AI standards.

Policy Alignment and Strategic Framework

Digital Twins in urban environments reflect the convergence of multiple European policy frameworks:

- The *European Green Deal* and the *Mission on Climate-Neutral and Smart Cities* set ambitious decarbonisation targets that depend on integrated, data-driven management.
- The *New European Bauhaus* promotes human-centric and aesthetic urban design, where Digital Twins serve as participatory tools for planning inclusive, livable spaces.
- The A*pply AI Strategy, GenAI4EU Initiative and ADRA SRIDA* position digital Twins as AI-enabled infrastructures that ensure transparency, trust and interoperability in urban systems.

Through these frameworks, Europe ensures that its cities not only become smarter but also more equitable and sustainable. Technological progress serving people and communities rather than displacing them.

The Path Forward

As cities evolve into complex data ecosystems, Digital Twins will serve as the **governance layer of the urban century**. They will connect physical infrastructure with real-time intelligence, enabling integrated management of energy, mobility, housing and environment.

By embedding Digital Twins into *Horizon Europe*, *Digital Europe Programme* and local innovation missions, Europe can transform its cities into living laboratories of sustainability, resilience and digital democracy. The result is a model of urban transformation that unites technology, design and participation, demonstrating that the European way of innovation is both human-centric and future-proof.

3.4 Healthcare and Social Robotics

Towards Predictive, Personalised and Preventive Healthcare through Digital Twins

The European healthcare system is undergoing a fundamental transformation driven by data, artificial intelligence and connected technologies. Digital Twins are at the heart of this shift, enabling a new paradigm of **predictive, personalised and preventive medicine.** By combining patient-specific data, biomedical models and real-time analytics, Digital Twins allow clinicians to simulate treatments, anticipate risks and optimise care delivery, transforming healthcare from reactive to proactive.

A **Healthcare Digital Twin** represents a dynamic digital replica of a patient, organ, medical device or healthcare process. Continuously updated with data from sensors, imaging, genomics and electronic health records, it reflects the real physiological or operational state of its counterpart. When combined with AI, these twins become powerful instruments for diagnosis, planning and intervention, enhancing safety, efficiency and patient outcomes.

Strategic Benefits for Europe's Healthcare Systems

- **Personalised Medicine and Precision Treatment**: Digital Twins allow doctors to test therapies in virtual environments before applying them to patients. They simulate drug interactions, surgical outcomes or rehabilitation paths, enabling tailor-made treatments with reduced risk and higher success rates.
- **Predictive and Preventive Healthcare**: Continuous monitoring and simulation support early diagnosis and risk prediction, reducing the incidence of chronic diseases and healthcare costs. This anticipatory model aligns with the *EU4Health Programme*[40] and the *European Health Union*[41] objectives.

40. https://health.ec.europa.eu/funding/eu4health-programme-2021-2027-vision-healthier-european-union_en
41. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/promoting-our-european-way-life/european-health-union_en

- **Operational Efficiency and Resource Optimisation**: Hospitals and healthcare networks use Digital Twins to optimise logistics, capacity planning and equipment maintenance. This increases efficiency and improves resilience during crises such as pandemics or resource shortages.
- **Ethical AI and Data Governance**: Europe's regulatory leadership ensures that Digital Twins operate within strict ethical, privacy and security frameworks. The *AI Act, Data Act and General Data Protection Regulation (GDPR)*[42] safeguard patient rights while fostering innovation.
- **Collaborative Research and Innovation**: Federated data infrastructures such as the *European Health Data Space (EHDS)*[43] and AI Testing and *Experimentation Facilities for Healthcare*[44] enable cross-border research and AI model validation while maintaining data sovereignty.

European Initiatives and Examples

- **Digital Twin for Cardiovascular Simulation**: The *SimCardioTest* project[45] develops personalised heart models using AI and simulation to predict disease progression and optimise treatment for each patient.
- **Virtual Brain Twin**: The *Human Brain* Project[46] and *EBRAINS* initiative[47] create brain Digital Twins to study neurological disorders and test potential therapies in silico.
- **Hospital Operations Twins**: Hospitals in Finland and Germany are deploying operational Digital Twins[48] to simulate patient flow, resource allocation and emergency scenarios, improving resilience and quality of care.

Alignment with EU Policies and Strategies

Digital Twins in healthcare directly contribute to Europe's broader digital and ethical vision for data-driven innovation. The **Apply AI Strategy** and **GenAI4EU** Initiative highlight healthcare as a priority domain where AI-powered Digital Twins can deliver measurable impact while respecting ethical and human-centric principles.

The ADRA SRIDA reinforces this by promoting cross-domain synergies between AI, Data and Robotics to support medical innovation under trustworthy governance frameworks. This coordination ensures that technology adoption strengthens public trust, accelerates medical breakthroughs and improves the efficiency of healthcare systems.

In parallel, the **European Health Data Space (EHDS)** provides the foundation for interoperable and secure data sharing, enabling Digital Twins to operate across hospitals, research centres and borders without compromising privacy or data ownership.

