Risk factors within techno-economic evaluation of soft-stimulation measures ›

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2nd March 2018

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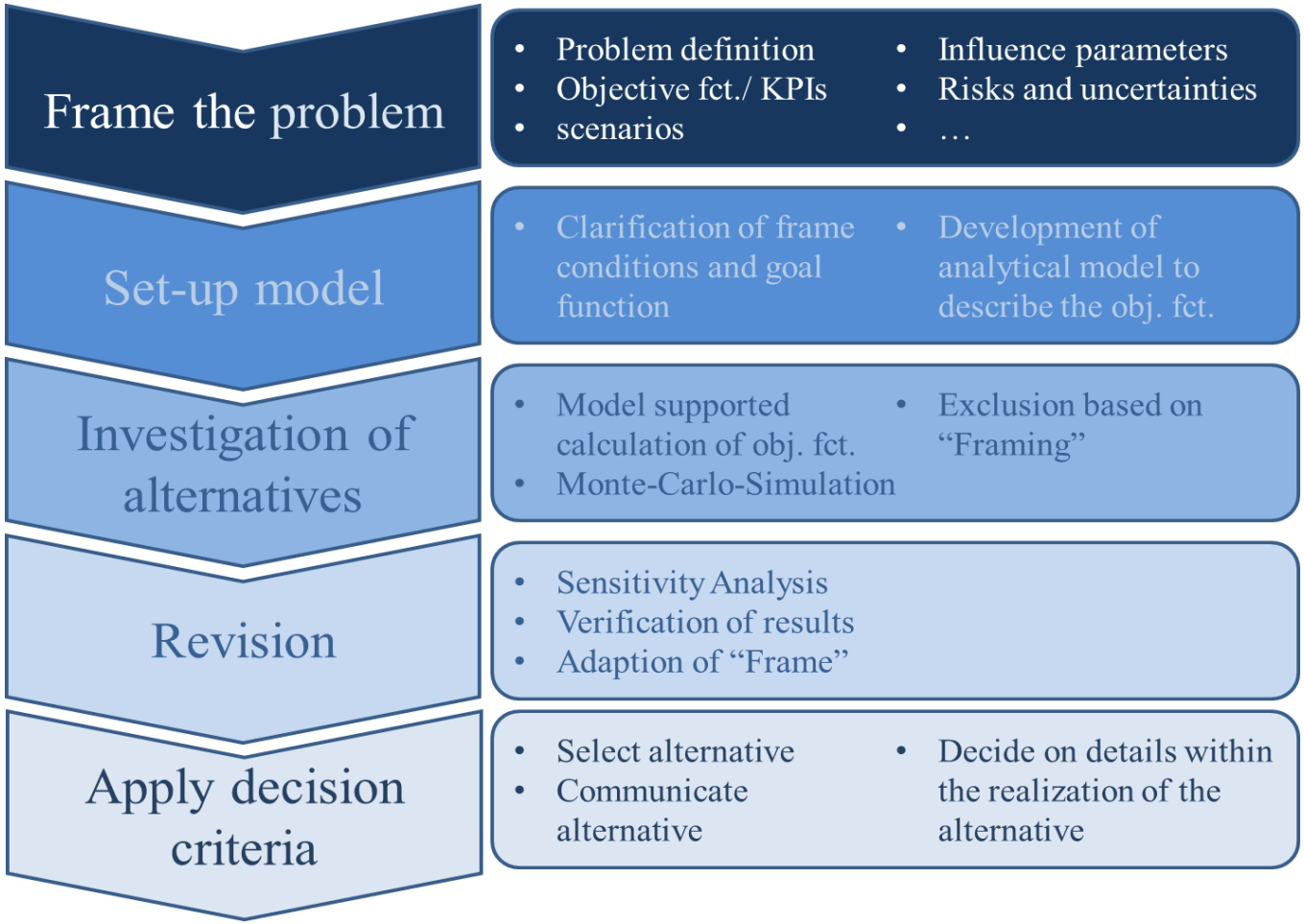
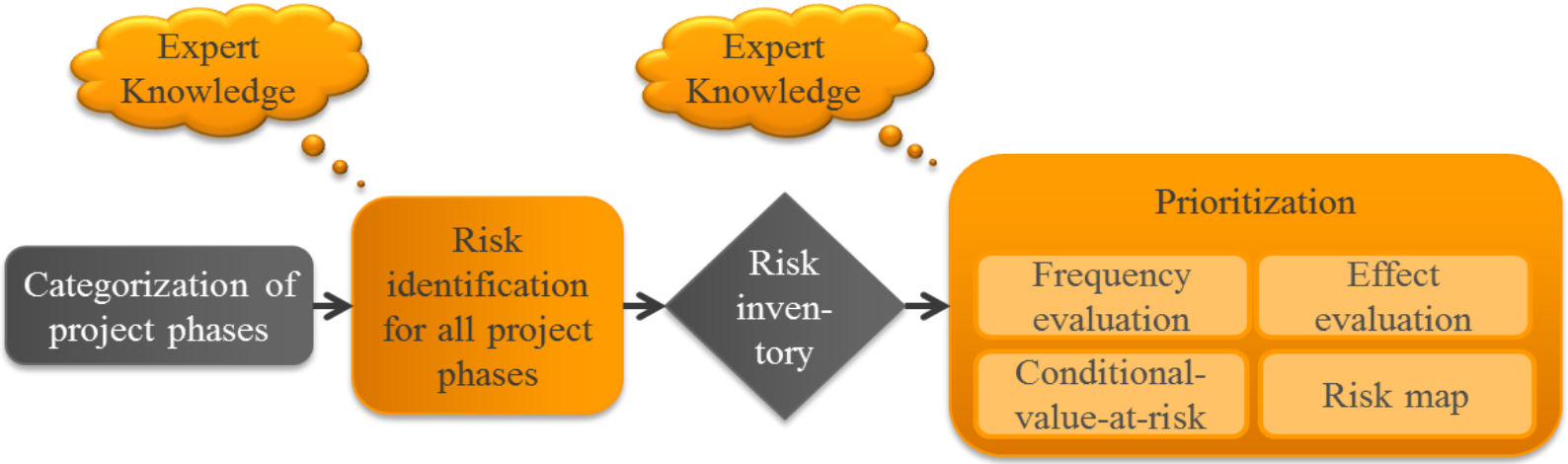
Decision analysis as methodological background



