REPORT

An Overview and Progress Report on the GoToTwin Project

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Abstract

The GoToTwin project (INTERREG IPA ADRION PROGRAMME) deals with integration of renewable energy sources thus strengthening the innovation capacities in the region that is presented by partners from North Macedonia, Slovenia, Croatia, Bosnia and Herzegovina, Serbia and Greece. The mentioned integration will go through a digital platform and will represent digital twins for each renewable energy source (sun, wind and water). Besides technical goals, this project will promote cross-sector collaboration, enable capacity building, create policies and establish cooperation networks across the region. This paper presents an overview of the project objectives together with a partial progress report since half of the project duration has passed.

Keywords: community, digital twin, renewable energy source.

1 Introduction

The GoToTwin project [1] responds to the shared challenge of accelerating the adoption and integration of renewable energy sources across the Adriatic-Ionian region. By utilising digital twin technology [2–4], the project aims to address critical energy and sustainability challenges affecting the region. The main outputs of the project include:

- Developed digital twin platform:
  A digital twin platform that can seamlessly integrate data from renewable energy and meteorological sources, which will enable real-time monitoring, command and control, and predictive maintenance of power plants. Leveraging latest AI/ML solutions, the platform can support accurate prediction of energy production, simulation of virtual power plants, enhancing its capabilities in modeling and optimizing renewable energy systems.

- Transnational integration and testing of four living labs into the digital twin platform:
  Integration of four living labs from different countries in the Adrion: Smart Living Lab from Greece, Solar Living Lab from North Macedonia, SGLab from Croatia and IMP Testbed from Serbia. These labs will provide the essential infrastructure for stakeholders to engage in experimentation and testing. The pilot action will demonstrate the digital twin platform replicability in a transnational perspective within the living lab environment.

- GoToTWIN network:
  Collaboration between project partners fostering

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networking and promoting greener Adrion. At least three thematic groups workshops will be organized focusing on specific areas of sustainable development, such as renewable energy, waste management, or eco- tourism. These working groups will bring together experts, professionals, and stakeholders with shared interests in the Adriatic- Ionian region.

- Joint strategy for digital twins on renewable energy in the Adrion:
  Informed by technology, and policy frameworks, the project will develop a joint strategy for digital twins reflecting the territorial needs in the Adrion. It will outline the vision, state of play, and recommendations for sustainable development in renewable energy, resource management, and environmental conservation. The strategy focuses on policymakers, stakeholders, and organizations in leveraging digital twins for a sustainable Adrion.

To ensure quality, at the beginning of the project, Quality manual was developed. The primary quality objectives stated in Quality manual are:

- Encouraging the early identification of risks and issues to reduce the costs of failure and minimize their impact on the project's schedule or the quality of deliverables.
- Ensuring that effective actions are taken to mitigate risks, address negative impacts, and resolve any issues that arise.
- Providing Project Partners (PPs) with necessary guidelines before undertaking critical activities, particularly those that could significantly influence the overall project outcomes.
- Establishing the general requirements for project reviews, reports, and collaboration among PPs to achieve the overall project goals.
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Project team consists of seven partners and nine associate partners (who are not stakeholders) from six countries: three EU and three non-EU countries.

Project partners are:

- Faculty of Electrical Engineering and Information Technologies (FEEIT), Ss. Cyril and Methodius University – Skopje, North Macedonia – lead partner and coordinator;
- Jožef Stefan Institute (JSI) – Ljubljana, Slovenia
- University of Western Macedonia (UOWM) – Kozani, Greece
- University of Zagreb Faculty of Electrical Engineering and Computing (UNIZGFER) – Zagreb, Croatia
- Institute Mihajlo Pupin (IMP) – Belgrade, Serbia
- University of Banja Luka (UBL) – Banja Luka, Bosnia and Herzegovina
- Serafimoski TEK - Serafimoski TEK DOOEL import-export – Skopje, Norh Macedonia

Associate partners are:

