Digital Twin of Geothermal Assets
An Open-Source Approach for the Geothermal Sector

P. Shoeibi Omrani[1,2], R. Octaviano[1], J. Poort[1], D. Palochis[1], H. Dashtaki Hesari[1]

1 Heat Transfer and Fluid Dynamics, TNO, The Netherlands
2 Environmental Technology, Wageningen University and Research

Email: pejman.shoeibiomrani@tno.nl

DRAFT

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
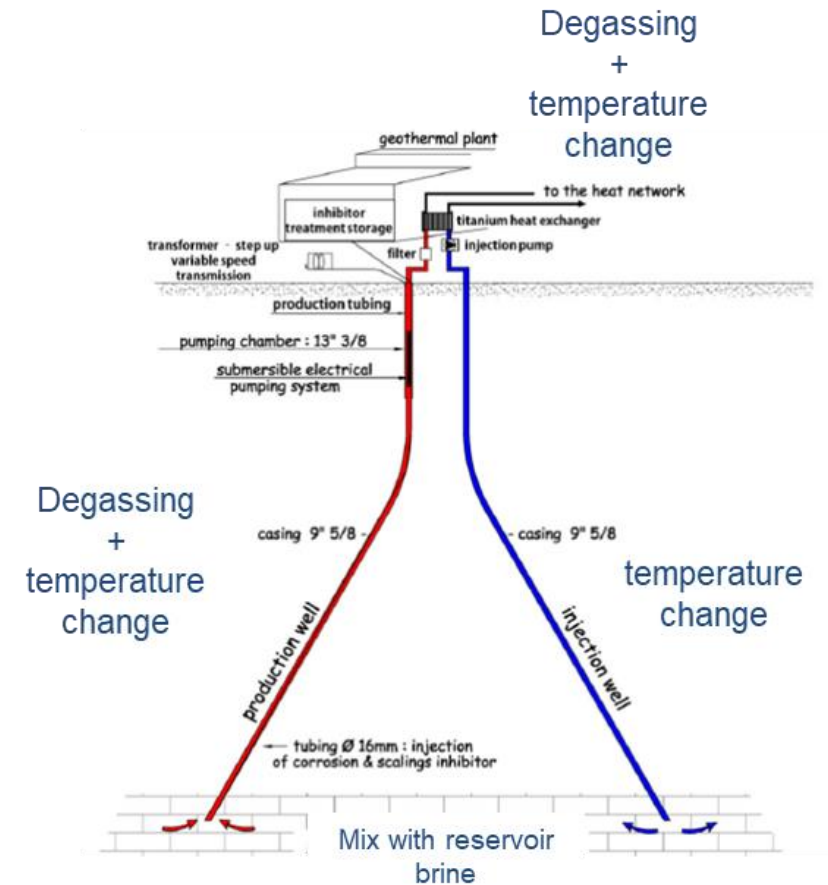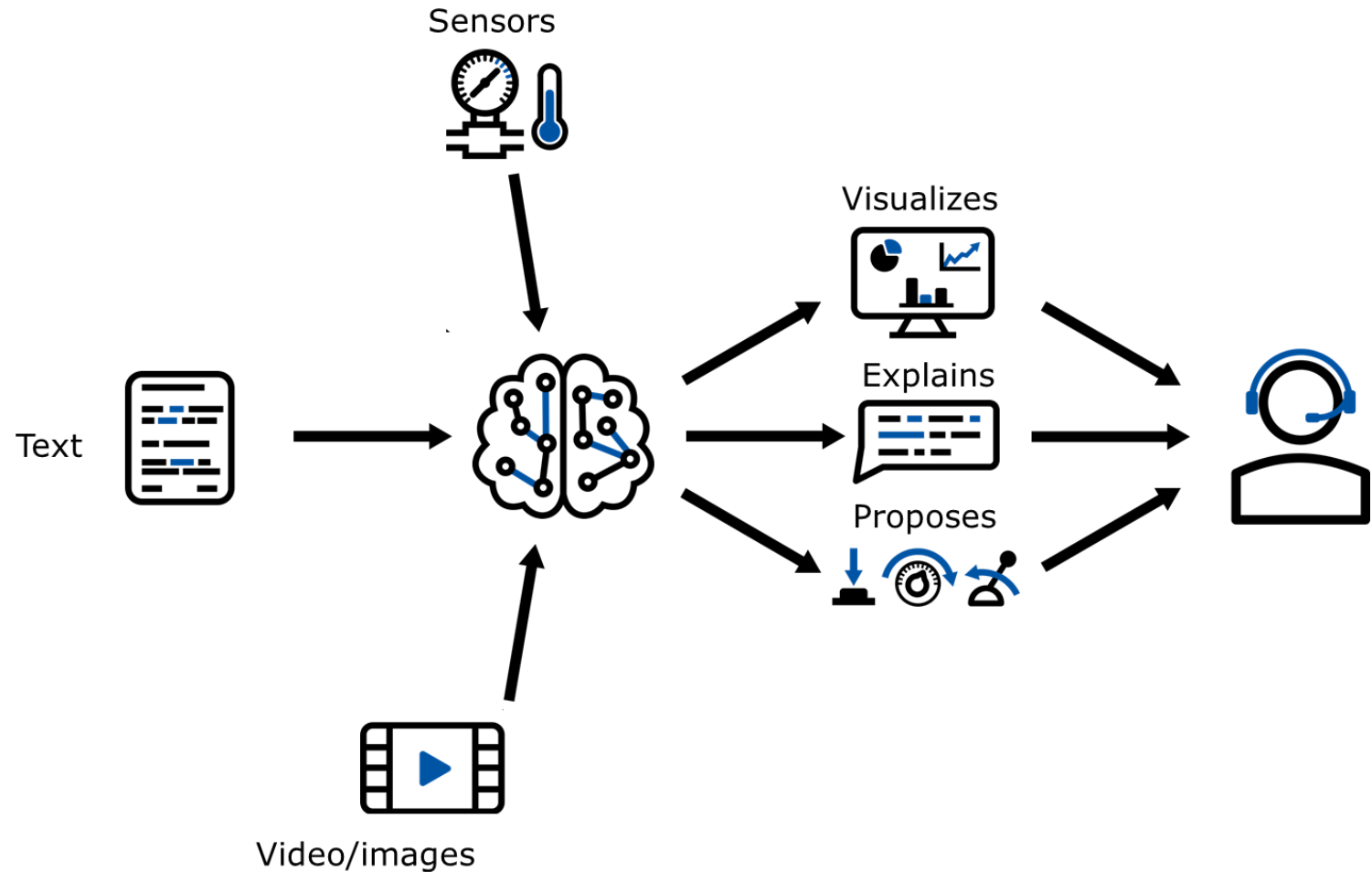

