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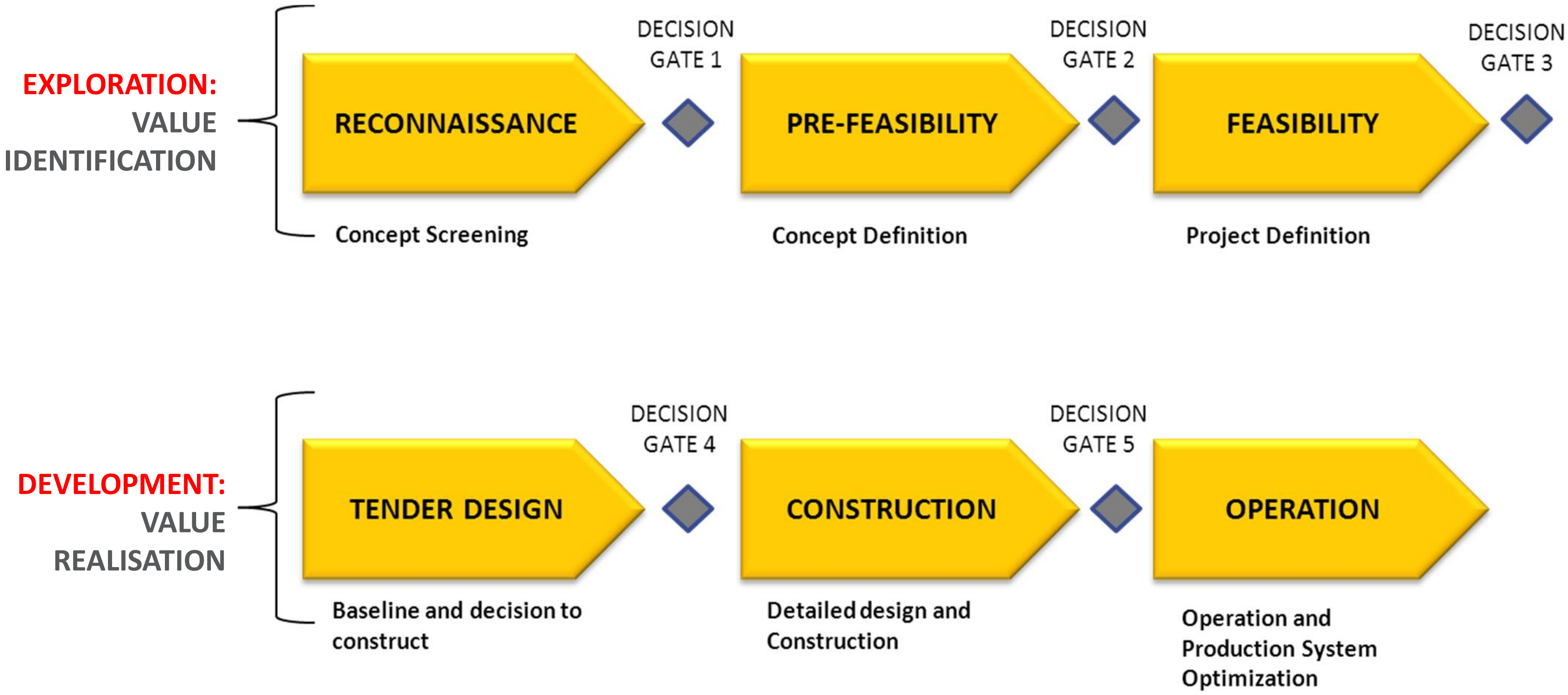
Geological risk mitigation

The Geothermal Project Lifecycle



Source: Geoelec project

Risks at various stages of a geothermal project

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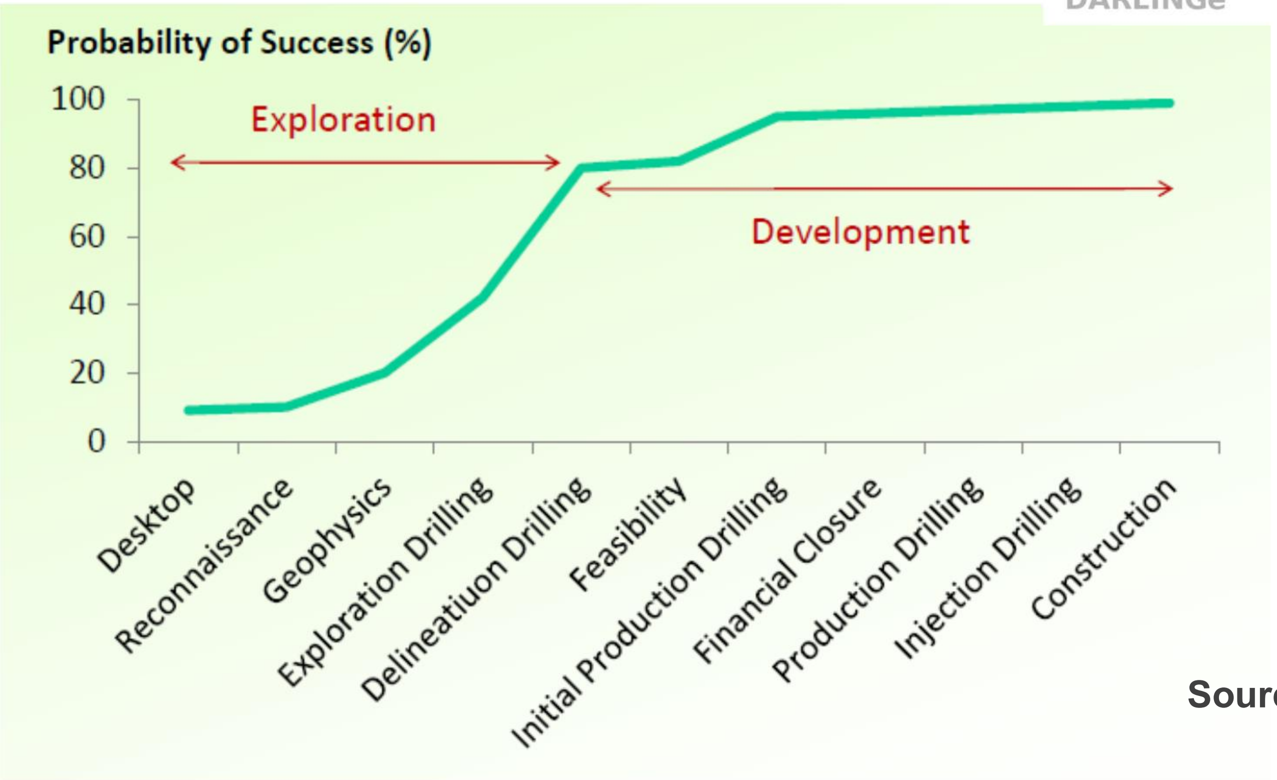

Source: GEA, 2008

Highest risk during exploration

Probability of success of the first drilling: 20-60% (depending on the location and pre-drilling geological-geophysical exploration

Reservoir parameters (temperature, flow-rate) can be estimated only after the first successful drilling

Geothermal Risks Characteristics

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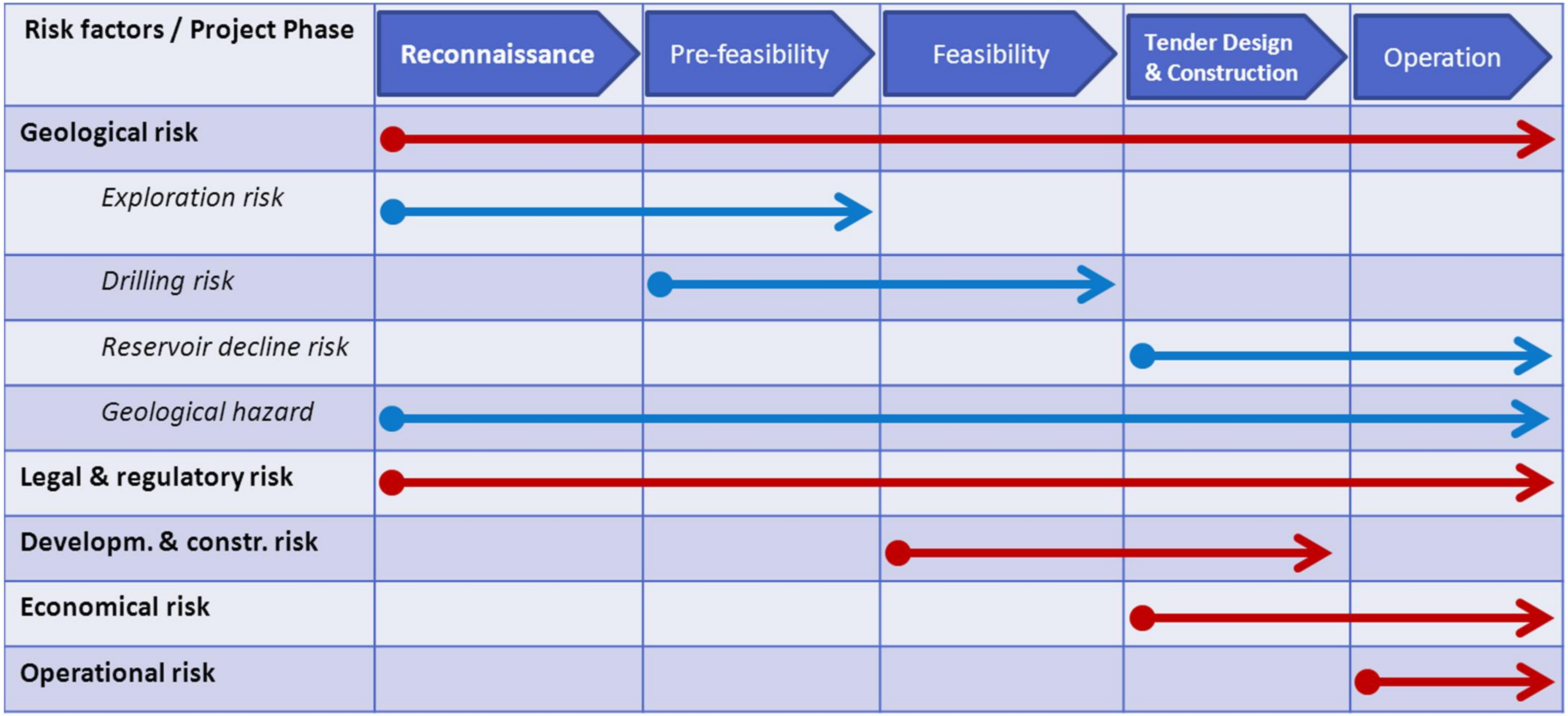
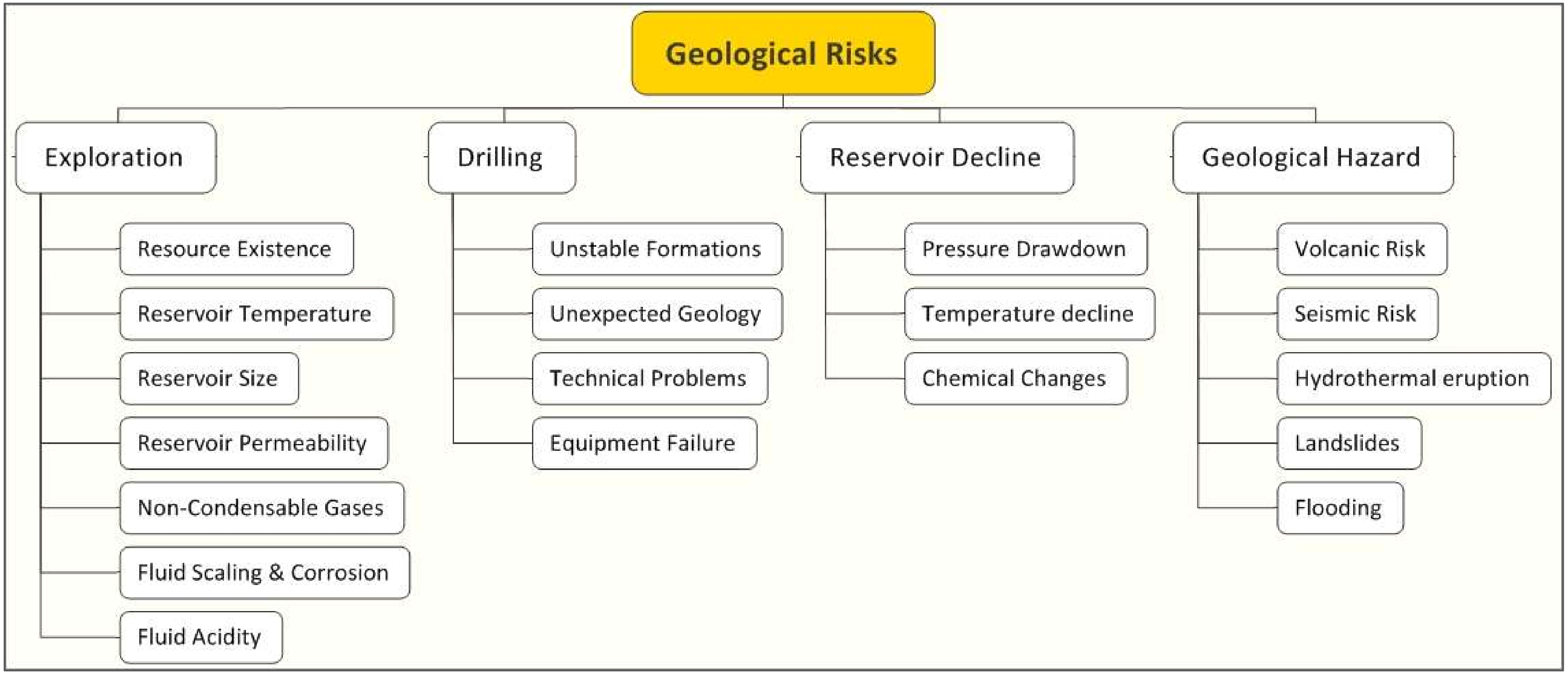


The geothermal resource cannot be accurately assessed until drilling has taken place

Geological Risk

- **Drilling phase : Short-term risk of not finding an economically sustainable geothermal resource (exploration phase)**
- **Exploitation phase : Long-term risk of the geothermal resource naturally depleting threatening the long-term economically profitable production (operation phase)**

Geological Risk Breakdown



Source: Geoelec project

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Potential risk treatment

- Prevention – I do not undertake
- Reduction - Spending on planning, exploration, construction, supervision
- Transfer - Involving other parties, insurance
- Acceptance - I undertake, I do not spend money (now)

If a well is underperforming the expectations:

- The evaluation of geology is inaccurate
- The planning of well and drilling work is inaccurate
- The construction of well is inaccurate
- The geology differs from what it seemed – uncertain geological data

How to reduce geological risks?

Evaluation of geology

- Detailed collection of existing data
- Complience of data
- Traceability of interpretations
- Request for second opinions

Planning of well and drilling works

- Geological prognosis based on geological evaluation
- The well structure to be completed safely should be appropriate for the aim
- Safety regulations
- Opportunity to drill further
- Quality of drilling and well's materials

Supervision of drilling works

- Independent entity
- Technical eligability
- Monitoring task
- Documenting task
- Decision on deviations
- Well logging

Geothermal Cost / Risk Development

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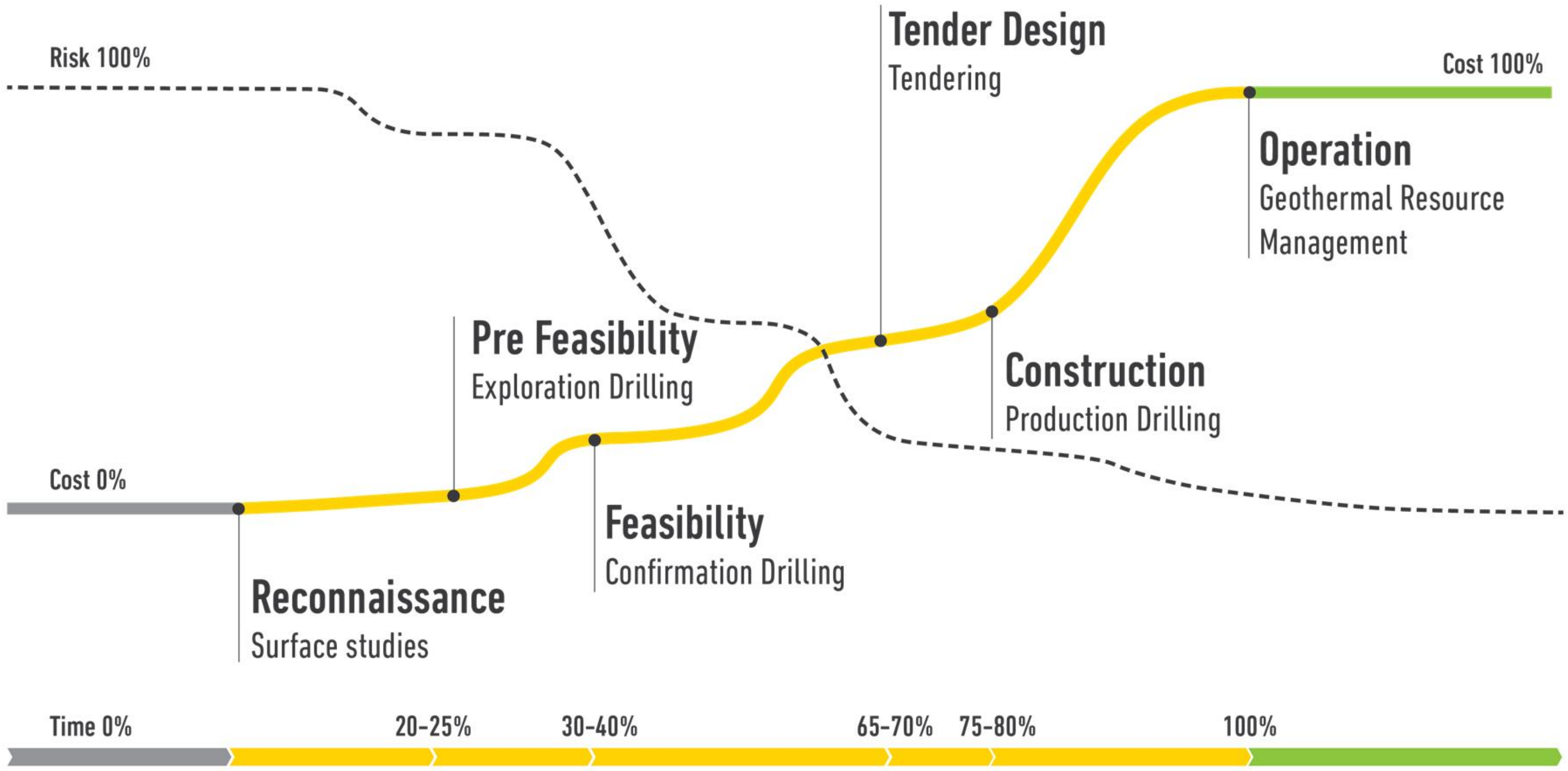

Source: Geoelec project

Project risk decreases with increased investment as the project is developed further with research and results from the first well drilling and testing

BUT HOW TO COVER THE COSTS / RISKS OF THE FIRST WELL?

