GEORISK Project

WP 2 Risk Assessment

Ferid Seyidov

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WP 2: RISK ASSESSMENT

MONTHS 1-15, Lead BRGM

1) Context and Identification of potential risks (BRGM) (months 1-6)

Geothermal risk register

2) Risk Assessment (GEC-CO) (months 5 to 12)

Geothermal Risk Matrix

3) Tools to assess the risks (BRGM) (months 5 to 15)

GeoRisk report: Online tool for developers globally recognized reporting code

Introduction

Context and definitions

- The objective of the work-package was to assess and present the risks that could be mitigated financially
- The first step of risk assessment is risk identification: providing the list of plausible risks (risk register)
- What risks are considered? From the point of view of an operator / developer; the risks of not being able to reach its initial (technical, economic, environmental, safety) objectives;
- A warning: at this stage we were only scanning everything that was plausible; it does not mean that all the risks are important !

Approach

- Review of previous European projects, including DARLINGE, GEOELEC, GEOWELL, etc.
- Review of existing literature: more than 70 documents including scientific papers, reports, presentations
- Experience of each partner from the consortium
- This led to a first risk register of 200+ risks, categorized with phases, causes, main events, consequences, risk factors, mitigation actions.
- This turned out too unpractical to manage, and to check for gaps and overlaps
- A internal workshop was organised to create a second version
  - Simpler structure: phases, description, consequences, mitigation actions
  - Simpler content with about 50 risks

Risk register overview

Categories	Id	Phases IE	DT	ED	PC	Description	Consequences EPA	HSE	Mitigation insurance	Comments
External hazards (natural or anthropogenic)	A-1		X	X	X	External natural hazards damaging the infrastructure	X	X	yes (sometimes	magmatic area is aggravating factor
	A-2		X	X	X	anthropogenic hazard damaging the infrastructure	X	X	yes (sometimes)	terrorism, trucks
Risks due to uncertainties in the external context	B-1		X	X	X	Changes in policies, laws, taxes and regulations put development/economy in jeopardy	X		no	This inludes the modification of exploitation zone to classified area, which is a change in local regulation but not at national level
	B-2	X	X	X		Lack of financing for the next phases	X		no	includes bankruptcy of project developer (SPV), developping in a unknown region, lack of experience of banks requiring irrealistic guarantees
	B-3	X	X	X		Low social acceptance put barrier to development	X		no	Lack of awareness in a given area is a factor
	B-4		X	X		Public opposition against nuisances from the exploitation	X		no	
	B-5		X	X		Unanticipated delays and costs in operations (materials, services, maintenance)	X		no	
	B-6	X	X	X		Lack or loss of clients	X		no	
	B-7		X	X	X	Other users of the subsurface cause a negative change to the reservoir parameters	X		no	Include transboundary issues, conflict between geothermal projects or with other users such as for thermal water, etc.
	B-8	X	X	X		Significant changes of energy costs	X		no	
	B-9	X	X	X		The research or exploitation permit is changed in favor of another resource		X	no	Depends on national permitting procedures. For example: area permitted to geothermal and then to 0&G exploration; another case is when the permit is for heat only but there is the opportunity to use the water for touristic/medical purposes. This can have heavy legal consequences
Risks due to internal deficiencies	C-1		X	X	X	Low financing for work leading to low safety standards		X	no	include abandonment, drilling, maintenance, etc.; the cause be a change in the economic environment such as inflation
	C-2		X			Suboptimal design of well leads to reduced flow rate	X		no	
	C-3	X	X	X		Best practices not applied leading to incidents or decreased performance	X	X	no	includes: wrong design of filters/screens, well architecture, materials for casing, other equipment, etc. (data acquisition modelling, decision making, design of wells / plants, construction)
	C-4		X			Unsuitable contracts (roles and responsibility not clearly defined) leading to suboptimal performance or exploding costs	X	X	no	depends on who takes the risk between financer/operator/subcontractor
	C-5		X	X		Human error leading to failure during drilling / work	X	X	no	Including either insufficient background and/or safety regulations
	C-6		X			Wrong choice of stimulation fluids or techniques damaging the reservoir/well	X		no	in case of acid stimulation, hydraulic or other types of stimulation
	C-7		X			Damage to the well/reservoir while drilling or testing	X	X	yes partly	leads to blowout, breakout. One of the main causes is the use of a mud with a wrond density; can be due to wrong estimation of high pressures, not considering in-situ gases. Damage reservoir flow (mud cakes etc)
	C-8		X	X		Organization is not experienced / financially robust enough for the challenge	X		no	includes the experience of the organization to undertake its role, the financial capacity to undertake the projects and to endure financial shock that may arise during the project implementation and the human resource capacity to undertake, manage and operate the projects; include also the capacity of the investors
	C-9	X		X		Demand analysis and forecast are inaccurate	X		no	electricity generation, heat production
Risks due to subsurface uncertainties	D-1		X			Flow rate lower than expected (reservoir)	X		dedicated fund	includes enthalpy/transmissivity
	D-2			X		Flow rate degrades over time	X		dedicated fund	Recharge of the aquifer; design of the wells; seismic activity which may have an influence
	D-3		X			Temperature lower than expected (reservoir)	X		dedicated fund	includes enthalpy/transmissivity
	D-4			X		Temperature degrades too quickly	X		dedicated fund	
	D-5		X			Pressure lower/higher than expected	X		dedicated fund	too high: difficult to inject, need to redesign the plan; too low: difficult to produce
	D-6			X		Pressure is changing during the operation in an unexpected way	X		dedicated fund	increase or decrease of pressure due to (no) reinjection, interferences with other wells
	D-7		X	X	X	Fluid chemistry/ gas content / physical properties are different from expected	X		dedicated fund	calcite scaling is easy to clean, lead scaling and silica scaling are more difficult to handle
	D-8			X		Fluid chemistry/ gas content / physical properties change	X	X	dedicated fund	Removal of gas in injection fluid can change properties (ph) in the reservoir
	D-9		X			Target formation is missing in the well	X		dedicated fund	could be a fault, a fault zones, a specific geology / unexpected geology, insufficient exploration
	D-10		X			Target formation has no/insufficient fluid for commercial production	X		dedicated fund	
	D-11		X			Geological lithology or stratigraphy is different than expected	X		dedicated fund	
	D-12		X	X	X	Excessive scaling in the geothermal loop	X		dedicated fund	
	D-13		X	X	X	Excessive corrosion in the geothermal loop	X		dedicated fund	Change of dissolved CO2 quantities is a factor, Ca-,Mg-, Si-, Pb- and other slt precipitations
	D-14			X		Particle production ("sanding")	X		dedicated fund	increase wear, decrease injectivity. Eg sand, clays, particles of scaling and corrosion; can affect the whole system
	D-15			X		Hydraulic connectivity between wells is insufficient for commercial use	X		dedicated fund	too high or too low is "bad". Problem is mainly with injection eg too fast cold front propagation from injection into production well/s /
	D-16		X	X		Re-injection of the fluid is more difficult than expected	X		dedicated fund	The operator should create provisions for well cleaning costs, even if there is no such a need in a given year
	D-17			X		Degradation of the reservoir (structure, properties, deteriorating whole-scale further commercial utilization)	X		dedicated fund	This can be caused by several factors, eg.: plugging by corrosion / scaling, sand and other's particles; too high production or injection pressure; rapid pressure change of production or injection pumping (without inverters); quality of the injected fluid; composition of stimulation fluids, etc.
Technical issues	E-1		X			Fluid losses leading to severe technical issues	X	X	yes partly	risk may be important where there are high productivity fractures comined with a low permeability matrix
	E-2		X			Wellbore instability	X		no, except in particular cases	one of the consequences is the impossibility to lower the casing string
	E-3		X			Trajectory issues (deviation from target)	X		yes partly	can induce cementing problems
	E-5		X			Technical failure/difficulties during drilling (due to any additional causes that were not mentioned)	X		yes partly	including irreversible, loss in energy supply, lost in hole, Swelling clay, stuck in fault, total mud losses or by dog leg; can be enhanced by special conditions such as high T, high corrosion, highly abrasive environment
	E-7		X	X		Issues in transporting/handling radioactive sources for logging	X		no	
	E-8			X		Technical failure of the equipment	X		yes partly	includes subsurface equipments, the plant (eg. heat exchangers,valves, pipes) and other elements of the above-surface infrastructure; prolonged breakdown and other downtime; a severe scenario is when frost provokes the failure, and the plant is not able to provide heat to customers.
	E-9		X			Well casing collapse	X		yes partly	if water is trapped between the cement and the casing, especially in the intervals where one casing is inside another, there is risk for casing collapse due to volume expansion. Over-pressured zones and tectonic stresses can also cause casing collapse
Environmental risks	F-1		X	X	X	Blowouts	X	X	yes partly	various causes: including damage to wellhead / surface installation / higher pressure than expected
	F-2		X	X	X	Fluid communication between different formations due to ineffective isolation of the well	X	X	no	also economic because loss of productivity
	F-3		X	X		Induced seismicity (above sensitivity level)	X	X	no / ?	includes st gallen case: excessive injection of mud, other factors: stimulation techniques, depressurization (no injection case), thermal difference, pore pressure increase (hydraulic stimulation); ? – however, in some cases in poorly explored areas shall be considered
	F-4		X	X	X	Surface subsidence or uplift		X	no / ?	fluid loss in anydrites or swelling clays, overpressure during exploitation; ? – however, in some cases in poorly explored areas shall be considered
	F-5		X	X		Toxic emissions due to gases and fluids produced in-situ		X	no/yes	H2S, CH4, , CO2, radioactive materials / elements ; In some cases toxic gasses may appear in geothermal fluid in course of its exploitation – and this situation is not predictable
	F-6			X		NCG emissions due to gases produced in-situ	X	X	no	NCG= Non Condensible Gas, in thermal water, include mainly CO2 as well as H2 and N2 ; can be problematic when development of project is supported by "green" funds requiring a performance in terms of reduction of emissions
	F-7		X	X	X	Lack or loss of integrity of the well/subsurface equipment	X	X	yes partly	cementing problems, casing problems, and plugs in the abandonment phase
	F-8		X	X	X	Loss of integrity of surface equipment	X	X	partly yes	e.g. leakage from he tanks, pipeline, heat-exchanger, etc.

