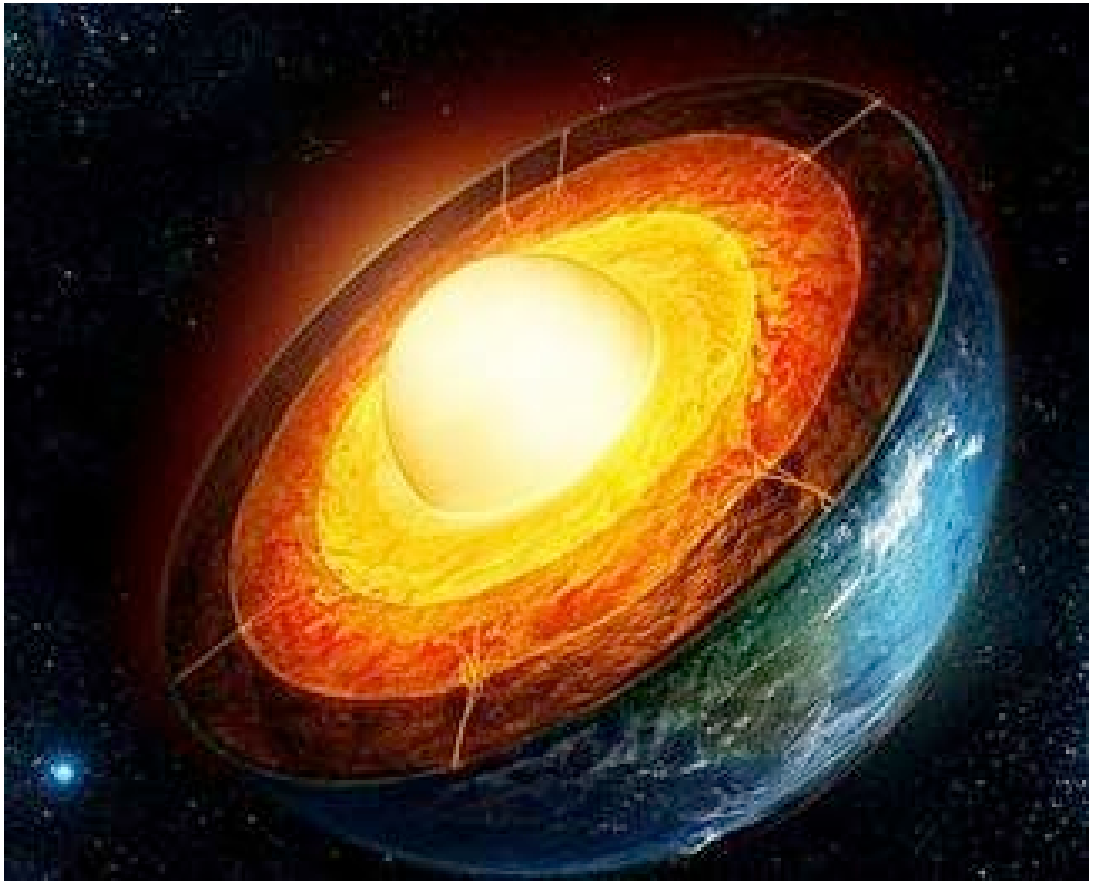

Geothermal Efforts in Groningen

Rien Herber
Alex Daniilidis

ESRIG Symposium, 27 march 2018