From Kervevan et al., 2014

Yearly Heat demand
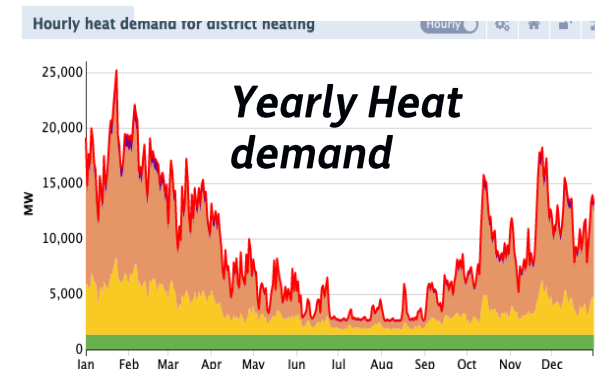
Vision: Optimum Operational Decisions

- 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

TNO innovation for life

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

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
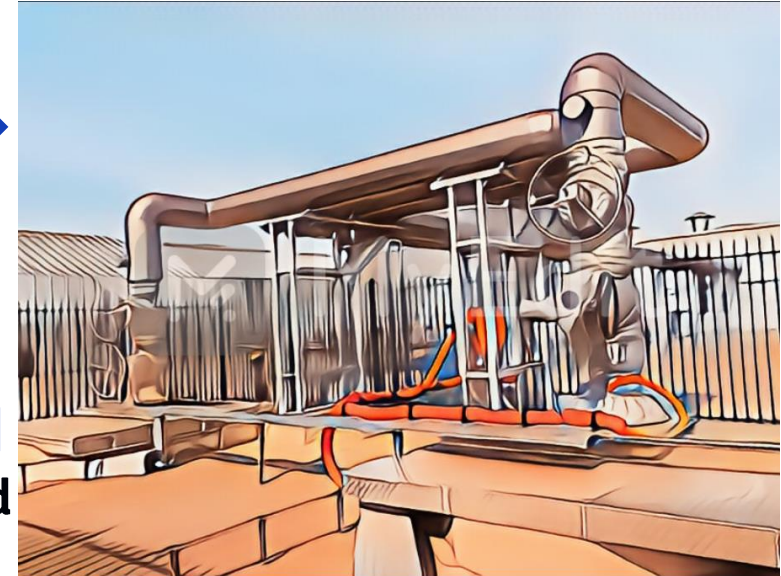
GEMINI