2 tabs:

- A « simple » tab containing about 50 individual risks
- A « detailed » tab with mitigation measures (110 entries)

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Geothermal Risk Matrix

3) Tools to assess the risks (BRGM) (months 5 to 15)

Development of an online tool for developers globally

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Objective of the Task

- Utilize the developed Risk Register to create the Risk Matrix.
- Evaluation of the main Risks that challenge the development of geothermal energy branch.
- Create a generalized overview of the main risks across the countries
- Focus the evaluation based on real data from the active projects developer.

Representation of the Risk Matrix

Where Likelihood (a) is taken as

- (0,001; 0,01; 0,1; 1)

Where Damage (b) is taken as

- (1.000; 10.000; 100.000; 1.000.000)

RI is Calculated as a sum of powers:

$$10^{a} x 10^{b} = 10^{(a+b)}$$

Here the values are interpreted as following:

- 2-4 – Low level of Risk
- 5-6 – Medium level of Risk
- 7-8 – Critical levels of Risk

Likelihood

Damage	1	2	3	4
1	2	3	4	5
2	3	4	5	6
3	4	5	6	7
4	5	6	7	8

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Questionnaire

- The questionnaire sheet is divided on 3 categories of risks
  - Socio Economical
  - Geology and Operational
  - Drilling
- The risk index (RI) of each entry is evaluated based on the specified Frequency and Damage
- Each given risk have attributed Risk Index and Relevance.

Questionnaire

General Information			Level of Experience*				Note
Output*	Reservoir Type*	County and Region*	Geology	Social/Economical	Drilling	Operation/Develop	
							Please visit The legend Sheet for information

Topic*	ID	IE*	DT*	OD*	PC*	Description	EPA*	HSE*	Likelihood*	Damage Level*	RI*	Relevance*	Comments*
		Phases					Consequences		Risk Evaluation				
Managerial and Social-Economic	A-1		X	X	X	External natural hazards damaging the infrastructure	X	X					
	A-2		X	X	X	Anthropogenic hazard damaging the infrastructure	X	X					
	B-1		X	X	X	Changes in policies, laws, taxes and regulations put development/economy in jeopardy	X						
	B-2	X	X	X		Lack of financing for the next phases	X						
	B-3	X	X	X		Low social acceptance put barrier to development	X						
	B-4		X	X		Public opposition against nuisances from the exploitation	X						
	B-6	X	X	X		Lack or loss of clients	X						
	B-8	X	X	X		Significant changes of energy costs	X						
	C-1		X	X	X	Low financing for work leading to low safety standards		X					
	B-5		X	X		Unanticipated delays and costs in operations (materials, services, maintenance)	X						
	C-2		X			Suboptimal design of well leads to reduced flow rate	X						
	C-3	X	X	X	X	Best practices not applied (data acquisition, modelling, decision making, design of wells / plants, construction)	X	X					
	C-4		X			Unsuitable contracts (roles and responsibility not clearly defined) leading to suboptimal performance or exploding costs	X	X					
	C-8		X	X		Organization is not experienced / financially robust enough for the challenge	X						
	B-9	X	X	X		The research or exploitation permit is changed in favor of another resource	X						
	C-9	X		X		Demand analysis and forecast are inaccurate	X						
Operation and Geology	D-1		X			Flow rate lower than expected (reservoir)	X						
	D-2			X		Flow rate degrades over time	X						
	D-3		X			Temperature lower than expected (reservoir)	X						
	D-4			X		Temperature degrades too quickly	X						
	D-5		X			Pressure lower/higher than expected	X						
	D-6			X		Pressure is changing during the operation in an unexpected way	X						
	B-7		X	X	X	Neighbouring operators cause negative changes to the reservoir parameters.	X						
	D-7		X	X	X	Fluid chemistry/ gas content / physical properties are different from expected	X	X					
	F-6			X		NCG Production	X						
	C-5		X	X		Human error leading to failure during work (including either insufficient background and/or regulations)	X						
	D-8			X		Fluid chemistry/ gas content / physical properties change	X	X					
	D-9		X			Target formation is missing in the well (unexpected geology, insufficient exploration)	X						
	D-10		X			Target formation has no/insufficient fluid for commercial production	X						
	D-11		X			Geological lithology or stratigraphy is different than expected	X						
	D-12		X	X	X	Excessive scaling in the geothermal loop	X						
	D-13		X	X	X	Excessive corrosion in the geothermal loop	X						
	D-14			X		Particle production ("sanding")	X						
	D-15			X		Hydraulic connectivity between wells is insufficient for commercial use	X						
	D-16		X	X		Re-injection of the fluid is more difficult than expected	X						
	D-17			X		Degradation of the reservoir (structure, properties, deteriorating whole-scale further commercial utilization)	X						
	F-8		X	X	X	Loss of integrity of surface equipments (leakage from the tanks, pipeline, heat-exchanger, etc.)	X	X					
Drilling	E-1		X			Fluid losses leading to severe technical issues	X	X					
	C-7		X			Damage to the well/reservoir while drilling or testing	X	X					
	E-2		X			Wellbore instability	X						
	E-3		X			Trajectory issues (deviation from target)	X						
	F-8		X			Loss of integrity of surface equipments (leakage from the mud mud pit; well head and etc.)	X	X					
	F-7		X	X		Loss of integrity of the wellbore (connection of well fluid with surface; inter layer fluid connection; etc.)	X						
	C-6		X			Wrong choice of stimulation fluids or techniques damaging the reservoir/well	X						
	E-7		X	X		Issues in transporting/handling radioactive sources for logging	X	X					
	E-8			X		Technical failure of the equipment	X						
	E-9		X			Well casing collapse	X						
	F-1		X	X	X	Blowouts	X	X					
	F-2		X	X	X	Fluid communication between different formations due to ineffective isolation of the well	X	X					
	F-3		X	X		Induced seismicity (above sensitivity level)	X	X					
	F-4		X	X	X	Surface subsidence or uplift	X	X					
	F-5		X	X		Toxic emissions due to gases and fluids produced in-situ	X	X					
	C-5		X	X	X	Human error leading to failure during work (including either insufficient background and/or safety regulations)	X	X					
	E-5		X	X	X	Technical failure/difficulties during drilling (due to any additional causes that were not mentioned)	X						
Additional Notes*													

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ID Interpretations

Topic*	ID	Phases IE*	DT*	OD*	PC*	Description
Managerial and Social-Economic	A-1		X	X	X	External natural hazards damaging the infrastructure
	A-2		X	X	X	Anthropogenic hazard damaging the infrastructure
	B-1		X	X	X	Changes in policies, laws, taxes and regulations put development/economy in jeopardy
	B-2	X	X	X		Lack of financing for the next phases
	B-3	X	X	X		Low social acceptance put barrier to development
	B-4		X	X		Public opposition against nuisances from the exploitation
	B-6	X	X	X		Lack or loss of clients
	B-8	X	X	X		Significant changes of energy costs
	C-1		X	X	X	Low financing for work leading to low safety standards
	B-5		X	X		Unanticipated delays and costs in operations (materials, services, maintenance)
	C-2		X			Suboptimal design of well leads to reduced flow rate
	C-3	X	X	X	X	Best practices not applied (data acquisition, modelling, decision making, design of wells / plants, construction)
	C-4		X			Unsuitable contracts (roles and responsibility not clearly defined) leading to suboptimal performance or exploding costs
	C-8		X	X		Organization is not experienced / financially robust enough for the challenge
	B-9	X	X	X		The research or exploitation permit is changed in favor of another resource
	C-9	X		X		Demand analysis and forecast are inaccurate
Drilling	E-1		X			Fluid losses leading to severe technical issues
	C-7		X			Damage to the well/reservoir while drilling or testing
	E-2		X			Wellbore instability
	E-3		X			Trajectory issues (deviation from target)
	F-8		X			Loss of integrity of surface equipments (leakage from the mud mud pit; well head and etc.)
	F-7		X	X		Loss of integrity of the wellbore (connection of well fluid with surface; inter layer fluid connection; etc.)
	C-6		X			Wrong choice of stimulation fluids or techniques damaging the reservoir/well
	E-7		X	X		Issues in transporting/handling radioactive sources for logging
	E-8			X		Technical failure of the equipment
	E-9		X			Well casing collapse
	F-1		X	X	X	Blowouts
	F-2		X	X	X	Fluid communication between different formations due to ineffective isolation of the well
	F-3		X	X		Induced seismicity (above sensitivity level)
	F-4		X	X	X	Surface subsidence or uplift
	F-5		X	X		Toxic emissions due to gases and fluids produced in-situ
	C-5		X	X	X	Human error leading to failure during work (including either insufficient background and/or safety regulations)
	E-5		X	X	X	Technical failure/difficulties during drilling (due to any additional causes that were not mentioned)

Operation and Geology	D-1	X			Flow rate lower than expected (reservoir)
	D-2		X		Flow rate degrades over time
	D-3	X			Temperature lower than expected (reservoir)
	D-4		X		Temperature degrades too quickly
	D-5	X			Pressure lower/higher than expected
	D-6		X		Pressure is changing during the operation in an unexpected way
	B-7	X	X	X	Neighbouring operators cause negative changes to the reservoir parameters.
	D-7	X	X	X	Fluid chemistry/ gas content / physical properties are different from expected
	F-6		X		NCG Production
	C-5	X	X		Human error leading to failure during work (including either insufficient background and/or regulations)
	D-8		X		Fluid chemistry/ gas content / physical properties change
	D-9	X			Target formation is missing in the well (unexpected geology, insufficient exploration)
	D-10	X			Target formation has no/insufficient fluid for commercial production
	D-11	X			Geological lithology or stratigraphy is different than expected
	D-12	X	X	X	Excessive scaling in the geothermal loop
	D-13	X	X	X	Excessive corrosion in the geothermal loop
	D-14		X		Particle production ("sanding")
	D-15		X		Hydraulic connectivity between wells is insufficient for commercial use
	D-16	X	X		Re-injection of the fluid is more difficult than expected
	D-17		X		Degradation of the reservoir (structure, properties, deteriorating whole-scale further commercial utilization)
	F-8	X	X	X	Loss of integrity of surface equipment (leakage from the tanks, pipeline, heat-exchanger, etc.)

