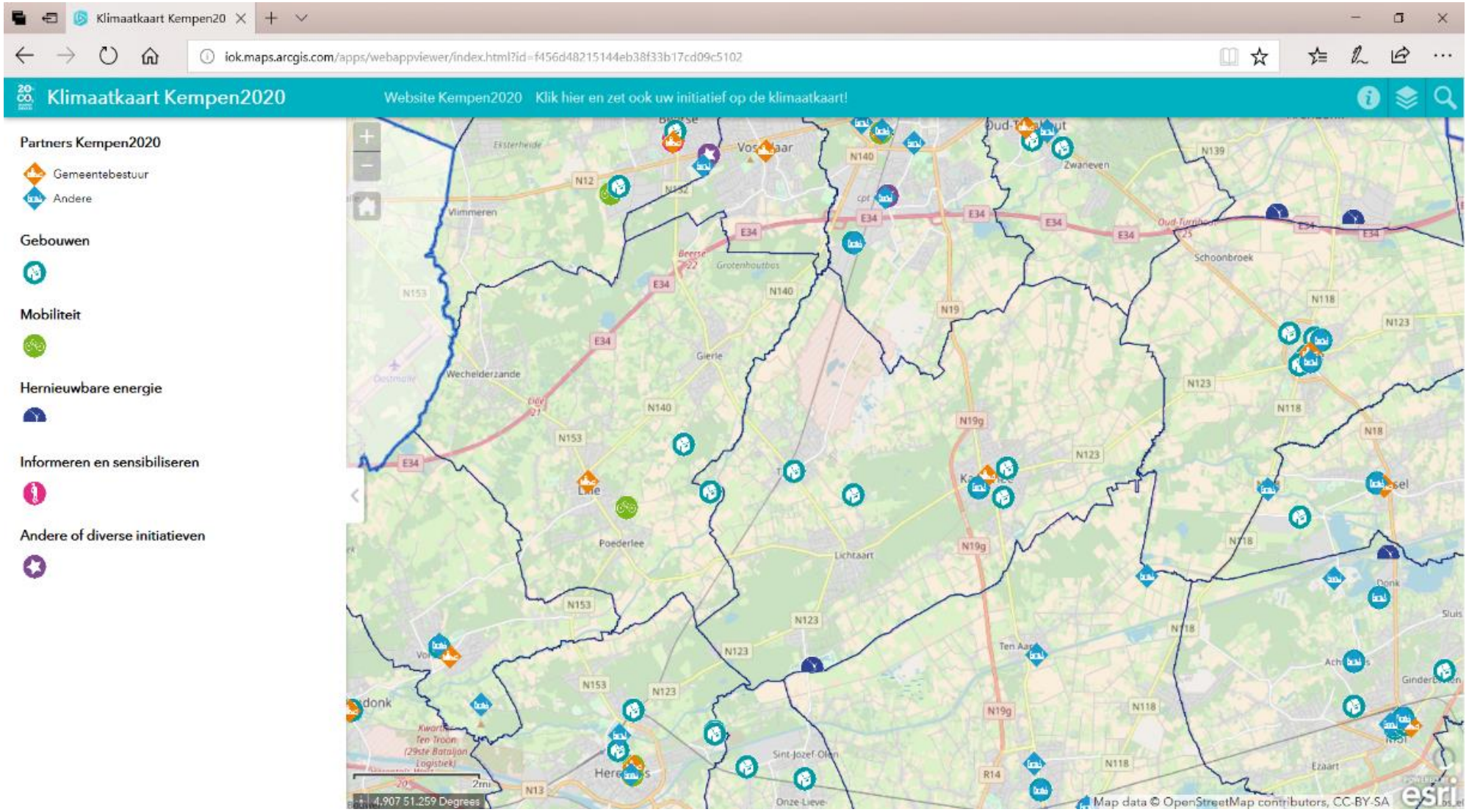
Experiences from the deep geothermal project in Mol, Belgium

VITO - Ben Laenen

Motivation to start the Balmatt project



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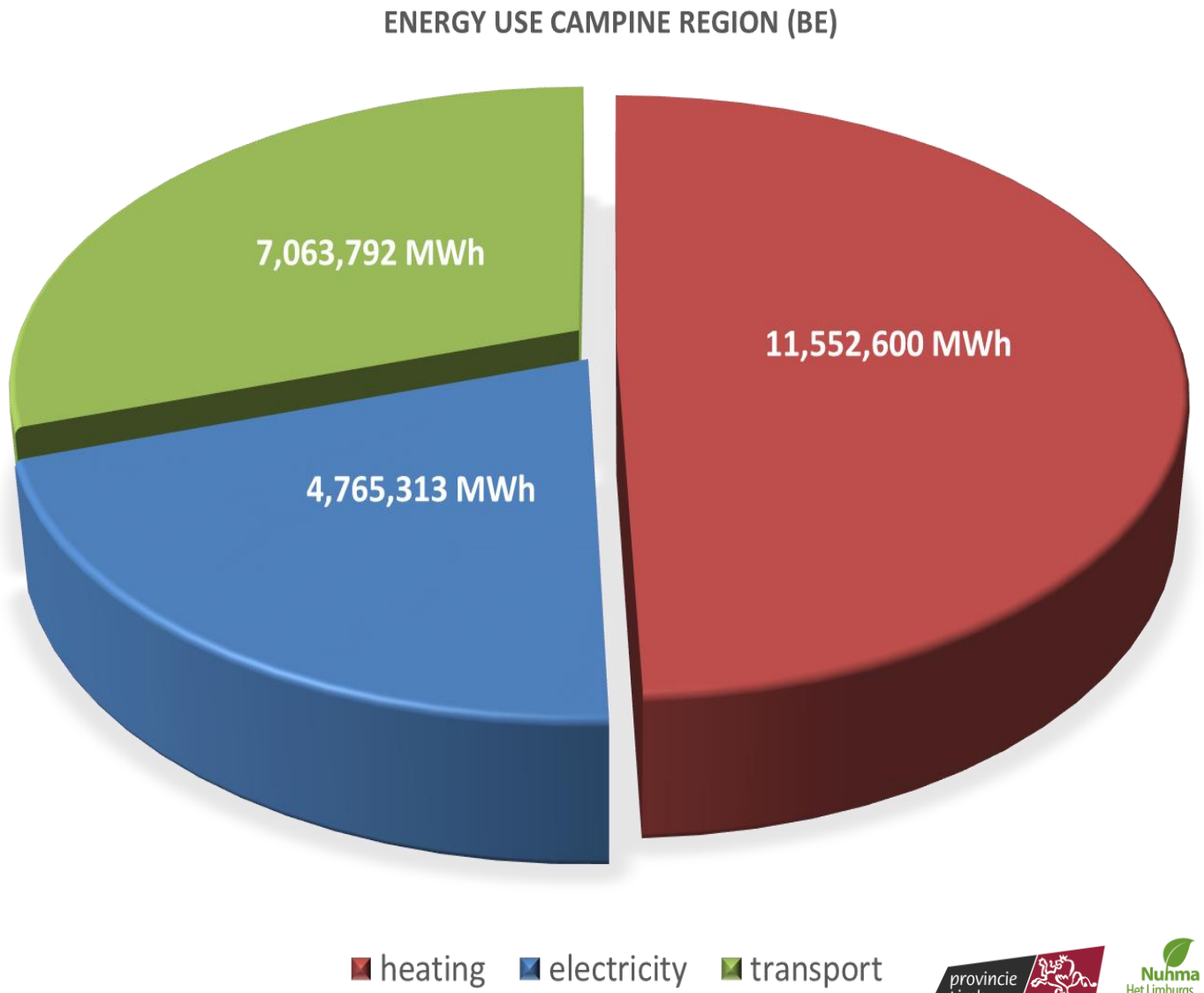