42. https://gdpr-info.eu/
43. https://health.ec.europa.eu/ehealth-digital-health-and-care/european-health-data-space-regulation-ehds_en
44. https://tefhealth.eu/home
45. https://digital-strategy.ec.europa.eu/en/news/simcardiotest-eu-funded-project-develops-new-predictive-tools-cardiac-pathologies
46. https://www.humanbrainproject.eu/en
47. https://www.ebrains.eu/
48. https://sciencebusiness.net/network-updates/business-finland-finnish-german-collaboration-health-data-accelerates-innovation

A New Model for Human-Centric Healthcare

The rise of Digital Twins marks a turning point in the European healthcare model. It empowers medical professionals with new tools for precision medicine, reduces the burden on healthcare systems and places patients at the centre of care. By combining ethics, excellence and innovation, Europe is shaping a future where technology amplifies, rather than replaces, human expertise.

Looking ahead, the integration of Digital Twins with AI, robotics and data spaces will make healthcare more predictive, sustainable and equitable. Supported by *Horizon Europe, the Digital Europe Programme and the EU4Health framework*, Europe is building a health ecosystem that reflects its values: trust, inclusion and solidarity.

Digital Twins are not just instruments of clinical progress; they are the **embodiment of Europe's commitment to responsible digital health**, ensuring that data and technology work together to protect, personalise and enhance human life.

3.5 Mobility and Logistics

Building Europe's Intelligent, Sustainable and Connected Transport Ecosystem

Mobility and logistics are the lifelines of Europe's economy. They connect citizens, businesses and industries across borders and form the backbone of the single market. Yet, the sector faces increasing challenges: congestion, emissions, fragmented infrastructures and disruptions in global supply chains. Digital Twin technologies are emerging as a key enabler for addressing these challenges, providing the intelligence, interoperability and foresight needed to build a **smart, efficient and sustainable European transport ecosystem.**

A **Mobility or Logistics Digital Twin** integrates real-time data from vehicles, infrastructure, traffic systems, weather services and sensors into dynamic virtual environments. These systems enable predictive simulation of transport flows, energy demand and logistics operations, allowing authorities and companies to anticipate disruptions, optimise performance and reduce environmental impact.

Strategic Benefits for Europe's Mobility and Logistics Systems

- **Predictive and Resilient Transport Management**: Digital Twins simulate mobility patterns, road conditions and traffic dynamics in real time. They enable transport operators and public authorities to anticipate congestion, manage fleets efficiently and plan maintenance proactively, improving safety and reliability.
- **Sustainable and Decarbonised Mobility**: By optimising energy use and routes, Digital Twins reduce fuel consumption and emissions. They also facilitate the integration of electric vehicles, alternative fuels and renewable energy infrastructures in line with the *European Green Deal* and *Fit for 55* targets.
- **Supply Chain Transparency and Efficiency**: In logistics, Digital Twins connect ports, warehouses, factories and distribution networks, creating end-to-end visibility. They enable predictive logistics, anticipating bottlenecks and disruptions, improving delivery times and resource use.
- **Multimodal and Connected Infrastructure**: Digital Twins allow seamless coordination between road, rail, air and maritime transport, promoting integrated planning across the *Trans-European Transport Network (TEN-T)*[49].
- **Safety, Security and Automation**: Combined with robotics and AI, Digital Twins improve vehicle autonomy, accident prevention and emergency management, ensuring compliance with safety and cybersecurity standards.

European Flagship Projects and Initiatives

- **Mobility Data Space**: A key component of the *European Data Strategy*[50], it provides the infrastructure for sharing transport and logistics data across sectors and borders. Digital Twins leverage this data to enable interoperable, real-time decision-making in logistics and urban mobility.
- **AI4CCAM (AI for Connected, Cooperative and Automated Mobility)**[51]: This *Horizon Europe* project uses Digital Twins to simulate traffic environments for autonomous vehicle testing and to optimise cooperative driving strategies.
- **Ports and Logistics Twins**: The *ALICE*[52] and *FEDeRATED*[53] initiatives use Digital Twins to connect European ports and logistics hubs, improving cargo tracking, customs management and environmental monitoring.
- **Air Traffic and Railway Digital Twins**: In the aviation sector, projects under *SESAR 3*[54] use Digital Twins to improve flight management and reduce emissions. In rail, *Shift2Rail*[55]

49. https://transport.ec.europa.eu/transport-themes/infrastructure-and-investment/trans-european-transport-network-ten-t_en
50. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-data-strategy_en
51. https://www.ai4ccam.eu/
52. https://www.etp-logistics.eu/
53. https://www.federatedplatforms.eu
54. https://www.sesarju.eu/
55. https://rail-research.europa.eu/about-shift2rail

and *Europe's Rail Joint Undertaking*[56] develop Digital Twins for predictive maintenance and asset management.

- **Urban Mobility Applications**: Cities such as Hamburg, Lisbon and Tallinn are deploying local Digital Twins to optimise public transport routes, improve traffic flow and coordinate low-emission zones.

