Geothermal Business Modell

Ruggero Bertani

Geothermal Innovation & Sustainability
Enel Green Power

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Enel Green Power

Geothermal project's evaluation process

Target & main elements

Project's economical viability evaluation

- Area's potential in terms of sustainable electrical capacity
- Evaluation and definition of all the technical aspects that affect the required Capex & Opex
  - Expected well's deliverability
  - Well's depth
  - Interference effects
  - Scaling or corrosion effects
  - Gas content
- Designing of the exploitation strategy
- Forecast the reservoir evolution (resource availability and/or temperature decline) along the project lifetime

MWe	Resource assessment (technology & plant size)
Mwe/well	required wells
#	M$/well
Spacing	wells per pad
$	Opex
%	Parassitic losses

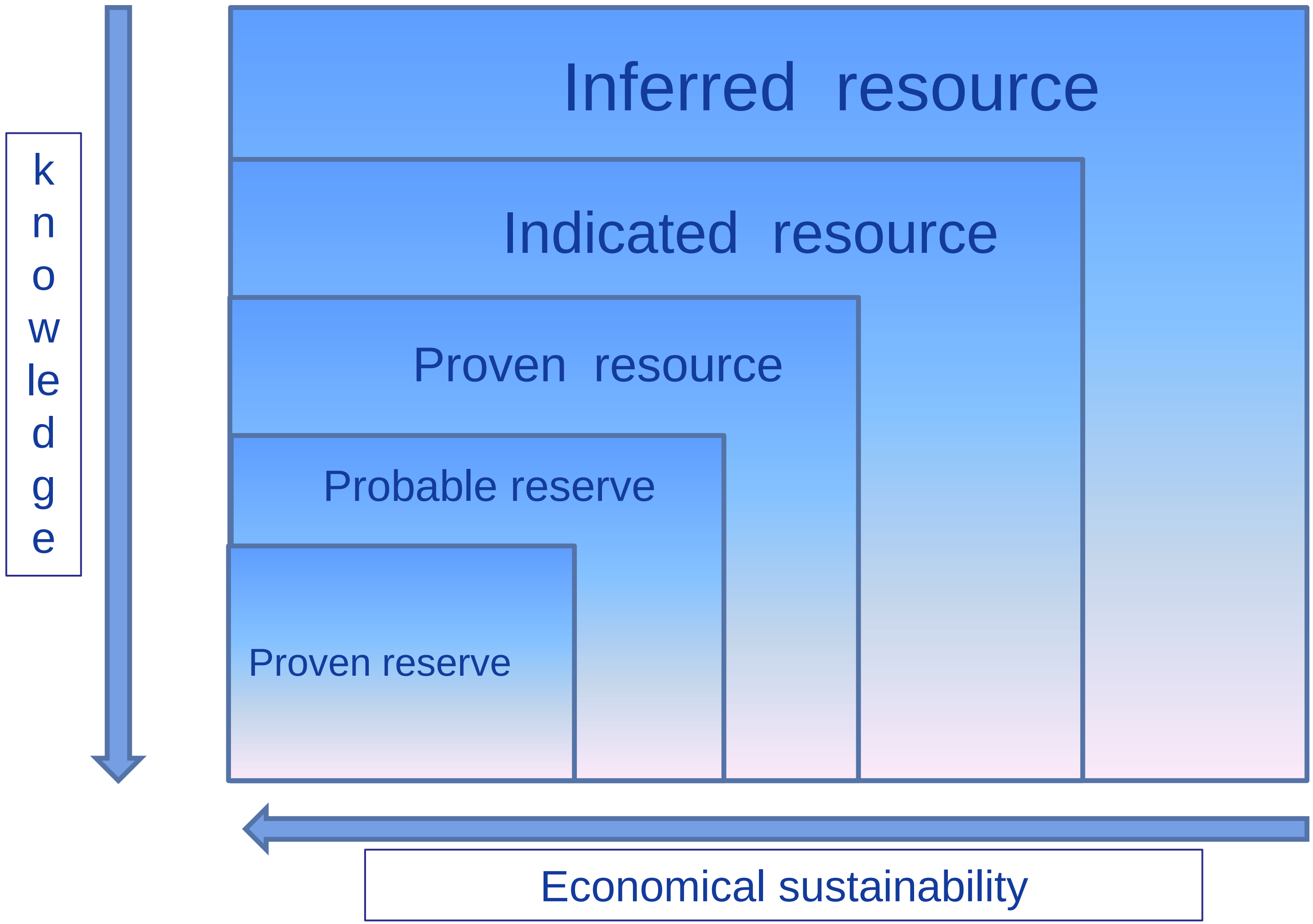
Prod. & Reinj.: where and how much

Production evolution and make up wells

Complex process that requires to define many parameters and to foresee their evolution along the time

Georesource assessment

Geothermal resource vs Geothermal Reserve



Overview of a Green Field Geothermal Project (40 MW)

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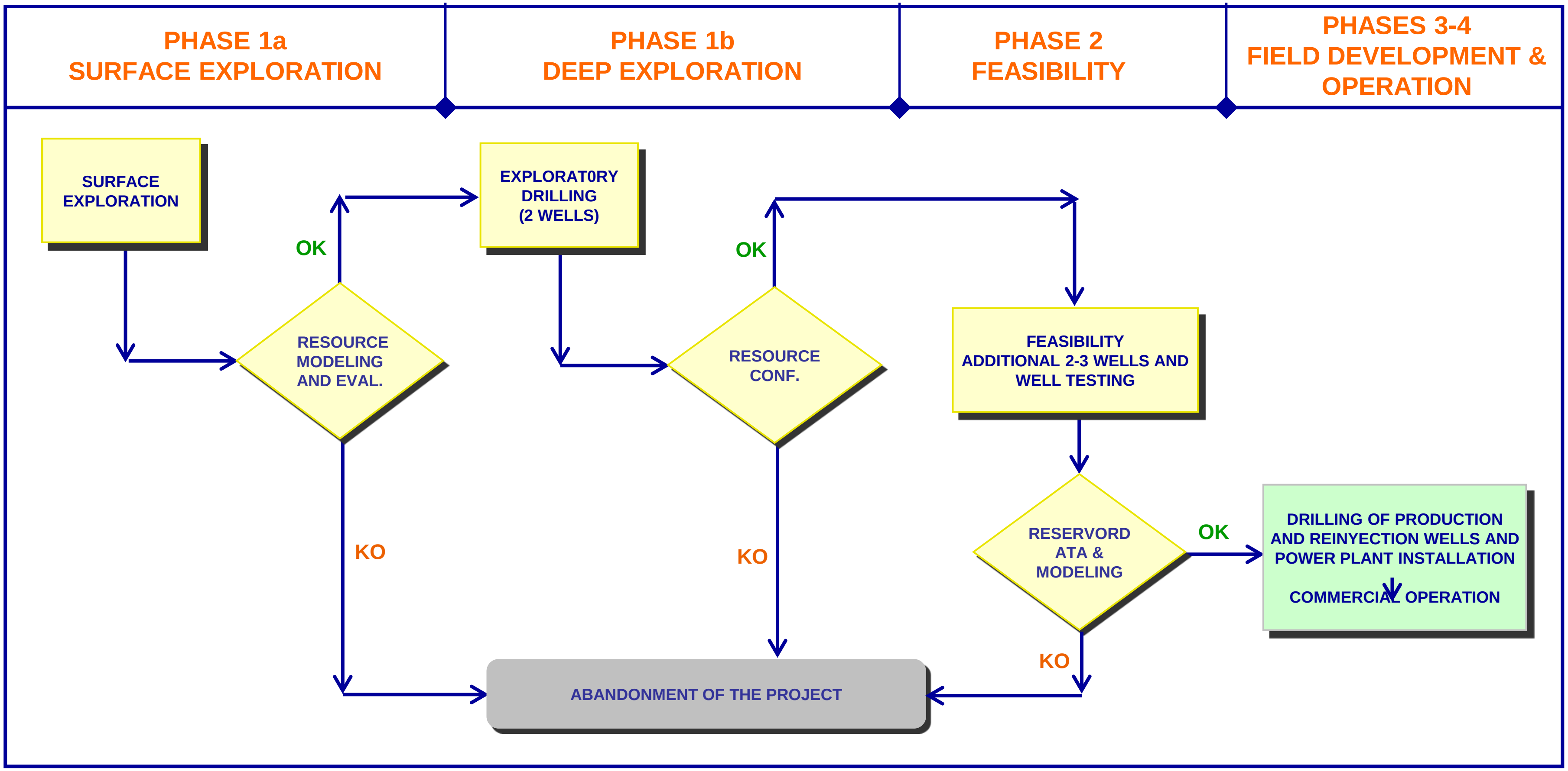
	Surface Exploration	Deep Exploration (Drilling)	Feasibility	Field Development
Uncertainty	High	Medium	Medium	Low
Complexity	Low	Medium	Medium	High
Schedule (months)	6 - 8	12 - 16	12 - 16	36 - 48
Cost (MUSD)	0,6 - 0,8	10 - 22	10 - 22	110 - 130
Activities	• Geological, geochemical and geophysical prospecting. • Integration of geoscientific data and resource modeling.	• Permitting and procurement • Well pads and roads design/construction • Well design/planning • Drilling (min. 2 wells)	• Permitting and procurement • Well pads and roads design/construction • Drilling (additional 2-3 wells) • Well testing	• Permitting and procurement • Production and reinjection wells (10-15 new wells) • Steam separation and gathering system installation • Power plant and transmission line construction
Scope	Preliminary evaluation of resource potential and characteristics. Location and planning of exploratory wells.	Resource confirmation	Reservoir assessment and feasibility study /design of commercial development scheme	Power Plant installation