- 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
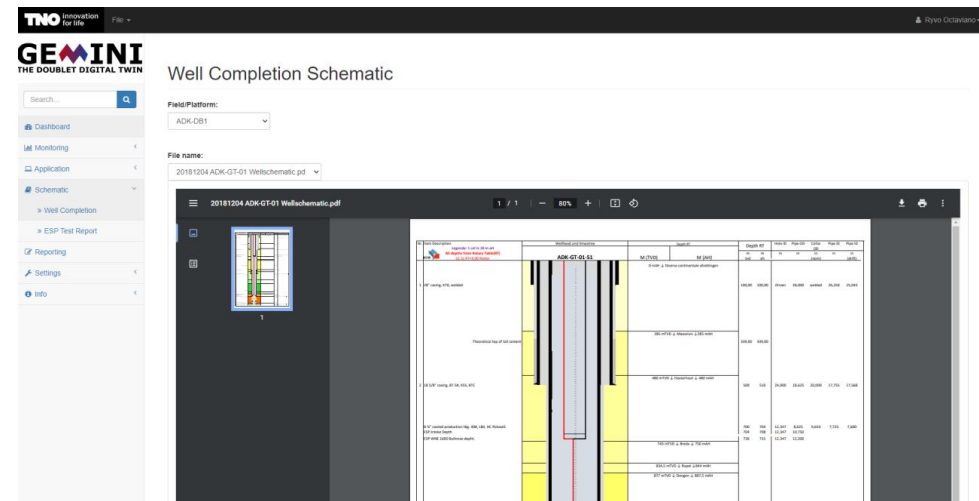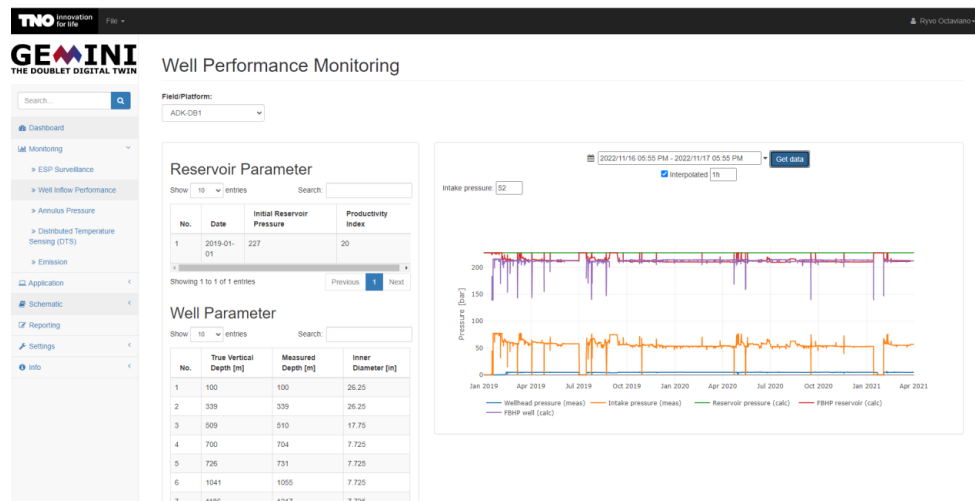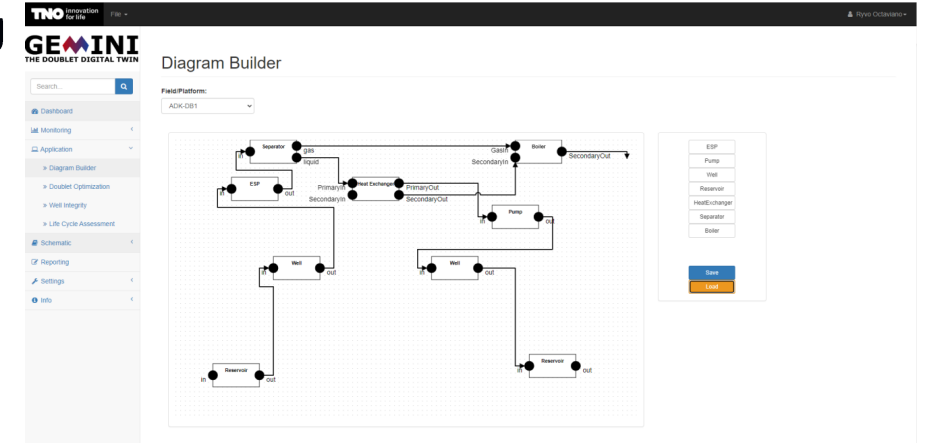
Digital Twin Key Components
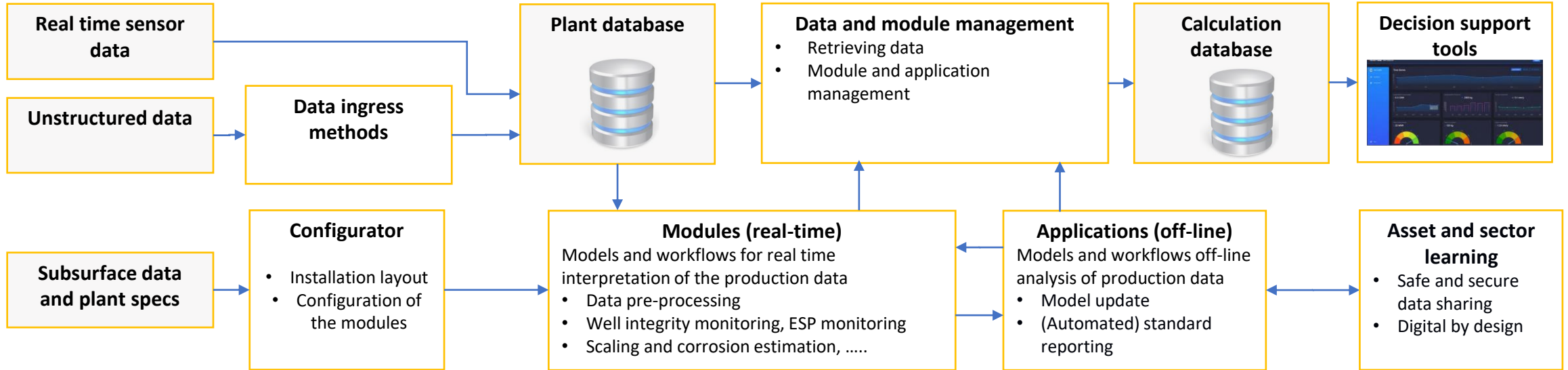
Key component	Functions
Data management system	Data retrieval, preprocessing, module management
Configurator	Plant lay out, configuration of the modules
Modules	Models and workflows for real time interpretation of the production data
Applications	Models and workflows off-line analysis of production data
Real time decision support tools	Modules for real time decision support, event detection, automated alarms , control, real time production advice.
GUI	User interface
Asset and sector learning	
Data ingress system	API production database, methods for ingress of intermittent and static data

