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Low-Enthalpy Geothermal Heating Systems Modeling: Reducing Risks for Decision Makers and Consumers

GEOOP

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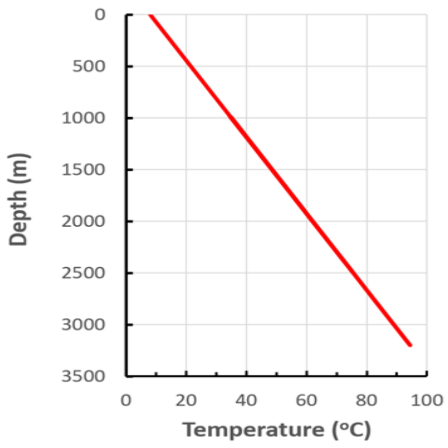
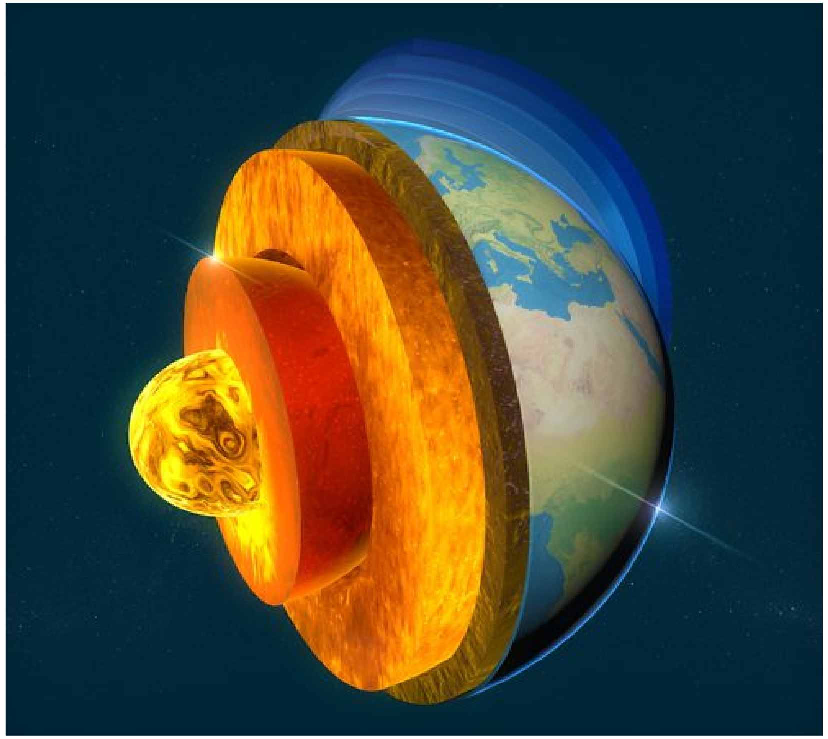
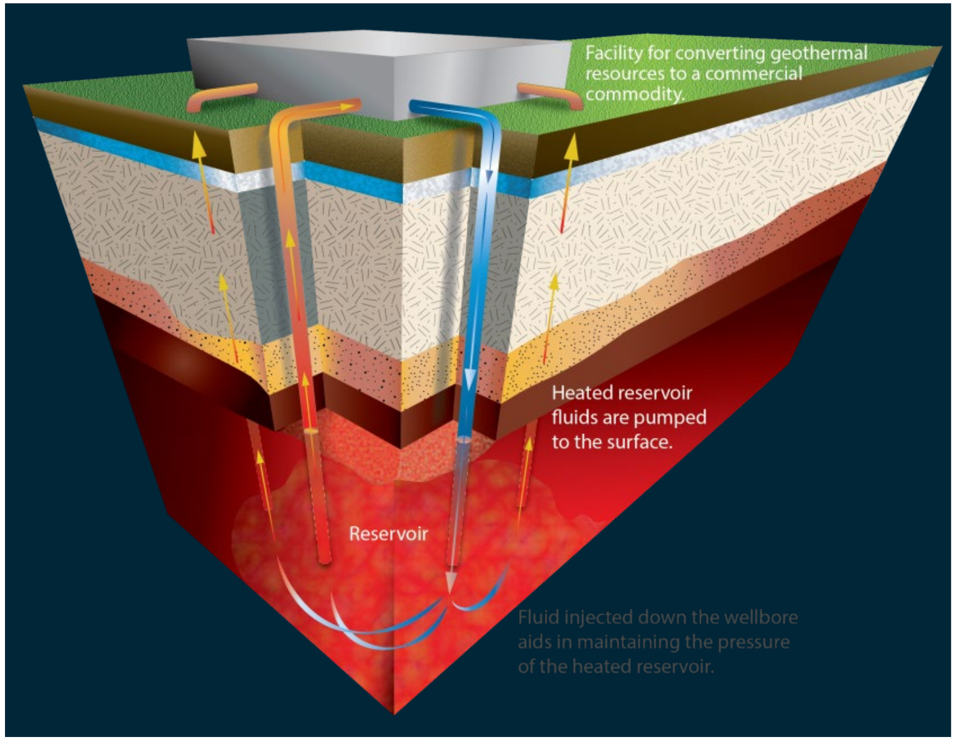
Geothermal Energy