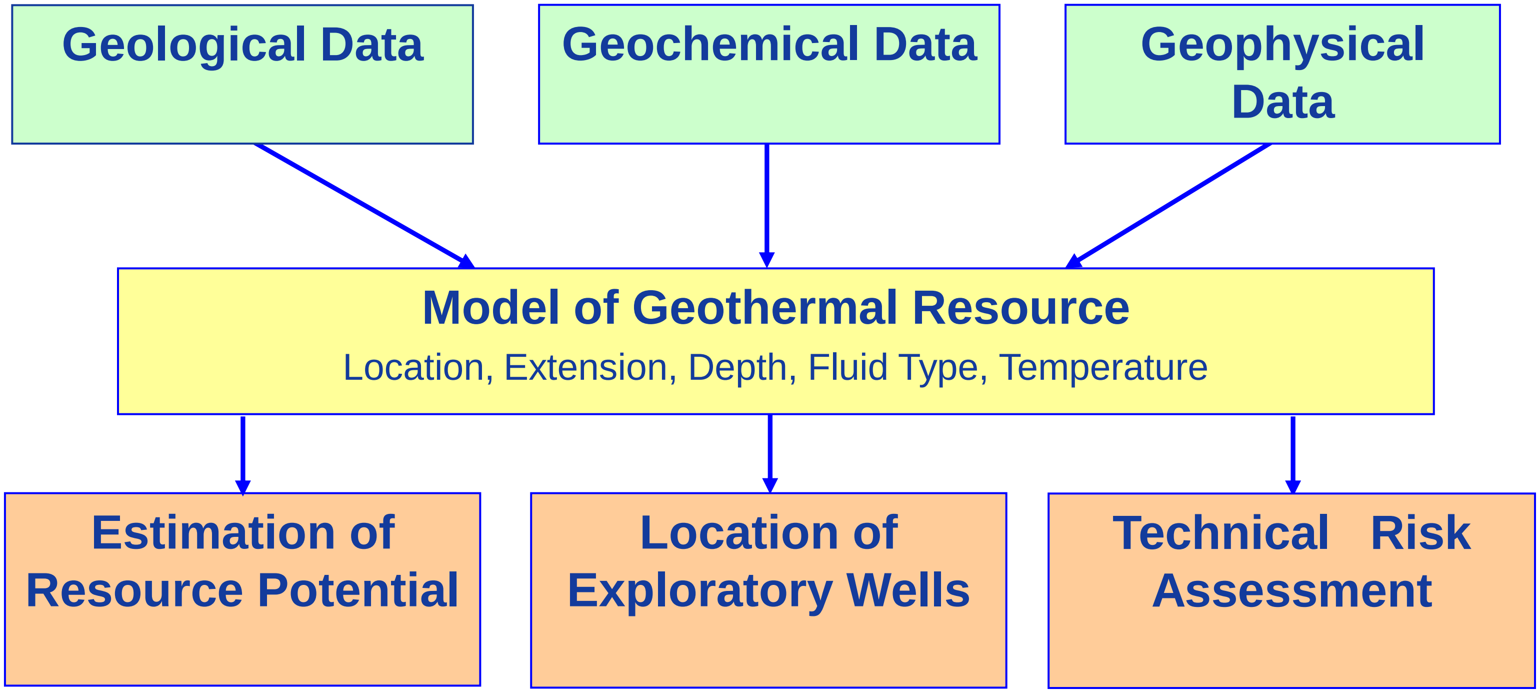
Decision Tree



Go/non go decision in phases 1a -1b, based on Real Option Methodology

Surface Exploration

Integration of Geoscientific Data and Resource Modeling Process



Skills and interaction with other functions

Business development → *Engineering* → *Construction* → *Operation*

Working Team

Hydrogeologist

Geophysicist

Geologist

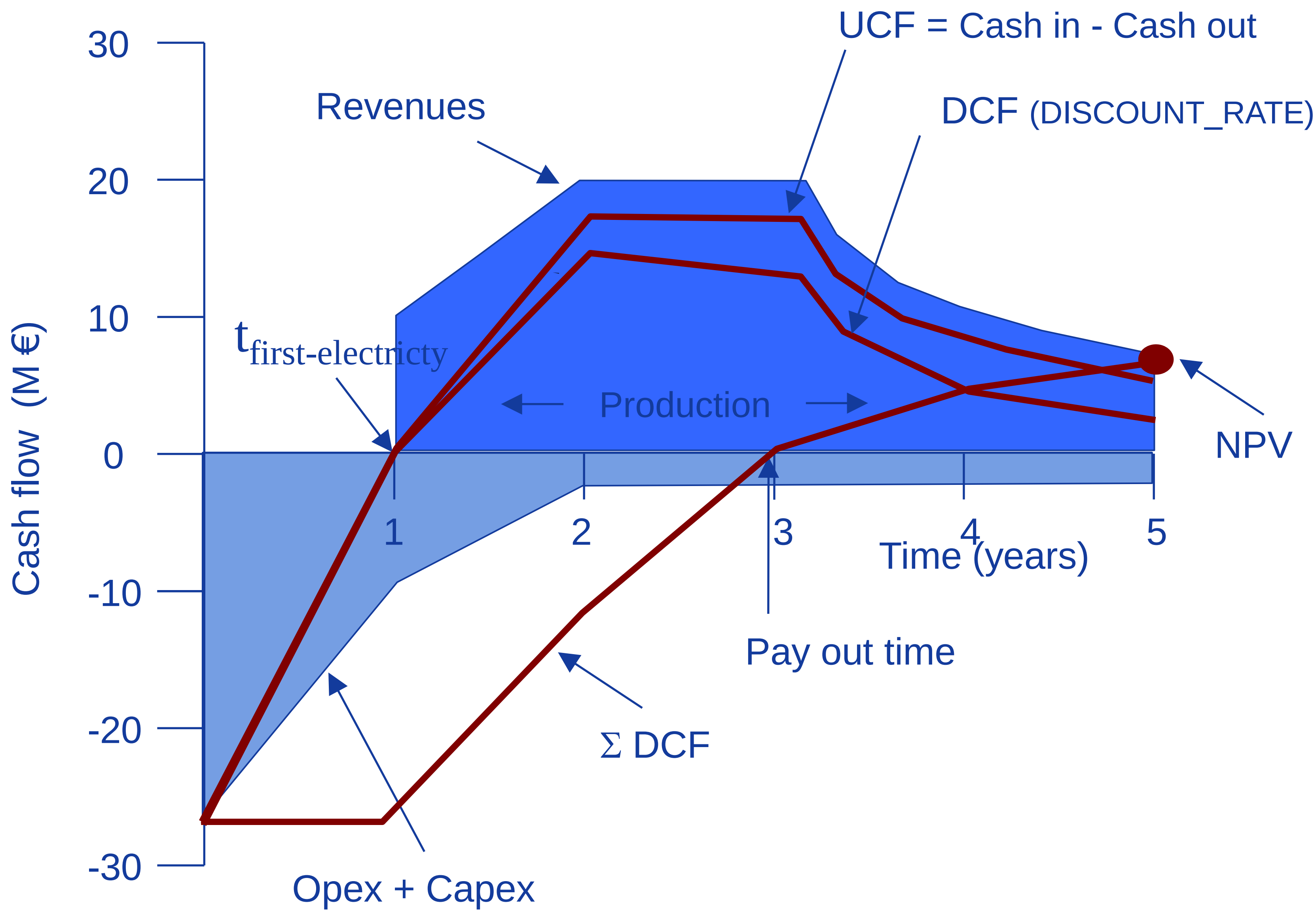
Geochemist

Reservoir Engineer

Site geologist

All the key competences must be involved in each project

Real option valuation approach



Real option valuation approach
Overview

- This approach consists of evaluating the Expected Monetary Value (EMV) of a managerial decision (such as do or abandon deep exploration).
- EMV is the probability weighted average of the NPV of each possible outcome of the managerial decision.
- If EMV is greater than zero then it is is convenient, from a financial perspective, to proceed with the project.
- Nevertheless, this amount does not reflects the value of the entire project, because the actual value of the entire project can be a number between its minimun NPV (worst scenario) and its max NPV (best scenario);
- EMV reflects the value for the shareholder of the “go ahead” decision under the current uncertain scenario.
- The Real Option valuation approach can be used as a **complementary tool to full cycle valuation to decide on deep exploration funding.** This approach models the effect of changing assumptions and consequent management response during the development of the project (such as go/no go based on deep exploration actual results and renewable incentives actually available when deep exploration is concluded).

A case study

It is necessary to commit deep exploration CAPEX before the end of the surface exploration. Hence the managerial decision needed is whether to fund the deep exploration phase or not

Some of the basic assumptions have materially changed:

1. The increased demand for oil rigs caused by the current oil and natural gas prices, drilling costs have materially increased (about doubled) Drilling costs – circa 100% increased

2. Although not yet approved, the parliament is analizing a law proposed by the government that would benefit renewable plants such as geothermal with a green credit capped at 20-25$/MWh

3. Higher expected well productivity (MW/well) – actual production tests carried out at another site, 25 km from our case study site, show about twice as much well productivity than previously assumed (its likely part of the same geothermal system) and further analysis of wells drilled in the past.

Full cycle valuation approach

Under the full cycle valuation approach a set of assumptions are defined as a base case, and this returns an NPV that represents the value creation to the share holder. If the new cost budget is considered for the standard valuation the NPV will be:

Including surface exploration sunk costs = **-23.9 MM US$**

Nevertheless, in this case, the use of this approach will bias the decision due to:

- 1 “average” scenario, without considering possible outcomes from diverse scenarios (different wells productivities and then available government incentives)
- It does not consider the possibility to walk away after knowing the outcomes from the deep exploration phase (the option to develop post exploration)
- It does not considers Green Credits incentives (the proposal of law is being discussed based on the Italian Law on Green Credits) neither the possibility of different levels of them

Real option valuation approach
The steps

Steps of this approach:

A. Define the scenarios (possible outcomes of the “go ahead” decision):
   - 6 scenarios of well productivity, of which each will have 3 sub scenarios of available tariff incentive (0, 10 or 20 US$/MWh); for a total of 18 possible outcomes

B. Define the probability of each scenario

C. Define the NPV for each scenario (full life cycle NPV, including exploration costs)

D. Determine the Expected Monetary Value. $EMV = \sum(P_k x NPV_k)$

If **EMV>0** the decision to go ahead will likely yield a positive return (it is more likely than not that after the deep exploration phase the project will have returns in excess of expectation and with sufficient value to offste the exploration costs),

If **EMV<0** the rational approach would be to abandon the project now

Real option valuation approach

Scenarios Definitions – Cost drivers

Cost drivers (wells productivity and drilling depth)	
Scenario	**Description**
1	8 MW/well 1000 m deep
2	8 MW/well 1250 m deep
3	6 MW/well 1000 m deep
4	6 MW/well 1250 m deep
5	4.7 MW/well 1250 m deep
6	3 MW/well 1250 m deep

The main cost drivers of a geothermal projects are:

-**Wells flow rate (tons of steam per hour)**

-**Steam temperature**

-**Wells depth**

The first 2 drivers translate into well productivity (MW/well), in order to avoid a tri-dimensional matrix of scenarios combining the 3 drivers, the first 2 have been combined in a single cost driver (MW/well).

Real option valuation approach

Scenarios Definitions – Value drivers

Incentive to Renewable Energy	
Description	**Scenario**
High green credit	US$20/MWh
Low green credit	US$10/MWh
No green credit	US$0/MWh

It is planned to achieve the target through an incentive system inspired to the Italian system of the "Certificati Verdi".