Lack of drilling capital as a main barrier to geothermal development

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Financial markets have shown a poor understanding of geothermal development projects and tend to overestimate resource risk

- **Lending institutions are unwilling to finance initial drilling and therefore equity is required to drill the first well**
- **Difficult to find equity investors willing to take on drilling/resource risk**
- **The project becomes „bankable" only after the exploration drill is completed and resource is confirmed, although in many cases lending institutions require majority of the well field to be drilled**

Need for specilized sources of capital to bridge the gap between exploration and construction

Existing geological risk mitigation and insurance policies

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Insured risk: short-term (drilling) ***(long-term risk – reservoir depletion is a technical risk to be handled by proper production strategy by the operator)***

Private insurance: Germany (market-based insurance companies: Munich Re, Swiss Re, Axa, Goather, R&V, Marsh és Willis) – project tailored individual fees (post-damage)

National insurance funds:

- **post-damage guarantee (France, the Netherlands, Switzerland)**
- **guaranteed loan (Iceland and Germany) – cost of the damage can be reimbursed up to a fixed amount**

Establishment of national funds: capital provided by the state (+ private equity)

Income during opertaion: insurance fees, taxes or other incomes (e.g. feeding back certain proportion of mining fees, etc.)

More diverse income sources - more stable funds

Operators of national funds:

Responsible ministries, governmental institutions

Existing geological risk mitigation and insurance policies

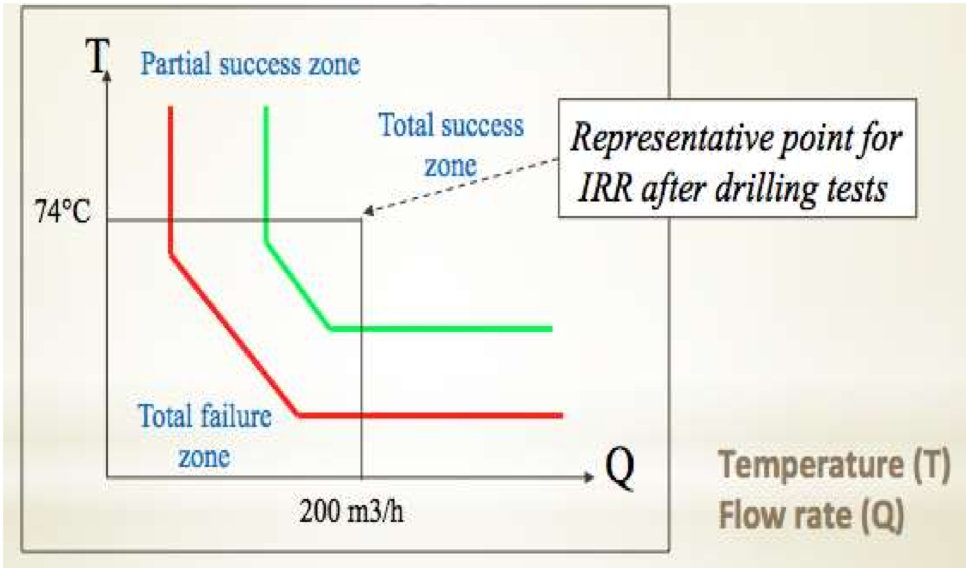
Contract between project developer and insurance company / fund

Conditions laid down in great details:

- Technical criteria: expected yield, temperature, concept for reservoir development, drilling techniques, etc. + probability of success (POS)
- Financial criteria: business plan, return rate of investment (ROI), etc.
- Regulatory criteria: all licenses available, information about the company, key-experts, etc.

Success criteria: i.e. full / partial failure at which yield / temperature

In case of damage experts compare declared damage by those laid down in the contract and decide on the rate / amount of insurance



Overview of risk mitigation systems

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Source: Rödl & Partner

	Key Actors	Funds Sum	Geo. Scope	Program Status	Budget Allocation	Risk Mitigation Instruments
Geothermal Risk Mitigation for Eastern Africa	KfW, AUC, GEF	50M USD ▪ KfW 20M ▪ EU-ITF 30M	East African Rift Valley Countries	Application phase	Drilling Projects ▪ 20% of infrastructure costs ▪ 40% of exploration drilling costs ▪ 30% of continuation drilling costs in exceptional cases	Surface Studies ▪ 20% of infrastructure costs ▪ 80% of surface study costs
Indonesian Risk Mitigation Fund	Indonesian Finance Ministry	302M USD	Indonesia	Budget announced June 2013	To finance the geothermal exploration activities up to initial drilling exploration well(s) Target: local governments.	Revolving fund: Local governments use funds to determine successful areas, private developers shall then repay exploration costs.
German KfW Risk Mitigation Scheme	KfW, German Ministry for Developmt.	Total budget unknown, Max. 16M €/ project	Germany	Ongoing since 2007	*Model 1* ▪ 100% indemnification for up to 80% of the eligible investment costs	*Model 2* ▪ 100% indemnification for up to 80% of the eligible investment costs ▪ Redemption grant in case of succesful drilling
French Geothermal Risk Guarantee System	French Agency for Energy Mgmt.	Total budget unknown	France	Ongoing	*Short term partial risk guarantee* Up to 90% or 3M € of the total costs of the 1st well. 1.5% of max. guaranteed sum payable to fund. Indemnity as per success.	*Long term partial risk guarantee* Compensates consequences of possible damage. 3.2% of max. guaranteed sum payable to fund
Swiss Geothermal Risk Guarantee	Swiss Office of Energy, Swiss Grid Company	Max. 125M €/year	Switzerland	Ongoing	▪ Guarantee covers up to 50% of the drilling and testing costs ▪ Guarantee is financed by by an additional fee per kWh borne by the end consumer (0.08€/kWh) ▪ In case of partial success, compensation is determined by independent Brain Trust	

European systems

Discovery risks only, any further technical risks (e.g. lost-in-hole during drilling) are not covered

Each system has own success criteria

Vision: Risk insurance scheme at European level

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Needed because of:

- Shortage of insurance policies
  - Limited current market size
  - No statistical basis to assess the probability of success
  - Allow the technology to progress along its learning curve (EGS)
- Pooling of the resource risk at a European level
- Not a competitor to national insurance policies
- When mature: replaced by private schemes

An exclusive management by an EU institution or a shared management with a national institution

A secretariat and a board (shareholders, geothermal professionals, experts, for some applications a representative of the national insurance system)

A seed capital of 50-100 Mio €

The obligation to disclose the data collected

Experience from geothermal and hydrocarbon concessional works in Hungary

Closed areas and the mining concession

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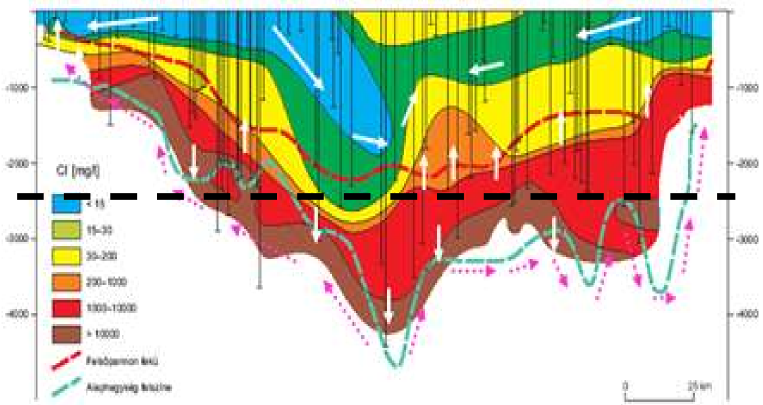
- **From 2011 (the first bid in 2013): the Minister of National Development (responsible for mining affairs) may lease tender on a closed area for**
  - **the exploration, development and exploitation of *mineral resources***
  - **the exploration, recovery and utilization of *geothermal energy*.**
- **The concession tenders are prepared by Hungarian Office for Mining and Geology (MBFH) supported by MFGI.**

Ministry of National Development
⇩
Hungarian Office for Mining and Geology (MBFH)
⇩
Geological and Geophysical Institute of Hungary (MFGI)

Legislation on geothermal energy in Hungary



I. Veto, I. Horvath, Gy. Toth (2004)

‘Free’ for GT
Legislation: Water law
(partly Mining law)
(Ministry of Interior)

2500 m - - - - - - - - - - - - - - - - - -

Closed zone for GT Concession
Legislation: Mining law
(Ministry of National Development)

The concession procedure

- 1. Selection of potential concession plots (areas)
  - ➢Investor's initiatives for proposed plots for tender (Areas requested by developers).
  - ➢Plots (areas) selected by MBFH, MFGI.
- 2. Complex vulnerability and impact assessments (reports)
  - ➢Are available, can be downloaded from the official website of the Hungarian Office for Mining and Geology MBFH) http://www.mbfh.hu/home/html/index.asp?msid=1&sid=0&hkl=538&lng=1
- 3. The Concession Call for Tender / Tender Announcement
  - ➢Based on the assessments, the minister announce the concession tender for those areas being favorable for exploiting mineral resources or recovering geothermal energy for energetic purposes.
  - ➢Data packets are compiled for all tendered plots that are available for all tender candidates in the Hungarian State Geological, Geophysical and Mining Databank operated by the MBFH
  - ➢Exploration data is in public domain after 3 years.
- 4. The Concession contract
  - Prospect for, extract and utilize HC (the duration of the concession is 20 years for hydrocarbon, which can be prolonged once with 10 years)
  - Prospect for, extract and utilize GtE (the duration of the concession is 35 years for hydrocarbon, which can be prolonged once with 12,5 years)
  - The applicant's exploration right regarding Hungary is restricted in case of hydrocarbons
(15,000 sq km) in order to secure competitive framework.

Up to 2017 3 concessions for geothermal energy (below 2500 m), and 21 for hydrocarbon

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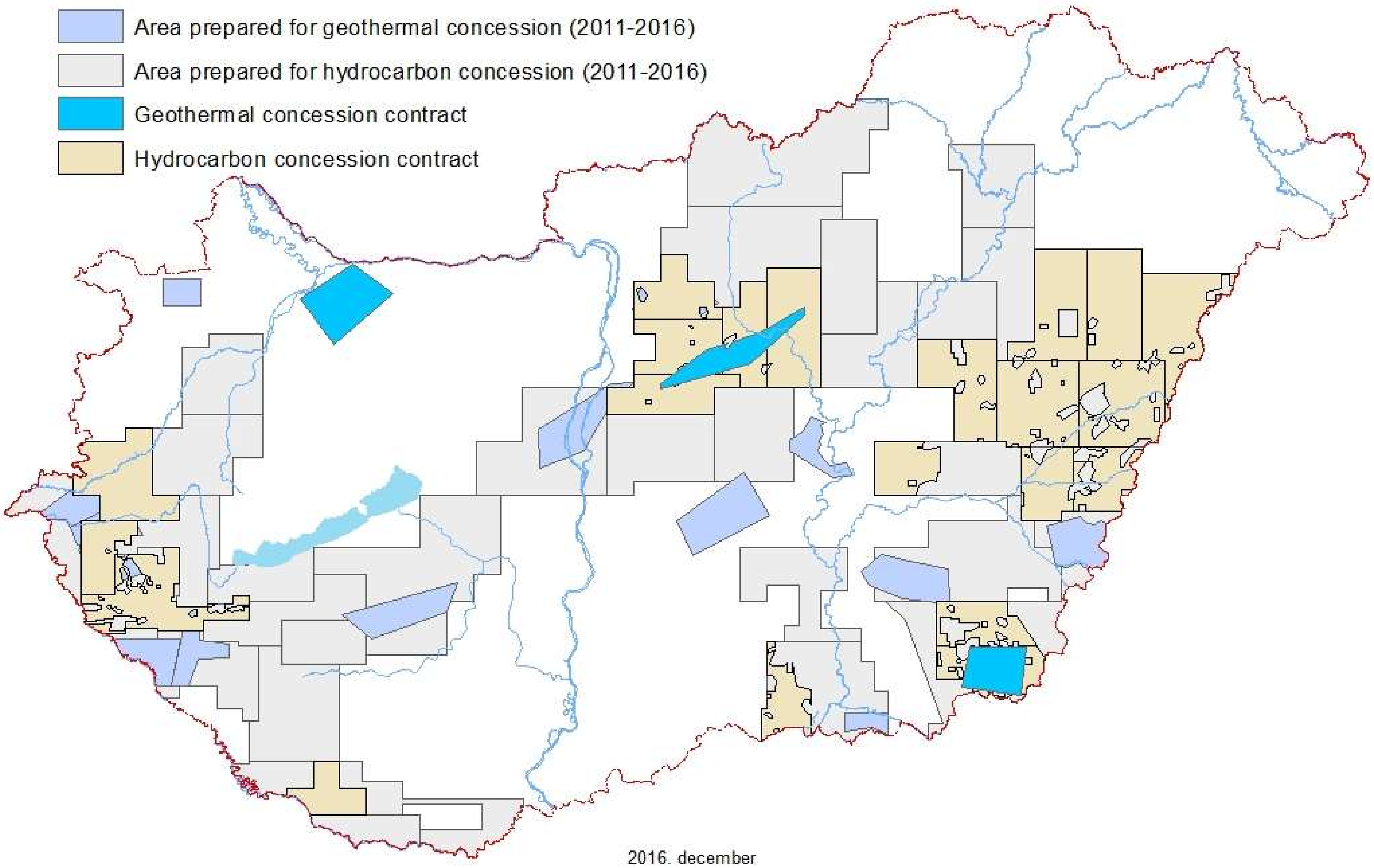
54 **potential concession areas were analyzed – 54 *Complex* vulnerability *and impact assessment studie*s were completed**
34 hydrocarbon, 17 geothermal, 2 coal, 1 ore.



Content of the Complex vulnerability and impact assessments study. Chapter 1

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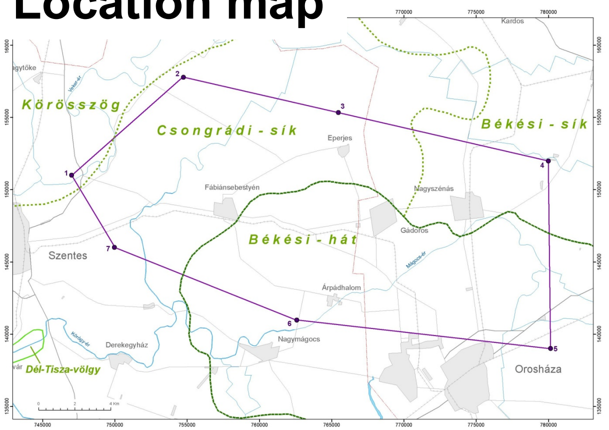
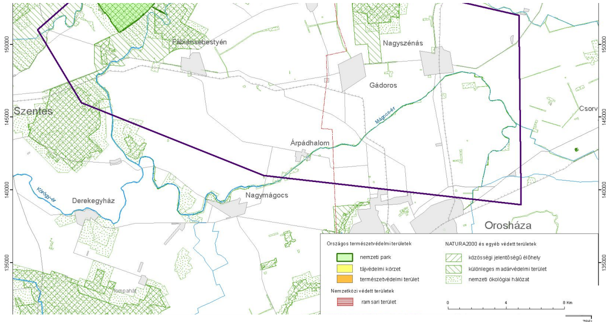
- **1. Description of the proposed concession area**
  - **1.1. Geographical description**
    - 1.1.1. Geographic and spatial location
    - 1.1.2. Soil and natural vegetation
    - 1.1.3. Land cover (land use) (Corine LC)
    - 1.1.4. Conservation (Nature protection)
  - **1.2. Geological, tectonic characterization, exploration level (geological and geophysical)**
    - 1.2.1. The geological and geophysical exploration level – available data in the Data store of MBFH, MFGI
    - 1.2.2. Tectonic characterization, large structures, structural developments, seismicity
    - 1.2.3. Formations of the Pre-Cenozoic basement
    - 1.2.4. Cenozoic formations
  - **1.3. Hydrogeology**
    - 1.3.1. Hydrogeological conditions of porous formations in the basin
    - 1.3.2. Reservoirs of the basement
    - 1.3.3. Natural recharge of the hydrogeological units
    - 1.3.4. Natural drainage of the hydrogeological units
    - 1.3.5. Groundwater quality
    - 1.3.6. Hydrodynamic systems, pressure condition
  - **1.4. River basin management**
    - 1.4.1. Surface waters, and surface and subsurface waterbodies
    - 1.4.2. Pressures and impacts on surface and subsurface waters
    - 1.4.3. Transboundary water bodies
    - 1.4.4. Monitoring System
    - 1.4.5. Quantitative and qualitative status evaluation
  - **1.5. Geothermal *utilization of thermal waters*, valid *exploration and mining licences* of raw materials and known mineral resources**
    - 1.5.1. Geothermal utilization of the thermal waters in the area
    - 1.5.2. Valid prospecting and mining rights of raw materials in the concession area
  - **1.6. Legislative *prohibitions and restrictions on mining* activity effecting the concession area and space**