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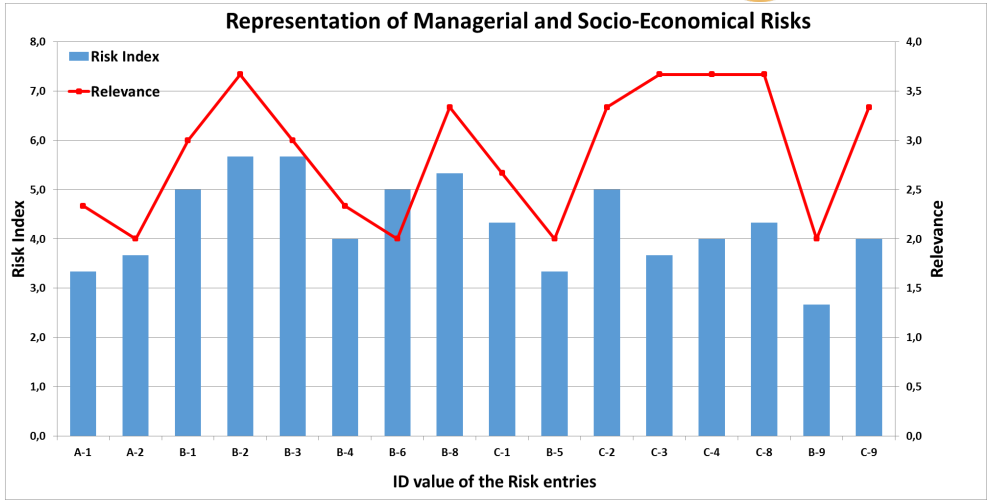
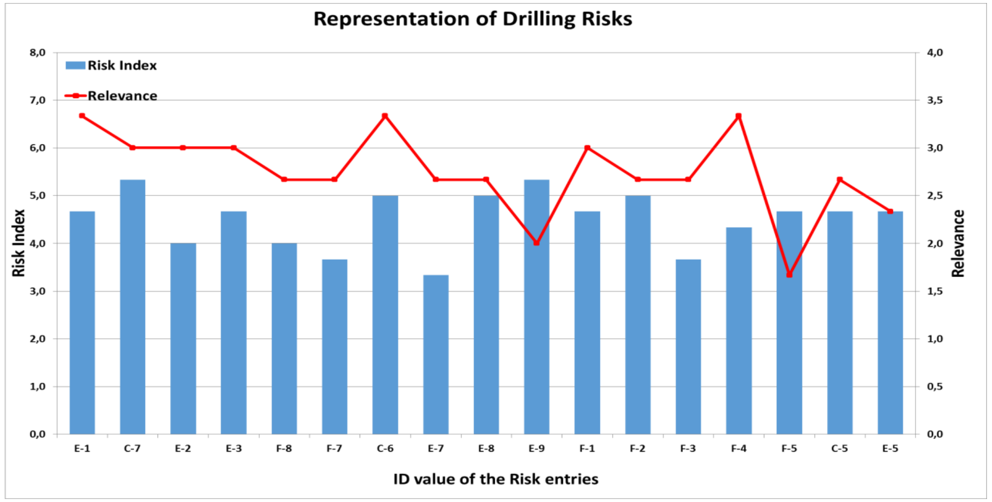
Survey Results

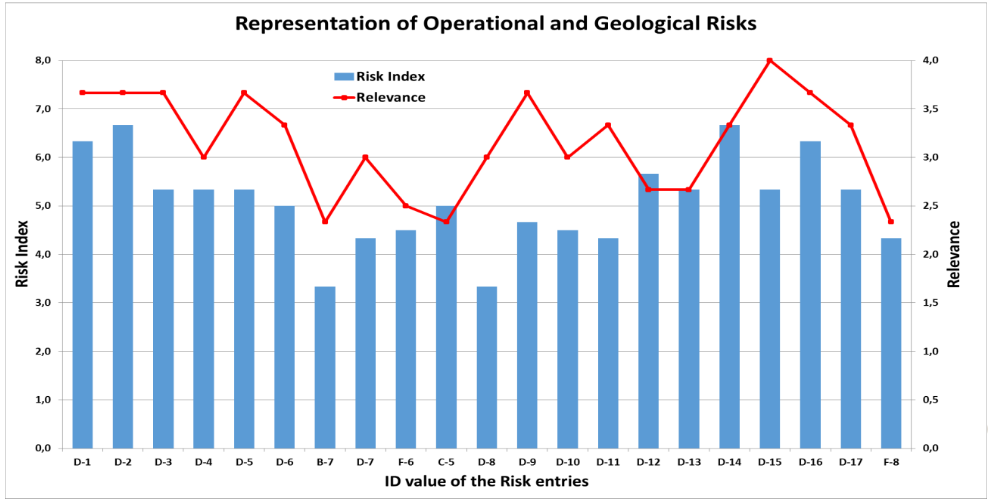
- France – 4 responses
  Dogger Basin
- Germany – 4 responses
  Molasse Basin
  Upper Rhine Valley
- Greece – 7 responses
  Shallow geothermal resources of Macedonia and Thrace
  Deep Sedimentary Reservoirs
  Aegean Volcanic Arc
- Hungary – 18 responses
  Middle depth Pannonian Basin
  Deep Panonian Basin
- Poland – 10 responses
  European Intracratonic Basin and North German Basin
- Turkey – 6 respondents
  Reservoirs in Wester Turkey
- Switzerland – 4 respondents
  Reservoirs in Eastern Switzerland

France – Dogger Basin

- Socio Economical Risk have an average RI of 4,3
- Geological Risks have an average RI of 5,1
- Drilling Risks have an average RI of 4,5
- Main challenge is in the category of geological risks:
  - Deviation of predicted properties from reality
  - Geochemistry and by-product production

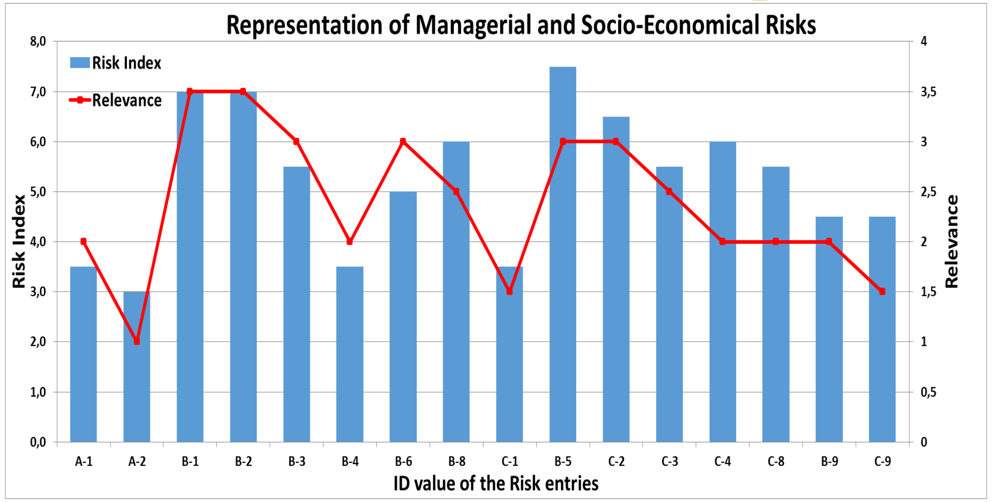


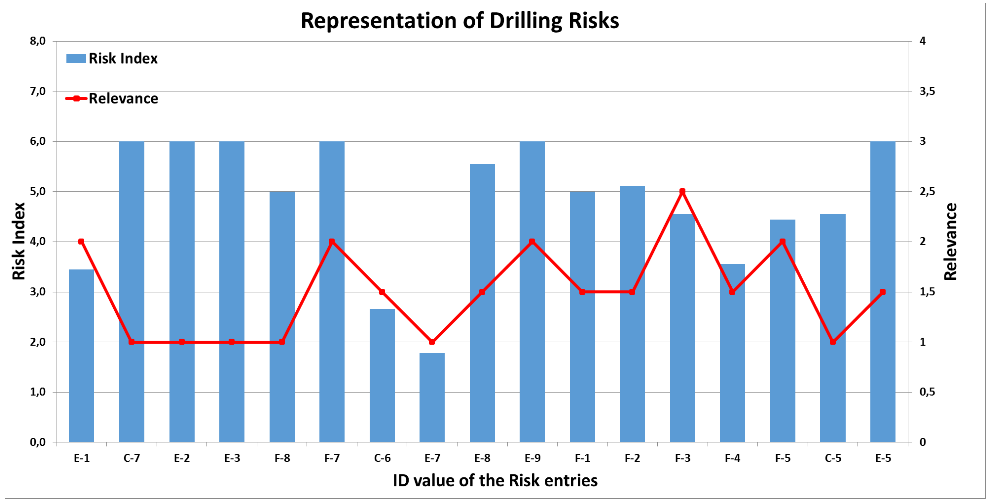


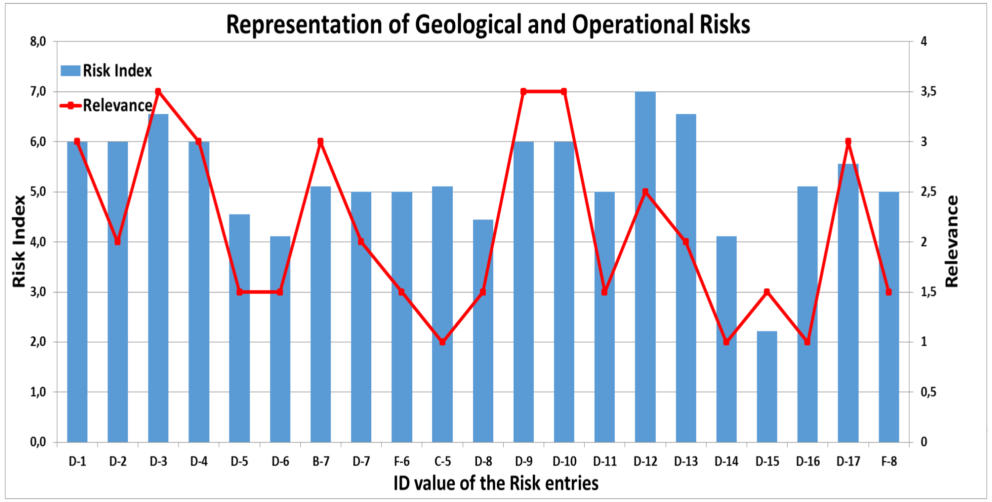


Germany - Molasse

- Socio Economical Risk have an average RI of 5,3
- Geological Risks have an average RI of 5,3
- Drilling Risks have an average RI of 4,8
- Main challenges are following:
  - Financing and instability of regulatory environment
  - Unanticipated costs
  - Securing geothermal resource is a challenge
  - Efficient Reservoir management