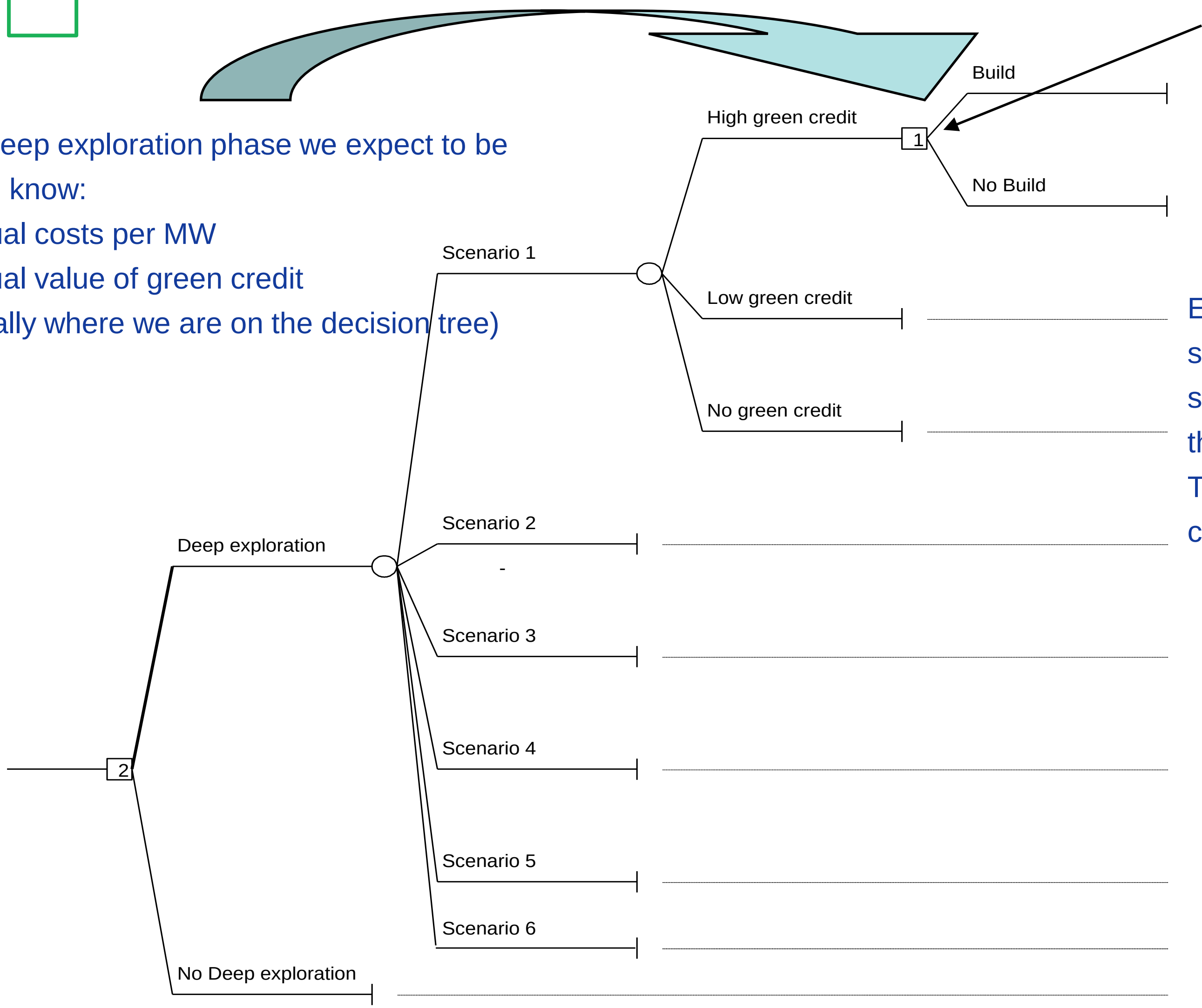
The latest draft foresees a cap to the value of the incentive equal to $20/MWh.

We expect that by the time deep exploration is concluded, the approximate value of the incentive will be known with better precision. As of today we do not know how much such incentive will be worth: in other words it can be any value between 0 and $20/MWh.

Real option valuation approach
Decision Tree

After deep exploration phase we expect to be able to know:

1) actual costs per MW
2) actual value of green credit
(basically where we are on the decision tree)



Each scenario will have 3 sub scenarios. Any of the incentives scenarios can happen to each of the productivity scenarios. Therefore, 18 possibles outcomes can happen.

Real option valuation approach

Probabilities definition

Scenario	Estimated Probability
1	10%
2	15%
3	20%
4	25%
5	25%
6	5%

The probabilities estimated the new scenarios are based on the previous data (data used to prepare the first investment memo), integrated with available information on wells (on going studies on exisitng wells), and using a different probabilistic approach (see below).

Previously (first investment memo) 3 cases "base, optimistic and pessimistic“ had been identified “a priori” based on expected reservoir temperature. Then a probability weighted average cost had been estimated for each case considering different flow rates and depths.

Now a certain number of representative cases (6) has been identified (**none of which is a “base case”**), the relevant probabilities are calculated starting from the probabilities of the 3 cost drivers (flow rate, temperature and depth).

Real option valuation approach

Probabilities definition

Incentive to Renewable Energy	
Description	**Estimated probability**
High green credit	18.5%
Low green credit	63.0%
No green credit	18.5%

The current uncertainty about the value of the incentive (between 0 and US$20/MWh) can be modeled with a Gauss distribution centered on the average value (US$10/MWh), and assuming the extremes (0 and US$20/MWh) as the 5th and 95th percentile:

- **average value (P50%) of US$10/MWh**
- **"very low value" (P5%) of US$0/MWh**
- **"very high value" (P95%) of US$20/MWh**.

The probabilities have been set discretizing the Gauss distribution with a three point approximation (Extended Pearson-Tukey Method) based on the median, the 5th percentile and the 95th percentile (P50%, P5% and P95%)*.

Real option valuation approach

NPV valuation

Scenario		NPV*	Notes
Productivity	Incentives		
8 MW/well 1000 m deep	High	39.9	
	Low	22.2	
	None	4.6	
8 MW/well 1500 m deep	High	36.7	
	Low	19	
	None	1.3	
6 MW/well 1000 m deep	High	31	
	Low	13.3	
	None	(4.3)	**After deep exploration NPV of plant > 0 but not enough to offset deep exploration costs**
6 MW/well 1500 m deep	High	26.5	
	Low	8.9	
	None	(8.8)	**After deep exploration NPV of plant > 0 but not enough to offset deep exploration costs**
4.7 MW/well 1250 m deep	High	12.2	
	Low	(5.4)	**After deep exploration NPV of plant > 0 but not enough to offset deep exploration costs**
	None	(21.2)	**After deep exploration NPV of plant still <0 therefore NPV = PV of deep exploration costs**
3 MW/well 1250 m deep	High	(21.2)	
	Low	(21.2)	
	None	(21.2)	

*Each NPV is calculated with the full cycle valuation approach using the standard greenfield valuation model.

Real option valuation approach

Expected Monetary Value Definition

Scenario		NPV	Probability Productivity	Probability Incentives	Expected Monetary Value (NPV * Probabilities)
Productivity	Incentives				
8 MW/well 1000 m deep	High	39.9	10%	18.5%	0.7
	Low	22.2	10%	63.0%	1.4
	None	4.6	10%	18.5%	0.1
8 MW/well 1500 m deep	High	36.7	15%	18.5%	1.0
	Low	19	15%	63.0%	1.8
	None	1.3	15%	18.5%	0.0
6 MW/well 1000 m deep	High	31	20%	18.5%	1.1
	Low	13.3	20%	63.0%	1.7
	None	(4.3)	20%	18.5%	-0.2
6 MW/well 1500 m deep	High	26.5	25%	18.5%	1.2
	Low	8.9	25%	63.0%	1.4
	None	(8.8)	25%	18.5%	-0.4
4.7 MW/well 1250 m deep	High	12.2	25%	18.5%	0.6
	Low	(5.4)	25%	63.0%	-0.9
	None	(21.2)	25%	18.5%	-1.0
3 MW/well 1250 m deep	High	(21.2)	5%	18.5%	-0.2
	Low	(21.2)	5%	63.0%	-0.7
	None	(21.2)	5%	18.5%	-0.2
Total					**7.6**

Financial Convenience

Under the decision tree approach and considering the new cost budget and the government incentives, valuation of the project yields a positive EMV as follows:

Including surface exploration (sunk costs) – Expectd EMV = **+7.6 MUSD**

The correct (academic) method to be applied for the decision whether or not to go ahead with deep exploration is the real option valuation approach based on decision trees.

Its application to the Project case, results in an Expected Monetary Value greater than zero "0", **then it is worth to invest capital in the deep exploration phase**

Nevertheless it is worth to state that the 7.6 M$ does not represents the NPV of the project because as it was represented before, **the NPV of the project can be any between -21.2 and 39.9 M$.**

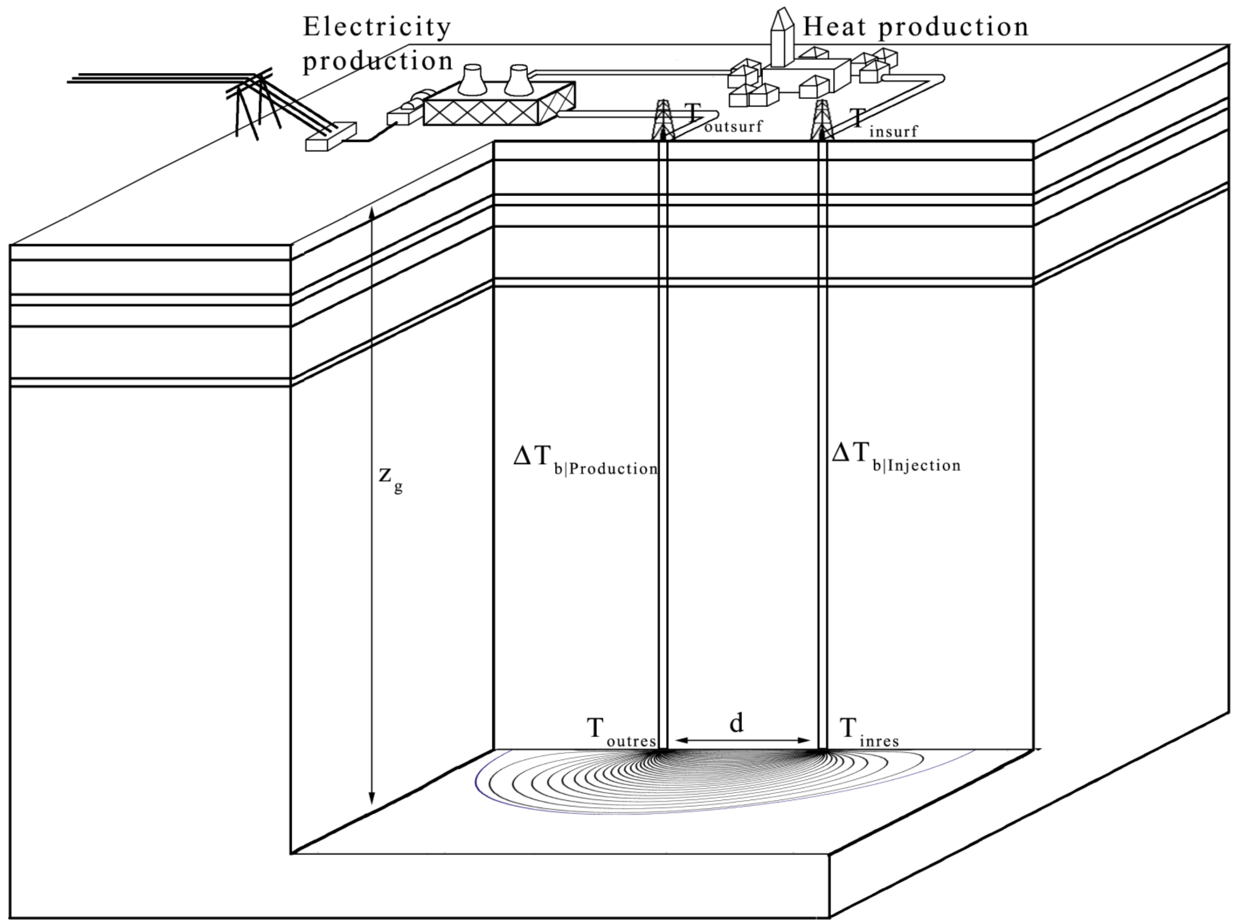
Conclusions

- The full life cycle is not optimal to provide management with a tool to decide whether or not it is economically convenient to invest in deep exploration because the project's value may change over time due to the availability of new information that will lead to managerial decisions influencing the path of the project (such as subsequent go/no-go decisions based on the actual results of deep exploration and outcome of available incentives for renewable generation);

