Probabilistic and decision tree approach to geothermal techno-economic performance

Netherlands Institute of Applied Geoscience TNO
- National Geological Survey

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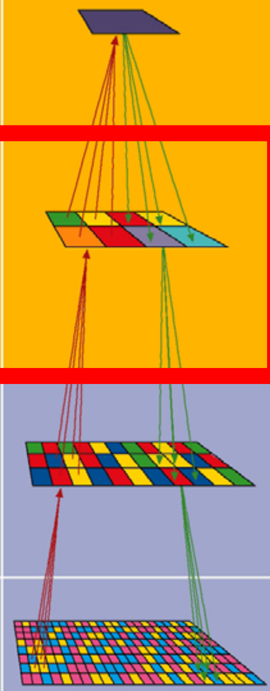
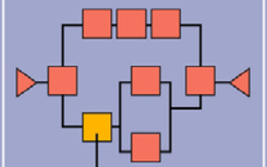
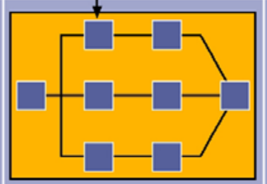
Contents

- **Background**
  - TNO: experience from Oil and Gas E&P
  - Best practices Asset development decisions
  - Decision support system
- **Demonstration trough example of techno-economic evaluation of re-use of oil and gas well for DBHE**

Decisions and Levels of Aggregation

			Techniques	Authorization	Time	Monetary value	Aggregated Information
Business or Commercial Decisions	Strategic		- portfolio management - efficient frontier	Corporate Management	year	10^{10}	
	Operational		- decision analysis - decision trees - Monte Carlo - utility theory - real options valuation - value of: information, flexibility, stepwise	ASSET Management	month	10^{8}	
Technicial Decisions	Business process (Workflow)		- Critical Path Analysis - Project Evaluation (PERT)	Multidisciplinary Team Management	week	10^{6}	
	Single activity		- methodologies - tools	Technical Expertise ↑ Information ↓ Authorization	day	10^{4}	↑ Aggregation Process ↓ Detailed Instructions

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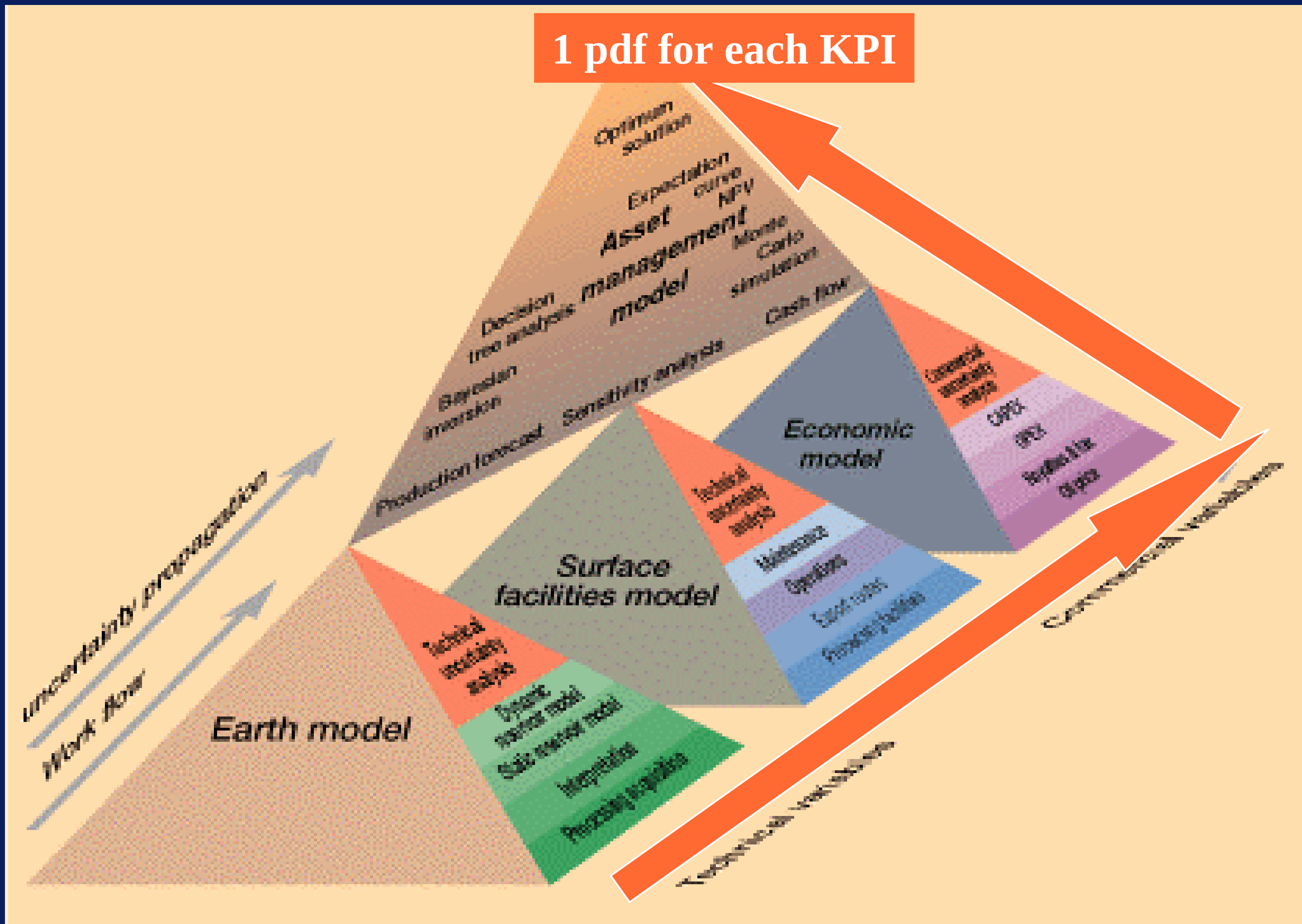
TNOs experience from Oil and Gas E&P
"Decision and risk management"
Research consortia (1997-2003)