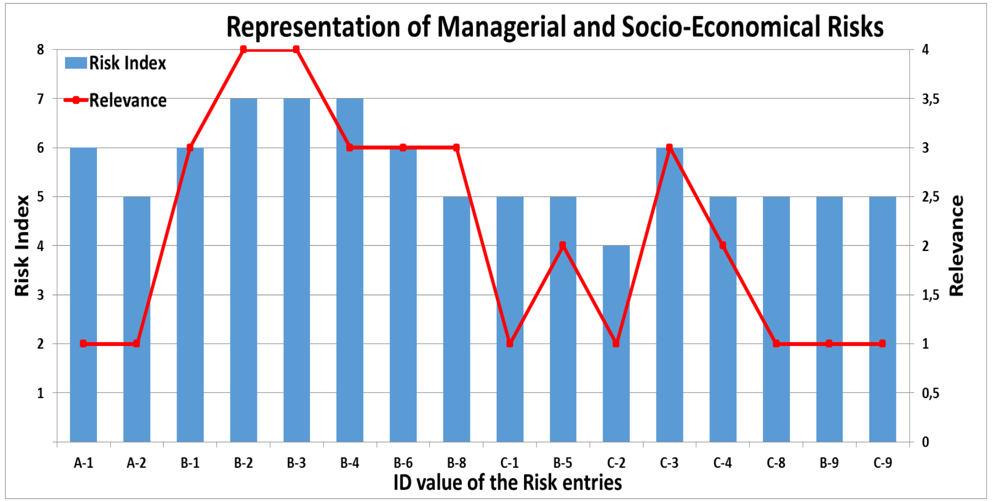


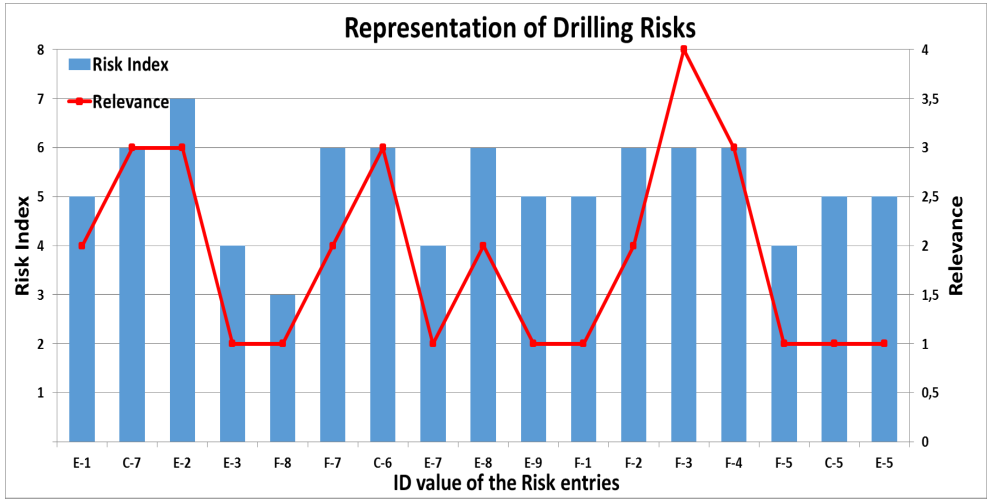


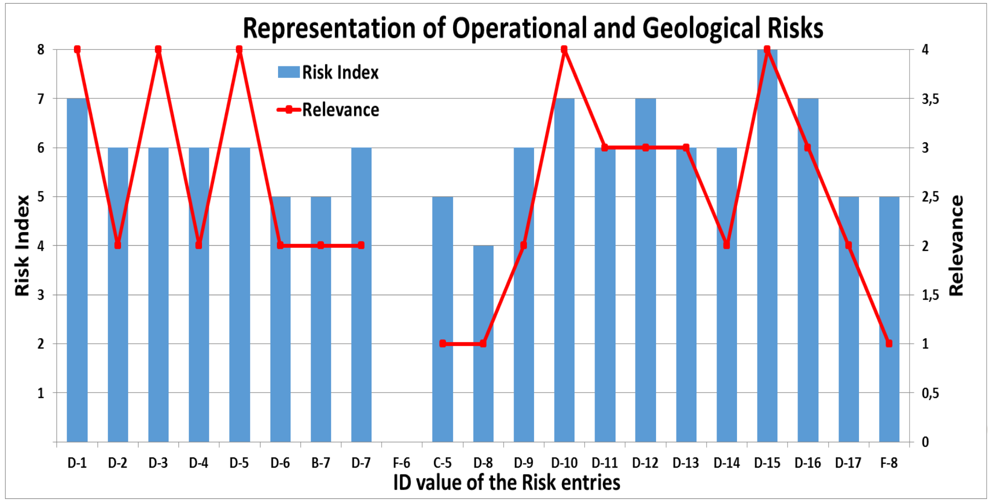


Germany – Upper Rhine Valley

- Socio Economical Risk have an average RI of 5,3
- Geological Risks have an average RI of 5,3
- Drilling Risks have an average RI of 4,8
- Main challenges are following:
  - Financing and instability of regulatory environment
  - Unanticipated costs
  - Social Acceptance
  - Securing geothermal resource
  - Efficient Reservoir management

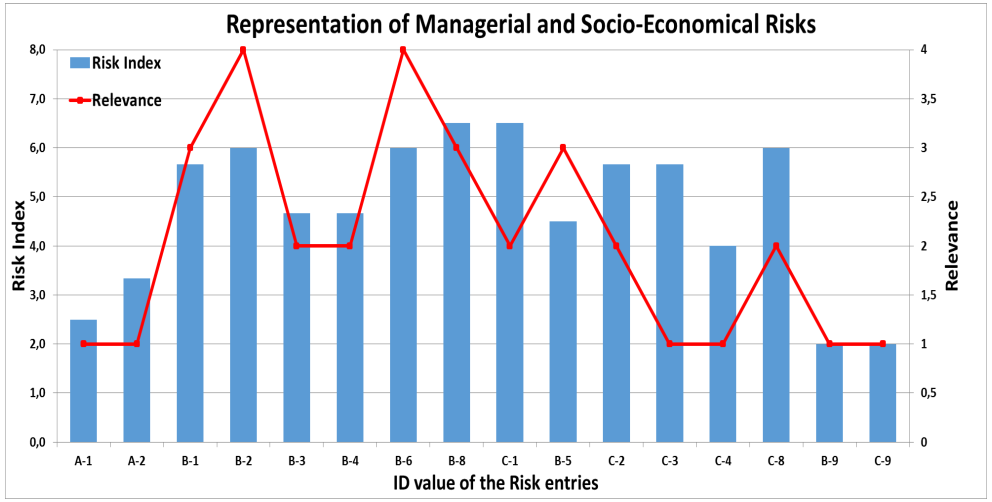


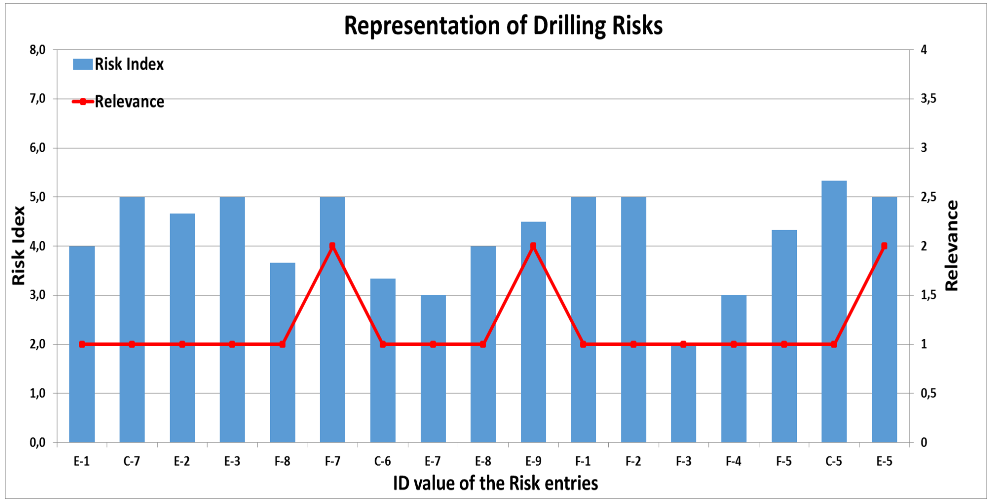


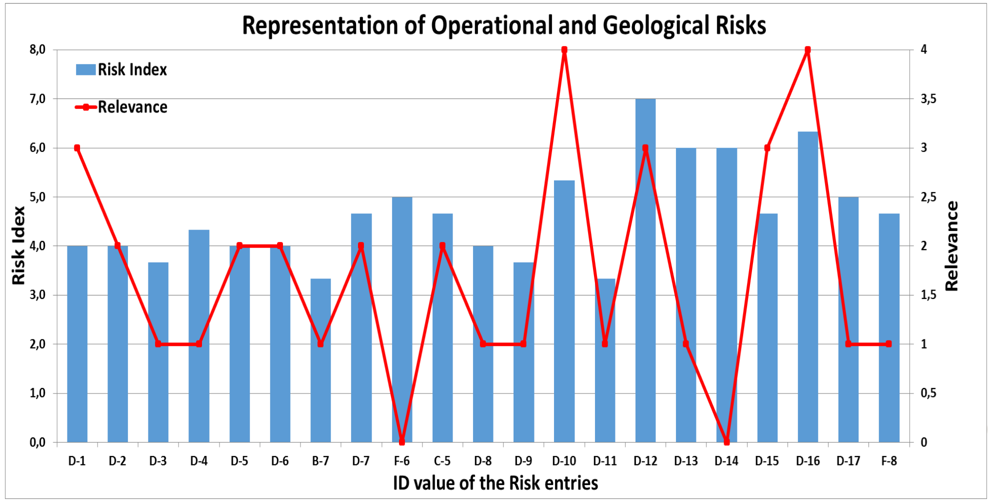


Greece – Macedonia and Thrace

- Socio Economical Risk have an average RI of 4,7
- Geological Risks have an average RI of 4,7
- Drilling Risks have an average RI of 4,2
- Main challenges are following:
  - Financing and instability of regulatory environment
  - Engineering and Design Optimization
  - Hydrochemistry of the thermal water

