Deep geothermal energy projects (EGS) in The Netherlands

Guus Willemsen

IF Technology

&

Jules Smeets

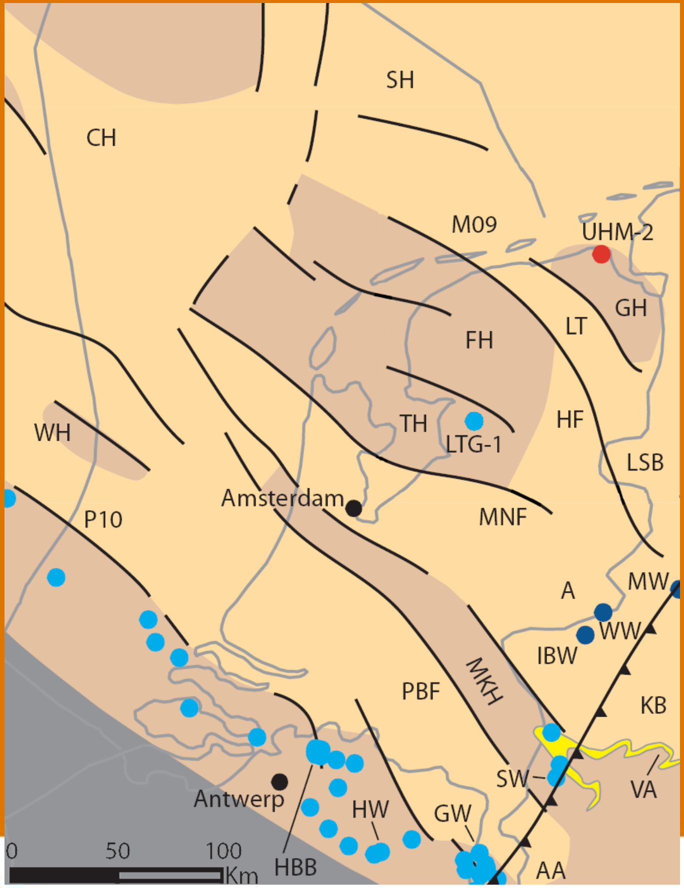
Kema

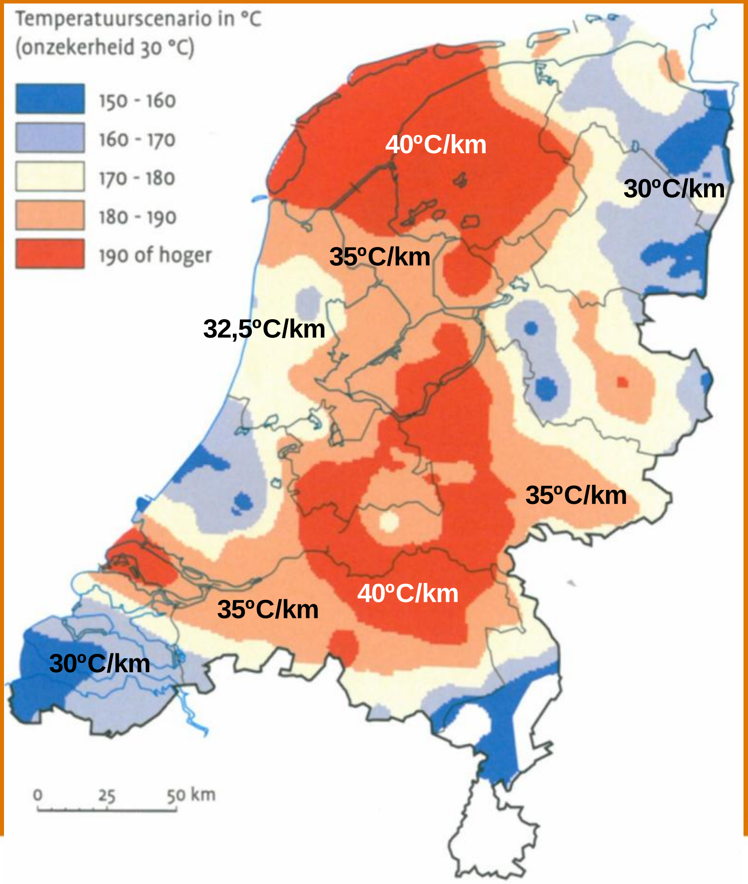
Deep geothermal energy production in The Netherlands is in development

- Feasibility studies are being performed for several locations, a.o.
  - Renkum
  - Hoogeveen
- Goal is to assess potential of deeper geological formations (>4 km) for steam/ electricity production
- Main target: lower carboniferous limestone, depth 4 to 7 km

if

Carboniferous limestone at an interesting depth and a reasonable temperature gradient is available in the Netherlands, having active fault zones and possibly karst





