

Digital Twin of Geothermal Assets Assisting the Production and Operational Decisions

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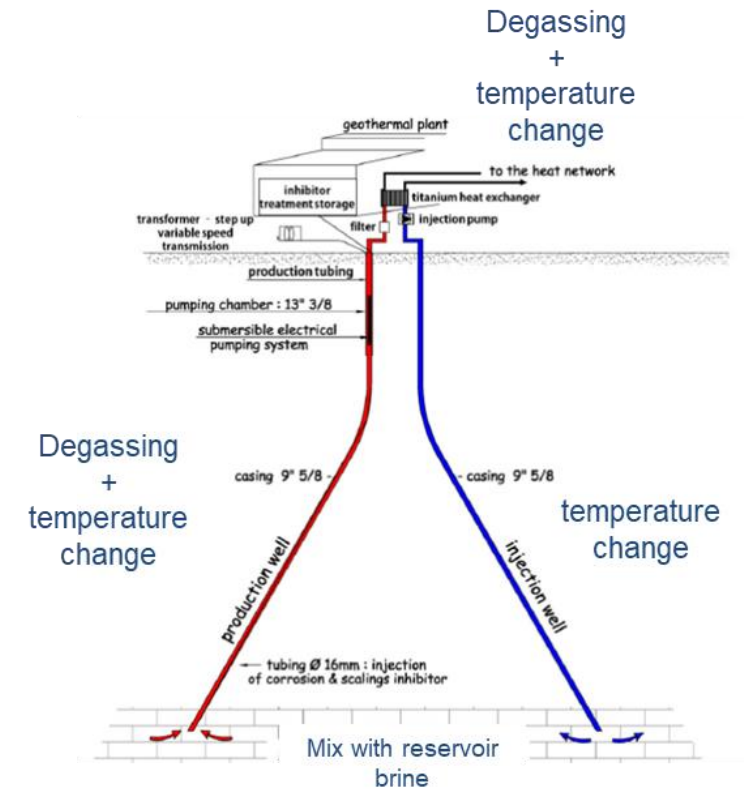
GeoTHERM
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Photo generated by AI

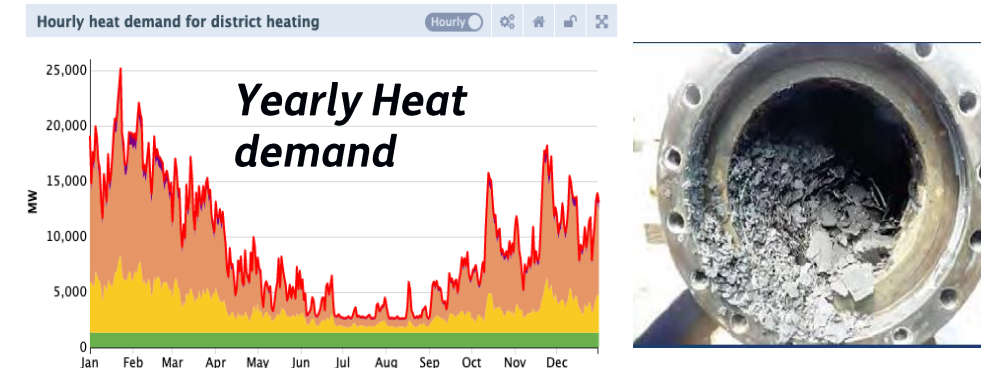


Motivation

- Growth in geothermal assets in NL and worldwide
- Increasingly complex production and operation
 - Responding to heat demand with a minimum environmental footprint
 - Complex operational challenges
 - Planned and unplanned maintenance
 - Learning curve for operators needs to be accelerated
- Need for a centralized, fast, optimum and robust operational decisions employing data in the life cycle of a plant



