



Guidelines for Geothermal Projects

The Verification Process for Geothermal Projects

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1. Guidelines for the verification of geothermal projects

These guidelines for the verification process of geothermal projects are focusing on the individual verifications to be performed during the course of a project. The purpose of such verifications primarily is to ensure an impartial third party to review and assess the technical basis and planning of the project in order to minimize any risk and create maximum value to the district heating company.

These guidelines being part of six guidelines concerned with geothermal projects were drafted to the Danish Energy Agency (DEA) in 2015, and are to be read as such.

Strategic approach to geothermal projects

Verification
process for
geothermal
projects

Regulatory
requirements

Organisation and
competences

Content of
standard
contracts

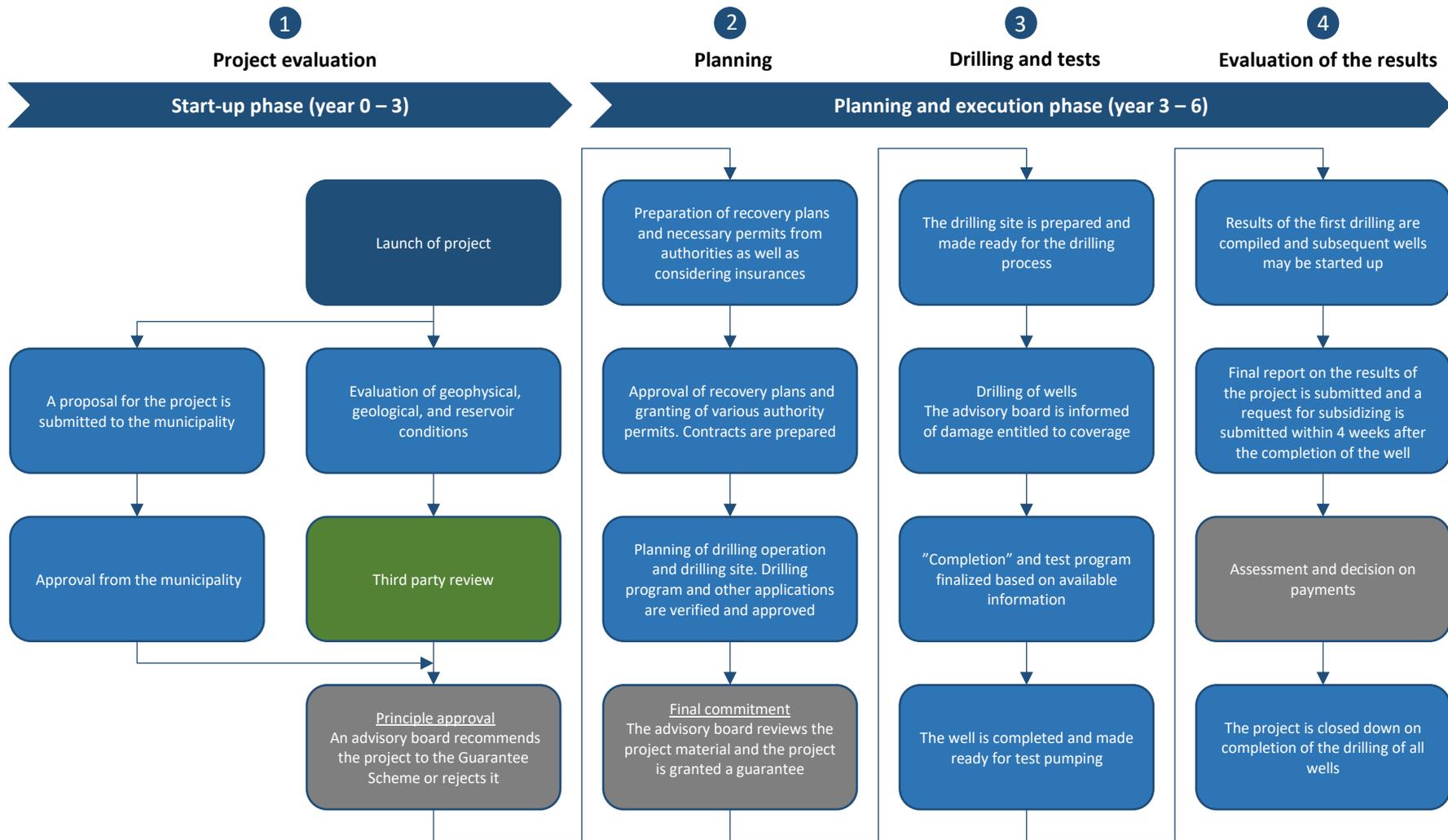
Budgeting for and
cost control of
geothermal wells

Typically, geothermal projects are an activity not particularly familiar to the individual district heating organisation. In most cases the projects are most costly and often the geological conditions present a degree of uncertainty till the wells have been tested. These factors call for risk management to be integrated into the planning and execution of geothermal projects.