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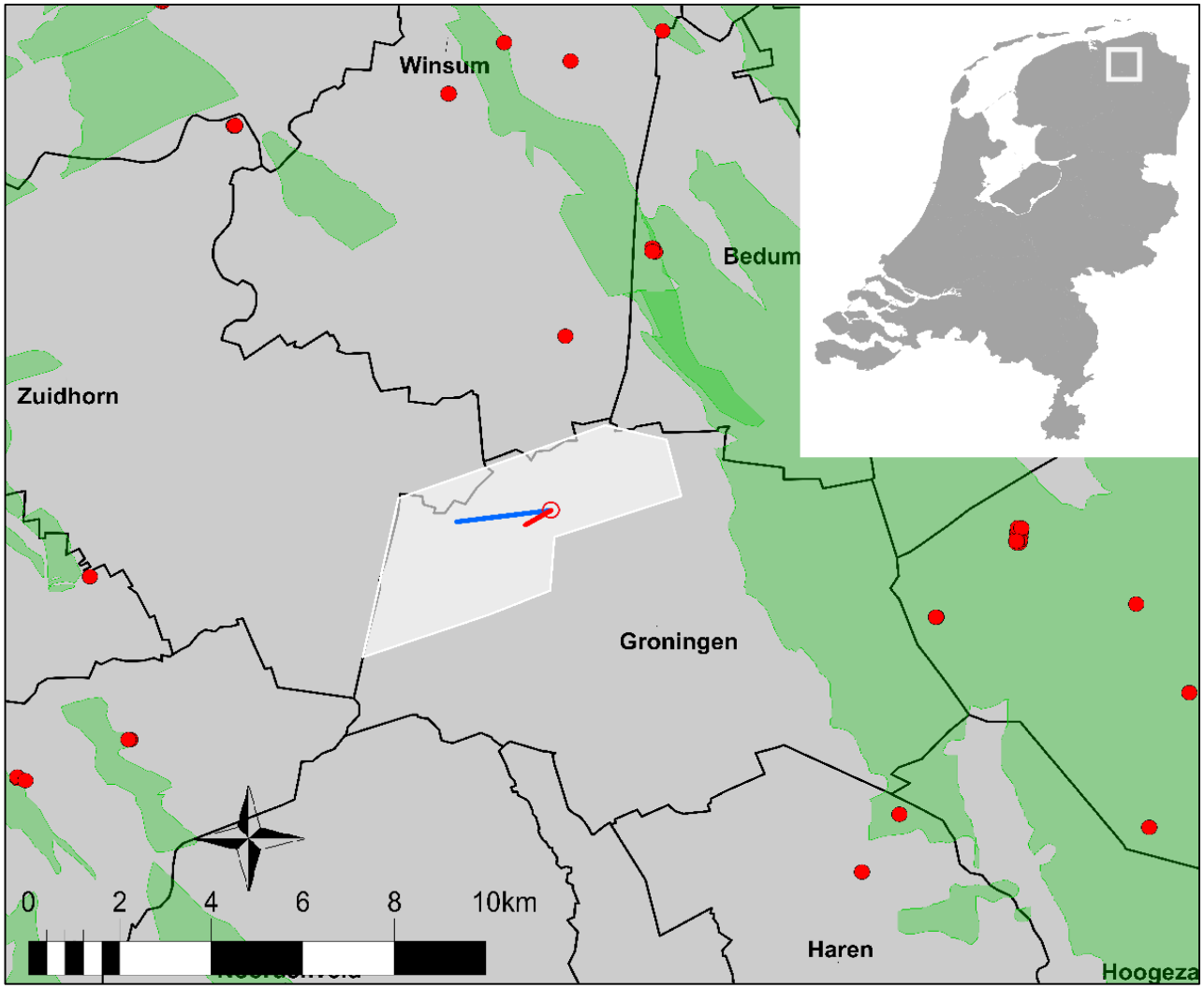
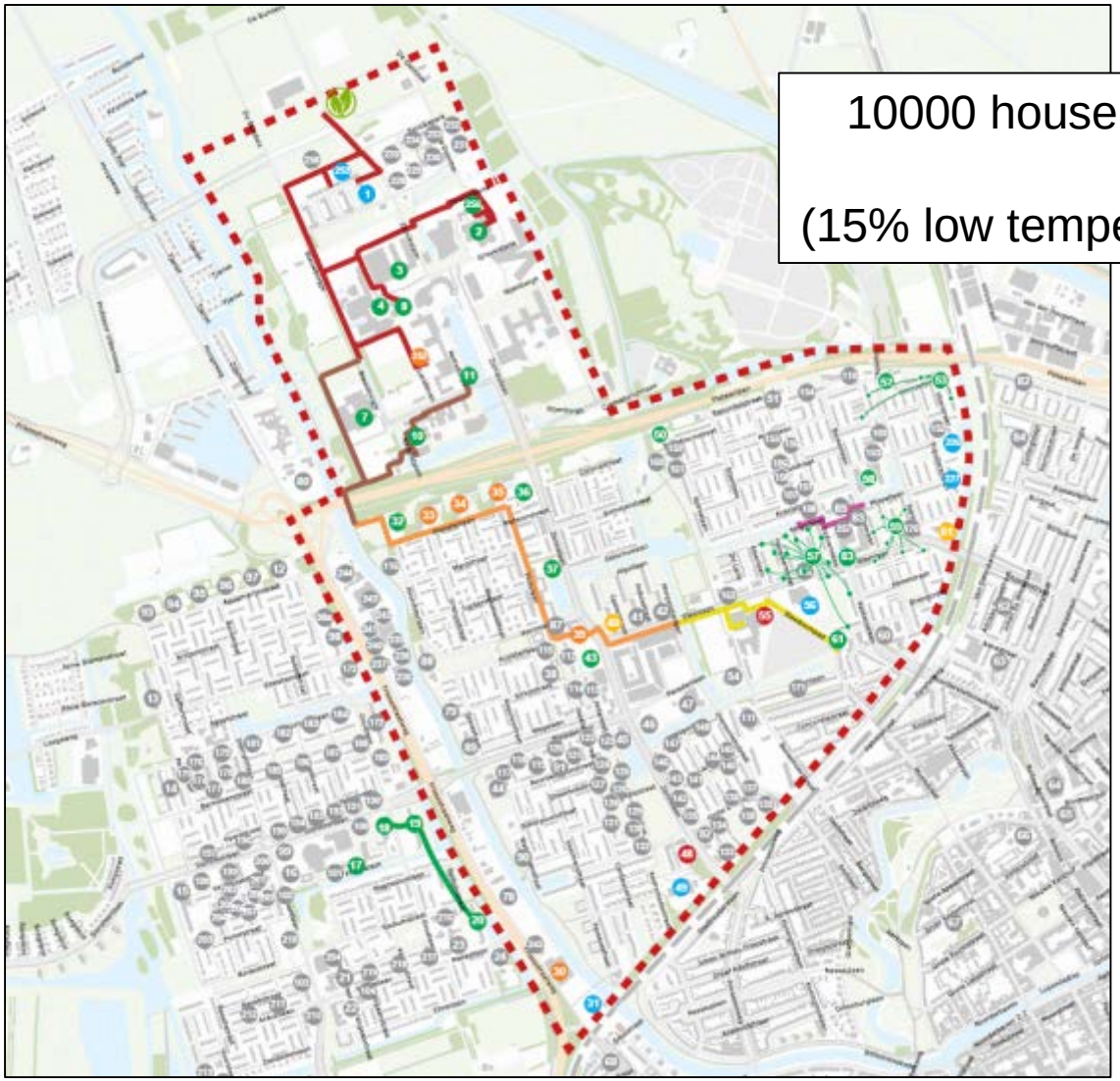
Location of Groningen Geothermal Concession