BHPBilliton

- **Scenarios AND Continuous probability functions (MC)**

Best practice: integrate techno-economics of workflow, linking technical uncertainty to economic performance



Key performance input / output (statistical distributions)

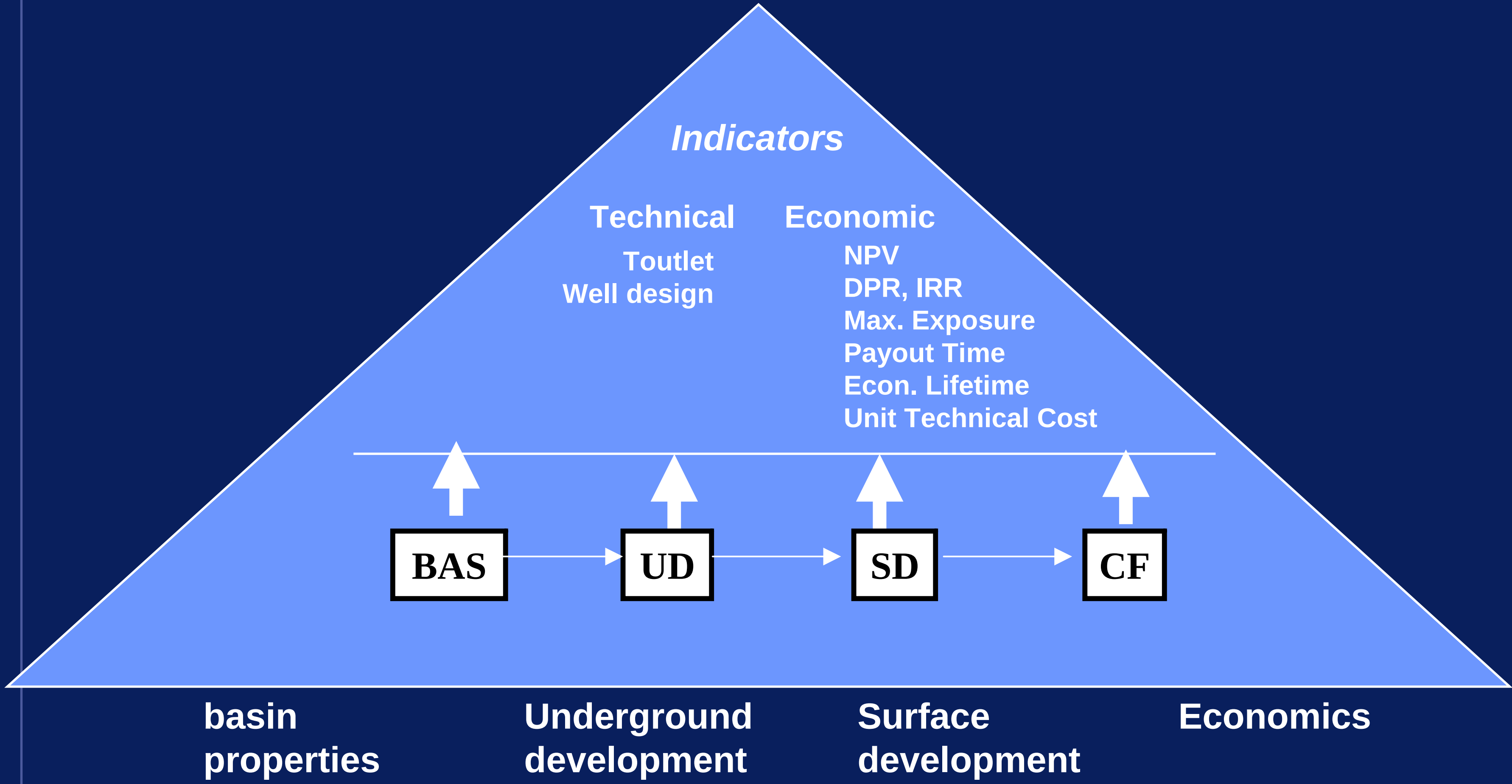
Input

- **Basin parameters**
  - Geotherm, conductivity
- **Underground development**
  - Workover oil& gas wells
  - Design parameters
- **Surface development**
  - Heat exchanger
  - transport
- **Production parameters**
  - Volumetric rate of water
- **Economic parameters**
  - discount rate, energy price
  - opex, capex, tax, royalty

Output (Key Performance Indicators)