Risk management is an ongoing, structured process to be anchored in the organisation and all phases of the project in order to provide a clear understanding of the effect of the individual risk to each element. The process consists of a number of tools used for identifying each risk elements and subsequently define how to mitigate the risk. Risk management has been thoroughly addressed in the report *Udredning om mulighederne for risikoafdækning i geotermiprojekter* (Memorandum on the possibilities of covering the risks in geothermal projects) (DEA, January 2014).

It is a prerequisite of these guidelines for the verification process that the work program stated in the model permit of the DEA is complied with.

The progress of a typical geothermal project is visualized below:



2. Project evaluation / start-up phase

When starting up a geothermal project a number of geophysical, geological and reservoir-related evaluations (underground evaluations) are to be performed establishing the basis for deciding if there is a sufficient technical basis for a geothermal plant. These evaluations normally end up in a number of reports/notes from a competent advisor who is familiar with the geological and reservoir-related conditions in the Danish underground.

Simultaneously, a proposal for a project is normally submitted to the municipality describing the technical plant and all related economical calculations as well as its consequences to local heating planning, supply, legislation and environment. This proposal must be accepted by the municipality.

Once the technical evaluations of the underground have been completed the geological and reservoir related work should be exposed to an assessment by a neutral third party possessing the right competences.

This will ensure that the project is based on a healthy foundation, and possibly critical areas will be spotlighted leading to a risk reduction as a part of the planning.

The concession holder will then submit relevant information to the Advisory Board which, based on this, will assess if the project may be recommended for the Guarantee Scheme. This will take place as a principle approval including identified risks and a statement on how to implement any risk reducing and mitigating activity.

In order to process the application for principle approval the Advisory Board as a minimum must receive the information described in Appendix 1 in these guidelines.

The principle approval of the project under the Guarantee Scheme is based on the information submitted to the Advisory Board. It is the responsibility of the concession holder that all submitted information is correct.

3. Planning

The concession holder may decide to continue the planning phase working out a preliminary recovery plan complying with the requirements and guidelines of the DEA. The recovery plan is a description of wells to be drilled and expected life span of the reservoir as well as needed surface installations – both regarding establishing and subsequent operation of the plant. The plan, furthermore, is to comprise schedules, budgets, costs of operation and a description of how geothermal heat is integrated into the district heating.

A preliminary plan for recovery is to be submitted to the DEA at the latest 6 months prior to start-up of the drilling the first well. Parallel to this, a number of permits and approvals are to be granted by the authorities: decisions on a mandatory EIA assessment, approvals related to local and municipal planning, permit for discharge as well as building permits. Furthermore, tenders for statutory insurances required by the Underground Act are to be called for as well as insurance related to the construction of the plant.

A contract-strategy is to be worked out, and advisors are to be contracted for the detailed planning of the drilling operation, construction of the drilling site etc. A drilling program is to be prepared, verified and finally approved by the DEA. Furthermore, a primary program for well design, development of the reservoir (`completion`) and procedure for well testing is to be submitted and approved.

Tenders are called for the most important contracts regarding the drilling activities and conditional contracts needed as the basis for the drilling budgets. Further information concerning contracts and drilling budgets may be found in the guidelines for budgeting & cost control of geothermal wells.

The concession holder submits information as stated in Appendix 1 to the Advisory Board. Based on this, commitment to a guarantee is given provided that all permits and approvals have been obtained, and an assessment is made to check that the project is sound and not too risky.

4. Drilling and testing

The planning and execution phase is continued:

- Contracts with suppliers and insurance companies are signed
- The drilling site is prepared
- The drilling process is ready for launch, and the drilling rig is mobilized

The first well is drilled in compliance with the approved drilling program, and the test program is carried out based on data obtained during the drilling process. The well is completed in compliance with the final development program and a test pumping is carried out. Subsequent wells are drilled and completed.

The concession holder shall inform the Advisory Board if conditions, expected to be entitled to financial coverage, have taken place during the drilling process.