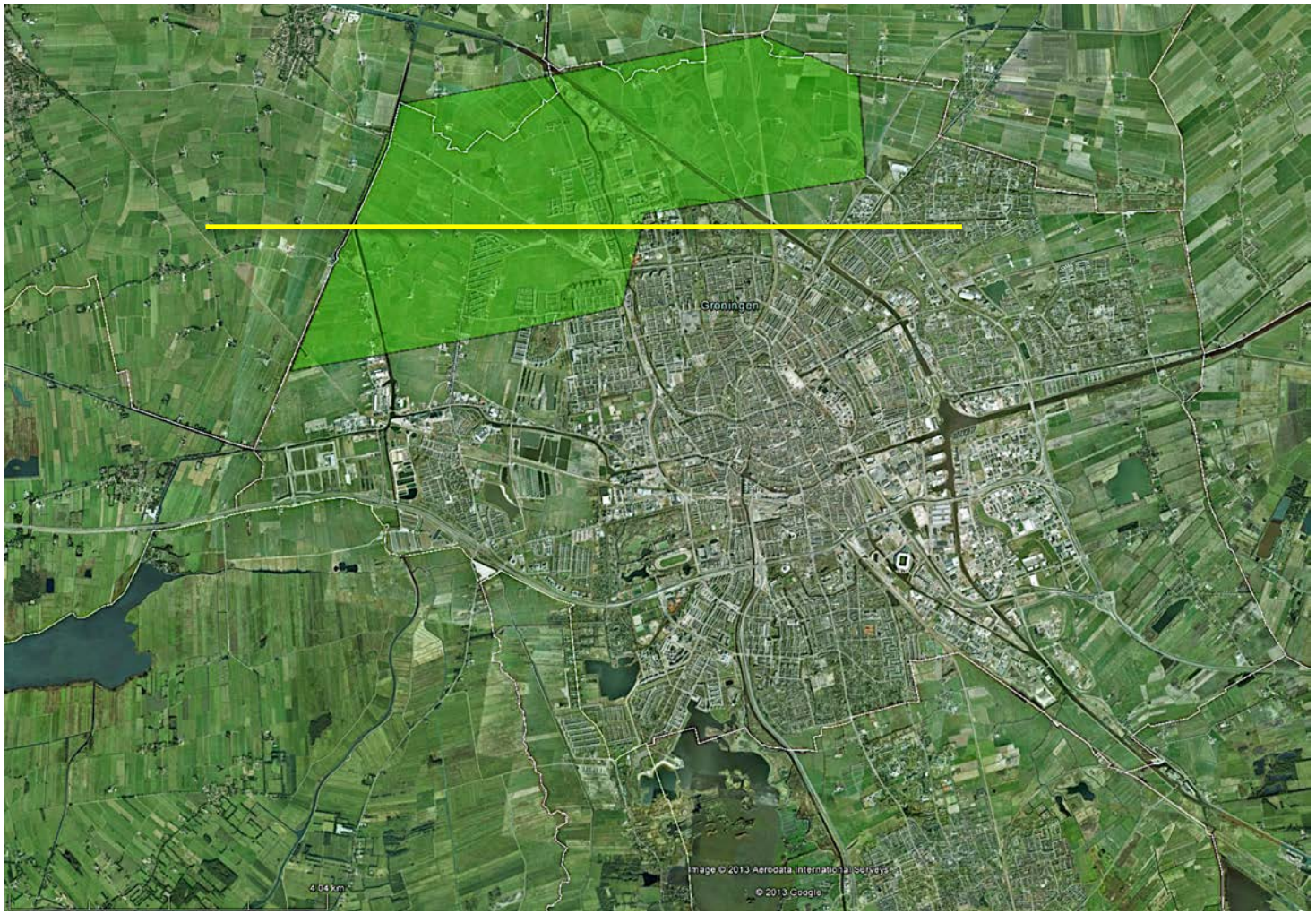
Geothermal Project Warmtestad

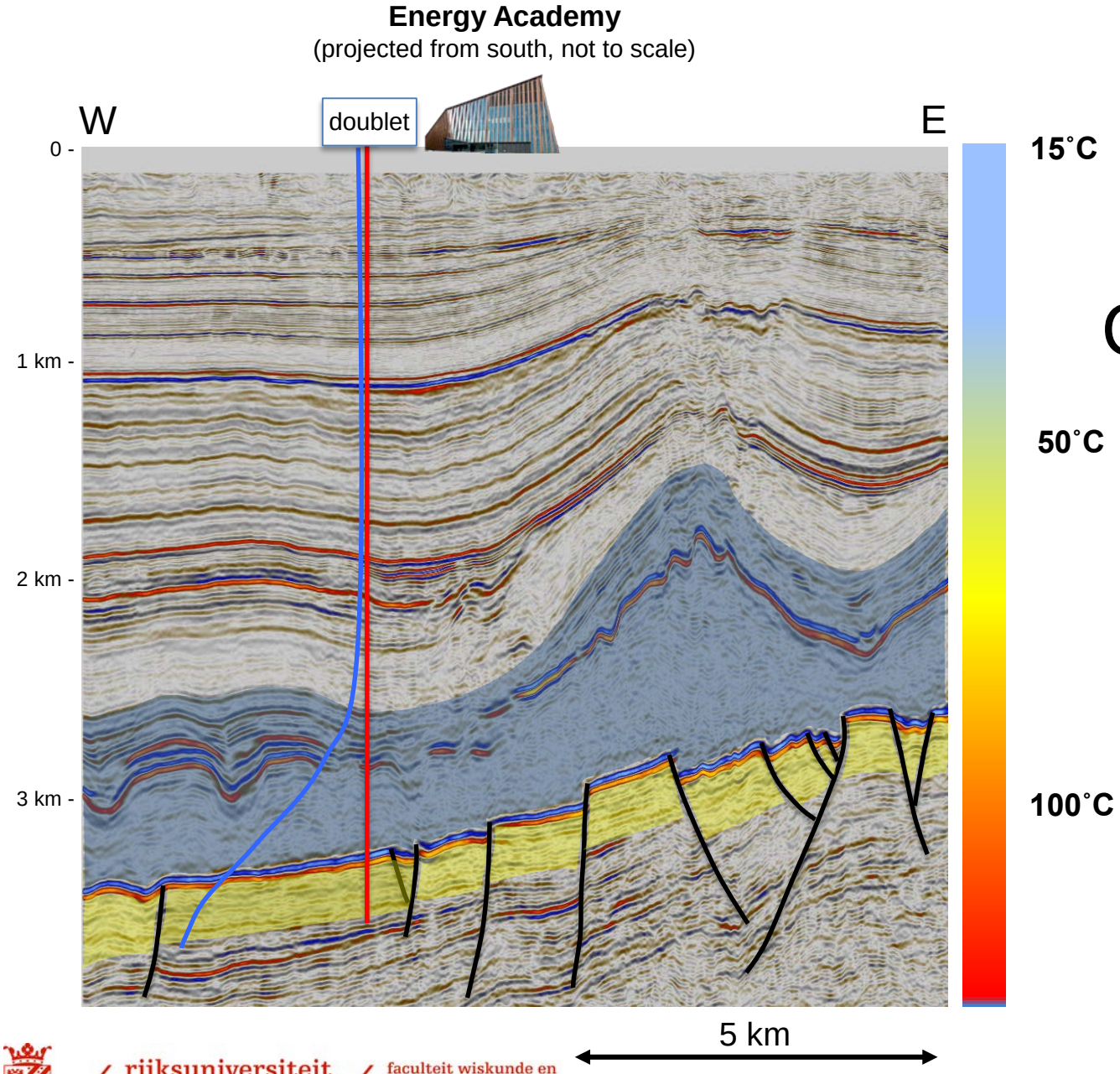


10000 households

(15% low temperature)

