Geothermal Energy in the Netherlands:

The ThermoGIS project ….

Taking advantage of the
oil and gas data and knowledge base

TNO | Kennis voor zaken

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www.Thermogis.nl

Content

- The Dutch setting:
  - Current development in use of geothermal energy
  - Market needs
- ThermoGIS project
  - Key parameters for performance
  - Geothermal aquifer characterization
  - Information system
  - Potential
- Scope for Electricity production (EGS)
- Conclusions

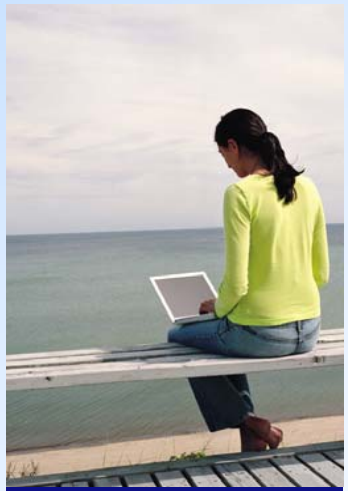
Introduction: core areas of TNO

TNO Quality of life

TNO Defence, security and safety

TNO Science and Industry

TNO Built Environment and Geosciences



TNO Information and Communication Technology

This independent research organization was established in 1932 to support companies and governments with innovative, practicable knowledge.

Number of employees: 5,400

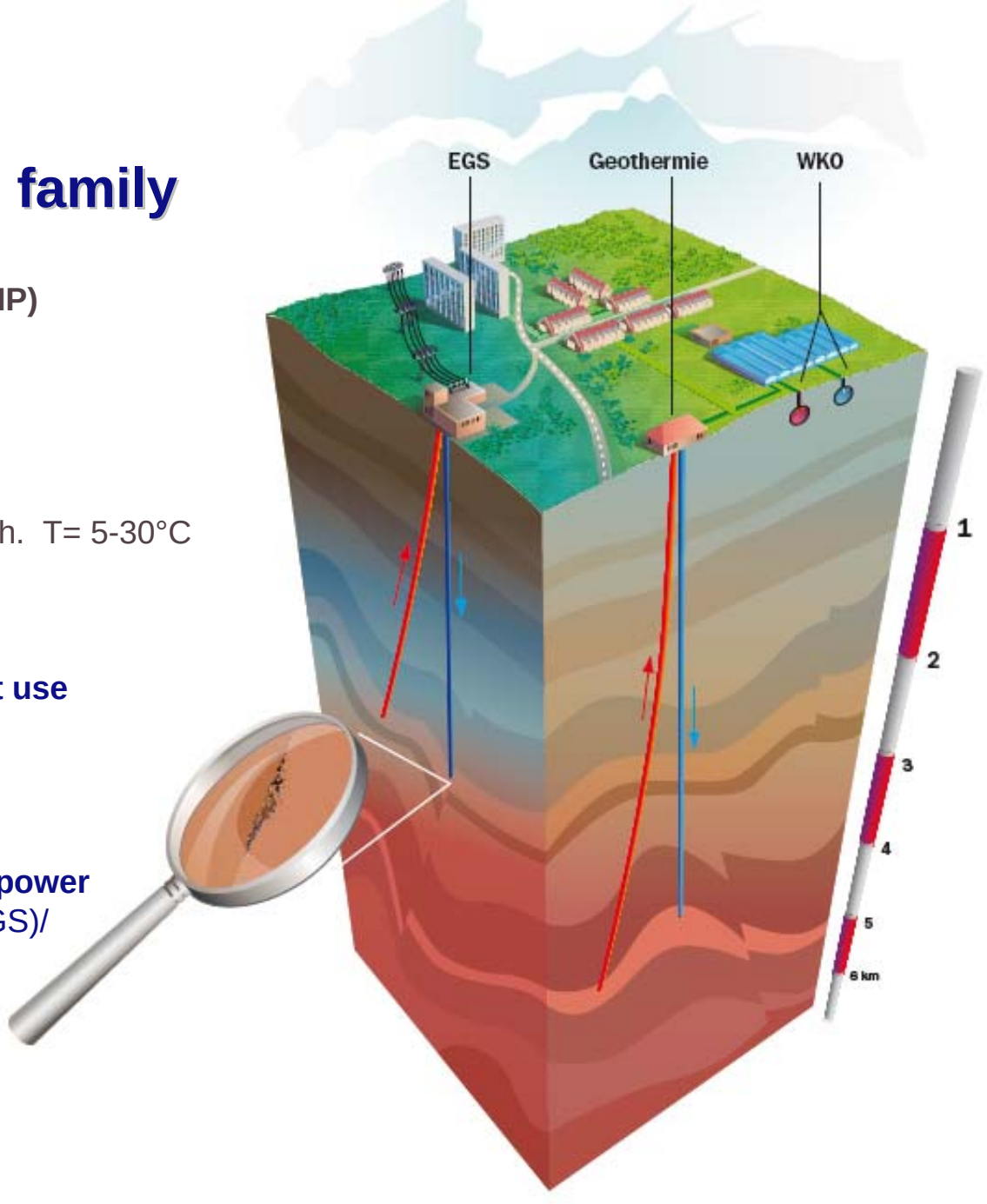
An introduction: the Dutch geothermal family

1. **Ground Source Heat Pumps (GSHP)**
   Horizontal or vertical (< 100 m)
   limited power <100 kWt
   1000s installed, individual houses

2. **Heat cold storage (WKO):**
   "shallow" aquifers: up to 250 m depth. T= 5-30°C
   power 0.1 - 10 MWt,
   ca 700 installed, offices mainly

3. **'Deep' geothermal energy – direct use**
   doublets, depths from ~1000m
   Temperature from ~40˚C
   2 installed, 3 drilled in 2010

4. **'Ultra-deep' Geothermal energy - power**
   Enhanced Geothermal Systems (EGS)/
   Hot Dry Rock (HDR)
   depths from ~3500 m,
   Temperatures from ~100˚C



Direct use of heat in The Netherlands

Drilling is finished this week!
The Hague
Depth: 2200 m
Temperature: 75 °C
Power : 6 MWth

District heating (4000 houses)

First succesful doublet
Greenhouse in Bleiswijk
Depth: 1750 m
Temperature: 60 °C
Power generated: 5 MWth

3 doublet planned
1 Delft
2x Pijnacker
Data not yet available

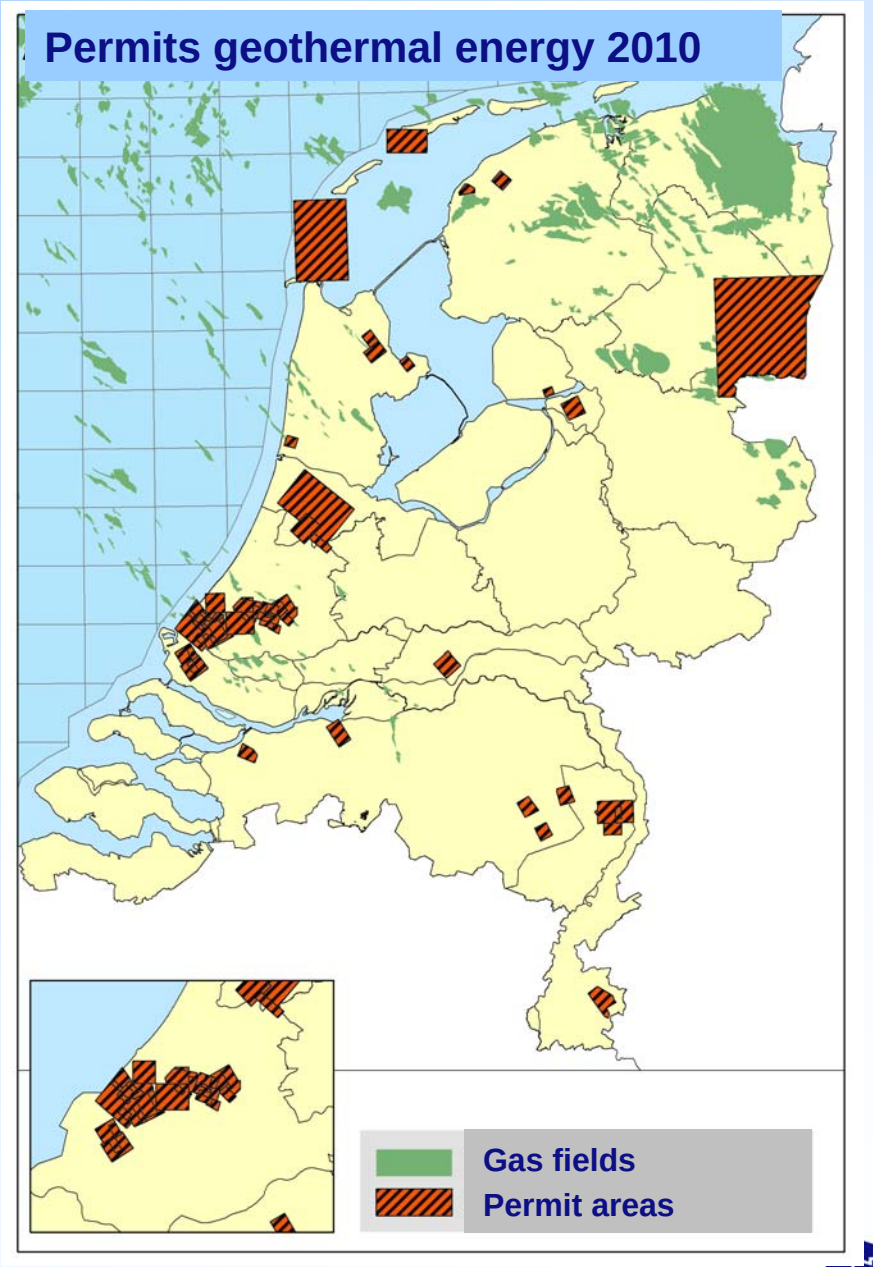
Market interest and needs

Interest is booming:

Currently over 80 permits granted by the Ministry of Economic affairs

Market needs

- Geological properties and uncertainties
- Independent analysis and information
- Overview potential areas and ‘hot spots’
- Performance assessment
- Economic feasibility
- Quickscan
- Control; Second opinion



Why ThermoGIS?

