Investigation of soft stimulation measures from a techno-economic point of view under consideration of risk factors ›

GeoTHERM 2019

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Stimulation of geothermal wells with a minimum environmental impact

Key facts:

Demonstration of stimulation measures within the EU H2020-program

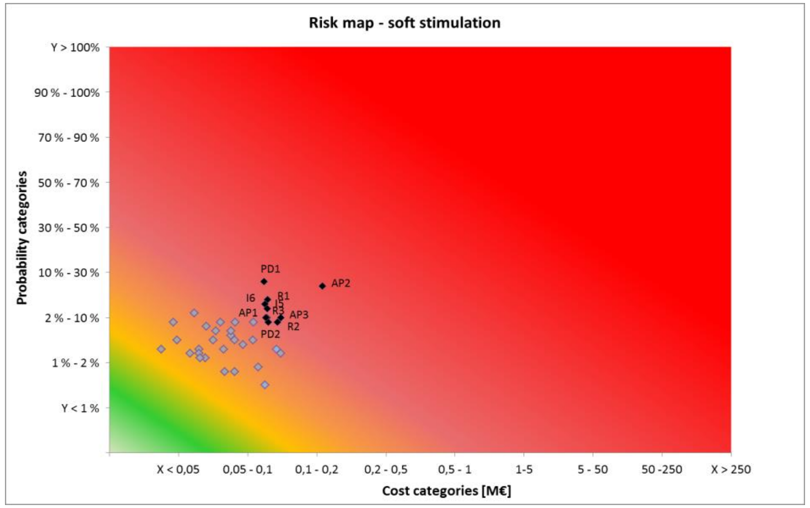
- 16 partners from the EU, Switzerland and South Korea
- 5 „demonstration sites“
- Mezöberény (HR), Soultz-sous-Forêts (FR), Middenmeer (NL), Geldinganes (IS), Bedretto (CH)
- 48 months – March 2016 – February 2020

Research goals:

Reservoir improvement → Preservation of injectivity → Minimizing environmental impact

Project status

- Modelling of stimulation activities is done and published
- Planning and tendering of stimulation activities are currently done
- Stimulations will be performed in 2019



Business case - key performance indicators based analysis

1. Technical modelling

- Simulation/optimization of geothermal plant
  1. Production reservoir
  2. Wellbore
  3. Thermal water circuit
  4. Energy utilization
  5. Wellbore
  6. Injection reservoir

2. Economic modelling

- Cost engineering based on technical input data
  - Module costing approach
  - Development of functions for specific geothermal items/services
  - Adaption to different European markets

3. Mapping of stimulation measures

- Mapping of stimulation activities
  - Costs of different stimulation measures
  - Effect of stimulation on reservoir properties
  - Probability of success of stimulation measures

4. Uncertainty/risk factors

- Identification & evaluation of uncertainties/risk factors unique to stimulation activities
- Uncertainties within techno-economic models

Why make it so complicated
or
advantages of probabilistic evaluation

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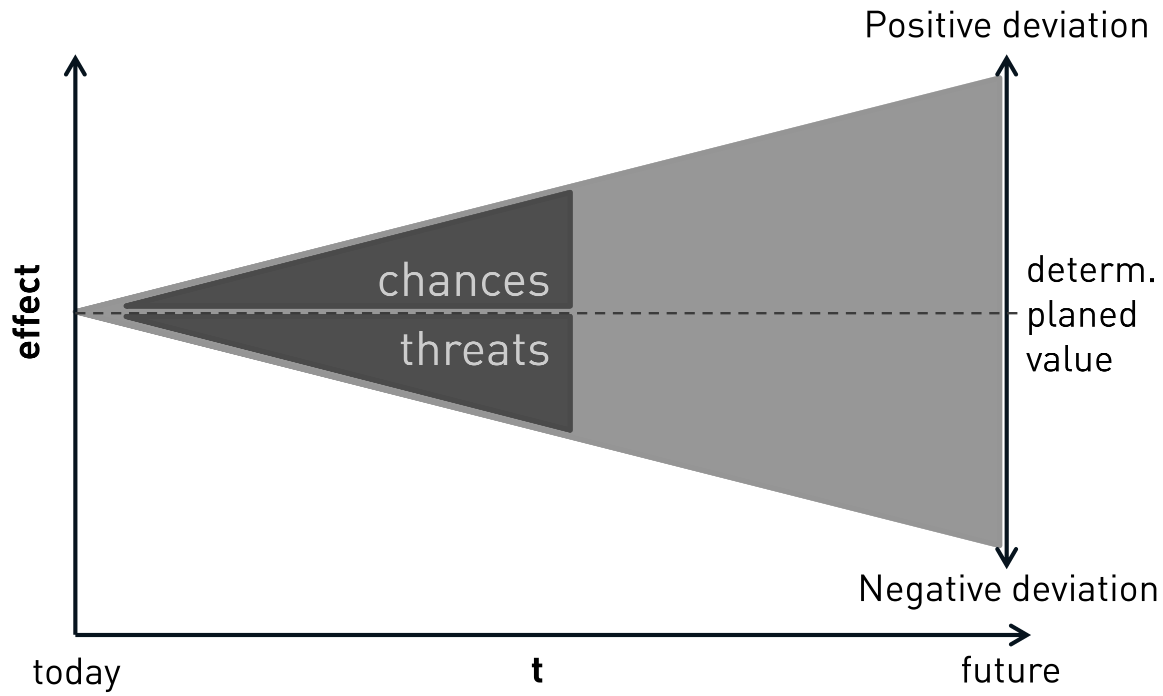