Geography and geology

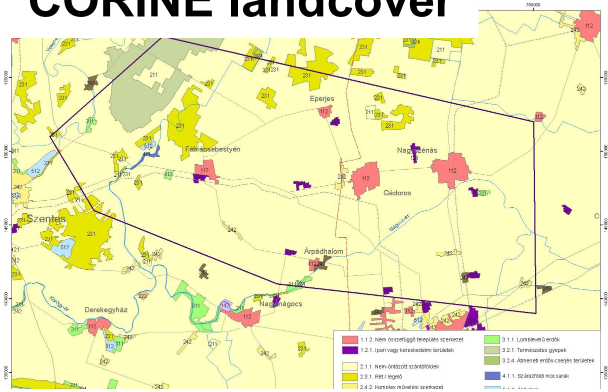
Location map



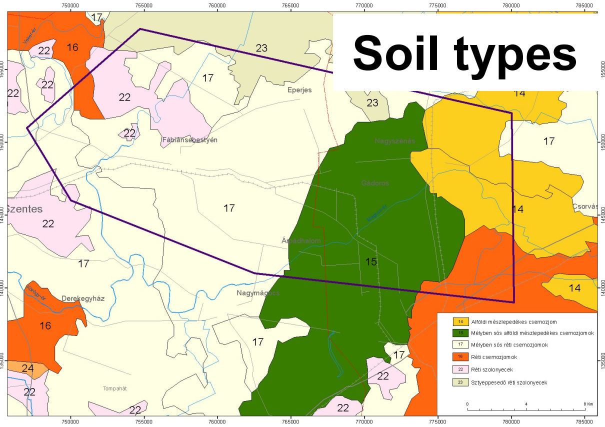
Protected areas National parks, Natura 2000 …



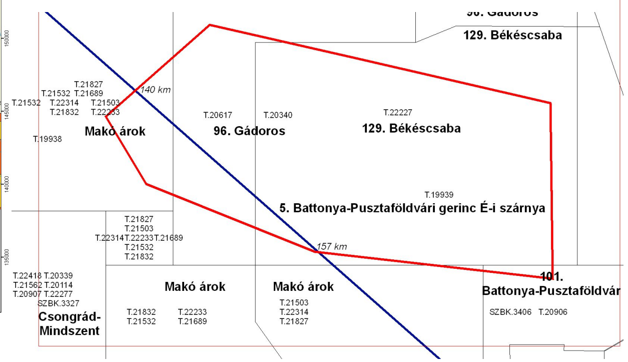
CORINE landcover



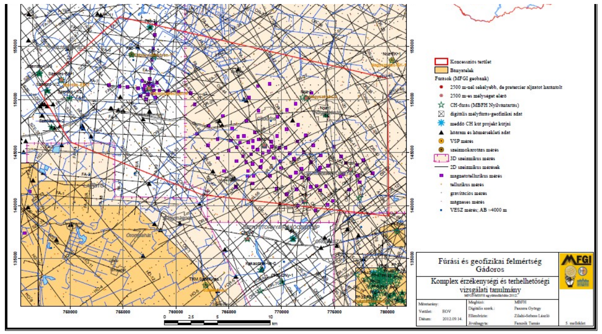
Soil types



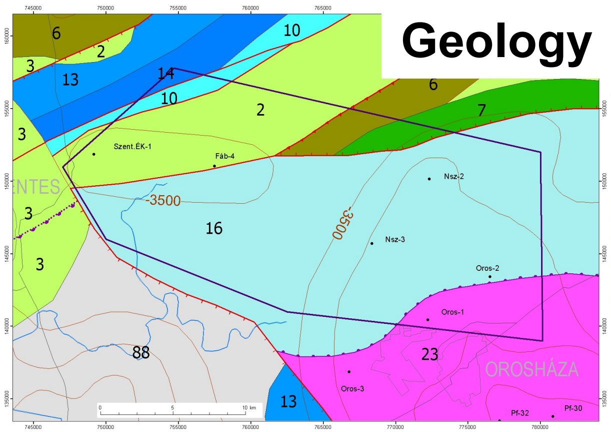
Former geological, HC reports



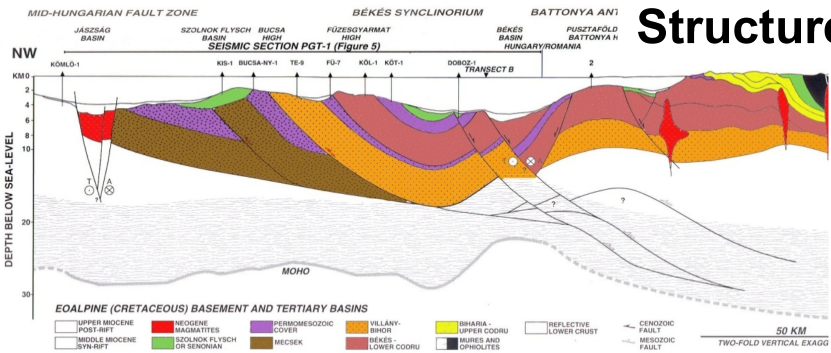
Available boreholes, surface geophysics, and well-loggings

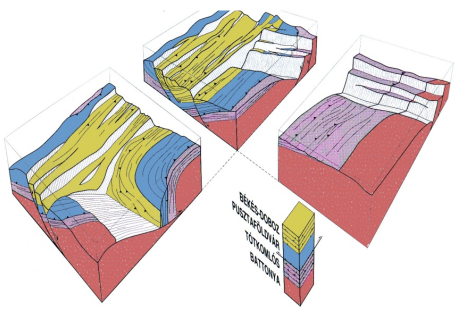


Geology



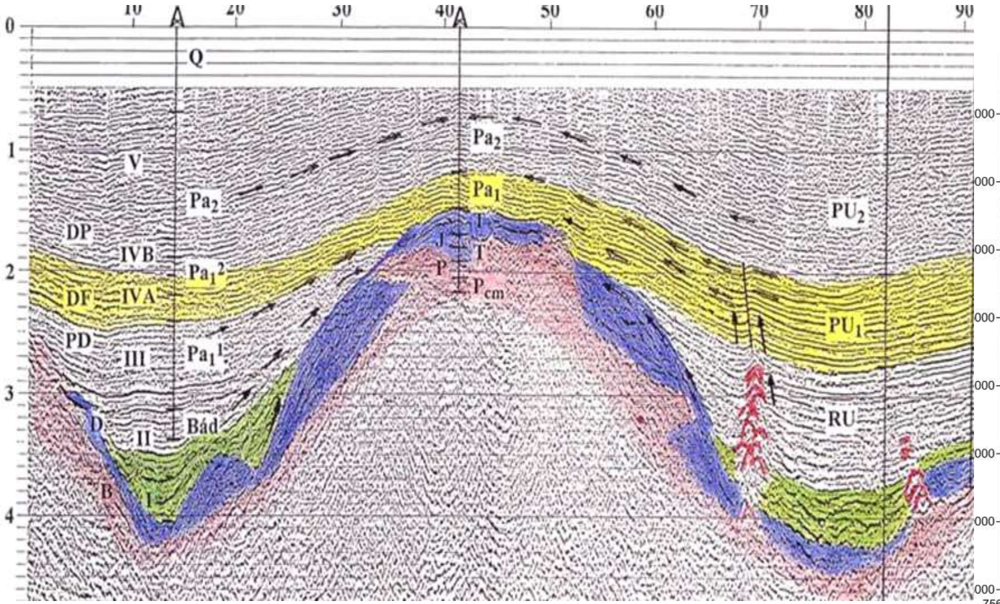
Structure, tectonics



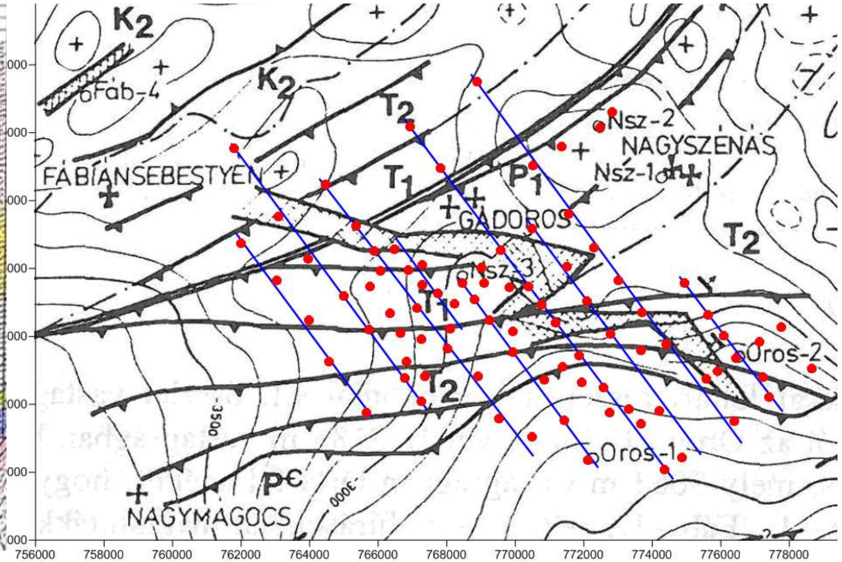


Geophysics for geology

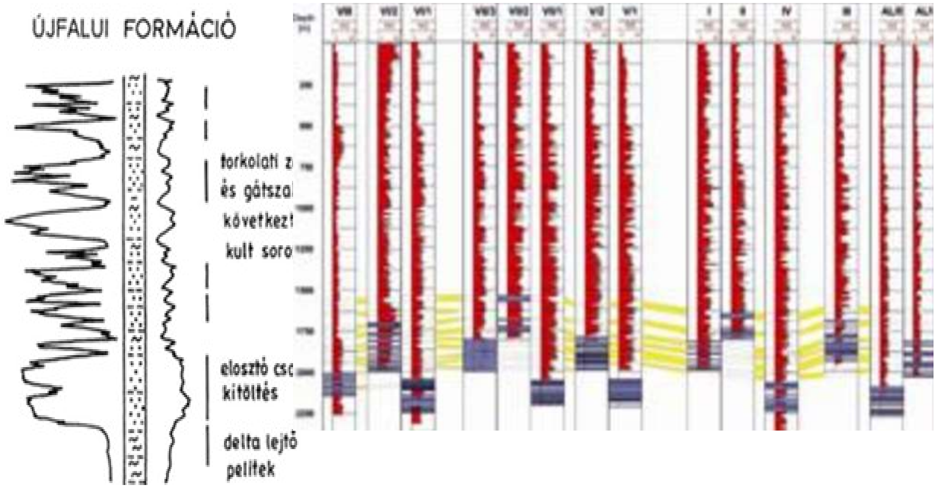
Seismics

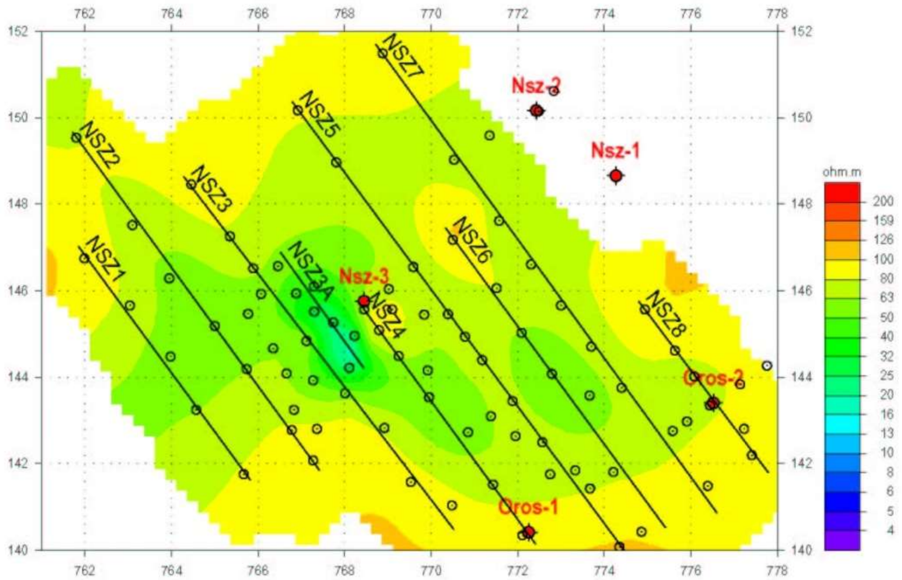


Magnetotellurics



Well-logging





Hydrogeology

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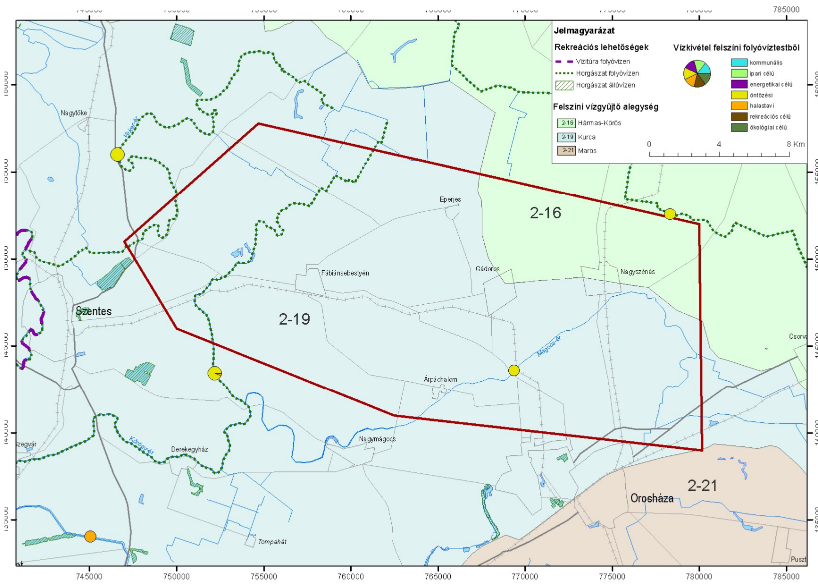
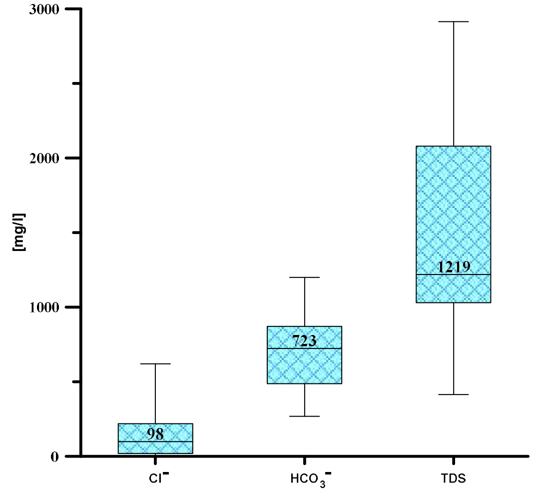
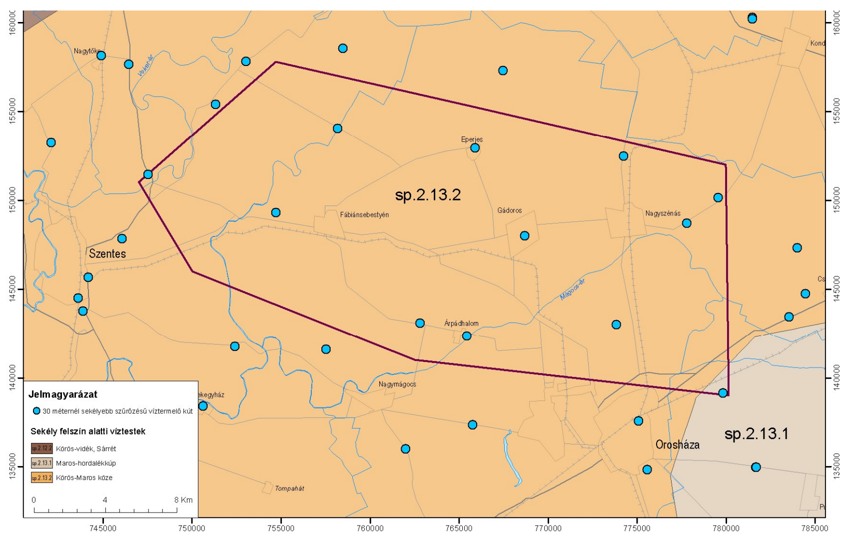
Surface water bodies