ThermoGIS is developed to:

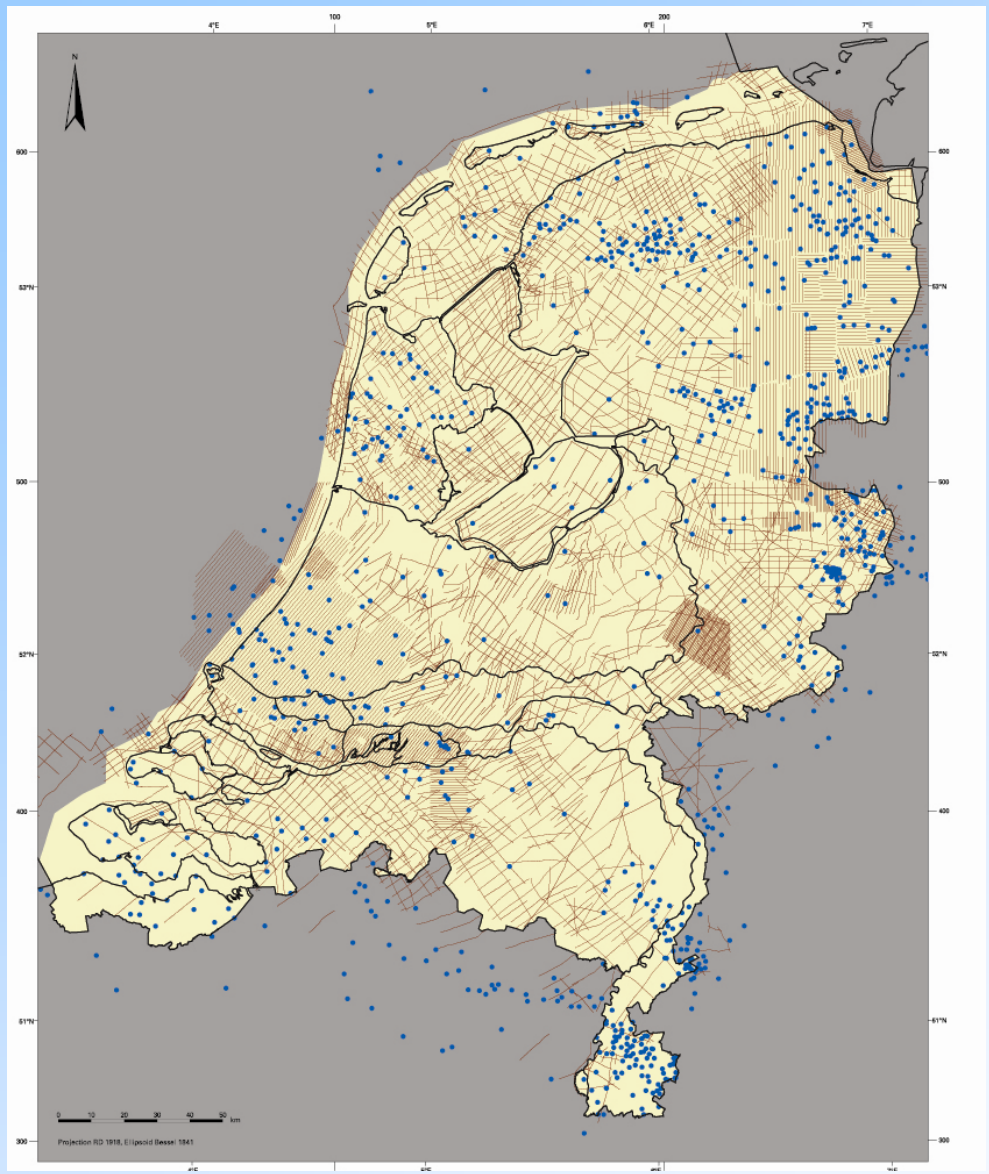
1. **answer to those market needs and**
2. **stimulate the use of geothermal energy in the Netherlands**

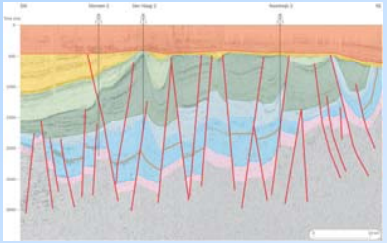
Basic information for geothermal needed

- Geothermal reservoirs **depth** and **thickness** lacking
- Reservoir properties lacking (**kH, T**)
- For users outside oil and gas

Effective use of oil and gas information crucial

Dutch database: over 50 billion Euro of data

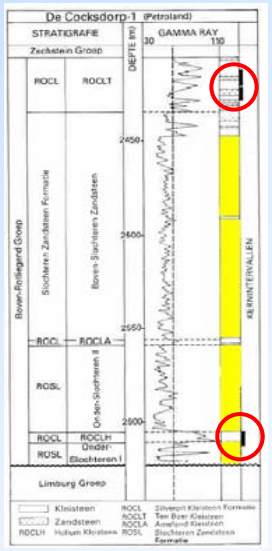




Well & Seismic Data

Wells: 5876 (onshore/offshore)

Seismic: 72.000 km (2D+3D lines)



Log data

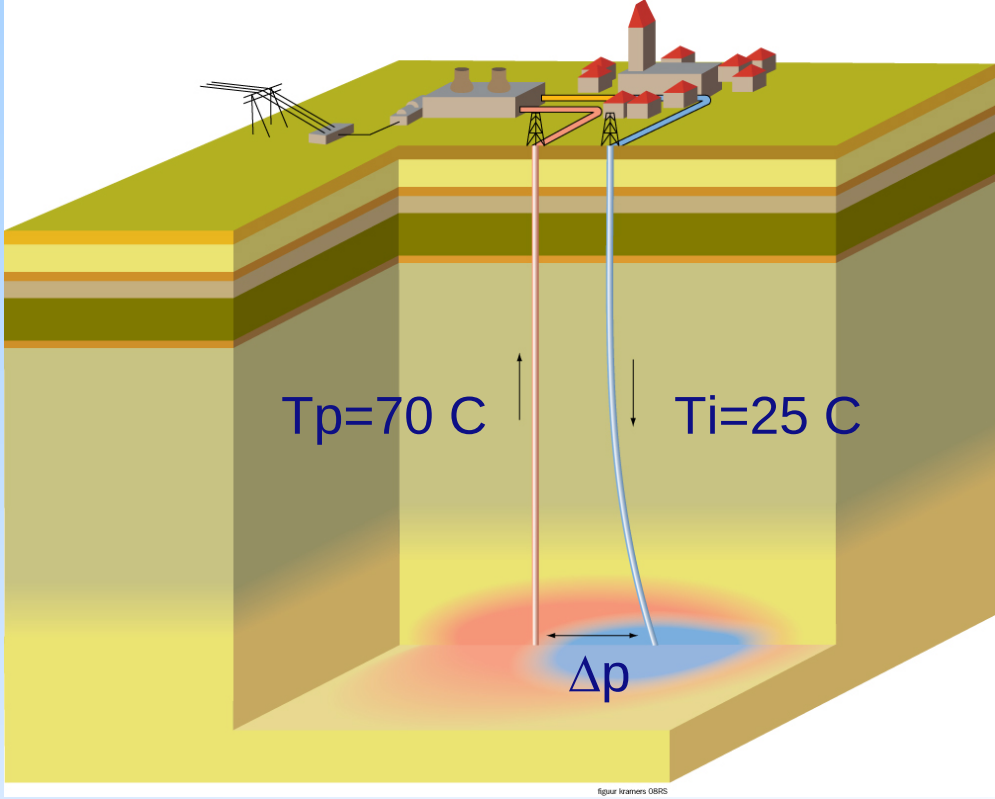
Gamma ray
Sonic
Resistiviteit

Petrophysics

cores: 100 km
Poro/perm: 60.000 measurements
(300.000 total)

Doublet performance

E [MWth] = Q*ΔT * C_P



Flow-rate Q

Permeability X thickness

$$Q = \Delta p \frac{2\pi kH}{\mu\left(\ln\left(\frac{L}{r_w}\right) - S\right)}$$

Viscosity

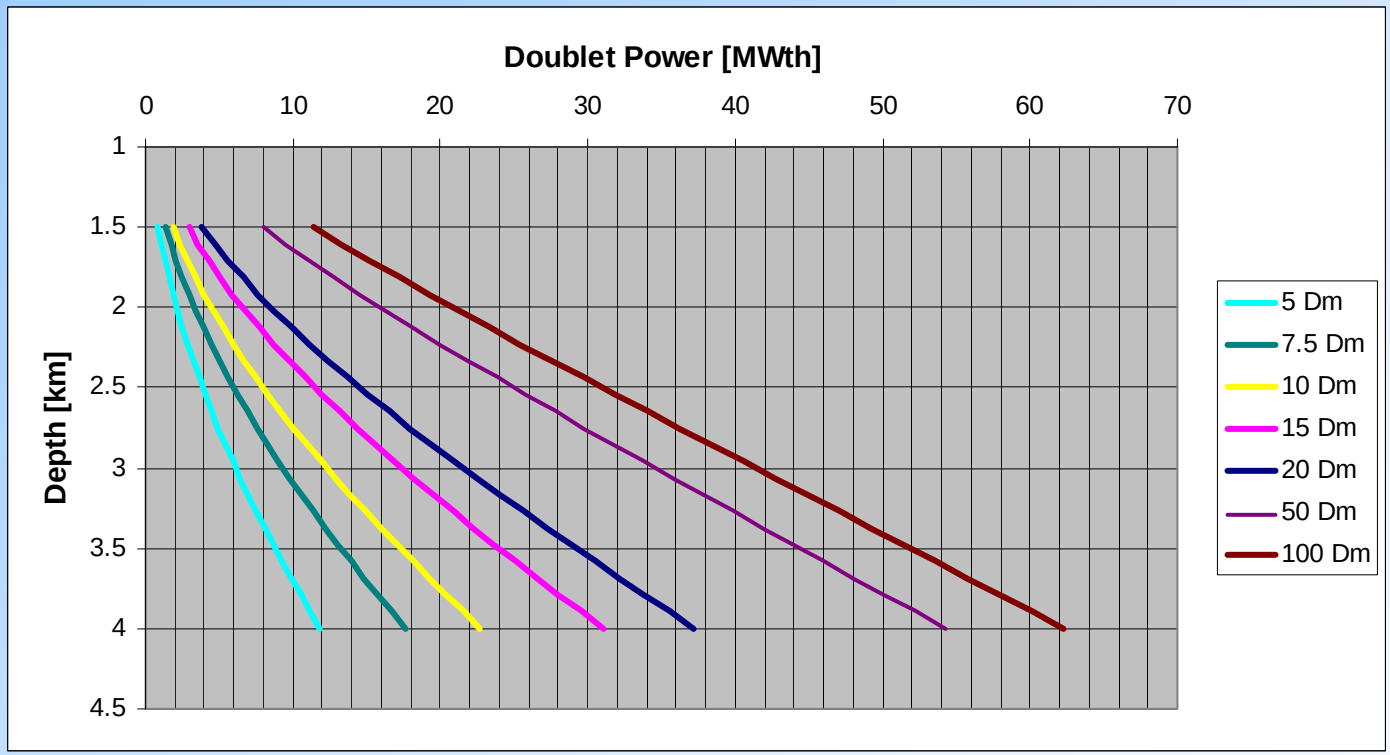
distance

Δp generated by pumps
Which consume electricity

Δp is restricted by safety measures

Δp at surface does not linearly lead to Higher flow rates (friction in tubes)

Sensitivity to transmissivity (kH)



Much effort put in mapping kH

Has strong effect in estimating

1. Performance
2. Potential
3. Economics

Assuming Tempature gradient = 30°C/km

T production = 45
T return = 25

ThermoGIS™ - project

Comprehends:

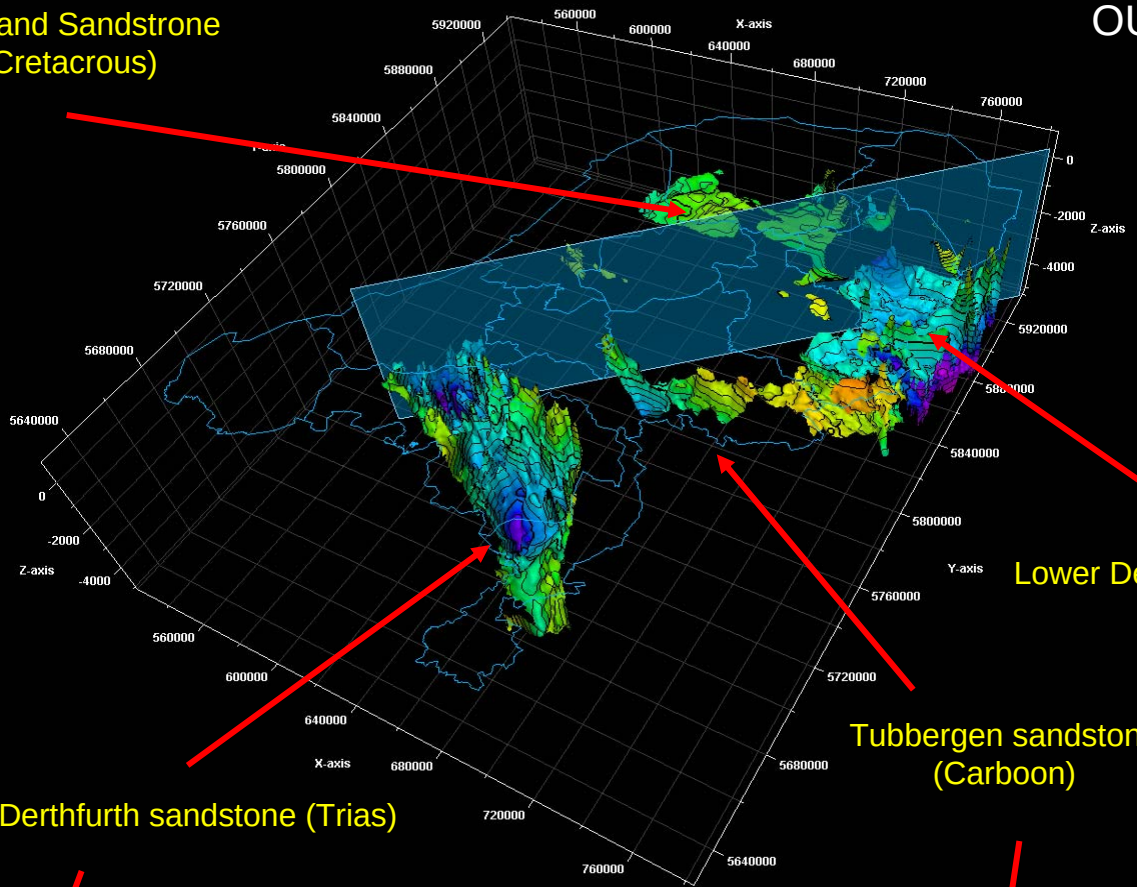
1. **3D mapping reservoirs (aquifers)**
   - Depth
   - Thickness
   - Porosity
   - Permeability
   - Uncertainties
   - Transmissivity (permeability x thickness)
   - Compute potential energy

2. **Development ThermoGIS application**
   - Visualisation map
   - Performance assessment tool
   - Economic assessment tool

3D-Geological model

Friesland Sandstrone (Cretacrous)

OUPUT DATA:
Depth
Thickness

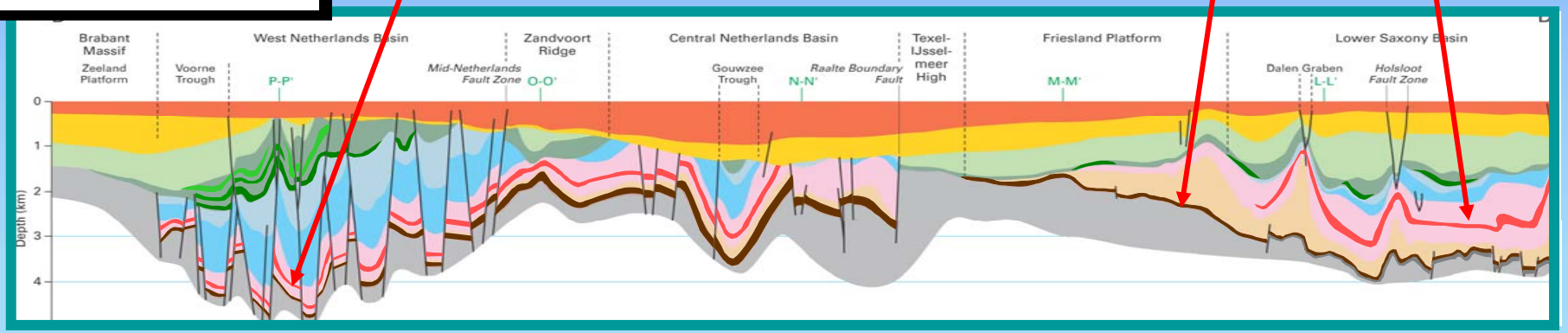


Upper North Sea Group
Lower and Middle North Sea Groups
Chalk Group
Rijnland Group
Schieland and Niedersachsen Groups
Altena Group
Lower and Upper Germanic Trias Groups
Zechstein Group
Lower and Upper Rotliegend Groups
Limburg Group
Carboniferous Limestone Group
Devonian
Silurian
Ordovician

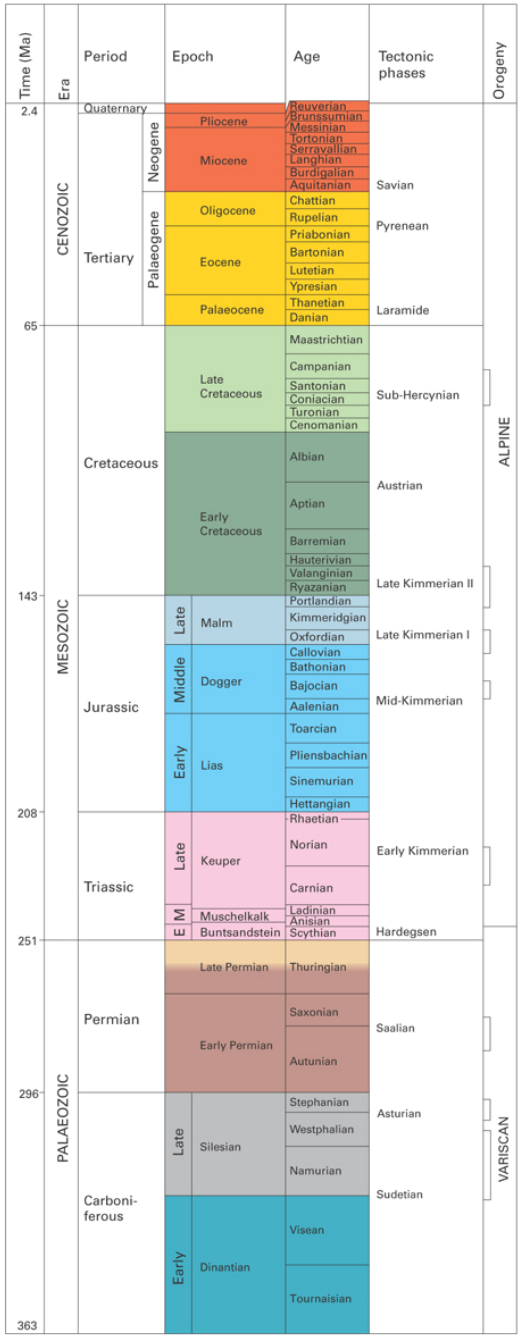
Lower Detfurth sandstone (Trias)

Tubbergen sandstone (Carboon)

Derthfurth sandstone (Trias)



Potential reservoirs



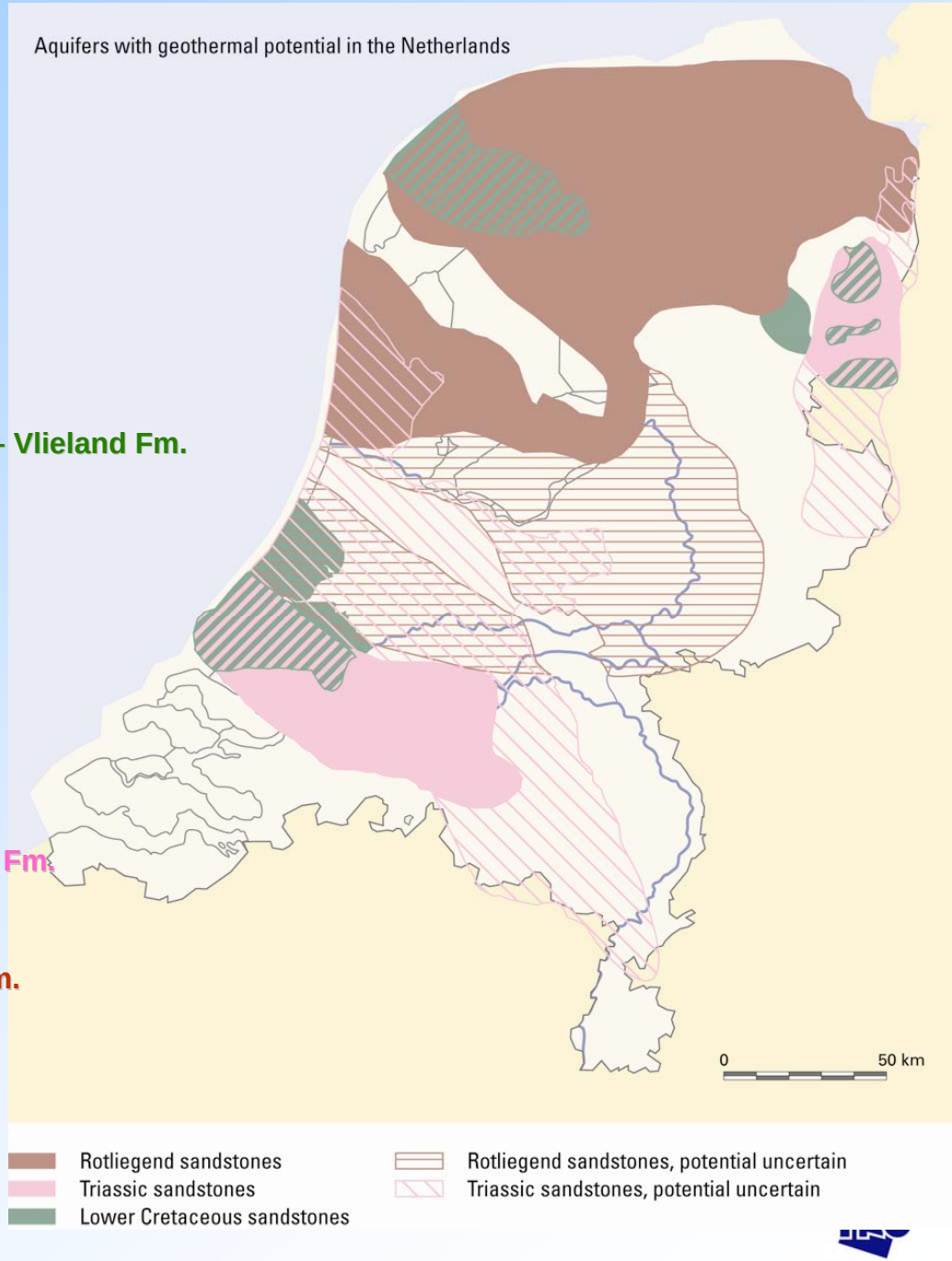
Lower Cretaceous – Vlieland Fm.