Alignment with EU Strategies and Policy Frameworks

Digital Twins are central to the implementation of the **Sustainable and Smart Mobility Strategy**, which envisions a climate-neutral, connected and resilient transport system by 2050. They operationalise the principles of efficiency, sustainability and safety outlined in this roadmap by enabling **data-driven, cross-modal and predictive management**.

The **Mobility Data Space** plays a pivotal role by providing the trusted environment required for sharing and using transport data in accordance with the *Data Act and the AI Act*. This federated approach ensures transparency, interoperability and European sovereignty over critical mobility infrastructures.

The **Apply AI Strategy**, the **GenAI4EU** Initiative and the **ADRA SRIDA** reinforce this direction by promoting large-scale testing of AI-powered Digital Twins for logistics optimisation, fleet management and connected vehicle ecosystems. Together, these initiatives ensure that Europe's mobility transformation remains aligned with ethical standards and human-centric innovation.

A Roadmap for Intelligent and Green Mobility

Digital Twins represent the next leap in Europe's transport evolution: from fragmented systems to a unified, intelligent and sustainable mobility network. By combining simulation, real-time analytics and AI, they allow Europe to anticipate disruptions, reduce emissions and manage its transport infrastructures proactively.

Looking forward, integrating Digital Twins into *Horizon Europe, Digital Europe Programme and Connecting Europe Facility (CEF)*[57] will accelerate deployment across all Member States. This integration will not only boost efficiency and safety but also reinforce Europe's **strategic autonomy in mobility technologies**, ensuring that the continent leads the transition toward a connected, carbon-neutral and resilient transport ecosystem.

56. https://european-union.europa.eu/institutions-law-budget/institutions-and-bodies/search-all-eu-institutions-and-bodies/europes-rail-joint-undertaking_en
57. https://cinea.ec.europa.eu/programmes/connecting-europe-facility_en

3.6 Agriculture & Agrifood Systems

From Precision Farming to Resilient and Sustainable Food Ecosystems

Agriculture and food systems lie at the core of Europe's sustainability and resilience agenda. As global pressures on food security, biodiversity and resource efficiency intensify, Europe must accelerate the transition toward smarter, greener and more resilient agri-food ecosystems. Digital Twin technologies offer the means to achieve this transformation, providing farmers, policymakers and supply chain actors with real-time insight, predictive capabilities and sustainable management tools.

A Digital Twin for Agriculture or Agri-Food Systems is a virtual representation of farms, crops, livestock or entire supply chains, continuously updated with data from satellites, drones, IoT sensors and weather models. By integrating this information with AI-driven analytics, Digital Twins make it possible to simulate outcomes, optimise production processes and anticipate environmental or market risks. They enable a shift from traditional monitoring to data-informed, adaptive decision-making, improving productivity while reducing ecological impact.

Strategic Benefits for Europe's Agri-Food Sector

- **Precision and Predictive Agriculture**: Digital Twins optimise the use of water, fertilisers and energy through continuous monitoring of soil, weather and crop conditions. They allow farmers to plan interventions at the exact time and place where they are needed, improving yields and reducing waste.
- **Sustainability and Climate Resilience**: By simulating the effects of extreme weather events and resource management strategies, Digital Twins help design adaptive farming systems that protect biodiversity and enhance resilience to climate change.
- **Traceability and Food Safety**: From farm to fork, Digital Twins ensure transparency and traceability along the entire food supply chain, enabling verification of sustainability standards and compliance with EU food safety regulations.

- **Circular and Carbon-Neutral Production**: Environmental modelling allows the measurement and reduction of emissions, waste and water use, supporting Europe's Farm to Fork Strategy and Green Deal commitments.
- **Data-Driven Policy and Rural Innovation**: By connecting local farms and cooperatives to shared data spaces, Digital Twins empower policymakers to design evidence-based agricultural policies and create new opportunities for rural economies.

European Flagship Initiatives and Examples

- **SmartAgriHubs**[58] **and AgriDataSpace**[59]: Under Horizon Europe and the Digital Europe Programme, these initiatives develop a federated data infrastructure for agriculture, enabling Digital Twins to operate across farms, regions and sectors.
- **IoF2020 (Internet of Food and Farm 2020)**[60]: One of the largest EU-funded projects applying IoT and AI technologies to farming, IoF2020 laid the foundation for interoperable Digital Twin architectures in precision agriculture.
- **Demeter**[61] **and Atlas Projects**[62]: These initiatives focus on standardising agricultural data exchange, allowing Digital Twins to integrate seamlessly with equipment, sensors and platforms from different providers.
- **TEFs and EDIHs for Agri-Food**: The *Agri-Food TEF* and regional EDIHs provide farmers and SMEs with test environments to validate and adopt Digital Twin technologies, improving decision-making and reducing entry barriers to digital transformation.
- **European Space Data Applications**: The *Copernicus* and *Galileo* programmes supply high-resolution satellite data that feed agricultural Digital Twins with environmental and geospatial information for crop management and climate forecasting.

Alignment with EU Policies and Strategies

Digital Twins are a core enabler of Europe's **Farm to Fork Strategy**, which aims to make food systems fair, healthy and environmentally friendly. By integrating AI, data and simulation, they turn policy objectives into operational tools for sustainability and competitiveness.