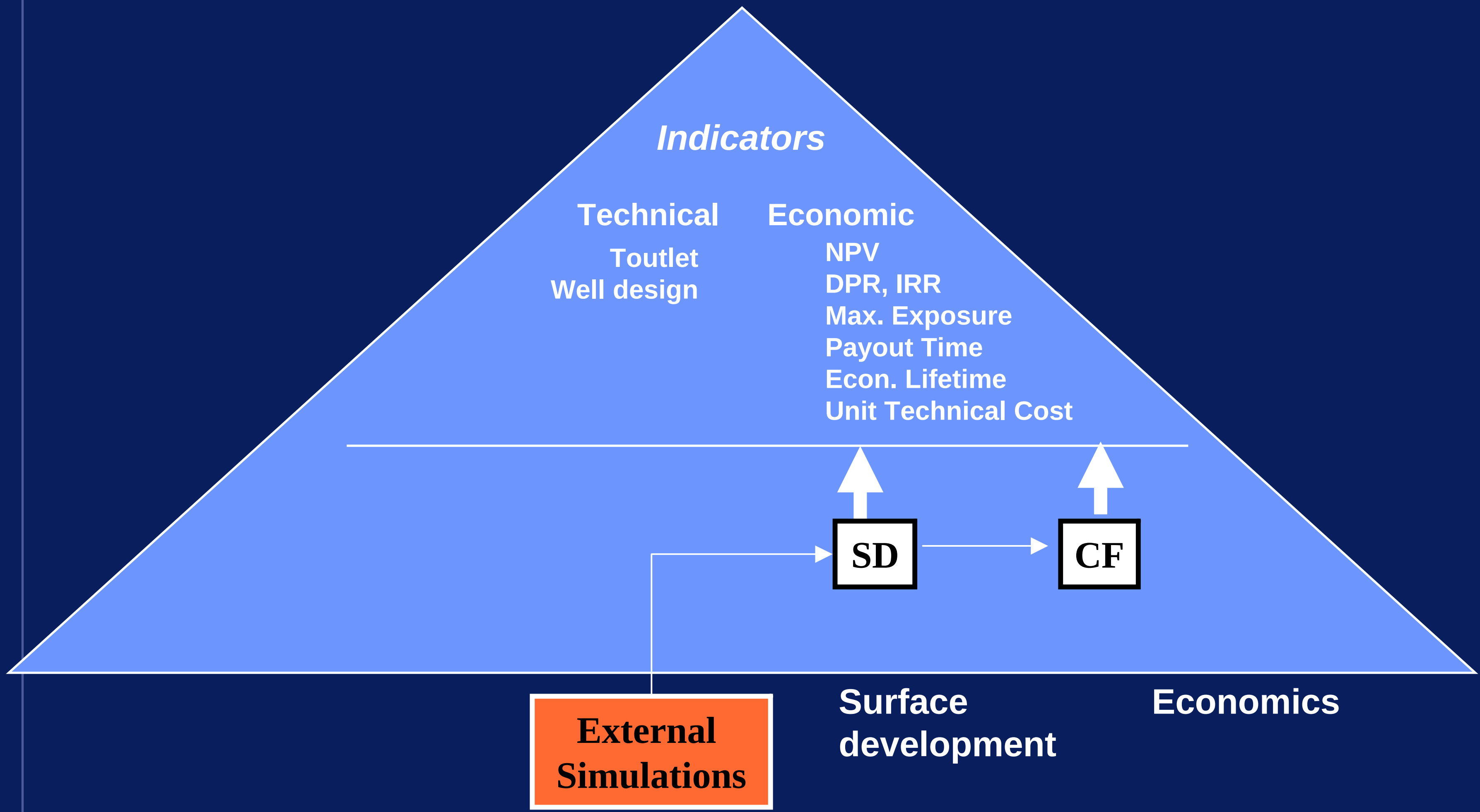
- **Technical**
  - Toutlet
- **Economic**
  - NPV, IRR, P/I ratio,
  - Max exposure, Pay-out time, economic life
- **Other (not as statistical distr.)**
  - HSE
  - Political
  - Public opinion

Techno-ecomonic calculation→
Fast computational models, split up in modules



driving philosophy is to trade-off accuracy for completeness

Techno-ecomonic calculation→
Expert data input (multiple runs from external simulation software)



Introduction
DBHE-layout (Prenzlau)

- **DBHE:**

Deep Borehole Heat Exchanger

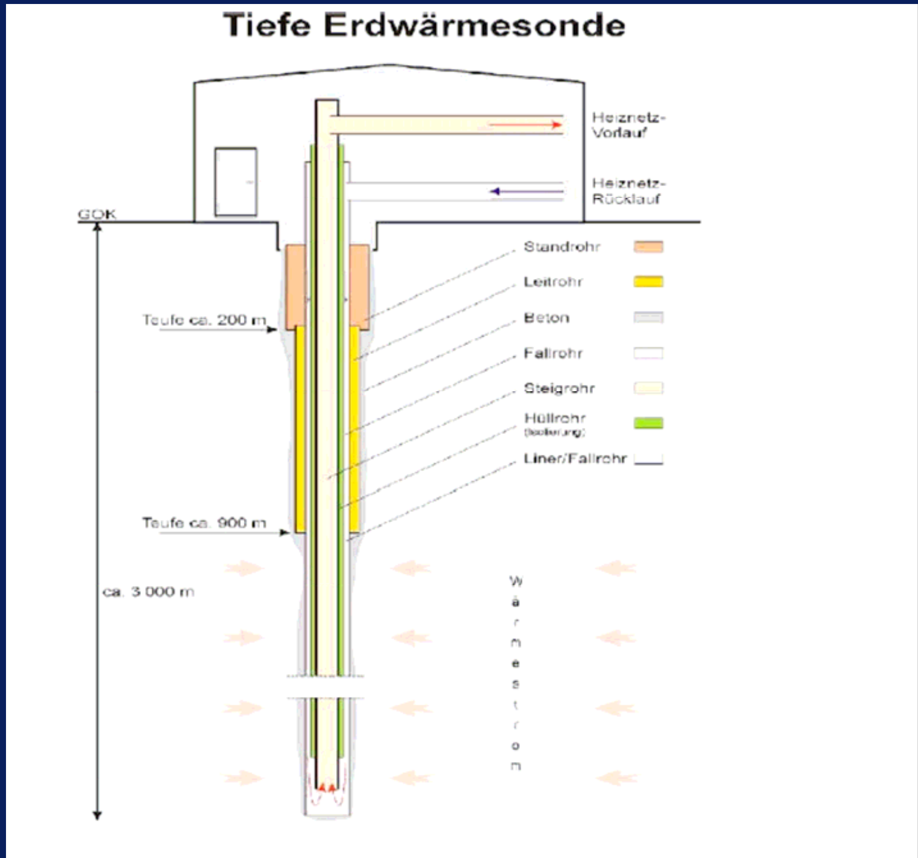


Figure 3 General layout of the DBHE in Prenzlau, Germany.