(Werkendam Fm.)

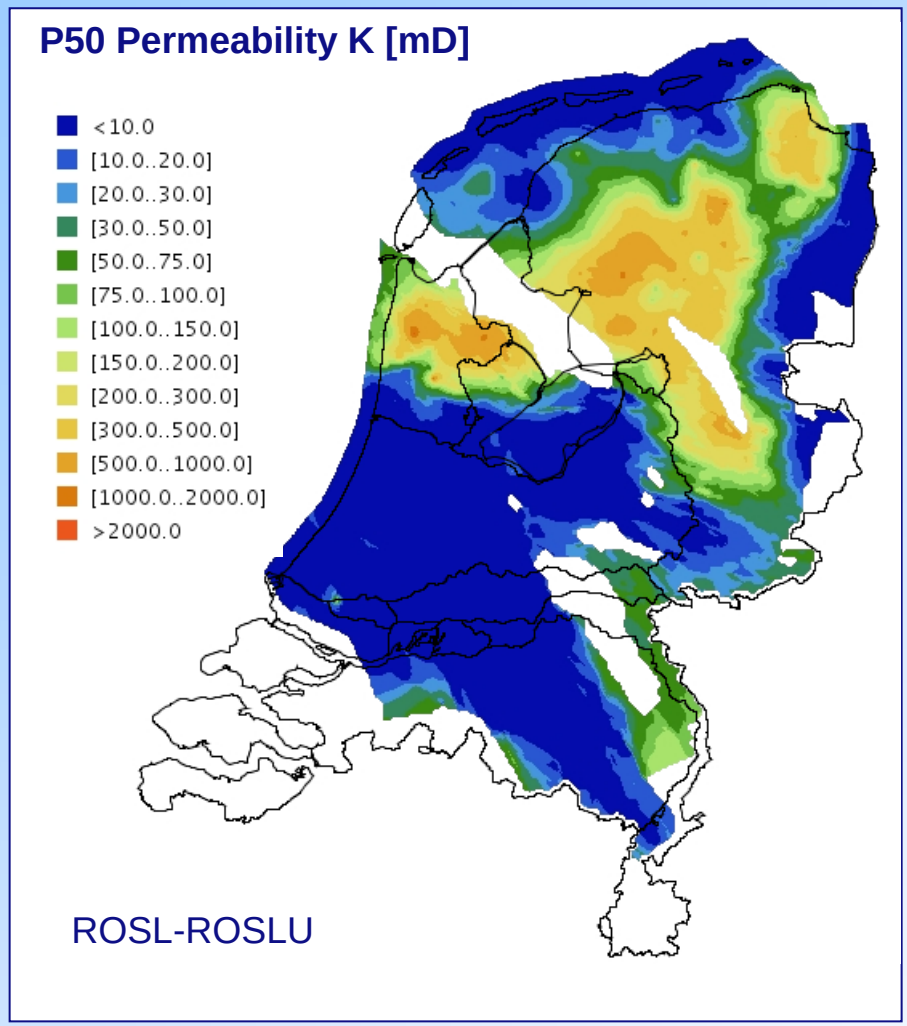
Röt Fm.
Detfurth and Volpriehausen Fm.

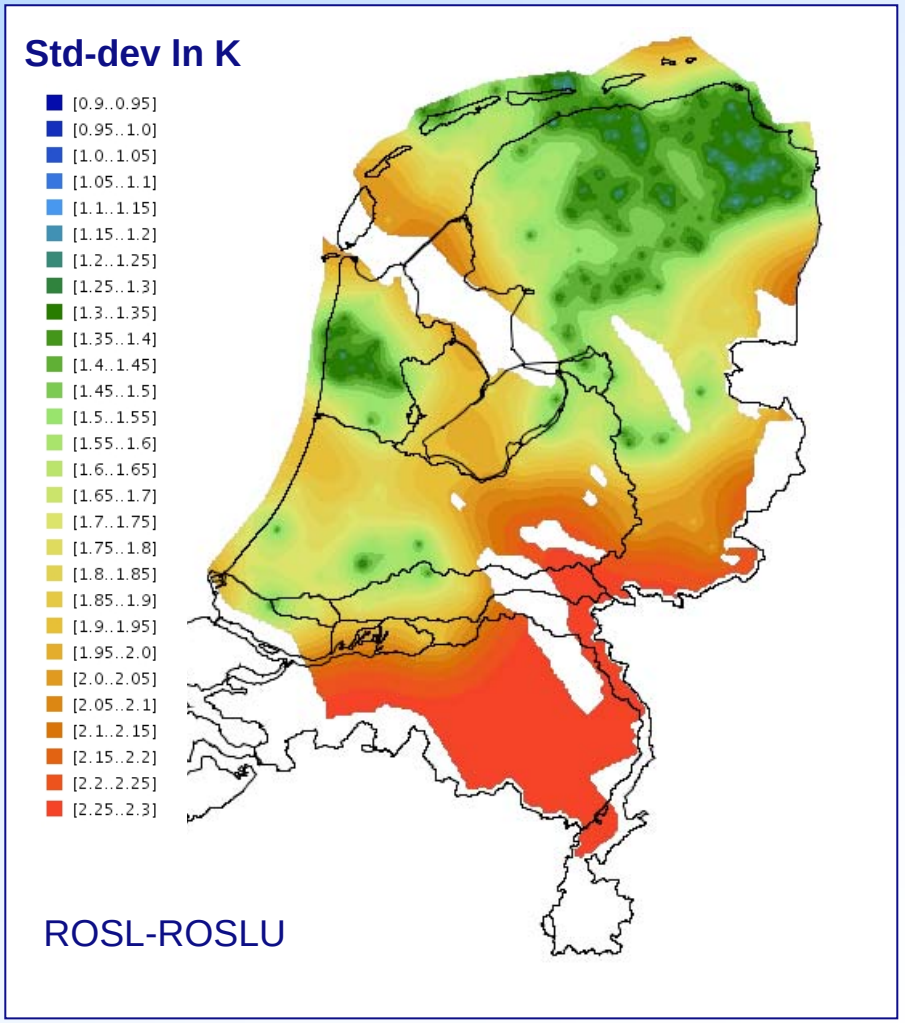
Slochteren Fm.

(Limburg Group)