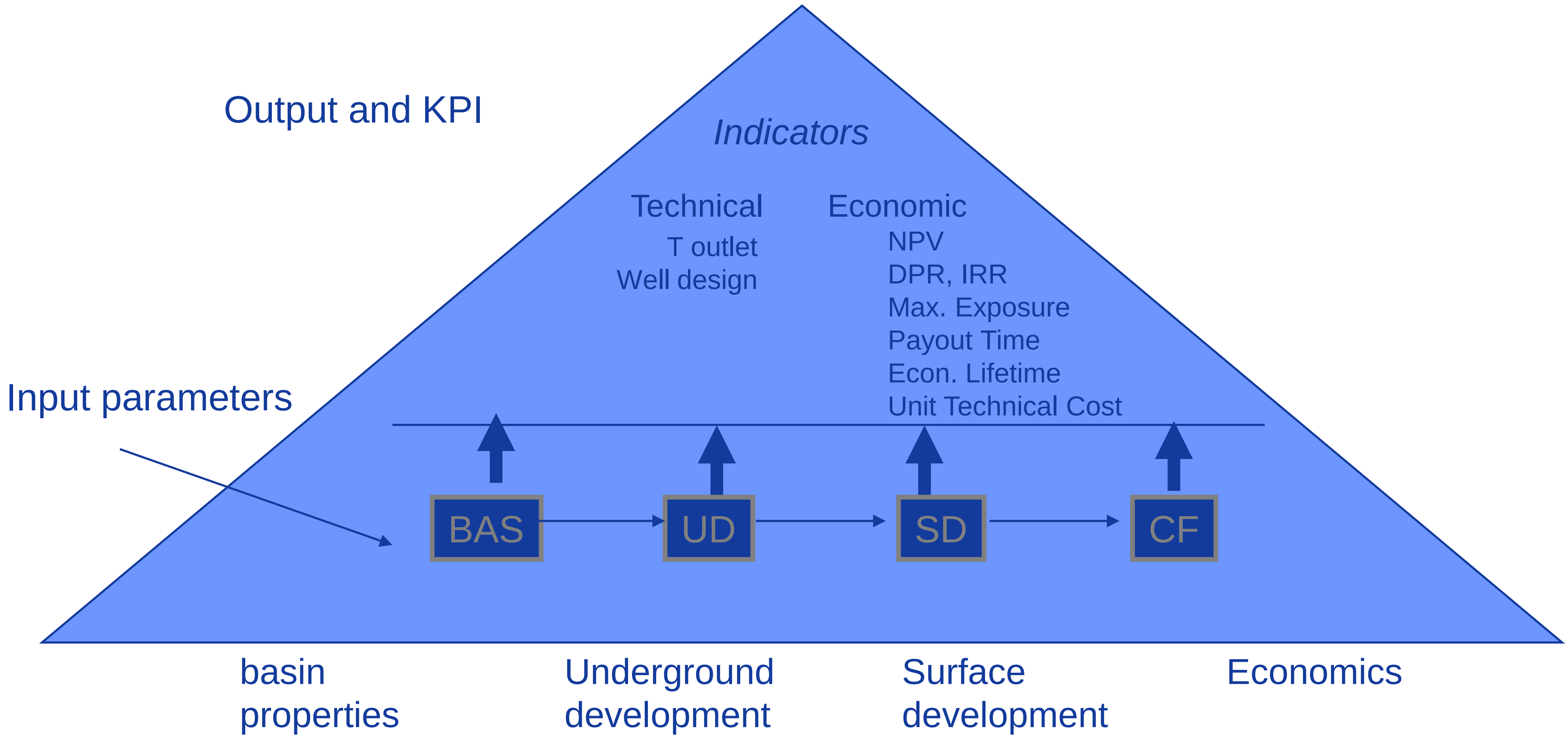
- The Real Option approach focuses on the potential value embedded in exercising the option once the uncertainty has been resolved;

- Full life cycle valuation approach will be used, post deep exploration, to decide whether to actually build the project or not (final go/no-go decision).

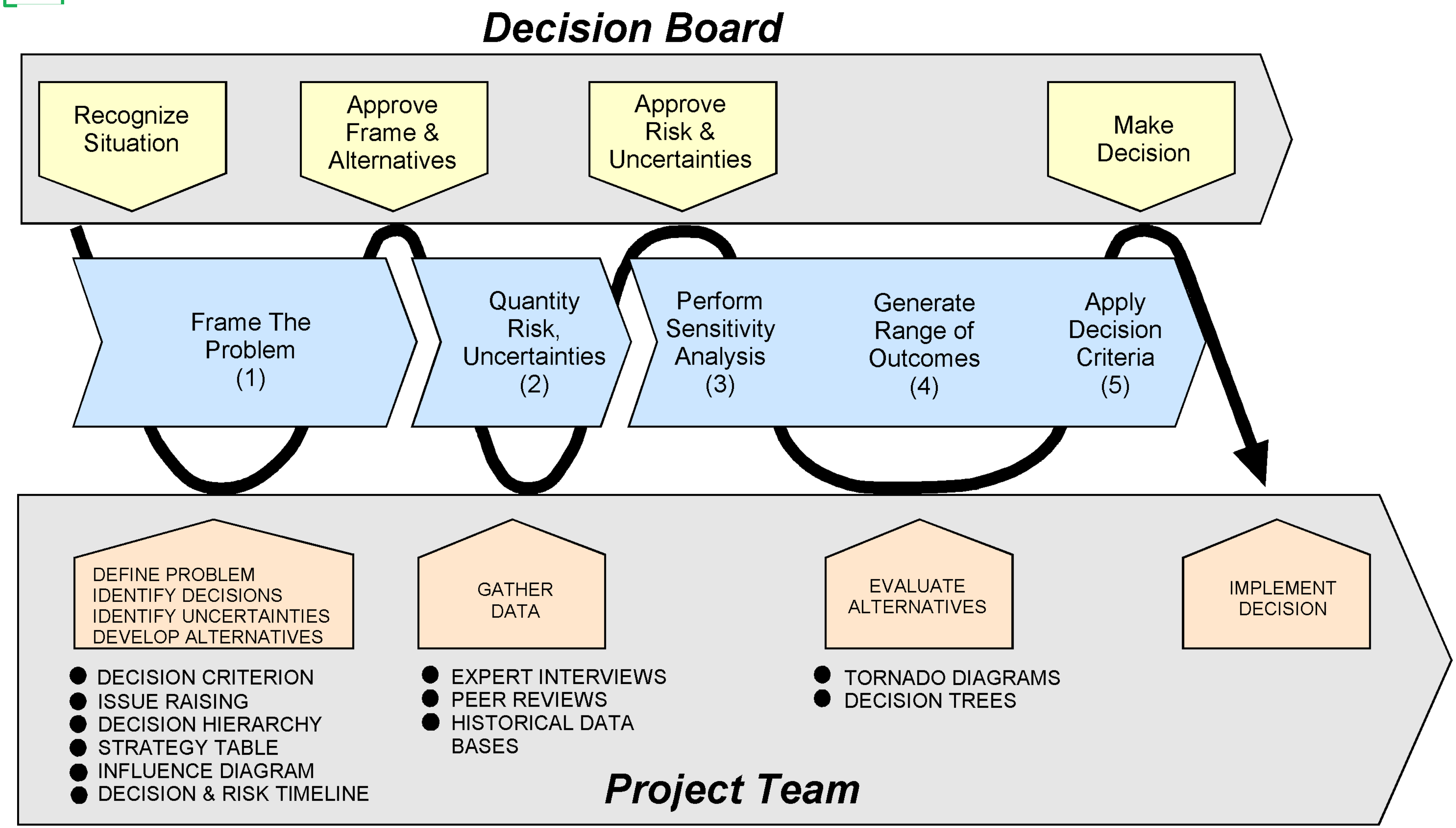
Decision Support System = DSS



DSS

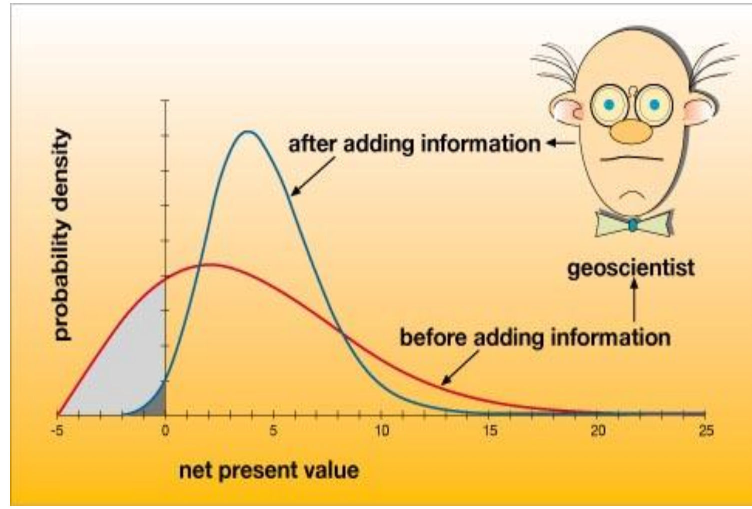

Output and KPI
Indicators
Technical
T outlet
Well design
Economic
NPV
DPR, IRR
Max. Exposure
Payout Time
Econ. Lifetime
Unit Technical Cost
Input parameters
BAS
UD
SD
CF
basin properties
Underground development
Surface development
Economics