- Geothermal energy is the heat generated and stored in the Earth.
- The energy originates from the original formation of the planet and from radioactive decay of materials
- It is considered renewable as there is a constant terrestrial heat flow
- The geothermal gradient drives a continuous conduction of thermal energy in the form of heat from the core to the surface





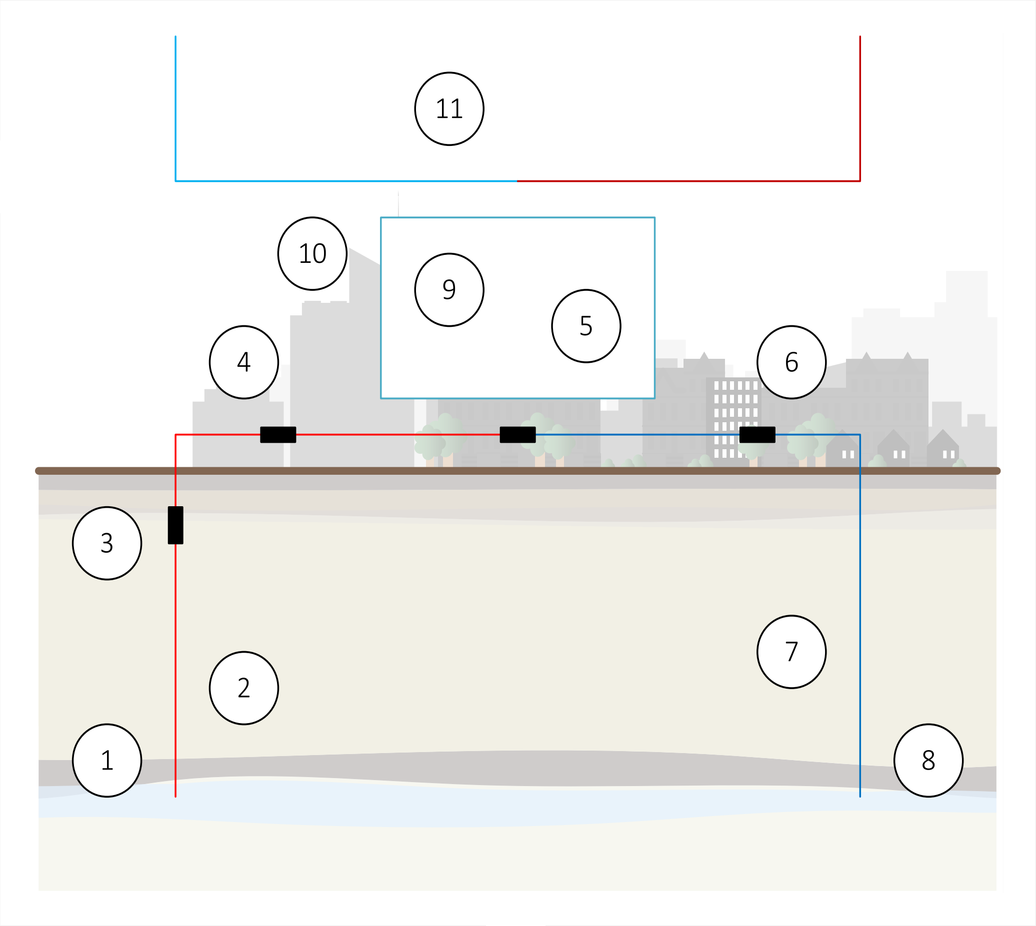


Geothermal District Heating

- Through the extraction of hot water from the subsurface, heating power can be produced and transmitted to district heating networks
- Each geothermal reservoir is unique
- There is a pressing need to accelerate the development of advanced technologies to provide clean energy