The most promising formation for deep geothermal energy production is the Zeeland Formation

- Limestones and dolomites from Early Carboniferous
- Some properties:
  - Thickness: 200 – 800 m
  - Very low porosity and permeability
  - Possible karstification/ dolomitization
  - Possible natural fractured reservoir near active faults

- Lithology and properties of deeper (Devonian) formations are largely unknown

Zeeland Fm core sample from LTG-01

if

Example case: The Hoogeveen municipality is currently in the process of founding a local energy company

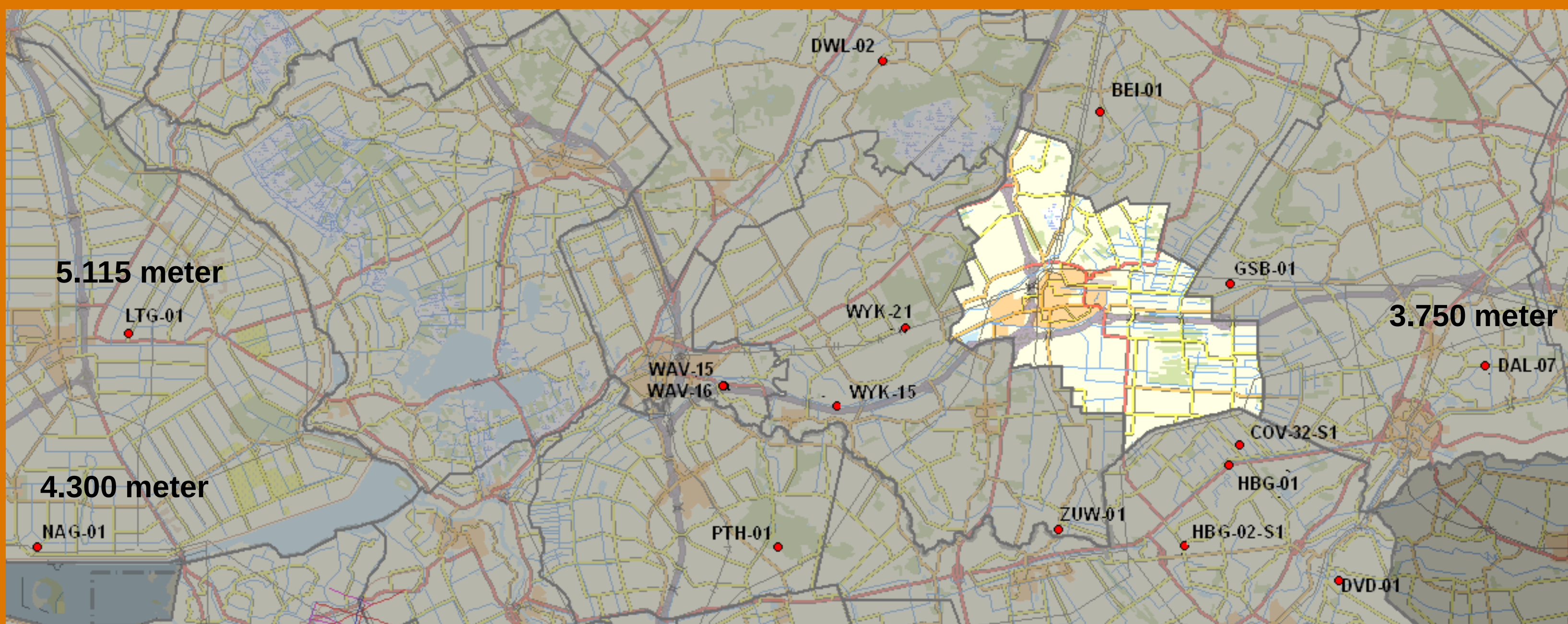
Case study – Geothermal power Hoogeveen

- **Carboniferous limestone at a depth of 6.500 to 7.000 meter**
- **Expected temperature 250 ºC**
- **A ‘self flowing’ system: no pumping of production well required!**