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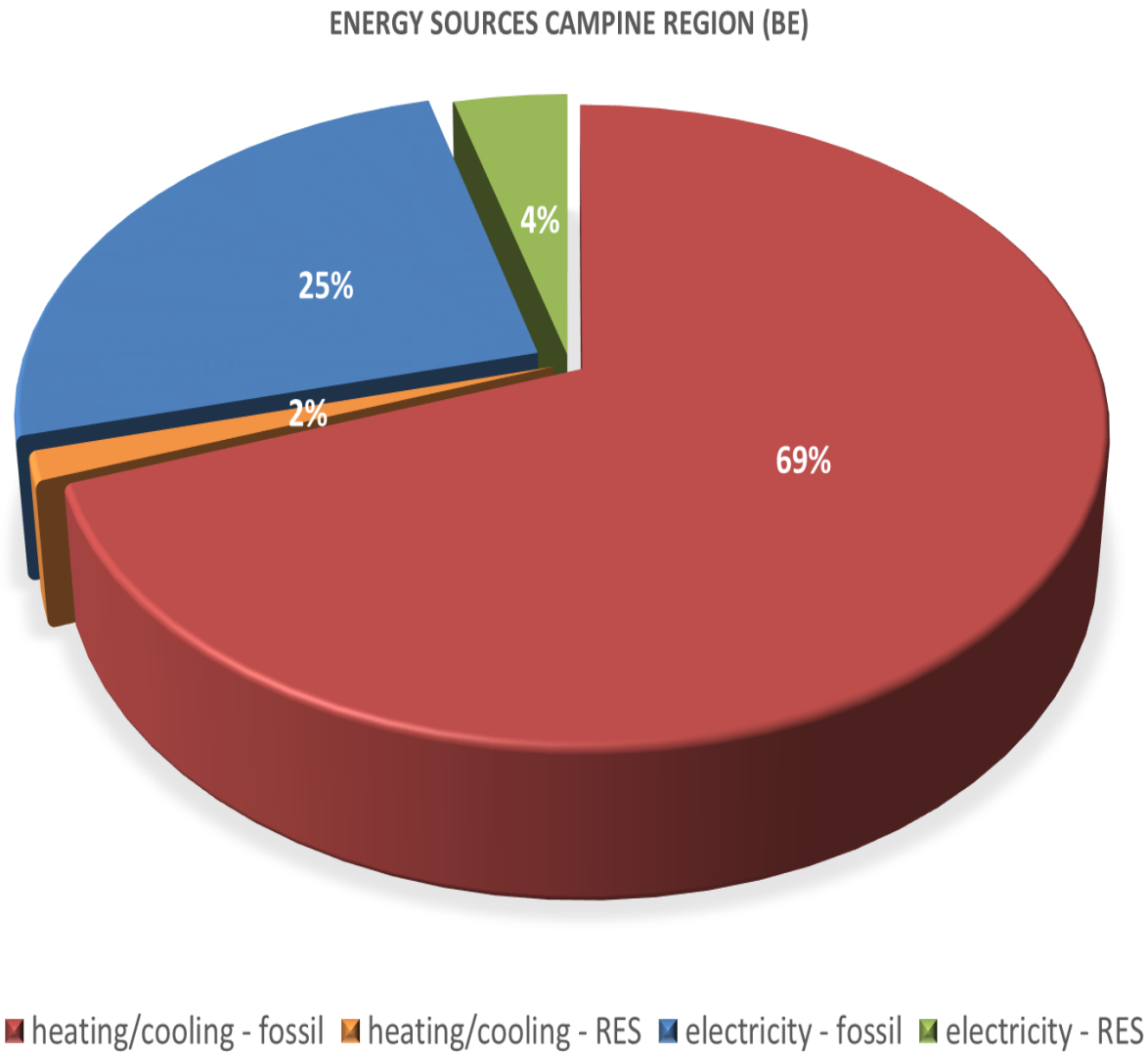