Their deployment aligns with the **Common Agricultural Policy (CAP)**[63], promoting smart rural development, innovation and environmental protection. At the technological level, initiatives such as the **Apply AI Strategy**, **GenAI4EU** Initiative and **ADRA SRIDA** recognise agriculture as a priority field for trustworthy, human-centric AI and cross-sectoral innovation.

58. https://www.smartagrihubs.eu/
59. https://agridataspace-csa.eu/
60. https://cordis.europa.eu/project/id/731884/news/es
61. https://h2020-demeter.eu/demeter-approach-towards-an-agricultural-interoperability-space/
62. https://www.aef-online.org/aef-news/atlas-focuses-on-the-standardization-of-interfaces-in-knowledge-based-farming.html
63. https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/cap-glance_en

A Foundation for Sustainable Food Sovereignty

Through Digital Twins, Europe can build a more transparent, resilient and autonomous agri-food system. They enable the continent to reduce dependency on external resources, anticipate disruptions and strengthen local value chains, while ensuring that food production remains aligned with ethical, environmental and societal values.

By embedding these technologies into *Horizon Europe*, the *Digital Europe Programme and the Green Deal Industrial Plan*, Europe can transform its agri-food systems into global benchmarks of sustainability, demonstrating that food security, technological sovereignty and environmental stewardship can coexist in a truly European model of innovation.

3.7 Construction & Urban Planning

Building a Sustainable and Resilient Europe through Digital Twins

The construction and infrastructure sector represents one of the greatest opportunities for Europe to advance its digital and green transformation. Responsible for nearly 40% of energy consumption and 36% of CO_2 emissions in the EU, the built environment plays a decisive role in achieving climate neutrality by 2050. Digital Twin technologies are redefining how Europe designs, constructs and manages its buildings and infrastructures, enabling **smart, efficient and sustainable environments** that adapt to human needs and environmental realities.

A **Construction or Infrastructure Digital Twin** is a virtual representation of a building, infrastructure asset or entire urban system that evolves alongside its physical counterpart throughout its life cycle. By integrating data from Building Information Modelling (BIM), IoT sensors, geospatial data and AI analytics, Digital Twins provide a comprehensive, real-time view of how assets perform, degrade and interact with their surroundings. This holistic approach allows decision-makers to design, build and maintain infrastructures that are both cost-efficient and climate-resilient.

Strategic Benefits for Europe's Construction and Infrastructure Sector

- **Lifecycle Optimisation**: Digital Twins enable continuous monitoring from design and construction to operation and decommissioning. They reduce delays, optimise materials use and improve maintenance planning, supporting circular economy principles.
- **Energy Efficiency and Climate Neutrality**: By tracking energy consumption and emissions in real time, Digital Twins help reduce the environmental footprint of buildings and infrastructures, contributing to *Fit for 55* and *Green Deal* targets.
- **Resilience and Risk Management**: Infrastructure Digital Twins simulate structural integrity and environmental exposure to anticipate failures caused by wear, natural disasters or climate events, enhancing safety and preparedness.
- **Data-Driven Design and Innovation**: Architects and engineers use Digital Twins to test design alternatives, optimise comfort and integrate renewable energy systems, advancing the vision of the *New European Bauhaus.*
- **Smart Asset Management**: Governments and operators use Digital Twins for predictive maintenance of roads, bridges, tunnels and utilities, reducing costs and downtime while extending infrastructure lifespan.

European Flagship Projects and Initiatives

- **Built4People Partnership**[64]: Under *Horizon Europe*, this partnership drives innovation toward sustainable and user-centric buildings. Digital Twins are central to its vision, supporting energy efficiency, safety and human well-being.
- **Energy-Efficient Buildings (EeB) Initiative**[65]: Promotes Digital Twin-based modelling for climate control, energy optimisation and integration with renewable energy systems.
- **InfraTwin and BIM4EEB Projects**: These *Horizon Europe* initiatives develop Digital Twin platforms that merge BIM, IoT and AI for predictive maintenance and building retrofitting.
- **Smart Construction TEFs and EDIHs**: The *TEF for Smart Construction* and related *EDIHs* enable companies to test, validate and adopt interoperable Digital Twin solutions, promoting cross-sector collaboration and SME participation.
- **National and Local Twin Deployments**: Countries such as Denmark, France and the Netherlands are pioneering national Digital Twin programmes for infrastructure monitoring, while cities like Vienna and Paris use Digital Twins for planning and managing large-scale construction projects.

Policy Alignment and Strategic Context

Digital Twins in construction and infrastructure directly contribute to several key European policy frameworks:

- The *European Green Deal* and the *Renovation Wave Strategy* aim to decarbonise Europe's building stock, a goal that Digital Twins make measurable and achievable.

64. https://built4people.eu/
65.

- The *New European Bauhaus* reimagines sustainable design through beauty, inclusion and functionality, supported by Digital Twin technologies that enhance participatory and data-driven planning.
- The *Apply AI Strategy (2024), GenAI4EU Initiative [11] and ADRA SRIDA [12]* provide the innovation framework for integrating AI, data and robotics into construction processes, ensuring that automation and sustainability evolve together.