GEMINI Architecture
Towards an Open-Source Implementation

An Impression of GEMINI
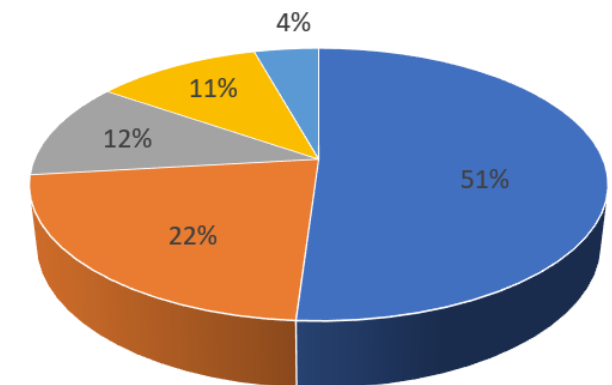
Example: Predictive maintenance

The current geothermal ESPs have several shortcomings;

- Relatively **short lifetime** (~ 1-2 years)

- Available ESP designs are optimized for oil wells (sub-optimum for geothermal conditions) leading to **frequent failures**

- ESP operational envelope should accommodate with production variations (P, rates, clogging,...)

- Lack of **proactive monitoring** of system performance during the operation

- High **costs** associated with **ESP inspection** and **replacement**

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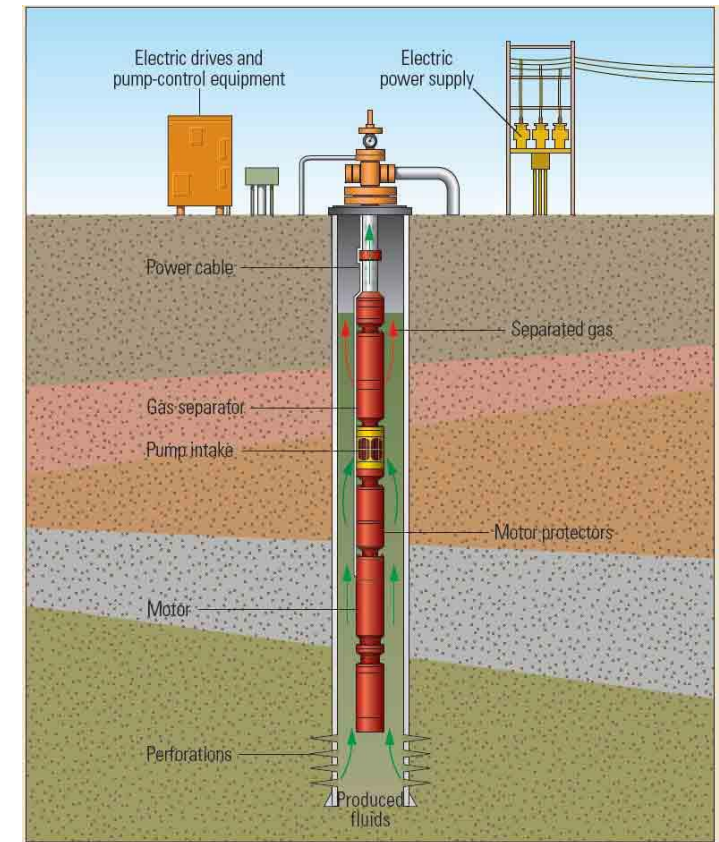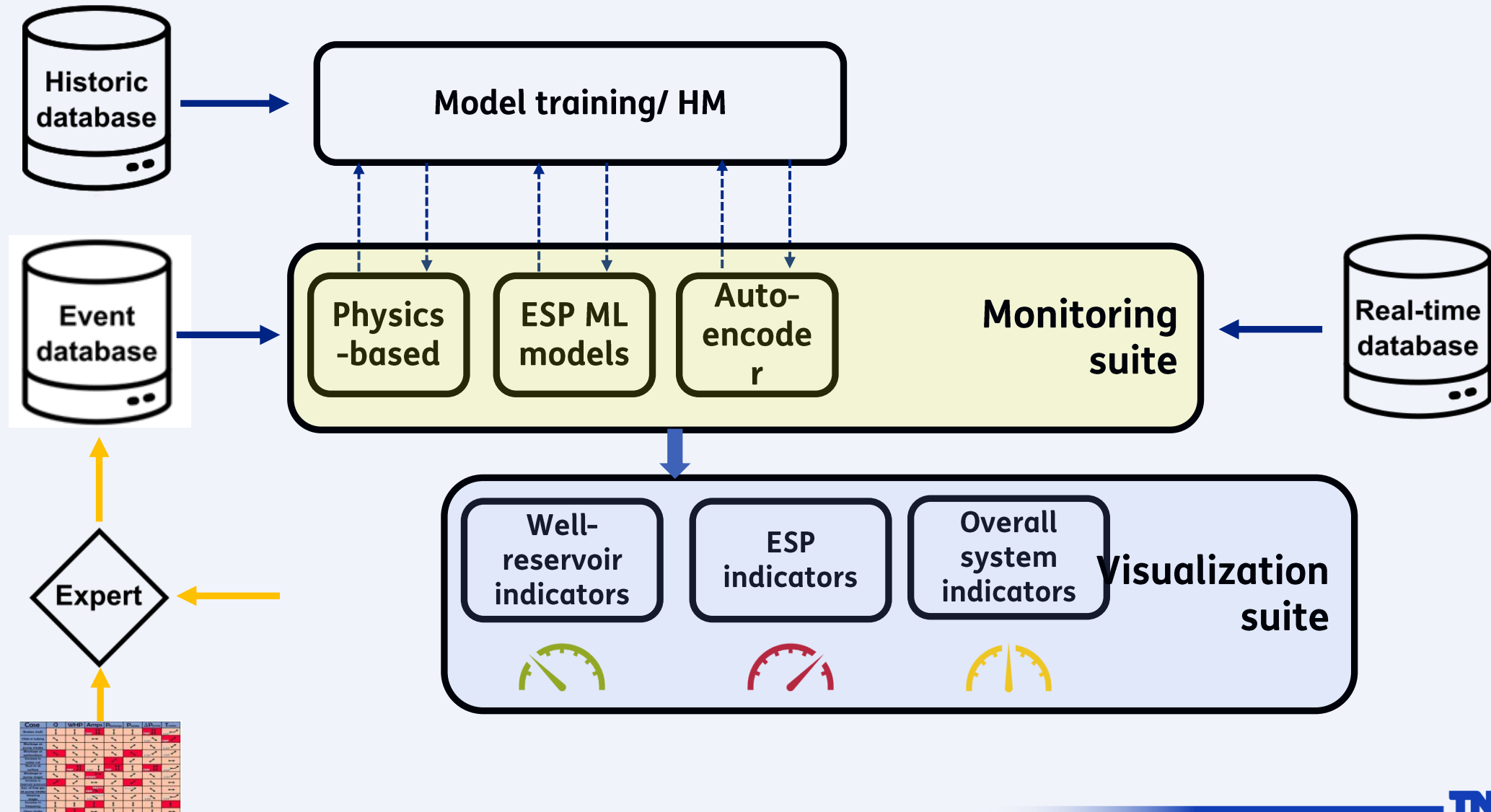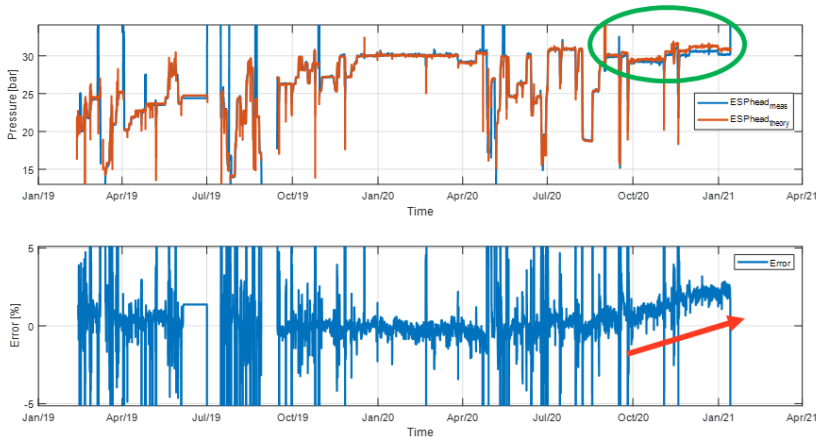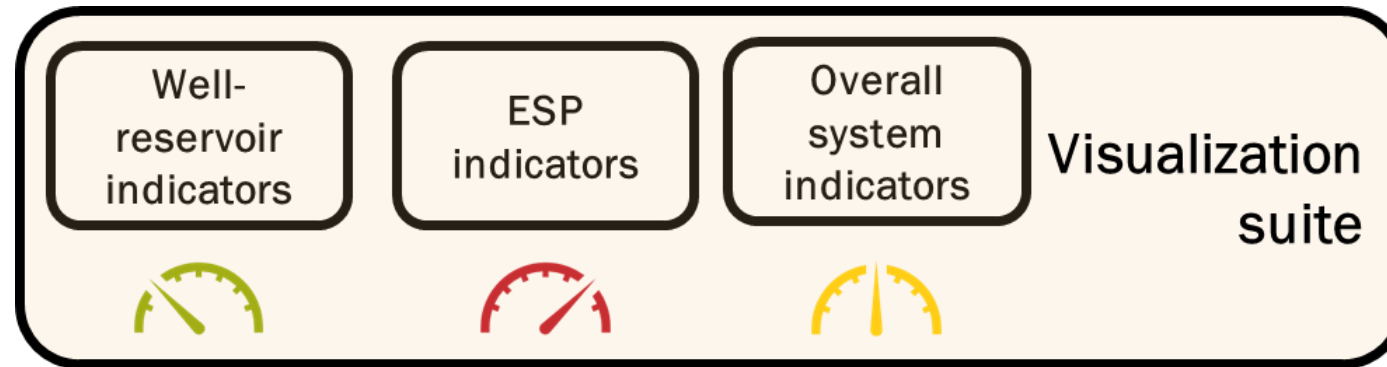

