

Update GEMINI Q2 2025

This article provides a short update on the status of the GEMINI digital twin for geothermal systems as developed within the Nieuwe Warmte Nu-programme (Datagedreven optimalisatie aardwarmtesystemen). The project is divided into five work packages. Below is presented a short update per work package.

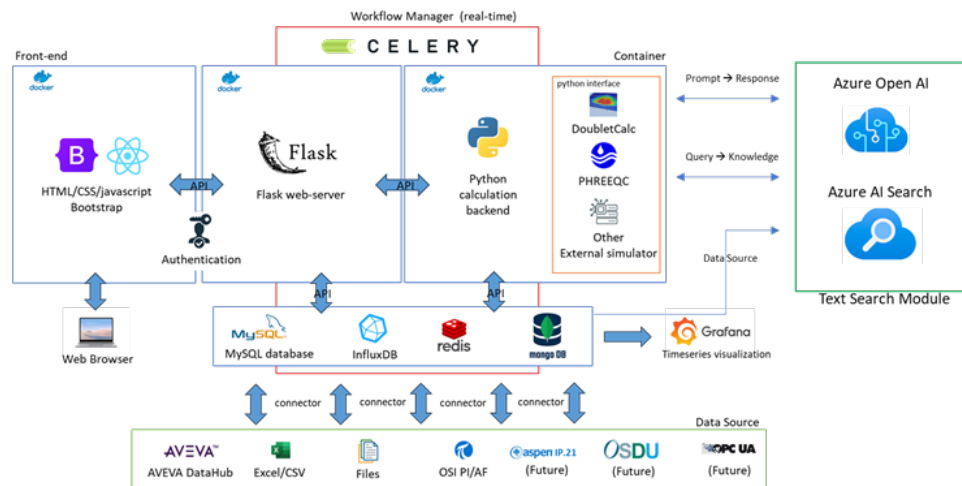


Figure 1— Proposed architecture for the open-source digital twin framework of geothermal assets.

The focus of the project is to develop and implement a digital twin for deep geothermal plants. This digital technology will enable monitoring and simulation of plant operations, allowing operators for performance optimization, optimized maintenance planning, and risk mitigation.

WP1: Framework for data collection and management

As part of the W1, it was developed a summary with guidelines on data management, which reviews the best practices for data management and integration with digital twin technologies tailored to geothermal plants and operational practices.

Also, in WP1 steps were done so far to demonstrate the added value of standardized data management for sector learning. Both technical and non-technical aspects are covered. From stakeholder interviews, performed by TNO, it became clear that common data standards, management systems and data governance aspects in the context of geothermal and HTO projects is important to be tackled.

Federated learning techniques for safe and secure data sharing, without harming individual confidentiality requirements or business interests, were explored and the results will be shared in the upcoming period.

WP2: Development of modules and applications

WP2 of the project focusses on developing the new functionalities of the digital twin and is mainly executed by TNO and WEP. As of Q2 2025 new functionalities that are in place include injectivity monitoring and ESP monitoring. In addition, workflows for automated result report generation and large-language model-based text search capabilities are nearing completion. Next to this, the first version of the well integrity management suite (WIMS) that includes corrosion monitoring is almost finished. Finally, developments of DTS data monitoring and processing models and the annulus pressure monitoring functionality of the WIMS are now underway.

WP3: Modules Integration and Visualization

WP3 focusses on integrating the functionalities developed in WP2 into the visual front-end interface of the GEMINI digital twin. As such, WP3 is closely interwoven with WP2 and most of the progress made within the work package is in line with that of WP2. Applications for all basic functionalities of the digital twin as well as injectivity monitoring are already in place and those for the ESP monitoring and WIMS applications are currently under development and near completion.

WP4: Evaluation and demonstration

In WP4 the functionalities that are developed in WP2 and WP3 are tested to ensure that they work as expected. In Q1 of 2025 the first version of the GEMINI digital twin including all completed applications as described in the WP3 section have been installed for the HAL and Trias Westland sites of GAIA and HVC respectively. At the moment these project partners are testing the digital twin and based on their feedback the software will be updated. In Q3 of 2025 the next version of GEMINI, including the ESP monitoring, WIMS, and report generation and search applications, will be shared with these partners.

WP5: Open-source software tool deployment and management

WP5 looks into the proper management of the source code of GEMINI for open-source publication within the project and fostering a community of interested parties to continue the development of the digital twin in the future. For the first half of the project, the focus in WP5 has been on setting up the appropriate templates and workflows to allow for structured code contributions to the project. In addition, systems have been put in place that help generate clear documentation for the codebase as well as users of the digital twin.