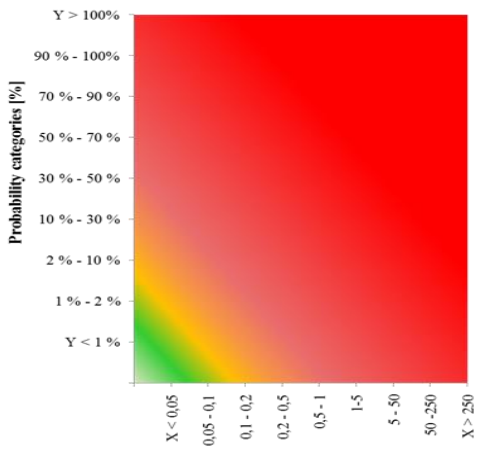
Identification and prioritization as part of risk analysis



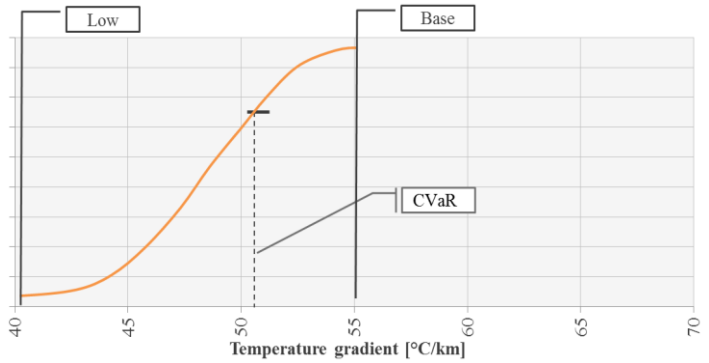
- Expert elicitation as data basis
  - Biased by subjectivity
  - Availability of data / Effort for data collection
- Structured approach for identification of risk factors
- Prioritization of risk factors
  - Fit-for-purpose modelling
  - Pre-selection before in-deep modelling