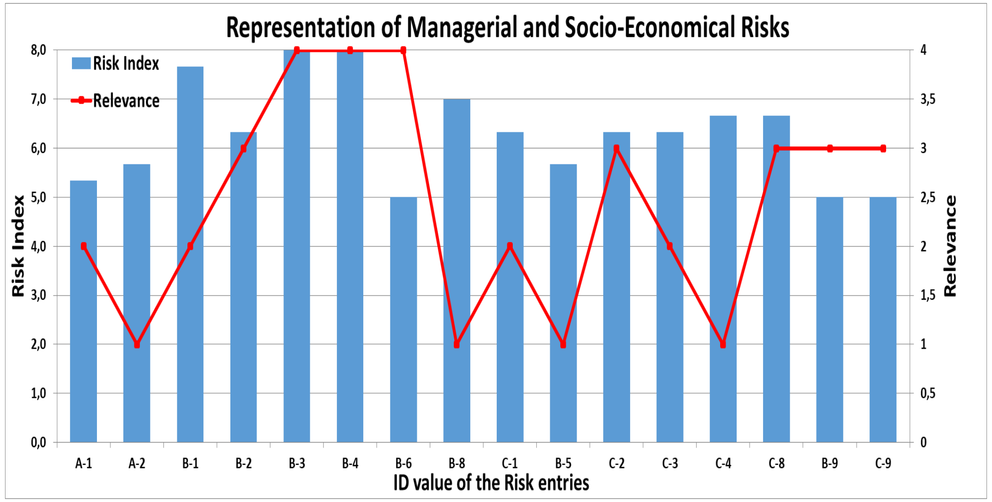


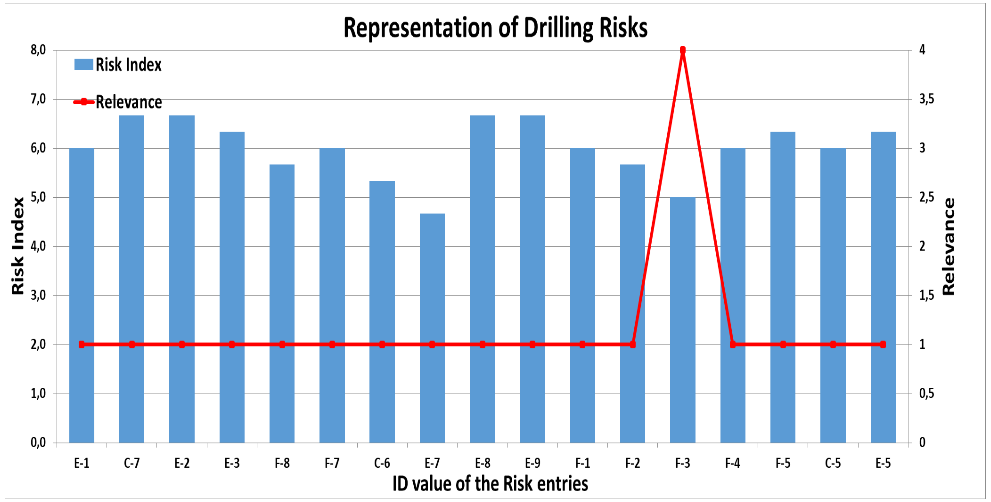


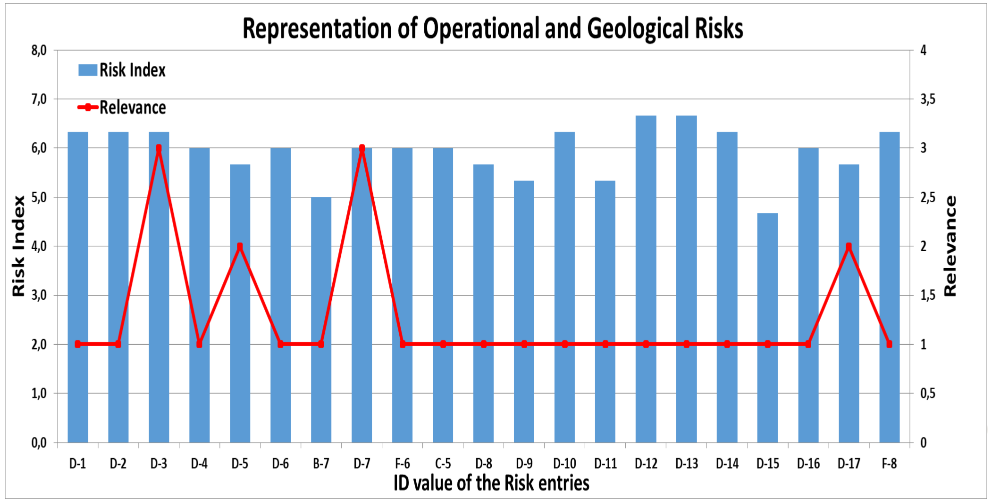


Greece – Deep Sedimentary Reservoirs

- Socio Economical Risk have an average RI of 6,3
- Geological Risks have an average RI of 5,9
- Drilling Risks have an average RI of 6,0
- Main challenges are following:
  - Social Acceptance
  - Lack of Clients
  - Engineering and Design Optimization
  - Hydrochemistry of the thermal water
  - Corrosion and leakage

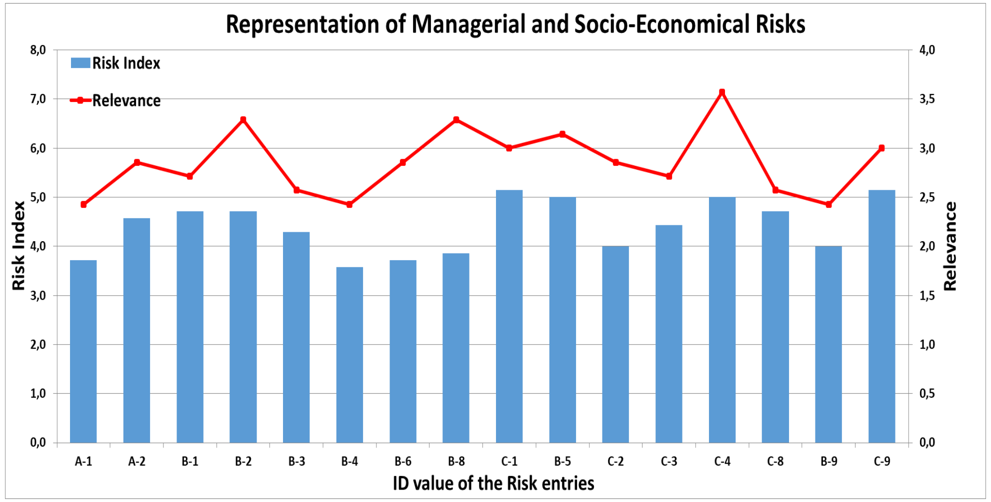


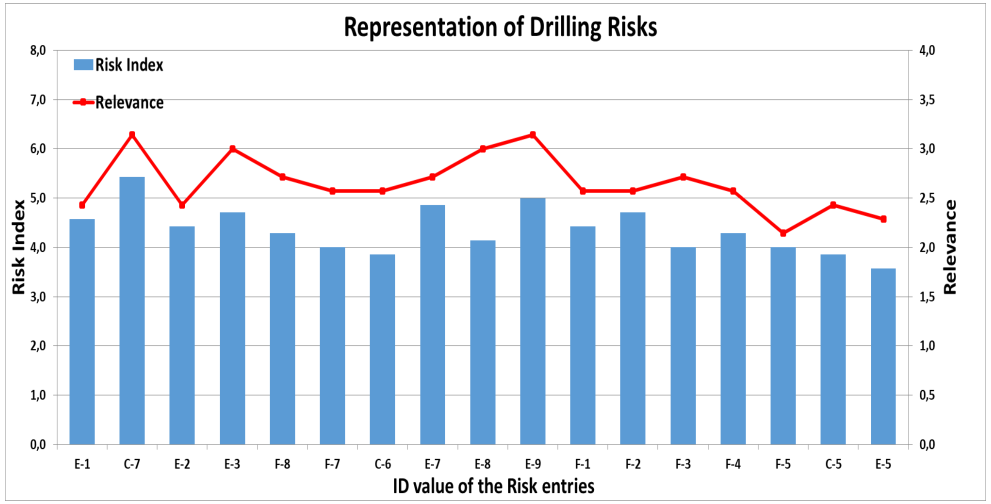


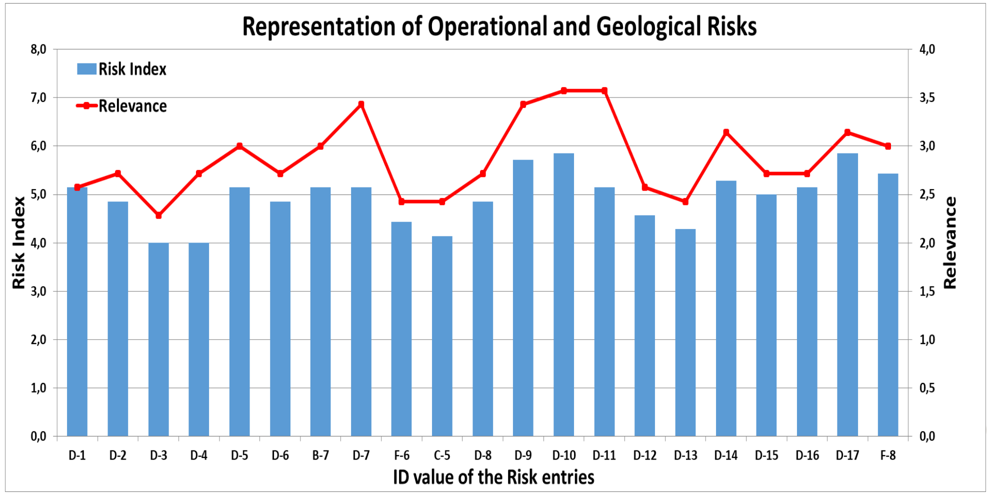


Hungary – Porous Reservoirs

- Socio Economical Risk have an average RI of 4,4
- Geological Risks have an average RI of 5,0
- Drilling Risks have an average RI of 4,4
- Main challenges are following:
  - Securing geothermal resource
  - Reservoir management
  - Fluid Reinjection