Groningen Geothermal Exploration Licence





Seismic Cross Section Zernike Campus

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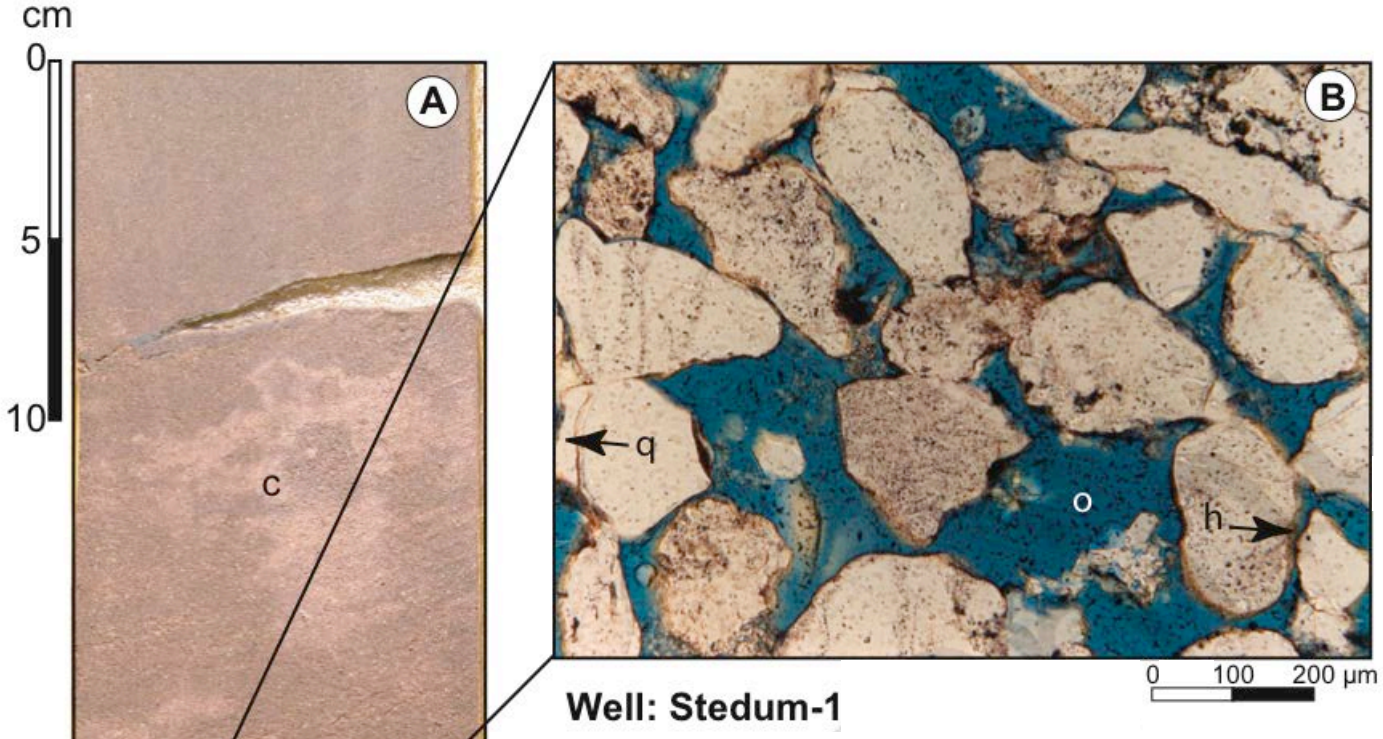
The Reservoir