Prioritization - Continuous distributions in a risk map

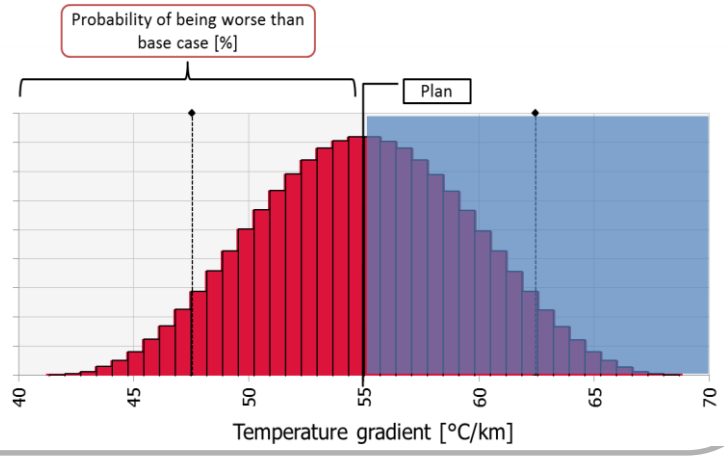
Risk map



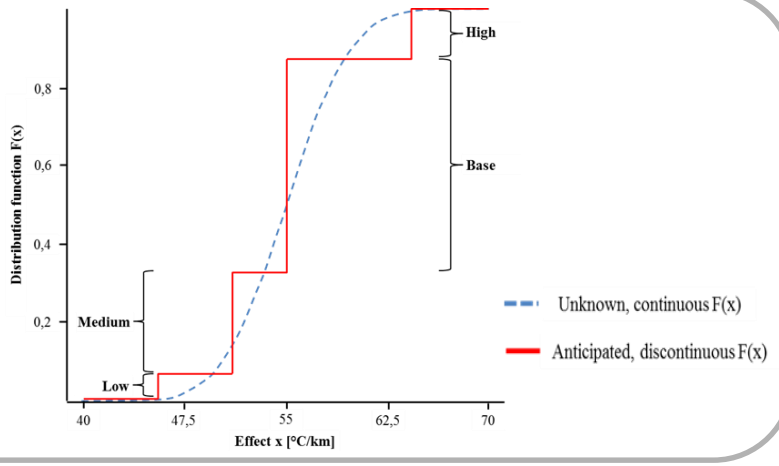
Conditional value at risk



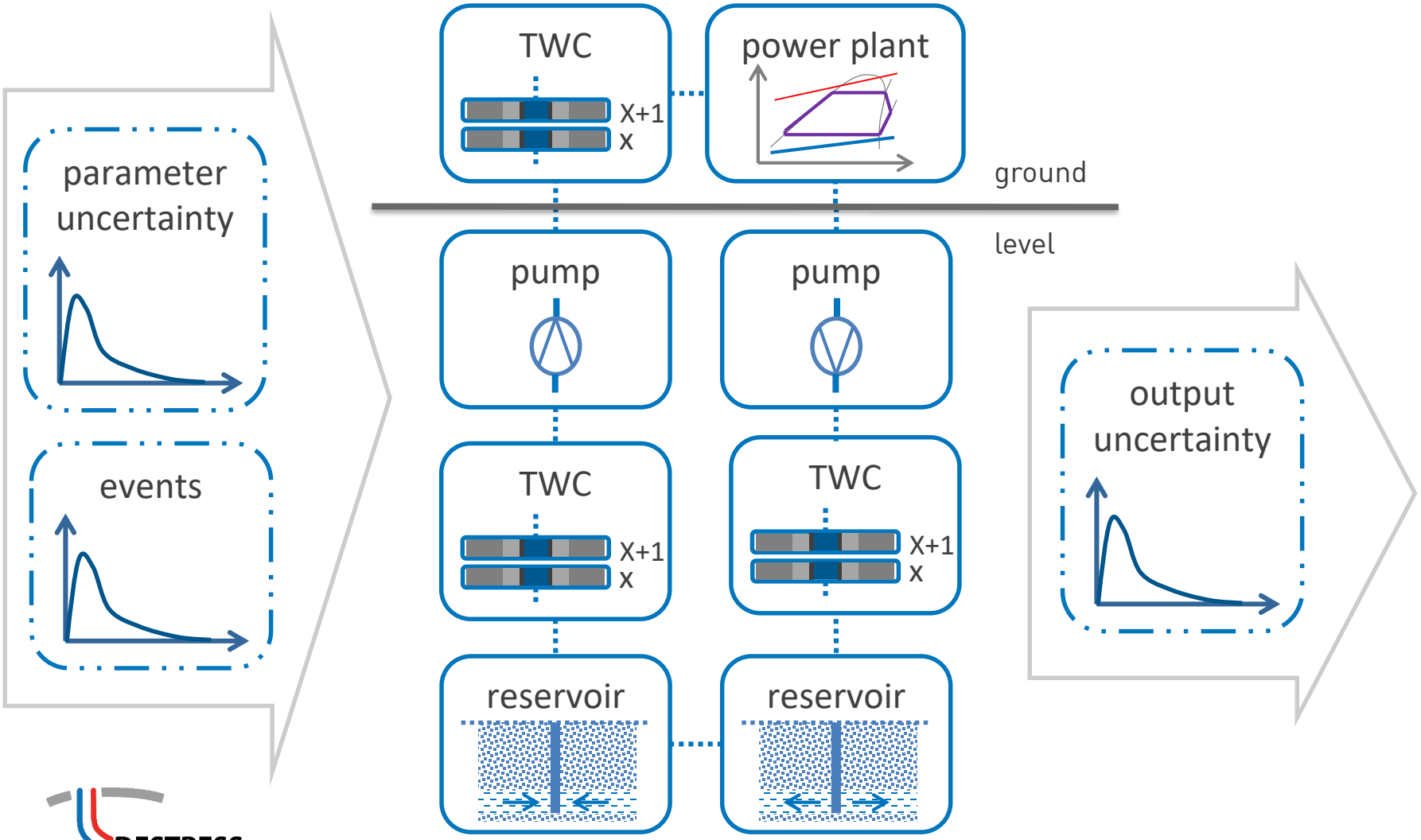
Binominal probability



Construction of PDF

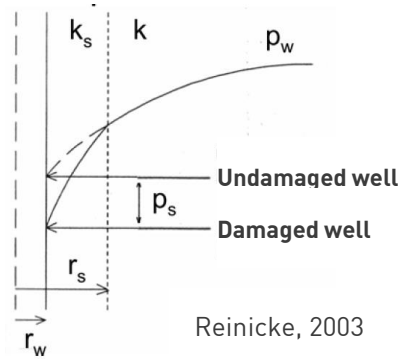


Integrated techno-economic model



Integrated techno-economic model

Reservoir simulation



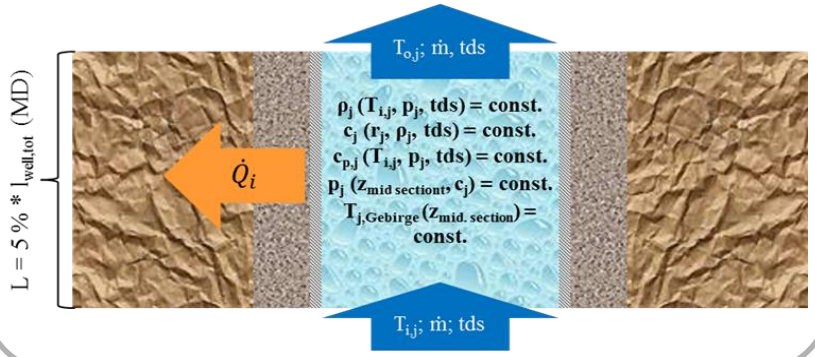
Reinicke, 2003

$$\Delta P_T = \Delta P + \Delta P_S$$

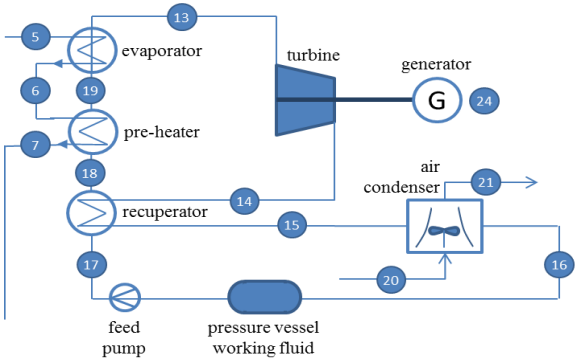