From Kervevan et al., 2014

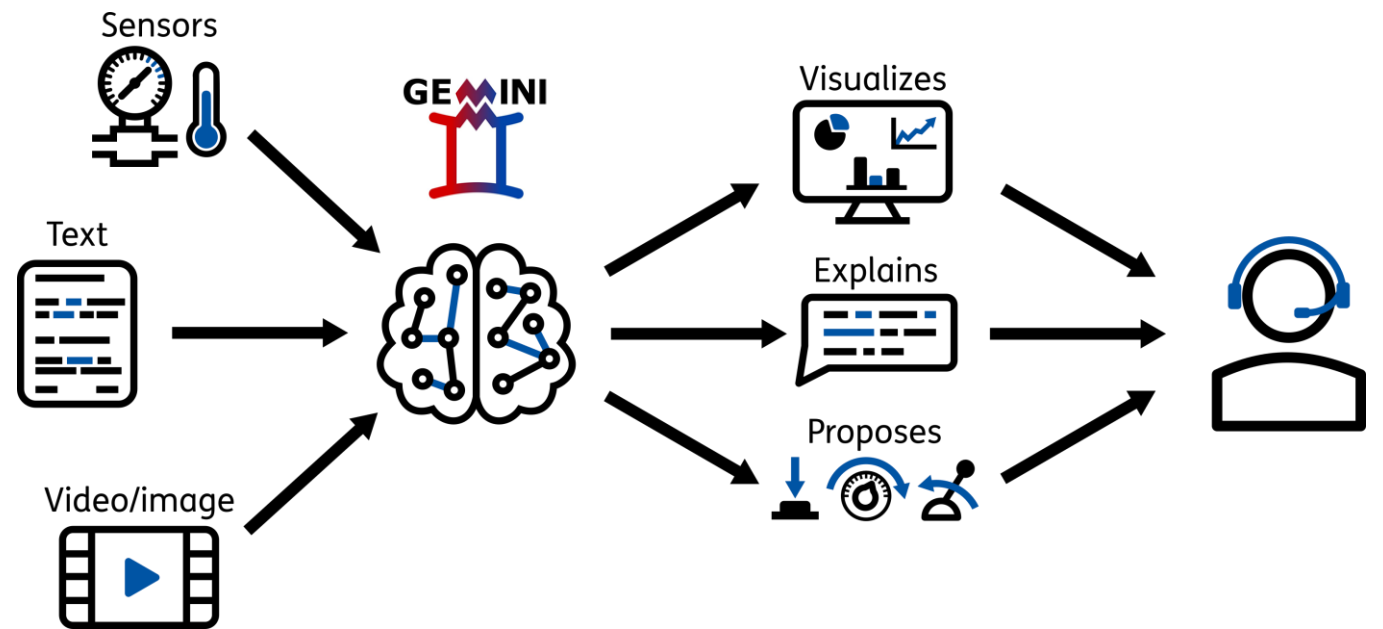


Motivation



Vision: Optimum Operational Decisions

- Towards an intelligent decision support framework
- Increase production efficiency
- Reduce risks and emissions
- Accelerate the learning curve in the sector
- Enabling the knowledge transfer from experienced operators to young operators



Development and Demonstration Projects



- A national growth fund project in the Netherlands to demonstrate GEMINI in geothermal systems and ATES
 - 3 sites, Live demonstrations
 - Monitoring the implementation for > 6 months
 - Full value chain onboard
 - An Open-Access tool to be available in 2025
 - Open-source libraries to be released in 2026



Rijksdienst voor Ondernemend
Nederland

Digital Twin of Geothermal Assets

- A virtual representation that serves as the real-time digital counterpart of a physical object or process (NASA)
- Dynamic processes, dynamic system changing overtime, variable demand, uncertainties in subsurface and surface processes
- Why? Minimize maintenance cost, maximize production, Reduce environmental footprint, ...