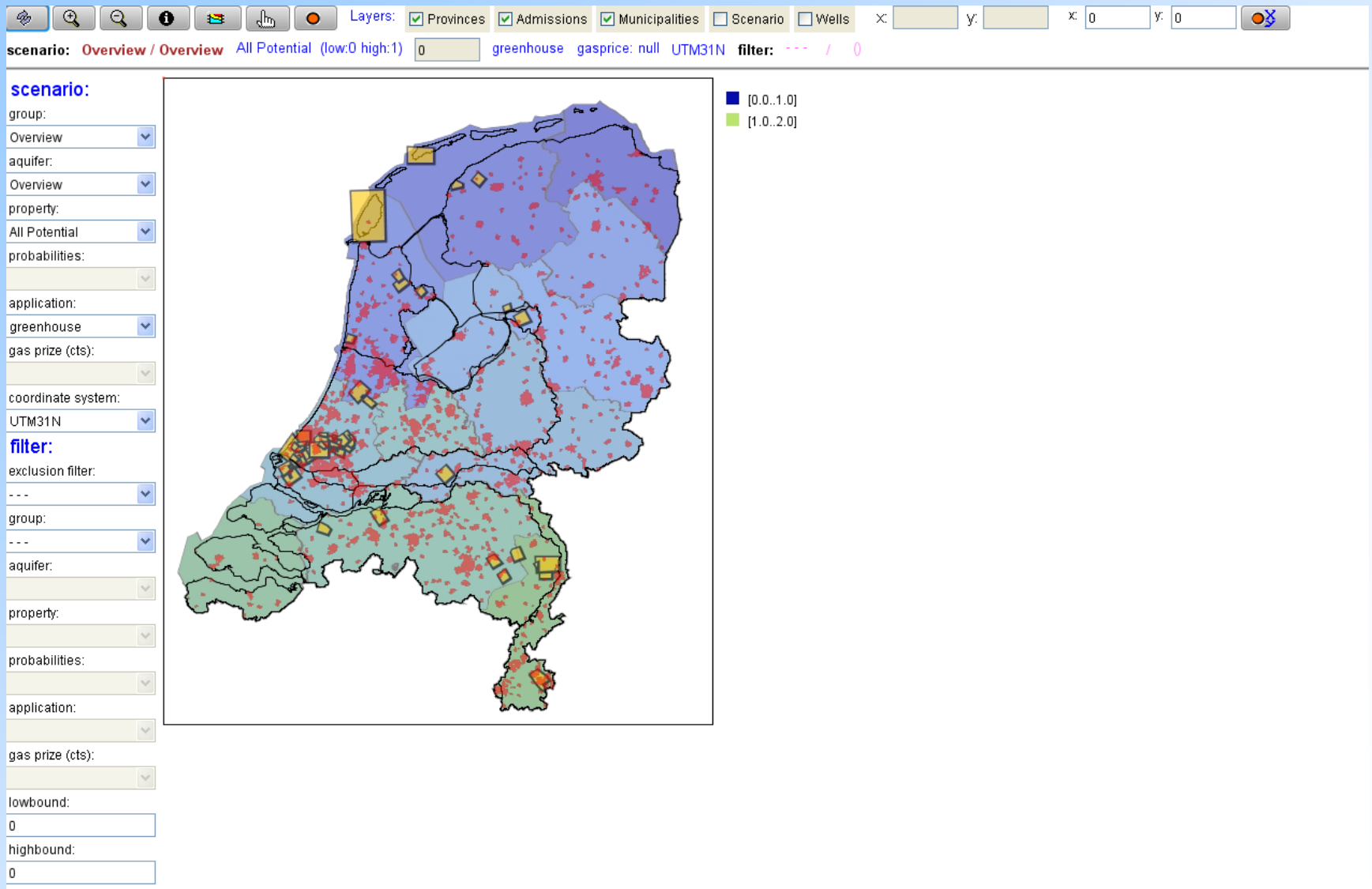


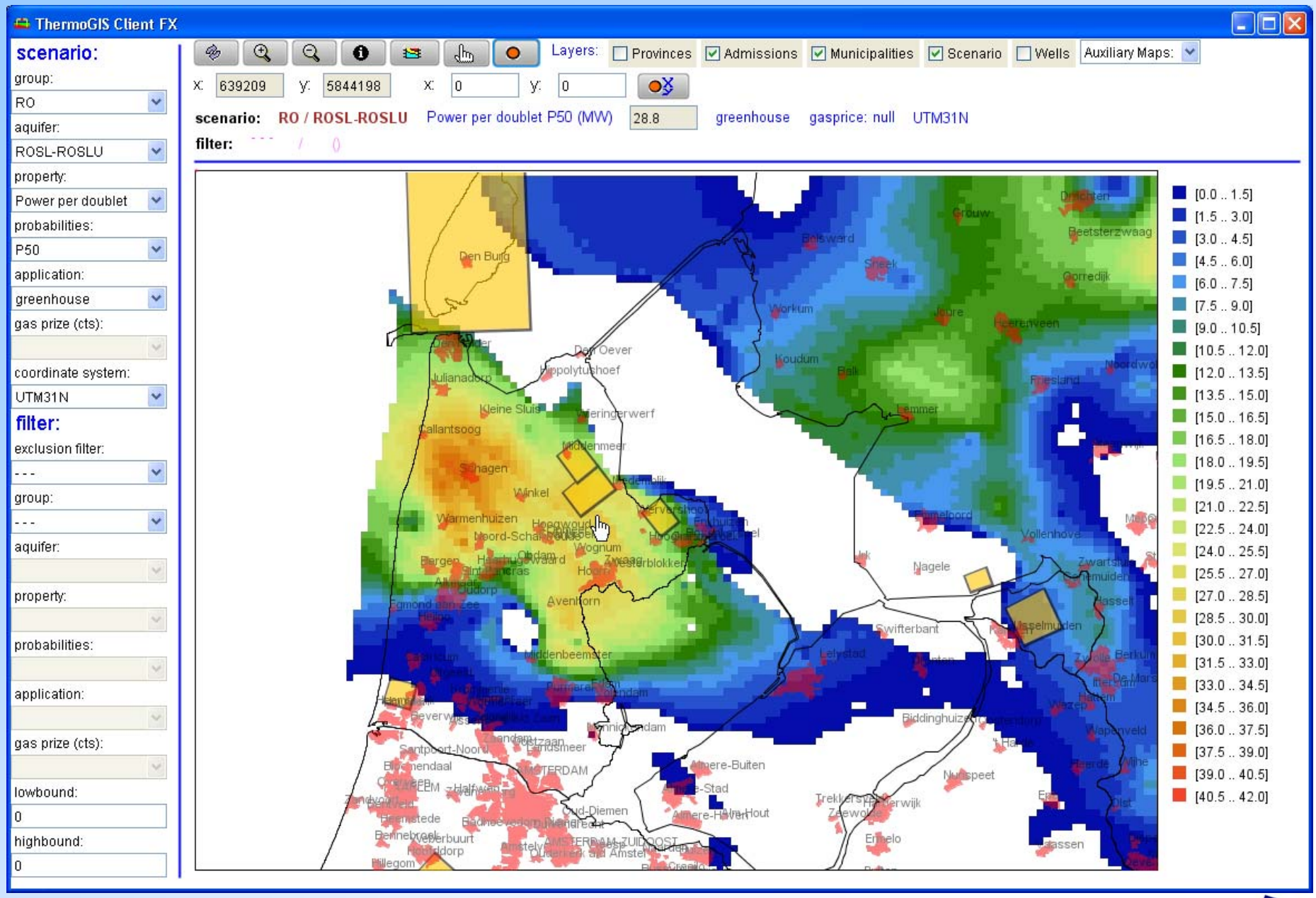
Example of permeability mapping and uncertainties





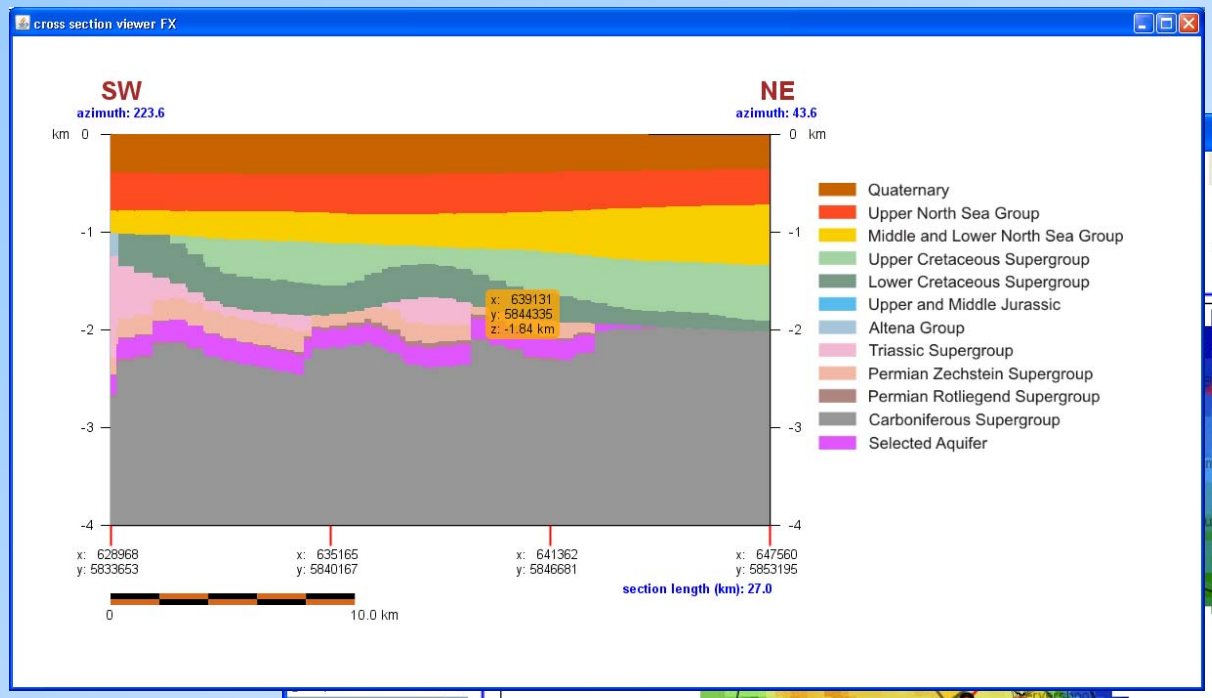
ThermoGIS™ - Opening screen





THERMOGIS Aquifer transmissivity [Dm]

ThermoGIS™ – Geological properties



THERMOGIS™ doublet thermal Power [MWth], site specific information

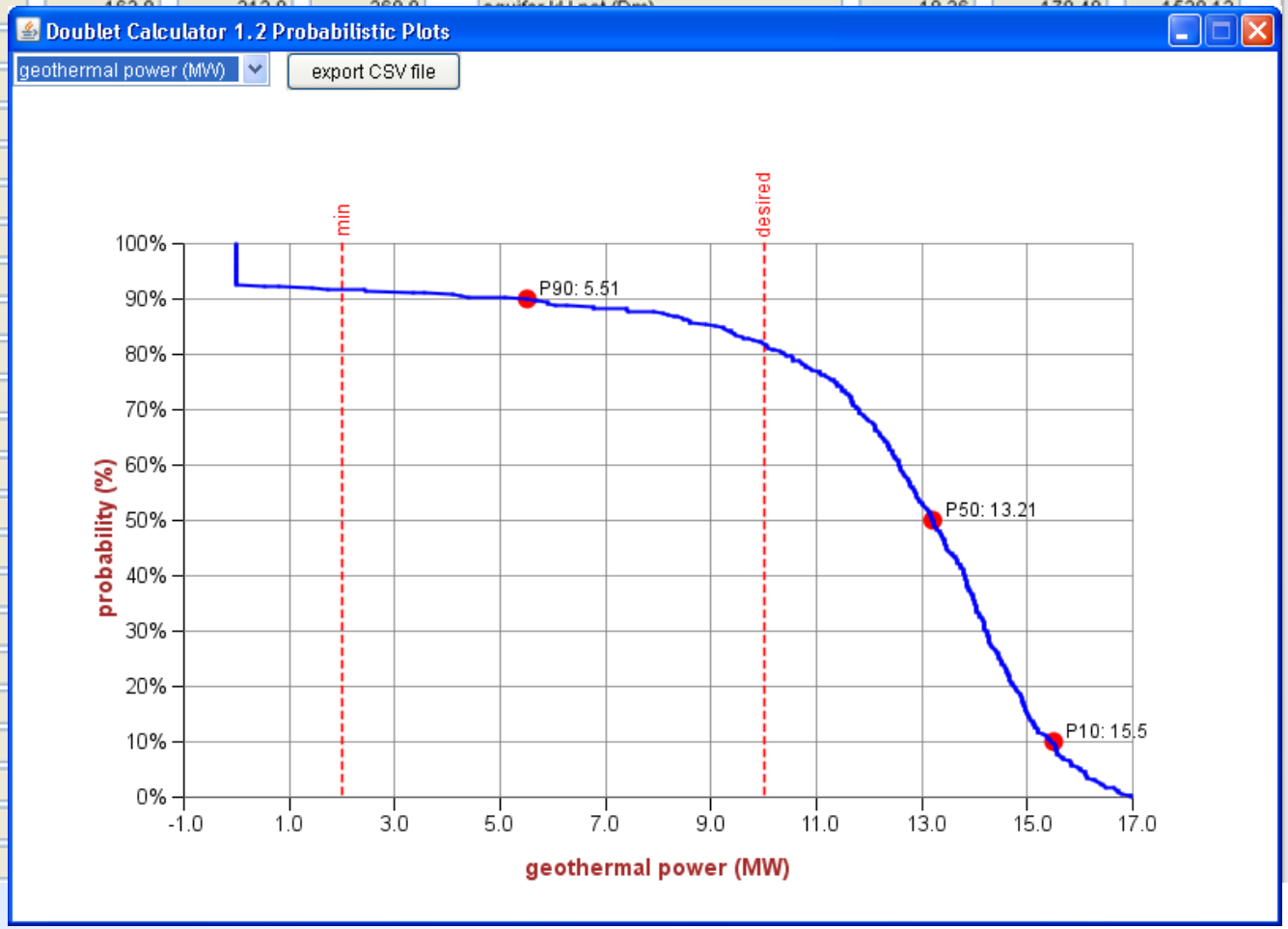
ThermoGIS™ – Performance assessment module

Geotechnics (Input)

	min	median	max
aquifer gross thickness (m)			
aquifer net to gross (-)			
aquifer permeability (mD)			
aquifer top of production (m)			
aquifer top of injection (m)			
[aquifer pressure production (bar)]			
[aquifer pressure injection (bar)]			
surface temperature (°C)			
geothermal gradient (°C/m)			
aquifer salinity (ppm)			
production well deviation (m)			
injection well deviation (m)			
well distance at aquifer level (m)			
tubing inner diameter (inch)			
well outer diameter (inch)			
tubing roughness (milli-inch)			
skin production (-)			
skin injection (-)			
production pump depth (m)			
pump efficiency (-)			
pump pressure difference (bar)			
injection temperature (°C)			
number of simulation runs (-)			

Geotechnics (Output)

Monte Carlo cases (stochastic inputs)	P90	P50	P10



ThermoGIS™ – Economical assessment module

time series plots | stochastic plots

Economics (Input)