$$\Delta P_S = s_F * \frac{Q}{2\pi T}$$

- Theis (1935)
- Williams (2013)
- Superposition of wells

Thermal water circuit & pumps



Power/Heat plant



Economic model

$$LCOE_{net} = \frac{I_0 + CPI + \sum_{t_{eco}=1}^{t_{eco}=n} \frac{C_{OPEX,t_{eco}} - E_{t_{eco}}}{q_{t_{eco}}}}{\sum_{t_{eco}=1}^{t_{eco}=n} \frac{W_{el,net,t}}{q^{t_{eco}}}}$$

$$with\ q = 1 + i$$

- Levelized costs of energy (LCOE)
- Module costing approach
- Cost functions specific to geothermal energy

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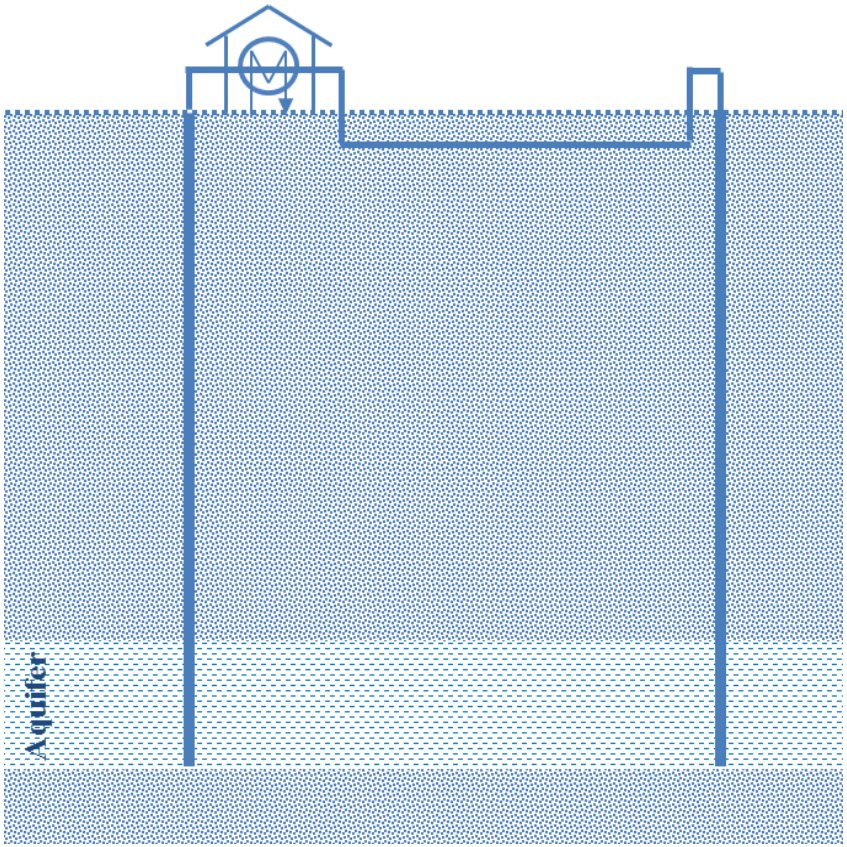
Techno-economic evaluation – base case

Base case – Vertical wells with connecting pipeline



Name	Unit	Value
Volume flow thermal water	m^3/s	0.085
Reservoir temperature production	°C	132.8
depth production well	m	2542
Reservoir temperature injection	°C	119.0
depth injection well	m	1877
Number of wells	#	2
Reservoir exploration method	-	Vertical drilling
Power plant entrance temperature	°C	125.9
Working fluid	-	R236fa
Total dissolved solids (GB2)	g/l	125