DSS

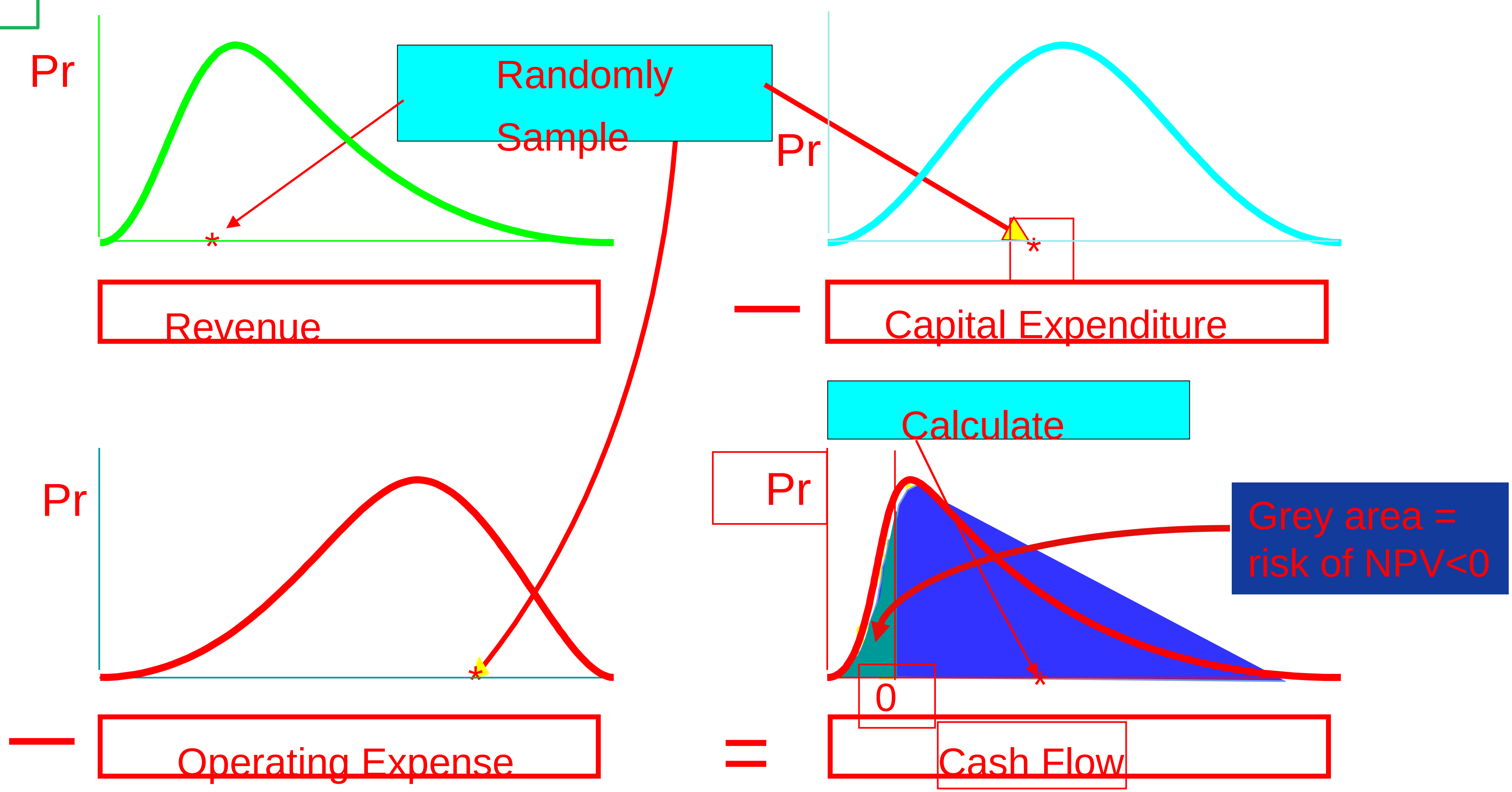

Decision Board
Recognize Situation
Approve Frame & Alternatives
Approve Risk & Uncertainties
Make Decision
Frame The Problem (1)
Quantity Risk, Uncertainties (2)
Perform Sensitivity Analysis (3)
Generate Range of Outcomes (4)
Apply Decision Criteria (5)
DEFINE PROBLEM
IDENTIFY DECISIONS
IDENTIFY UNCERTAINTIES
DEVELOP ALTERNATIVES
GATHER DATA
EVALUATE ALTERNATIVES
IMPLEMENT DECISION
DECISION CRITERION
ISSUE RAISING
DECISION HIERARCHY
STRATEGY TABLE
INFLUENCE DIAGRAM
DECISION & RISK TIMELINE
EXPERT INTERVIEWS
PEER REVIEWS
HISTORICAL DATA BASES
TORNADO DIAGRAMS
DECISION TREES
Project Team

DSS: risk reduction

- The decision-maker should then specify his/her risk-tolerance: for the project in question, and given other (portfolio) considerations, which cumprob x average NPV, i.e. if it is <0, am I prepared to accept?
  - **Risk-tolerance criterion can then be used as optimisation constraint to cut out bad decision-alternatives**

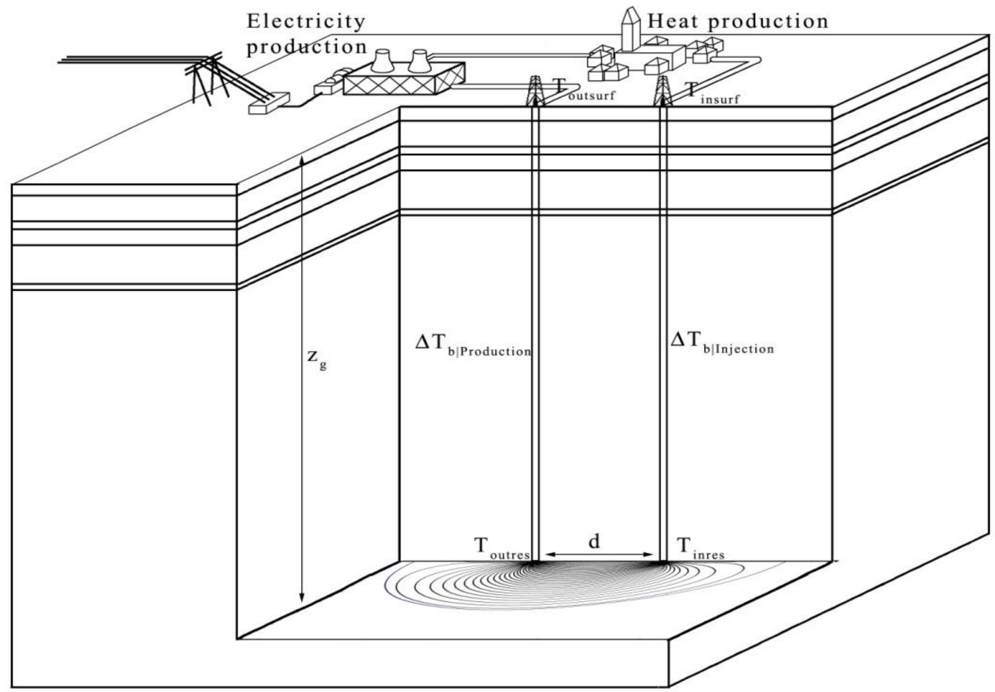


DSS: Montecarlo method

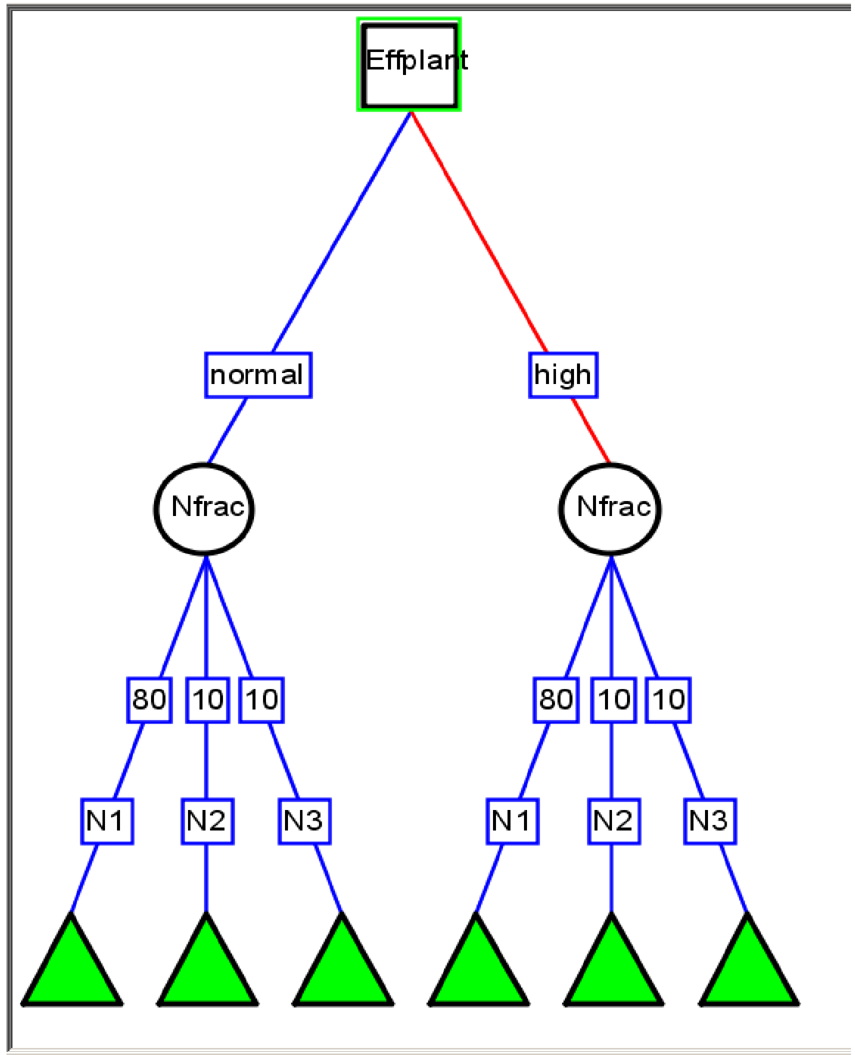


DSS: Montecarlo method

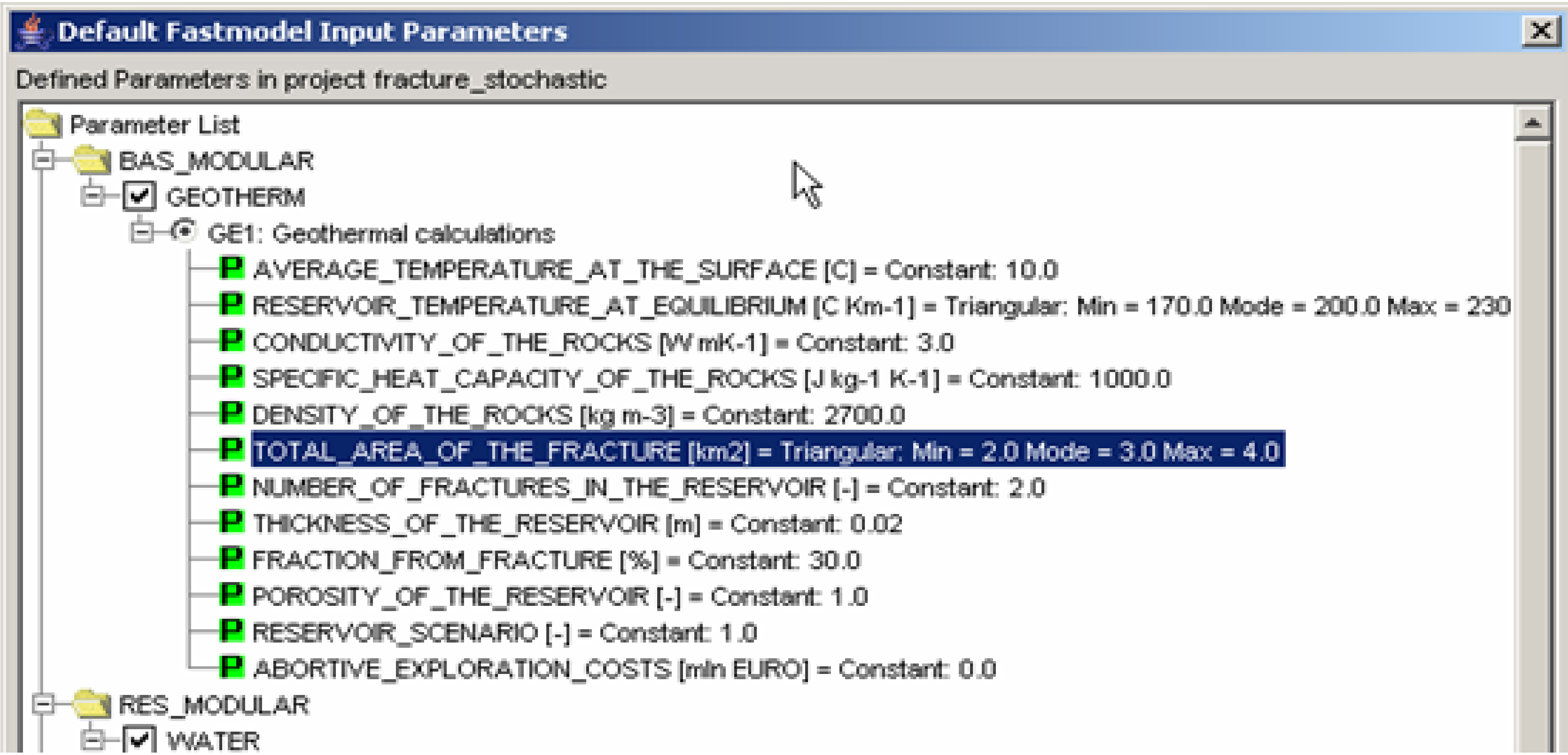
Input parameters are regrouped in the “Cashflow” spreadsheet classified intro 4 main categories representatives of the parts of the system



