

GOTOTWIN: Driving Renewable Energy Innovation with Digital Twin Technology

The Adriatic-Ionian region has long been rich in renewable resources, yet its energy systems are fragmented and cross-border collaboration is limited. GOTOTWIN – a project under the Interreg ADRIION programme – aims to change this by creating an open, digital-twin platform for renewable-energy integration. Universities, energy providers and technology companies from Greece, Croatia, Slovenia, Serbia, Bosnia and Herzegovina and North Macedonia are working together on a platform that will help stakeholders monitor assets in real time, simulate complex scenarios and plan investments.

Mapping the market and stakeholders

The project began by taking stock of the renewable-energy landscape. A market assessment found huge untapped potential in wind, solar, hydro and biomass resources across the region and emphasised that digital-twin technology can help unlock these resources. Because renewable energy flows across national borders, the study argued that collaboration between EU and non-EU countries is essential to meet European Green Deal targets and the REPowerEU plan; investment in digital-twin platforms and coordinated policies were identified as key enablers.

At the same time, the team mapped the ecosystem of actors involved in renewable energy. Local surveys and workshops produced a comprehensive directory of power-plant operators, grid operators, regulators, municipalities, research institutes, technology vendors and citizen groups. The mapping process followed four steps – local identification, consolidation, categorisation and validation – to ensure no important player was missed. Established energy networks provide a solid foundation, but the project notes that start-ups and community energy groups must be included in the digital-twin ecosystem to drive innovation.

Understanding digital-twin technologies

A digital twin is a virtual replica of a physical system that couples real-world data with computational models. GOTOTWIN's technology review explains that a full twin consists of three components: a **monitoring** module that collects and stores real-time data from sensors; a **simulation** module that uses this data to replicate the grid, forecast future states and test scenarios; and a **maintenance** module that manages updates, trouble-shooting and proactive interventions. When real-time constraints are tight, a lighter “digital shadow” can provide quick feedback while more detailed simulations run offline.

Digital twins come in different varieties. Component twins model individual devices such as sensors or wind-turbine blades; asset twins represent products or services like battery storage units; process twins simulate operations such as power-plant maintenance; and system twins cover entire networks. System twins are the most powerful because they enable optimisation of entire grids and integration of renewables across borders.

GOTOTWIN is building a scalable system twin that can be extended with future modules for forecasting, optimisation, trading and policy analysis.

From vision to architecture

Once the landscape was understood, the partners gathered detailed requirements for the digital-twin platform. Through questionnaires, interviews and workshops they identified functional and non-functional requirements. Three pilot use-cases were prioritised: data sharing between renewable assets and grid operators; AI-based forecasting and optimisation services; and an experimentation environment to test new market and policy scenarios. The requirements underline the need for real-time data acquisition, high data throughput, secure communication, user-friendly interfaces, compatibility with existing systems and compliance with EU data regulations.

These requirements led to a conceptual architecture with three layers. A **communication gateway** at the bottom connects renewable-energy assets (wind, solar and hydro power plants, and weather sensors) using standard protocols. In the middle, a **digital-twin core** ingests, stores and analyses data. At the top, a **visualisation layer** offers dashboards for real-time monitoring, predictive maintenance, energy forecasting and virtual power-plant aggregation. The diagram below shows how data flows from physical assets into the twin core and out to different visualisation modules for operators, policy-makers and researchers.

With a clear vision, the team designed a modular, service-oriented and cloud-native system. The architecture relies on **Kubernetes** to orchestrate microservices and scale resources; **Eclipse Hono** acts as the IoT gateway for secure device connectivity; **Eclipse Ditto** manages the digital-twin state; **InfluxDB** stores time-series data; and **Grafana** provides interactive dashboards. Open standards and open-source tools ensure interoperability and avoid vendor lock-in. The design emphasises modularity, scalability, interoperability and security.

The updated logical architecture begins with the IoT gateway, which authenticates devices and normalises data streams. Data flows into a **digital-twin manager** that synchronises the virtual and physical states. A **historical data storage** component preserves long-term measurements, while a **simulation toolkit** and **prediction toolkit** support scenario analysis and machine learning. A **model-training environment** lets data scientists build and deploy AI models. Finally, **visualisation modules** built with Grafana and custom dashboards provide real-time monitoring, predictive-maintenance alerts and energy-production forecasts. The architecture is flexible: modules can be deployed on-premises or in the cloud and additional services such as optimisation algorithms or blockchain-based trading can be added as needed.