Source: SPB Atlas, 2011

Desert Deposits

Well sorted
and
rounded sand grains



Rotliegend Sandstone

A. In core

B. Under the microscope

Groningen Geothermal Project

Geological model in Petrel

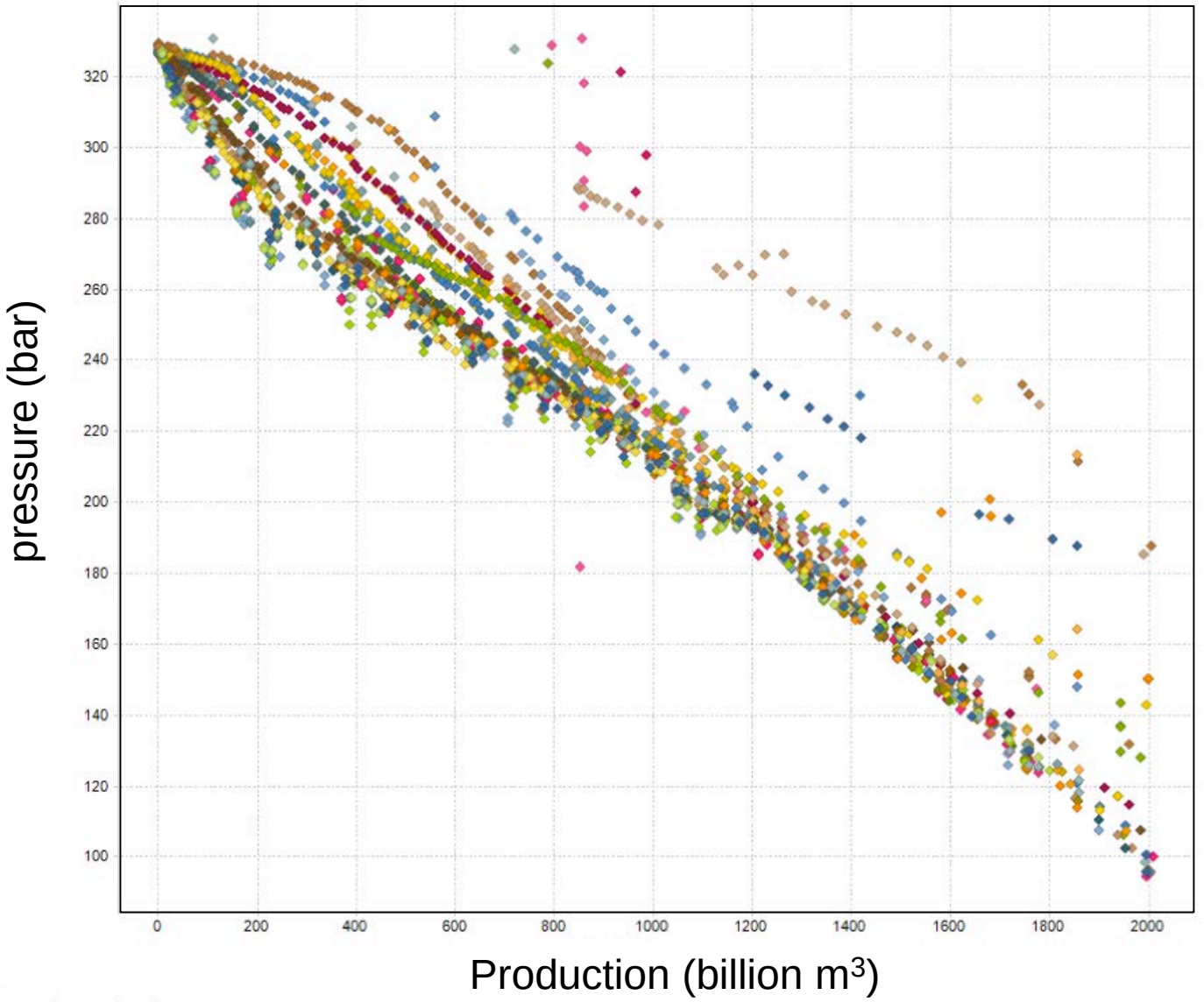
Daniilidis, 2015

Critical Model Parameters

Initial reservoir conditions

- Pressure levels
- Gas saturation

Groningen Gas Reservoir – Pressure Behaviour



Bron: NAM, 2012

Critical Model Parameters

Initial reservoir conditions

- Pressure levels
- Gas saturation

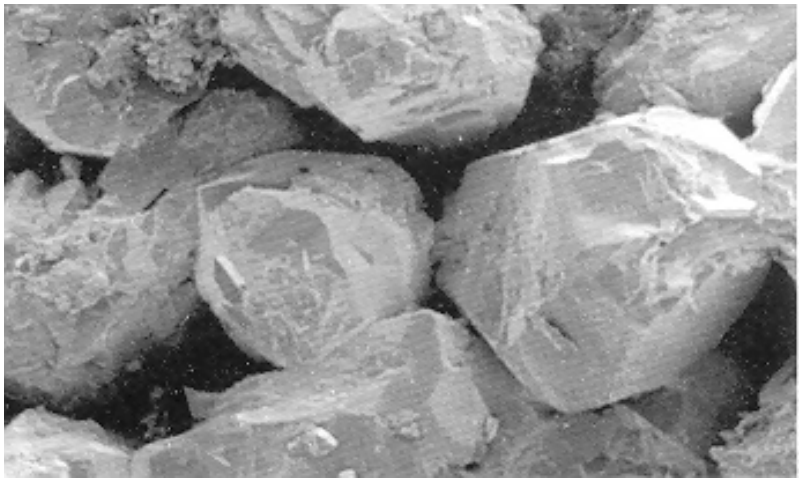
Geological parameters

- Layer permeability, porosity,
- Net-to-Gross
- Fault permeability

Reservoir Quality

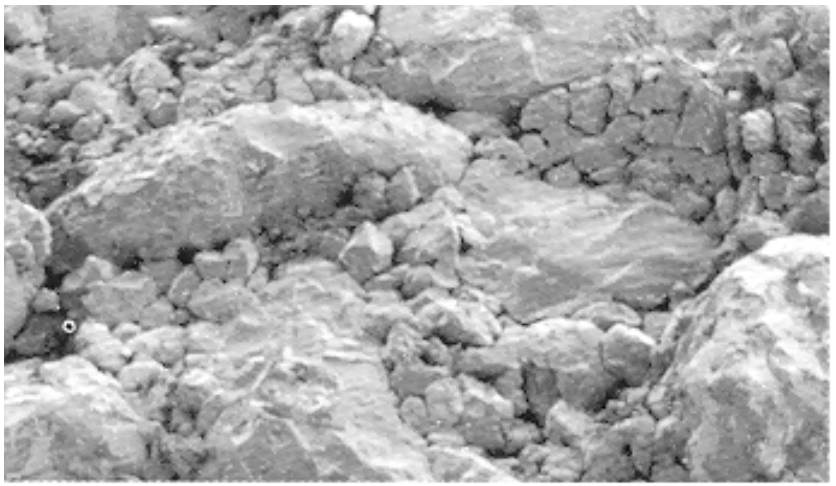
Determined by: Porosity Ø (%) & Permeability k (mD)

GOOD



Porous and permeable rock

BAD



Pores filled with minerals

50 µm

Critical Model Parameters

<u>Initial reservoir conditions</u>
- Pressure levels
- Gas saturation

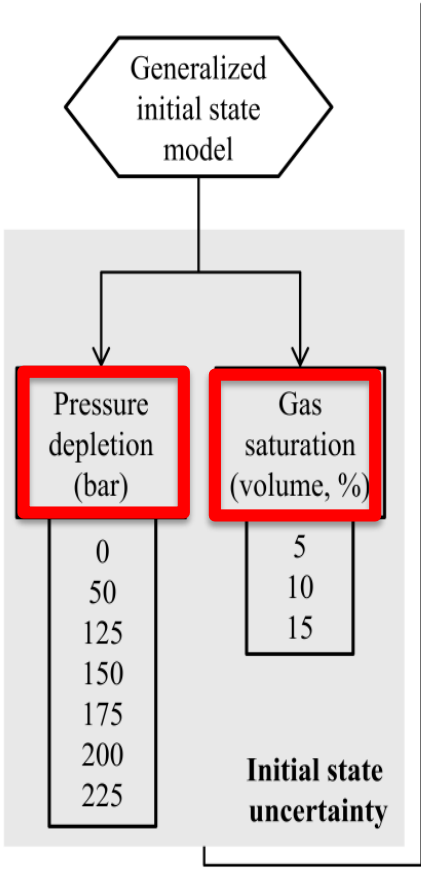
<u>Geological parameters</u>
- Layer permeability, porosity,
- Net-to-Gross
- Fault permeability

