


Dealing with Uncertainties in Geothermal projects*

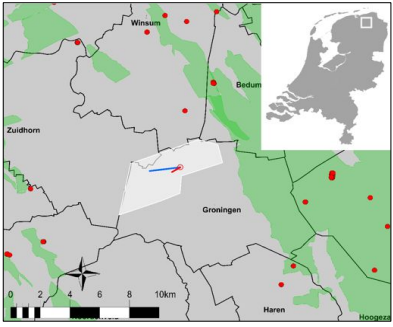
Rien Herber
Alex Daniilidis


DAP Symposium
15th March 2017

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Location of Groningen Geothermal Concession






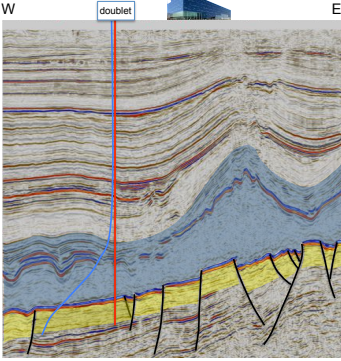
Groningen Geothermal Exploration Licence



Daniilidis, 2015

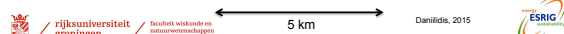


Seismic Cross Section Zernike Campus

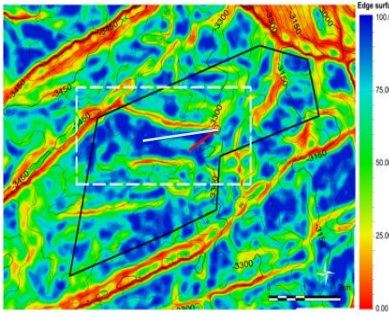



Bernoulliborgh (not to scale)

Daniilidis, 2015

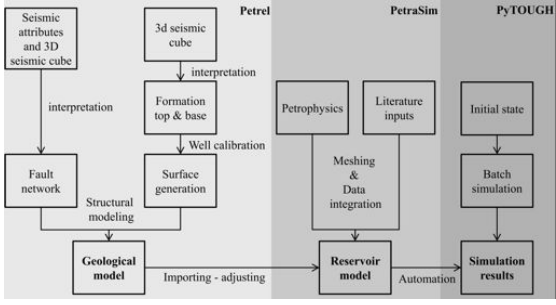



Top Rotliegend - Fault Pattern (Edge Detection on 3D Seismic)





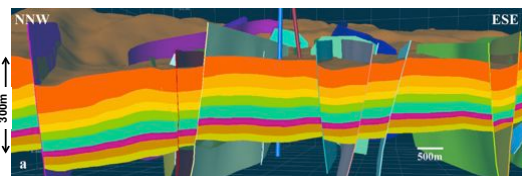
Overall Workflow





Groningen Geothermal Project

Geological model in Petrel

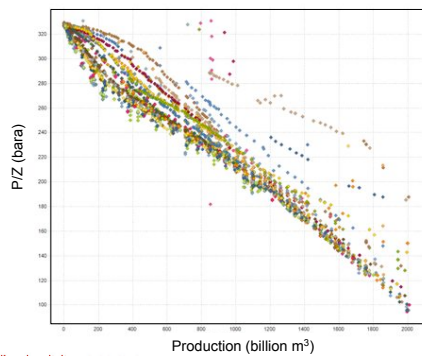


Danilidis, 2015

Critical Model Parameters

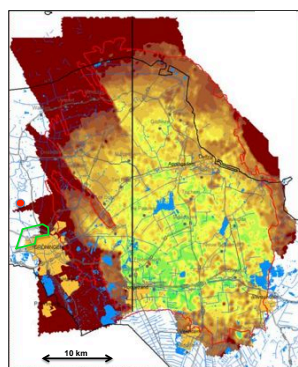
Initial reservoir conditions
Pressure levels
Gas saturation

Groningen Gasfield – Pressure Behaviour in Wells



Source: NAM, 2014

Groningen Field Pressure Distribution (2014)