5. Evaluation of the results

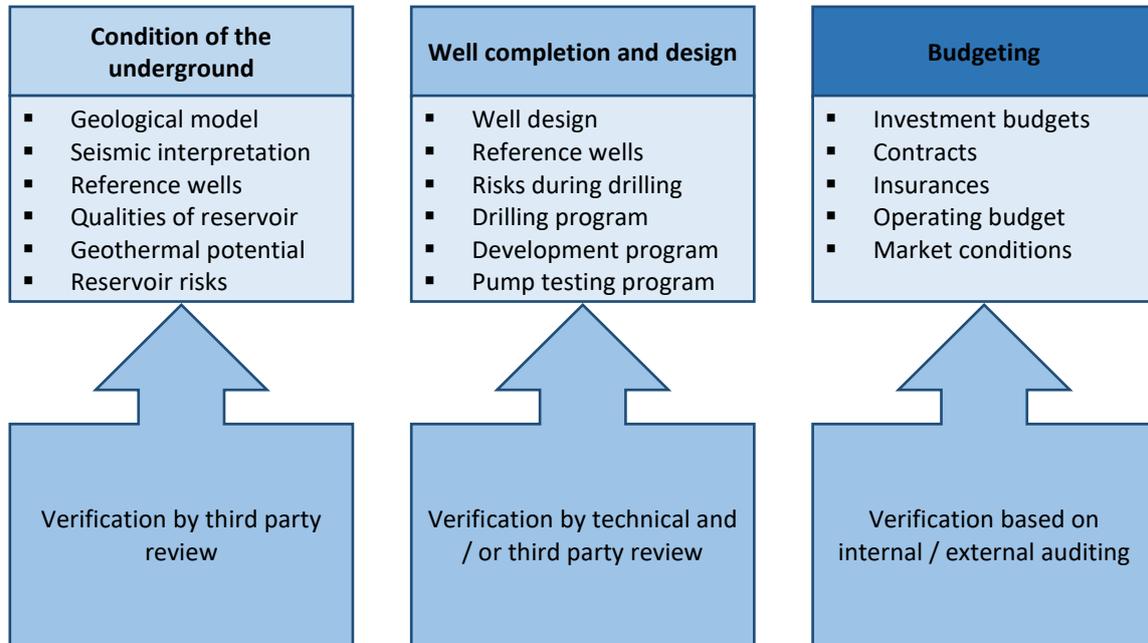
Results from the first well drilled are compiled and evaluated before decision is taken to drill subsequent wells. Approval of subsequent well must have been obtained, too, before new activities are started up.

The concession holder shall request the Advisory Board for coverage under the Guarantee Scheme if incidents entitled to coverage have taken place.

The Guarantee Scheme for the projects shall come to an end when the planned program for drilling of one or more wells and their testing have been completed and requests for financial coverage have been processed.

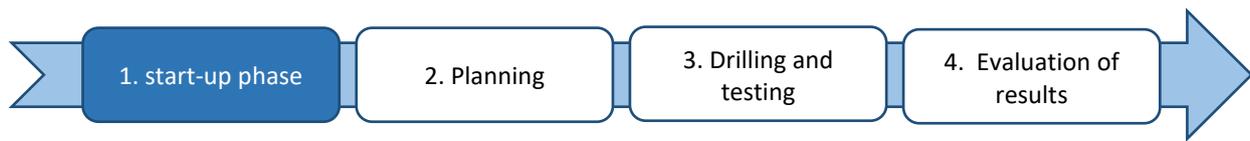
6. Verification

The verification process being an integrated part of the process of a geothermal project is contributing to ensuring that the right permits are granted based on sufficient and timely information. The documentation required primarily falls within the following topics:



The subsequent sections describe the individual phases of the project and how verification will assist in reducing risks related to the individual project.

6.1. The verification process of the individual phases – The start-up Phase



The purpose of the activities of this phase is to clarify the potential for geothermal heat, its integration into district heating and calculate the economy and the most realistic risks. Furthermore, during this phase the project may obtain a principle approval for participating in the Geothermal Guarantee Scheme. It is of paramount importance to a well-functioning and profitable geothermal plant that the geological preconditions are met.

Consequently, an assessment of the underground and third-party review is some of the most important parameters for the Advisory Board when assessing if a project may fall under the Geothermal Guarantee Scheme.