<u>Operational parameters</u>
- Flow rate
- Injection temperature

Defined by location

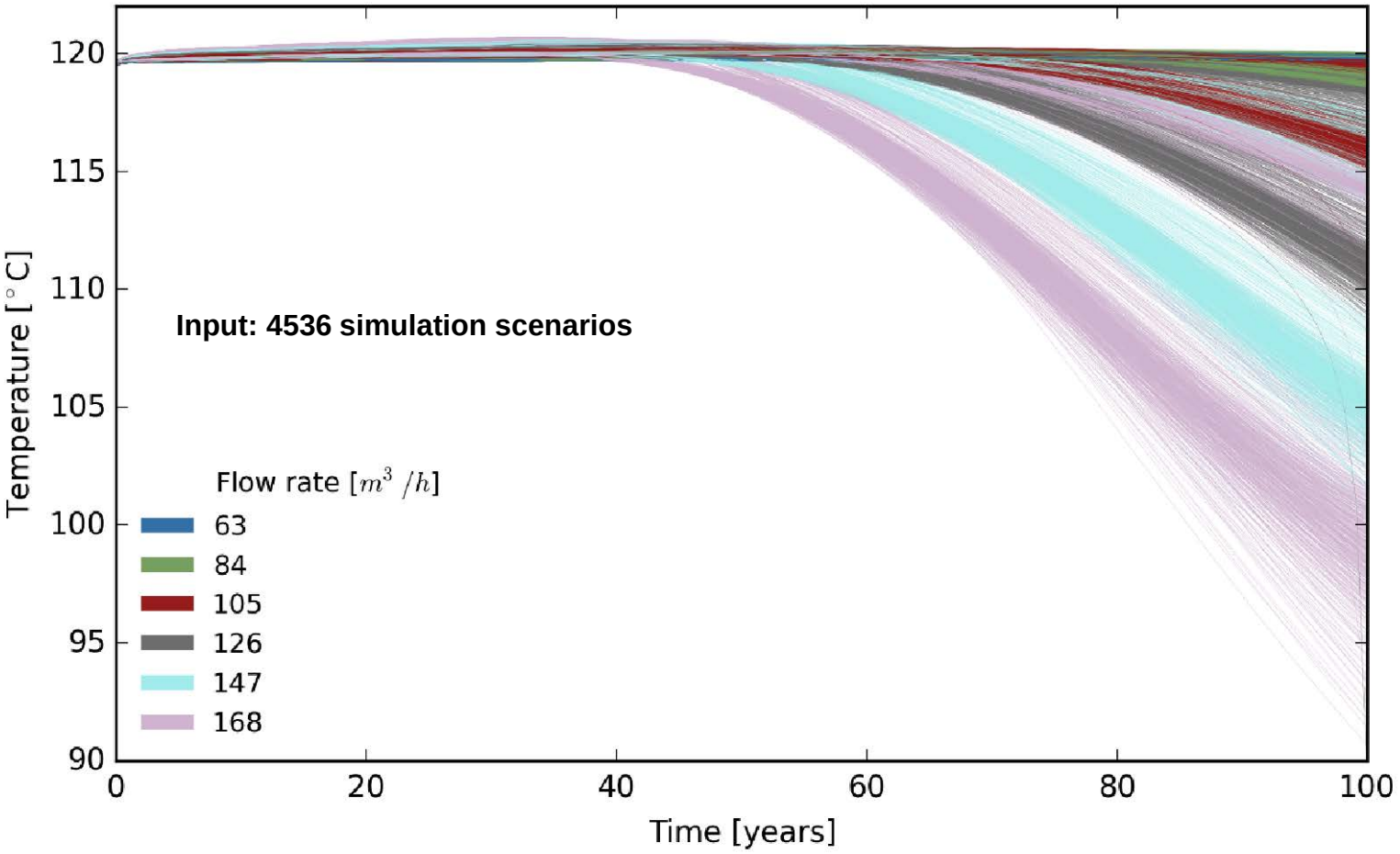
Defined by operator

Workflow: Dealing with Uncertainties



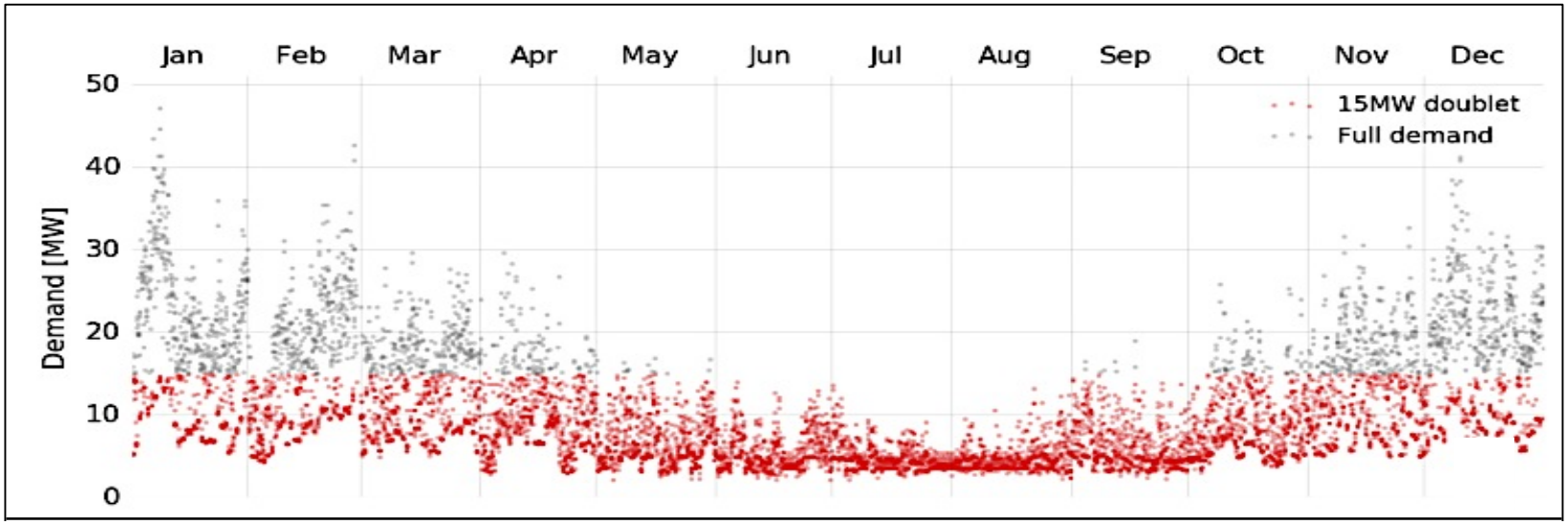
21 scenarios x 216 scenarios = 4536 simulations

Groningen Doublet – Temperature/Time Distributions



Source: Daniilidis, 2016

Seasonal Heat Demand and Load Factor



Input Data: Equipment/Installations

Probability Distributions

Heat Network Length
Heat Network Unit Cost

Producer well contingency
Injector well contingency
POS injection well
POS production well
Drilling location cost
Duration of dev't phase