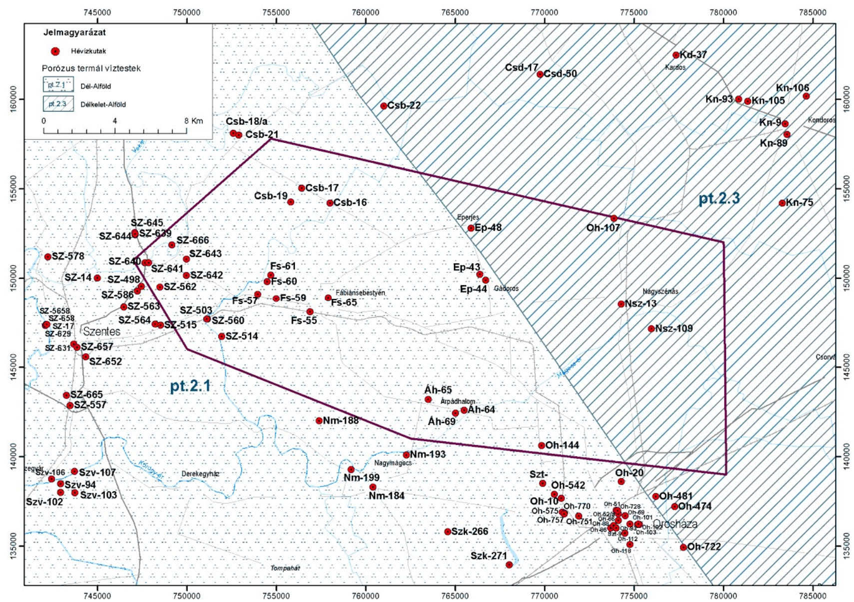


Water chemistry

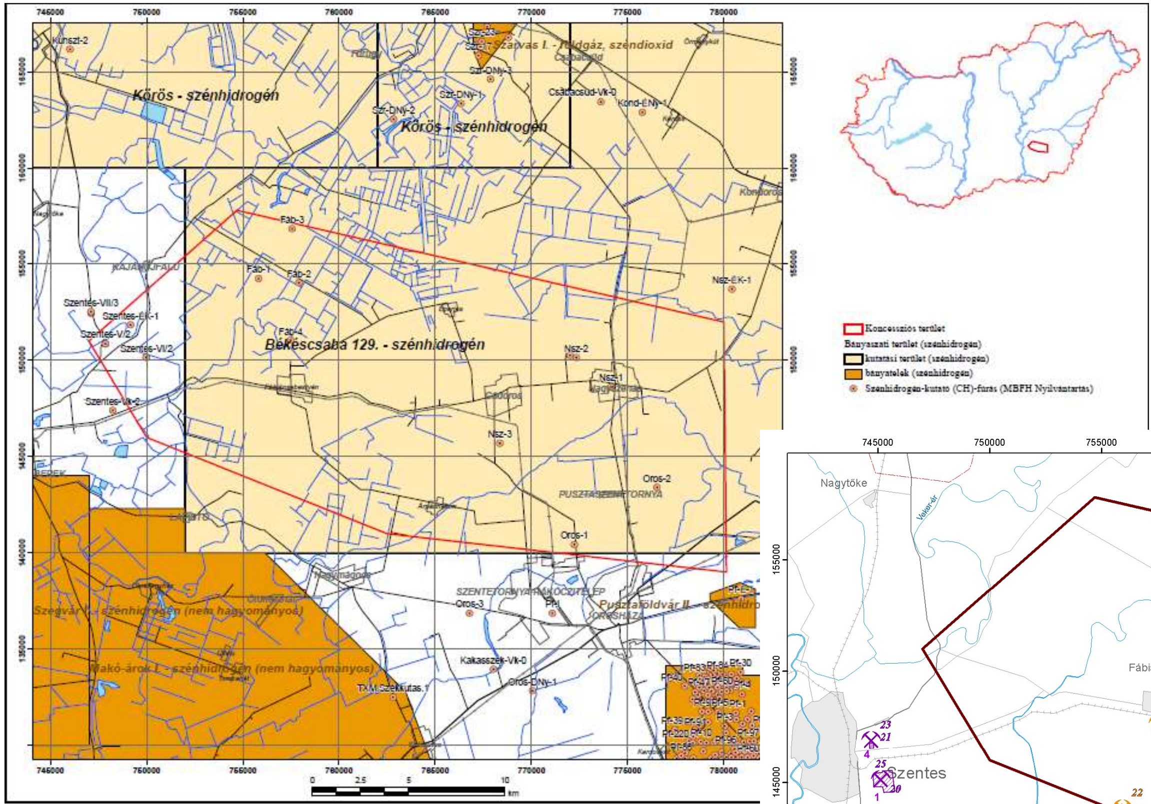
Shallow groundwater bodies, shallow wells



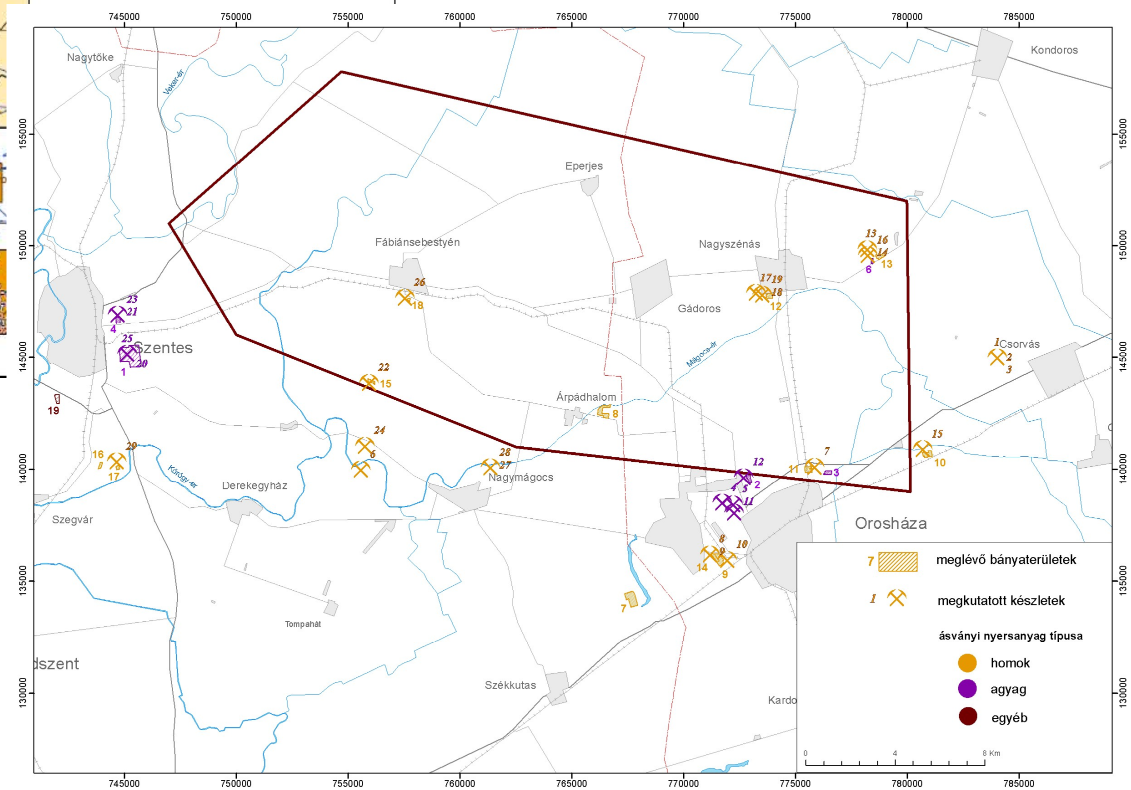
Thermal water bodies with thermal wells



Commodities, mineral resources



Hydrocarbon
Geothermal (under mining law)
Exploration licence areas
Mining licence areas



Metallic and Nonmetallic mineral resources

Content of Comlex vulnerability and impact assessments study. Chapter 2

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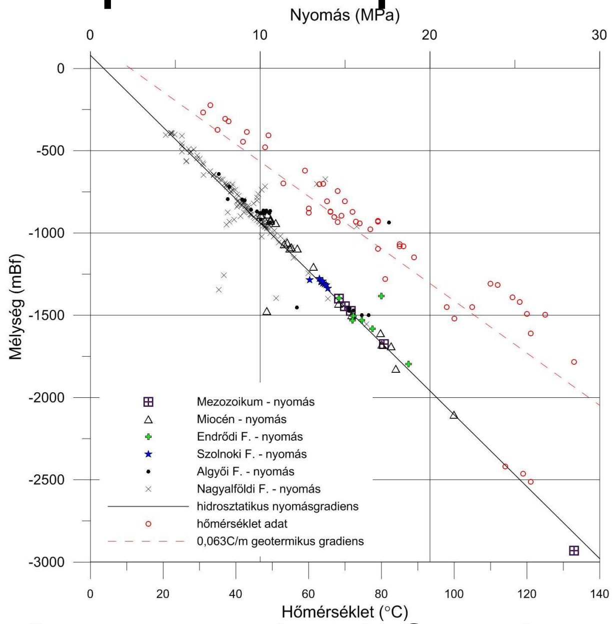
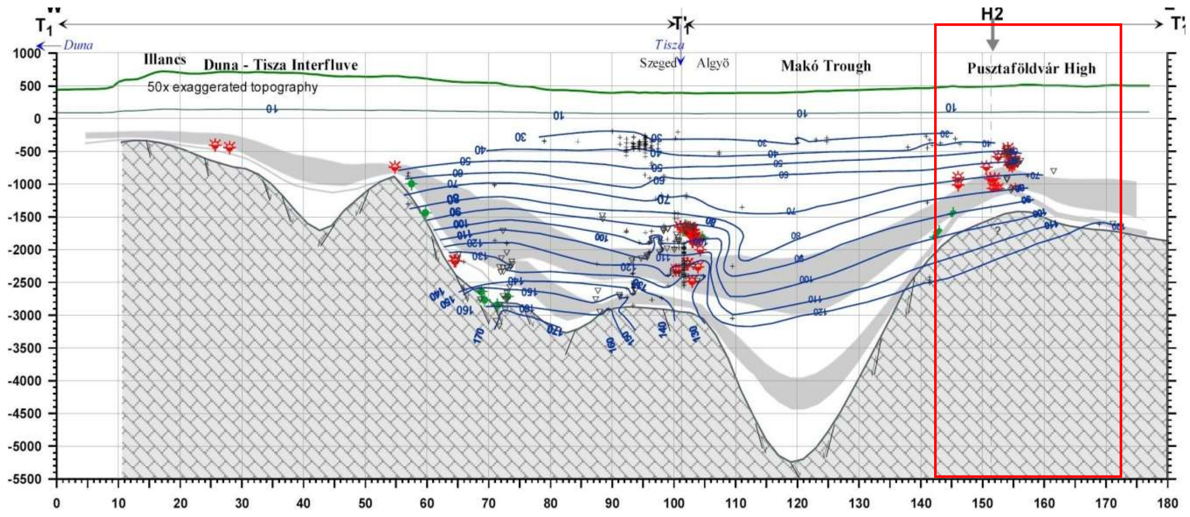
- **2. Study of the proposed mining concession activities**
  - **2.1. Data on geological characteristics, productivity and expected volume of raw material or geothermal energy subject of concessions**.
    - 2.1.1. Geothermal conditions of the area
    - 2.1.2. Expected volume of geothermal energy
  - **2.2. Presentation of the expected *exploration and production methods* and known mining technologies implemented during mining operations**
    - 2.2.1. Presentation of the expected research and exploration methods (technologies)
    - 2.2.2. Presentation of the expected production methods (technologies)
    - 2.2.3. Presentation of the expected known mining technologies implemented during mining operations
  - **2.3. General description - Possible related activities - transport, storage, waste management, energy supply, water supply**
  - **2.4. Infrastructure**
    - 2.4.1. Road and railway network
    - 2.4.2. Energy Network
  - **2.5. Presentation of *mineral resource management* and energy supply objectives implemented in the course of mining operations**
  - **2.6. Presentation of the mining activities in mineral resource management perspective, as well as the expected *national economic and social benefits***
  - **2.7. Expected *duration of the load***
  - **2.8. The most important expected *mining risks*.**

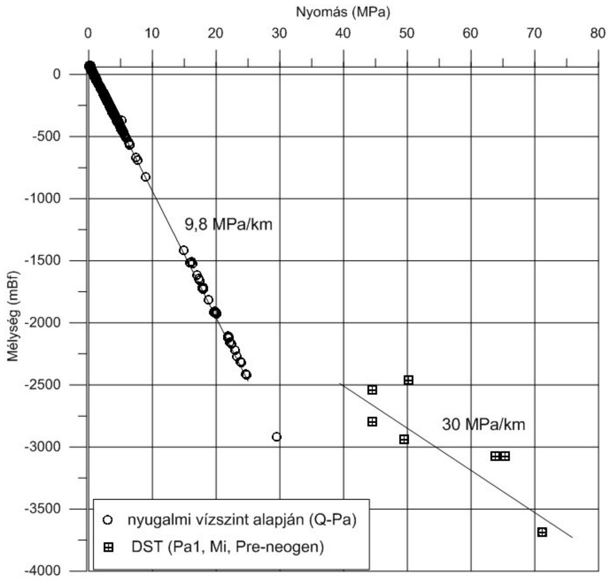
Geothermal conditions

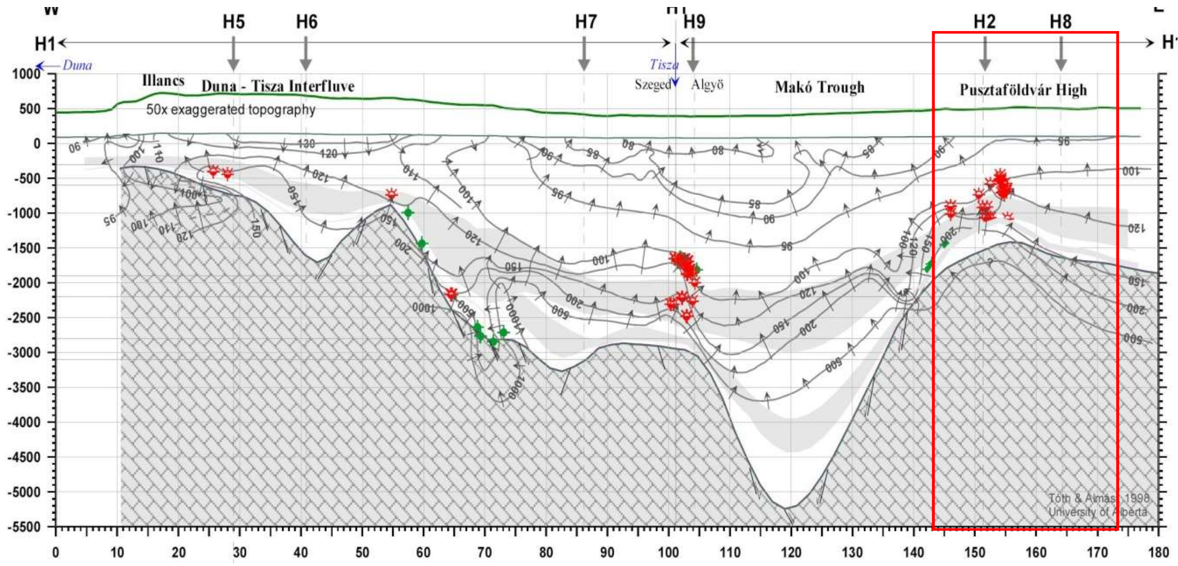
Temperature–depth functions T(z), sections, maps





Pressure–depth functions P(z), sections, maps





Geothermal conditions

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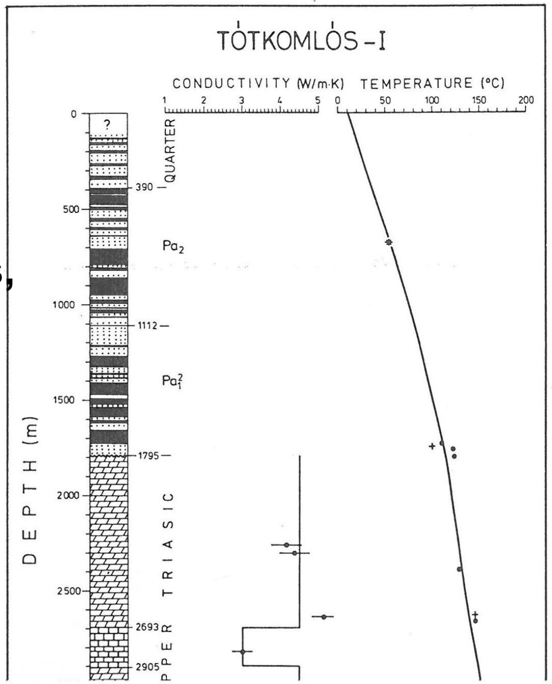
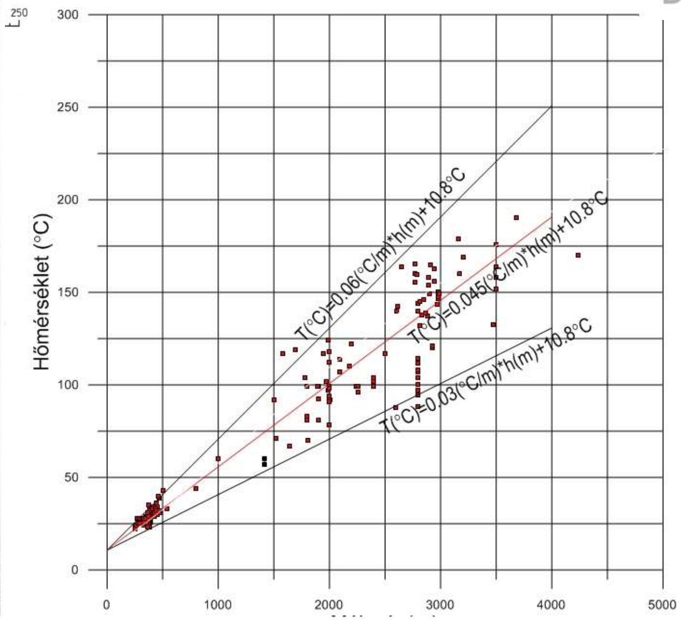
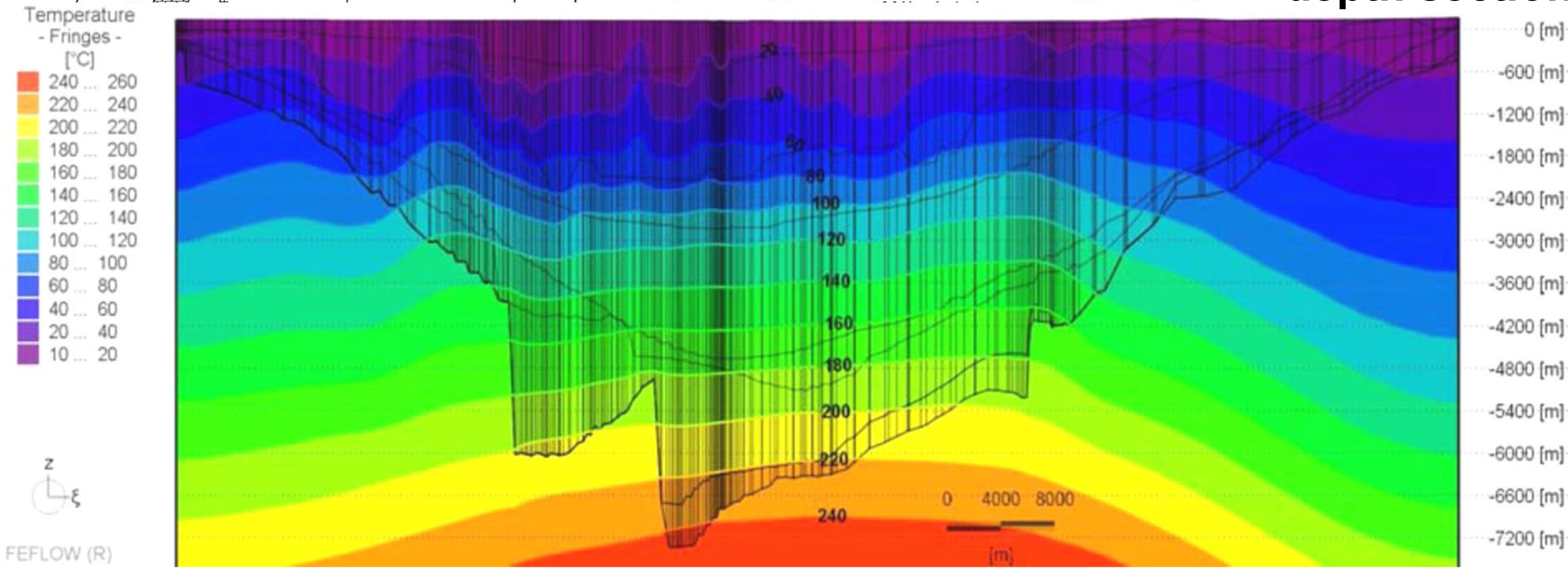
Heat-flux heat capacity from boreholes, samples