Physical object



Static and real-time data

Mechanisms

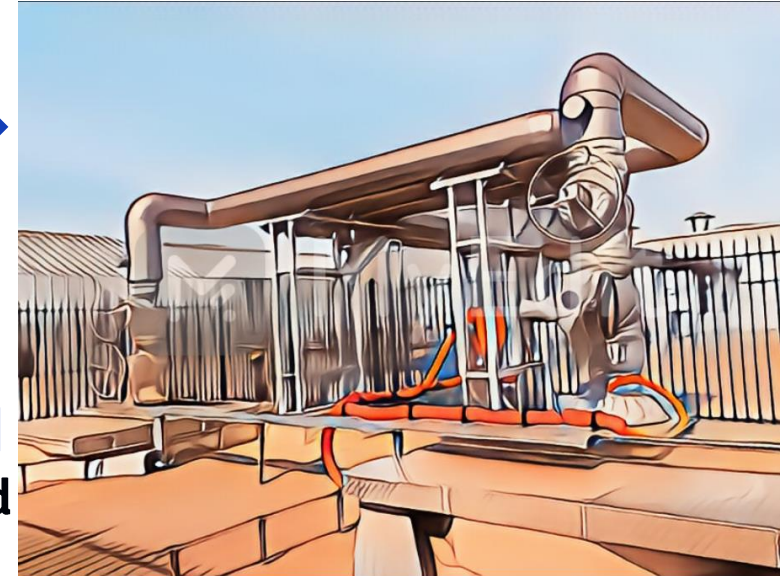


Data exchange



Information, actions and
feedbacks

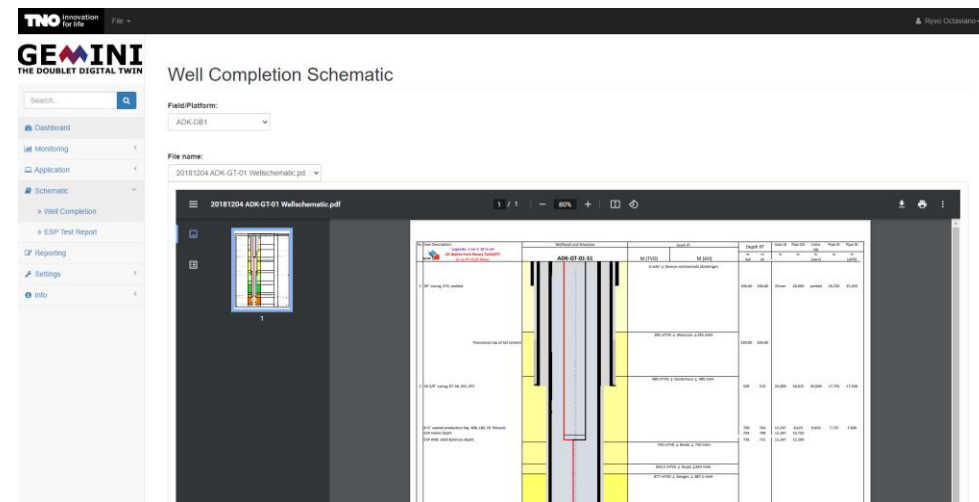
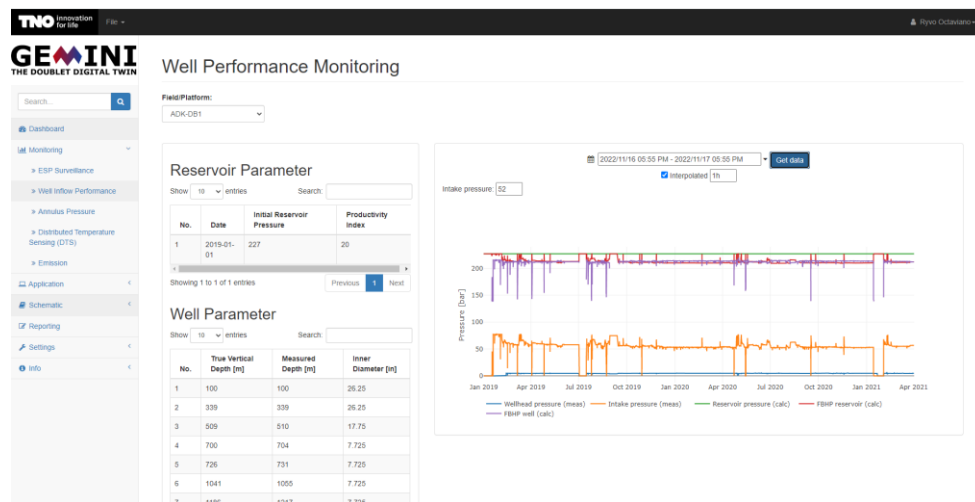
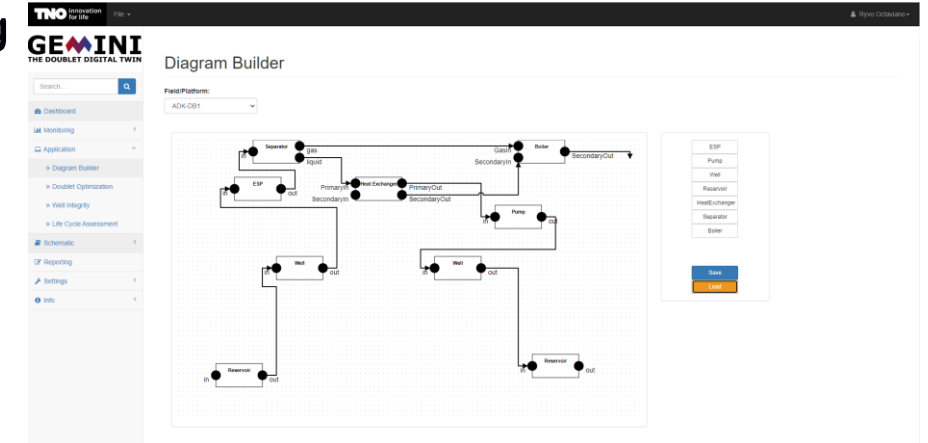
Digital object



GEMINI



- A flexible web-based framework for real-time **monitoring**, **forecasting** and **optimization**
- Act as an assistant to the operators of geothermal and ATEs systems
- Centralized location to access all the (updated) data
 - Performance, integrity and environmental footprint monitoring
 - Critical processes (scaling, erosion, corrosion)
 - Production and operation advisory system