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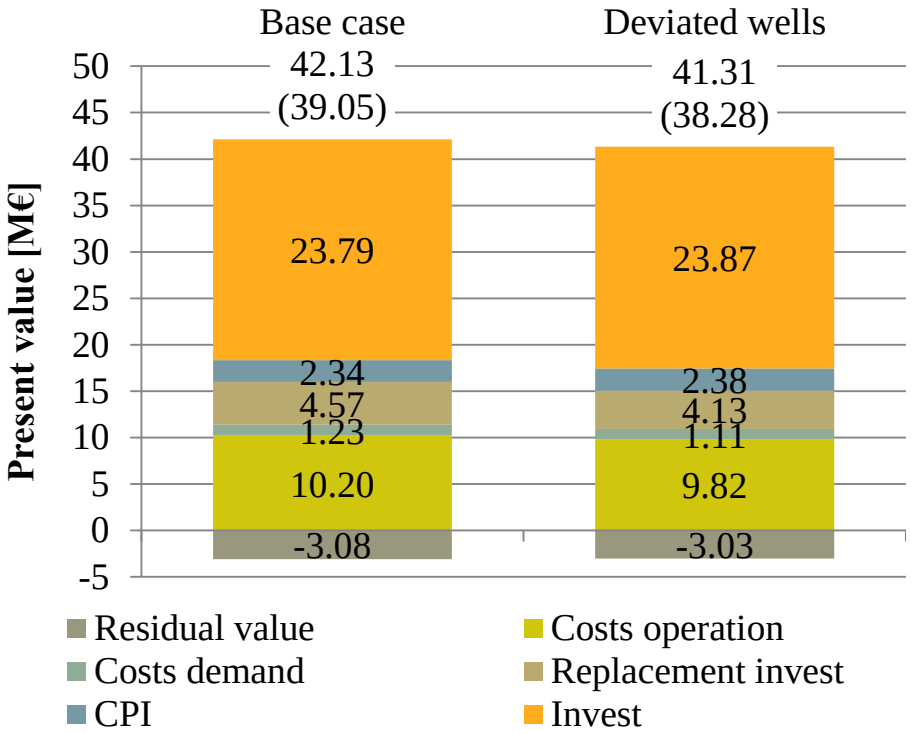
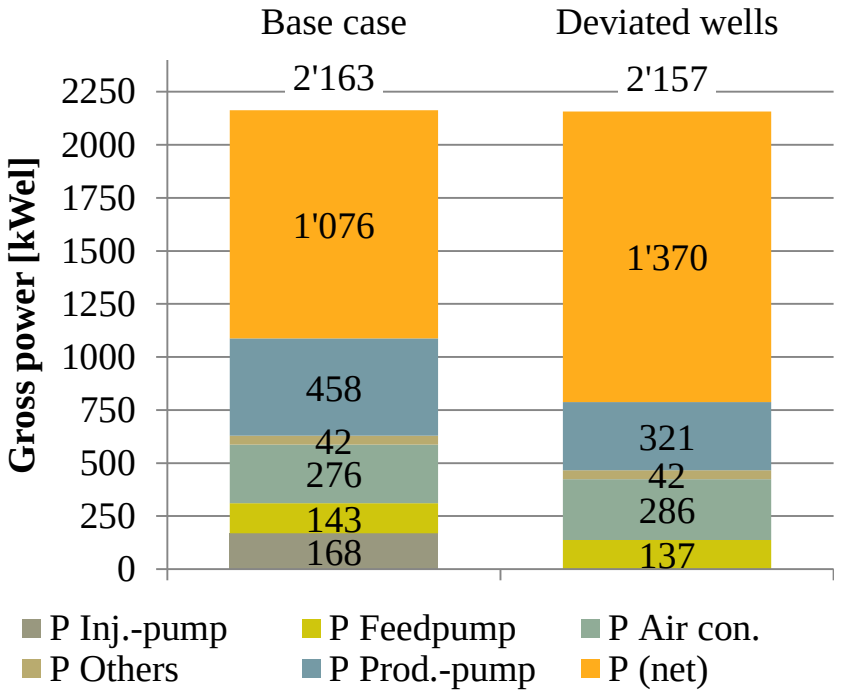
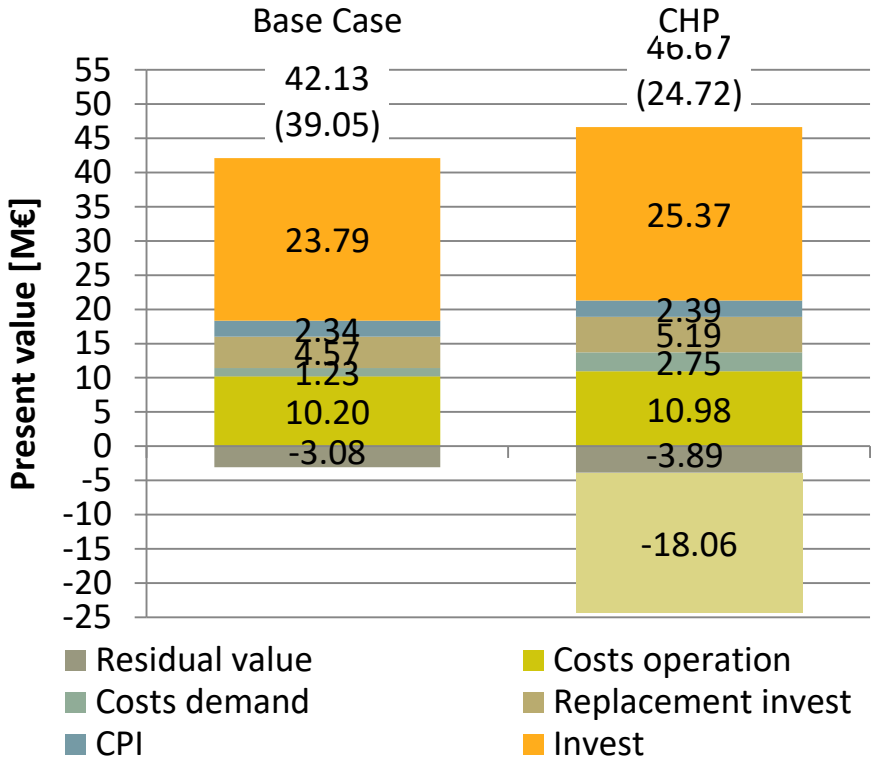
Techno-economic evaluation – deviated wells