Low Enthalpy Geothermal District Heating Plant

1. Producer, lower completion
2. Producer (well bore)
3. Production Electrical Submersible Pump (pESP)
4. Filtration
5. Heat Exchangers
6. Injection Pump (iP)
7. Injector (well bore)
8. Injector, Lower completion
9. Heat Pump
10. Auxiliary systems
11. Heating loop (distribution)



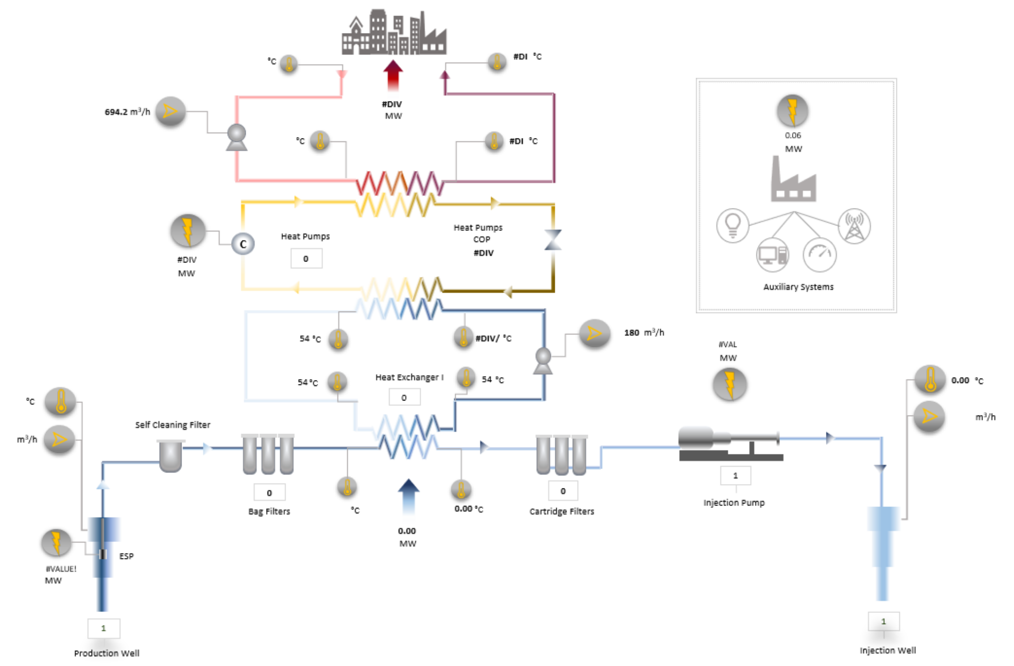
Geothermal Industry Development Barriers

- Geological Uncertainties
- Regulatory Environment
- Government Incentives
- Financing
- Energy Production and Cost prediction

Geothermal BuSiness CALculAtor - SCALA

SCALA is an Excel® calculator tool developed to reduce the risks of the decision-making process of low enthalpy geothermal projects, by generating:

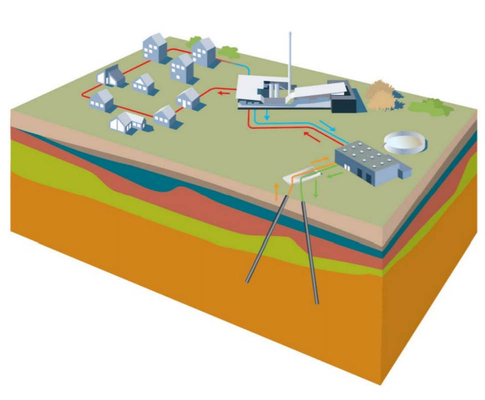
- Basic assessment of the facilities
- Energy production forecast
- Detailed CAPEX/OPEX cost estimate