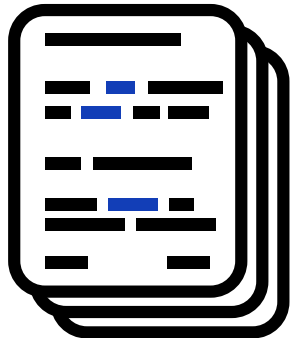
Case studies

- Three sites:
 - Trias Westland
 - HAL
 - GENOVATIVE Storage well at RCSG

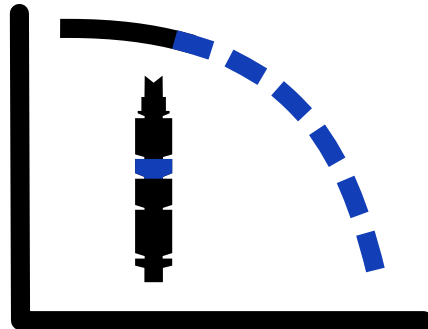


- The functionalities to be developed and demonstrated in the project:

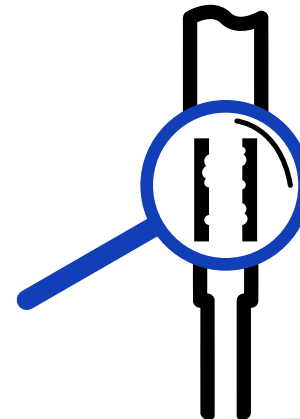
Text data analysis



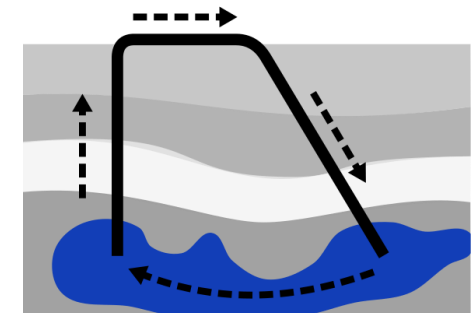
Predictive maintenance



Well integrity management



Subsurface integration

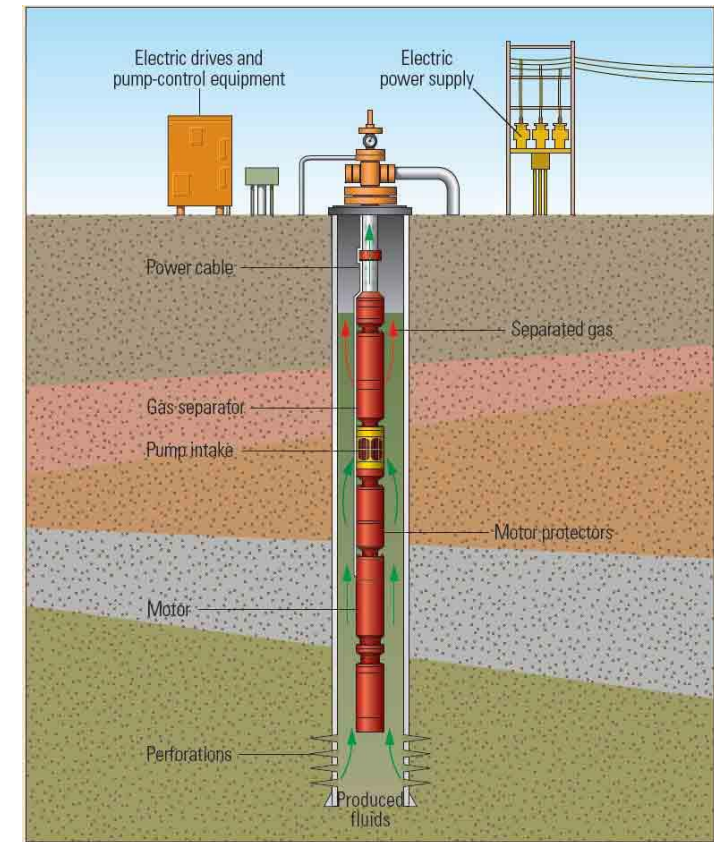


Example: Predictive maintenance

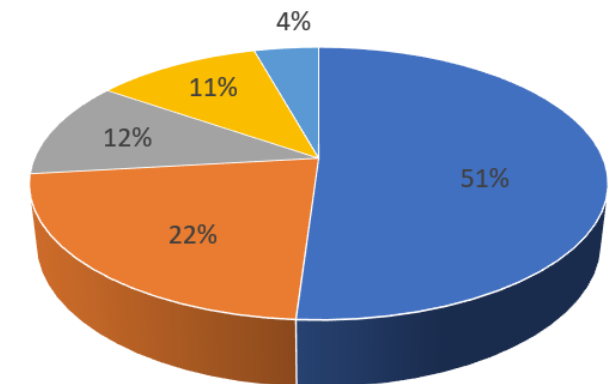
A critical equipment in geothermal assets is ESP;