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- Sensitivity analysis
  - Impact factors can be identified and evaluated
  - Automatically available through Monte-Carlo-Sampling
- Robustness of results
  - Unbiased by scenario definitions
  - More/all uncertain parameters can be evaluated
  - Interaction of different parameters can be considered

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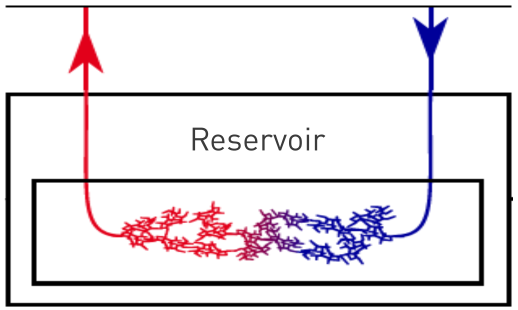
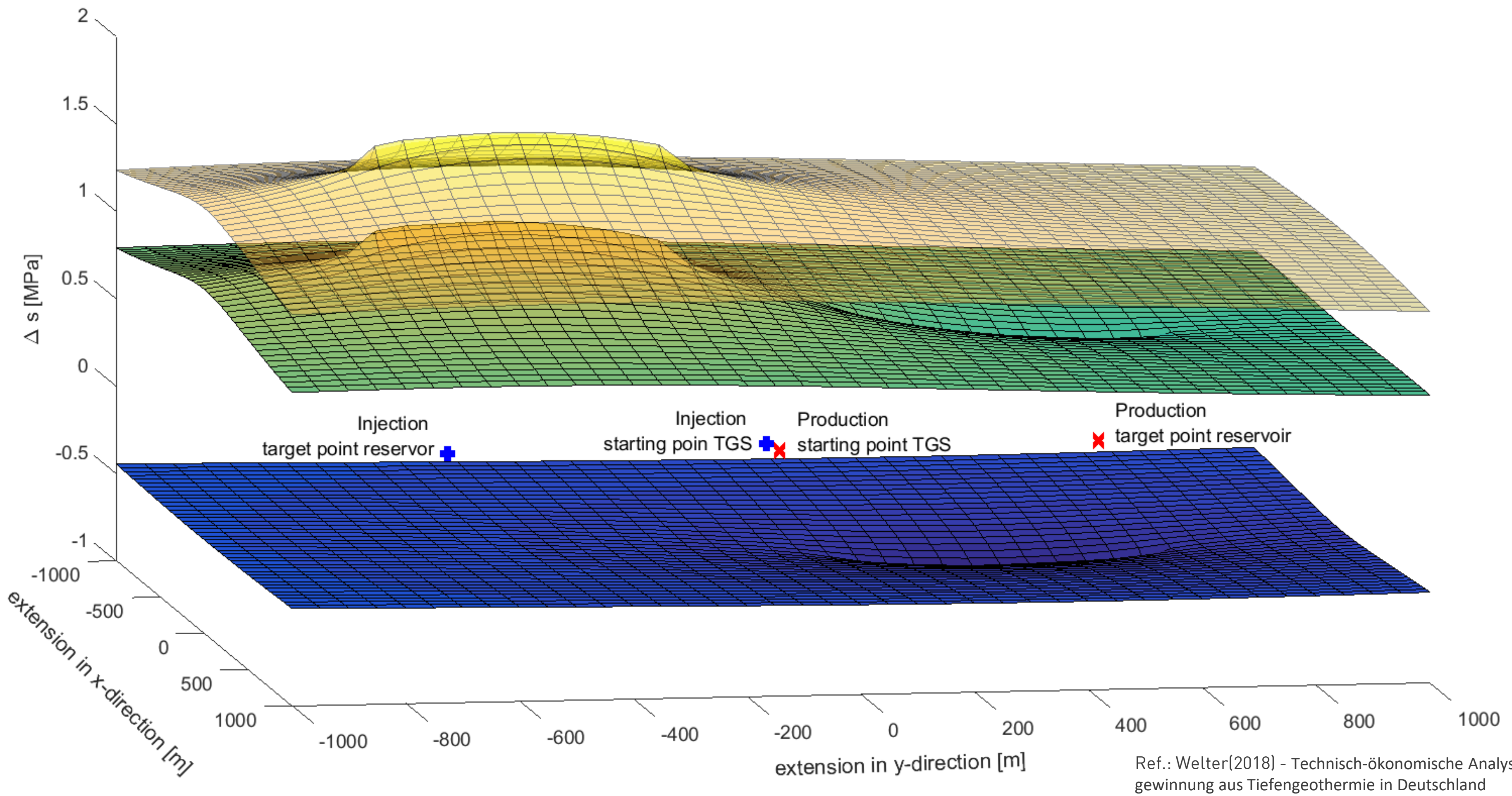
- More effort
  - Collection of probability distribution functions
    - Expert elicitation
    - Historical data
  - Setting up a techno-economic model
- More complex to present and understand
  - Methodology of Monte-Carlo simulation
  - Probabilistic KPIs

Integrated geothermal model (IGM)