Reservoir
pressure
in bar

Critical Model Parameters

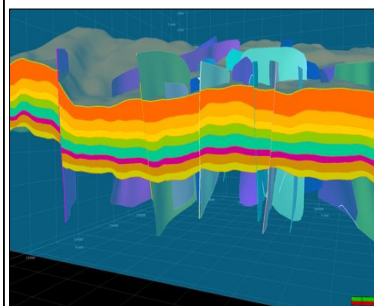
Initial reservoir conditions

Pressure levels
Gas saturation

Geological parameters

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

Rotliegend Reservoir Permeability



P90-P50-P10

RO7: 1 – 2 – 9 mD

RO6: 15 – 44 – 151 mD

RO5: 14 – 44 – 140 mD

RO4: 14 – 46 – 152 mD

RO3: 11 – 35 – 114 mD

RO2: 3 – 11 – 42 mD

RO1: 4 – 15 – 48 mD

Critical Model Parameters

Initial reservoir conditions

Pressure levels
Gas saturation

Geological parameters

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

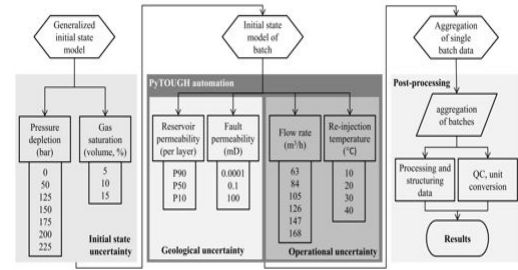
Operational parameters

Flow rate
Injection temperature

Defined by location

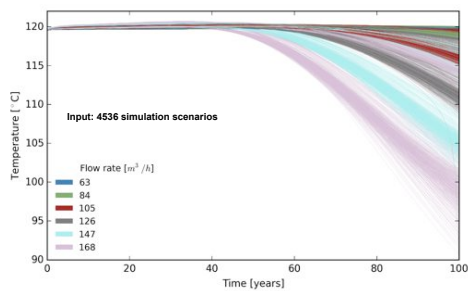
Defined by operator

Workflow: Dealing with Uncertainties



21 scenarios x 216 scenarios = 4536 simulations

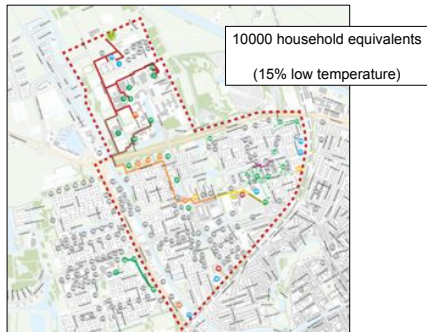
Groningen Doublet – Temperature/Time Distributions



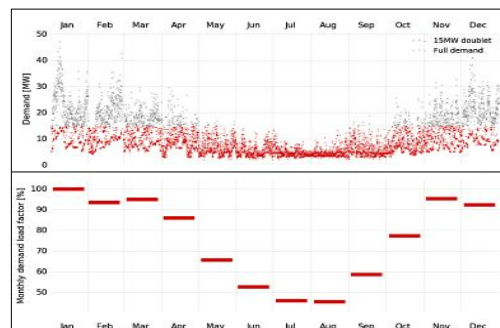
Risk Matrix

	Thermal power [MW]	Δp producer-injector [bar]	Δp producer-hydrostatic [bar]	Producer T [°C]	Gas to brine ratio (m³/m³)
Depletion [bar]					
Gas Saturation [%]					
Reservoir Perm [-]					
Fault Perm [mD]					
Flow Rate [m³/h]					

Tackling the Business Case



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

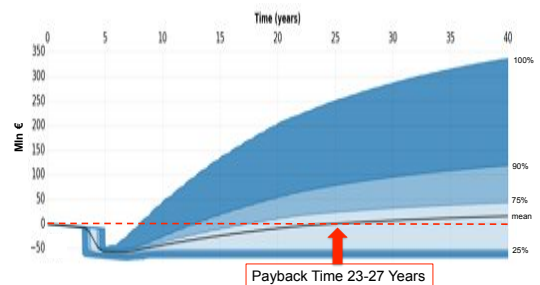
Inflation Rate
Interest Rate
Discount Rate
Depreciation Rate

Ratio Geothermal to Gas Price
Amount of Subsidy
Annual OpEx

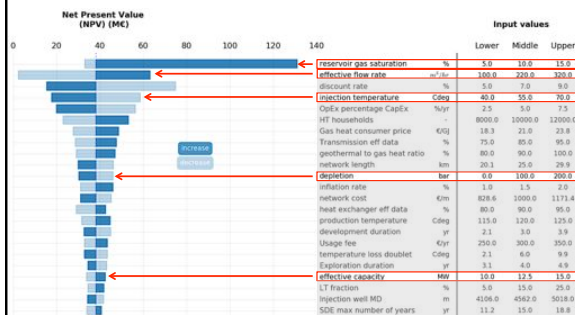
Consumer Connection Fee
Consumer Annual Usage Fee

Cumulative Discounted Cashflow

(20.000 Monte Carlo Simulations)



Sensitivity Analysis for Net Present Value



Conclusions / Recommendations

- Avoid Single Number Analyses for Investment Proposals
- Build the investment plan stepwise, e.g. construct the network only after drilling the wells
- The presence of low saturation gas in the aquifer is a boost for profitability
- Drilling costs are not the highest ranking in terms of impact on profitability
- The load factor for geothermal heat production is of prime influence for economic viability. This may lead to the inclusion of storage facilities

Acknowledgements

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