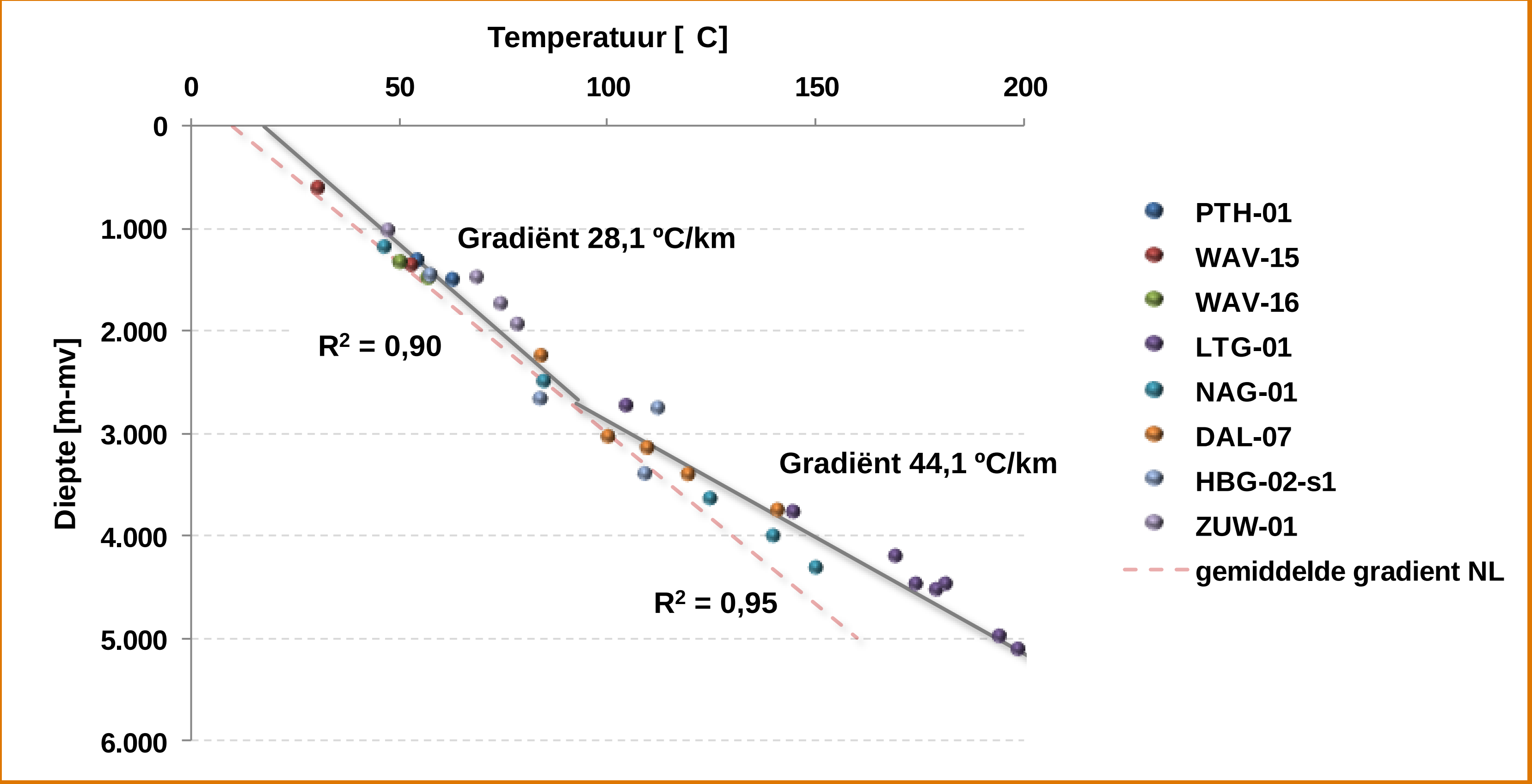
➢ **The electric capacity generates enough energy for all households in the city of Hoogeveen**

Parties involved

Information from a number of deep wells is available



The temperature gradient increases at about 3.000 meters, due to insulating clay layers with high OC, above lower carboniferous