Integrated geothermal model

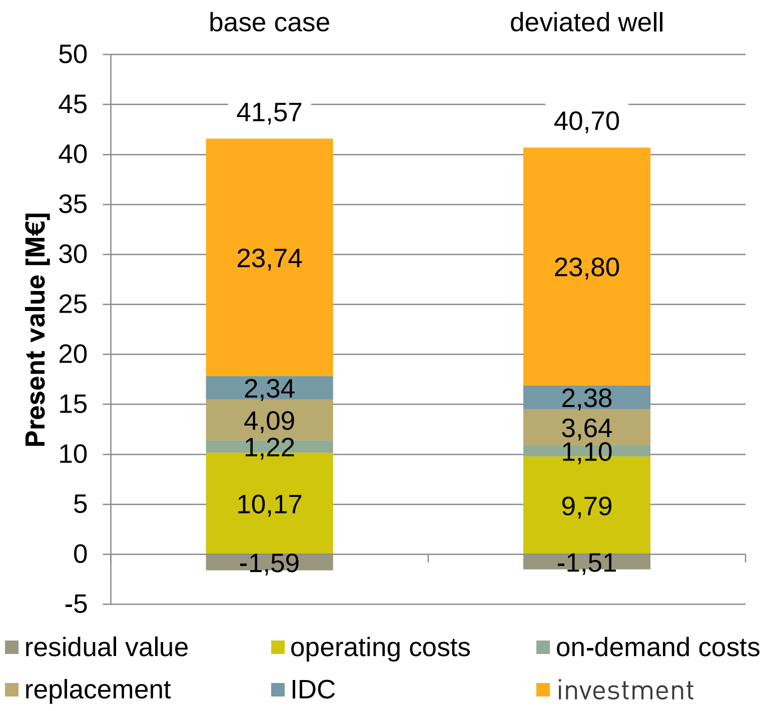
Hydraulic effects of deviated wells

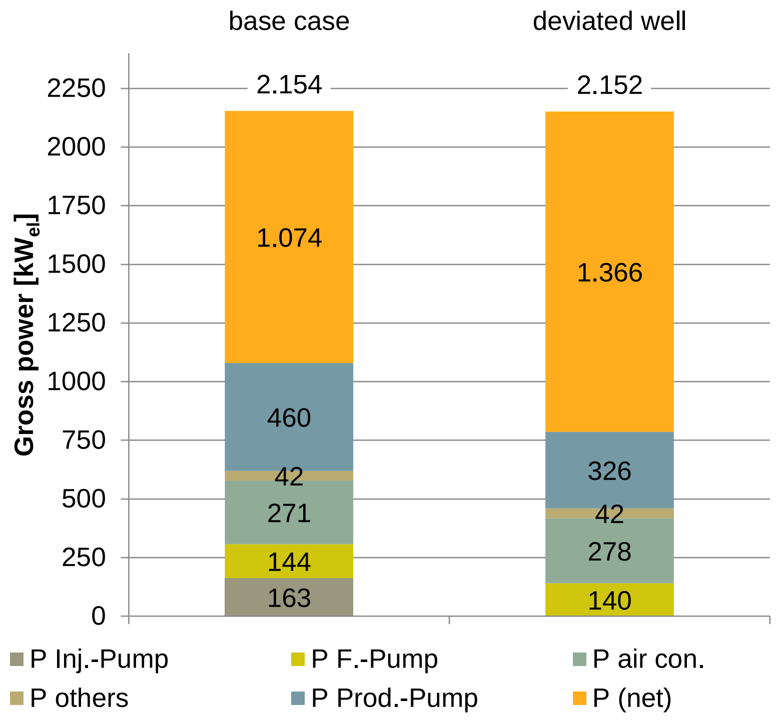


Ref.: Welter(2018) - Technisch-ökonomische Analyse der Energie-gewinnung aus Tiefengeothermie in Deutschland

Detailed evaluation of deviated wells

Techno-economic comparison of deviated wells to the base case





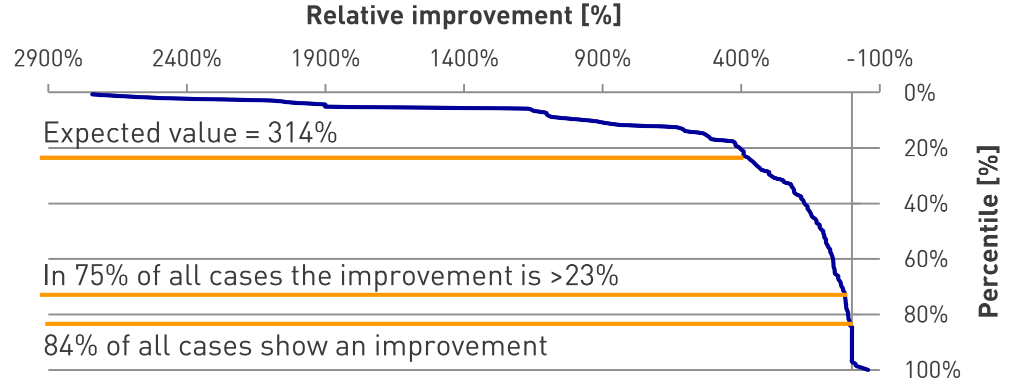
	Present value [M€]	Δ-%	Net power [kW]	Δ-%	Levelized costs of energy [€/kWh]	Δ-%
Base case	42,13		1.076		0,21	
Deviated wells	41,31	-1,93%	1.370	27,29%	0,16	-22,97%