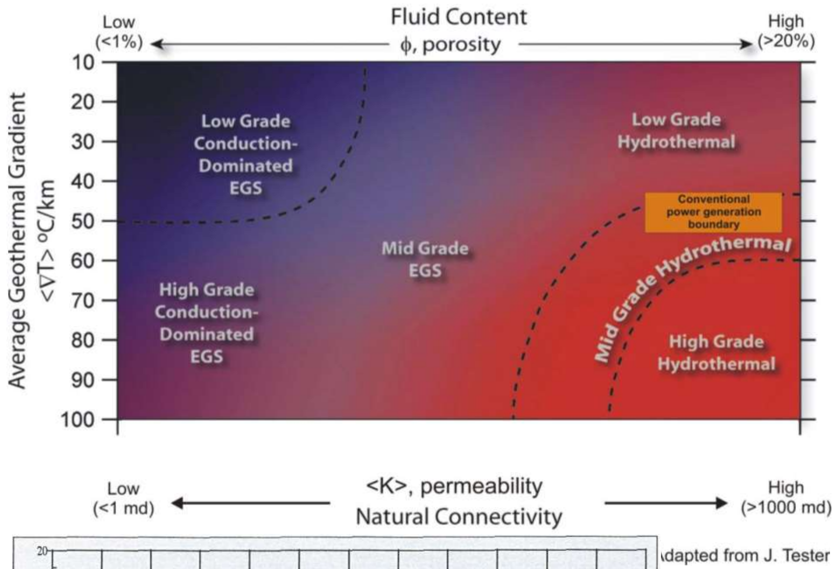


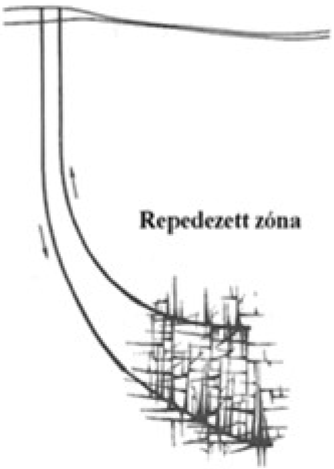
Temperature – depth function from the boreholes of the area

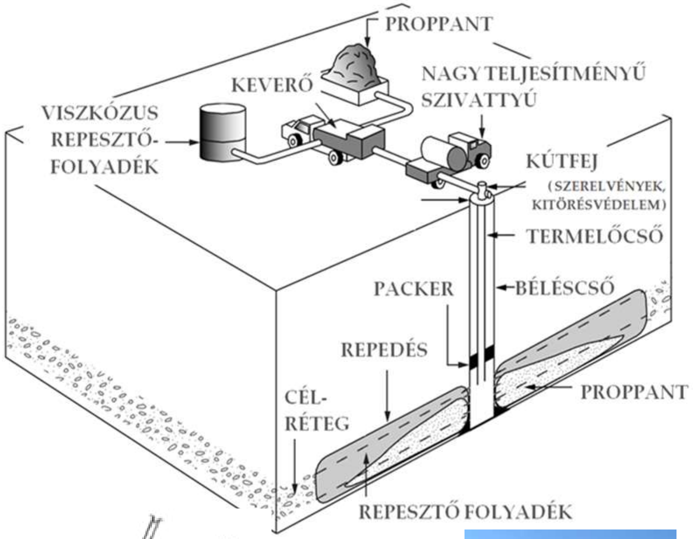
Temperature – depth section

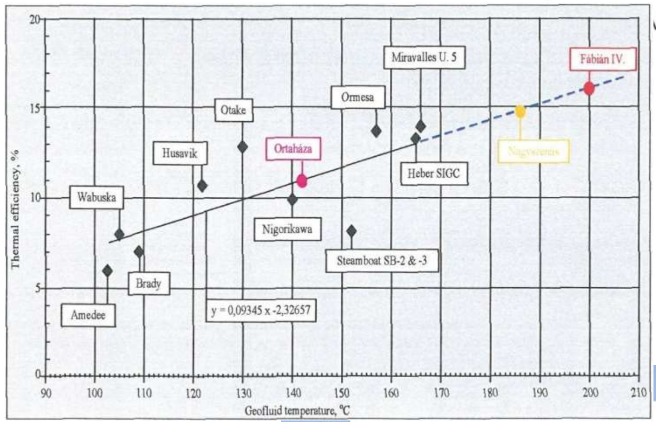


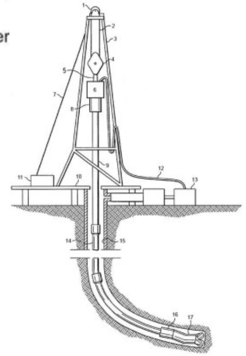
Research, exploration, production methods

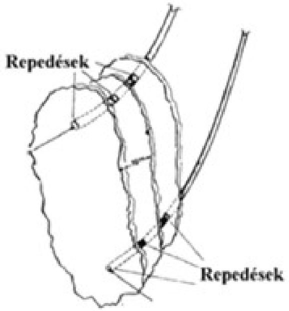


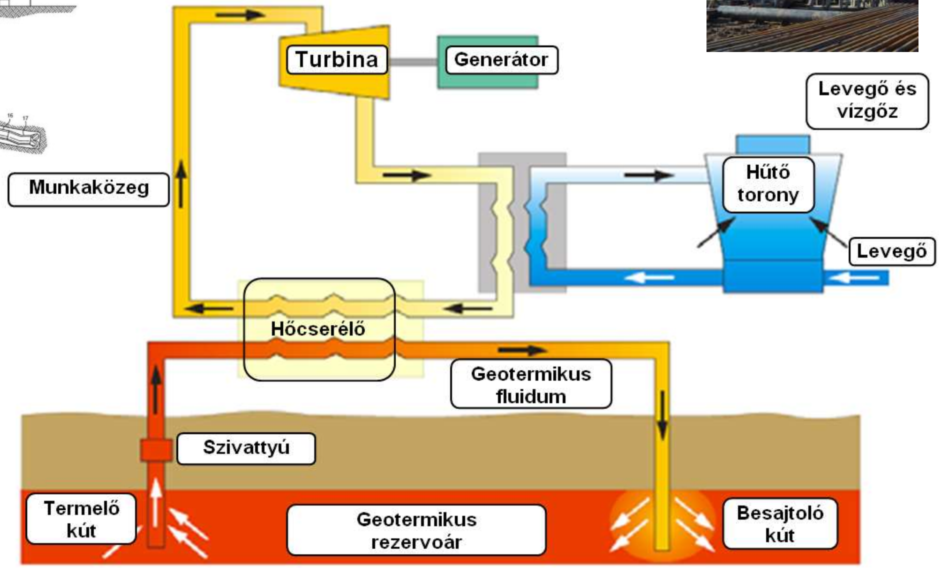


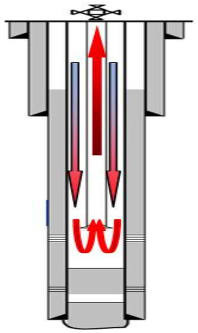


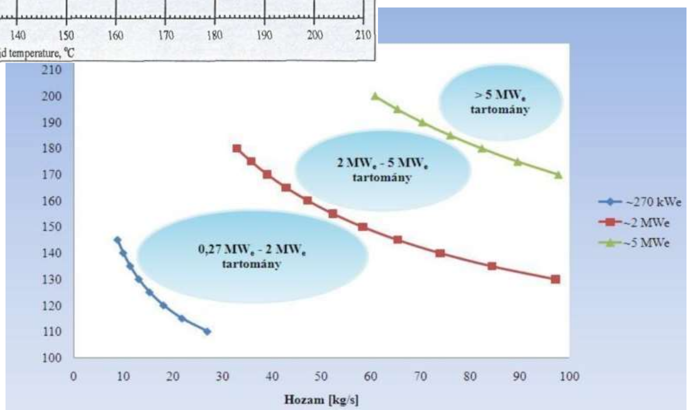






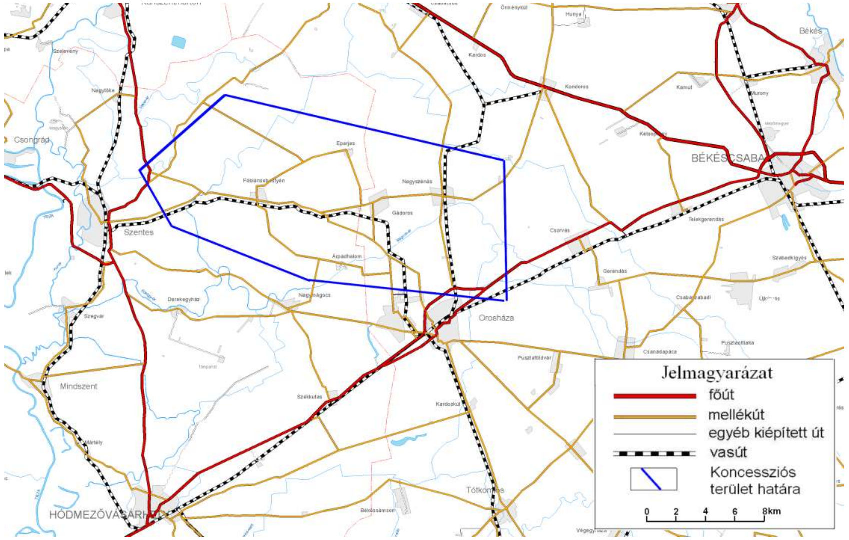


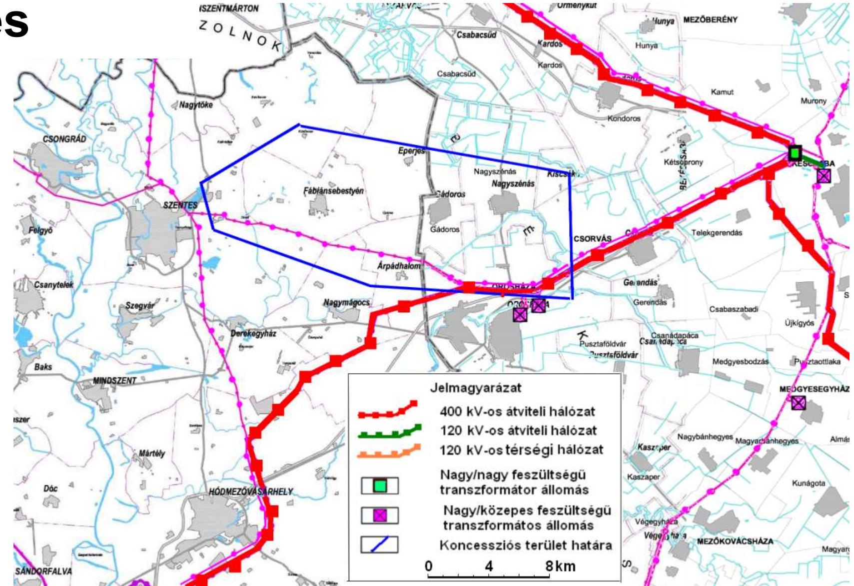


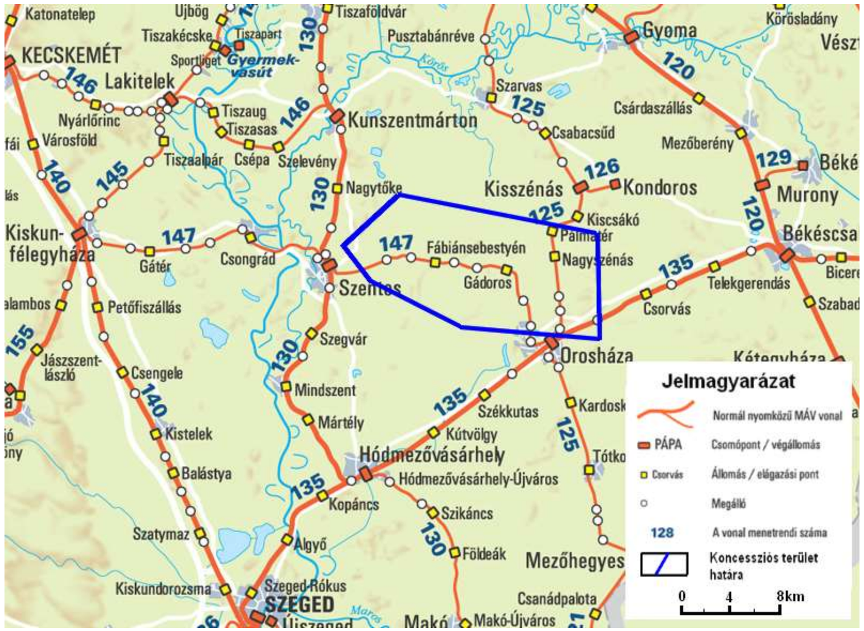


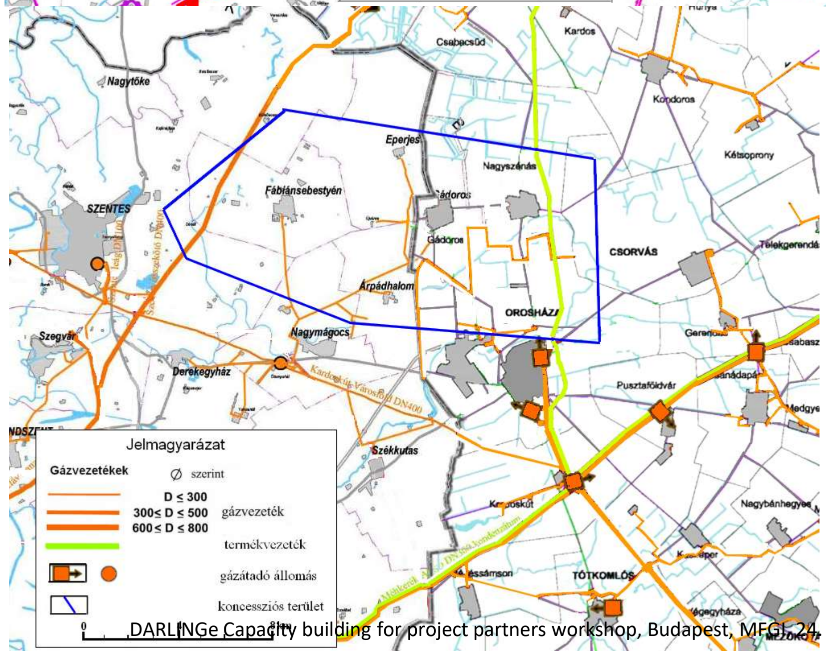
Infrastructure

Transport and transfer:
Roads, railways, pipelines, electric lines









Content of the Vulnerability and loading capability assessments study. 3. chapter

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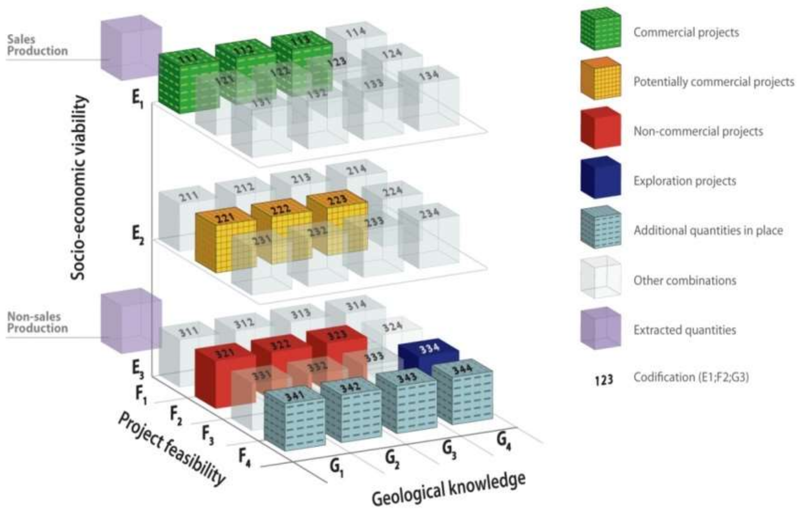
- **3. Effects, consequences and forecast analysis**
  - **3.1. Outline of those elements of the area and space, that may significantly be influenced by the planned activity**
    - 3.1.1. Porosity conditions of the penetrated layers
    - 3.1.2. Pollution-sensitivity of the penetrated layers
    - 3.1.3. Impact bearing surface environmental elements
    - 3.1.4. Environmental stresses caused by mining activity
    - 3.1.5. Air Quality Protection
    - 3.1.6. Noise and vibrations
    - 3.1.7. Impacts on groundwater
    - 3.1.8. Impacts on surface water
    - 3.1.9. Conservation (Nature protection)
    - 3.1.10. Landscape Conservation
    - 3.1.11. Land and soil protection
    - 3.1.12. Forestry and wildlife protection
    - 3.1.13. Health protection
    - 3.1.14. The built environment and cultural heritage
  - **3.2. Evaluation of the impacts of mining operations on surface and groundwater bodies, drinking water, and protected Natura 2000 sites, listing the expected changes and their regional and transboundary effects**.
    - 3.2.1. Impacts in the geothermal reservoirs
    - 3.2.2. Interaction between the geothermal reservoirs and surface
    - 3.2.3. Impacts on the surface
    - 3.2.4. Transboundary impacts
    - 3.2.5. Summary evaluation of the various impact
  - **3.3. List of *restricted or prohibited mining technologies* on the area due to its environmental impacts**

THE UNFC-2009 classification scheme as a possible tool for complex project characterisation and ranking

The UNFC-2009 scheme



Generic, principles-based system *(now applied for solid minerals, fossil energy, injection projects and geothermal)*

Classifies a certain project in a numerical and language independent coding scheme.