Through these initiatives, Europe is developing a federated and interoperable Digital Twin ecosystem that bridges architecture, engineering and urban management. This integration reinforces Europe's global competitiveness while aligning digitalisation with social and environmental priorities.

A Foundation for the Built Environment of the Future

Digital Twins are redefining how Europe builds and maintains its physical world. They turn buildings and infrastructures into intelligent, responsive and sustainable systems, a living network of assets connected by data and guided by AI.

- By embedding these technologies into *Horizon Europe, Digital Europe Programme* and *Built4People Partnership*, Europe can lead the global shift toward **net-zero**, **human-centric** and **resilient infrastructures**. This transformation embodies the spirit of the New European Bauhaus: merging technology with design, sustainability with aesthetics, and innovation with societal well-being.

3.8 Public Administration Security and Defense

Strengthening Europe's Resilience and Strategic Autonomy through Digital Twins

Public administrations, security agencies and defence organisations operate increasingly complex systems — from critical infrastructure and public services to national and cross-border security networks. Ensuring that these systems remain secure, resilient and efficient is a strategic imperative for Europe. Digital Twin technologies are emerging as a powerful enabler of this goal, offering predictive, data-driven and interoperable solutions for governance, crisis management and strategic decision-making.

A Digital Twin for Public Administration, Security or Defence provides a virtual environment that mirrors operational systems, policies or missions. It enables decision-makers to simulate scenarios, anticipate risks, optimise resources and test policy outcomes before implementation. By connecting data from multiple domains — energy, mobility, communication, health and defence — Digital Twins create a comprehensive and dynamic picture of national and European resilience.

Strategic Benefits for Public Sector and Security Systems

- **Evidence-Based Policy and Governance**: Digital Twins support governments in designing, evaluating and refining policies based on real-world data. They enable simulations of economic, environmental or social impacts, improving transparency and accountability.
- **Crisis and Emergency Management**: In disaster response, civil protection and humanitarian operations, Digital Twins simulate floods, wildfires, pandemics or infrastructure failures to coordinate interventions and optimise resource deployment in real time.

- **Infrastructure Security and Cyber Resilience**: By modelling digital and physical infrastructure interdependencies, Digital Twins help identify vulnerabilities and simulate cyberattacks or systemic disruptions, strengthening Europe's capacity to prevent and respond to crises.
- **Defence Planning and Operational Readiness**: In the defence sector, Digital Twins are used to replicate weapon systems, mission environments and logistics chains. They enhance simulation-based training, mission planning and maintenance of military assets, supporting the objectives of the *European Defence Fund (EDF) and the Permanent Structured Cooperation (PESCO)*.
- **Cross-Sector Coordination and Situational Awareness**: Digital Twins enable real-time data fusion across agencies, improving coordination between civil protection, transport, energy, and communication systems. This fosters a holistic approach to European security and resilience.

European Flagship Initiatives and Applications

- **Digital Twins for Civil Protection**: Projects under the Union Civil Protection Mechanism use Digital Twins to simulate and coordinate disaster response scenarios, optimising logistics and inter-agency communication.
- **Defence Digital Twins**: The *EDF*-funded *TACTIC* and *MOD4EU* projects employ Digital Twins for maintenance and mission simulation in land and air defence systems, improving readiness and interoperability among Member States.
- **Cybersecurity and Critical Infrastructure Twins**: Initiatives under the *Joint Cyber Unit and European Cybersecurity Industrial, Technology and Research Competence Centre (ECCC)* leverage Digital Twins to test resilience against cyber threats and ensure compliance with the NIS2 Directive.
- **Public Administration Twins**: Governments in Finland, Estonia and France are experimenting with Digital Twins of administrative processes to enhance public service efficiency and transparency through secure, interoperable data management.

Alignment with European Strategies

Digital Twins reinforce Europe's policy objectives under the **EU Security Union Strategy** and the **Cybersecurity Strategy for the Digital Decade**, which seek to protect citizens, institutions and infrastructures through innovation and cross-sector collaboration.

The **Apply AI Strategy**, the **GenAI4EU** Initiative and the **ADRA SRIDA** further promote AI-powered Digital Twins as instruments for trustworthy automation, situational awareness and strategic foresight. These frameworks ensure that technological deployment in security and defence respects European values — legality, proportionality and human oversight — while strengthening sovereignty and collective resilience.

Towards a Secure and Sovereign Digital Europe

Digital Twins are becoming the **strategic intelligence layer** of Europe's public governance and defence systems. They integrate data, AI and simulation to enhance foresight, coordination and autonomy — ensuring that Europe can anticipate and manage crises,

4. Strategic Priorities and Roadmap

A call for European Coordination and Acceleration

Europe stands at a decisive moment. The foundations for Digital Twin technology — scientific excellence, industrial capacity and ethical governance — are already in place. The challenge now is to **move from pilots to scale**, from research to deployment, and from fragmentation to federation.