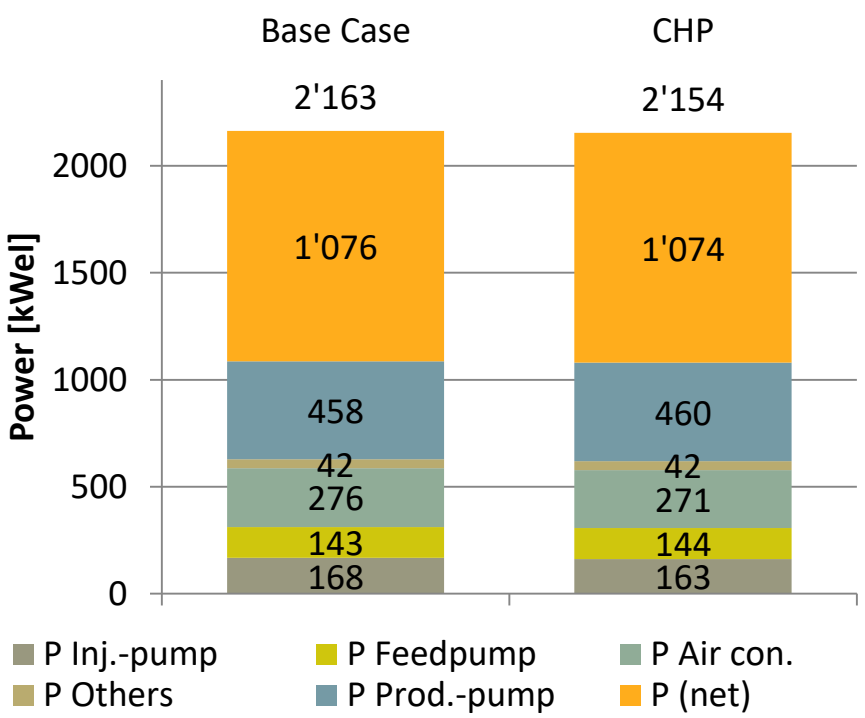




	Present value [M€]	Δ-%	Net power [kW_{el}]	Δ-%	Levelized costs of energy [€/kWh]	Δ-%
Base case	42.13		1'076		0.21	
Deviated wells	41.31	-1.9%	1'370	27.3%	0.16	-23.0%