Introduction
Why modelling a DBHE?

- **New interest in geothermal energy**
- **The DBHE is experimental, but there are several setups (Prentzlau, Weggis)**
- **Interesting option in the Netherlands**
  - Not necessary to drill new wells, use existing E&P wells
  - Possible positive effect of the heating of the surrounding rocks during production of oil or gas
  - Restriction:
    - Short distance from the source to the consumer

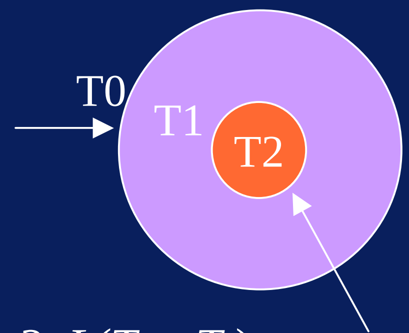
Introduction
Heat transfer in DBHE

- **The Fastmodel is based on the paper of Kujawa and Nowak, 2000b- *Thermal calculations of geothermal heat utilising one-well systems with both injection and production (validated by finite difference calculations)***

- **The heat flux in the analytical model is calculated as follows: (cf. Kohl et al., 2002)**

  - Isolated outer tube:

$$J = \frac{2\pi L(T_1 - T_0)}{[\frac{1}{h_z r_z} + \frac{\ln(r_{zo} / r_z)}{\lambda_s}]}$$



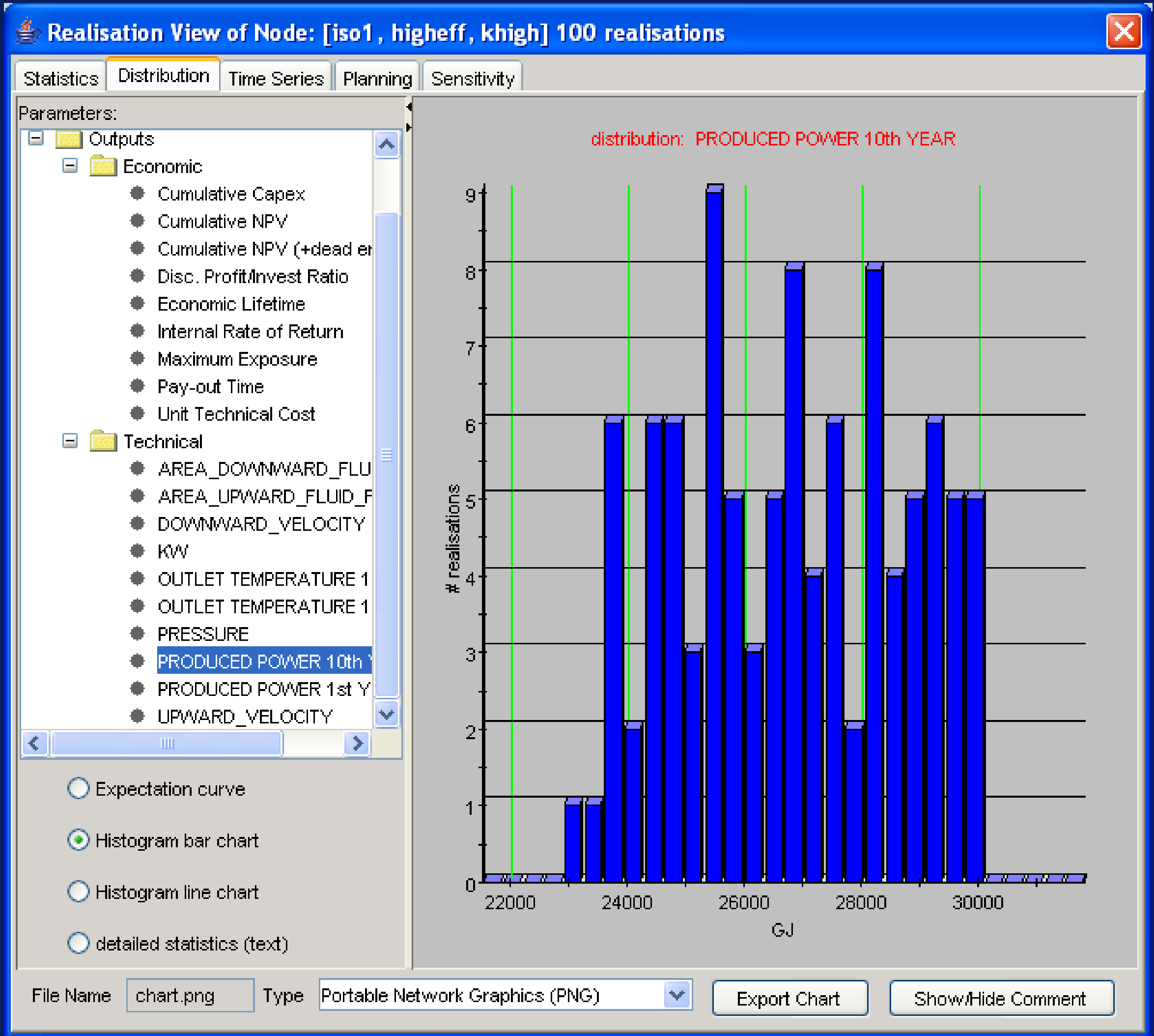
  - Isolated inner tube:

$$J = \frac{2\pi L(T_2 - T_1)}{[\frac{1}{h_w r_{wi}} + \frac{\ln(r_{wa} / r_{wi})}{\lambda_s} + \frac{\ln(r_{wb} / r_{wa})}{\lambda_{ins}} + \frac{\ln(r_w / r_{wb})}{\lambda_s} + \frac{1}{h_z r_w}]}$$