Digital Twins are the **operational layer** of Europe's Twin Transition, linking data, AI and physical systems to drive competitiveness, sustainability and sovereignty. To realise their potential, Europe must accelerate action across three strategic pillars: **Technology and Infrastructure, Ecosystem and Governance, and People and Skills**.

4.1 Technology and Infrastructure

Europe's technological capacity is world-class, but fragmented. Scaling Digital Twins requires interoperable data architectures, secure computing power and trusted AI integration. Europe must invest in a federated digital infrastructure that connects edge, cloud and high-performance computing (HPC) with shared data spaces across all sectors.

Key priorities:

- **Interoperability and Standards**: Accelerate implementation of *RAMI 4.0, OPC UA and the Asset Administration Shell (AAS)* to ensure cross-domain communication.
- **Federated Data Spaces**: Expand sectoral data spaces (mobility, health, manufacturing, energy) through *Gaia-X and the Data Spaces Support Centre (DSSC)*, ensuring data sovereignty and accessibility.
- **Advanced Computing and Connectivity**: Strengthen *EuroHPC* and edge computing networks to power large-scale simulation and real-time analytics.
- **Cybersecurity and Trust**: Enforce the *Cyber Resilience Act and NIS2 Directive* to guarantee the integrity of Digital Twin operations.
- **AI Integration**: Leverage *GenAI4EU and ADRA SRIDA* to merge physics-based modelling and AI under transparent, human-centric governance.

Through this technological foundation, Europe can ensure that every Digital Twin, whether industrial, environmental or societal , operates within a **secure, interoperable and sovereign European framework.**

4.2 Ecosystem, Investment and Governance

Europe's leadership will depend on its ability to coordinate stakeholders, align funding and establish coherent governance. Building a thriving Digital Twin ecosystem means connecting innovation, industry and policy under a shared European mission.

Key priorities:

- **Unified European Coordination**: Establish a *Digital Twin Coordination Council* involving the Commission, Member States, *ADRA*, and industrial alliances (*Made in Europe, AI, Data and Robotics PPP*).
- **Aligned Funding and Investment**: Combine *Horizon Europe, Digital Europe Programme, InvestEU* and national funds to support interoperable, cross-border projects with measurable impact.
- **Public–Private Partnerships**: Mobilise industry participation through partnerships and mission-oriented projects that link R&I with large-scale deployment.
- **Regional Acceleration via EDIHs and TEFs**: Empower *EDIHs* and *TEFs* to provide SMEs and local administrations with testing, financing and technical support.

- **International Leadership in Standards**: Strengthen Europe's voice in *ISO, IEC and CEN–CENELEC* to promote European interoperability frameworks globally.

This coordinated governance model turns Europe's diversity into a strength — ensuring that investment, innovation and regulation advance together toward a **federated European Digital Twin ecosystem.**

4.3 People, Skills and Inclusion

Technological leadership depends on people. Europe must develop a skilled and inclusive workforce able to design, manage and govern Digital Twin systems responsibly. This requires investment in hybrid education, lifelong learning and ethical digital culture.

Key priorities:

- **Hybrid Training and Education**: Integrate AI, data, simulation and systems engineering into curricula through *Erasmus+, Pact for Skills and Digital Europe Programme*.
- **Reskilling and Lifelong Learning**: Provide continuous training for workers in industry, construction, energy and public administration via regional *EDIHs*.
- **Attracting and Retaining Talent**: Strengthen Europe's innovation environment under *Horizon Europe and EIC Pathfinder* to retain world-class researchers and engineers.
- **Competence Frameworks**: Align education with the *Apply AI Strategy (2024), GenAI4EU and ADRA SRIDA* to define the skills needed for trustworthy AI–DT integration.
- **Ethical and Human-Centric Innovation**: Embed European values (transparency, inclusion and sustainability) at the core of all training initiatives.

By fostering digital talent and inclusion, Europe ensures that the Digital Twin transformation is not only technological but **social**, empowering citizens and professionals to shape the future of Europe's intelligent industries and public services.

4.3 Implementation Roadmap 2025-2030

From Strategy to Action

The implementation of Europe's Digital Twin Strategy should follow a **phased and coordinated roadmap** aligned with the Digital Decade targets and the Competitiveness Compass (2025):

Phase	Main Objectives
Phase I Foundation (2025–2026)	Establish governance through the Digital Twin *Coordination Council*. Launch flagship cross-sector pilots via *Horizon Europe and Digital Europe Programme*. Expand interoperability testing under EDIHs and TEFs.
Phase II Expansion (2027–2028)	Scale deployment in key sectors (manufacturing, energy, health, cities). Integrate federated data spaces and *EuroHPC* access. Develop EU-wide certification schemes for trustworthy Digital Twins.
Phase III Consolidation (2029–2030)	Achieve full cross-sector interoperability, embed Digital Twins in policy frameworks, and position Europe as the global standard-setter for ethical and sustainable Digital Twin ecosystems.

By 2030, Digital Twins should form the **digital nervous system of Europe's economy and society**, ensuring that innovation, sustainability and sovereignty evolve together — and that Europe leads by example in building a digital future centred on trust, people and progress.