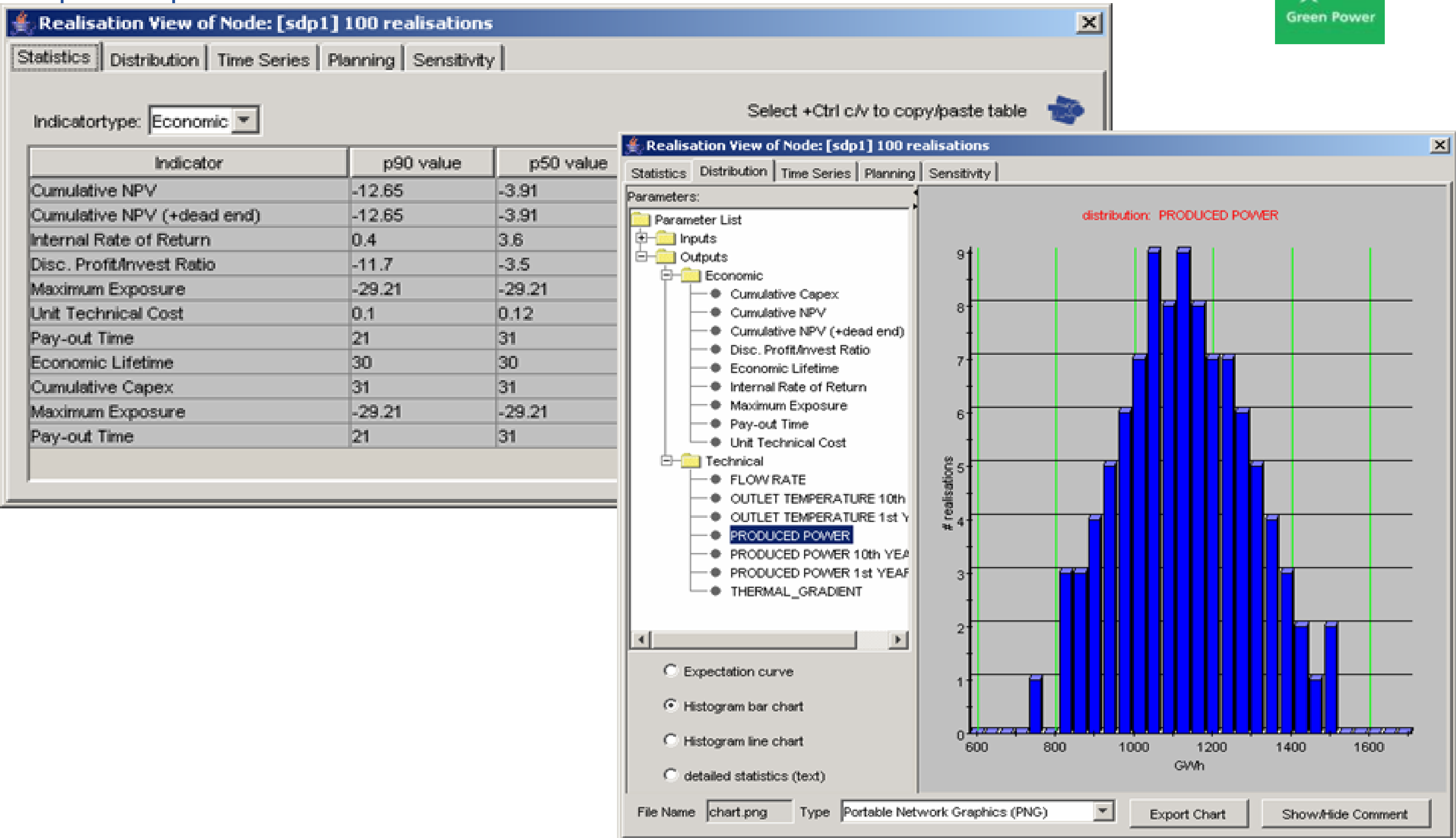
Combining controllable and not controllable



Example of INPUT

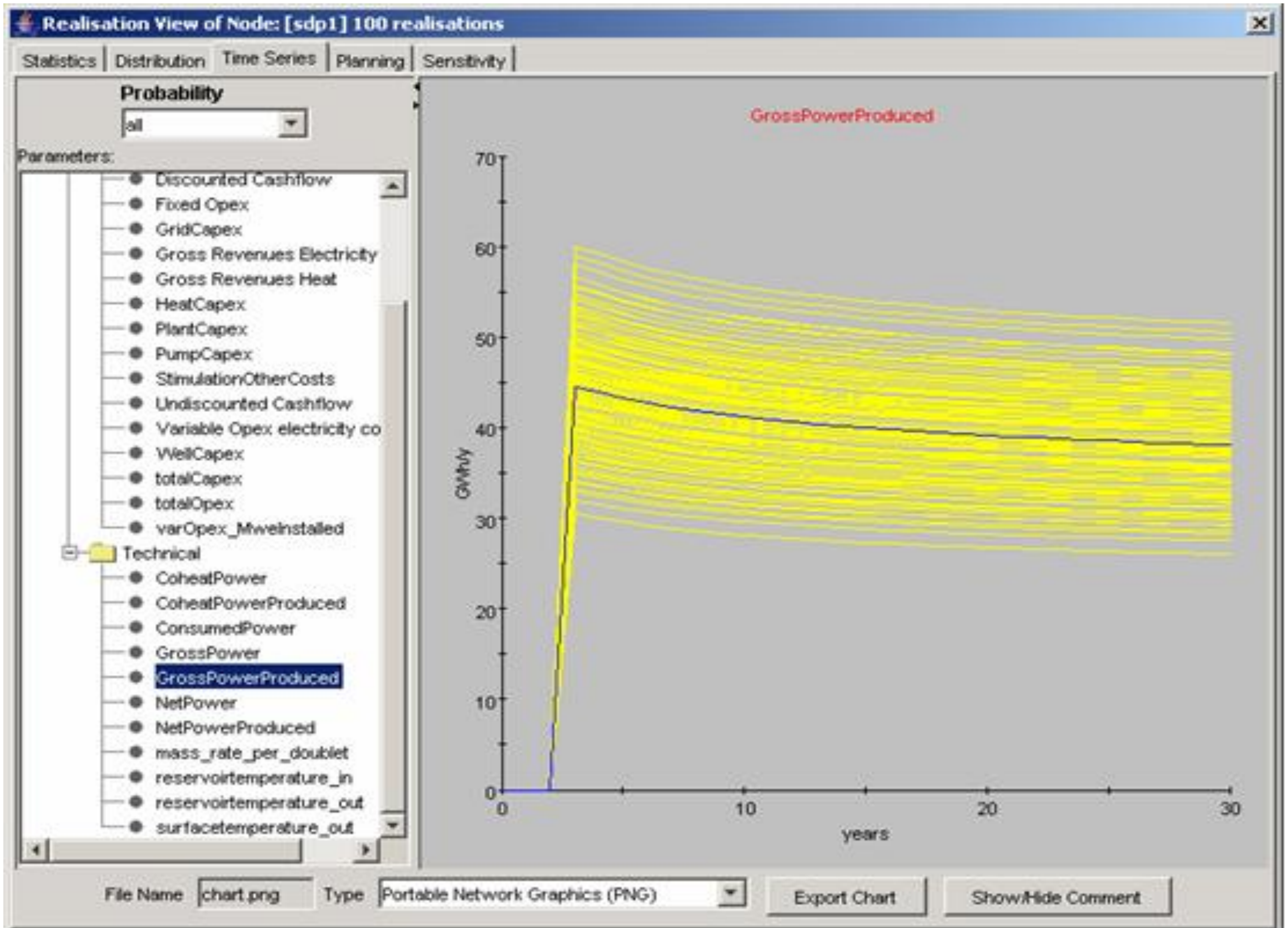


Example of OUTPUT



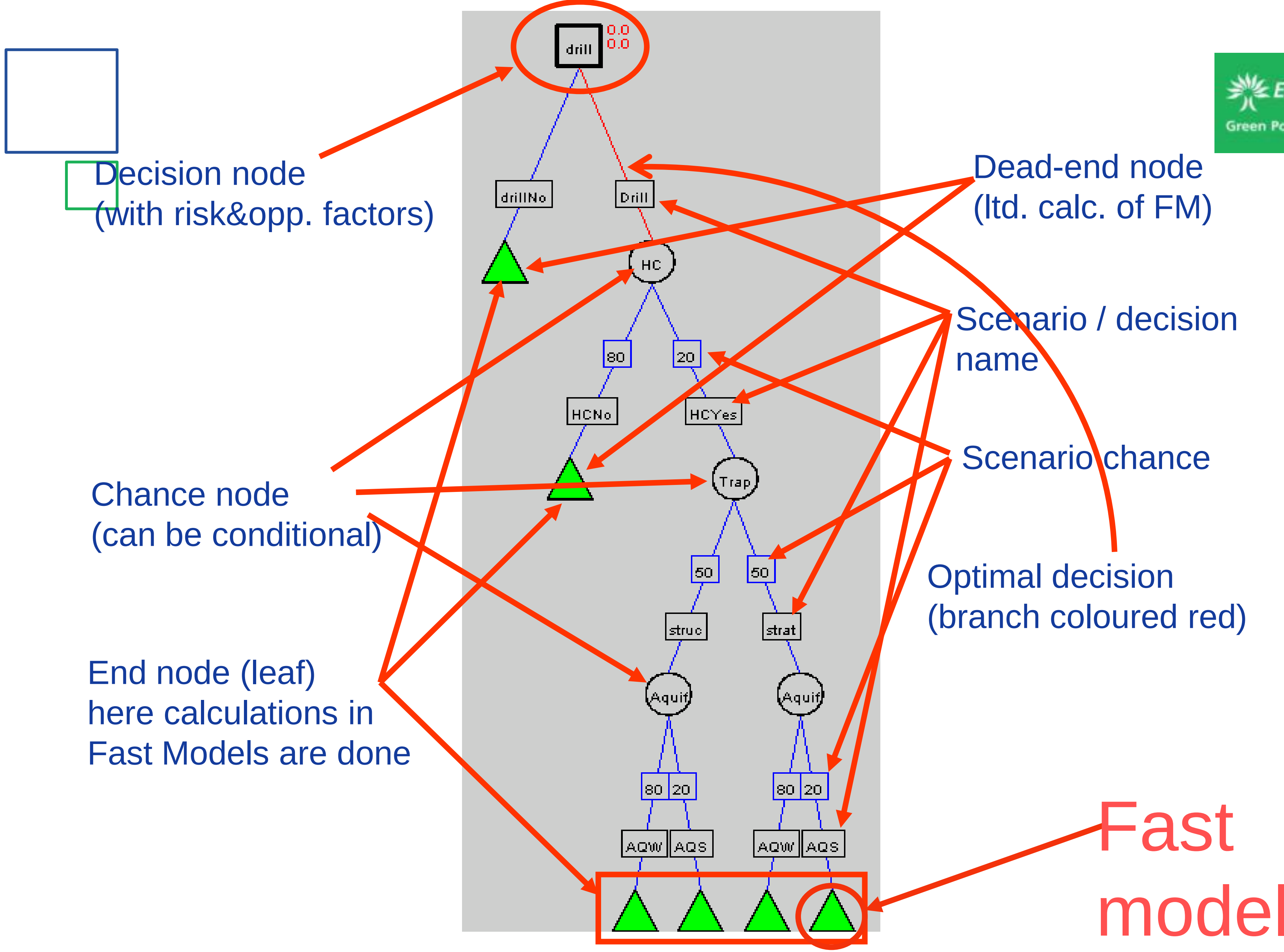
Indicator	p90 value	p50 value
Cumulative NPV	-12.65	-3.91
Cumulative NPV (+dead end)	-12.65	-3.91
Internal Rate of Return	0.4	3.6
Disc. Profit/Invest Ratio	-11.7	-3.5
Maximum Exposure	-29.21	-29.21
Unit Technical Cost	0.1	0.12
Pay-out Time	21	31
Economic Lifetime	30	30
Cumulative Capex	31	31
Maximum Exposure	-29.21	-29.21
Pay-out Time	21	31