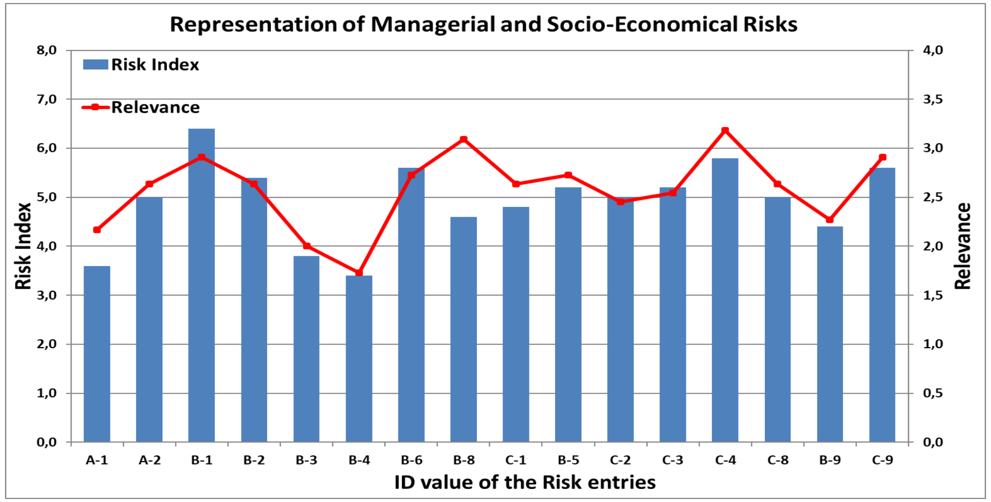


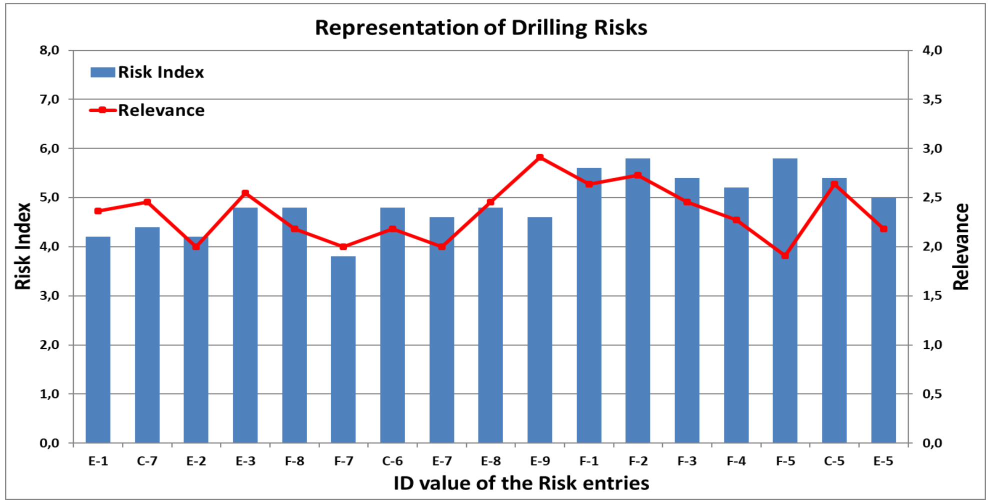


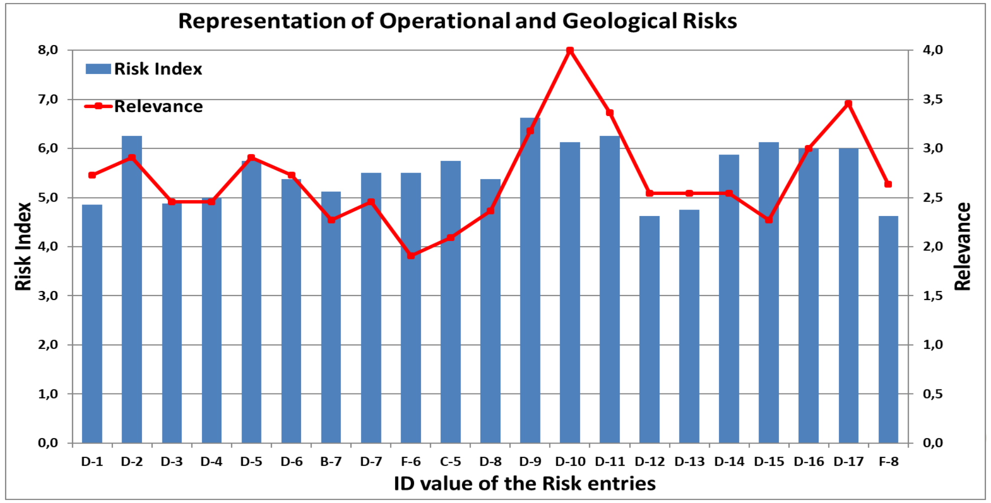


Hungary – Deep Fractured Reservoirs

- Socio Economical Risk have an average RI of 4,9
- Geological Risks have an average RI of 5,5
- Drilling Risks have an average RI of 4,9
- Main challenges are following:
  - Financing and instability of regulatory environment
  - Securing geothermal resource
  - Hydrochemistry
  - Reservoir management

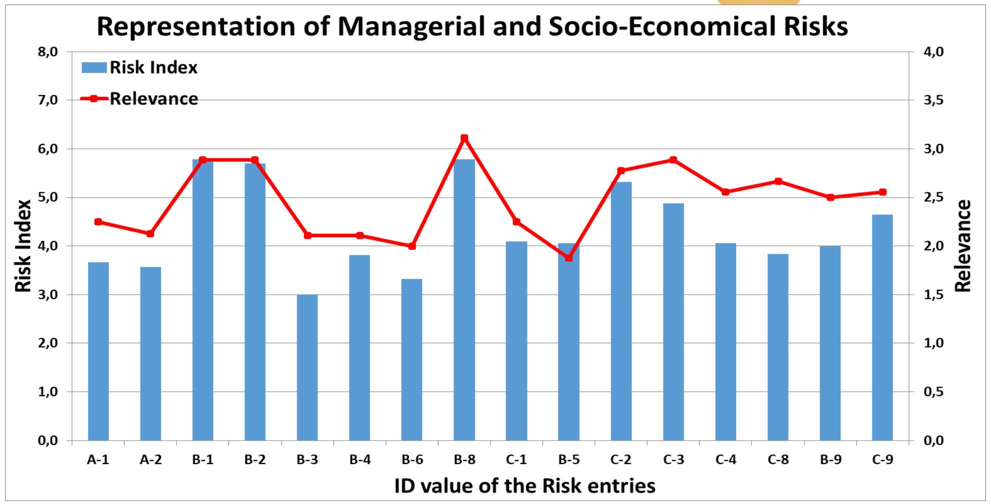


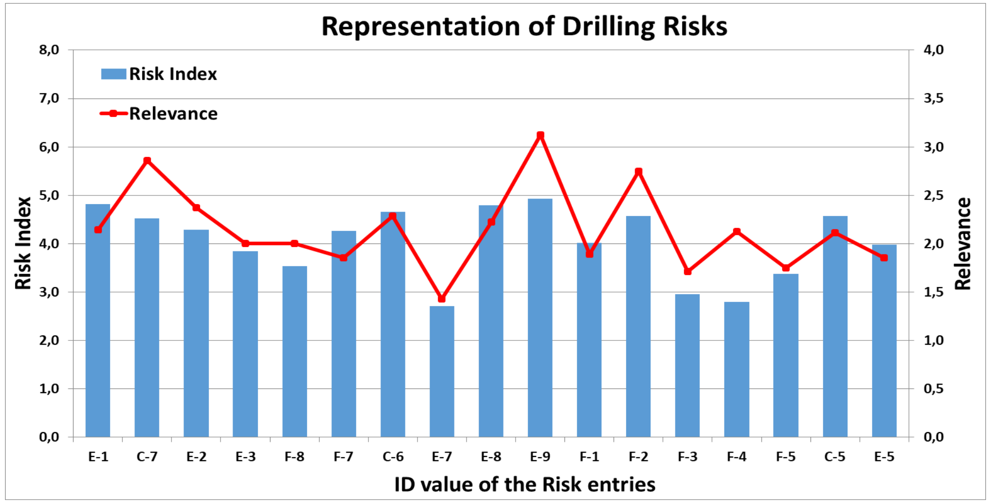


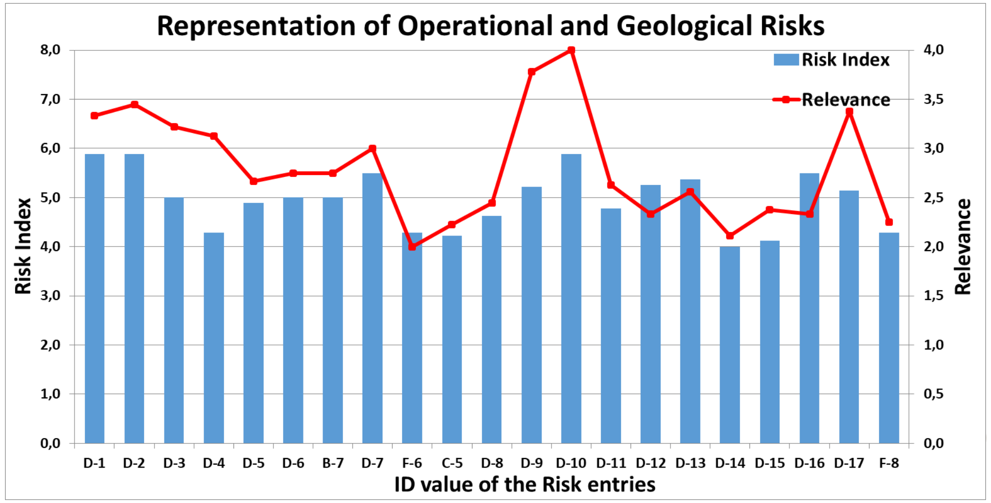


Poland – Intracratonic basin

- Socio Economical Risk have an average RI of 4,3
- Geological Risks have an average RI of 5,0
- Drilling Risks have an average RI of 4,0
- Main challenges are following:
  - Financing and instability of regulatory environment
  - Securing geothermal resource
  - Well Casing Collapse