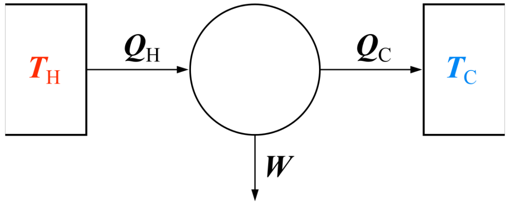


The Model

The model is build based on some main assumptions:

- Closed loop system with standard facilities configuration
- Operations and facilities costs calculated based on suppliers quotes and GEOOP expertise (Danish market prices)
- Energy production calculation using simplified heat transfer formulas





$$Q = \int_{T_i}^{T_f} m c_p \, dT = m c_p \Delta T$$

Workflow

1 - Inputs

The main inputs that should be provided to the model when generating a new scenario are:

- Reservoir/District Heating temperatures and flowrates
- Number of production and injection wells
- Expected equipment´s efficiency
- Operational hours per year and contract period
- Basic financial inputs such as: electricity cost, financing rates, well costs, FEED and desired heat selling price

Process Input Parameters

Production temperature (˚C)	56
Production/Injection flowrate (m^3/h)	180
Injection temperature (˚C)	17
District heating low temperature (˚C)	56
Desired heating high temperature (˚C)	75
Heat exchangers effectiveness	0.85

Flowrate at production heat exchanger loop (˚C)	180
Temperature at production heat exchanger loop (˚C)	54

Number of production Wells	1
Number of production pumps	1
Number of injection Wells	1
Number of injection Pumps	1

Operational hours per year	5500
Number of Years	30

Clean

Adjust Flowrate

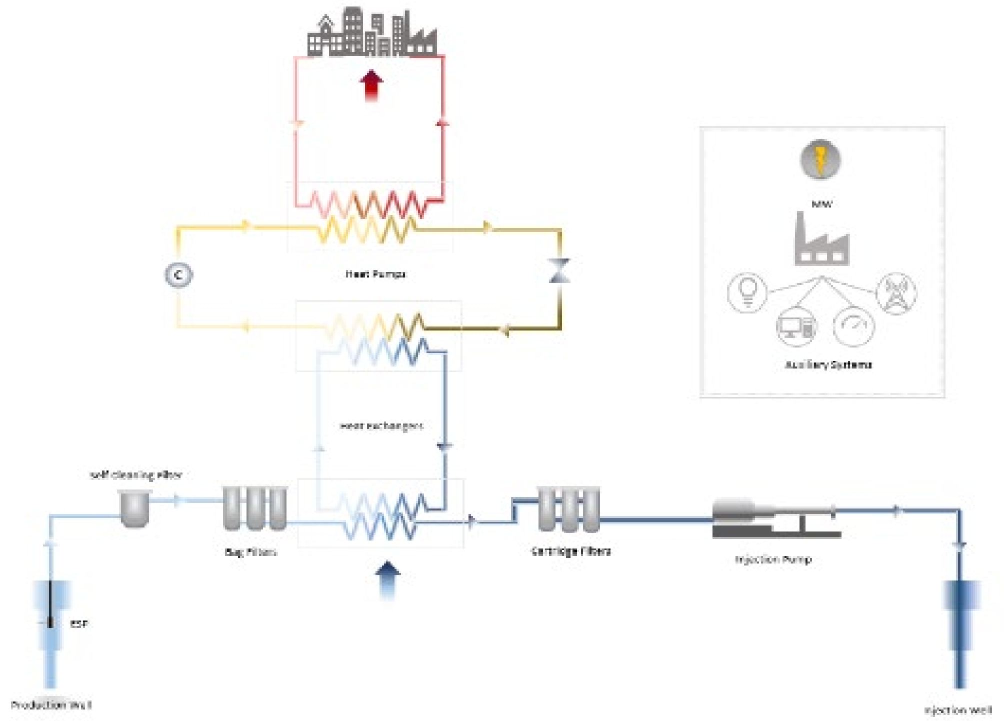
Economics Inputs

Electricity Cost (DKK/KWh)	0.389
Financing - Interest Rate	0.05
Well Cost (DKK)	13000000
FEED (DKK)	10000000
Heat Price (DKK/MWh)	400