Example of OUTPUT

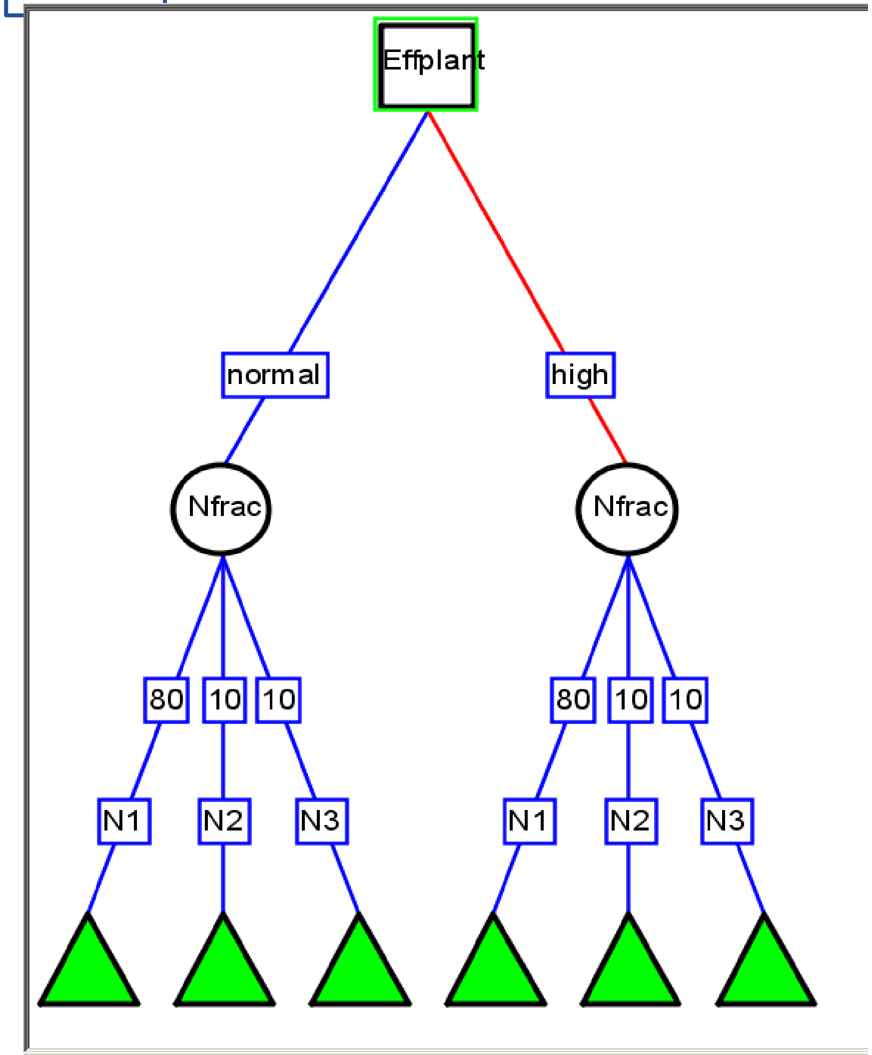


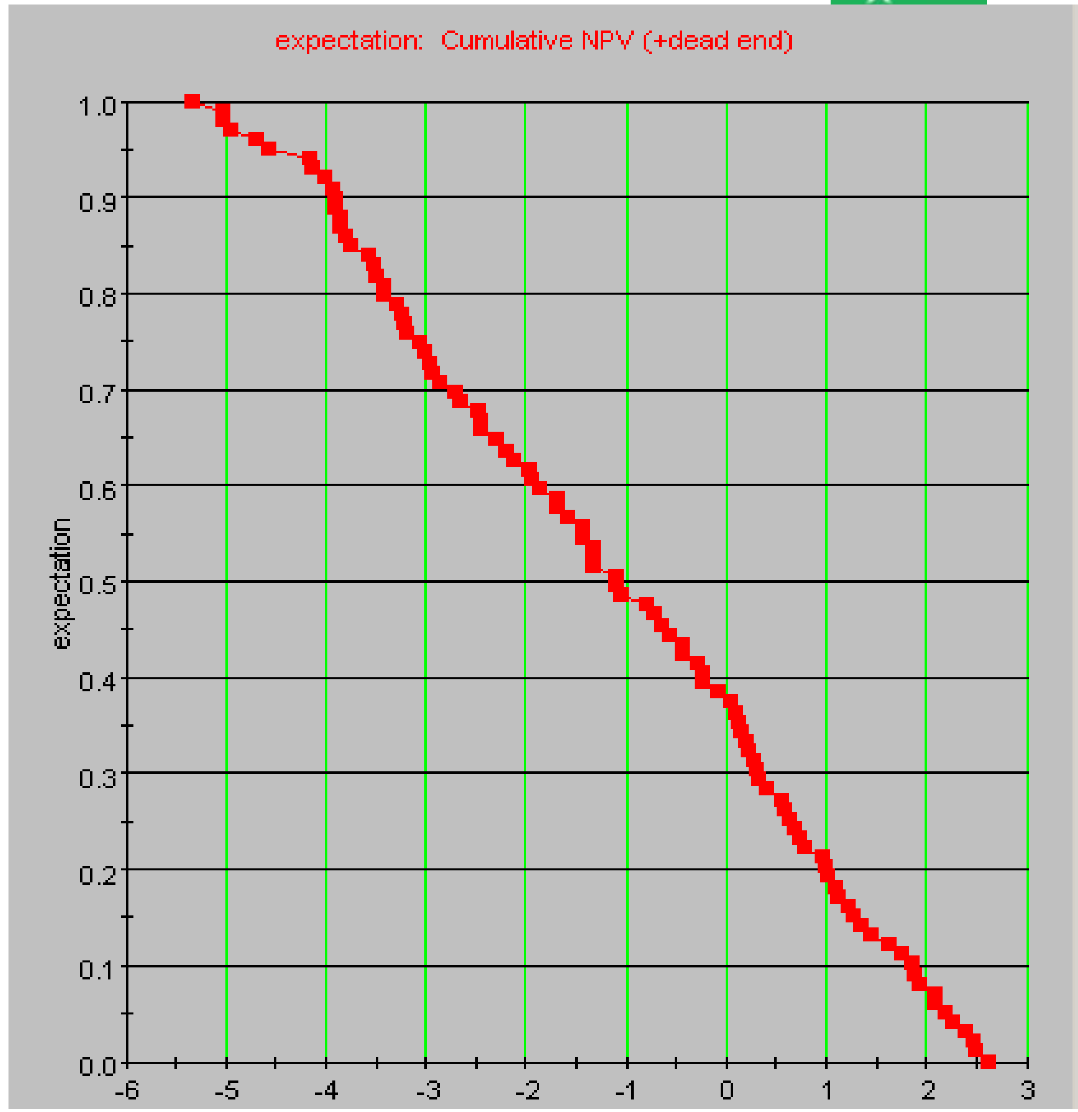
DSS structure

- Tree consists of branches
- Branches are interconnected by (any sequence of):
  - **Decision nodes: action under control of company**
  - **Chance nodes: scenario not under control of company**
  - **End nodes: the “leaves” at the end of the branch where concatenated fast model calculations are done**
- Special features
  - **Mutually exclusive and unique scenario combinations (“pruning of tree”)**
  - **Dead-end nodes: to model abortive courses of action**
  - **Scenario dependencies: conditional probabilities using hierarchy**
  - **Expert data can be imported (to circumvent use of Fast Models)**


Decision node
(with risk&opp. factors)
Dead-end node
(ltd. calc. of FM)
Scenario / decision
name
Scenario chance
Chance node
(can be conditional)
Optimal decision
(branch coloured red)
End node (leaf)
here calculations in
Fast Models are done
Fast
model
drill
0.0
0.0
drillNo
Drill
HC
80
20
HCNo
HCYes
Trap
50
50
struc
strat
Aquif
Aquif
80
20
80
20
AQW
AQS
AQW
AQS