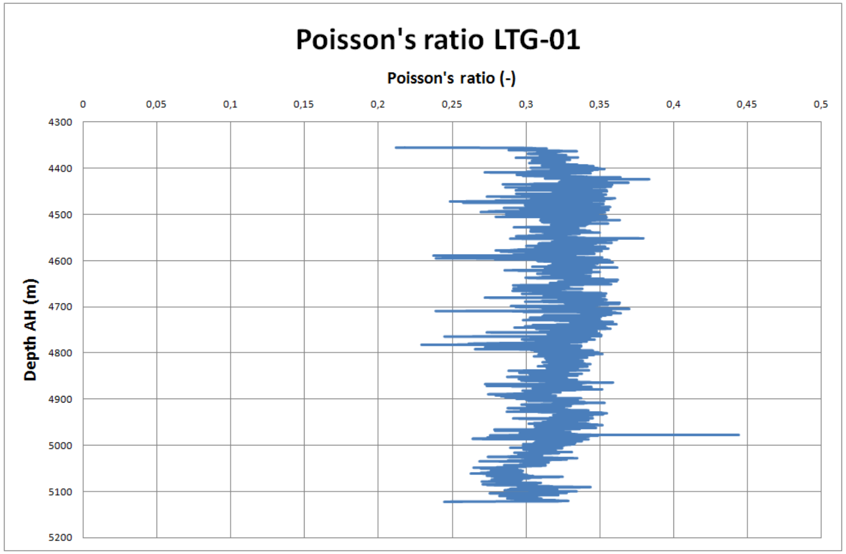


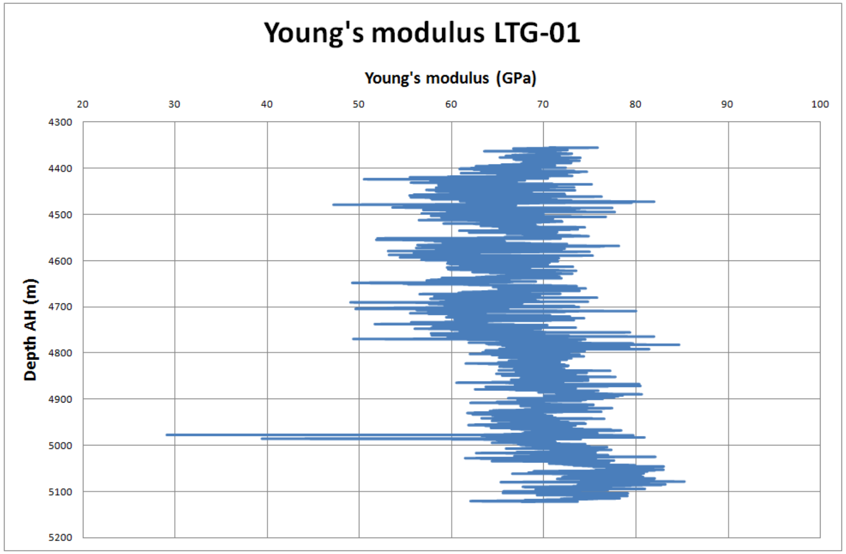
Primary permeability of the limestone formation will be too low for efficient natural fluid flow

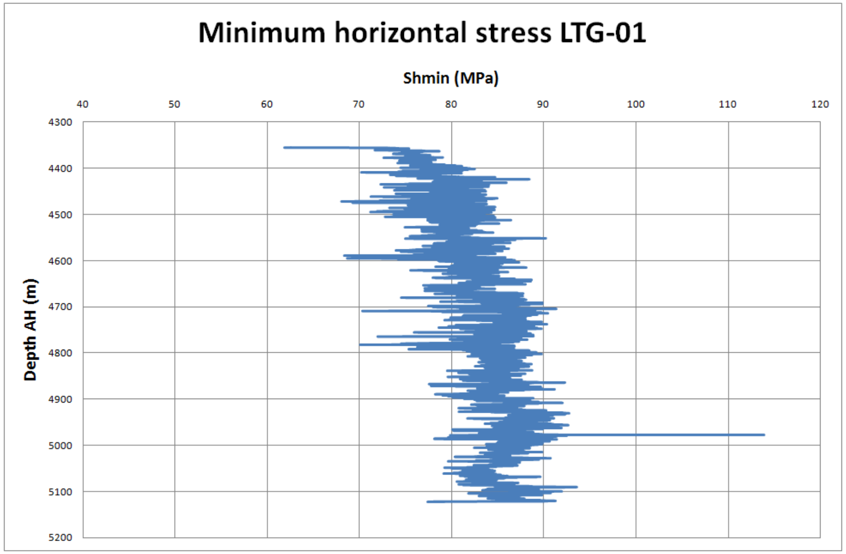
- Indication for LTG-01 (closest deep well to project locations)
  - Φ_{avg} = 0.3 %
  - k_{avg} = 0.025 mD
- Solutions:
  - Natural fractured network/Karstified limestone (secondary permeability): predictable?
  - Reservoir stimulation: shear fracs: predictable?
  - Reservoir stimulation: propped fracs: can be engineered!