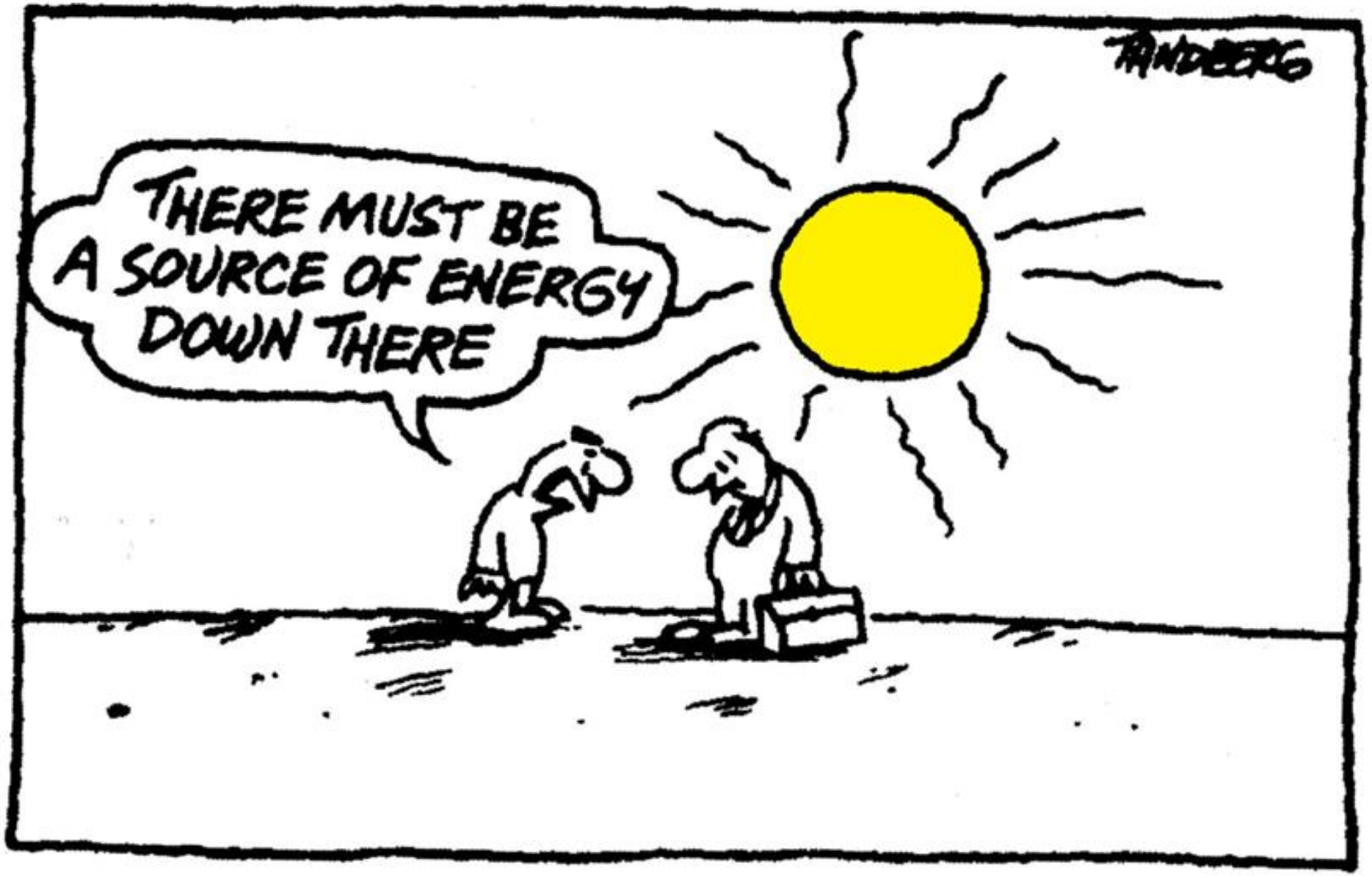
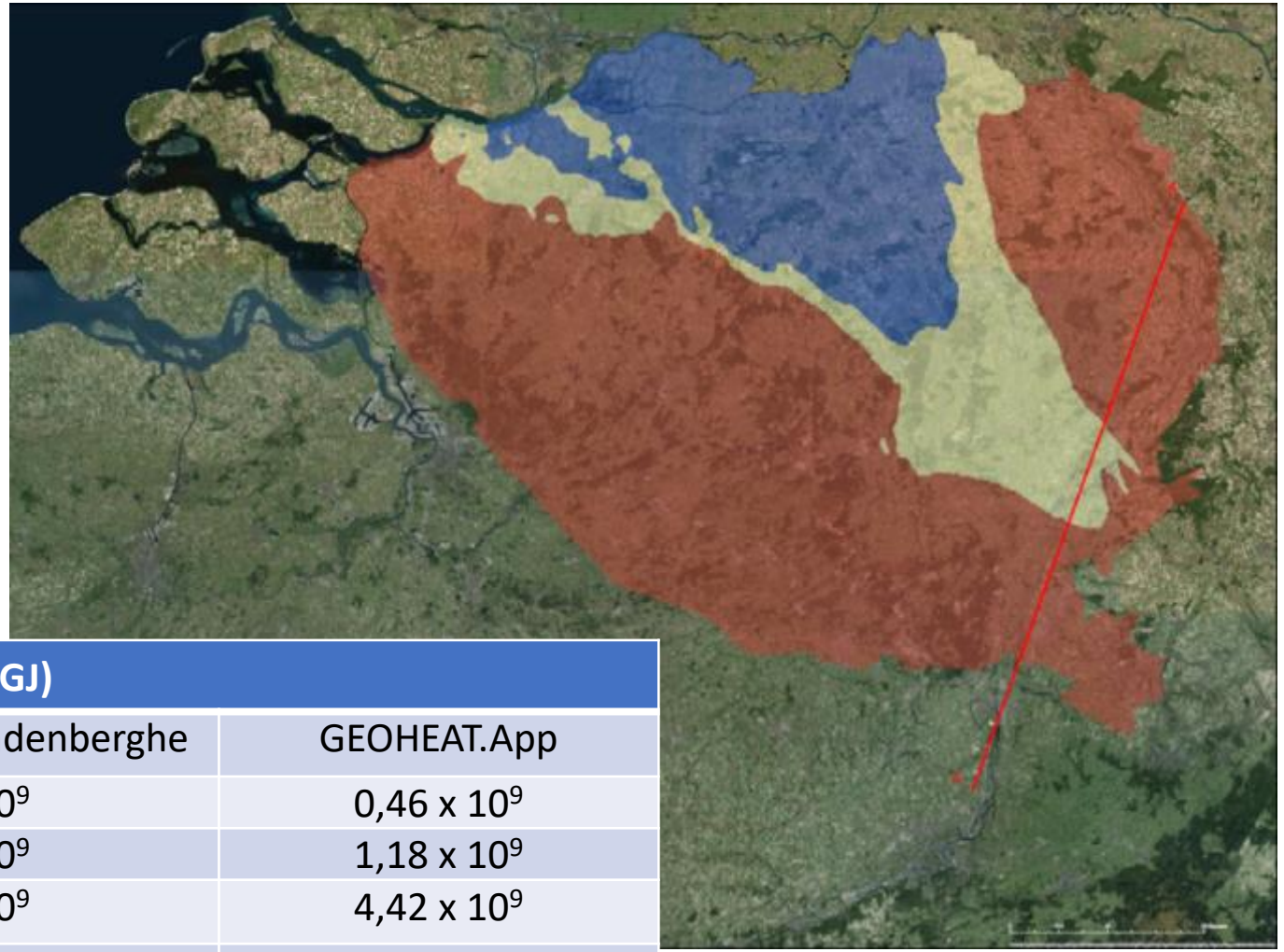