Ref.: Welter(2018) - Technisch-ökonomische Analyse der Energiegewinnung aus Tiefengeothermie in Deutschland

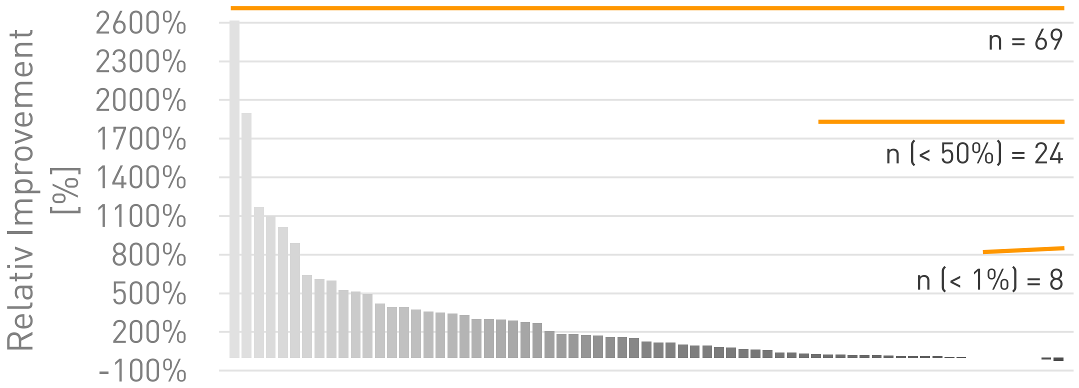
Probability of success

Statistical evaluation of geothermal stimulation measures worldwide

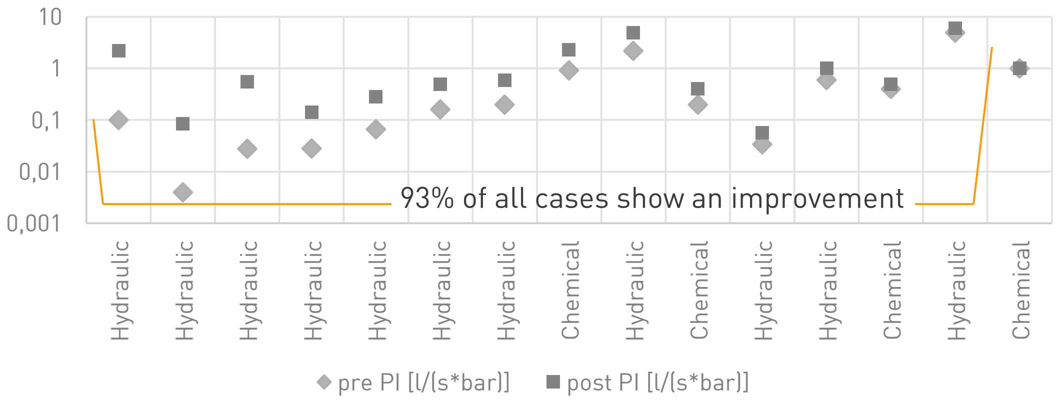
Relative improvement through stimulations



Stimulations with published II



Stimulations with published PI



Key messages

- Statistical evaluation of 181 geothermal stimulation jobs since 1970 in 15 countries
  - Growing number of cases increases validity of distribution function
- Relative Improvement shows a wide range depending on technical and geological issues
- Probability of having no or negative improvement is 26%
- For wells with published injectivity 88% show an improvement
- When focusing on stimulations with PI-data, the probability of no-effect decreases to 7%

Modelling of pump technology

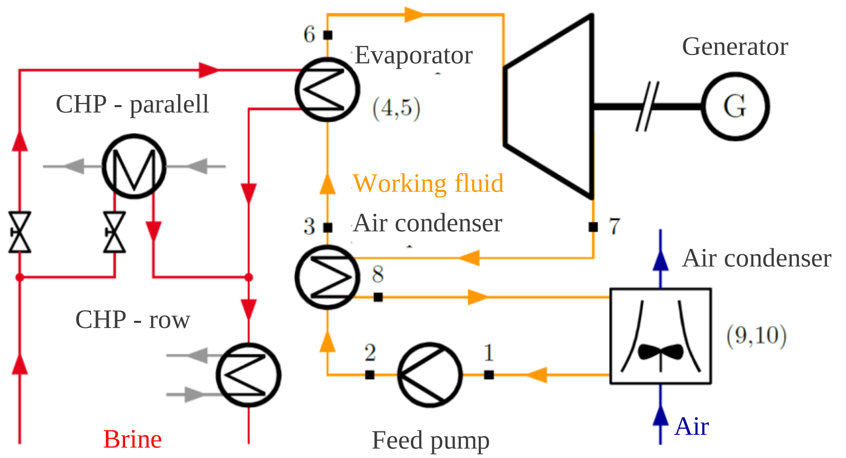
Line Shaft Pump (e.g. Soultz-sous-Forêts)