Annual OPEX of each component, operator 1

4%
11%
12%
51%
22%

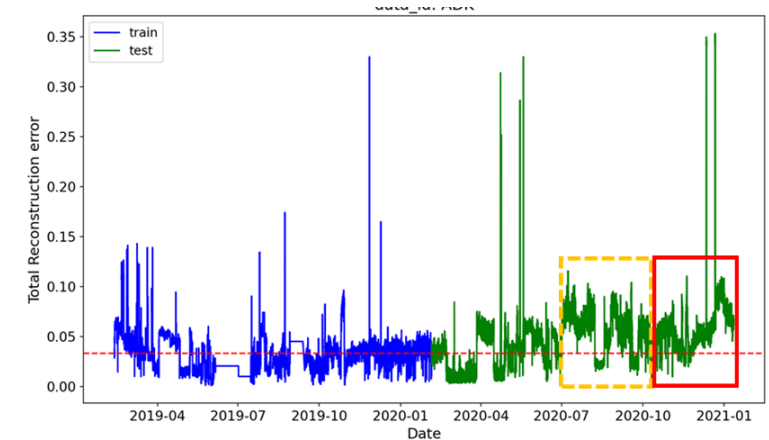■ ESP: ■ Production well: ■ Surface facilities: ■ Injector well: ■ Filters:

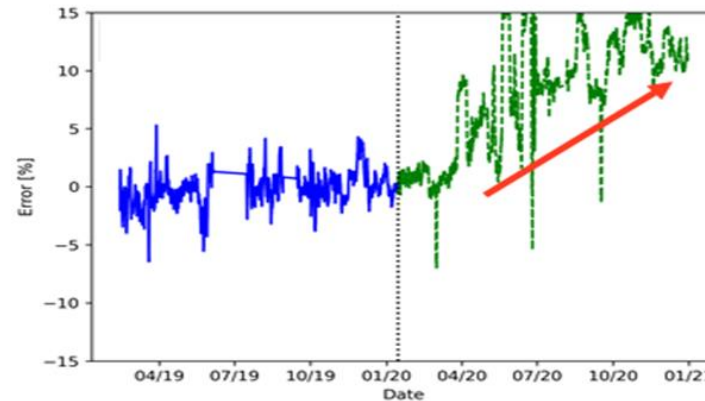# Workflow for Predictive Maintenance

Example: Predictive maintenance

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

Operation Scenarios Evaluation

- Optimize geothermal operating condition parameters

- Maximizing based objective functions:

  - Total produced power

  - Minimum power consumption

  - Minimum CO2 emission
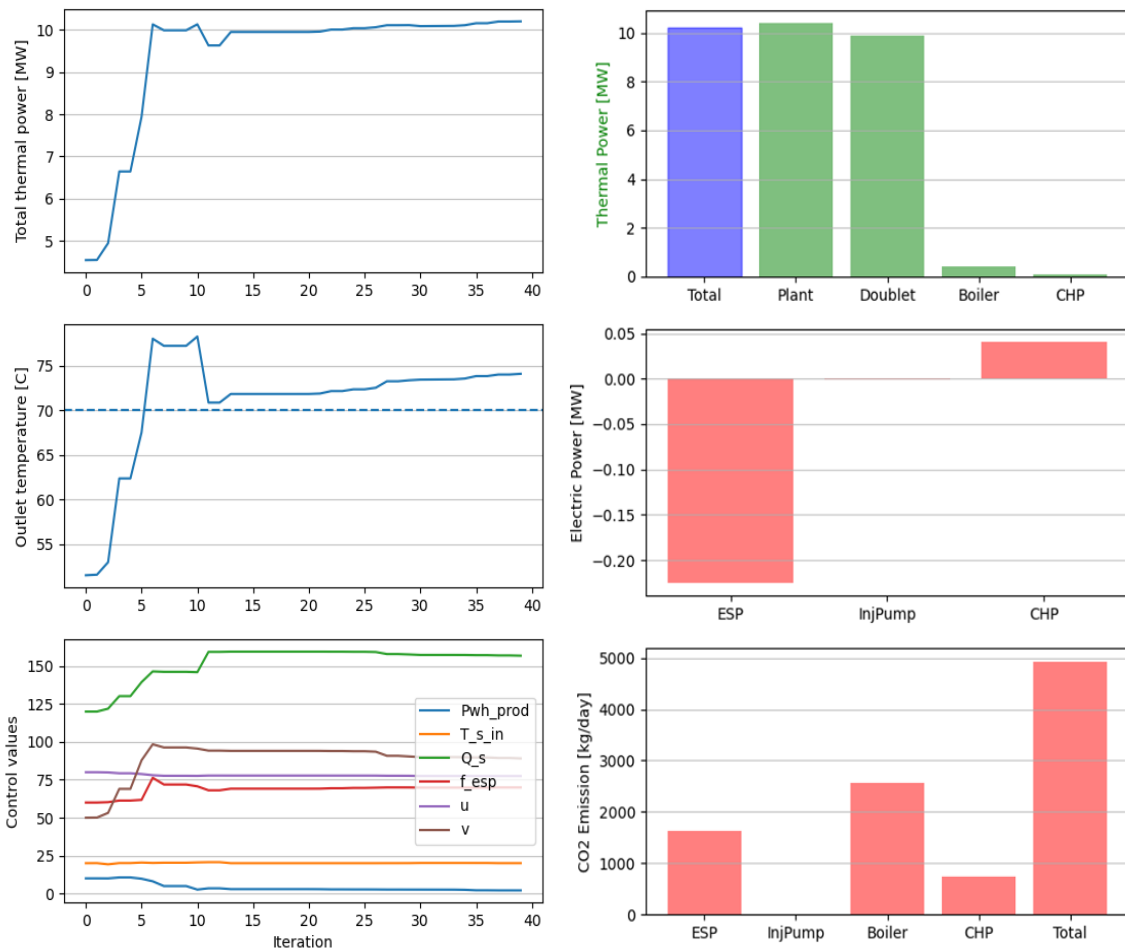
Operation Scenarios Evaluation
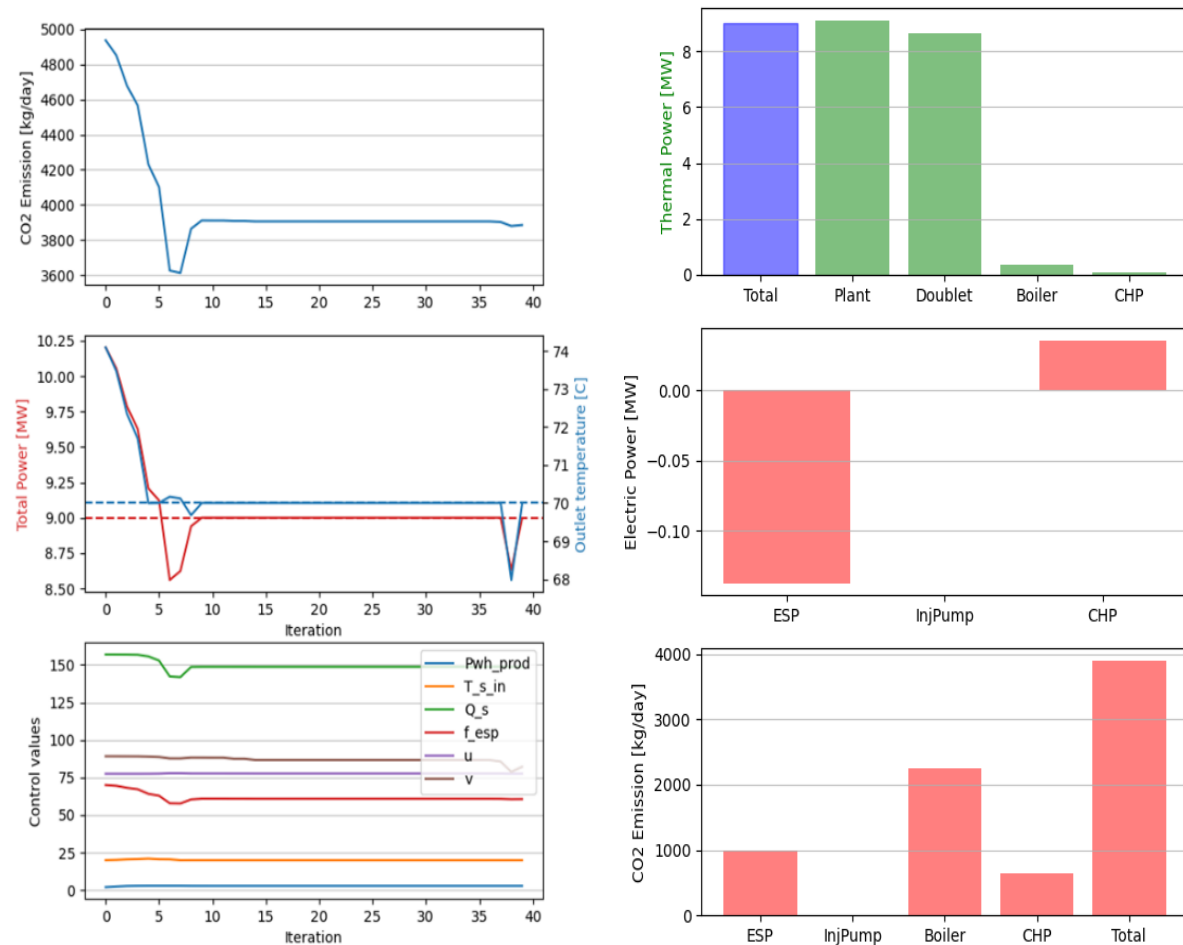
The emission reduction ~ 12% (from 5.7 kg CO_2/GJ to 5.0 kg CO_2/GJ)