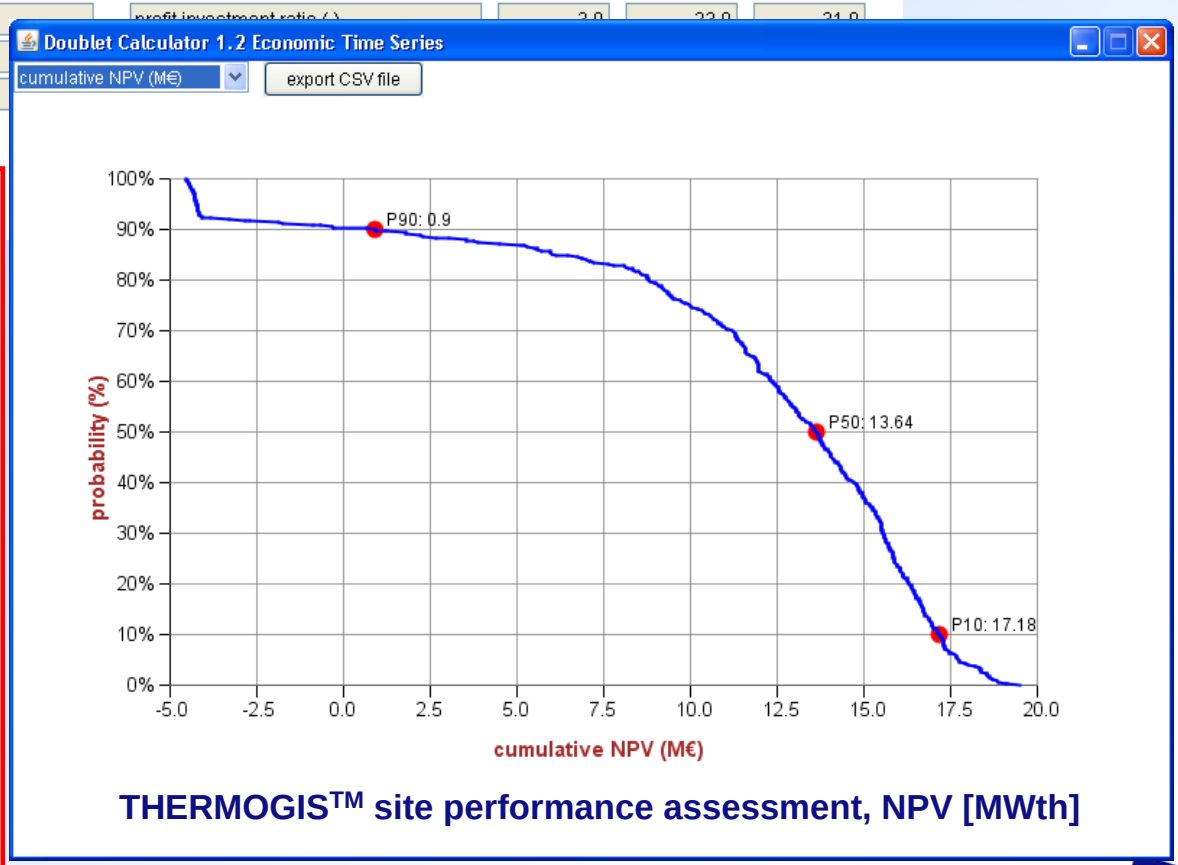
	min	median	max
uplift (yrs)		0.0	
depreciation (yrs)		10.0	
tax rate (%)		26.0	
discount rate (%)		7.0	
electricity price to buy (cts/kWh)	8.0	8.0	
heat price to sell (€/GJth)	6.0	6.0	

Economics (Output)

	P90	P50	P10
CAPEX well (M€)	6.0	7.0	7.0
cumulative NPV (M€)	0.0	5.0	7.0
internal rate of return (%)	6.0	17.0	19.0

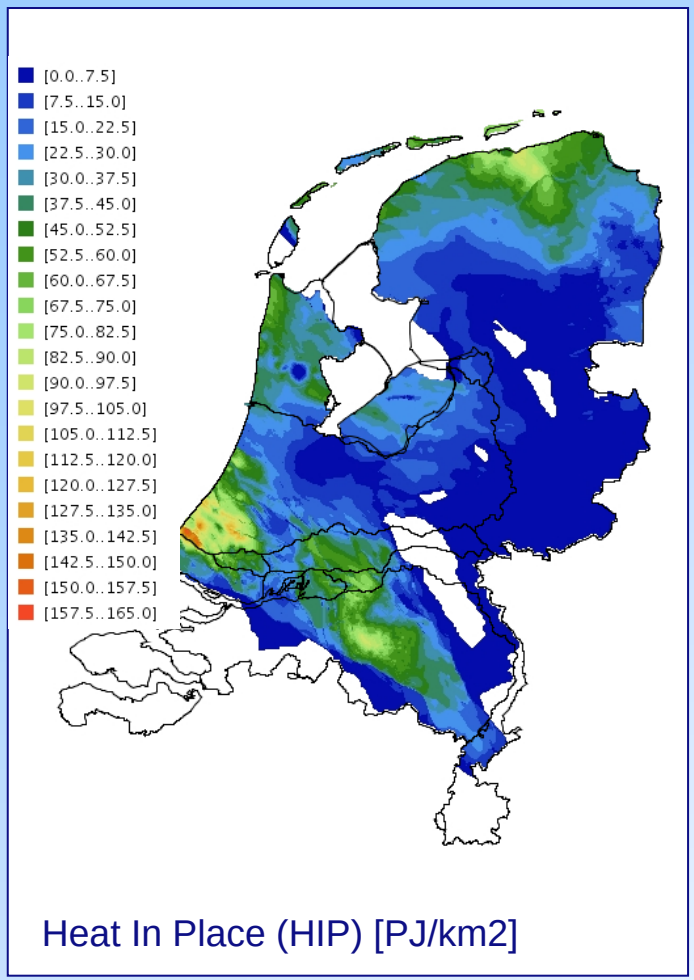
Also

- pump power produced
- fixed opex rate
- total OPEX
- total CAPEX
- CAPEX well
- CAPEX heat exchanger
- CAPEX stimulation
- CAPEX pump
- variable OPEX TS
- thermal power per year
- undiscounted CF
- DCF
- cumulative DCF
- gross revenues heat
- opex electricity buy

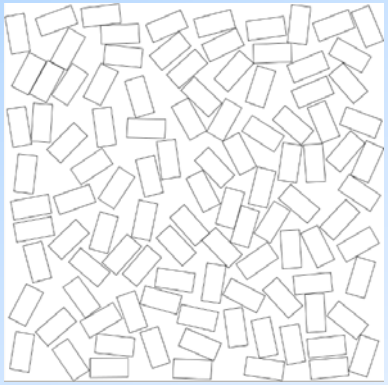


THERMOGIS™ site performance assessment, NPV [MWth]

ThermoGIS - Potential energy maps

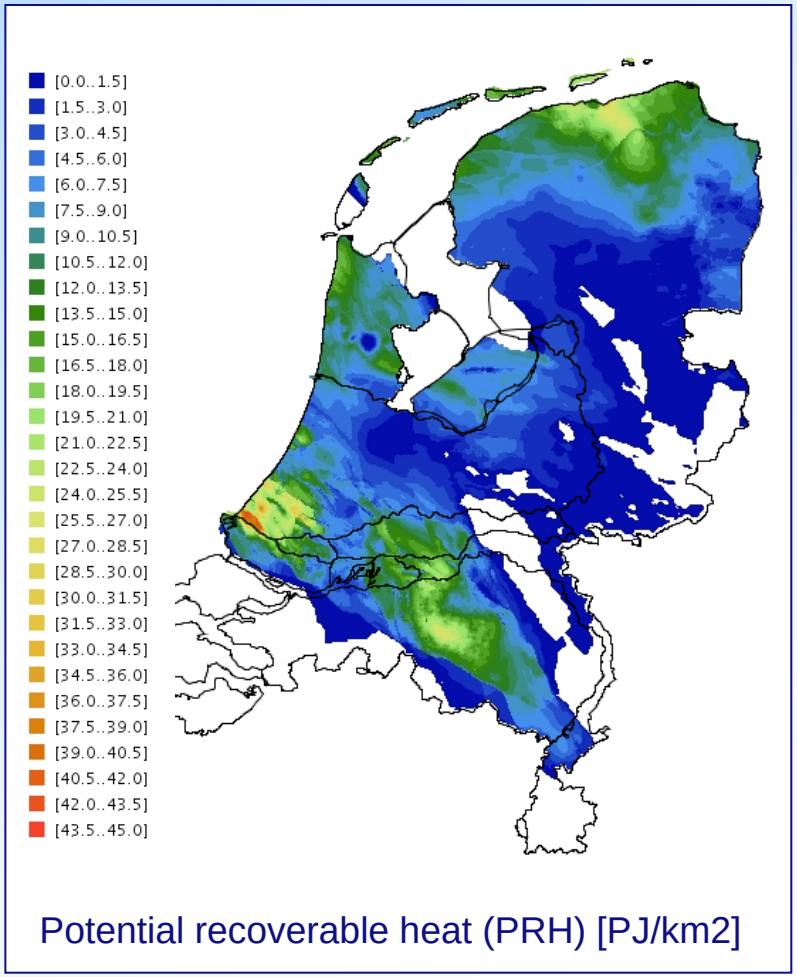


Heat In Place (HIP) [PJ/km2]



Due to infrastructure and geology (e.g. faults) spatial distribution of doublet will be random distributed

= less efficient use of heat



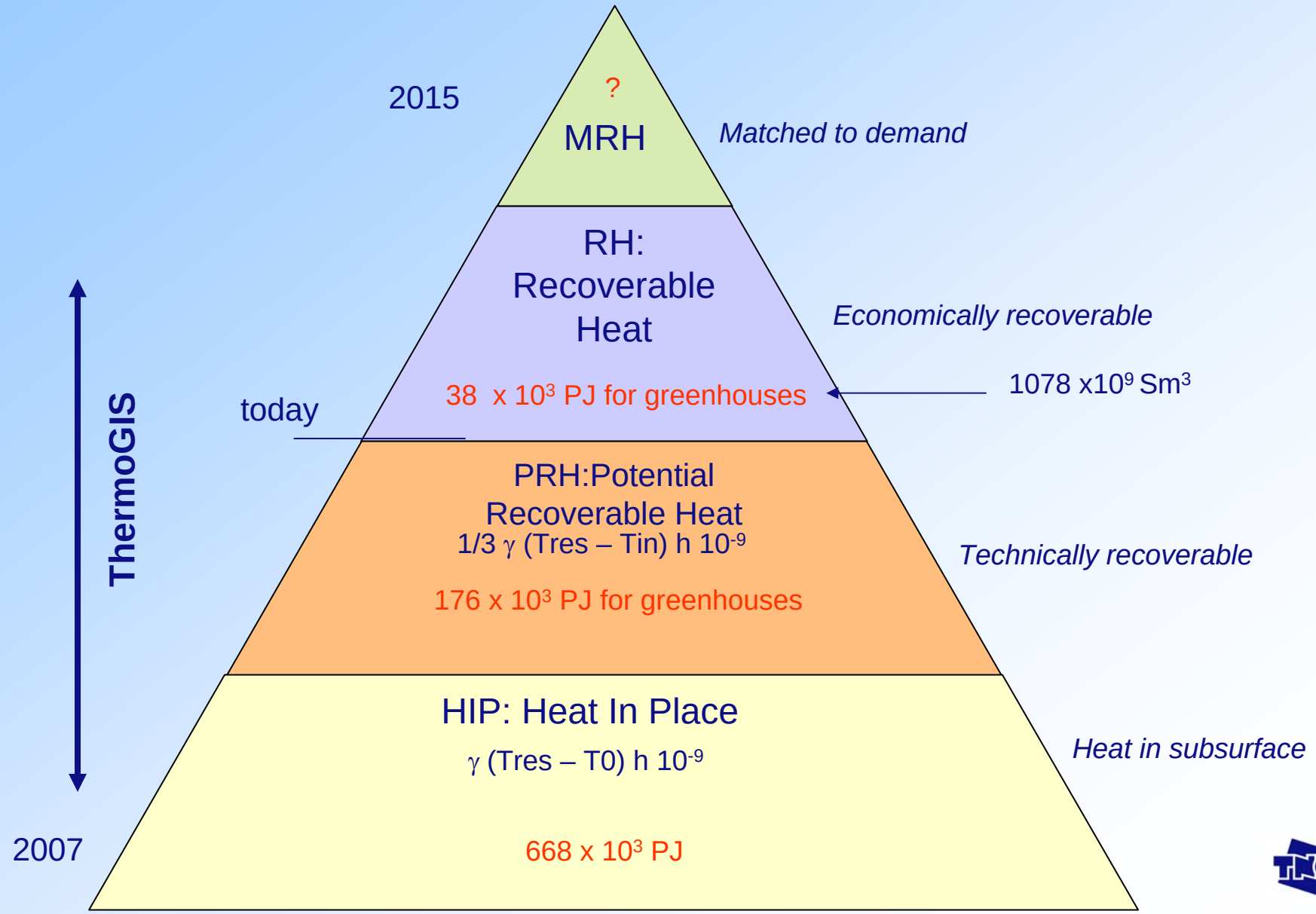
Potential recoverable heat (PRH) [PJ/km2]