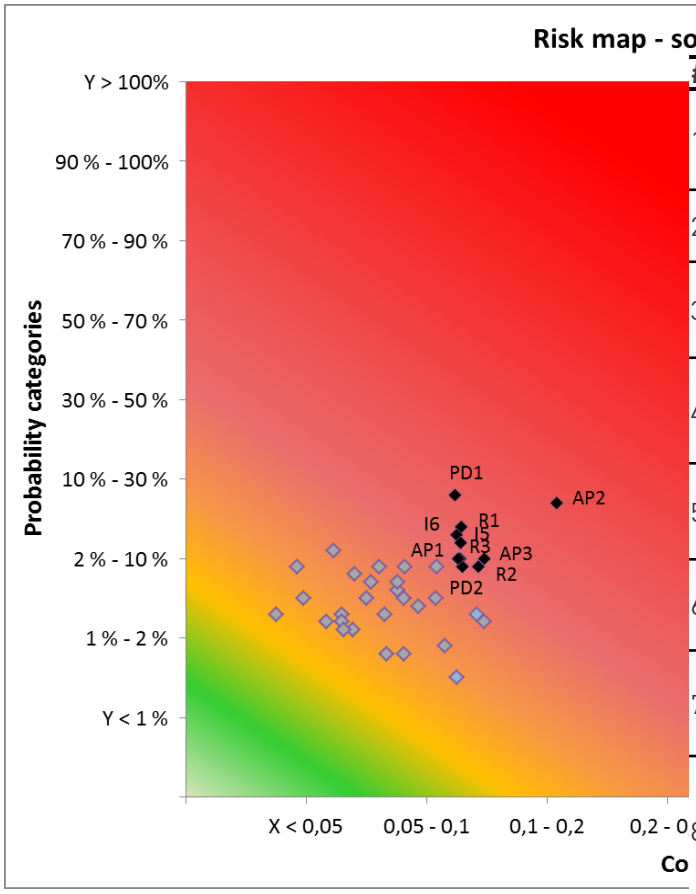
Techno-economic evaluation – CHP





	Present value [M€]	Δ-%	Net power [kW_{el}]	Δ-%	LCOE [€/kWh_{el}]	Δ-%	Disc. .el. energy [GWh_{el}/30a]	Δ-%	Disc. th. energy [GWh_{el}/30a]
Base case	42.13		1'076		0.21		189		-
CHP	46.67	10.8%	1'074	-0.2%	0.17	-17.5%	131	-30.4%	816

Uncertainty – Top-10 risk factors



#	Phase	Risk	Description of effect
1	ALL Phase	Public Acceptance	Loosing permission, strong delay, loss of bankability (after planning before drilling)
2	Project Development	Lack of information	More/additional measuring effort → redesign based on the new information,
3	Reaction	Induced seismicity (with time delay after injection)	Losing public acceptance, surface damage, losing permission depending on the regulations, Project shut down
4	ALL Phase	Change in legislations	Losing permission, strong delay, not receiving permission
5	Injection	Induced seismicity exceeding threshold	Losing public acceptance, surface damage, losing permission depending on the regulations, Project shut down
6	Injection	Loss of effectivity	Not achieving the expected permeability increase, loss of project (becomes uneconomic)
7	Reaction	Fluid-rock interactions	Clogging of well, reduction of permeability, loss of project
8	Reaction	Fluid-fluid interactions (thermal brine and chemicals)	Clogging of well, reduction of permeability, corrosion, production H_2S and other gasses
9	ALL Phase	Political Instability	Losing permission or get extra official requirements
10	Project Development	Lost in hole (measuring tool)	Workover or fishing needed, Losing the well, delay

Conclusions

Decision analysis

- Structured approach for the evaluation of different alternatives

Risk analysis

- Adaption of risk analysis to geothermal energy
- Mapping of continuous distributions in binominal evaluation tool

Techno-economic model

- Detailed techno-economic simulation with focus on central European frame conditions

Risk factors

- Identification and prioritization of risk factors for soft stimulation

Future developments

- Further model development (computation efficiency, adaption to different markets ...)
- Detailed evaluation of identified risk factors

Acknowledgement

Acknowledgement:

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 691728

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DESTRESS is co-funded by

National Research Foundation of Korea (NRF)
Korea Institute for Advancement of Technology (KIAT)
Swiss State Secretariat for Education, Research and Innovation (SERI)

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