- AD Mepso Skopje – Skopje, North Macedonia – responsible partner – FEEIT
- Centre for Technology Transfer and Innovations (INNOFEIT) – Skopje, North Macedonia – responsible partner - FEEIT
- ComSensus – Dob, Slovenia – responsible partner - JSI
- Public power corporation S.A. – Athens, Greece – responsible partner – UOWM
- Municipality of Servia – Servia, Greece – responsible partner – UOWM
- Energy Platform Living Lab (EPLL) – Zagreb, Croatia – responsible partner – UNIZGFER
- University of Rijeka Faculty of Engineering (RITEH) – Rijeka, Croatia – responsible partner – UNIZGFER
- ICT Network – Belgrade, Serbia – responsible partner – IMP
- Elnos Group – Banja Luka, Bosnia and Herzegovina – responsible partner – UBL

2 Project work packages

GoToTwin project has four work packages:

- WP1 - Market analysis in the Adrion
- WP2 - Digital twin as an enabler of future resilient Adrion
- WP3 - Capacity building in the Adrion
- WP4 - Strategies and policies

2.1 WP1 - Market analysis in the Adrion

The specific objective of this WP is to examine the current state and the potential for future market developments of the renewable energy market in the Adriatic Ionian region. Moreover, it will explore the existing stakeholders in the Adrion and identify their needs and requirements in terms of digital twins. The work package will also investigate the technology readiness level, legal and policy constraints that may impact the implementation of digital twins in renewable energy systems. Lastly, it focuses on identifying state-of-the-art solutions for digital twins in renewable energy systems. This involves exploring cutting-edge digital twin technologies and assessing their suitability for the digital twin platform. Emphasis will be placed on open-source solutions to maximise accessibility and foster collaboration.

There are three activities within this work package:

- Activity 1.1 - Market assessment, needs and transnational benefits from digital twins of renewables
- Activity 1.2 - Mapping of excellence in renewables in the Adrion
- Activity 1.3 - State-of-the-art technologies and requirements

Deliverables are attached to each activity:

- D1.1 - Market assessment, needs and transnational benefits from digital twins of renewables
- D1.2 – Renewable energy stakeholder mapping and collaboration framework in the Adrion
- D1.3.1 - State-of the art technologies as assessment report
- D1.3.2 - Digital twin requirements specification

2.2 WP2 - Digital twin as an enabler of future resilient Adrion

This work package focuses on the transnational implementation of a robust and reliable digital twin platform for renewable energy systems in the Adriatic Ionian region, that seamlessly integrates dana from diverse renewable energy sources and meteorological data. This platform will enable accurate predictions and optimised resource allocation, ensuring efficient and reliable operation of renewable energy systems. It will also facilitate real-time monitoring, command and control capabilities, and predictive maintenance features for digital twins of renewable power plants. To further enhance its capabilities, the platform will also support virtual power plant modelling and simulations. A key aspect of this work package is the integration of the digital twin platform across borders within the Adriatic Ionian region. By facilitating cross-border cooperation, the platform will contribute to the efficient management and optimization of renewable energy systems on a regional scale.

There are three activities within this work package:

- Activity 2.1 - Digital twin platform architecture design
- Activity 2.2 - Digital twin cloud and applications
- Activity 2.3 - Integration across borders

Deliverables are attached to each activity:

- D2.1.1 - Initial digital twin platform planning workshop
- D2.1.2 - Digital twin system architecture and infrastructure design
- D2.2.1 - Mid-term hands-on digital twin platform implementation workshop
- D2.2.2 - Mid-term digital twin platform implementation report
- D2.3.1 - Final digital twin platform implementation report
- D2.3.1 - Final living labs hands on integration workshop
- D2.3.2 - Regional integration and testing report

2.3 WP3 - Digital twin as an enabler of future resilient Adrion

This work package strengthens capacity in the Adriatic Ionian region using living labs as testing grounds for stakeholders. It aims to foster networking, promote a greener Adrion, and enhance stakeholder capacity in sustainable development. Thematic working groups will be formed to facilitate regional capacity building through discussions and collaborations. Living labs provide hands-on opportunities for stakeholders to test sustainable practices and technologies, enabling them to gain hands-on experience, knowledge, and skills. Through active engagement in testing activities, the project aims to build the capacity and expertise of stakeholders in promoting sustainable development in the Adriatic Ionian region. Initially, four living lab sites have been conceived: UOWM's Smart Living Lab - Kozani, FEEIT's Solar Living Lab - Skopje,