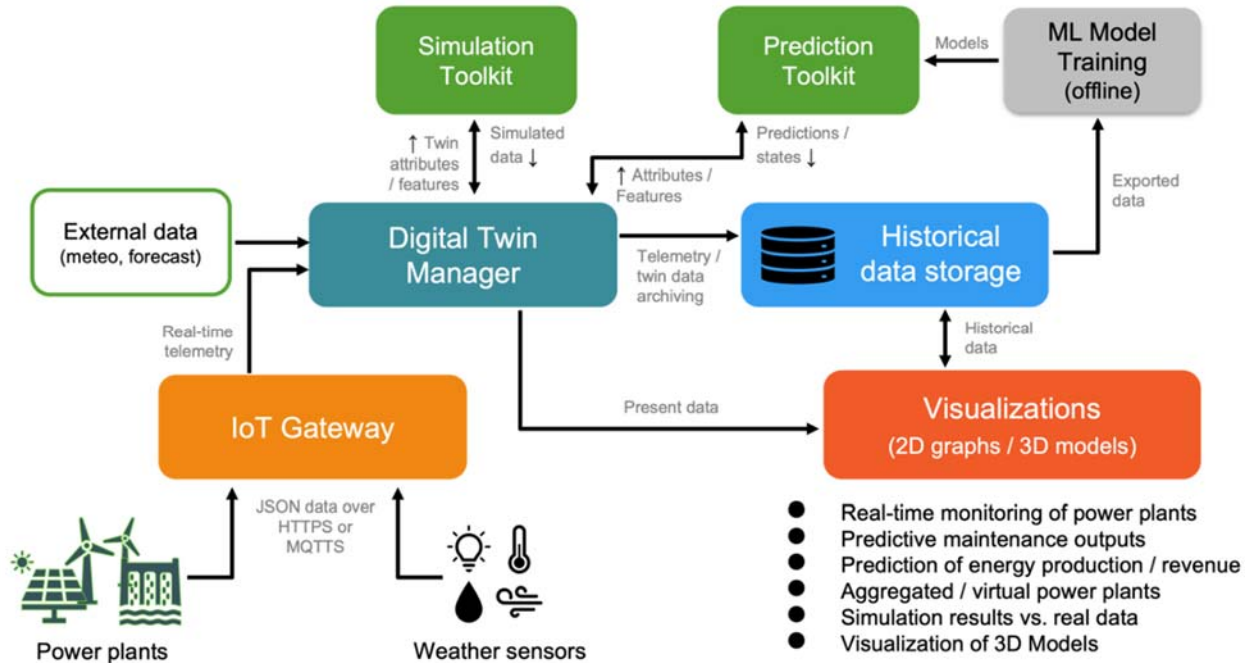


Figure 1. Architecture of the GOTOTWIN digital twin platform

Collaborative planning and policy dialogue

Technical design is only part of the story; collaboration and policy alignment matter too. In May 2025 the partners met in Kozani, Greece for a two-day planning workshop. On day one they compared microservice frameworks, selected open-source components and planned how to integrate sensors, edge devices and renewable assets into living labs across North Macedonia, Serbia, Greece and Croatia. They also discussed cross-site experimentation and how to harmonise sensor types, data formats and APIs so that datasets can be shared. Day two shifted to policy: participants identified cybersecurity risks, data-ownership issues and inconsistent regulatory frameworks across countries and concluded that coherent policies and long-term investment are needed to support digital-twin adoption and regional energy integration.

A subsequent policy workshop brought together government agencies, regulators and industry stakeholders to delve deeper into cybersecurity, interoperability and data governance. The discussions called for harmonised regulations, clear rules on data ownership and privacy, and incentives for investment in digital-twin infrastructure. Participants also stressed the importance of involving citizens and small businesses in the energy transition, ensuring that digital-twin tools support social innovation as well as technical optimisation.

Current state and next steps

By early 2026 GOTOTWIN has delivered a suite of foundational reports, defined a clear architecture and built consensus among stakeholders. The partners are now implementing the modular platform. A first prototype integrates sensors from living labs, collects real-time

data via Eclipse Hono, stores it in InfluxDB and displays it through Grafana dashboards. The team is developing AI modules for short-term forecasting and anomaly detection and preparing cross-border experiments that connect living labs in different countries.

The next phase will expand the platform to include advanced optimisation algorithms for balancing supply and demand, market-simulation tools for testing regulatory scenarios and policy-analysis modules to help governments design supportive frameworks. GOTOTWIN will continue engaging stakeholders through workshops and dissemination events. As digital-twin technology matures, the project aims to become a benchmark for regional cooperation in renewable energy, showing how open platforms can accelerate the energy transition and deliver economic and environmental benefits.