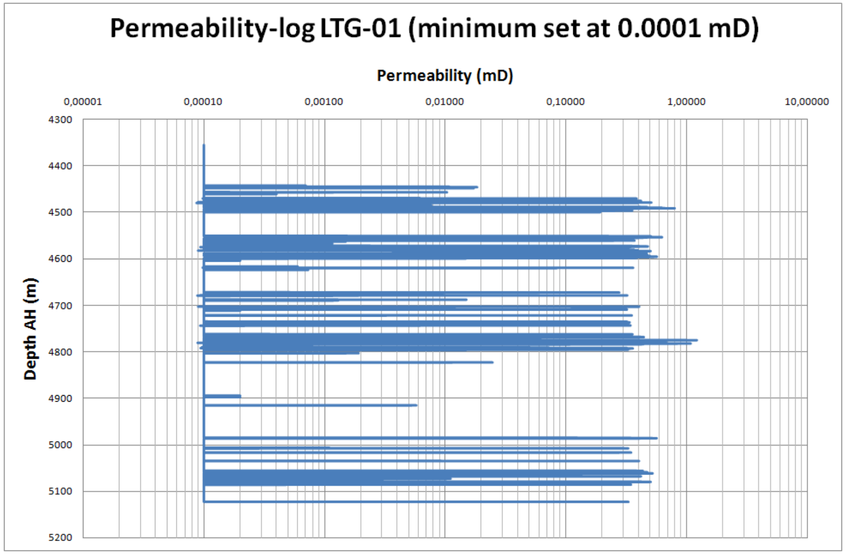
if

Rock properties have been determined as an input for hydraulic fracturing modeling of LTG-01





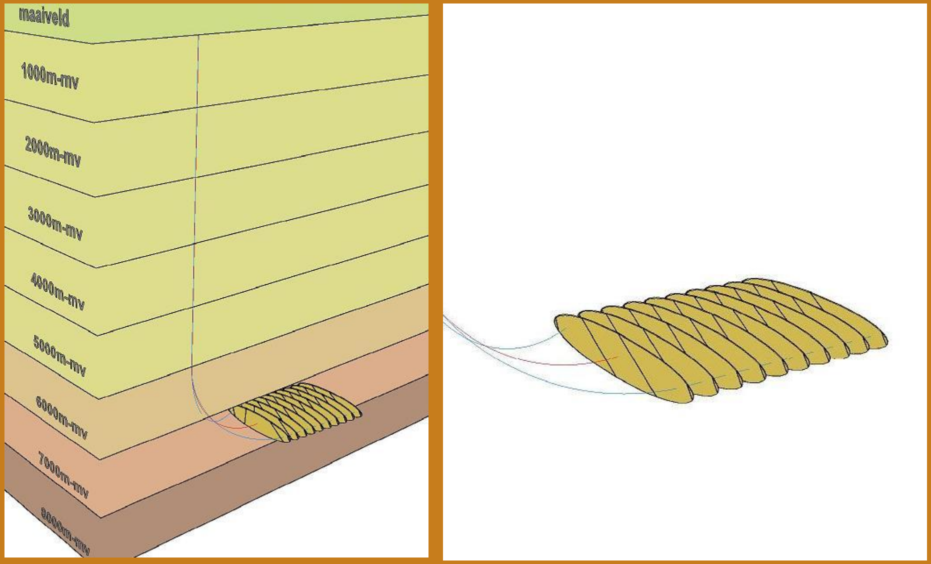




Effects of hydraulic fracturing of the limestone formation are simulated

Dimensions of fracture depend on:

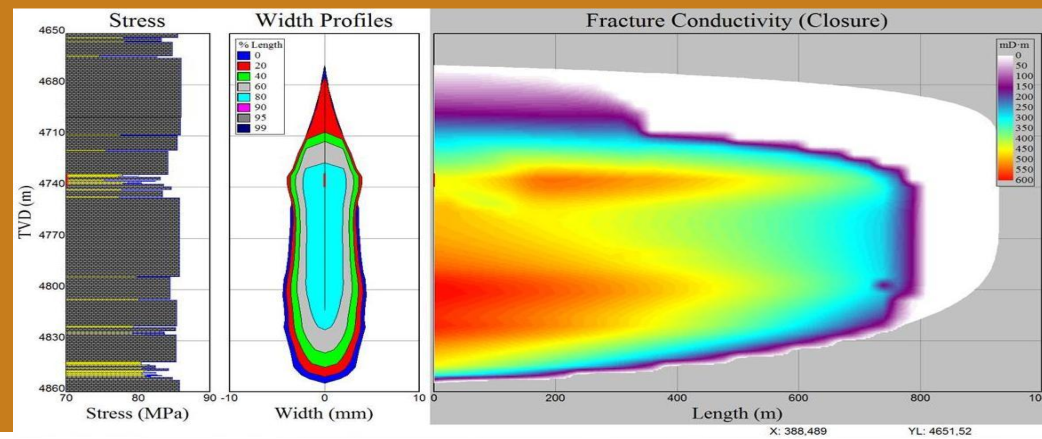
- Rock properties (external parameters)
  - Permeability
  - Geomechanical properties
  - Minimum horizontal stress
- Treatment schedule (design parameters)
  - Injected volume of fracture fluid
  - Viscosity fracture fluid
  - Proppant type and concentration