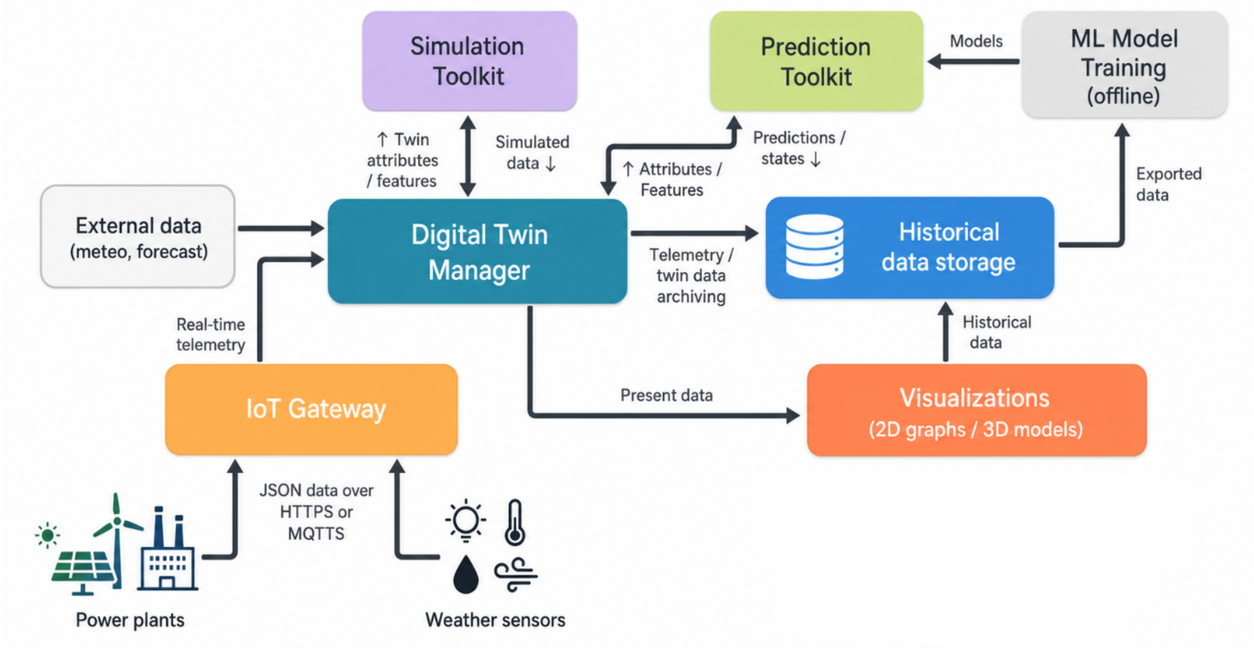

Figure 1. GoToTwin platform architecture.

UNIZGFER's Energy platform living lab - Zagreb, and IMP's Testbed - Belgrade.

There are three activities within this work package:

- Activity 3.1 - Open call for experiments.
- Activity 3.2 - Thematic working groups and stakeholder engagement.
- Activity 3.3 - Training and education programs.

Deliverables are attached to each activity:

- D3.1 - Open call and experiments report.
- D3.2.1 - First thematic working group workshop.
- D3.2.2 - Second thematic working group workshop.
- D3.2.3 - Third thematic working group workshop.
- D3.2.4 - Capacity building strategy document.
- D3.3.1 - Training materials and resources.

2.4 WP4 - Strategies and policies

The specific objective of WP4 is to develop comprehensive strategies and policies that facilitate the widespread adoption of renewable energy sources in the Adriatic Ionian region. It aims to advocate for favourable policies and regulatory frameworks that promote the utilisation of digital twin technology, overcome potential regulatory obstacles, and facilitate a harmonised policy framework aligned with EU trends. Additionally, WP4 focuses on raising awareness and promoting understanding of the administrative and regulatory challenges associated with the development and implementation of digital twin platforms for renewable energy sources. By addressing these challenges and advocating for policy reforms, WP4 aims to foster an environment conducive to the successful deployment and integration of digital twin technology for renewable energy in the region.