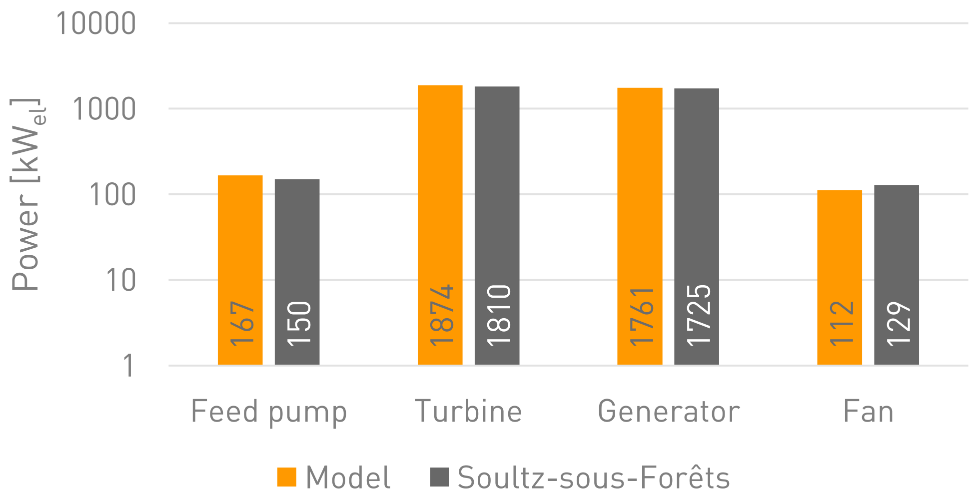
- + Easy maintenance
  - Motor above ground
  - Line shaft drives turbine
- + Longer service life
  - ~ 4 years
- − More expensive
  - $CAPEX(z) = 775000 + 500 * z$
- + Higher efficiency
  - ~ 70%
- − Limited in depth
  - ~ 700 m

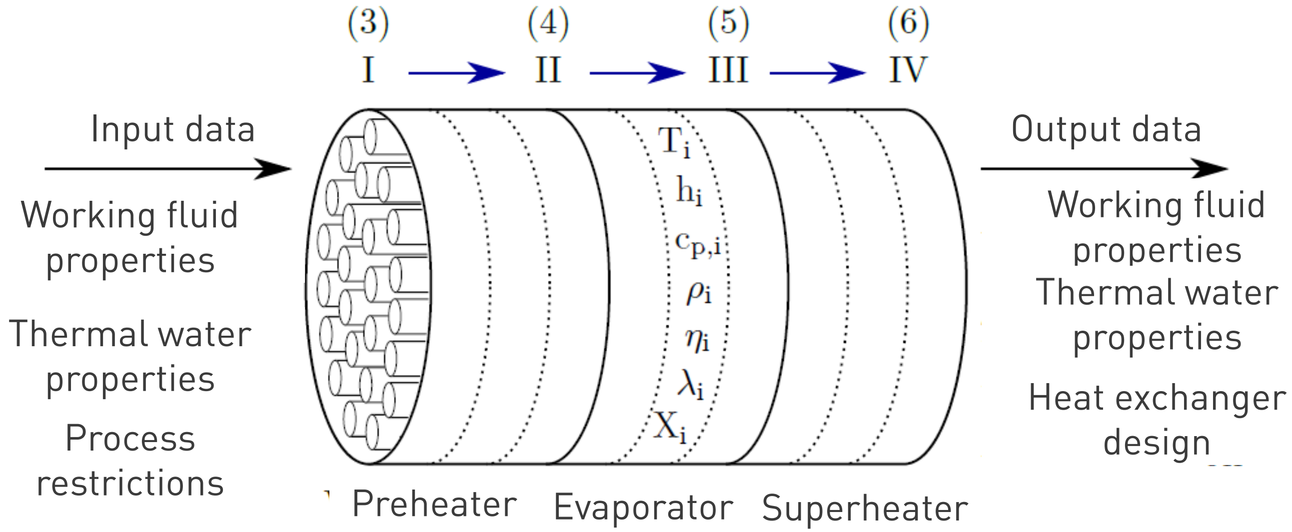
Electrical submersible pump (e.g. Bruchsal)

- − Shorter service life
  - Motor below ground
  - Motor directly drives pump
  - ~ 1 year
- + Cheaper than LSP
  - $CAPEX(P_{hydr}; z) = P_{hydr}$*(14,2* $P^{hydr^{-0,319}} + C_{Cabel}(z) + C_{Pipe}(z)$
- + No depth limits (< 1000 m)
- − Lower efficiency
  - 50% - 60% (Welter, 2018)