HIP [PJ/km2] $=\gamma$ (Tres – T0) h 10^{-9}

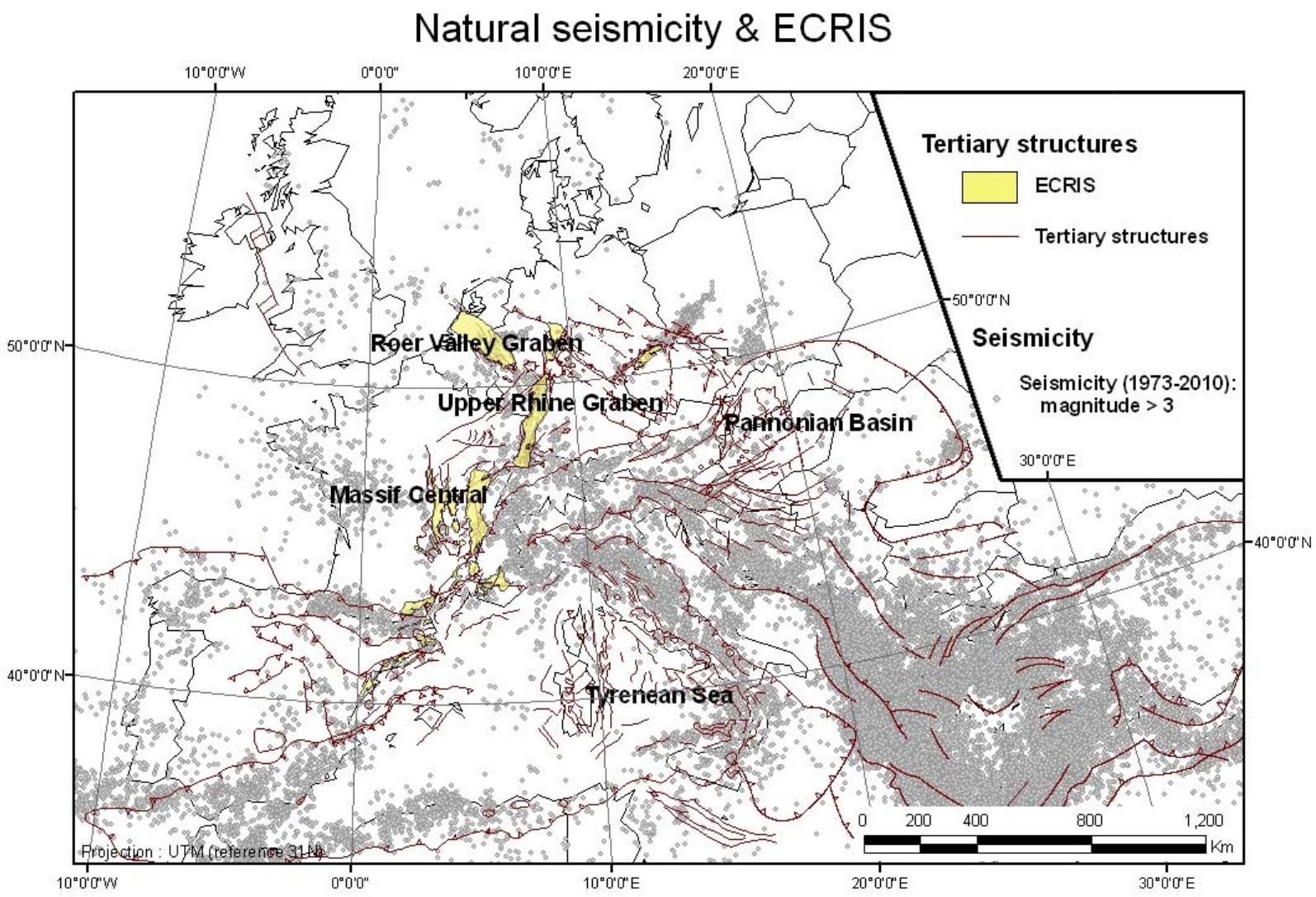
PRH [PJ/km2] = 1/3 HIP

Greenhouse Tres = 45C, Tin =25C

Heat production: from theoretical to practical capacity

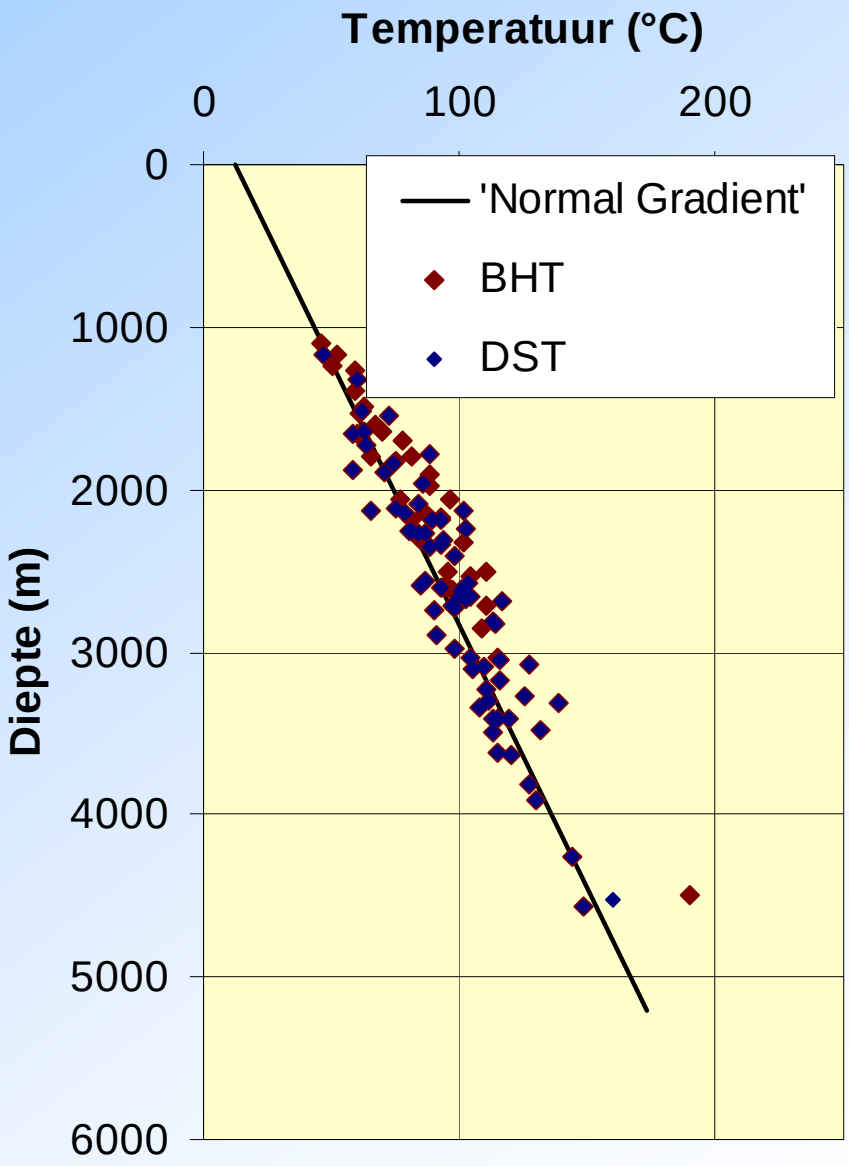


Scope for Electricity production (EGS)