There are three activities within this work package:

- Activity 4.1 - Policy and regulatory analysis and recommendations.
- Activity 4.2 - Policy advocacy and lobbying.
- Activity 4.3 - Joint strategy for digital twins in the Adrion.

Deliverables are attached to each activity:

- D4.1.1. - Workshop on identification of policy inconsistencies, barriers, and administrative burdens.
- D4.1.2 - Policy and regulatory guidelines and recommendations.
- D4.2.1 - Policy advocacy and lobbying report.
- D4.3.1 - Digital twins Adrion strategy.

3 Results and progress

Since half of project duration passed, there is significant progress within this project. Deliverables

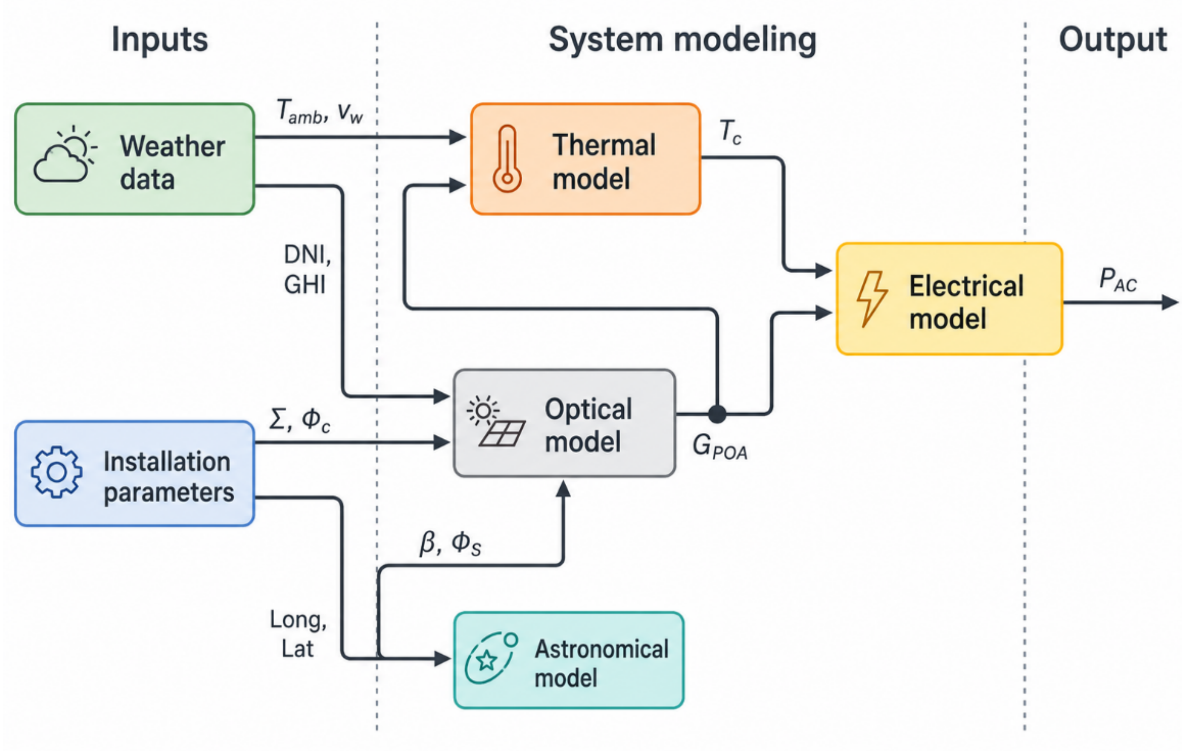

Figure 2. PV system model from Simulation toolkit.