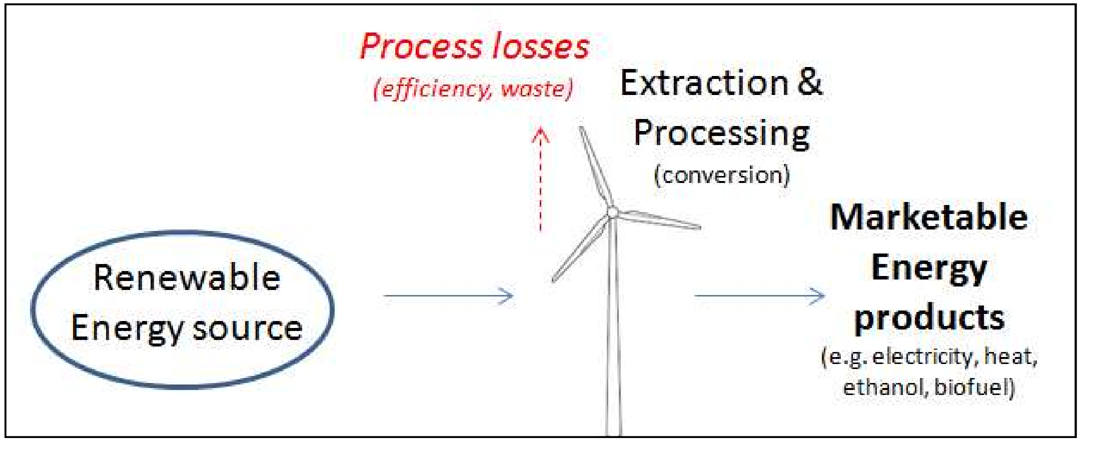
E-axis: 'Economic and social viability' *(degree of favourability of social and economic conditions in establishing commercial viability of project , e.g. market prices, relevant legal, regulatory, environmental and contractual conditions)*

F-axis: 'Field project status and feasibility' *(maturity of studies and commitments necessary to implement project)*

G-axis: ' Geological knowledge' *(level of confidence in the geological knowledge and potential recoverability of the quantities)*

The classification process

1) **defining a project**, **link between a geothermal energy source (*equivalent to the terms ‘deposit’ or ‘accumulation’ used for solid minerals and fossil fuels*) and the product *(heat, electricity)***



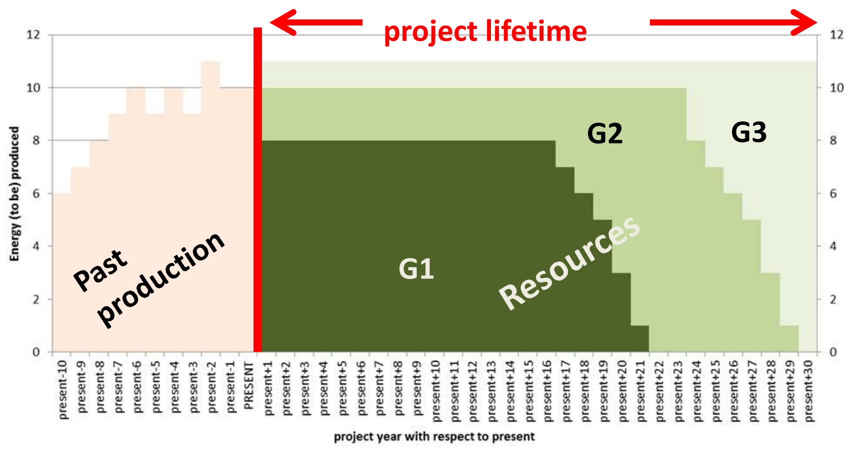
„Project” can be:

- **Expansion of an existing project**
- **Greenfield development**
- **Project in pre-drilling exploration phase**
- **Regional evaluation of a geothermal play**

The classification process

2) estimating the quantities of energy that can be recovered and delivered as 'products' by the given project *from the effective date of the evaluation forward* (till the end of the project lifetime/limit), measured or evaluated at the *reference point* (a defined location in the production chain).

Estimation method / quantification (e.g. production forecast, probabilistic resource estimation) is NOT PART of the classification exercise! – no standard method uniformly accepted



3) classifying the quantified geothermal energy resource based on the criteria defined by the E, F and G (sub)categories

E-categories

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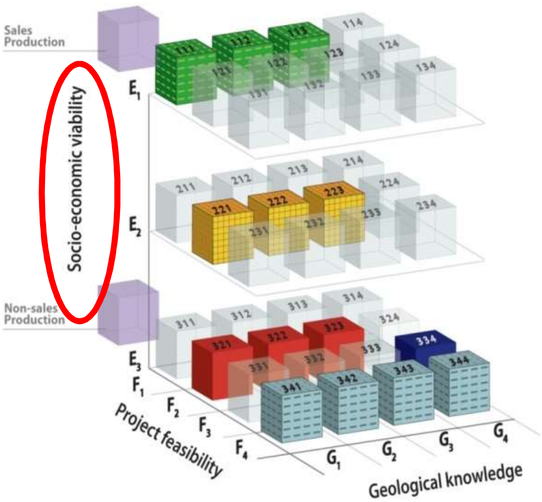
degree of favourability of social and economic conditions in establishing commercial viability of project (market prices, relevant legal, regulatory, environmental and contractual conditions, etc.)



- **E1: Extraction and sale economically viable**
- **E2: Extraction and sale economically viable in the foreseebale future (5 yrs)**
- **E3: Extraction and sale not expected to be economically viable in the foreseebale future, or too early stage for evaluation**

F-categories

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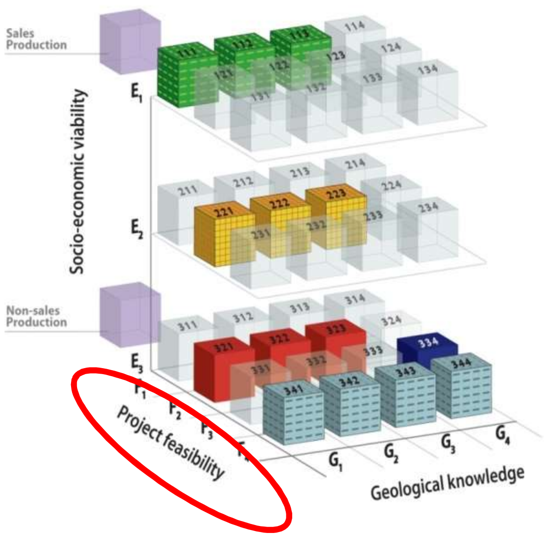
project status and feasibility / technology (maturity of studies and commitments necessary to implement project)



F1: feasibility of extraction confirmed (ongoing production)

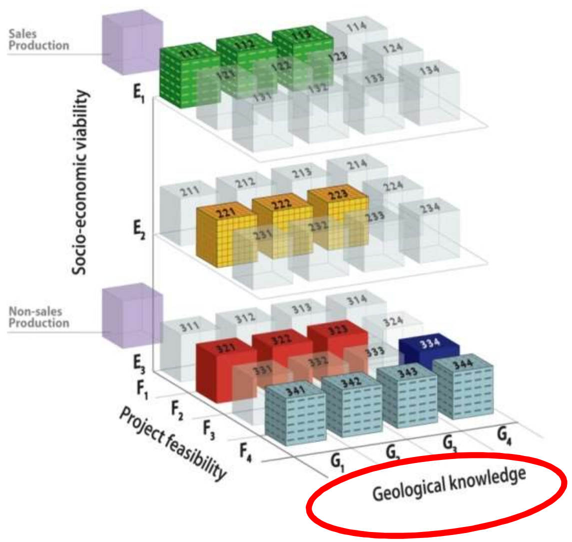
F2: preliminary studies exist, but feasibility of extraction subject to further evaluation (e.g. first well drilled)

F3: exploration phase, limited technical data (e.g. pre-drilling exploration)

F4: no project development identfied (in-situ quantities)

G-categories

geological knowledge (level of confidence in the geological knowledge and potential recoverability of the quantities)



G1: Quantities associated with a high level of confidenece (low estimate – P90)

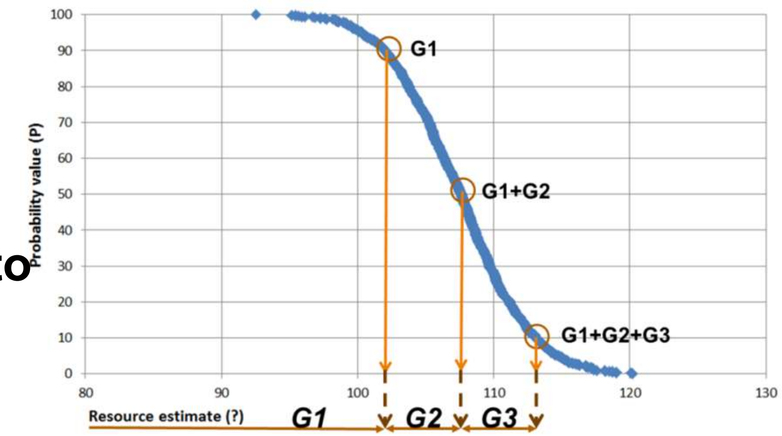
G2: Quantities associated with a moderate level of confidenece (best estimate – P50)

G3: Quantities associated with a low level of confidenece (high estimate – P10)

G4: Potential based on indirect evidence

MC: repeated calculations with stohastically changing parameters (e.g. reservoir volume, temperature, etc.)

Confidental data can be incorporated into a probability distribution!



Example: Hódmezővásárhely geo-DH

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- HU’s oldest geo-DH system
- operating since 1954,
- 8 production, 2 re-injection wells
- Upper Miocene porous reservoir
- partial reinjection
- 2725 flats, 130 public consumers
- municipality owned company

Estimating the quantities: MC-based estimation of recoverable heat (volumetric method)

	Input parameters					Calculated parameters			
	A	B	C	D	E	F	G	H	I
	Reservoir area (km^2)	Reservoir thickness (km)	Porosity (V/V)	Reservoir temperature (˚C)	Recovery factor	**Total volume (km^3)**	**Pore volume (km^3)**	**Porosity heat content (PJ)**	**Recove-rable heat (PJ)**
Calculation formula						A*B	C*F	4.187*G*(D-30)	**(H*E)**
Hódmezővásárhely									
Min	12,5	0.080	0.06	58	0.1				
Max	15,5	0.150	0.18	108	0.2				
"p90"	*12.8*	*0.087*	*0.07*	*63*	*0.11*	1.21	0.109	20.5	**2.88**
"p50"	*14*	*0.115*	*0.12*	*83*	*0.15*	1.6	0.185	38.7	**5.69**
"p10"	*15.2*	*0.143*	*0.17*	*103*	*0.19*	2.01	0.29	70.5	**10.85**

Classification of the Hódmezővásárhely project

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Category	UNFC-2009 Definition	Reasoning for classification
E.1.	Extraction and sale is economic on the basis of current market conditions and realistic assumptions of future market conditions	• existing heat market • all production licenses available and guaranteed within reasonable timeframe • very positive and quantified effects on the reduction of gas consumption and decreased CO_2 emission, as well as reduced heating costs
F.1.	Extraction is currently taking place.	• project has been operating for 25 yrs • technically feasible use (district heating, communal hot water supply, individual space heating) with good thermal efficiency
G.1.	Quantities associated with a known deposit that can be estimated with a high level of confidence *(High confidence / low estimate)*	A volumetric Monte Carlo assessment has indicated a 90% probability of 2,88 PJ of recoverable geothermal energy
G.2.	Quantities associated with a known deposit that can be estimated with a moderate level of confidence *(Moderate confidence / best estimate, incremental to G1)*	A volumetric Monte Carlo assessment has indicated a 50% probability of 5,69 PJ of recoverable geothermal energy. Therefore G2 is 5,69-2,88= 2,81 PJ,
G.3.	Quantities associated with a known deposit that can be estimated with a low level of confidence *(Low confidence / high estimate, incremental to G2)*	A volumetric Monte Carlo assessment has indicated a 10% probability of 10,85 PJ. Therefore G3 is 10,85-2,81= 8,04 PJ,

2.88 PJ (E1, F1, G1) 2,81 PJ (E1, F1, G2) 8,04 PJ (E1, F1, G3)

Full granularity

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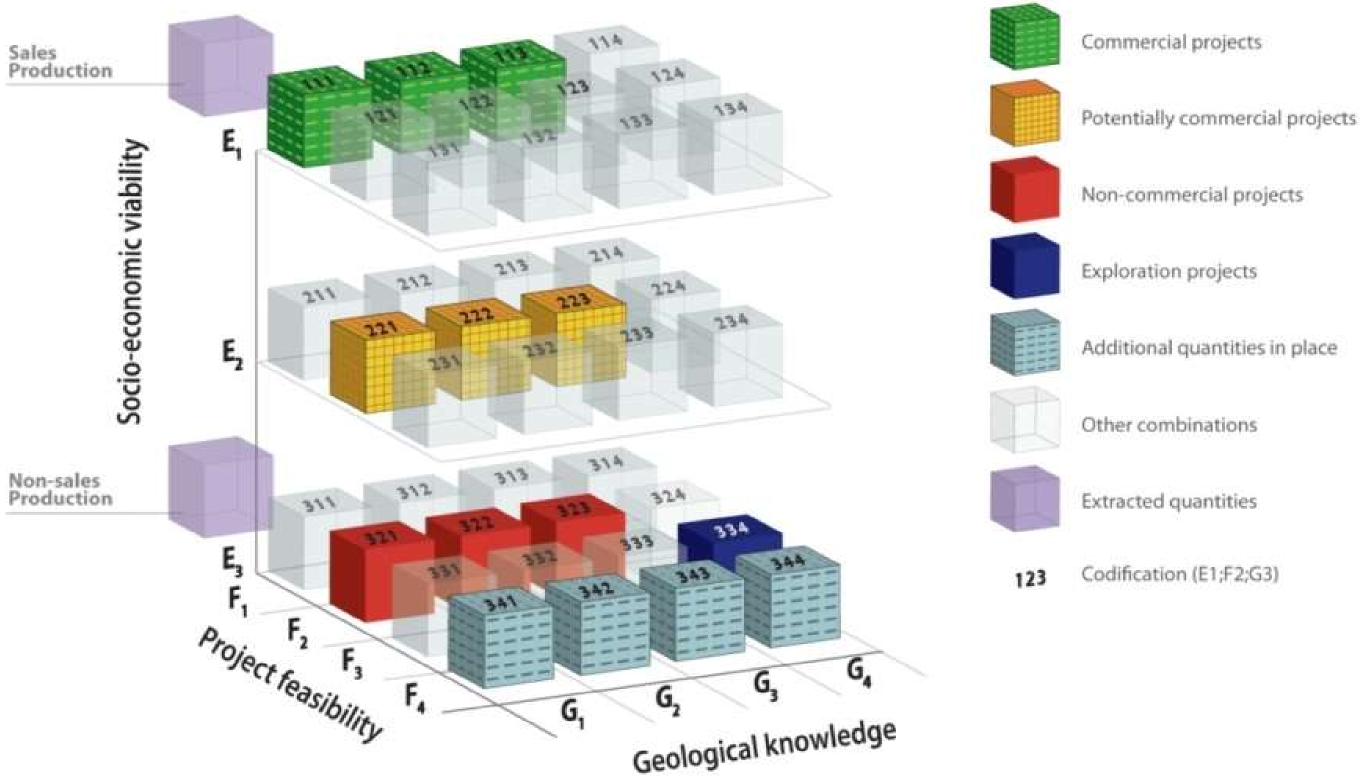

IGA webpage on the UNFC Geothermal Specifications

https://www.geothermal-energy.org/resources_and_reserves/working_groups/unfc_2009_working_group.html

Part IV – Geo-techno-economic and environmental aspects of geothermal direct use projects

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Economic considerations of geothermal projects

TAIEX Expert Missn on Geothermal Heating and Cooling,
July 24-26, 2017, Amman, Jordan