- Sometimes relatively **short lifetime** (~ 1-2 years)
- ESP operational envelope should accommodate with production variations (P, rates, clogging,...)
- Lack of **proactive monitoring** of system performance during operation
- High **costs** associated with **ESP inspection** and **replacement**

Suboptimum operation of the ESP caused by lack of proper monitoring and operator errors

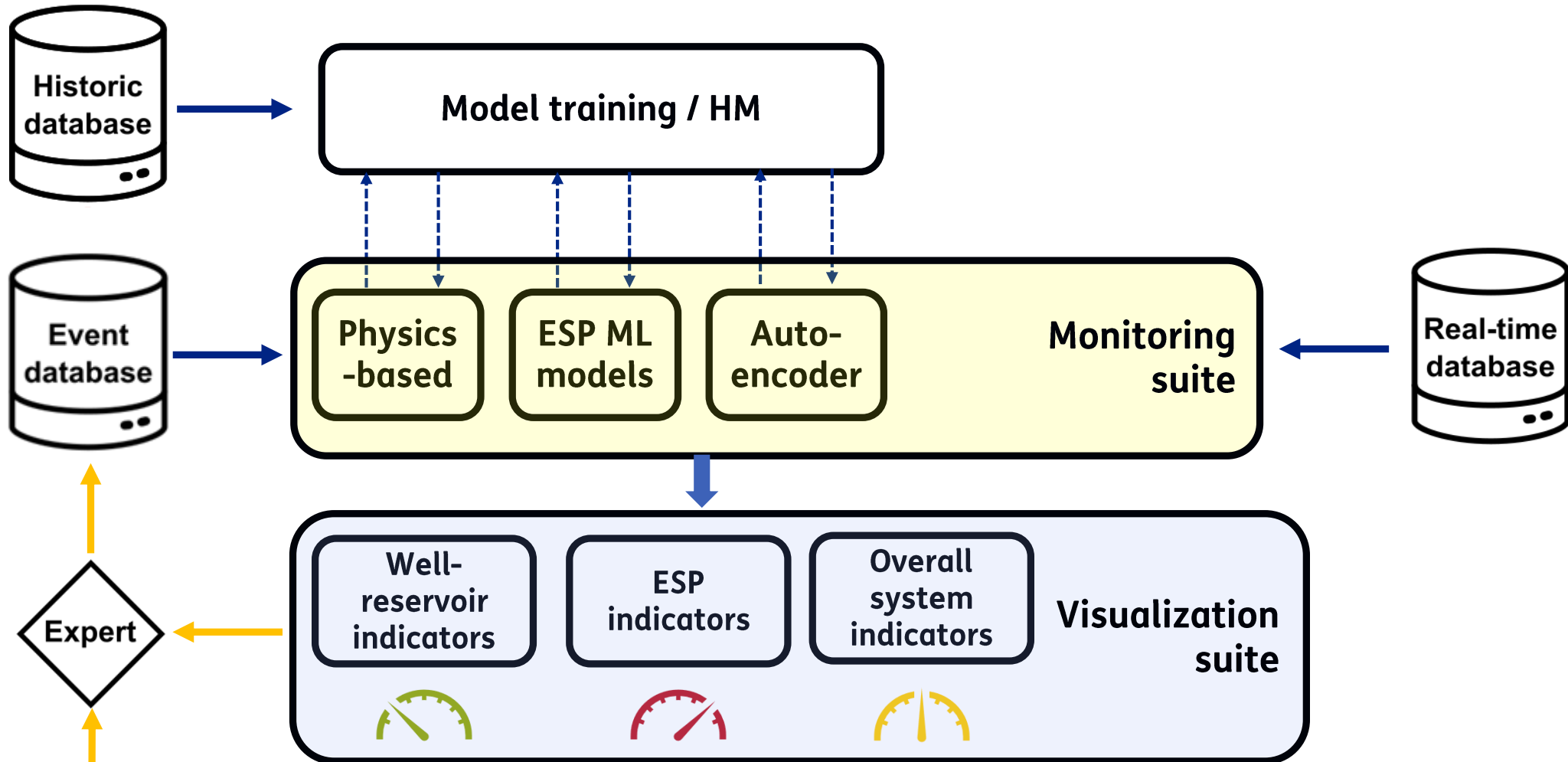


Annual OPEX of each component, operator 1



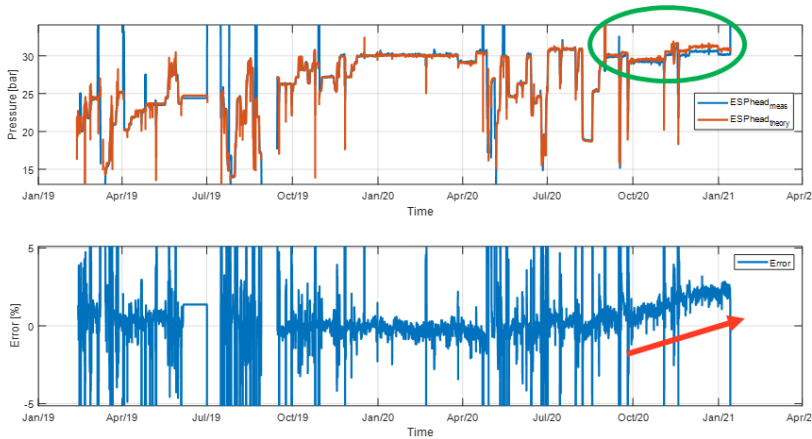
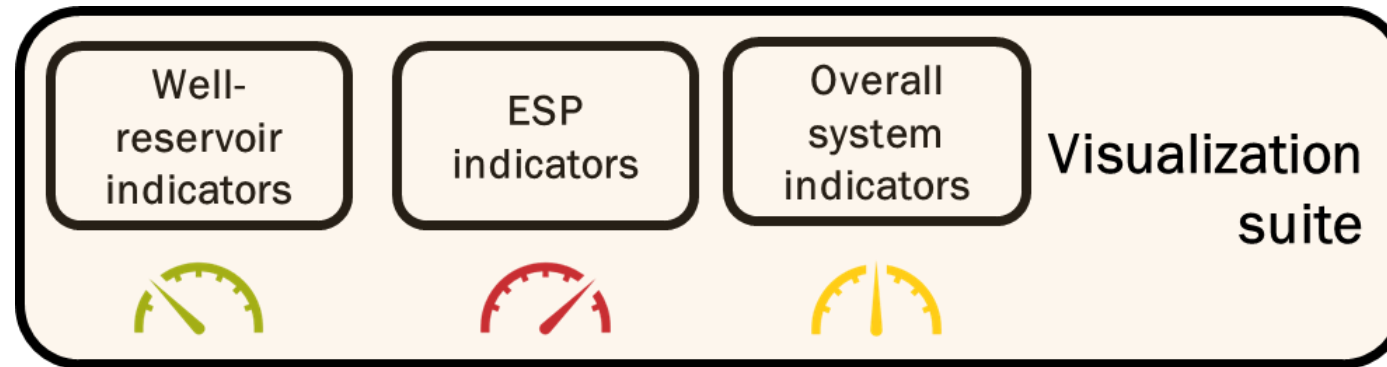