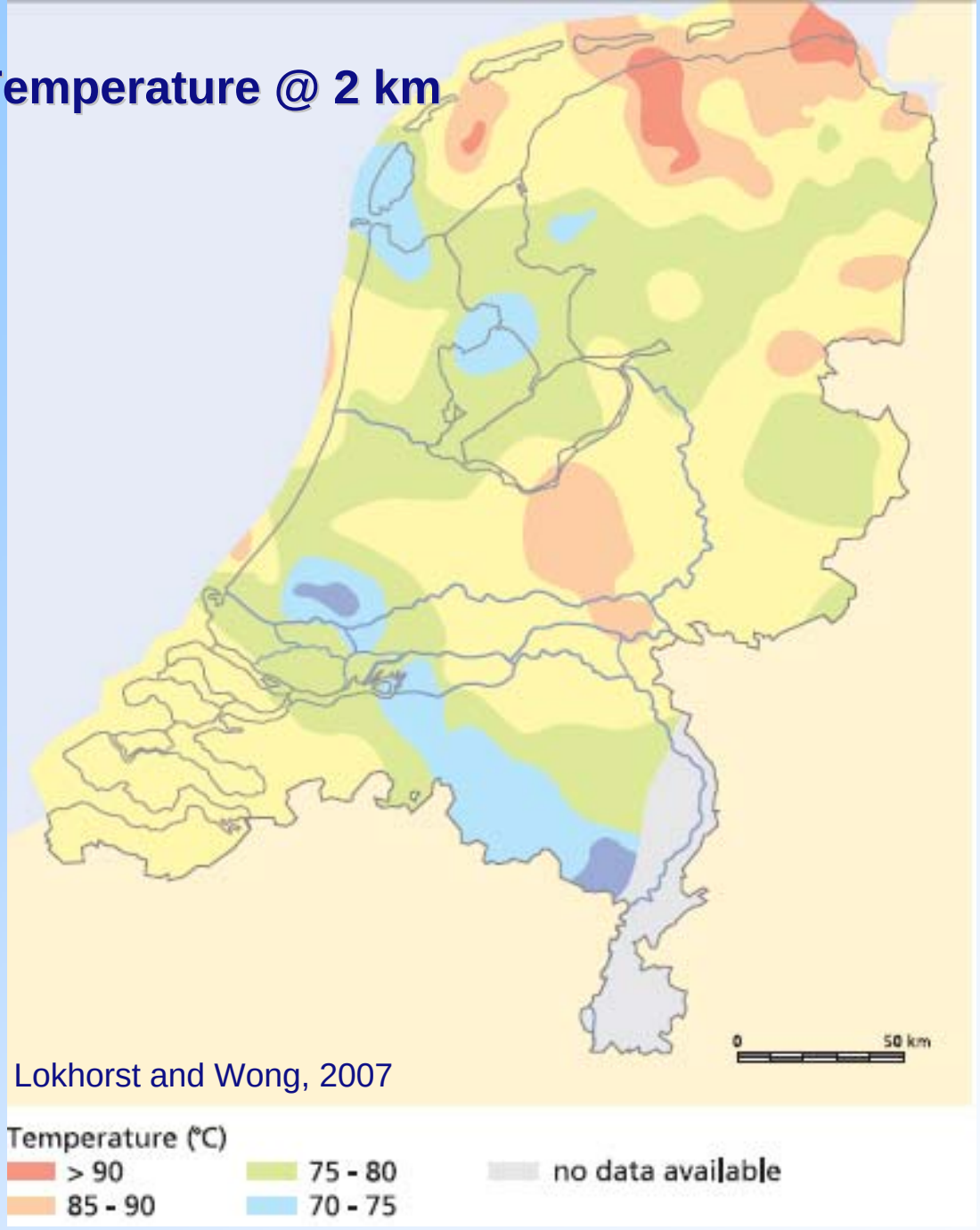


Temperature data

- First order assumption gradient 30 °C/km
- Recent compilation of Drill Stem Test (DST) and Bottom Hole Temperatures (BHT) corrected wells show temperature in access of gradient

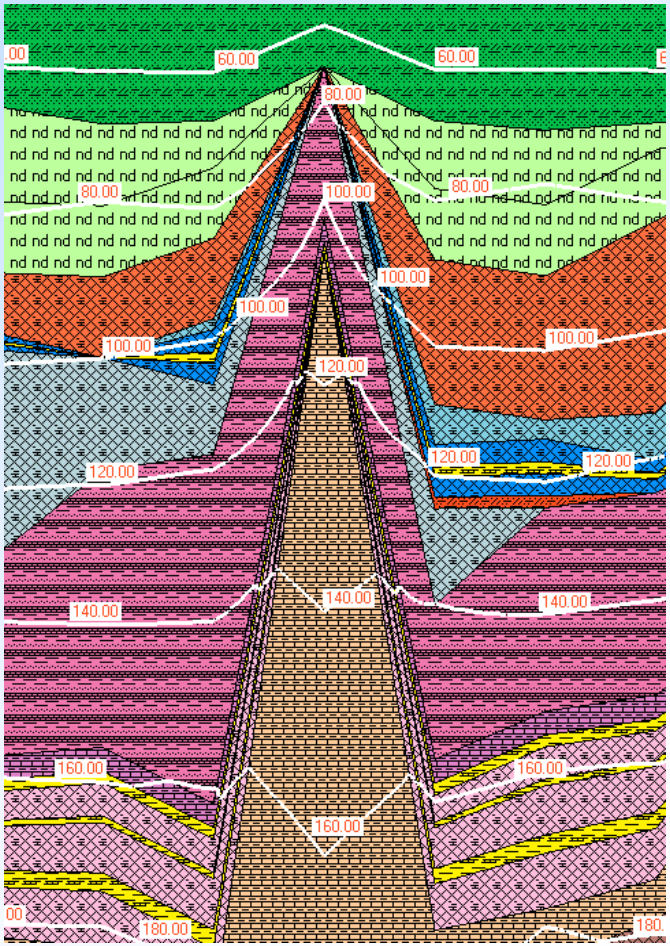


Temperature @ 2 km



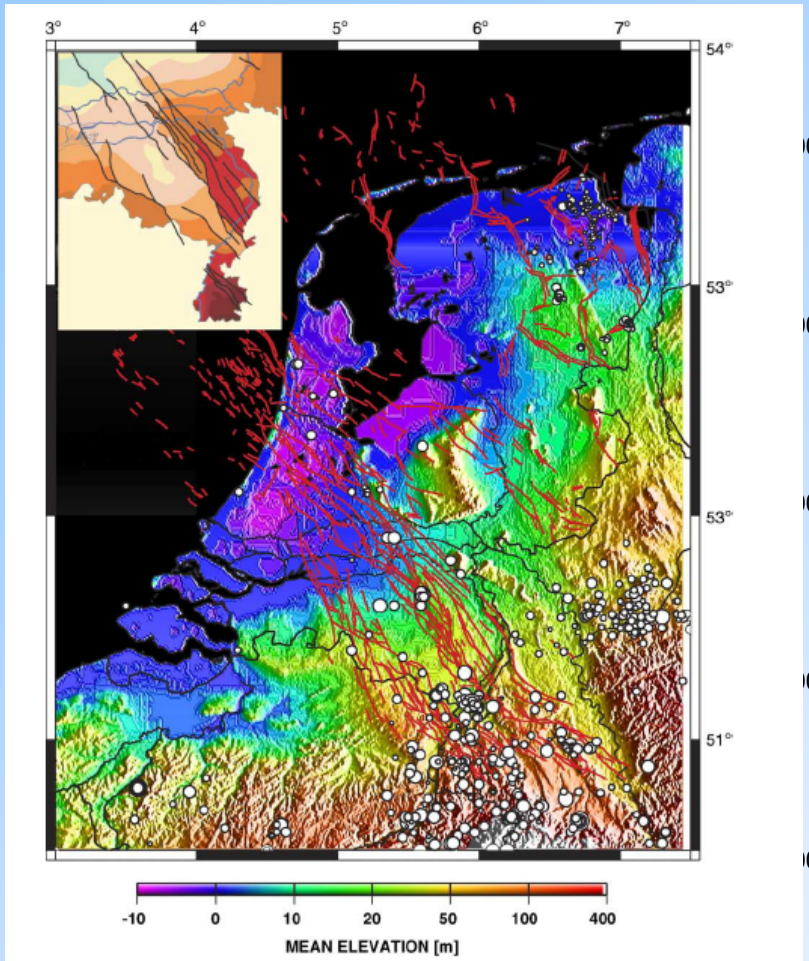
Lokhorst and Wong, 2007

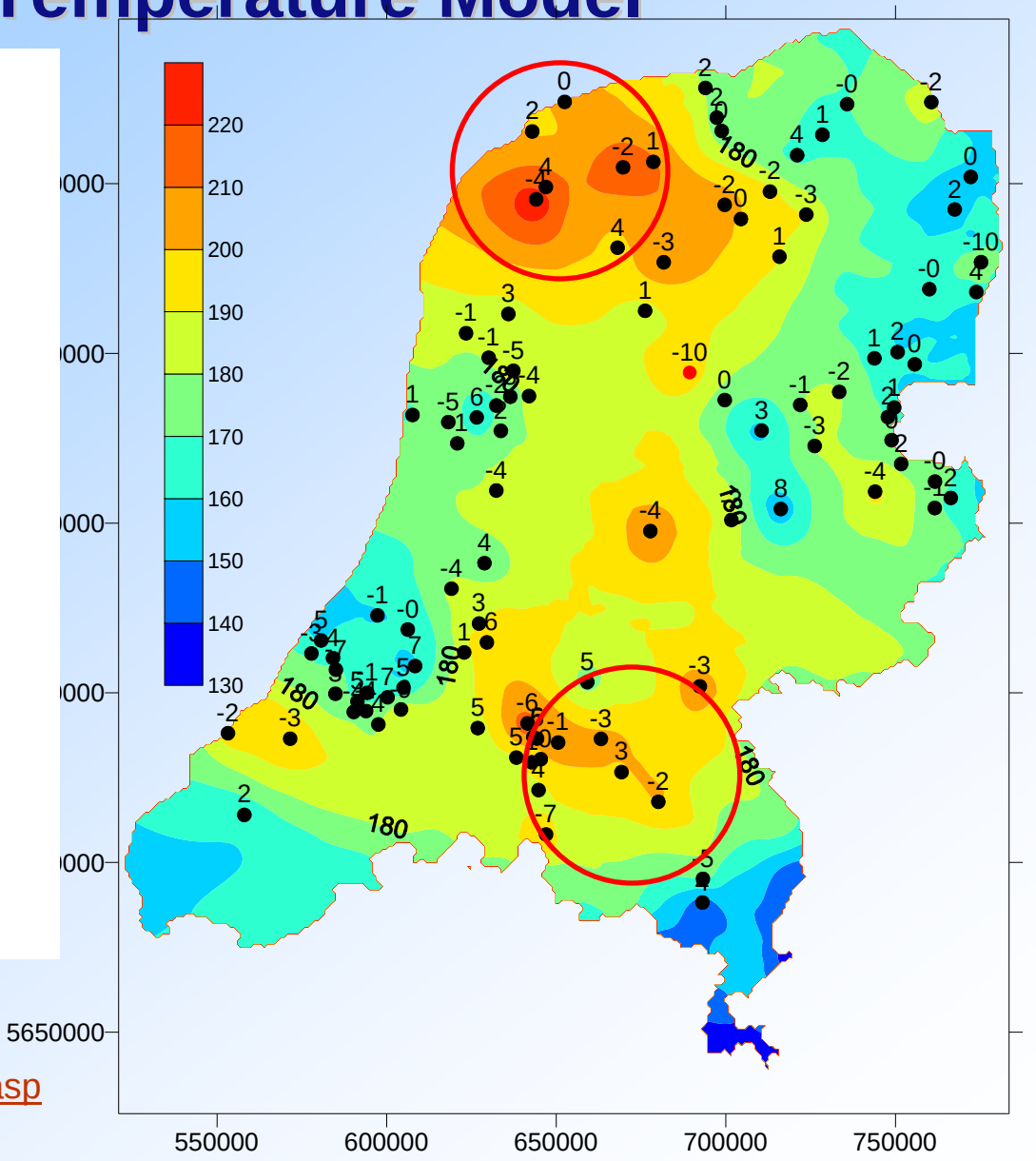
Deeper/lateral Requires better models



average ca 30 °C/km

Under construction: Temperature Model





FAST ANALYTICAL MODEL for EGS, EXCEL
http://engine.brgm.fr/DecisionSupportSystem.asp

Potential 100MWe - 3GWe

Conclusions

- Oil and gas data excellent stepping stone for geothermal exploration
- Strong diversity of stakeholders in geothermal
- ThermoGIS
  - Mapping and compilation tailored to stakeholders questions
  - Dedicated information extraction and performance assessment tools
  - Freeware

- Expected realisation 30-70x10^3 PJ → 150PJ/y for 100s of years
- Expected realisation electricity 100s MWe – 3GWe

- 2020-2030: 1-3% CO2 reduction, mostly by direct use of heat
- 2050: 10% CO2 reduction including EGS

www.ThermoGIS.nl

….Thank you for your attention…

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