Progress in power plant modelling

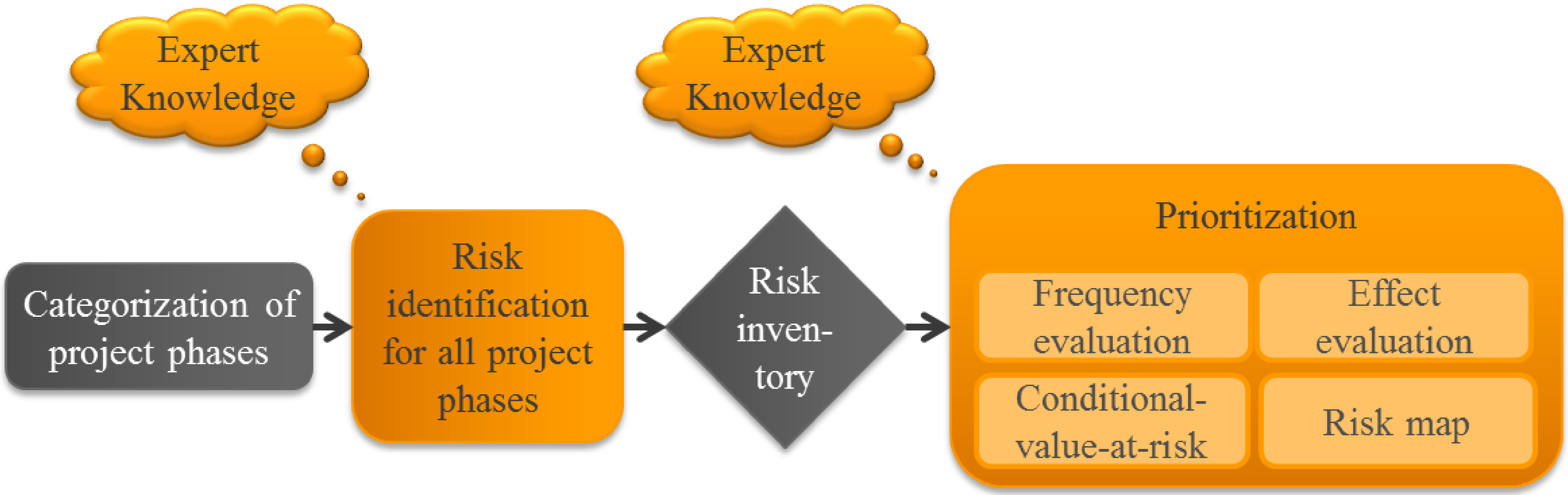






- Optimization of power plant
  - Monte-Carlo-Simulation instead of heuristic optimization
  - Pressure condenser outlet; Pressure feed pump outlet; Temperature superheater outlet; Recuperated energy
- Adaption of heat exchanger
  - Tube heat exchanger instead of plate heat exchanger
- Validation of power plant
  - Revision of superheating
  - Revision of condensator

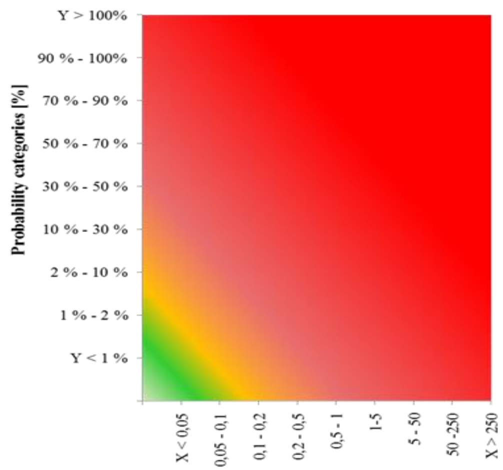
Identification and prioritization as part of risk analysis



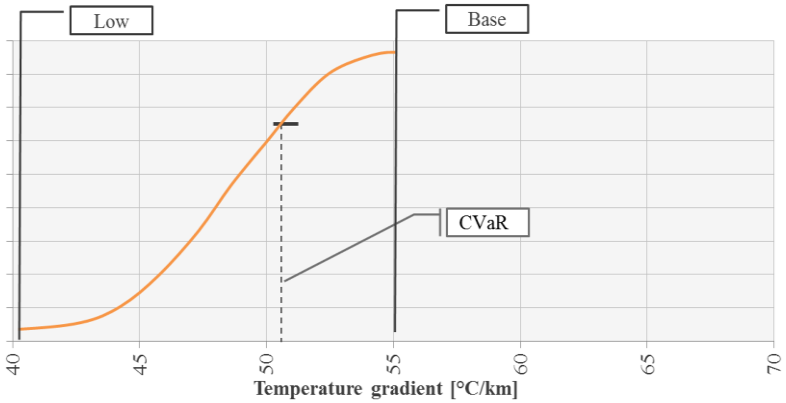
- Expert interviews as data basis
  - Biased by subjectivity
  - Availability of data / Effort for data collection
- Structured approach for identification of risk factors
- Prioritization of risk factors
  - Fit-for-purpose modelling
  - Pre-selection before in-deep modelling