Fist steps and assumptions



Geothermal potential of the Lower Carboniferous Limestone

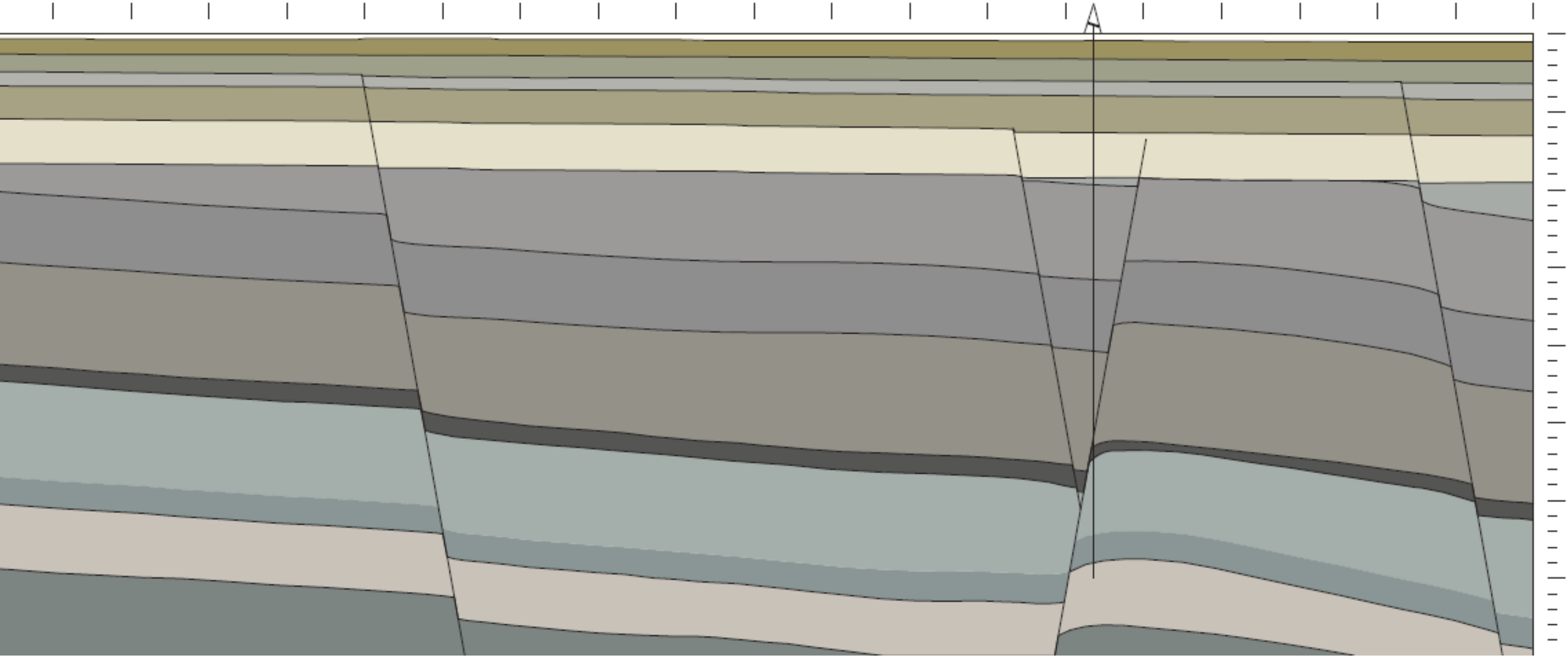


Aquifer	Exploitable heat (GJ)	
	Berckmans & Vandenberghe	GEOHEAT.App
Chalk Group	1,77 x 10^9	0,46 x 10^9
Trias sandstones	5,08 x 10^9	1,18 x 10^9
Neeroeteren sandstone	0,12 x 10^9	4,42 x 10^9
Carboniferous limestone	4,45 x 10^9	13,02 x 10^9
Total	11,42 x 10^9	19,07 x 10^9

Assumption and uncertainties at start of the project

- **Drilling of an exploration well**
  - **Mol – Donk: brown field Balmatt industries)**
  - **Expected depth of the reservoir: 2.800 - 3.600 m**
  - **Expected reservoir temperature: 132 - 138°C**
  - **Expected flow rate per well: 35 – 50 kg/s**
- **Heat supply to an existing (>80°C) and new, low temperature (< 65°C) heating grid**
- **Electricity production using a flexible organic Rankine cycle (prototype)**

Geological uncertainty

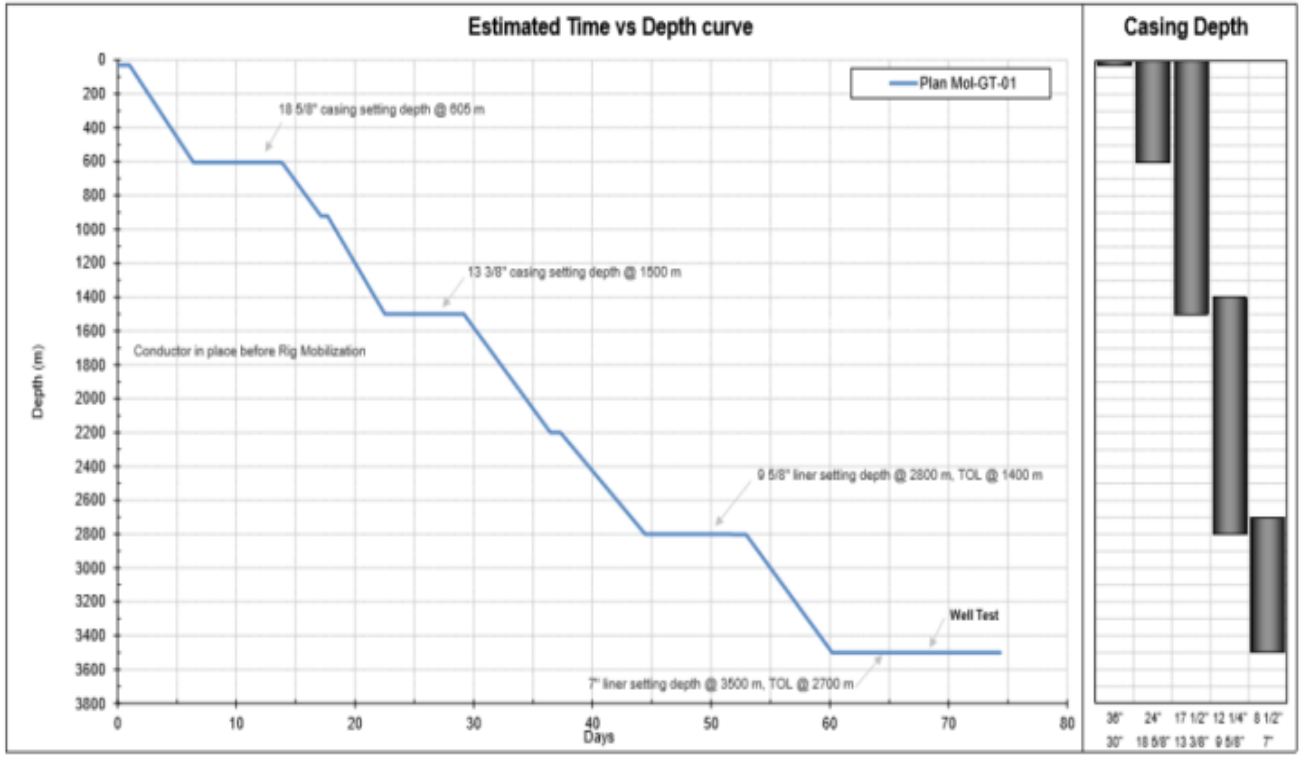


Drilling of exploration well MOL-GT-01

OPERATIONAL PLAN | MOL-GT-01

Operator	VITO	Well Profile	Vertical
Well	Mol-GT-01	Start Date	1. Sep. 15
Rig	Bentec DS 10	Planned End	14. Nov. 15
Planned Depth[MD/TVD]	3500/3500	Estimated Duration	74 days