Increase in Levelized Cost of Heat (LCoH) ~ 11.8%

Towards Sector Learning

- Added value for sector learning through standardizing the digital twin of geothermal assets

- No need to share data, but share the learnings

- Decentralized methods to be deployed on top of digital twin technologies to develop global models of processes, components and equipment

  - Uses local information to build global knowledge, without the need to disclose data
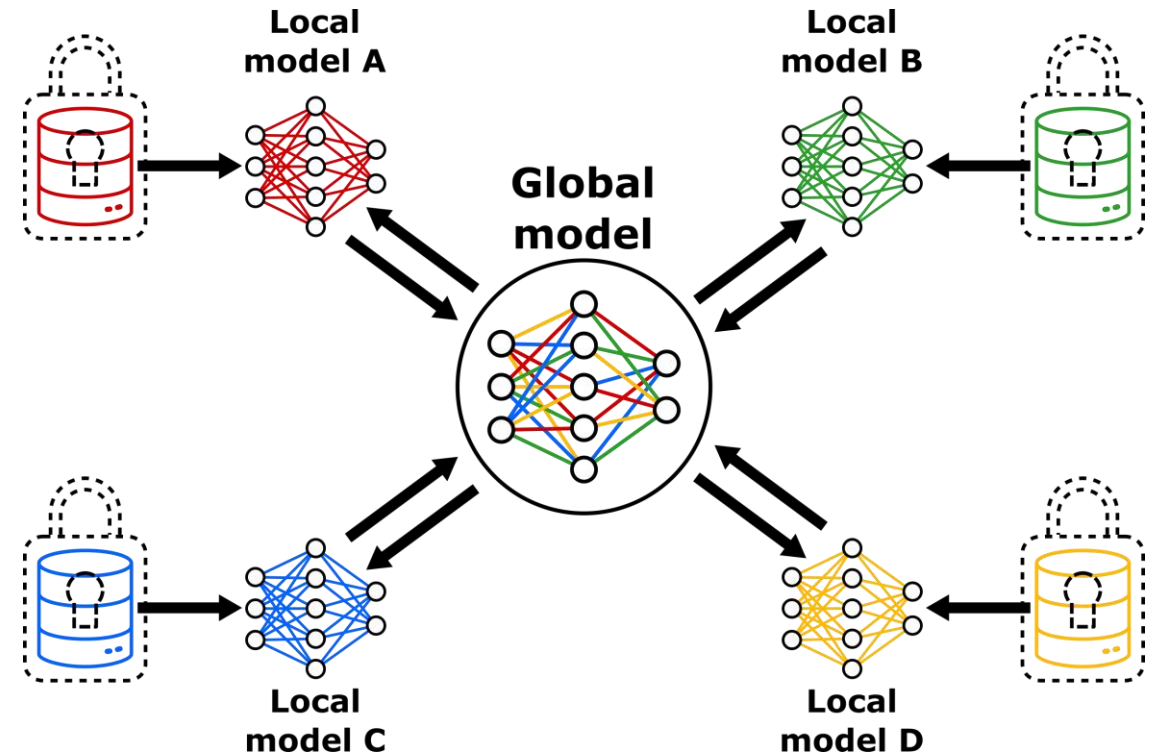
  - Enables learning a single model across multiple distributed devices using local data samples

Local model A

Local model B

Global model

Local model C

Local model D

Summary and Next Steps

- Digital twin 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)

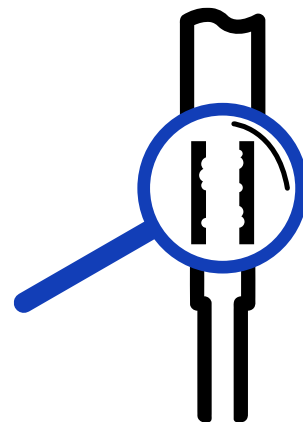- We plan to extend/develop GEMINI's functionalities in the following areas:
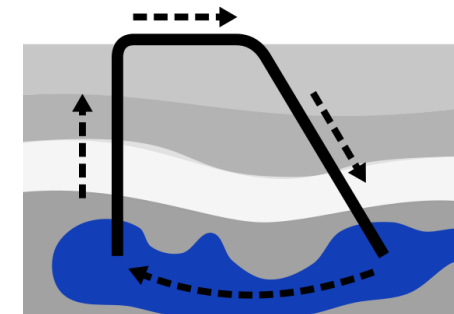
Text data analysis

Predictive maintenance
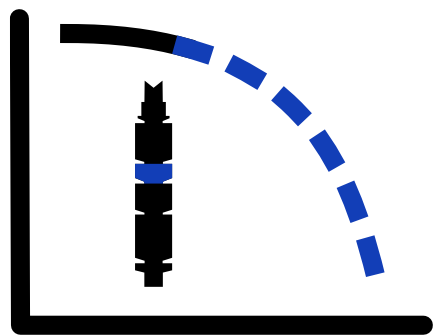
Well integrity management

Subsurface integration

TNO innovation for life