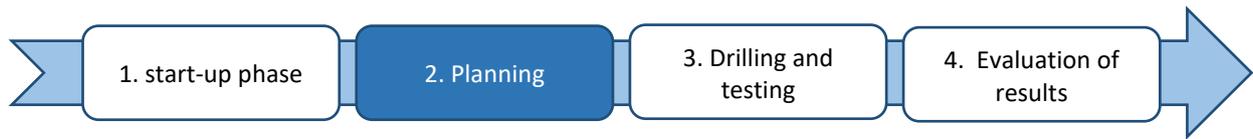
Table 1 states verifications / approvals of underground conditions, drilling & development and budget.

	Input	Output	Activity
Conditions of the underground	<ul style="list-style-type: none"> Seismic interpretations Geological model Depth and thickness of formation Percentage of sandstone in the formation Permeability Porosity Temperature gradient Texture / diagenesis / cementation Salinity and composure of produced water Sedimentological and structural continuity 	<ul style="list-style-type: none"> Verification of seismic interpretation, reference wells and tie-in Verification of depth contour lines Description of the potential of the reservoir Estimate of production Verification of faults in and around the area Verification of life span of the well Verification of secondary / tertiary potential Assess precipitation risk of salt and other minerals 	<ul style="list-style-type: none"> Reports on geological and reservoir conditions Third party review Proposal for further activities
Drilling & development	<ul style="list-style-type: none"> Information on nearby wells Possible location of drilling site 	<ul style="list-style-type: none"> Screening of nearby wells 	<ul style="list-style-type: none"> Risk register Conceptional well and development design No formal requirements for verification during this phase
Budgeting	<ul style="list-style-type: none"> Geological information and conceptional well design Use of index numbers 	<ul style="list-style-type: none"> Budgeting 	<ul style="list-style-type: none"> Investment budget for use in project proposal Input for principle approval

Table 1 Verification during the start-up phase.

During this phase budgeting will be based on preliminary information and use of index numbers is recommended. Further information may be found in the Guideline for budgeting and cost control of geothermal projects.

6.2. The verification process of the individual phases – Planning



The purpose of work during this phase is to ensure a detailed planning of the project for risks to be identified and mitigating activities implemented.

This phase calls for several formal approvals, like approval of the recovery plan and the drilling program as well as formal approval of the participation in the Guarantee Scheme. The former approvals are granted by the DEA and the latter by the Advisory Board.

Final commitment to joining the Guarantee Scheme requires that the Advisory Board based on the submitted documentation will assess the geological and operational conditions for geothermal recovery as being satisfactory, and that the Advisory Board has previously granted a principle approval.

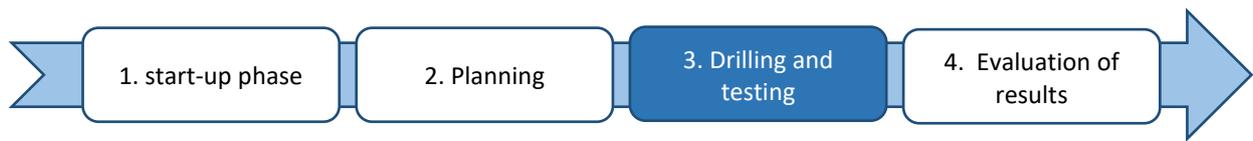
Table 2 states verifications / approvals for underground conditions, drilling & development and budget, respectively.

	Input	Output	Activity
Conditions of the underground	<ul style="list-style-type: none"> General updating of geological model and reservoir information incl. yield factor for the reservoir and distribution of probability Finished geology program incl. logging, sampling etc. 	<ul style="list-style-type: none"> Work out recovery plan, drilling, development and test program Contract strategy Available services and deliveries 	<ul style="list-style-type: none"> Recovery plan approved by the DEA. Drilling program approved by the DEA Development and test program approved by the DEA
Drilling & development	<ul style="list-style-type: none"> Geological prognosis Pressure & temperature profiles Drilling program Requirements to drilling site List of insurances taken List of signed contracts and their main conditions 	<ul style="list-style-type: none"> Gather approvals from local municipality Work out recovery plan, drilling, development and test program Contract strategy Available services and deliveries Procedure for test pumping of the geothermal wells 	<ul style="list-style-type: none"> Drilling program approved by the DEA Development and test program approved by the DEA Recovery plan approved by the Danish Energy Agency Decision if EIA is mandatory Approvals i.a.w. Local / municipality plan
Budgeting	<ul style="list-style-type: none"> Drilling program Service contracts 	<ul style="list-style-type: none"> Budget planning i.a.w. Guidelines 	<ul style="list-style-type: none"> Detailed budget for the drilling and test phases Advisory Board's verification of budget

Table 2 Verification of the planning phase.