Prioritization - Continuous distributions in a risk map

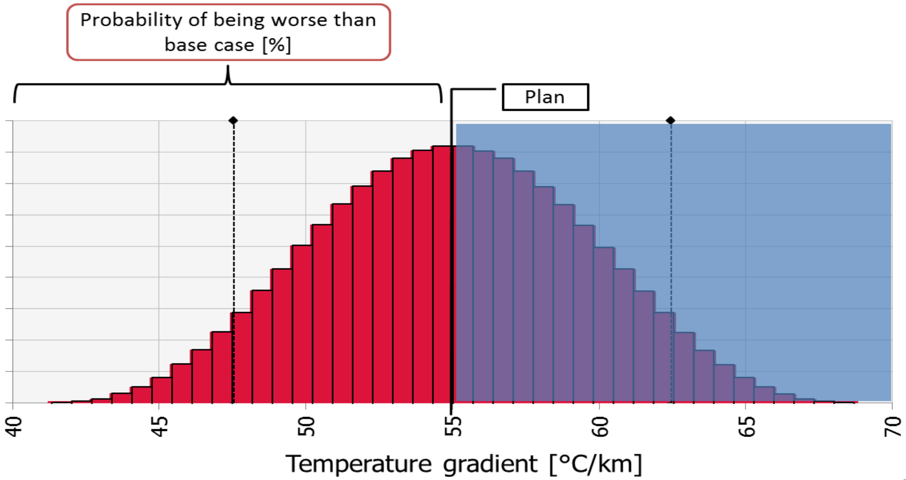
Risk map



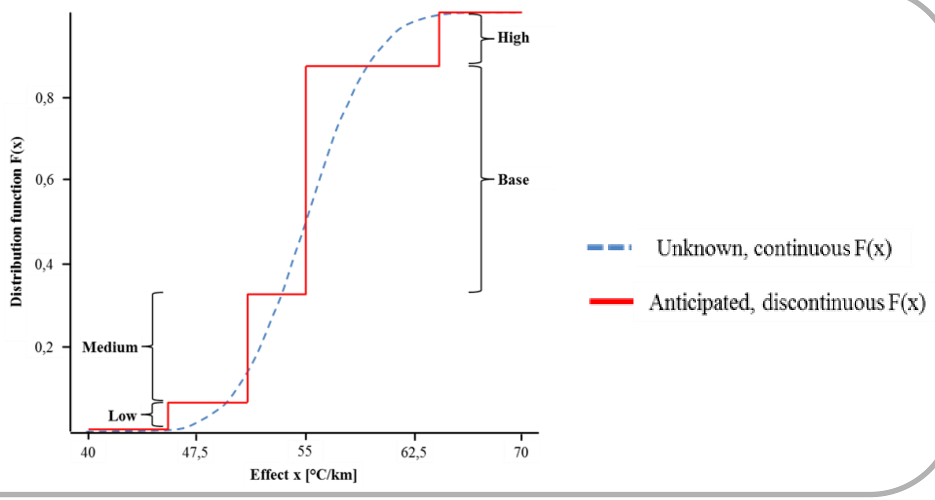
Conditional value at risk



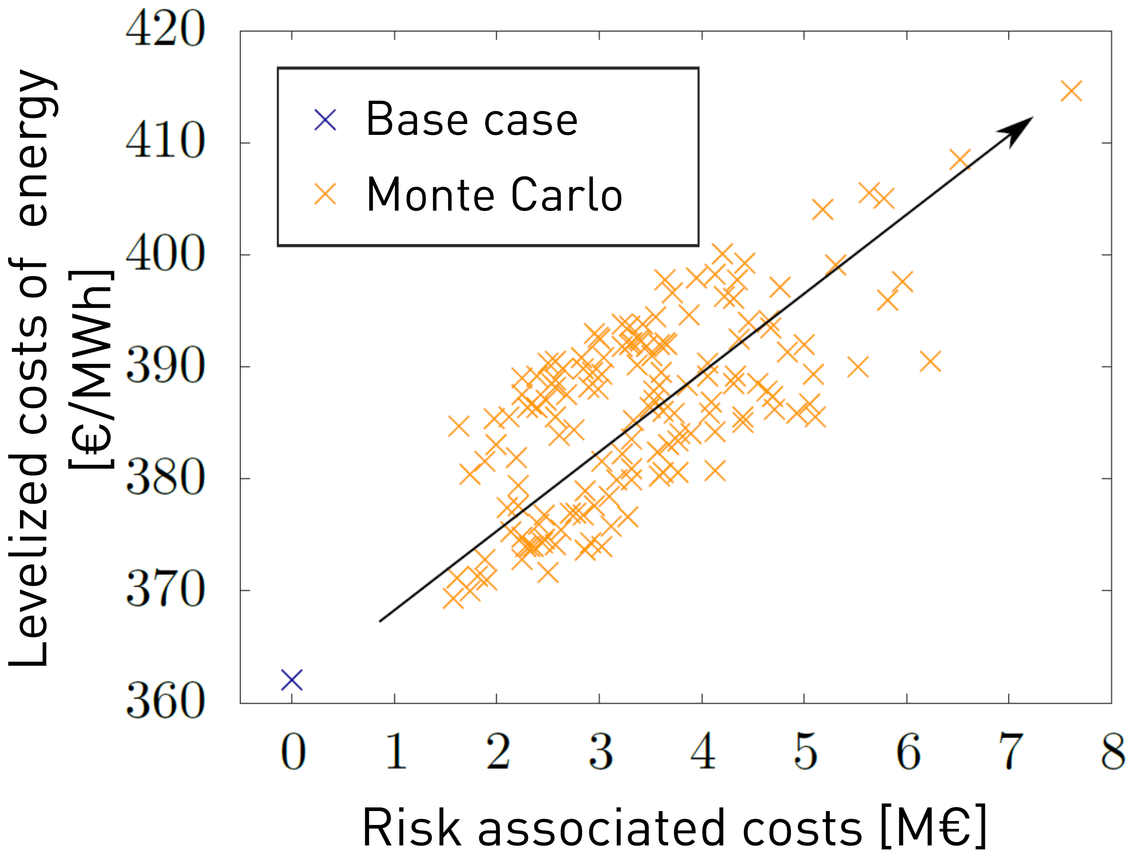
Binominal probability



Construction of PDF



Case study Soultz – Monetary influence of risk factors



Frame conditions

- Electricity production, no heat
- 150 iterations for risk factors

Technical frame conditions Soultz project

- R&D character
  - Deep wells