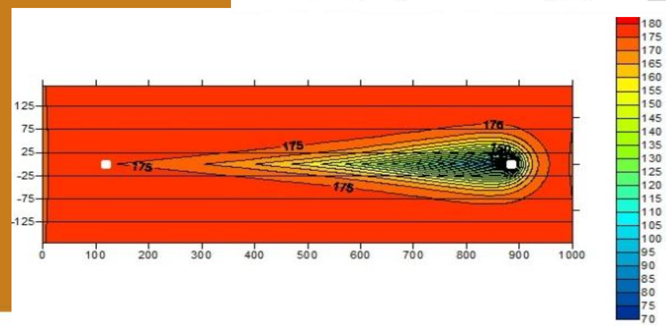


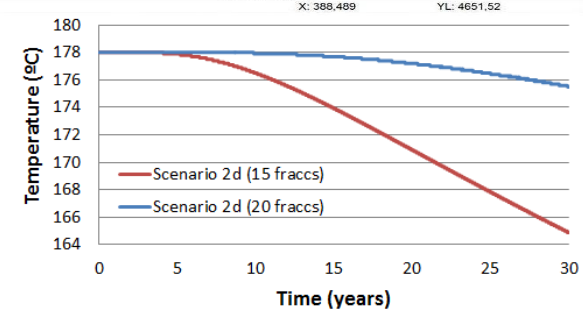
The heat will be extracted through a number of fractures

A hydraulic fracturing treatment is suitable for a cost-effective project

- Results of fracture and reservoir modeling comprise of:
  - Fracture dimensions
  - Minimum spacing
  - Production rates
  - Temperature evolution
  - Number of fractures
  - Flow rate 100 kg/s
  - No thermal breakthrough



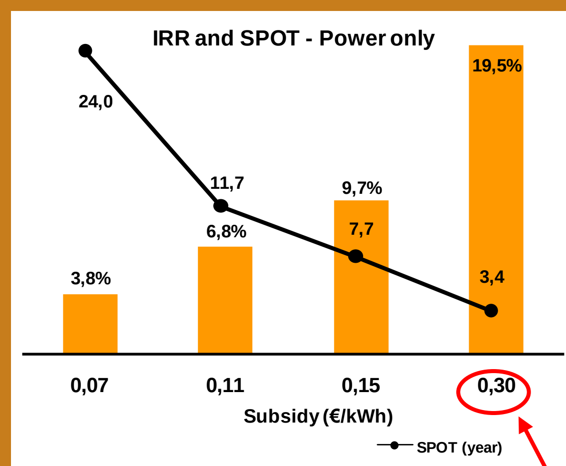


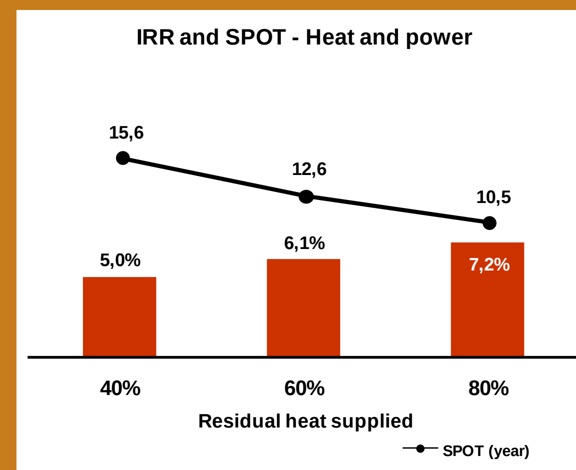


With an increased SDE and use of residual heat the projects are very attractive
Use of EGS for direct heat only is very attractive!

- Drilling costs are the largest investment
- The current subsidy on geothermal projects is too low
- Using residual heat significantly increase the IRR

Investment	Unit	7.000 m
Research and seismic survey	M euro	2,0
Other preperation cost	M euro	3,0
Two wells	M euro	78,7
Stimulation	M euro	12,0
Powerplant	M euro	36,8
TOTAL	M euro	132,5





Subsidy Germany

SDE power: 0,07 €/kWh
SDE heat: 18,60 €/GJ

EGS projects in the Netherlands are feasible, however additional research is required