D1.1, D1.2, D1.3.1, D1.3.2, D2.1.1, D2.1.2, D2.2.1, D2.2.2, D4.1.1. and D4.1.2 are completed and delivered. Of course, it was not only paperwork, but there is also significant progress within software and hardware tools. Among others, GOTOTWIN platform (Figure 1) was designed and largely realised.

This platform architecture consists of several parts. The IoT Gateway securely connects physical assets, such as weather stations and power plants, to the cloud, handling JSON telemetry over HTTPS/MQTTS communication protocols, as well as device authorization and authentication, acting as a Monitoring DT component. The Digital Twin Manager serves as the central DT component, maintaining and updating each renewable asset's virtual twin using live telemetry, simulation and prediction outputs, and external meteorological data, while also managing lifecycle operations and schema-based validation. A Simulation Toolkit runs quasi-static models to generate realistic synthetic telemetry from asset parameters and weather conditions, feeding this data to the Digital Twin Manager for scenario analysis and comparison with real performance as a Simulation DT component. In parallel, a Prediction Toolkit uses offline-trained machine-learning models to infer future states, such as fault likelihood or short-term energy production, from current attributes, writing these predictions back into the DT. All telemetry and DT states are archived in a time-series Historical Data Storage for retrospective analysis, AI/ML training, compliance, and audits, and full traceability over time. Finally, a Visualization Layer provides dashboards and alerts for different user roles to inspect real-time and historical data, compare simulations with actual behaviour, and monitor individual or aggregated assets, with Grafana OSS [5], a widely adopted open-source platform, as the main tool for visualizing and monitoring data from the digital twins. Grafana transforms raw time-series data into configurable dashboards that show key performance indicators, system status, historical trends, and outputs from simulation and prediction components, using panels such as graphs, gauges, tables, and alerts tailored to different user roles. Grafana is connected to the InfluxDB OSS v2 database, enabling both real-time and retrospective views. Built-in alerting lets users define rules for query results and route notifications via channels such as email or collaboration tools, while authentication and workspace separation protect dashboard access.

Furthermore, UNIZGFER, together with UBL, is responsible for creating model for solar power plant. PV system model, shown in Figure 2, is represented by four coupled submodels: astronomical, optical, thermal, and electrical.

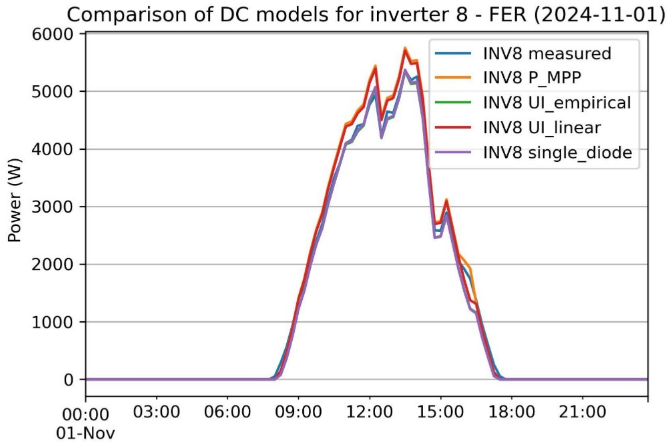

Figure 3. Comparison results of DC models for inverter 8 (UNIZGFER, 2024-11-01).

These submodels together map site parameters and meteorological inputs to the AC power output P_AC of the plant, consistent with common PV simulation frameworks. The astronomical model computes the solar altitude β and solar azimuth ϕ_S from time and location, following standard solar geometry formulations as described in [6]. These angles feed the optical model, which converts global horizontal irradiance (GHI) into plane-of-array irradiance G_POA by first decomposing GHI into direct normal irradiance (DNI) and diffuse horizontal irradiance (DHI) with empirical or quasi-physical decomposition models (for example, Orgill–Hollands, Erbs, Boland, DISC, DIRINT) and then transposing them to the tilted module plane using isotropic and anisotropic sky models such as Liu–Jordan, HDKR, and Perez [7]. The thermal model estimates the module temperature T_c from G_POA, ambient temperature T_amb, and optionally wind speed v_w, using two-variable (NOCT, HOMER) or three-variable (Faiman, Sandia) correlations developed from heat-transfer theory, reflecting the strong temperature sensitivity of PV efficiency highlighted in recent reviews. The electrical model then transforms G_POA, T_c, and system design parameters into DC and AC power. PV modules are described either by power-based performance relations, as implemented in tools such as PVWatts and HOMER, or by equivalent-circuit and I-V models such as those of De Soto, Villalva, and Walker, which allow detailed operating-point simulation. Inverter behavior is captured with empirical efficiency curves or models such as PVWatts [8], and Sandia [9], to represent load- and voltage-dependent losses. Finally, Figure 3 shows the comparison of various DC models used in the PV system model for the inverter 8 measurements at the UNIZGFER location for the date 2024-11-01.