Cost characteristics of geothermal projects

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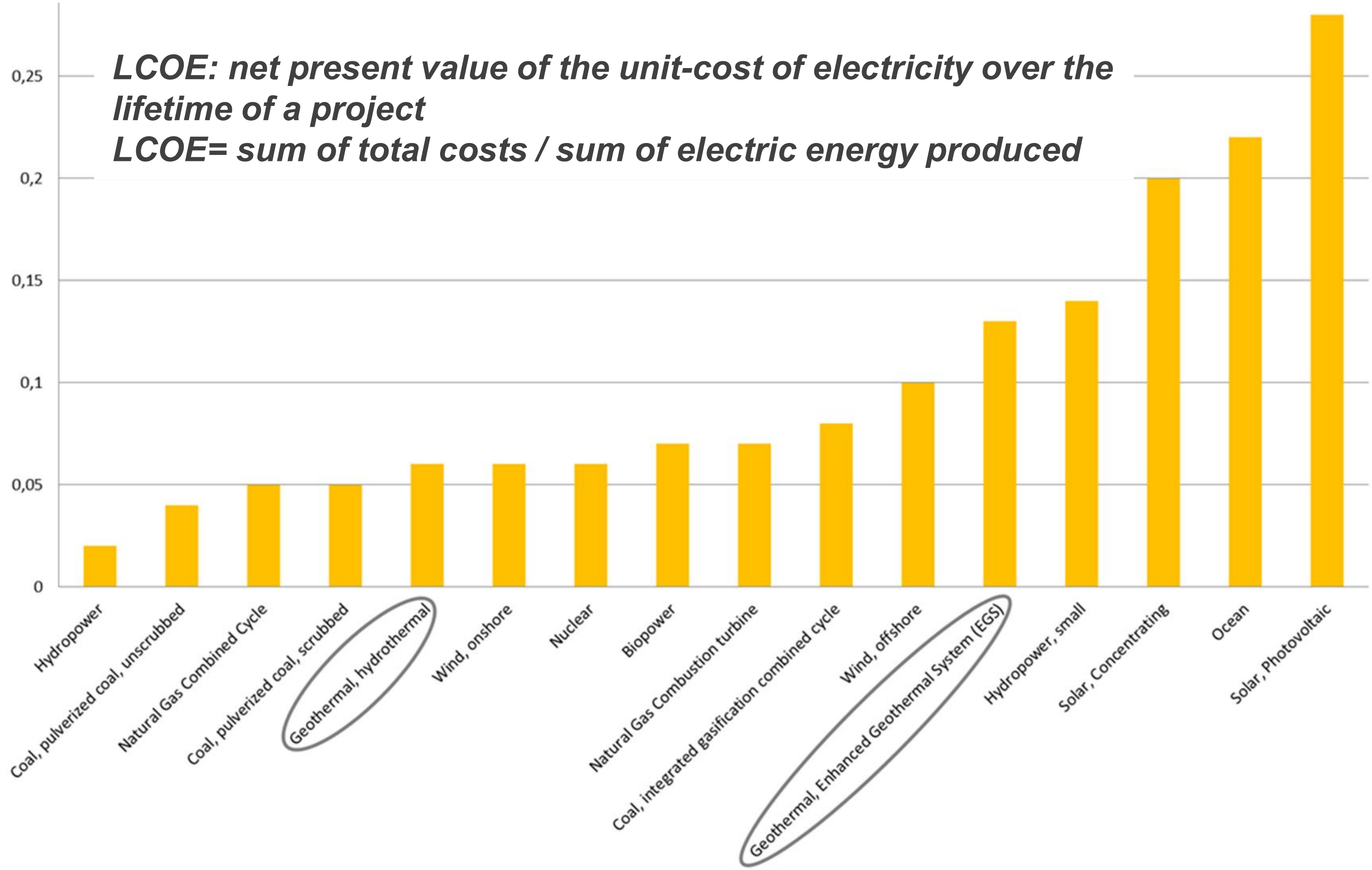
Levelized cost of energy (LCOE) of different technologies ($ / kWh)

LCOE: net present value of the unit-cost of electricity over the lifetime of a project
LCOE= sum of total costs / sum of electric energy produced



Source: http://en.openei.org/apps/TCDB/

Cost characteristics of geothermal projects

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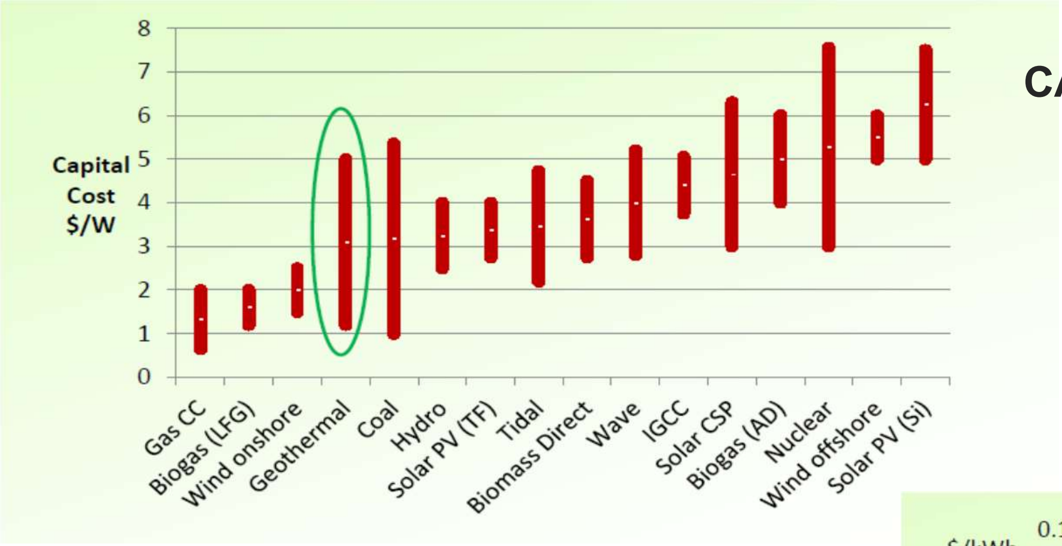
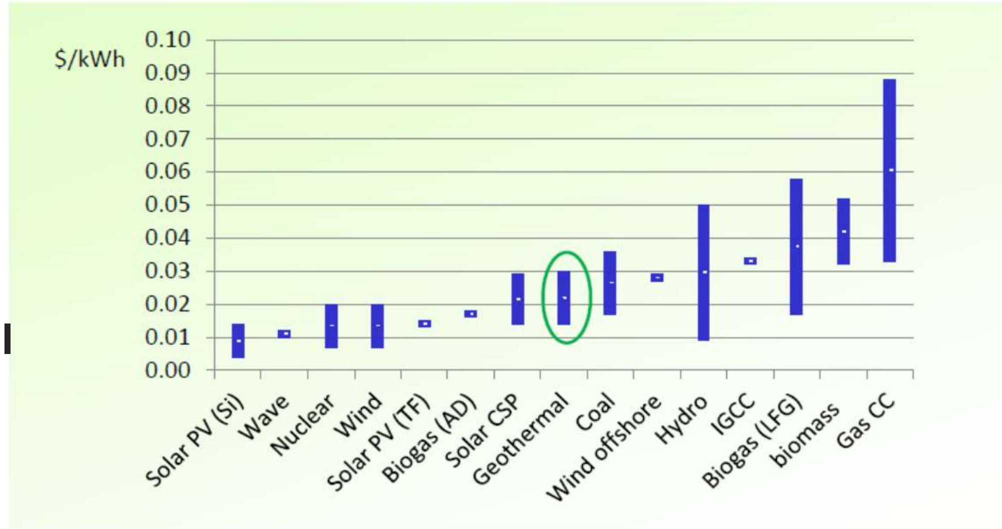
Long Project Lifecycle – Patient investment

High CAPEX (upfront investment – 55-65% of total costs), low OPEX



CAPEX of geothermal

OPEX of geothermal



Source: Clean Energy Trends, 2010

Cost characteristics of geothermal projects

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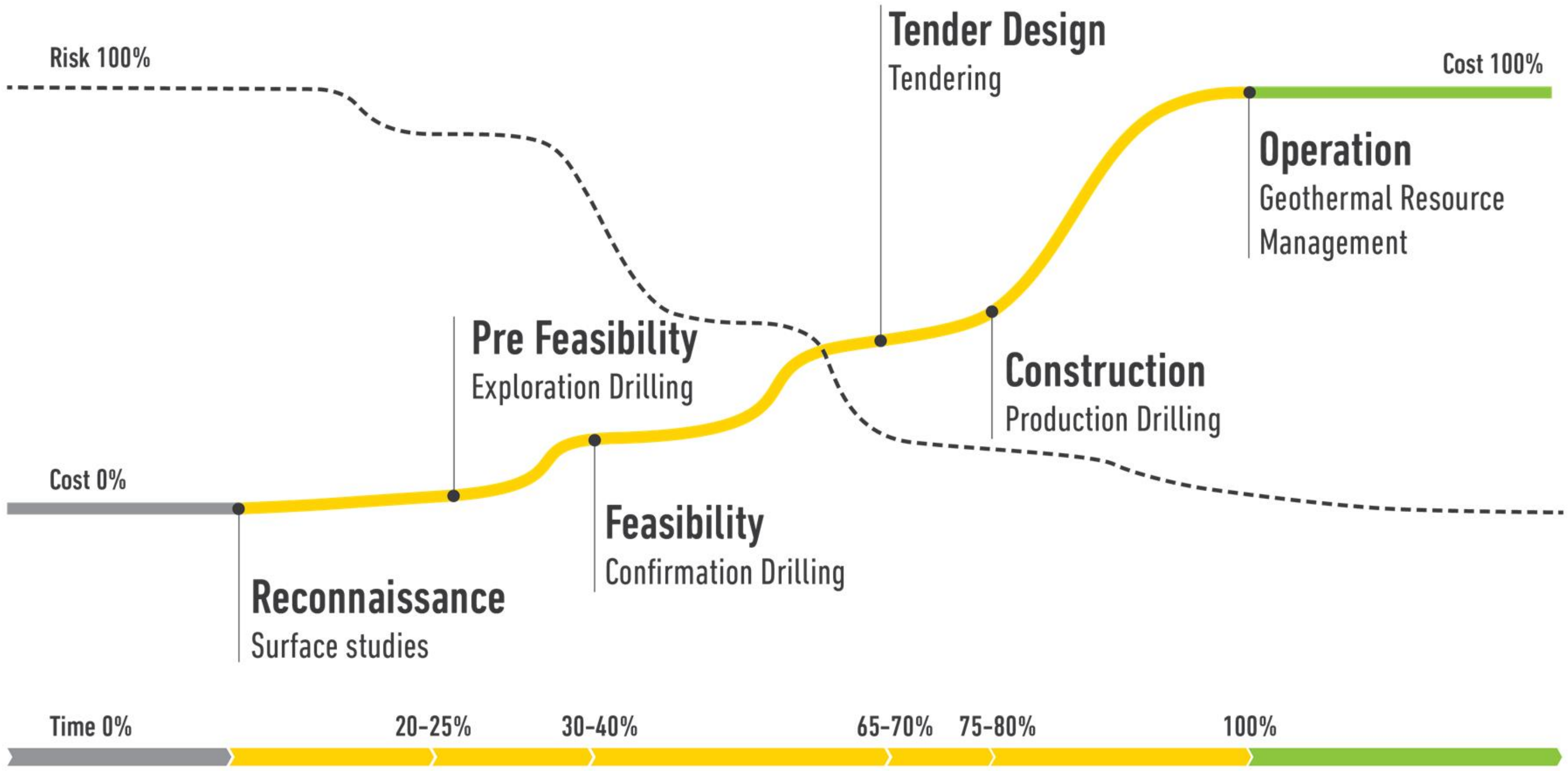
Cost Category	Approximate percentage of CAPEX
Preparation & drilling	54%
Turbine-generator & auxiliary systems	13%
Steam supply system	10%
Design & supervision	11%
Buildings & ancillary systems	7%
Roads & camps	3%
Electrical, control & protection systems	2%

Source: Geoelec project

** Example from a 5MW low enthalpy binary Power Plant in Central-Europe*

Geothermal Cost / Risk Development

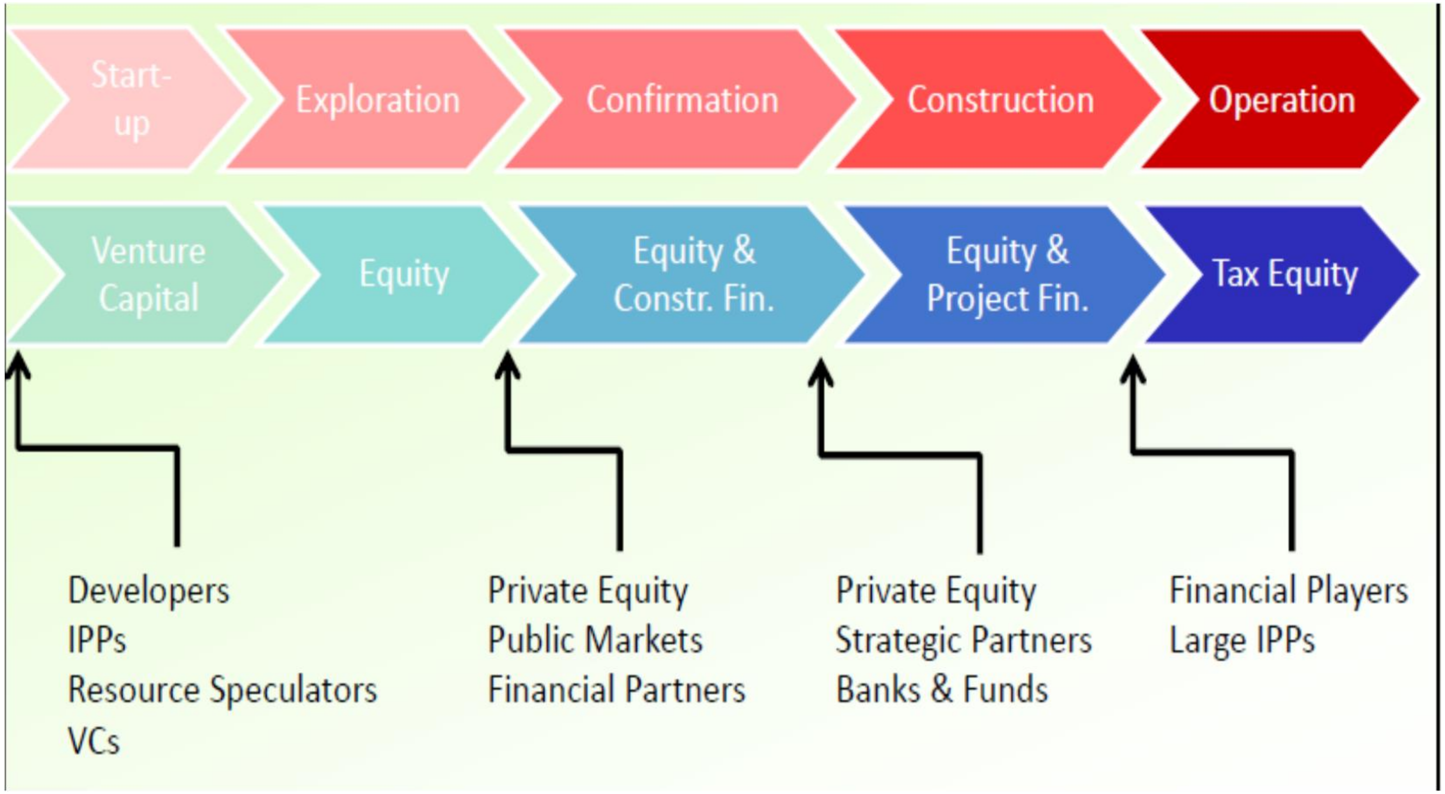


Source: Geoelec project

Project risk decreases with increased investment as the project is developed further with research and results from the first well drilling and testing

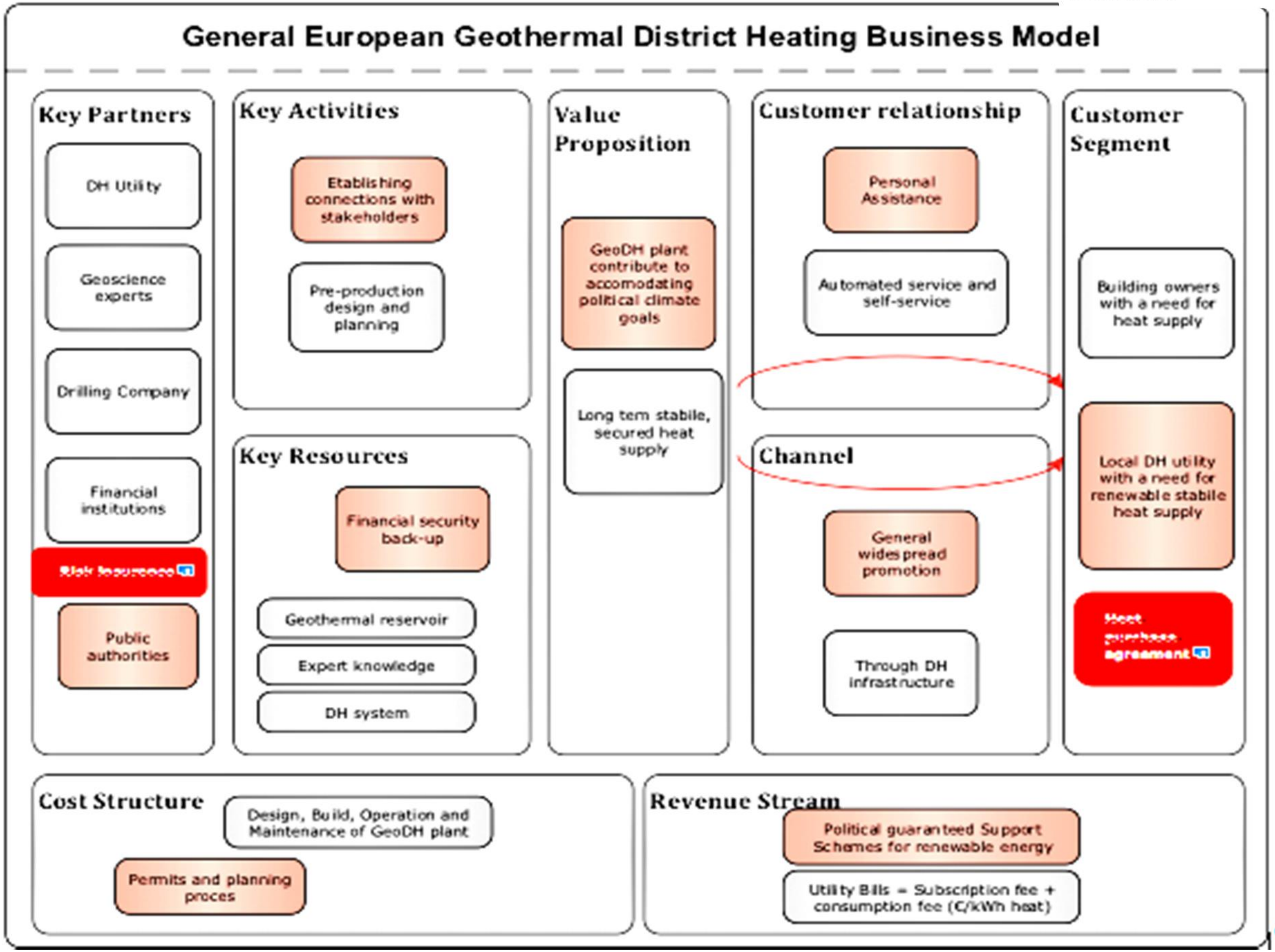
BUT HOW TO COVER THE COSTS / RISKS OF THE FIRST WELL?