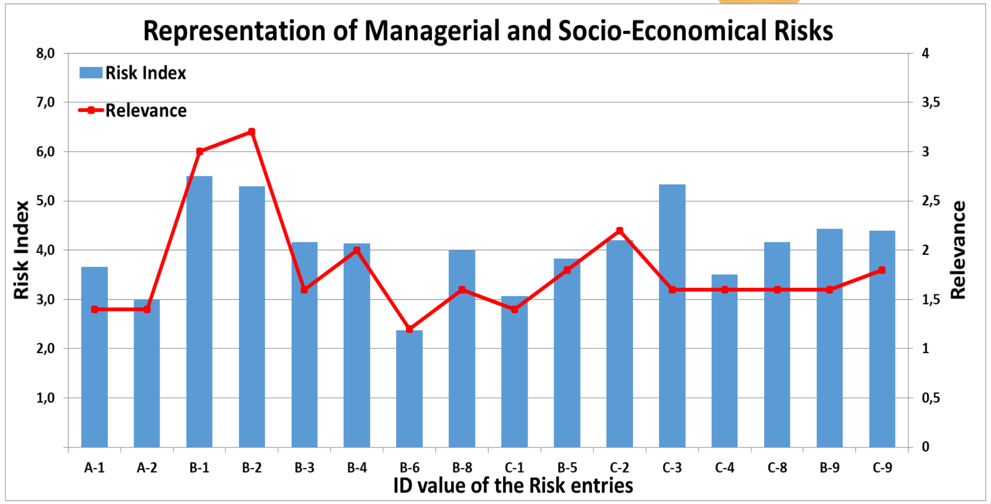


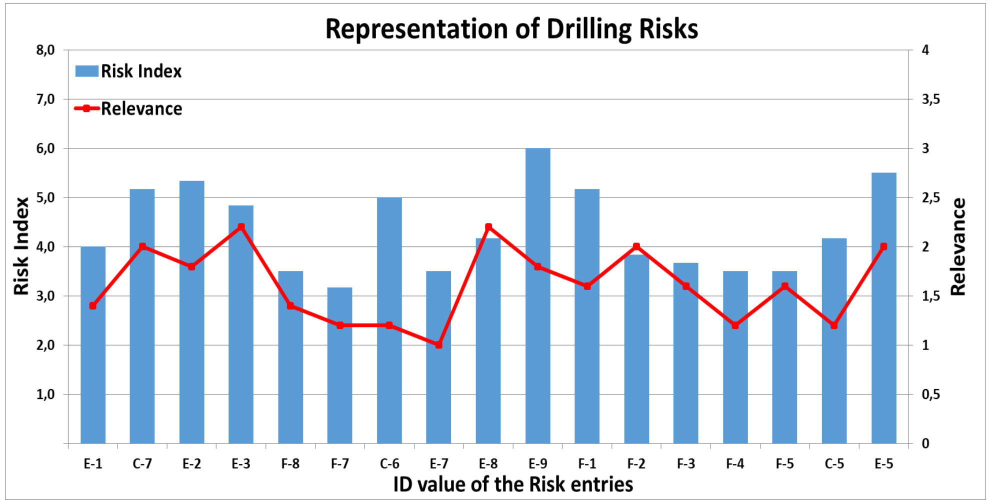


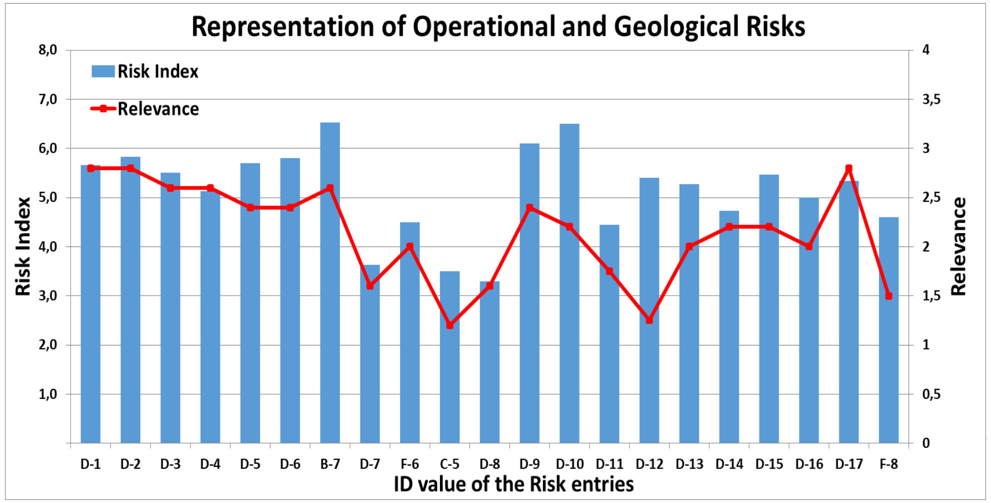


Turkey – Aegean Region

- Socio Economical Risk have an average RI of 4,1
- Geological Risks have an average RI of 5,1
- Drilling Risks have an average RI of 4,4
- Main challenges are following:
  - Financing and instability of regulatory environment
  - Engineering and Design Optimization
  - Securing geothermal resource
  - Reservoir Management
  - Well casing collapse

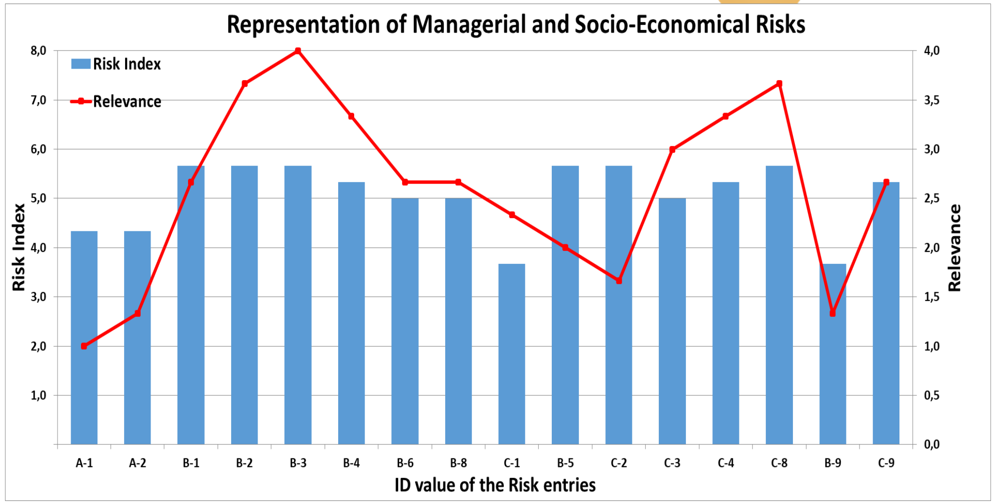


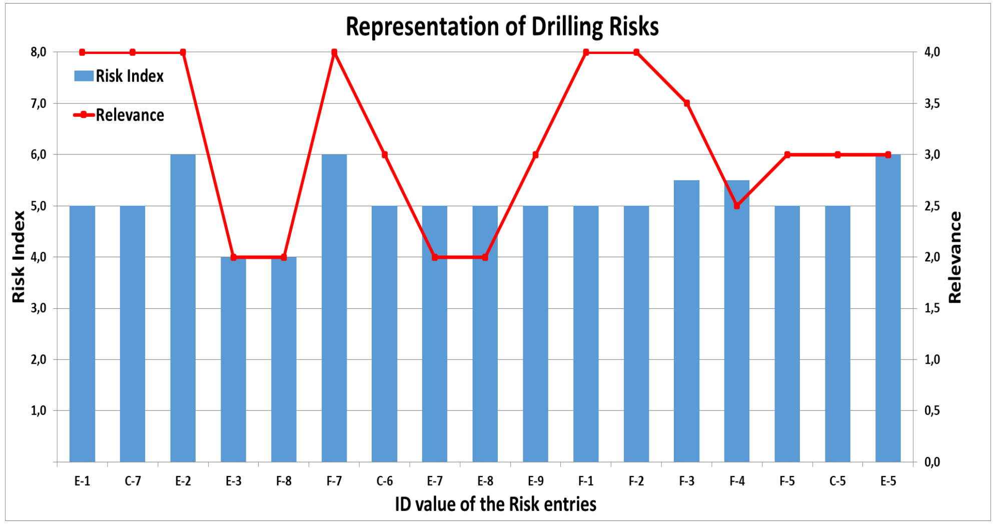


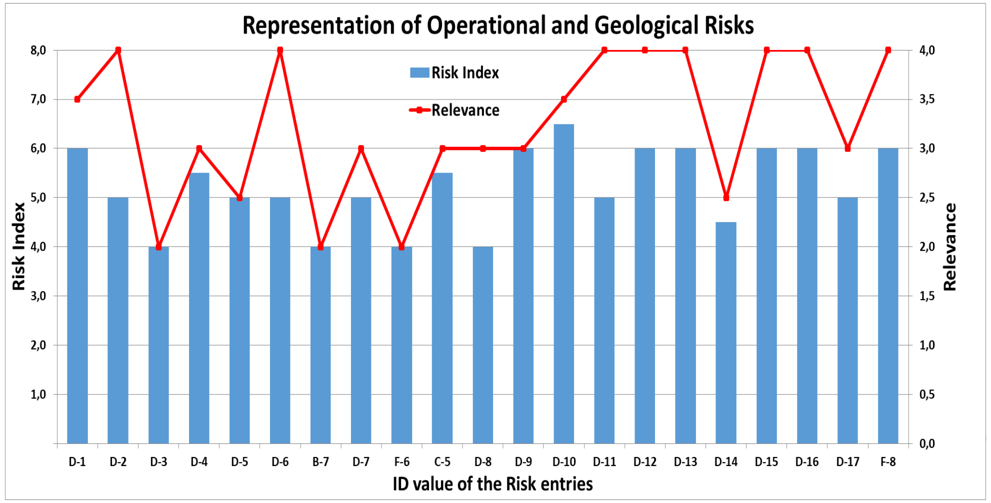


Switzerland – Hydrothermal Reservoirs

- Socio Economical Risk have an average RI of 5,1
- Geological Risks have an average RI of 5,2
- Drilling Risks have an average RI of 5,1
- Main challenges are following:
  - Financing and instability of regulatory environment
  - Social Acceptance
  - Engineering and Design Optimization
  - Securing geothermal resource
  - Hydrochemistry
  - Wellbore Instability