■ ESP: ■ Production well: ■ Surface facilities: ■ Injector well: ■ Filters:

Workflow for Predictive Maintenance

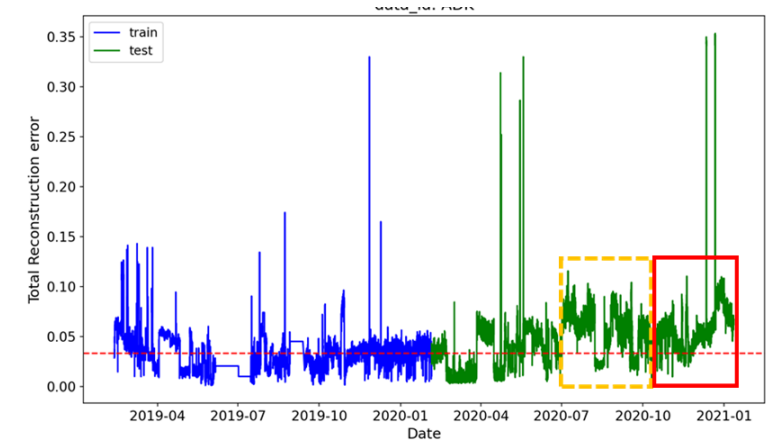
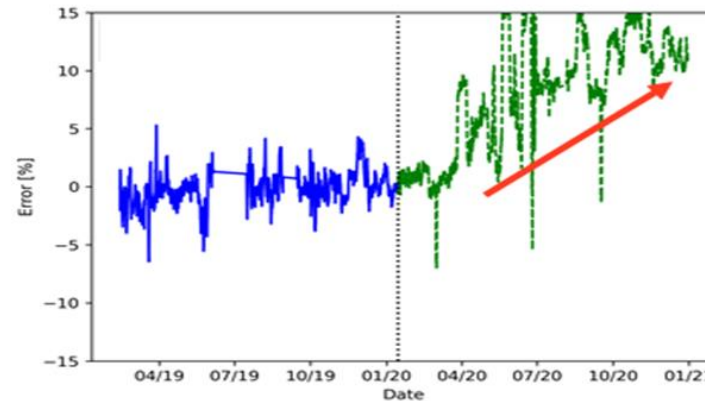


Case	Q	WSP	Ampl	PS	P _{sum}	AW _{sum}	T
1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1
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47	1	1	1	1	1	1	1
48	1	1	1	1	1	1	1
49	1	1	1	1	1	1	1
50	1	1	1	1	1	1	1

Example: Predictive maintenance



ESP vibration



Early signs of degradation visible 6 months prior to the failure.