Daldrup & Söhne AG
Bohrtechnik



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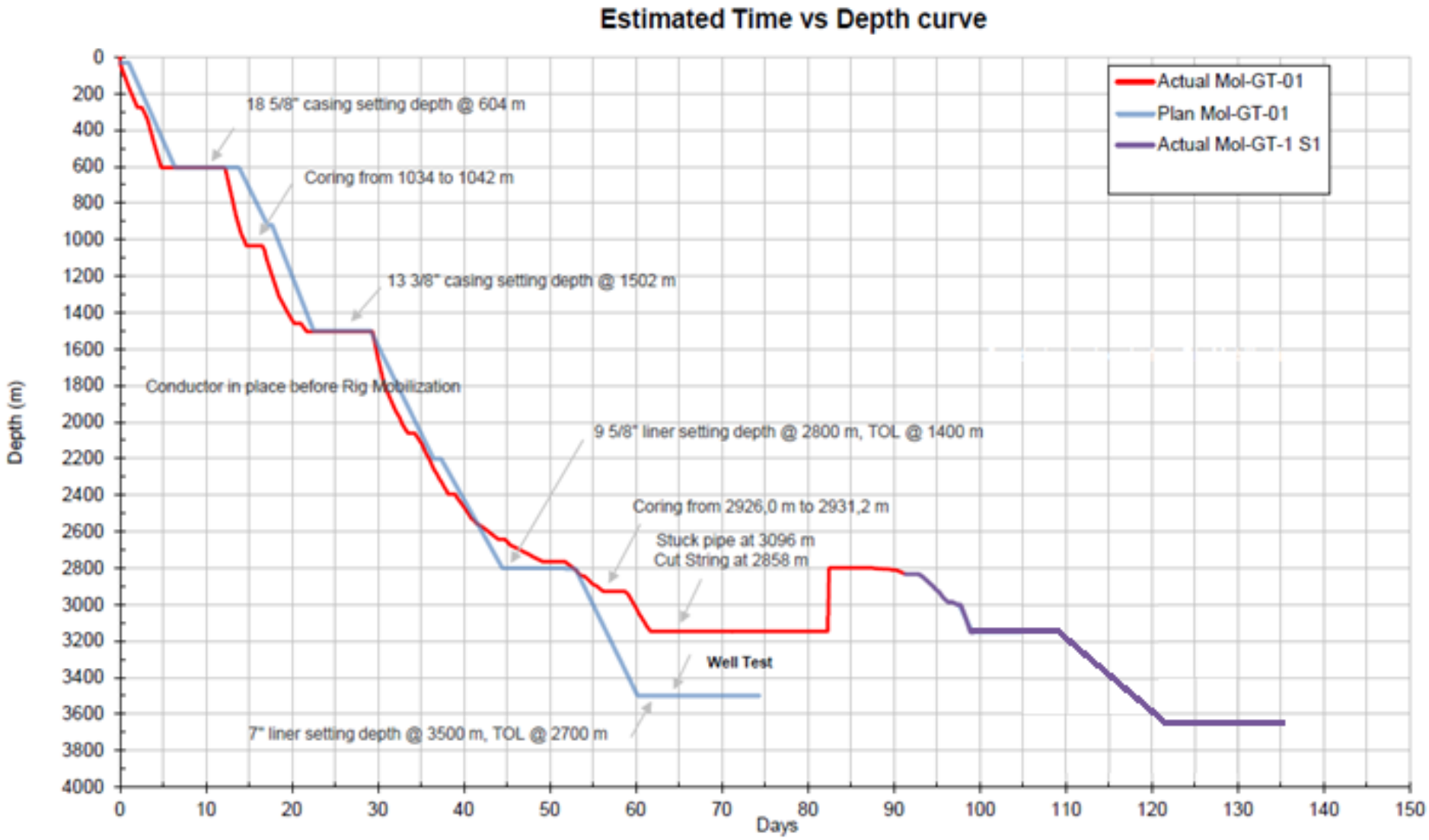
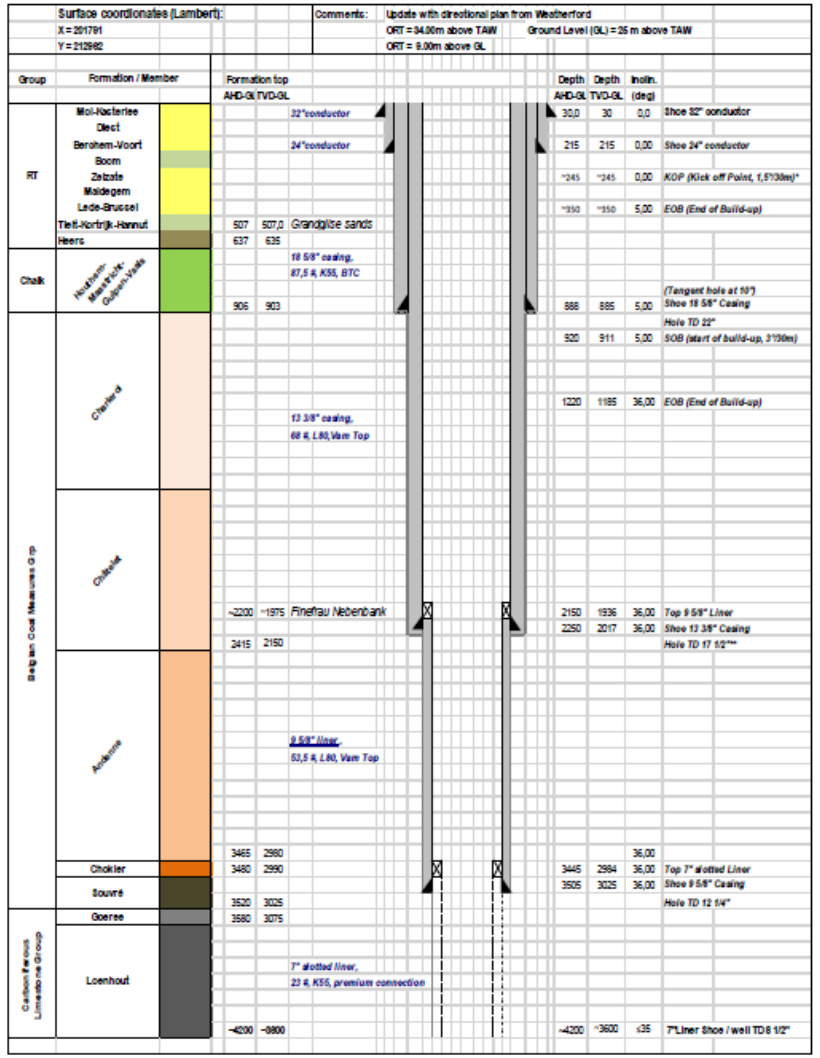
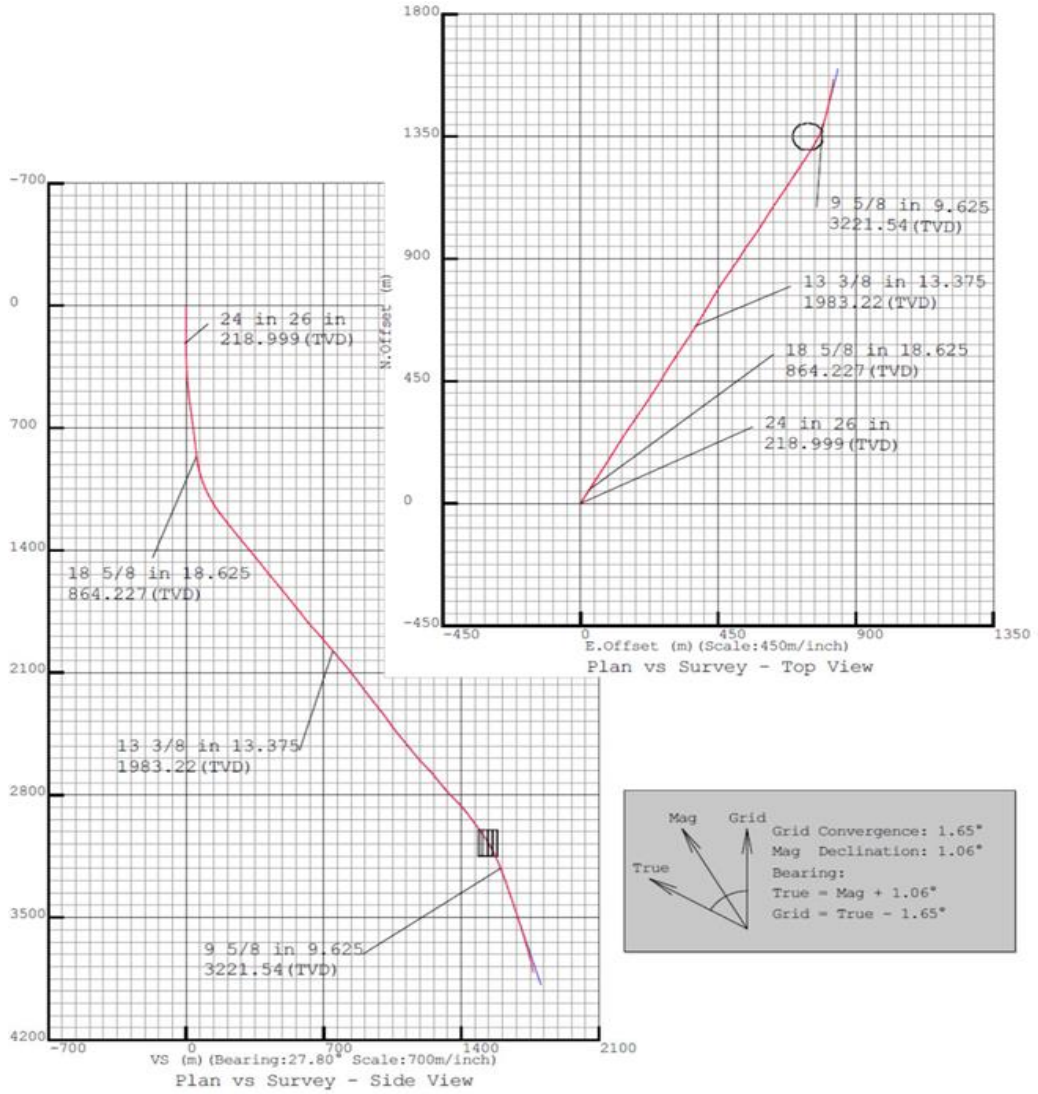