2 - Facilities Assessment and Heat Production Calculation

Based on the basic inputs the model sizes equipment and facilities:

- Number of filter units
- Heat exchangers configuration
- ESP, Heat Pump and Injection Pump sizing and energy consumption
- Auxiliary system structure



3- Outputs

The main outputs generated by the model are:

- Thermal energy production
- Energy consumption
- System´s COP
- Equipment sizing
- Deterministic OPEX and CAPEX costs

Process Outputs

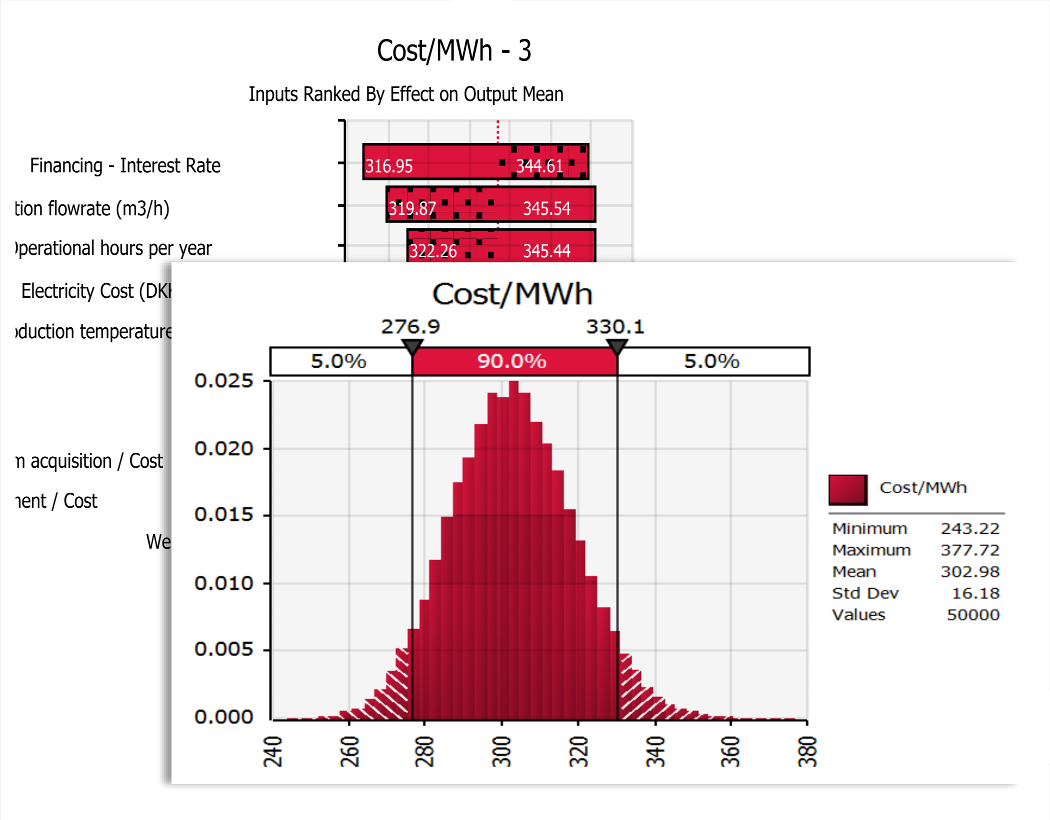
Heat pump COP	5.40
District heating flowrate (m^3/h)	433.2
Total heat extracted from produced water (MW)	7.66
Heat produced on Heat Exchanger (MW)	0.00
Heat delivered by HP (MW)	9.40
Total energy Delivered (MW)	**9.40**
Energy consumed by heat pump (MW)	1.74
Injection temperature (˚C)	17.00
Final district heating high temperature (˚C)	75.00
System COP	5.40

Plant Design

Number of heat pumps	6
Number of bag filters	8
Number of cartridge filters	6
Number of self cleaning filters	1
Number of heat exchangers units	3
Number of process pumps (internal loops)	2