Virtual Platform - Operation Scenarios Evaluation

- Optimize geothermal operating condition parameters
- Maximizing the following objective functions:
 - Total produced power
 - Minimum power consumption
 - Minimum CO2 emission

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File
Ryvo Octaviano

Doublet Optimization Application

Field/Platform: Select Field

Optimization Variable	Lower Bound	Initial Value	Upper Bound
<input checked="" type="checkbox"/> Wellhead pressure [bar]	<input type="text" value="1"/>	<input type="text" value="5"/>	<input type="text" value="10"/>
<input checked="" type="checkbox"/> ESP Frequency [Hz]	<input type="text" value="30"/>	<input type="text" value="52"/>	<input type="text" value="60"/>
<input checked="" type="checkbox"/> Temp secondary side [C]	<input type="text" value="20"/>	<input type="text" value="41"/>	<input type="text" value="62"/>
<input checked="" type="checkbox"/> Flow secondary side [m3/h]	<input type="text" value="50"/>	<input type="text" value="200"/>	<input type="text" value="400"/>
<input checked="" type="checkbox"/> Gas flow percentage [-]	<input type="text" value="0"/>	<input type="text" value="0.05"/>	<input type="text" value="1"/>
<input checked="" type="checkbox"/> Water flow percentage secondary side [-]	<input type="text" value="0"/>	<input type="text" value="0.9"/>	<input type="text" value="1"/>

Constraints	Lower Bound	Upper Bound
<input checked="" type="checkbox"/> Temperature Output [C]	<input type="text" value="60"/>	<input type="text" value="100"/>
<input checked="" type="checkbox"/> Total Power [kW]	<input type="text" value="1000"/>	<input type="text" value="8000"/>
<input checked="" type="checkbox"/> Electricity Surplus [kW]	<input type="text" value="300"/>	<input type="text" value="1000"/>

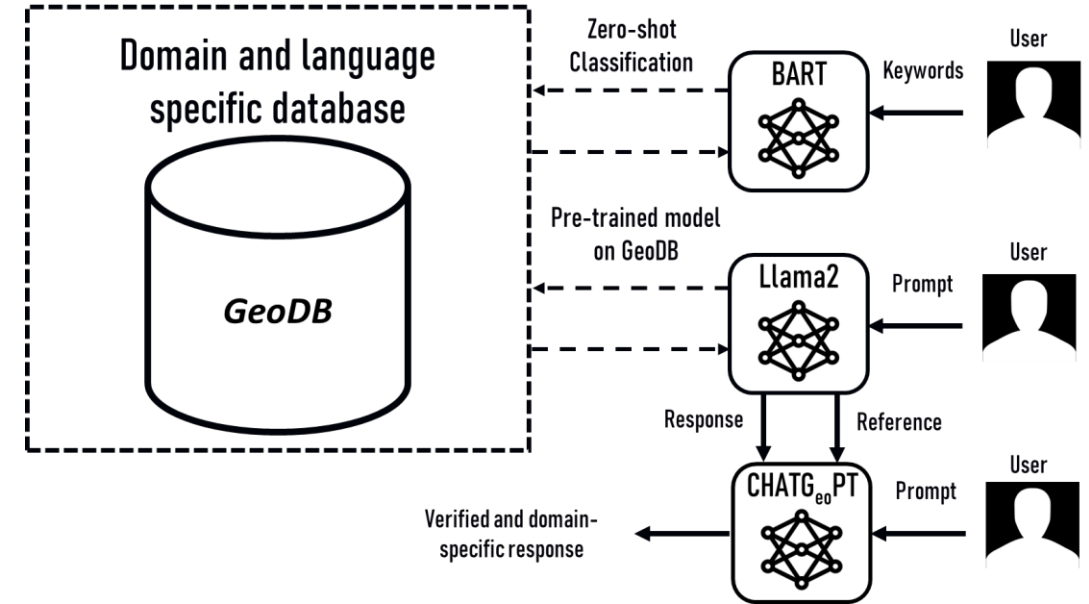
Objective Function:
Maximize total net energy

Optimize

The top chart shows CO2 Emission for Doublet and Total. The Doublet emission is approximately 2.5, and the Total emission is approximately 2.4. The bottom chart shows CO2 Emission for components: ESP (approx. 200), Injection Pump (approx. 500), Boiler (approx. 400), and CHP (approx. 300). The Total emission is approximately 1400.