5. Call to Action and Policy Reccomendations for Europe

From Vision to Execution: Europe's Moment to Lead

5.1 Europe's Strategic Imperative

The decade ahead will determine whether Europe remains a standard-setter or becomes a standard-taker in digital transformation.

To secure its leadership, Europe must:

- Treat **Digital Twins as critical infrastructure**, integrating them into industrial, environmental and societal systems under a European governance framework.
- **Invest strategically** in data spaces, HPC and edge computing to guarantee technological independence and interoperability.
- Build a **single European market for Digital Twin solutions**, underpinned by shared standards, ethical rules and cross-border collaboration.
- Anchor **trust and human oversight** at the heart of AI-powered Digital Twin systems, ensuring compliance with the *AI Act, Data Act and Cyber Resilience Act*.
- **Mobilise citizens and industry** in the co-creation of digital transformation, ensuring inclusion and transparency across regions and sectors.

5.2 Policy Recommendations

1. **Create a European Digital Twin Mission (2025–2030).** Launch a flagship EU mission under *Horizon Europe and the Digital Europe Programme* to coordinate cross-sector deployment, with measurable sustainability and competitiveness goals.
2. **Establish a European Digital Twin Coordination Council.** Bring together the European Commission, Member States, industry alliances (*ADRA, Made in Europe*), and research bodies to oversee implementation, funding alignment and policy coherence.
3. **Deploy Federated Data and AI Infrastructures.** Accelerate the integration of *Gaia-X, EuroHPC, AI Factories* and sectoral data spaces to enable

secure and interoperable Digital Twin operations across Europe.

4. **Scale Regional Capacity through EDIHs and TEFs.** Empower *EDIHs* and *TEFs* to provide SMEs, regions and public administrations with access to testbeds, finance and training — ensuring that innovation benefits all Europeans.
5. **Invest in Skills and Ethical Competence.** Develop hybrid AI–DT curricula and microcredentials via the *Pact for Skills and Erasmus+*, embedding European values and sustainability in technical education.
6. **Reinforce Europe's Global Leadership in Standards.** Strengthen Europe's voice in *ISO, IEC, CEN and CENELEC* to promote interoperability frameworks such as *RAMI 4.0, OPC UA and the Asset Administration Shell (AAS)* as global benchmarks.

5.3 A Shared European Vision

Digital Twins embody the essence of Europe's approach to digitalisation: **open, ethical, inclusive and sustainable**. They connect science with society, data with purpose, and innovation with trust. By uniting its strengths under a single European strategy, Europe can lead the global transformation toward intelligent and responsible digital ecosystems.

This is not just a technological project; it is a **European mission**, to ensure that digital progress serves people, strengthens industry, and safeguards sovereignty.

The time to act is now. **Europe must not only imagine the future, it must design it**.

6. Technology Roadmap for Europe

Accelerating Europe's Twin Transition through Digital Twin Infrastructure

The **Digital Twin Technology Roadmap** defines Europe's pathway to position DTs as the **core infrastructure** enabling AI, Data Spaces, and Robotics.

It aligns with the A**DRA Strategic Research, Innovation and Deployment Agenda (SRIDA)** and with the goals of the **Green Deal**, and the **EU Industrial Strategy**. It supports the objectives of the **Digital Decade 2030** and **Competitiveness Compass**, linking research, innovation, deployment, and regulation.

The roadmap is structured along three-time horizons: **short-, mid-, and long-term**, to connect research, deployment, and policy priorities.

6.1 Short-Term Goals (2-3 years)

Objective: Accelerate adoption and improve interoperability for scalable deployment.

Priorities:

- Simplify DT design and reduce deployment time/cost.
- Standardize data integration, interoperability, and cybersecurity.
- Train professionals and certify expertise via EDIHs, TEFs and EU-aligned curricula.
- Demonstrate value through pilot projects for SMEs and public sector.

Technology Focus:

- Data integration and validation using standardized protocols and IoT infrastructure.
- Edge and cloud scalability for real-time performance.
- Cybersecurity-by-design, aligned with ENISA and the EU Cybersecurity Act (Reg. 2019/881).
- Interoperability through open APIs, semantic models, and AAS/OPC UA profiles.

Milestones:

- M1: Launch a universal Data Toolkit for integration.
- M2: Establish an Interoperability Certification Scheme.
- M3: Deply Cybersecurity Protocol for DTs.

- M4: Introduce Sector-Specific Training Curriculum.
- M5: Deliver ROI and compliance pilots for SMEs.

Expected Outcome: Early-stage interoperability, standardized toolchains, and a skilled workforce accelerating Europe's DT adoption and integration with AI and Data Spaces.

6.2 Mid-Term Goals (3-5 years)

Objective: Embed advanced technologies and broaden adoption across sectors.

Priorities:

- Integrate AI, ML, and AR/VR for predictive, autonomous, and user-friendly DTs.
- Deploy cross-sector pilots linking manufacturing, energy, health, and mobility.
- Establish sector-wide interoperability standards and governance models.