Fixed Values

ESP cost
Heat Exchanger cost
Gas Separation unit cost

Production well cost
Injection well cost
Drilling insurance cost
Well Abandonment cost

Input Data: Production Parameters

Probability Distributions

Injection temperature
Reservoir Permeability
Gas Saturation
Pressure Depletion
Gas Production

Doublet Temperature Loss
Desired Capacity
Transmission Efficiency
Pump Efficiency
Pump failure Rate

Fixed Value

Production Temperature

Input Data: Economic Parameters

Probability Distributions

Mean Gas Heat Price
Mean Natural Gas Producer Price
Mean Electricity Price

Fixed Values

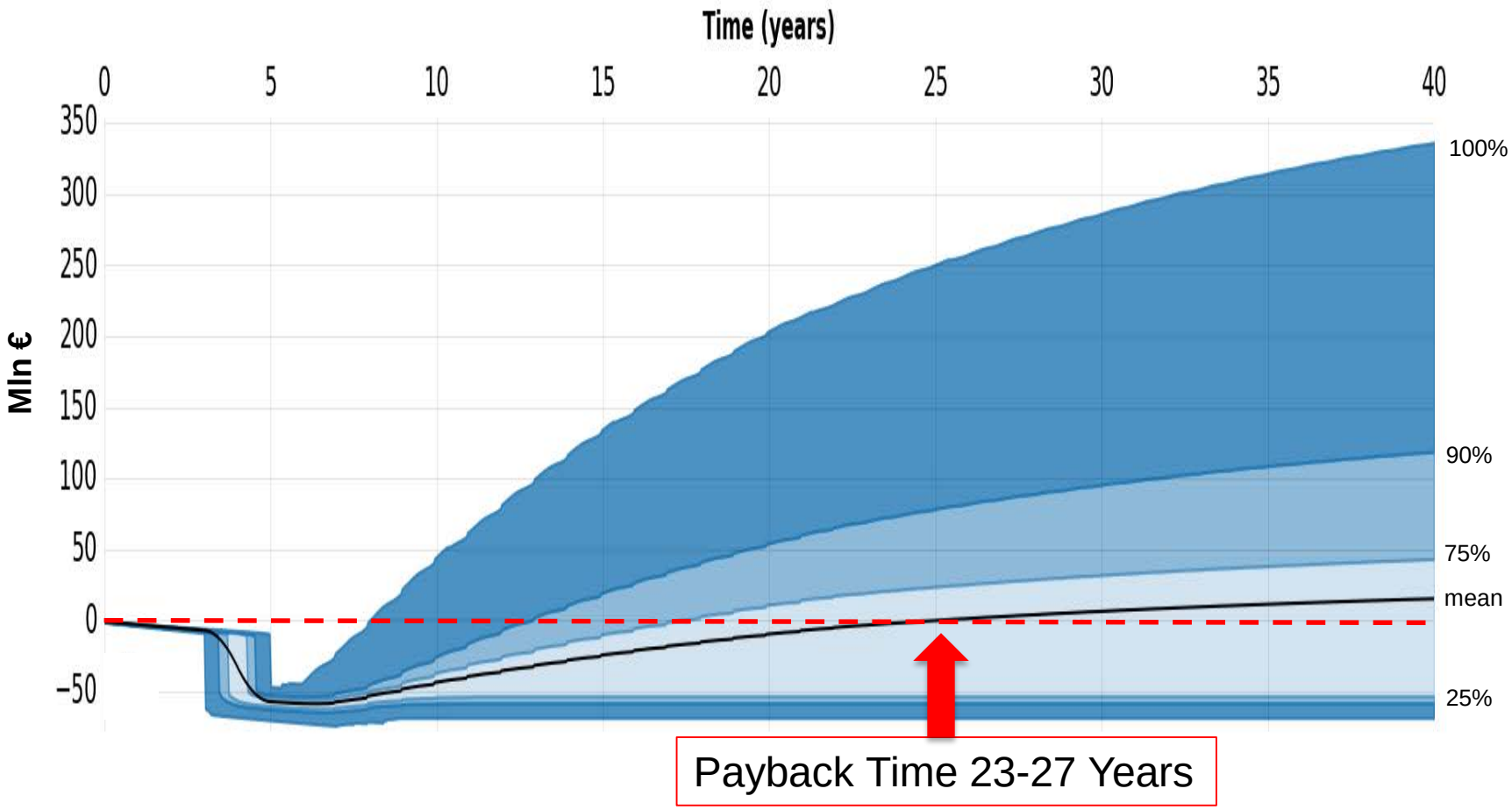
Inflation Rate
Interest Rate
Discount Rate
Depreciation Rate

Ratio Geothermal to Gas Price
Amount of Subsidy
Annual OpEx

Consumer Connection Fee
Consumer Annual Usage Fee

Cumulative Discounted Cashflow

(20.000 Monte Carlo Simulations)