Faster Access to Documents

- On average 20% of time is spent to search for the correct document
- Shift and maintenance reports
- Tests reports
- Product catalogues and specifications
- The rise in Large Language Model (LLM) can significantly speed up the process
- ChatGeoPT functionality in GEMINI:
 - Connecting to a large publication and article database
 - Connecting to company internal documents
 - Provide references for the provided responses



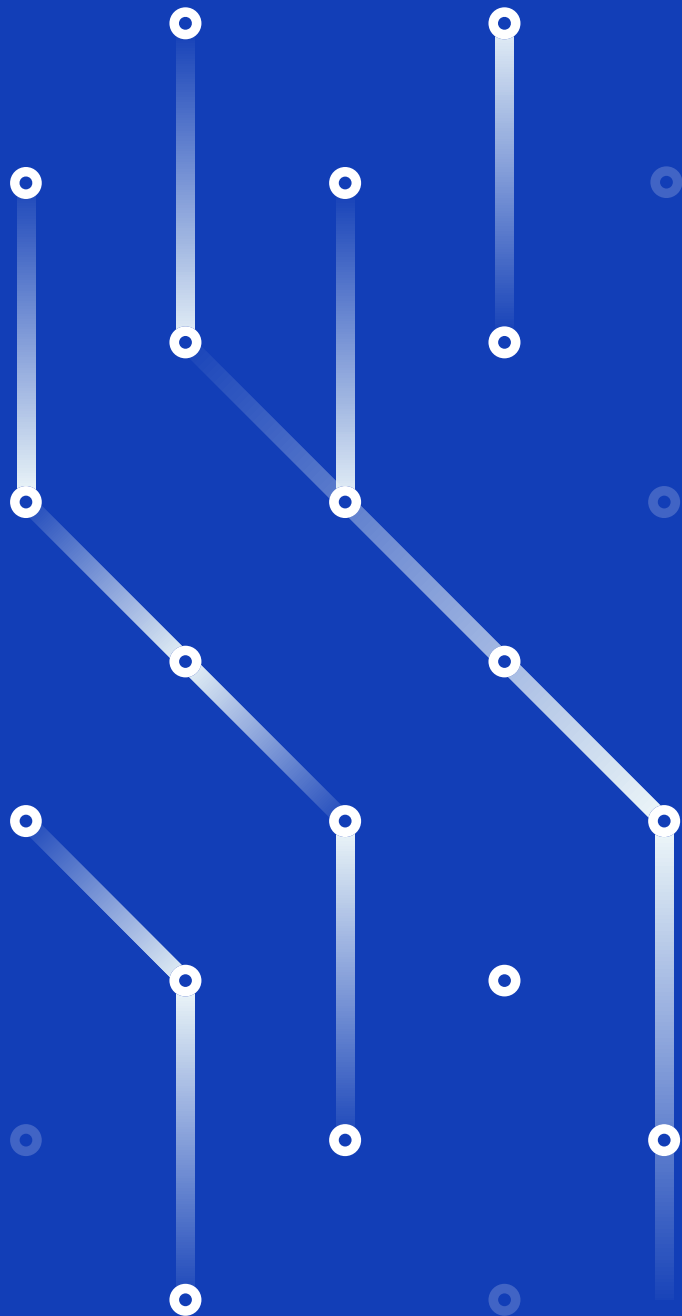
The screenshot shows the GEMINI interface. On the left is a sidebar with navigation options: Search, Dashboard, Monitoring, Application, Schematic, Well Completion, ESP Test Report, Reporting, Settings, and Info. The main content area displays the 'CHAT_{eo}PT' chat window. The title is 'LLM for Geothermal Applications'. There is a 'Show References?' checkbox and a text input field containing the question: 'What are corrosion issues in the Netherlands?'. Below the input field, the chat response is visible, discussing corrosion issues in the Netherlands and mentioning Corodys (France) and Ohio University (USA). To the right of the chat window is a technical diagram of a geothermal system, labeled 'TRIAS WESTLAND'.

Why Open-Source?

Project goals	Why open source?
<ul style="list-style-type: none">• Improvement efficiency, flexibility and safety	<ul style="list-style-type: none">• Efficient tool development for a growing market
<ul style="list-style-type: none">• Efficient & uniform data for<ul style="list-style-type: none">• regulators and other stakeholders• benchmarking and for collective learning• monitoring system performance and emission	<ul style="list-style-type: none">• Common set of public (open source) models for the calculation of key parameters
<ul style="list-style-type: none">• Accelerate sector learning	<ul style="list-style-type: none">• Transparent and trustworthy workflows which are reviewed by the whole community

Summary

- Digital twins can improve the operation of geothermal assets aiming at saving cost, increasing production and reduce downtime.
- A workflow is proposed to be demonstrated and being made open-source for the geothermal assets (direct use, heating).
- Further extension to power systems is possible.
- You can already be part of the community.



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