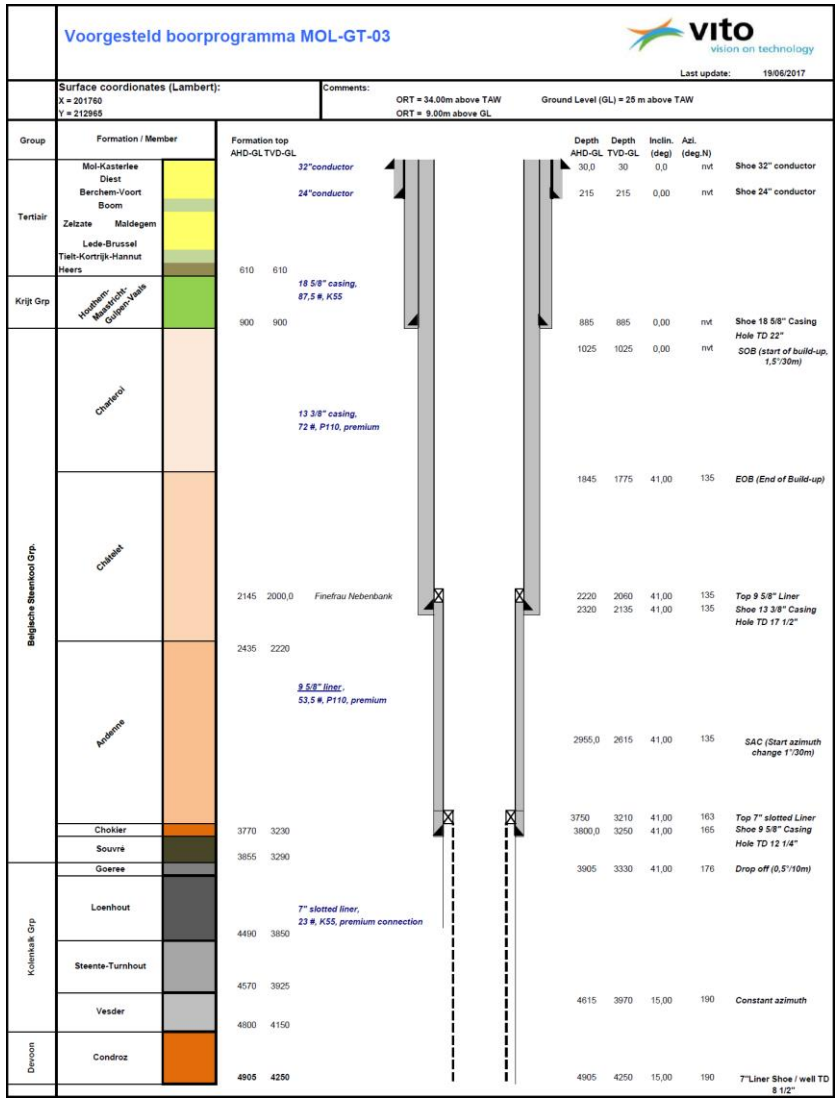
- Update geological model
- Optimized well design
  - Deviated well for injection
  - Covering the full stratigraphic thickness of the Lower Carboniferous Limestone Group
  - Shorter 3th section for better stability
  - Adapted mud program