Conclusions

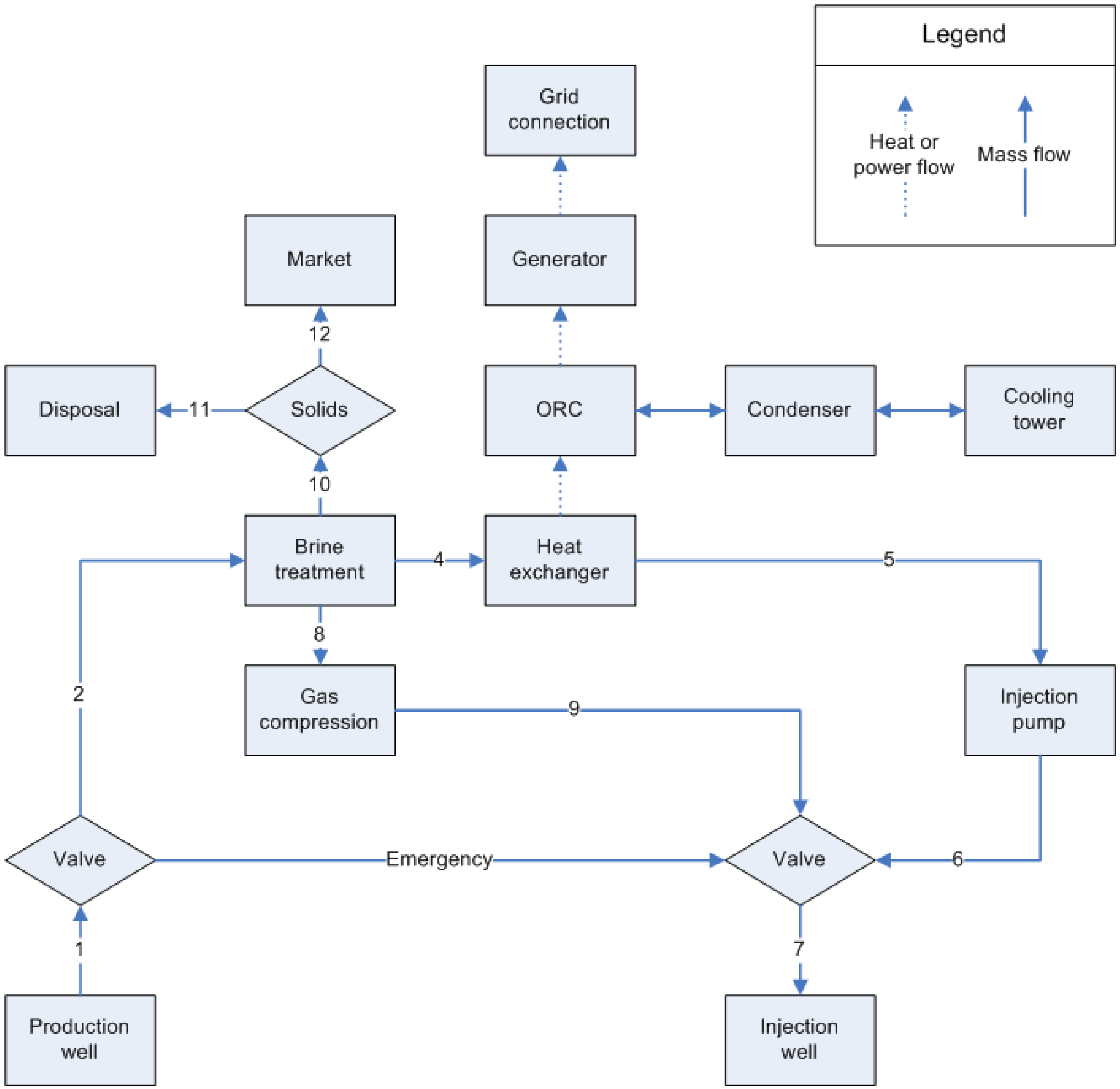
- The estimated depth, thickness and temperature of the Zeeland Fm meet the requirements of an interesting deep geothermal reservoir
- There are active fault zones and possibly karstified zones in this limestone (plan A)
- Reservoir stimulation should be seriously considered to improve the productivity of the Zeeland Fm as a plan B/C
- A high flow rate (100 kg/s) subsurface heat exchanger can be engineered
- Further research necessary in: reducing uncertainty geology and naturally fractured reservoirs

if

Power plant conceptual design (KEMA)

- ***Focus on main components & potential 'show stoppers'***
  - Organic Rankine Cycle (ORC)
  - Selection of cooling method
  - Grid integration & connection
- ***Operational issues:***
  - Fouling, scaling & corrosion
  - Gas/oil separation from brine
  - Basic process control
- ***Safety issues:***
  - None during normal operation
  - Organic (flammable) fluids
  - Brine with a high pressure, temperature & flow rate
  - Emissions during calamities
- ***Economic aspects:***
  - Investment costs
  - O&M costs
  - Sensitivity analysis