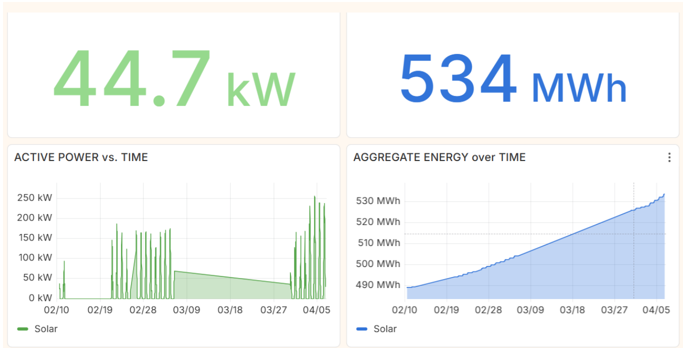

Figure 4. Grafana dashboard with total data for UNIZGFER solar power plant.

Data from solar power plant located in Zagreb started to arrive to GoToTwin platform 10.02.2026. From 20.02.2026. information starts to flow continuously with one failure of measurement system power supply between 06.03.2026. and 30.03.2026. Figure 4 shows Grafana display with total data period. Also Figure 5 shows data from 03.04.2026. to 07.04.2026. and shows typical three to five days of solar power plant operation.

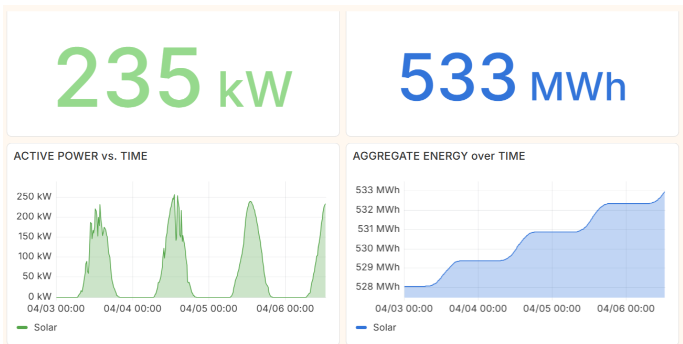

Figure 5. Grafana dashboard with data for UNIZGFER solar power plant – zoomed data.

4 Conclusion

So far, as expected, all deadlines are met and all deliverables were finished successfully and delivered on time. Of course, a lot of work is still to come but the established teams, mutual cooperation, constant quality control and overall project management ensures that deadlines till the end of the project will be met with quality products, results and documents as was so far.

All power plants that are within this project will be eventually connected to GOTOTWIN platform and presented in Grafana and that data will be available for experimentation publicly. The first test will soon come when, during July 2026., there will be open call for experiments. The purpose of this activity is to invite participation from various stakeholders from the Adrion region, such as SMEs (Small and Medium Enterprises), BSOs (Business Support Organizations) to conduct experiments within the established living labs. The focus of these experiments is on exploring new algorithms, technologies, and solutions related to renewable energy based on the digital twin concept. That will be the fist real test of this concept and the whole project in general.

Data Availability Statement

Data will be made available on request.

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Conflicts of Interest

The authors declare no conflicts of interest.

AI Use Statement

The authors declare that no generative AI was used in the preparation of this manuscript.

Ethical Approval and Consent to Participate

Not applicable.

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