- **High torque and friction**
  - Base of Lower Carboniferous nor reached
  - TD: 4341 m - TVD: 3820 m
  - Deviation: 1769 m
- **Drilling time**
  - Estimated: 90 days
  - Actual: 110 days

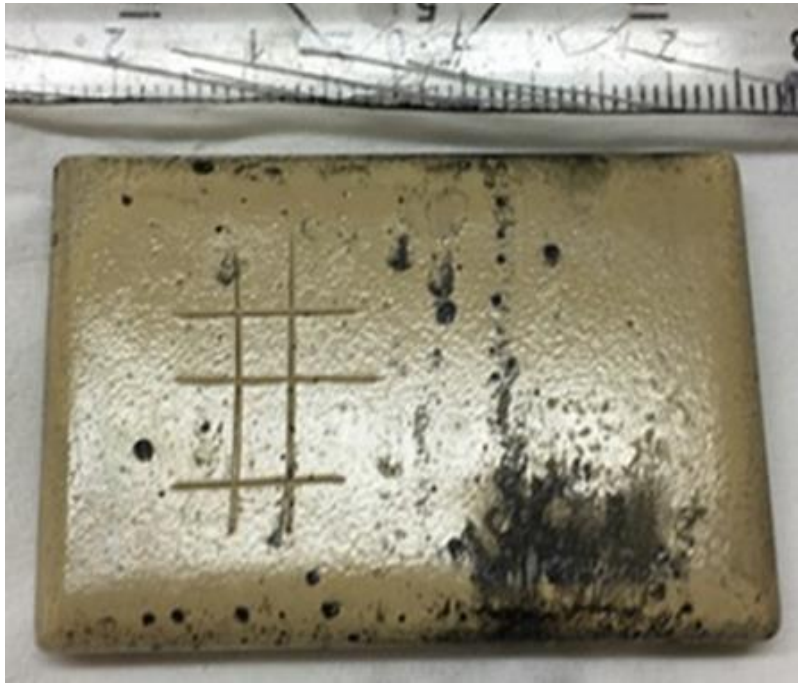


- # Ambition
  - Covering full stratigraphic thickness of the Lower Carboniferous Limestone
  - Explore geothermal potential of Evieux Formation (Upper Devonian)
  - Test fault zone at larger depth for additional production



- **3 wells completed and tested**
  - Reservoir between 3200 – 3800 m
  - Reservoir temperature: 138 – 142°C
  - Fracture and dissolution related permeability
  - Highly available permeability: 0.01 – 100 mDarcy
  - Complex reservoir geometry
  - Review of depositional model for the Upper Dinantian needed
  - Revision of the exploration model
  - Uncertainty remains even after drilling of 3 wells

Other technical challenges



Corrosion and scaling

- Material selection
- Monitoring
- Prevention
- New concepts / materials

Emissions

- Geothermal brine (salts)
- Dissolved gasses
- Degassing
- NORM

Seismicity

- Seismic hazard and risk
- Monitoring
- Traffic light systems

Technical challenges due to gas content

Parameter	unit	MOL-GT01-3400m	MOL-GT01-3280m
Nitrogen	$\%_{vol}$	2.38	4.01
Argon	$\%_{vol}$	0.07	0.07
Carbon dioxide	$\%_{vol}$	77.3	75.8
Methane + ethane	$\%_{vol}$	8.23	8.46
Helium	$\%_{vol}$	0.23	0.27
Hydrogen	$\%_{vol}$	11.7	11.4
Dissolved gas content	Nm^3/m^3	2.557	2.392
Bubble point	bar		25 – 32 bar

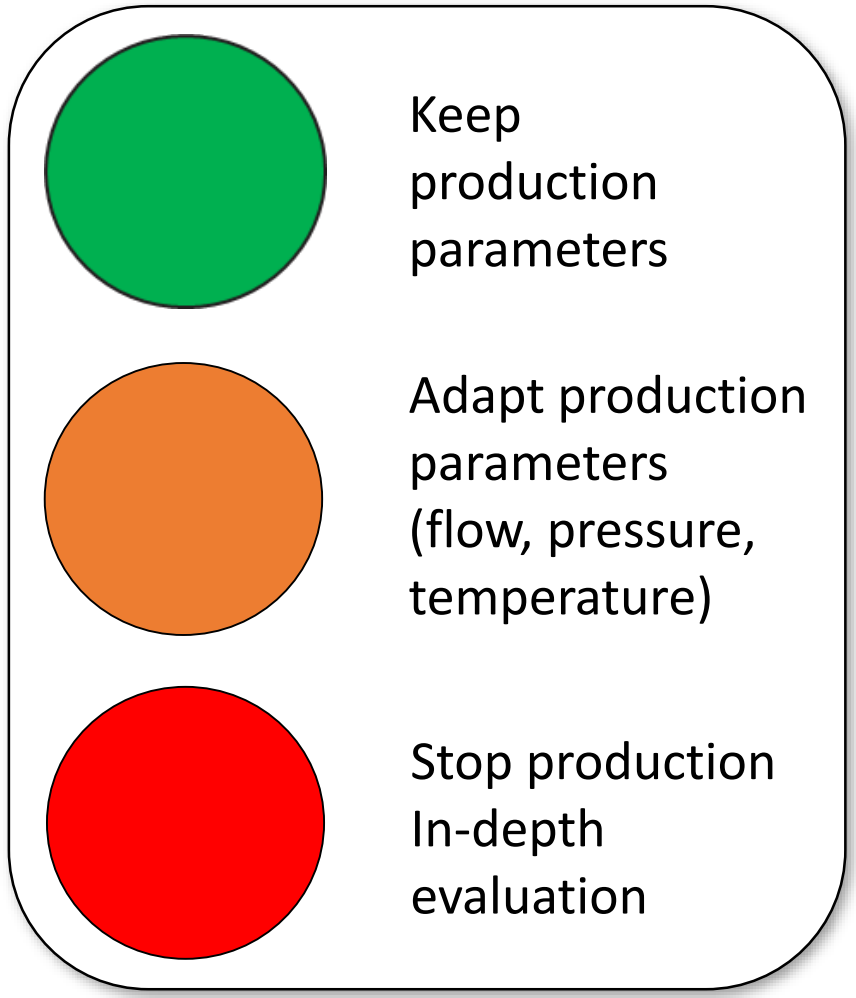
Technical challenges due to gas content

- **High pressures:**
  - Design pressure 60 bar
  - Operating pressure: 40 bar -> 45 bar
- **Gas separation tank**
- **Gas re-injection column**
  - Restrictions due tot dissolution kinetics
  - Avoiding hammer effects