  - High temperature losses
  - Low flow rate

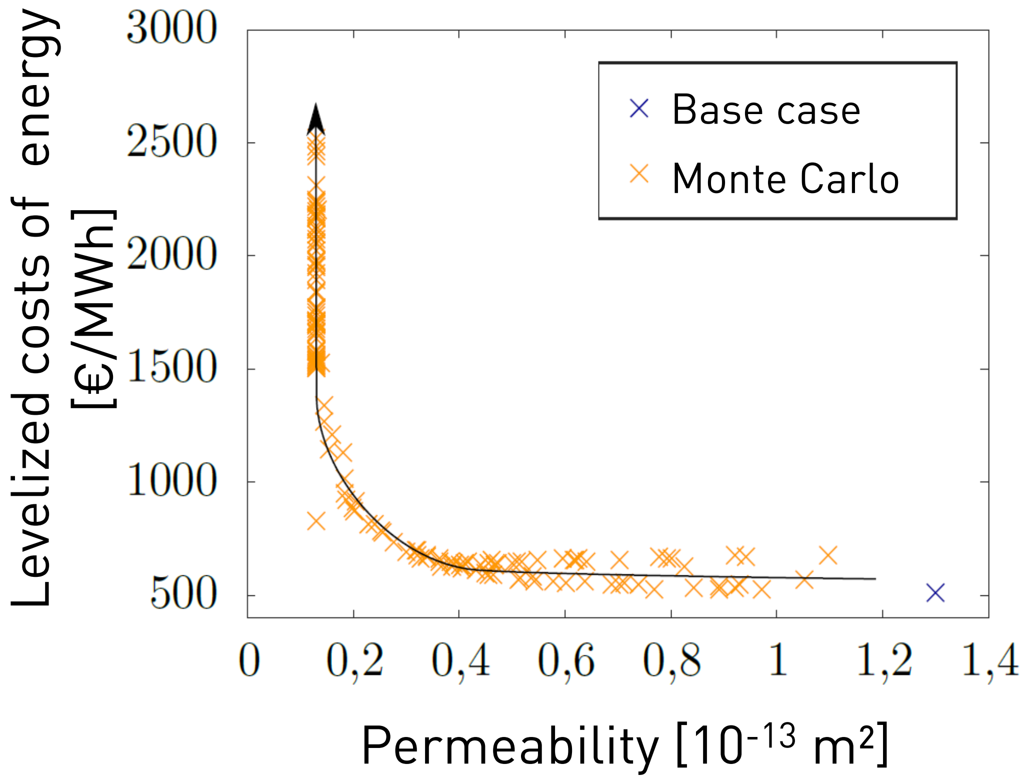
  → Economic LCOE were not a focus of project development

The risk associated costs show a linear influence on the LCOE

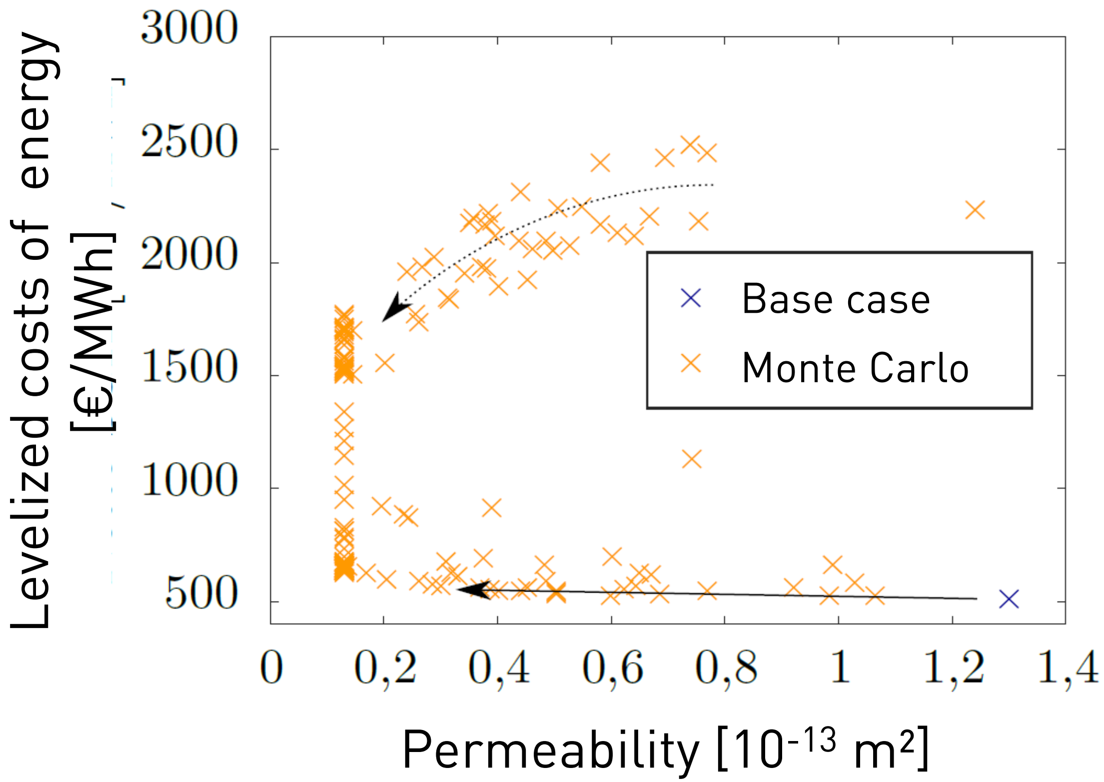
- Find different modelling approaches?
- Go rather for a technical implementation of risk factors?

Case study Soultz – Technical influence of risk factors

Injection well



Production well



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