Technology Focus:

- AI integration: Reinforcement learning and generative AI models for predictive operations, supported by GenAI4EU [11].
- AR/VR interfaces: For immersive monitoring, simulation, and workforce training.
- Advanced cybersecurity frameworks and certification.

Milestones:

- M1: Validate DT cybersecurity frameworks in 3 sectors.
- M2: Ensure 70% of new DTs include AI components.
- M3: Deploy AR/VR in 30% of new DT systems.
- M4: Expand cross-sector adoption in 5 major industries.

Expected Outcome: AI-driven, secure, and accessible DTs underpinning Europe's industrial digital transformation.

6.3 Long-Term Goals (5-7 years)

Objective: Achieve systemic impact through interconnected, sustainable DT ecosystems.

Priorities:

- Build federated networks of Digital Twins across domains (manufacturing, mobility, energy, healthcare, smart cities).
- Reinforce sustainability and circularity through DT-enabled monitoring and optimization.
- Integrate DTs as operational pillars of the EU Green Deal, SDGs, and Digital Decade targets (75% digitized businesses by 2030).

Technology Focus:

- Interconnected DT systems enabling cross-sector data sharing and real-time collaboration.
- Frugal AI models: low-energy, physical-informed algorithms reducing environmental footprint.
- lagship Projects: Large-scale initiatives such as Destination Earth (DestinE), Digital Twin of the Ocean (DTO), and AI Factories/EuroHPC as DT compute backbones [5][15].

Milestones:

- M1: Launch 5 low-energy DT pilots by 2026-2027.
- M2: Integrate DTs into 30% of EU-funded energy projects by 2027.
- M3: Deploy DT platforms in 40 EU cities by 2027.
- M4: Establish 3 cross-sector DT hubs by 2028.

Expecetd Outcome: A connected, sustainable, and sovereign European DT ecosystem driving global standards and societal value.

Digital Twin Technology Roadmap Overview

Time Horizon	Key Objectives	Technology Priorities	Structural Priorities	Milestones
Short Term (2–3 yrs)	Accelerate deployment and adoption	• Data integration • Interoperability • Cybersecurity • IoT readiness	• Raise awareness • Education & training • Certification & stakeholder engagement	• Data toolkit • Interop standards • Cybersecurity protocols • ROI pilot cases
Mid Term (3–5 yrs)	Integrate advanced technologies	• -AI/ML integration • AR/VR use • Enhanced security	• Sector-wide standards • UX design • Showcase pilots	• DTs with AI & AR/VR • Multi-sector adoption • Usability feedback from operators
Long Term (5–7 yrs)	Achieve systemic impact & interconnection	• Interconnected DTs • Sustainability focus • Energy efficiency	• 75% digitization of EU businesses • Alignment with Green Deal	• Energy-efficient DTs • Urban planning DTs • Cross-industry collaboration

7. Europe's Path to Digital Twin Leadership

Designing a Sustainable, Competitive and Sovereign Digital Future

Europe stands at the threshold of a new technological era, one defined by the convergence of **data, artificial intelligence and physical systems** through Digital Twins. This technology is not a future vision; it is already reshaping Europe's industry, cities, energy networks, agriculture, healthcare and governance. Digital Twins are becoming the **operational backbone** of the continent's **Twin Transition**, digital and green.

Across all sectors, Digital Twins enable systems that learn, adapt and optimise in real time. They enhance productivity, accelerate decarbonisation, and support better policy decisions. From predictive factories and smart grids to personalised medicine and climate modelling, they are transforming how Europe creates value and manages complexity.

But technology alone is not enough. Europe's leadership depends on its capacity to **act together**, to align policies, mobilise investment, and train the next generation of digital talent. The Apply AI Strategy, GenAI4EU Initiative and ADRA SRIDA have already laid the groundwork for this collective ambition. Now, it must be scaled.

The roadmap outlined in this strategy defines three strategic pillars:

1. **Technology and Infrastructure**: building interoperable, secure and sovereign data and computing systems through initiatives such as Gaia-X, EuroHPC and Data Spaces.
2. **Ecosystem and Governance**: aligning policies, funding and standards to create a federated European Digital Twin ecosystem.
3. **People and Skills**: empowering Europe's workforce with hybrid AI–DT competences rooted in ethics, inclusion and sustainability.

Through these pillars, Europe can transform its excellence in research into **industrial and societal impact**, ensuring that innovation is both responsible and globally competitive.

The proposed **implementation roadmap (2025–2030)** calls for immediate action: establishing a European Digital Twin Coordination Council, scaling deployments through Horizon Europe and Digital Europe Programme, and positioning Europe as the **global reference for trustworthy and interoperable Digital Twins**.

This is more than a technological agenda; it is a **European mission**. A mission to ensure that digital progress reflects Europe's values: human dignity, openness, sustainability and solidarity. By acting now, decisively and together, Europe can lead the world toward a future where digital transformation strengthens people, industry and democracy alike.

The time to act is now. Europe must not only follow the digital age, it must shape it!.

The AI Data Robotics Association

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