Induced seismicity

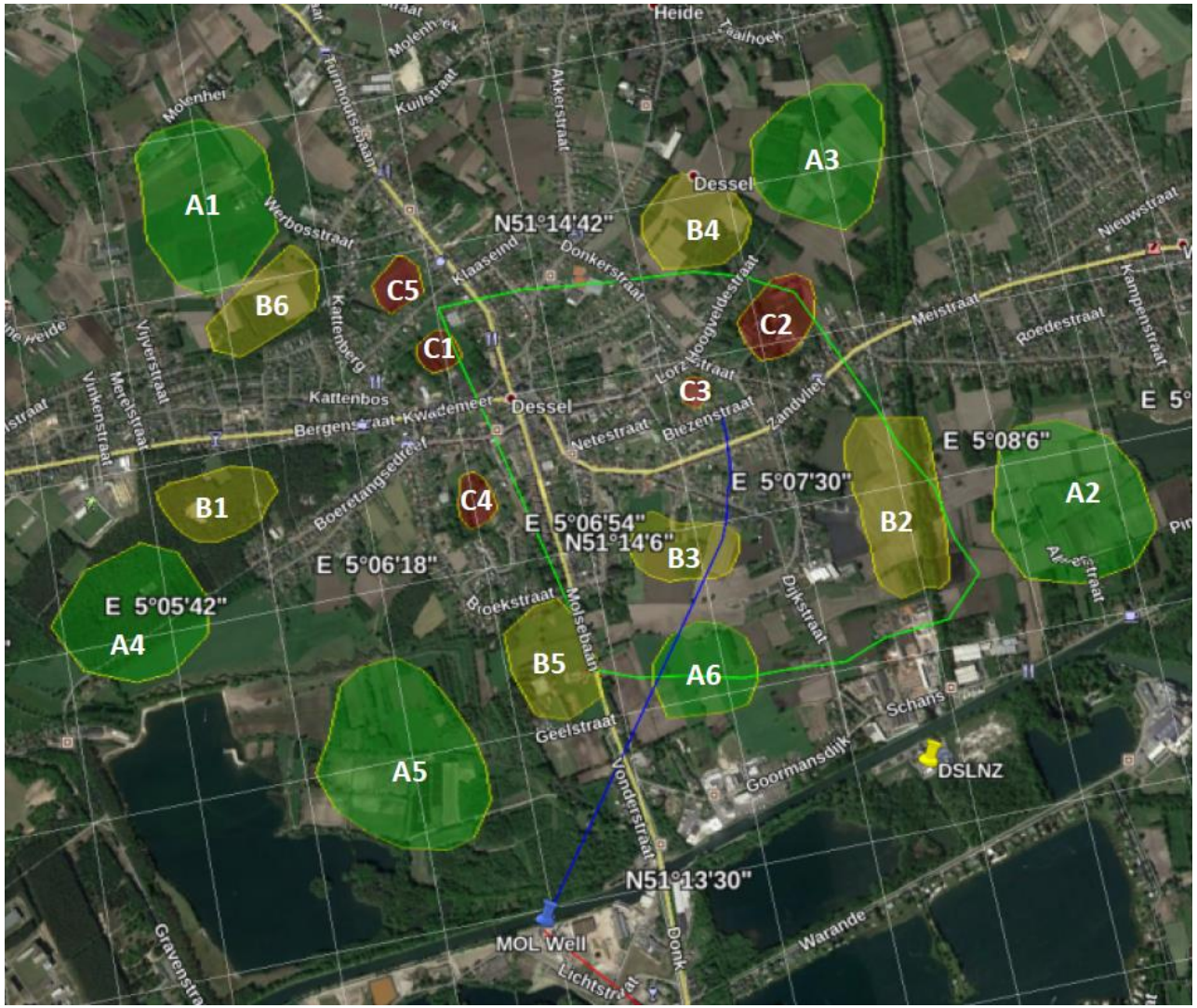
Score	Basement connected	Distance to fault [km]	Orientation of faults in current stress field	Net injected volume [1000	Inter-well pressure communicatio	Reinjection pressure [MPa]	circulation rate [m³/h]	Epicentral distance to natural	Epicentral distance to induced	
10	yes	< 0.1	favourable	> 20	no	> 7	> 360	< 1	< 1	
7	possible	0.1 - 0.5	shearing possible	5 - 20	unlikely	4 - 7	180-360	1 - 5	1 - 5	
3	unlikely	0.5 - 1.5	shearing unlikely	0.1 - 5	likely	1 - 4	50-180	5 - 10	5 - 10	
0	no	> 1.5	locked	< 0.1	yes	< 1	< 50	> 10	> 10	
Score:	7	7	10	3	3	10	3	0	0	4

- **Installation of a seismic monitoring network**
- **Implementation of a traffic light system**
  - **Three control levels**
  - **Based on local magnitude, location with respect faults, frequency of events and ground motion (PGV, PGA)**
- **Ambition to avoid sensible earthquakes**
  - **Sensible event on 23 June 2019**



Further research on induced seismicity

- Quantification on uncertainty of mapped main fault orientation, location and dip
- Improvement of the location accuracy
- Relationship geothermal exploitation - seismic activity based on field measurements
- Investigate apparent absence of seismic events in the immediate vicinity of the injection point
- Evaluation role of aseismic slip



Transition towards a new energy landscape

Conclusions: technical challenges faced in Mol

- **Prediction and assessment of geothermal resources**
  - Better understanding of complex and deep geological processes
  - Better predictability of underground conditions
  - Optimize use of resources and increase energy production
- **Resource access and development**
  - More efficient drilling
  - Increase flow rates or thermal output
- **Heat and electricity generation and system integration**
  - Reduce impact
  - Maximize generation at the lowest lifetime cost
  - Hybrid, multi-source and multipurpose high-efficiency systems embedding geothermal

Concluding remarks

Changing the world is too big an effort for one man. Only by working together in respect and confidence we can create a new world where it is good to lo live for all.

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