WP 2: RISK ASSESSMENT

MONTHS 1-15, BRGM

1) Context and Identification of potential risks (BRGM) (months 1-6)

Geothermal risk register

2) Risk Assessment (GEC-CO) (months 5 to 12)

Geothermal Risk Matrix

3) Tools to assess the risks (BRGM) (months 5 to 15)

GeoRisk report: Online tool for developers globally recognized reporting code

RISK ASSESSMENT TOOL

Main objectives and functions

- Present the results from WP2 of GEORISK:
  - Risk register
  - Possibilities of risk mitigation
  - Risk analysis
- Help/Assist geothermal developers/investors in structuring a risk management approach for their project
- Heighten awareness to the main risks and the possibilities to mitigate them ; some actors interested in the development of geothermal energy may lack basic understanding of the technical details
- Highlight the risks needing insurance schemes

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ONLINE RISK REGISTER

Low social acceptance put barrier to development

- **Category:** risks due to uncertainties in the external context
- **Id:** B-3
- **Phases:**
  - Identification / Exploration
  - Drilling / Testing
  - Exploitation / Development
- **Consequences:**
  - Economic / Performance / Acceptability
- **Comments:** Lack of awareness in a given area is a factor

- **Mitigation:**
  - Technical
    - Thorough Preparation of PR Program
    - Information Campaigns
    - Training Materials
    - Early engagement with local people (in project preparation phase)
  - Legal / Policy
  - Insurance: no

PROTOTYPE

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RISK ASSESSMENT RESULTS

RESULTS FROM GEORISK

Click on the region you are interested in or get more info HERE

RISK

Questionnaire (quantitative analysis)

General Information			
Output*	Reservoir Type*	Country and Region	Estimated Total Value of Project (in M€)
Heat	Sedimentary	France – Nouvelle Aquitaine	10,0

Topic*	ID	Phases IE*	DT*	ED*	PC*	Description	Risk Evaluation Probability	Percentage of Loss	Expected loss (k€)	Comments*
Managerial and Social-Economic	A-1		X	X	X	External natural hazards damaging the infrastructure	2	25	50	
	A-2		X	X	X	Anthropogenic hazard damaging the infrastructure	10	10	100	
	B-1		X	X	X	Changes in policies, laws, taxes and regulations put development/economy in jeopardy	25	50	1250	
	B-2	X	X	X		Lack of financing for the next phases	25	75	1875	
	B-3	X	X	X		Low social acceptance put barrier to development	10	80	800	
	B-4		X	X		Public opposition against nuisances from the exploitation	10	50	500	
	B-6	X	X	X		Lack or loss of clients	20	40	800	
	B-8	X	X	X		Significant changes of energy costs	15	15	225	
	C-1		X	X	X	Low financing for work leading to low safety standards	30	10	300	
	B-5		X	X		Unanticipated delays and costs in operations (materials, services, maintenance)	40	1	40	
	C-2		X			Suboptimal design of well leads to reduced flow rate	30	25	750	
	C-3	X	X	X	X	Best practices not applied (data acquisition, modelling, decision making, design of wells / plants, construction)	1[illegible]	[illegible]	[illegible]50	
	C-4		X			Unsuitable contracts (roles and responsibility not clearly defined) leading to suboptimal performance or exploding costs	25	15	375	
	C-8		X	X		Organization is not experienced / financially robust enough for the challenge	20	15	300	
	B-9	X	X	X		The research or exploitation permit is changed in favor of another resource	2	50	100	
	C-9	X		X		Demand analysis and forecast are inaccurate	50	10	500	

PROTOTYPE

Results

GEORISK

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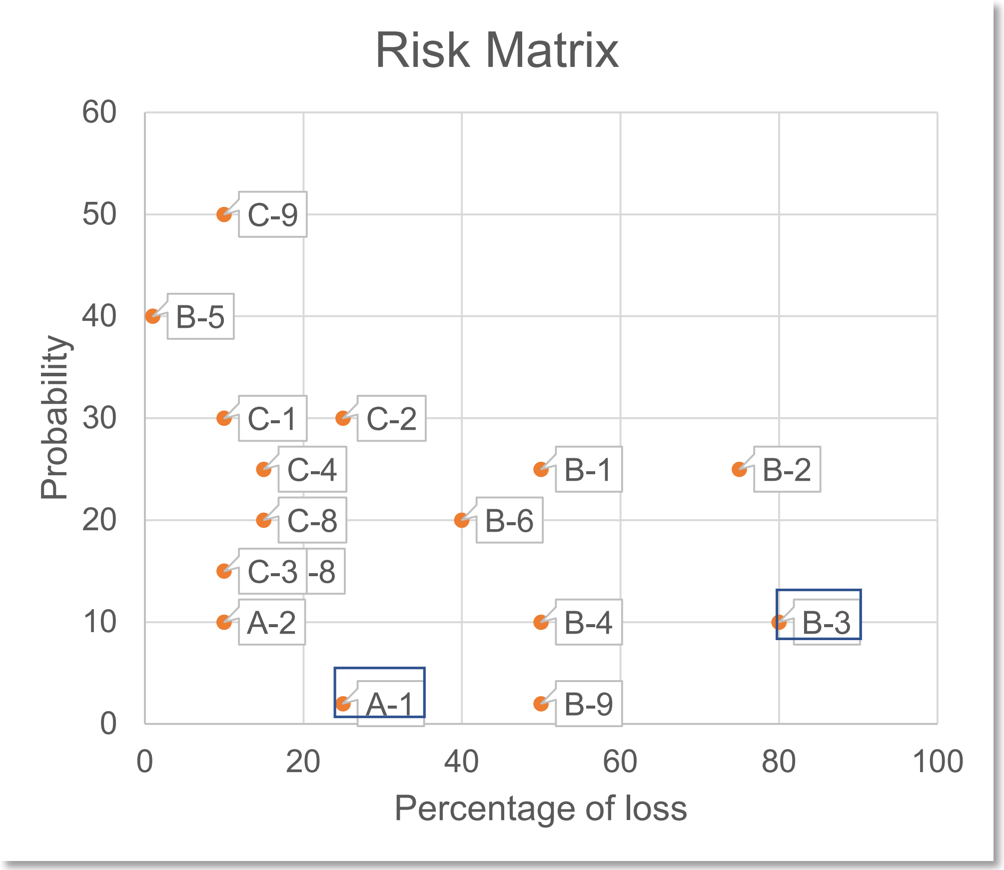
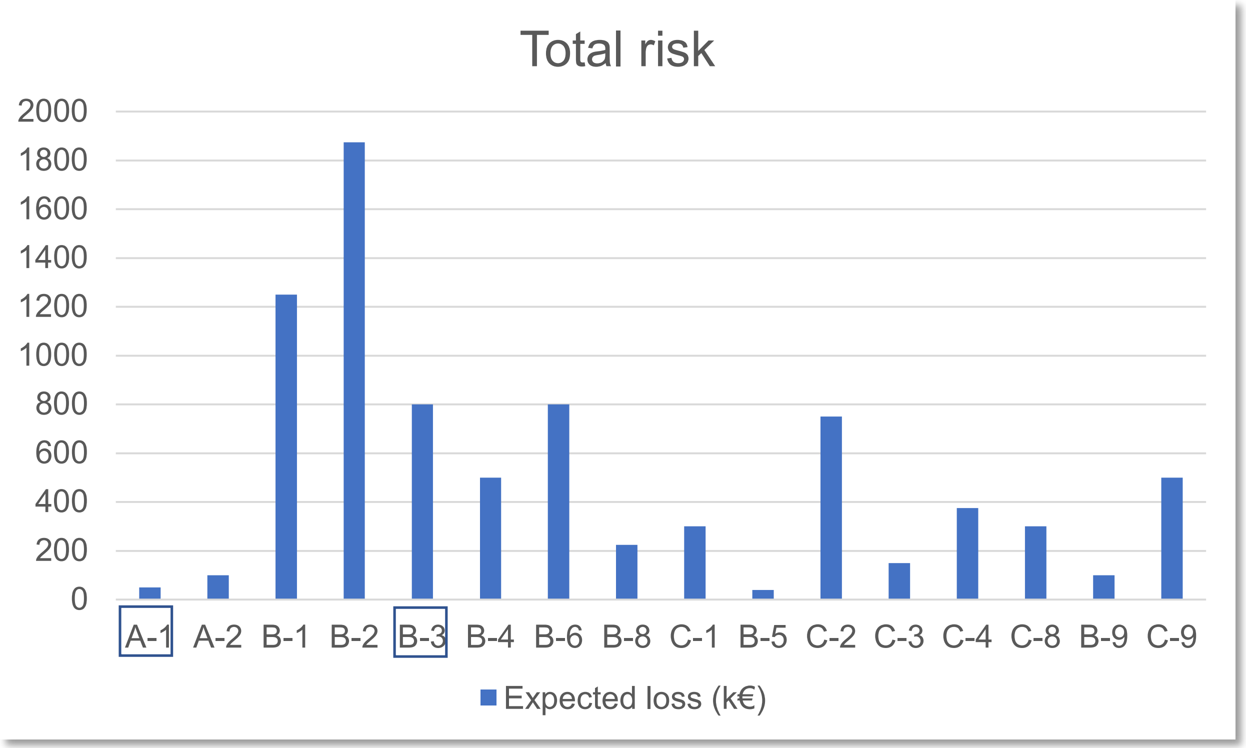
Results (qualitative analysis)





PROTOTYPE

GEORISK

RISK ASSESSMENT TOOL

UNDER DEVELOPMENT

- Feedback welcome (t.leguenan@brgm.fr) : what would be most useful for developers?
- What additional information should be available?

GEORISK

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and innovation program under grant agreement No [818232 — GEORISK]