Potential financing sources during various stages of a geothermal project



Source: Icelandsbanki

Business Model



Source: GeoDH project

GO / NOGO road of a geothermal district heating plant construction

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Pre-feasibility study which includes:

A - Pre-Sales: Project pre-design, MoU for heat purchase agreement with customers and financing research
B - Preliminary survey
C - Prefeasibility study (surface and sub-surface)

→ **GO / NOGO**

Geothermal expected potential confirmed and existing customers ready to buy heat at a fixed cost for a long duration which has to exceed the loan period

Exploration and feasibility study which includes:

A - Detailed studies, including geophysics if possible and permitting to obtain the right to drill a doublet system
B - Negotiation to get a coverage for the first and second well + geothermal loop testing
C - Project economical review and financing strategy

→ **GO / NOGO**

Confirmation of geothermal potential (depth, temperature, flow-rate), insurance coverage secured and financial details arranged

GO / NOGO road of a geothermal district heating plant construction

Drilling of wells which includes

A – Drilling of first well (preferably vertical)

→ **GO / NOGO**

The project is stopped if the result of the first well is under a ratio temperature/flow-rate under the limits of the success curve built and annexed in the insurance contract

B – Drilling of the second well and loop test

→ **GO / NOGO**

The project could be stopped at that time if the capacity of the second well is much lower or does not accept to reinject the totality of the flow rate

District heating construction which includes:

A – Equipment of the geothermal loop (submersible pump, surface injection pumps, electrical variators, heat exchanger installation, chemical treatment if any), monitoring of the loop and testing
B – Construction of the piping network or adaptation of the existing network
C – Construction of the heating station (the closest possible from the drilling pad) or adaptation of the existing one

GO / NOGO road of a geothermal district heating plant construction

Commissioning of the whole installation which includes:

A – First year of operation with detailed measurements on the geothermal loop (levels in the wells, well-head pressure, physico-chemistry of the water, pumps electrical consumption, etc …)

B – First year of operation with detailed measurements on the DH network (temperature, water flow rate, return temperature to the exchanger, follow up of back up boilers and calculations of energy balance with the coverage of geothermal

C – Normal exploitation of the plant including well controls, repairs and heavy maintenance and equipment replacement.

Environmental aspects and social acceptance

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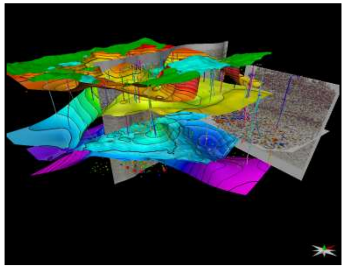
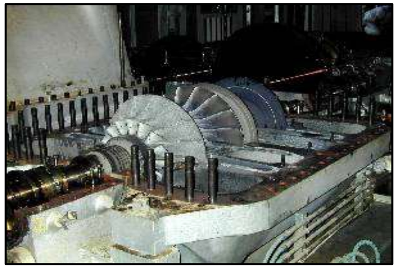
Environmental Impacts of geothermal projects

Most stages of development of a geothermal project potentially produce an impact on the environment

RESOURCES ASSESSMENT → WELL DRILLING AND TESTING → POWER DESIGN AND CONSTRUCTION → OPERATION AND MAINTENANCE → DECOMMITIONING




Environmental impact assessment, mitigation and monitoring

Environmental Impacts of geothermal projects

- **surface-visual effects** (land use, landscape, flora and fauna);
- **physical effects** (induced seismicity, subsidence, geological hazards);
- **acoustic effects** (noise during drilling, construction and management);
- **thermal effects** (release of steam in the air, ground heating and cooling for fluid withdrawal or injection).
- **chemical effects** (gaseous emissions into the atmosphere, re-injection of fluids, disposal of liquid and solid waste).

EIA is the assessment of the possible impact (positive or negative) that a proposed project may have on the environment, together consisting of the natural, social and economic aspects

EIA studies are required by authorities at various project phases (to various degrees of details)

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Atmospheric emissions

Mostly power production, negligible at low temperature resources (heating/cooling)

Sources:

- **Geyser, fumaroles, diffuse emissions**
- **Wells (during well testing operation)**
- **Power plants**

High temperature geothermal fluid average composition

- **Water** *85-98%*
- **Non-condensable gas** *2-15%*
  - CO_2 95%
  - H_2S 1%
  - CH_4 1%
  - H_2 2%
  - N_2 1%
  - O_2, Ar, He, CO, Hydrocarbons, Hg, As, B, Rd 0-traces
- **Particulate** *0-traces*

Noise

- Well drilling and testing phase
- Plant construction and equipment installation
- Power plant commissioning and operation

The intensity of the generated noise depends on the installed capacity and other acoustic parameters.

Visual impact and land use

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Exploration phase: removal of vegetation, preparation of the areas, construction works, infrastrctures (e.g. new roads)

Operation phase: presence of pipelines, power plant

How to minimize visual impacts?

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- avoid tourist areas, locations of natural/historical value, ecologically sensitive areas;
- apply good architectural principles in the design and layout of facilities;
- enclose the wellheads in small structures integrated well with the surroundings;
- prefer areas with tall trees that mitigate the visual impact;
- use reforestation with native plant species type;
- paint the pipelines green and brown;
- underground the power transmission lines, except in wooded areas (to limit the deforestation).

Land subsidence

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extraction of large amount of fluid from the underground

surface deformations can cause damage not only to facilities and infrastructure but to homes, if present in the vicinity of the field.

Control

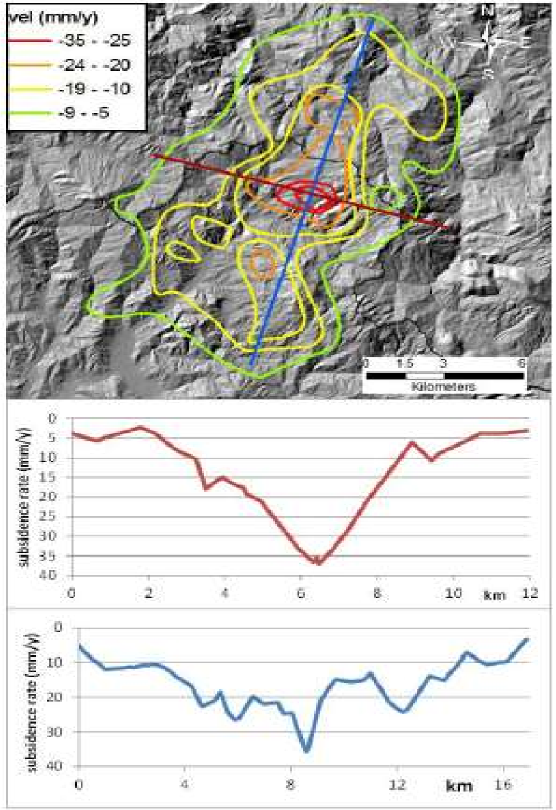
Reinjection of spent geothermal fluid

Monitoring

Leveling
GPS survey
InSAR techniques

Prediction

Numerical forecast model on reservoir behaviour



Larderello:
25-35 mm/a
(Rosi e Agostini, 2013)

Liquid and solid waste

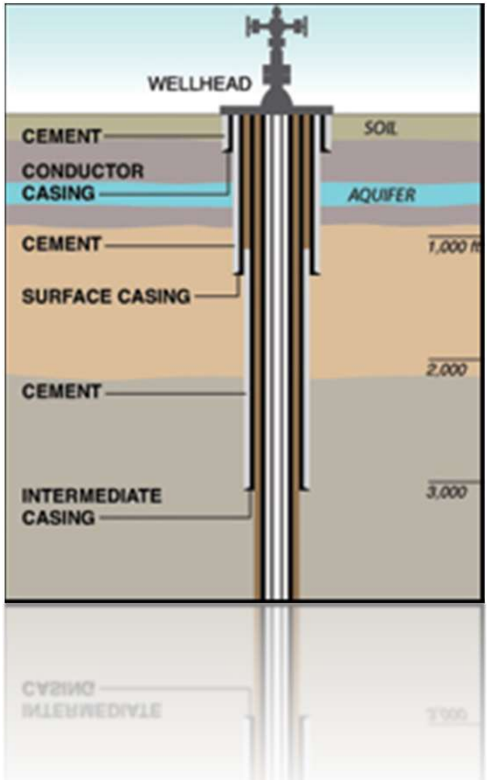
- fluids (drilling mud and other drilling fluid additives like cement slurry, diesel and lubricant leakages, lubricant spill, cleaning fluid waste);
- solids (earth and rock excavation, construction wastes, like waste timber, metallic waste, packing, cement);

Generally these wastes are "not dangerous"

The contractor doing the work should be made responsible by contract for cleaning and transporting away all such waste to an approved waste dump after his work is completed. Such a performance should also be prescribed in a health, safety and environment (HSE) management program for the whole project.

Water pollution

The extraction, reinjection, and discharge of geothermal fluids may affect both the quality and quantity of surface and groundwater resources.



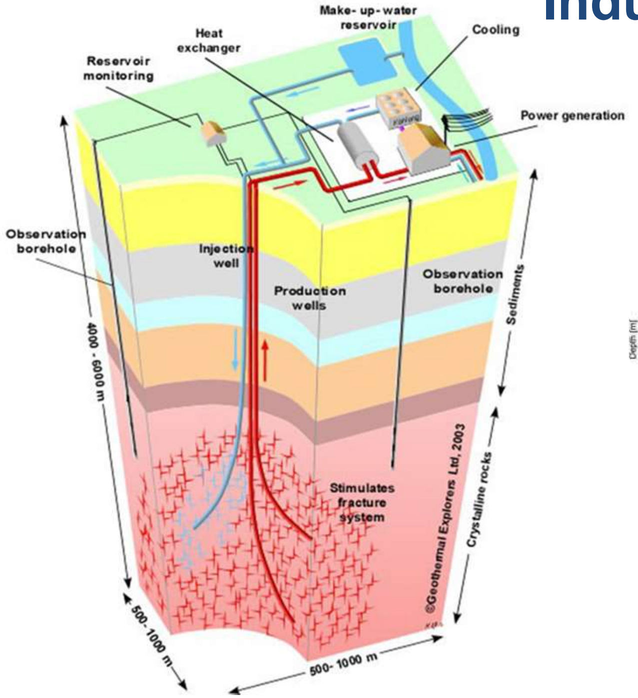
The well casing is the first barrier against pollution of groundwaters. Damaged casings may allow brines to mingle with fresh water aquifers: to install and cement multiple casings at shallow depths to provide extra barriers.

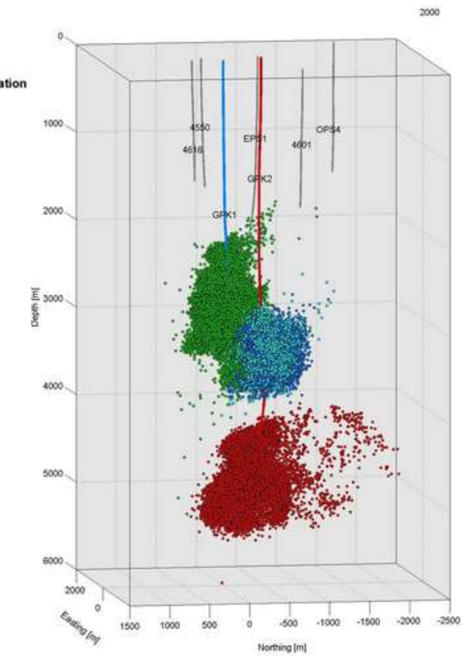
fluids discharging during well testing must be stored in impermeable holding ponds;

Monitoring wells strategically located in the well field to rapidly detect any problems

Completion of a hydrogeologic and water balance assessment during the project planning stage to identify hydraulic connections between the geothermal extraction and reinjection points and any sources of drinkable water or surface waters

Induced seismicity (EGS)





Hydraulic fracturing to incresae permeability

Normal operation produces microseismic activity (low magnitude events), at no risk

Often difficult to discern natural from induced seismic events:

- **collect baseline data prior to field development**
- **seismic monitoring**
- **establish a traffic light system (threshold definition, Go-No GO set up)**

Potential damages to the built environment: public acceptance

Social acceptance

„Social acceptability is attained if the project activities do not result in drastic changes from the regular conditions of the area, and if the affected sectors can see some advantages issuing from the project" (de Jesus, 1995)

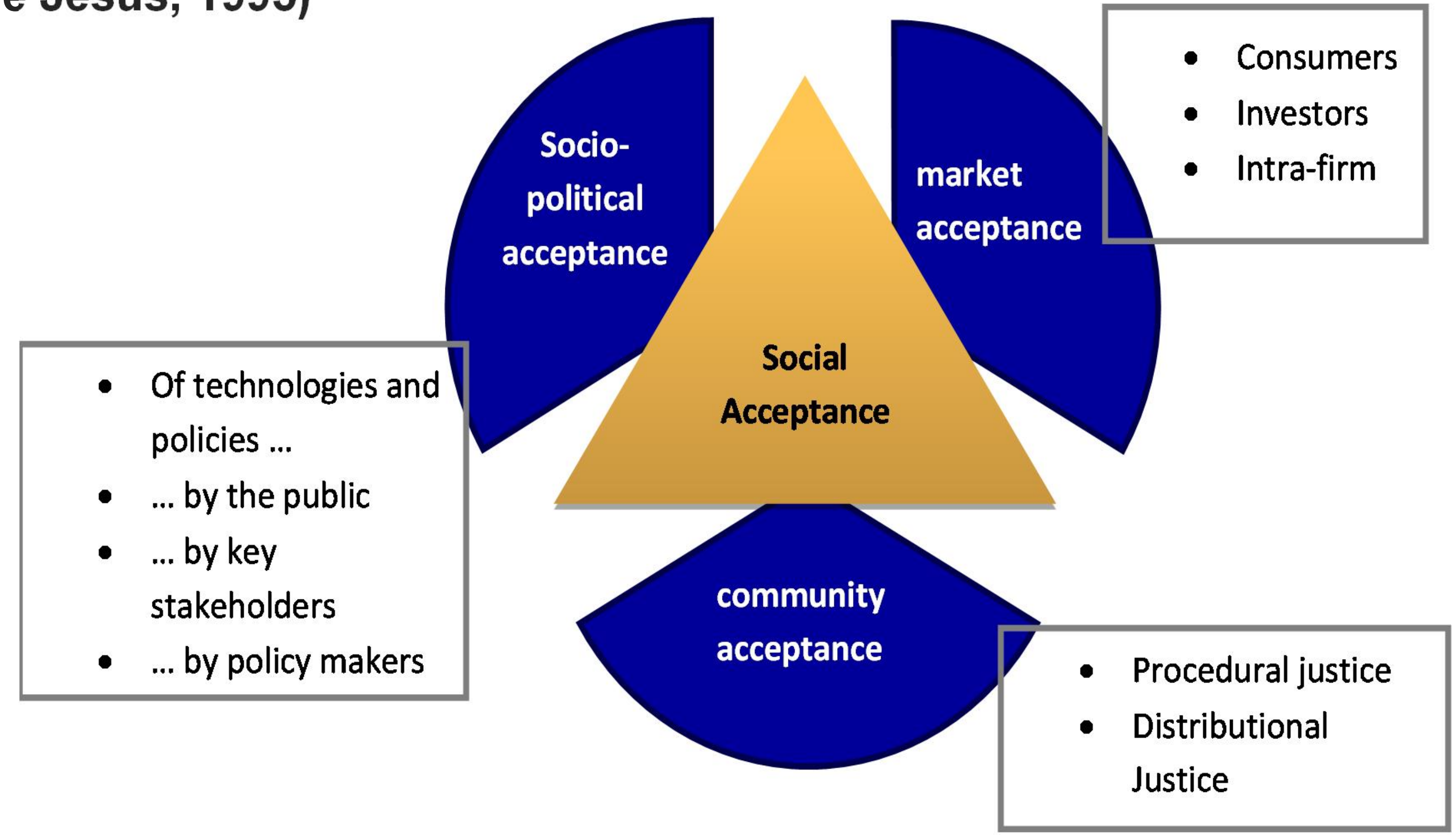


Figure 1: The triangle of social acceptance of renewable energy innovation (Wüstenhagen, Wolsink and Bürer 2007)

Social acceptance: a multiple stakeholders approach

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Type of stakeholders	Why are they against a project?	Counter-argument
Politicians Local authorities	- Sustainable development of their city is not a priority - Historically committed to fossil energies - Fear of not being (re)-elected	- Cost of energy
Neighboring communities	- Preserving quality of life against disturbances (traffic, noise, environmental aspects, …)	- Special actions and communication campaigns
Environmental pressure groups	- Geothermal energy not considered as a renewable energy - Confusion with shale gas	- Special actions <u>and more technical</u> communication campaigns

Actions to win social acceptance

Public relations and information campaign during the planning /execution stage of the project:

- **Contacts with public administrators of the area concerned, not only to provide them with information on the project objectives, but also to start having an idea of the people's attitude towards the new initiative;**
- **Preparation of public opinion through a plain and timely information campaign on duration of works, potential impacts of the construction and benefits during the operating phase;**
- **Presentation to regional authorities, public administrators, and important entities of the area, of a brochure outlining the project objectives, the environmental measures in program, and the social benefits that the project is expected to produce;**
- **Study tours, help-desk (information).**