Annual Operational Cost

Producer Lower Completion	DKK	1,431,995.2
Producer (wellbore)	DKK	372,948.2
Production Electrical Submersible Pump (pESP)	DKK	1,371,598.7
Filtration	DKK	58,468.0
Heat exchanger	DKK	130,000.0
Injection Pump (iP)	DKK	922,920.0
Injector (wellbore)	DKK	348,711.9
Injector Lower Completion	DKK	1,372,672.1
Heat Pump	DKK	4,426,512.7
Auxiliary systems	DKK	926,518.7
Heating Loop (distribuition)	DKK	-
Financing		
Total Annual OPEX	DKK	11,362,345.5
Input temperature on heat exchanger 1		16.7459854



4 - Probabilistic Analysis

After the calculation of the deterministic costs based on the main inputs and assumption, in order to reduce uncertainties of the initial assessment, a Monte Carlo analysis can be performed using *@Risk®* software.

By doing that, is possible to obtain a spread of the probable costs and identify system´s main cost driver.

SCALA Results

Basic assessment of the costs and energy production during first feasibility analysis of new projects.

Identification of the main cost drivers impacting on the project

Development status

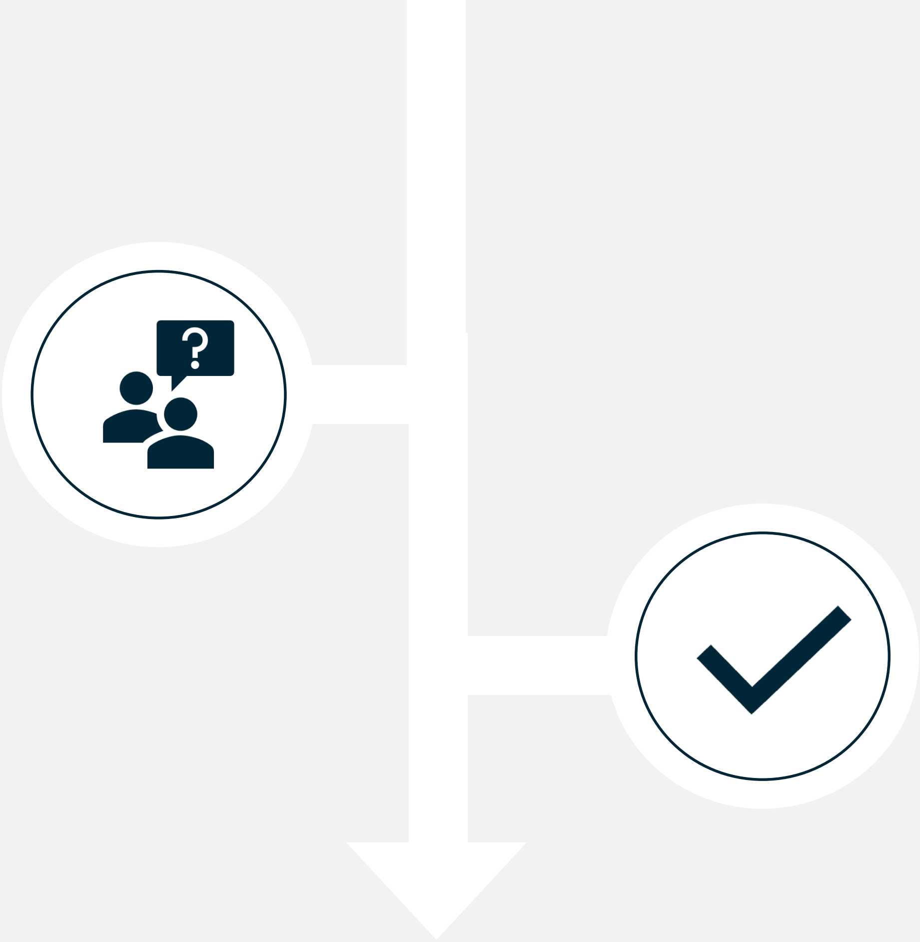
SCALA is under development

The cost database and calculations are being improved to make the model more robust and accurate

Next Steps

- Enhance the model with more data (different cost sources and parameters)
- Validate the model and calculations with operational plants data.
- Calculate CO_2 /Greenhouse gas savings

Questions?



Thank you!

SCALA was developed as part of the GEOTHERM
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