Expected Monetary Value

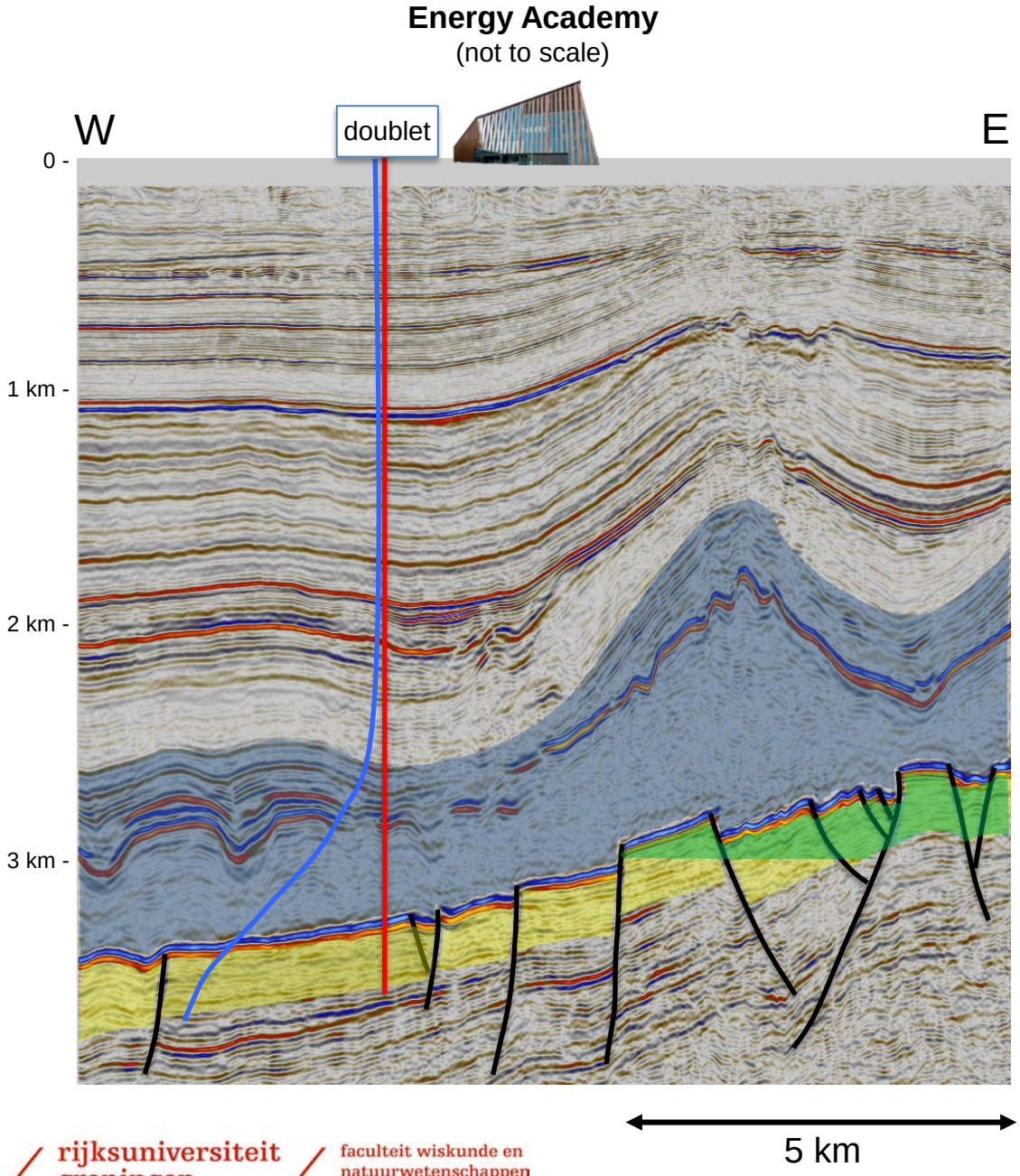
$$EMV = POS \times NPV_{success} - (1 - POS) \times \text{Cost of Failure}$$

$POS_{inj.well} = 70\%$ $POS_{prod.well} = 90\%$ $POS_{overall} = 63\%$

From the NPV frequency distribution, construct an expectation curve:

	$NPV_{success}$	Cost of Failure
P10	141	50
P50	33	55
P90	5	61

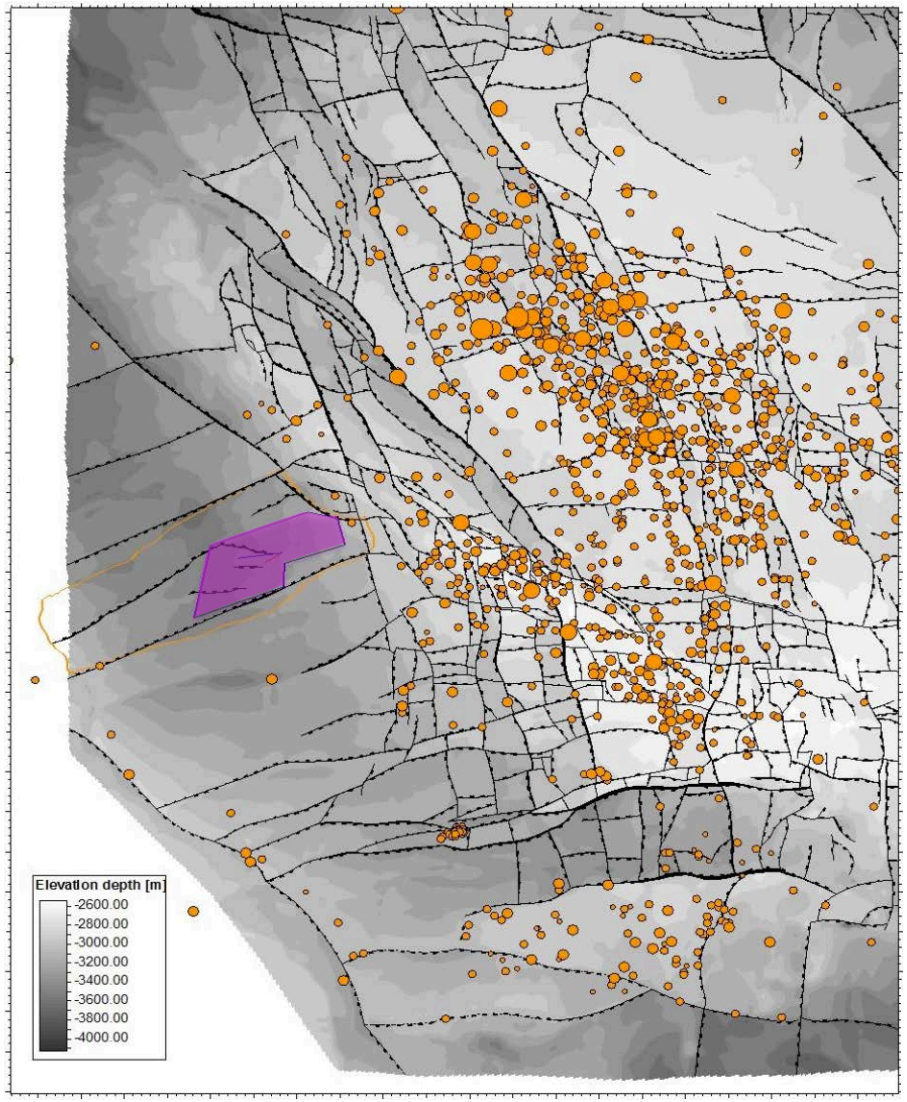
Monetary values in mln €



Seismic Cross Section Zernike Campus

Groningen Gas Field

Geothermal Location in proximity to Groningen Gasfield



Mw: 0.5 - 1.5
Mw: 1.5 - 2.5
Mw: 2.5 - 3.5
Mw: 3.5 - 4.0

Zernike license boundary

0 5000 10000m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