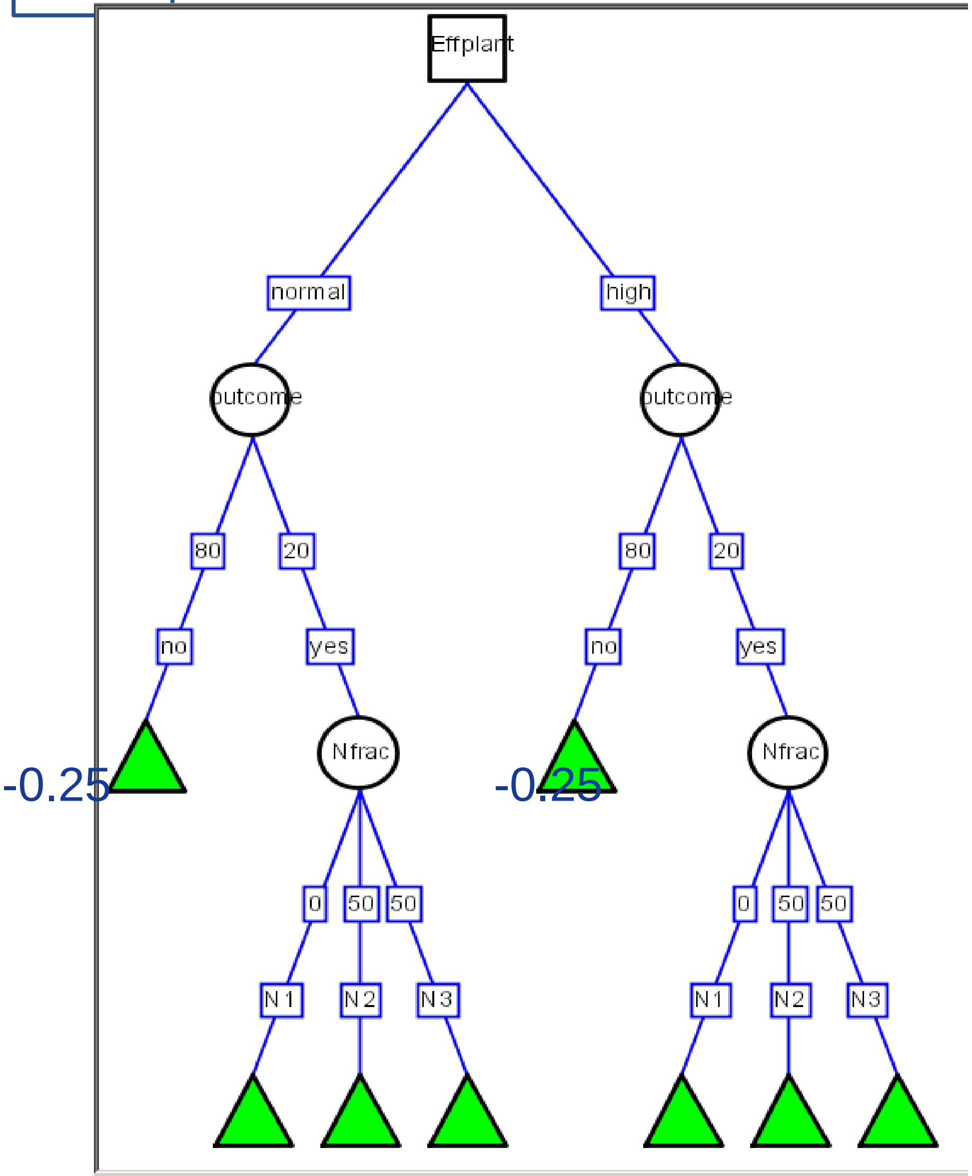
DSS structure





NPV

DSS structure

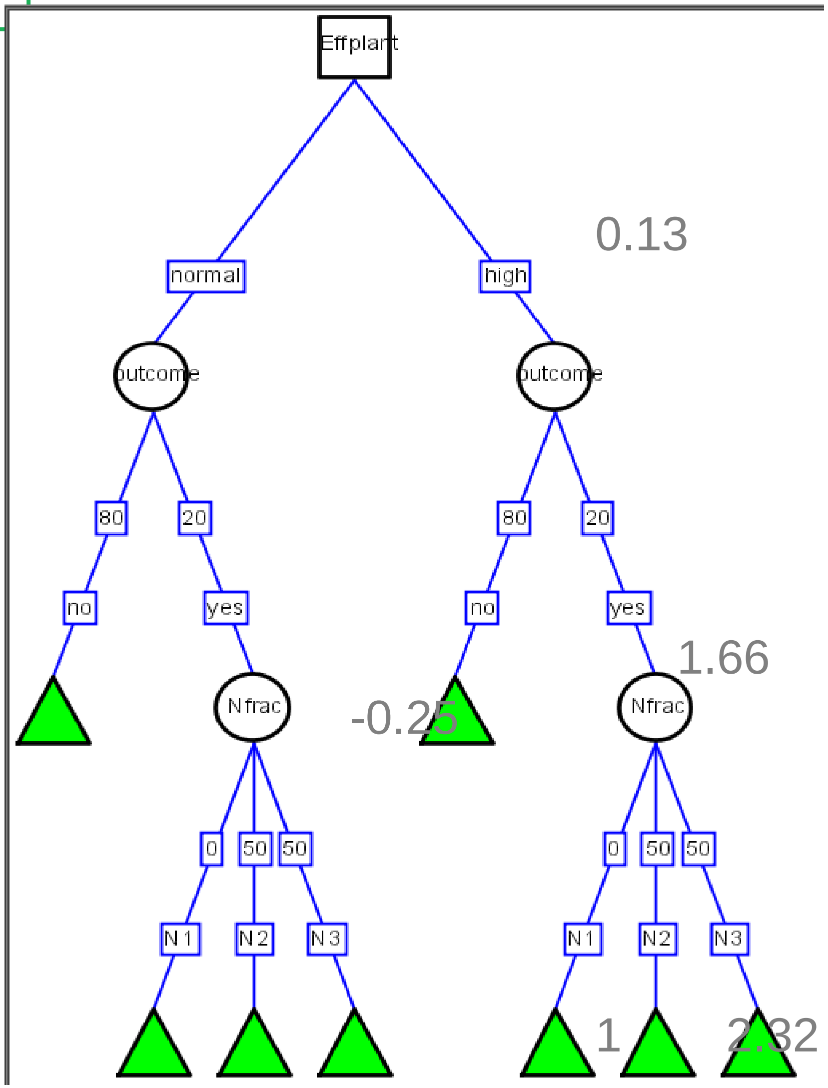


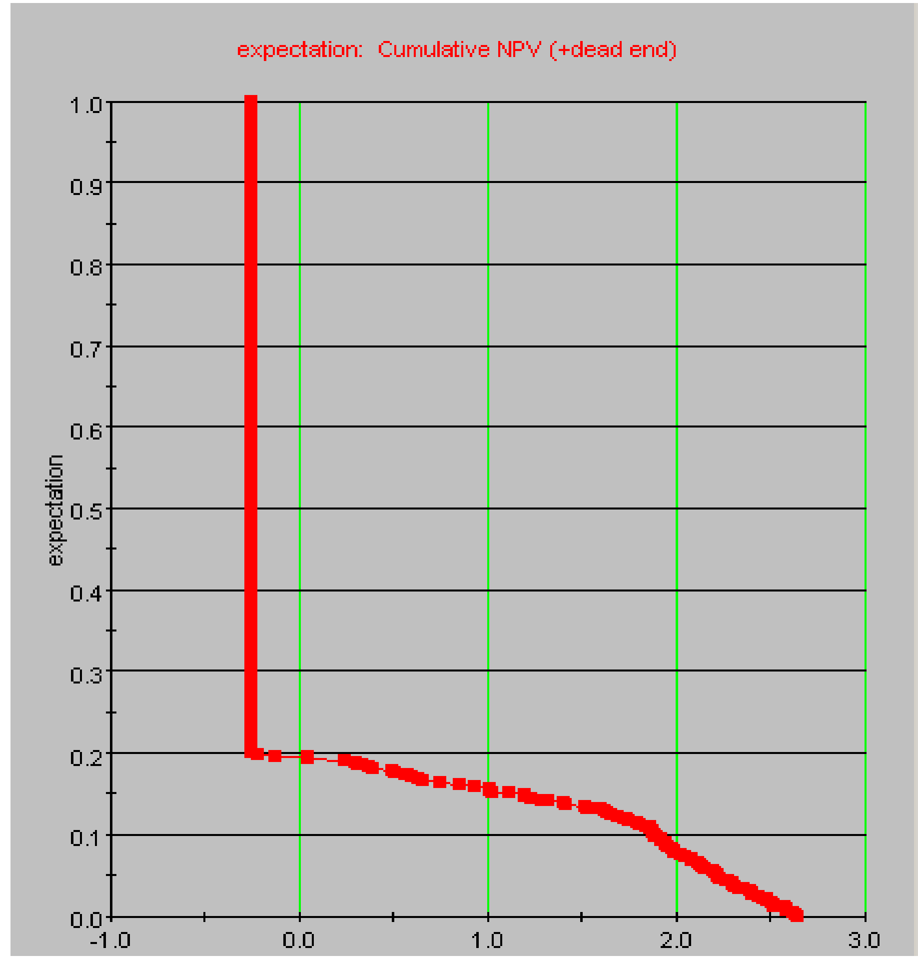
Introducing an information acquisition phase, which allows to rule out N1

Costs are 250 kEURO

DSS structure

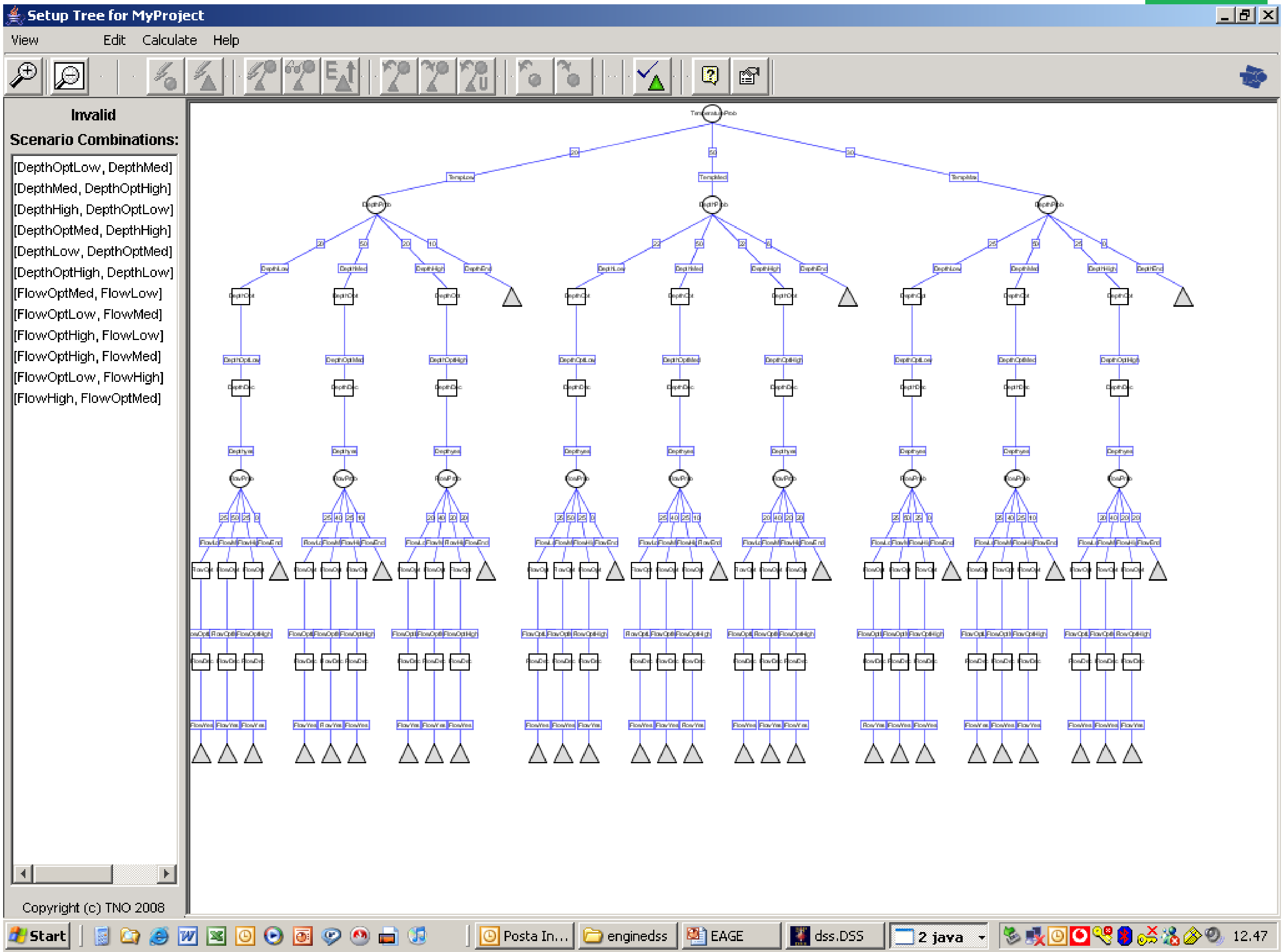
-0.25





NPV

DSS structure



THANKS FOR YOUR KIND ATTENTION!