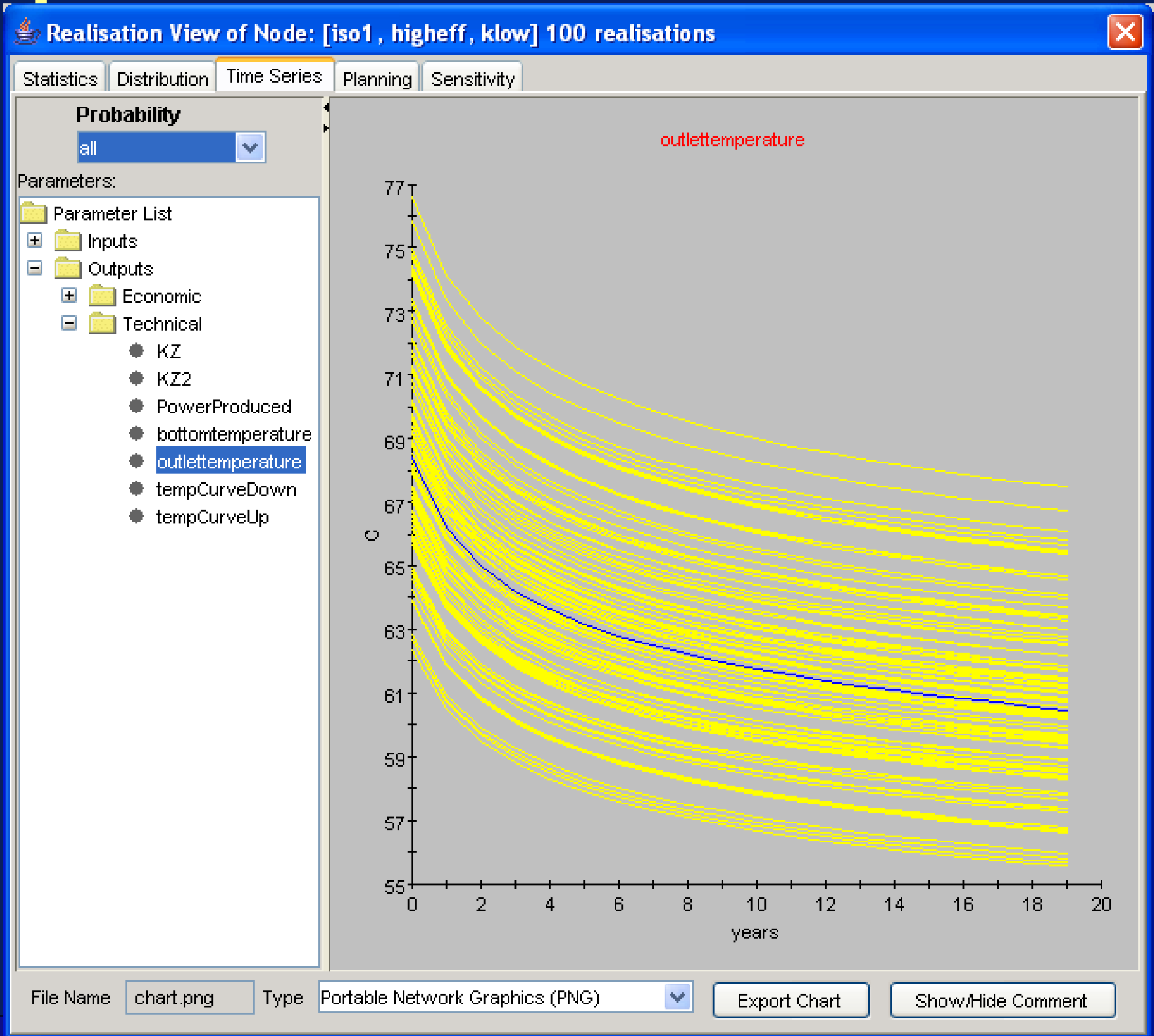
Thermal boundary layer

Thermal boundary layer

Output Value, scalar: power produced Year 10

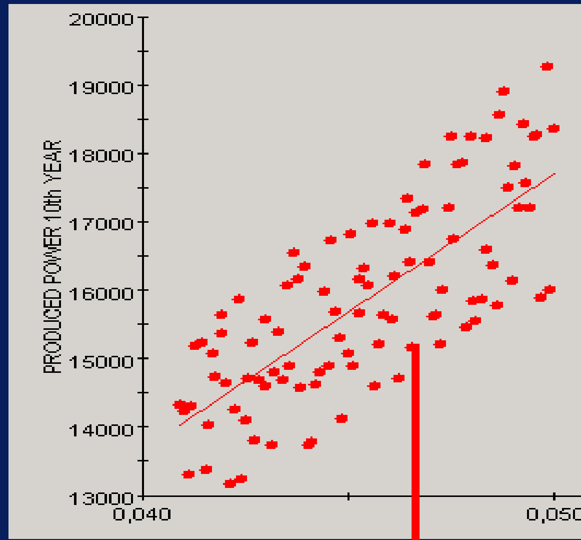


Output Value, timeseries :Toutlet --> power

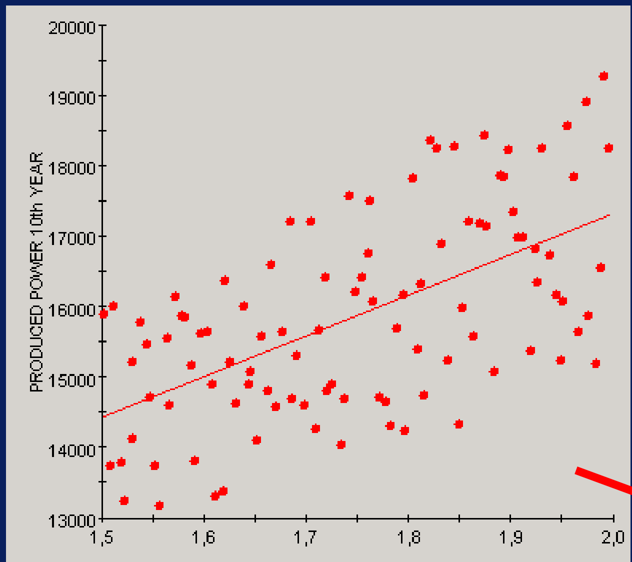


Uncertainty because of:
K = 1.5..2
Geotherm = 40..50 C/km

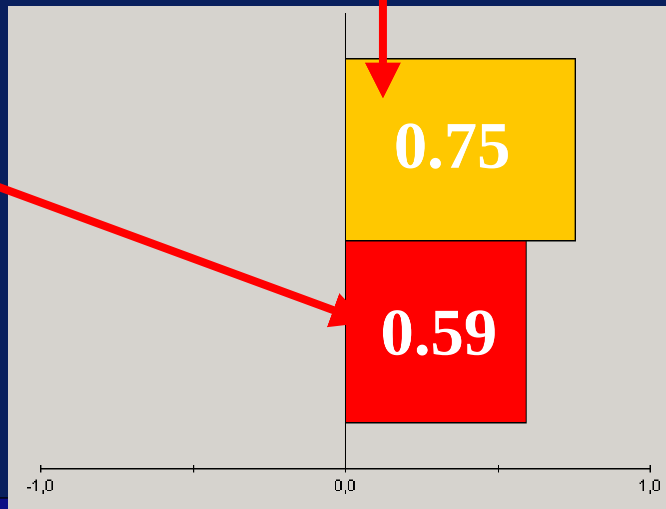
Sensitivity of Power to ..



Geotherm [C/m]



conductivity

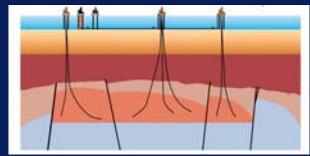


Tornado-
plot

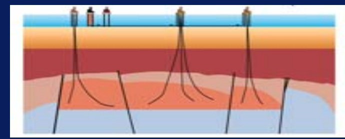
SCENARIO ANALYSIS: Description of DBHE case