Schematic power plant process layout



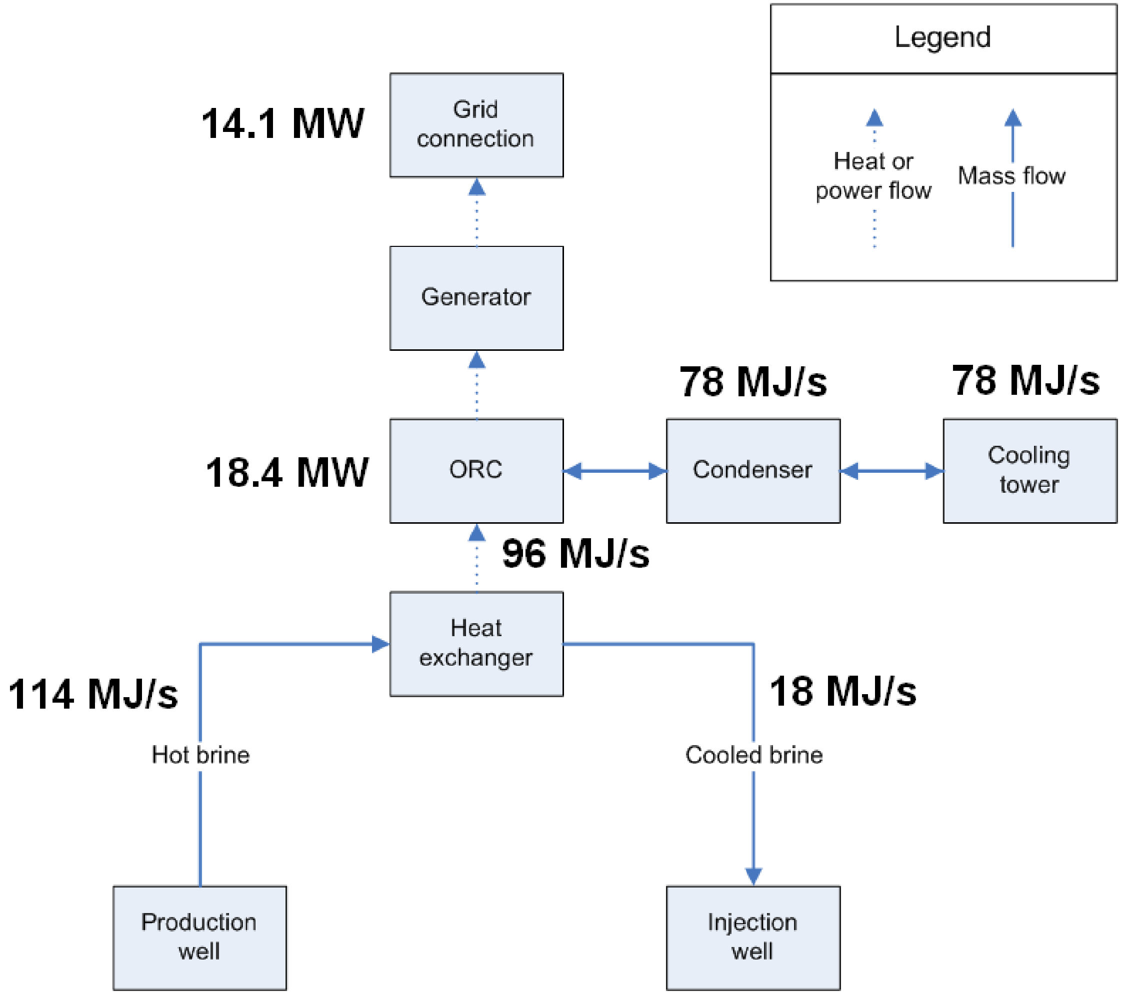
Power plant thermodynamic model

- ***Quick scan of different power plant cycle types:***
  - Single flash
  - Double flash
  - Single ORC
  - Cascade ORC
  - Combined cycle flash & ORC
  - → Optimal thermodynamic cycle selection

- ***SPENCE model for partial load calculation***

- ***Optimization ORC cycle for Hoogeveen situation:***
  - Process parameters (temperatures, pressures, flow)
  - Condenser cooling parameters (type, WBT, range, approach)
  - Process fluid (hexane)

Energy flows: potential heat supply



- ***16.1% of brine heat is converted to electricity***
- ***Large amount of low temperature heat (<50°C)***
- ***Heat use (CHP) improves business case***
- ***Heat use complicates the project & increases development time***