DECISION
UD model

isolation



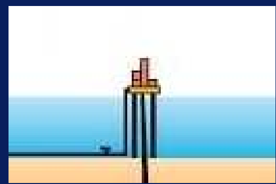
vacuum=0.5 cm,
50 kEUR



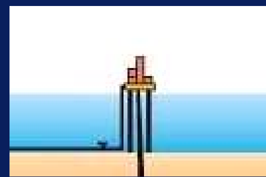
vacuum=1 cm
100 kEUR

DECISION
SD model

Heat exchanger

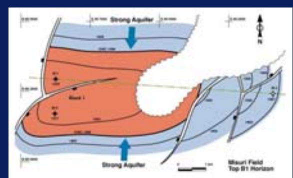


100 kEUR eff= 0.9

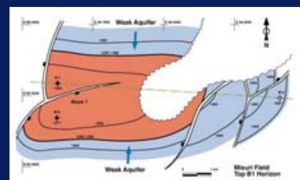


50 kEUR Eff= 0.8

UNCERTAINTY
BAS Model

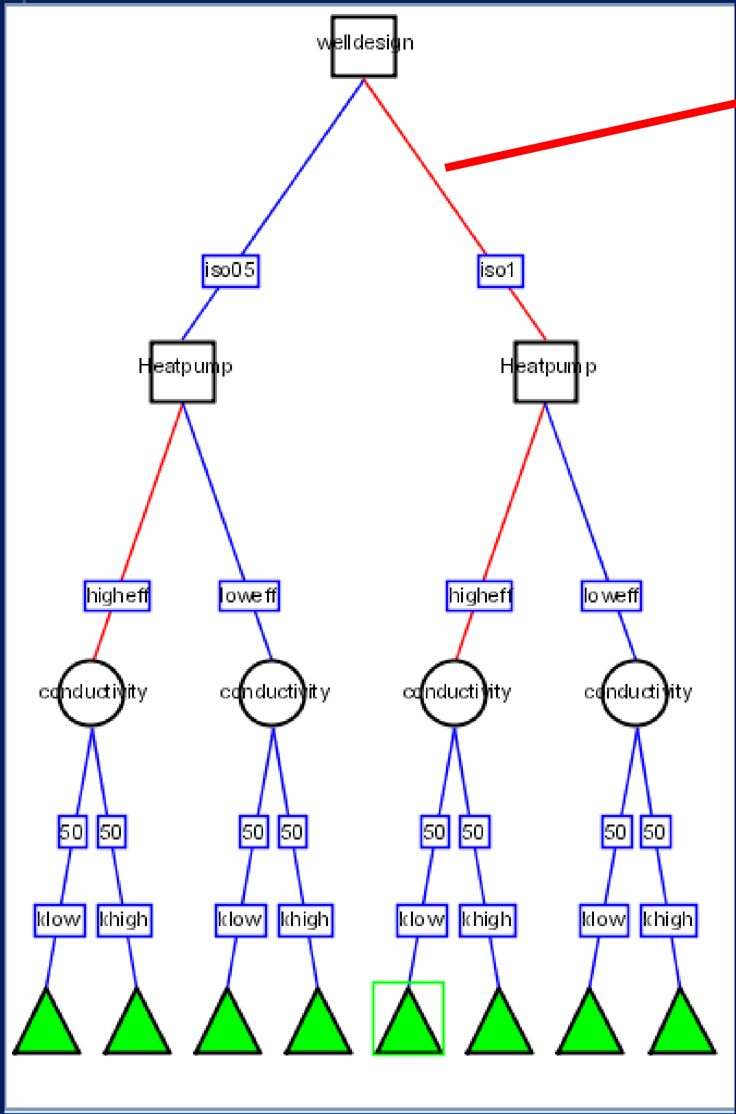


K=1.5-2

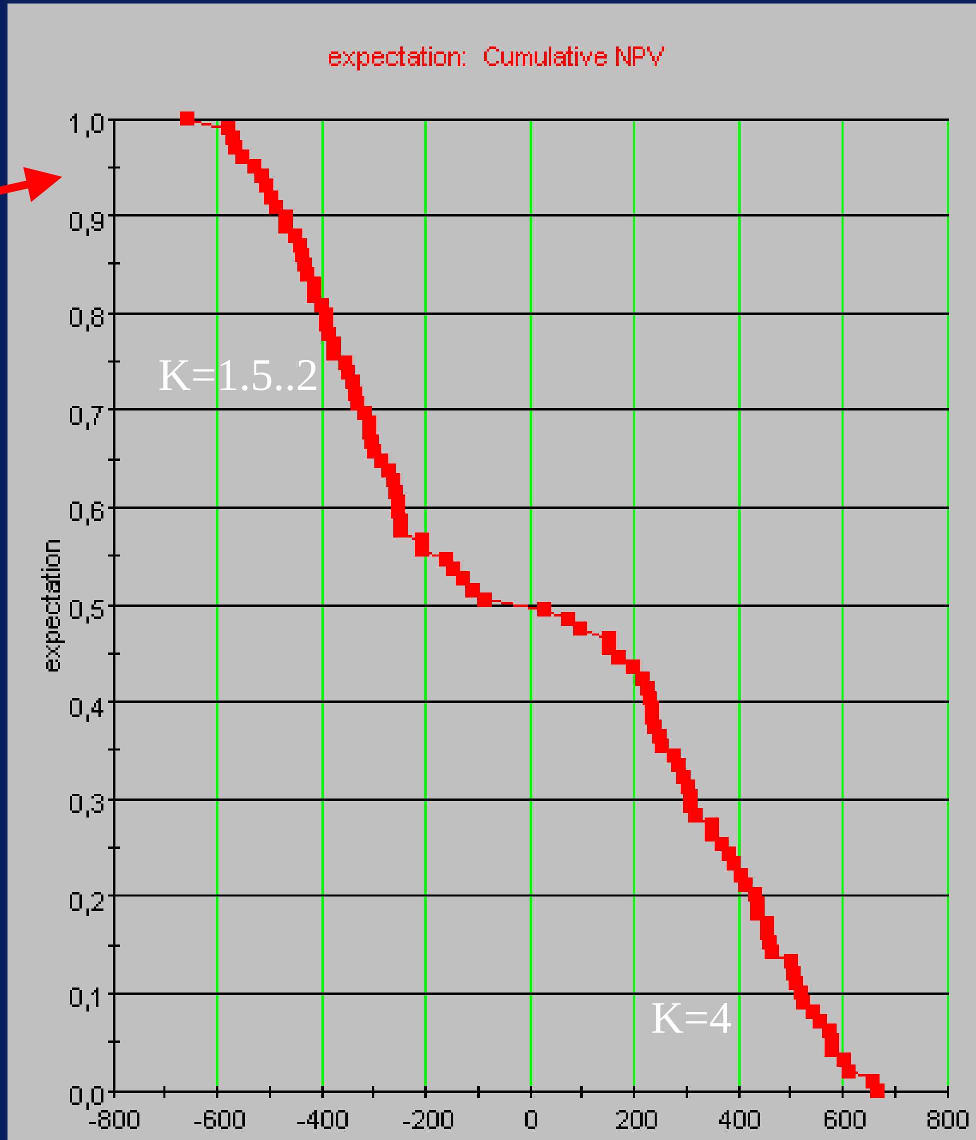


K=4

Decision Tree

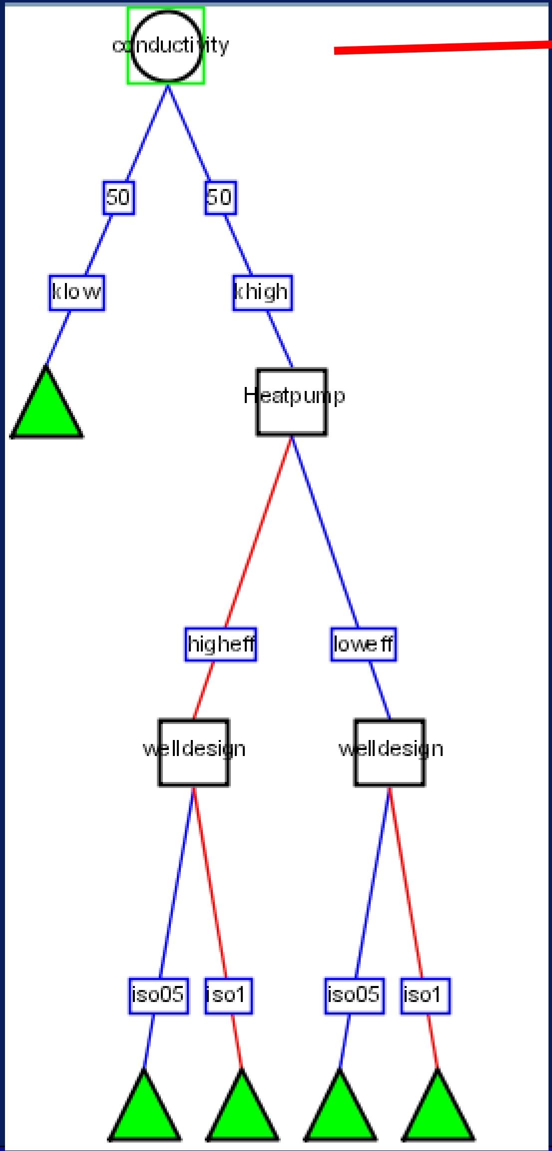


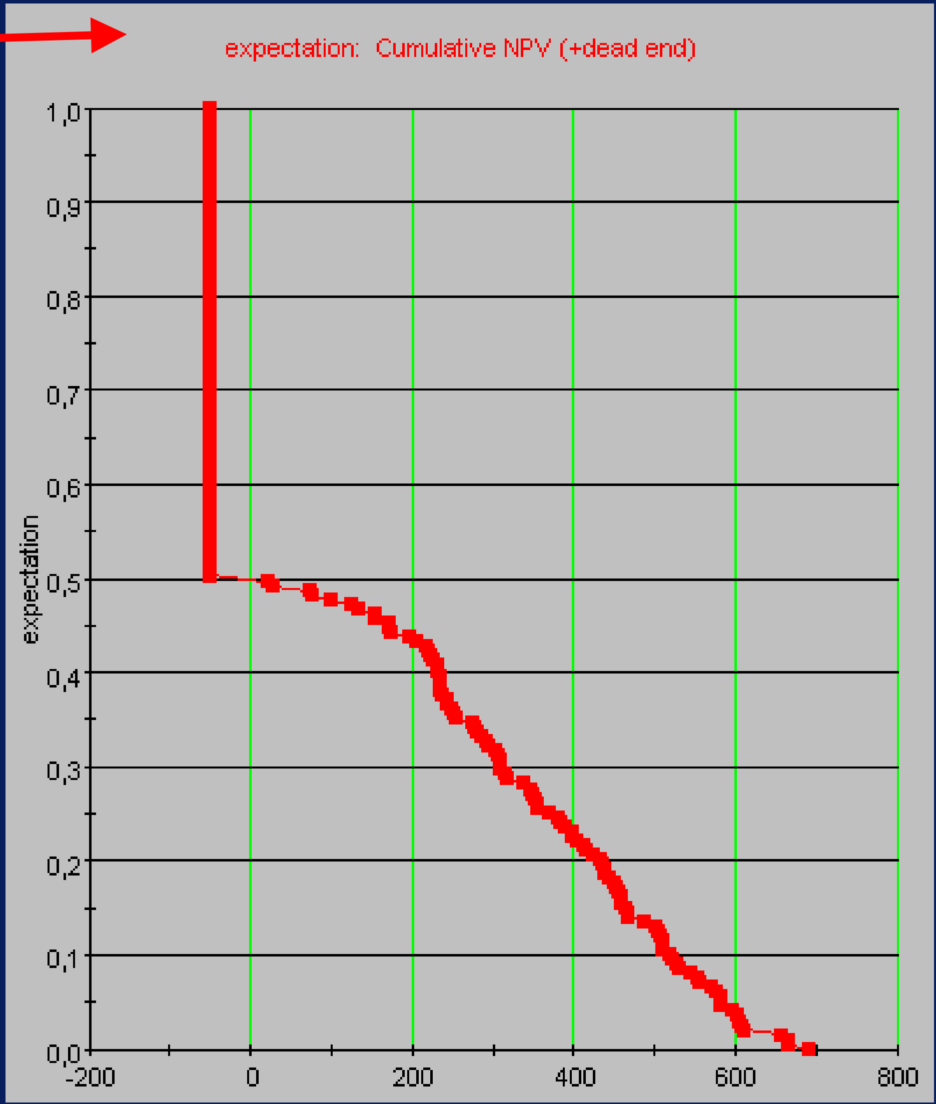
DOWNSIDE BECAUSE OF k=1.5..2 scenarios



NPV [kEUR]

Decision Tree – K=1.5..2 scenarios excluded (assesment with costs 50 kEUR prior to use)





NPV [kEUR]

Conclusions

- **Usefull to adopt decision and risk management best practices from Oil and Gas industry**
  - Understanding of sensitivity of performance to uncertainties beyond control
  - Selection of optimum design scenarios

- **DBHE specific**
  - Geotherm, and conductivity of prime importance
  - Isolation inner-outer tube important
  - (not shown in this presentation) Preceding oil and gas production leads to pre-heating of well which can increase power by 20-30%

- **DSS aproach very generic and usefull for other applications**