During this phase budgeting will be based on the geological prognosis and service contracts. Budgeting is recommended to comply with Guideline for budget for and cost control of geothermal wells.

6.3. The verification process of the individual phases – Drilling and testing



During this phase, the purpose of work is to carry out the well drilling and production testing of the geothermal project.

Upon final commitment from the Advisory Board as to the Guarantee Scheme planning and practical operation can be carried on:

- Drilling site is prepared
- The drilling process is launched, and the drilling rig is mobilized

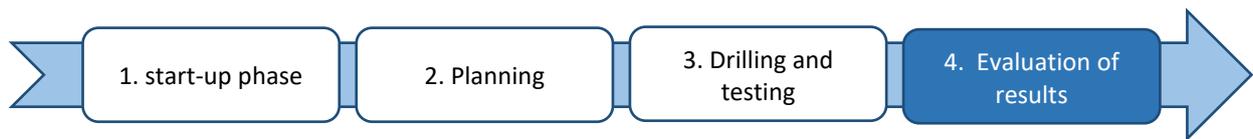
The first well is drilled in compliance with the approved drilling program, and development and test programs are carried out based on the current data gathered when drilling the well.

The well is test pumped and subsequent wells are drilled and completed if the geothermal potential is satisfactory.

	Input	Output	Activity
Conditions of the underground	<ul style="list-style-type: none"> ▪ Current data from the drilling are compiled and used for various models and analyses ▪ During drilling of the well the geological model is updated with updated data from the first well 	<ul style="list-style-type: none"> ▪ Tests from the drilling ▪ Geological studies ▪ Logging ▪ Core samples 	<ul style="list-style-type: none"> ▪ Detailed recommendation regarding final completion design (placing of screens, size of gravel pack etc.)
Drilling & development	<ul style="list-style-type: none"> ▪ Drilling, development and test information ▪ Reports from service companies ▪ Various measurings 	<ul style="list-style-type: none"> ▪ Control of deviations from plan ▪ Test of the well 	<ul style="list-style-type: none"> ▪ Proposal for changes are submitted to the DEA for approval ▪ Final development / test plan
Budgeting	<ul style="list-style-type: none"> ▪ Daily costs in compliance with the guidelines of the DEA and the budget of the project 	<ul style="list-style-type: none"> ▪ Daily reporting of the drilling and test budget ▪ Working out of prognosis concerning the expected total costs of the drilling of the well ▪ Auditing of the service companies 	<ul style="list-style-type: none"> ▪ Investment budget for use in project proposal ▪ Input for principle approval

Table 3 Verification during the operational phase.

6.4. The verification process of the individual phases – Evaluation of results



The results of the first drilling are collected and assessed before a decision to drill further wells may be taken. Approval of subsequent wells must be in place before such activities are started up.

	Input	Output	Activity
Conditions of the underground	<ul style="list-style-type: none"> Gather experience from the drilling operation and integrate this information into the next drilling and in future projects 	<ul style="list-style-type: none"> Analysis of specific subjects Updating of geological interpreting and geological model Updating of reservoir model 	<ul style="list-style-type: none"> Final geological report (contribution to Final Well Report)
Drilling & development	<ul style="list-style-type: none"> Accumulate experience from the drilling operation and incorporate this experience into the next drilling activity and future projects 	<ul style="list-style-type: none"> Prepare final report in compliance with the requirements of the DEA 	<ul style="list-style-type: none"> Prepare and submit Final Well Report Logs, test data cuttings, cores etc.
Budgeting	<ul style="list-style-type: none"> Finalize budgets compiling all actual costs 	<ul style="list-style-type: none"> Verification of the actual costs Close-down of accounts Audits 	<ul style="list-style-type: none"> Final accumulation of all costs Any insurance claims to be settled

Table 4 Verification of the evaluation phase.

7. Appendix 1 – Checklist for compilation of information

7.1. Necessary documentation for a principle approval

1. Project proposal related to the District Heating Act to be approved by the Municipality.
2. Description of the geological-geophysical database used (seismic lines and deep wells).
3. Description of relevant reference wells (oil, gas, geothermal, storage and water wells).
4. Relevant depth contour lines, if possible also showing thickness of reservoir formation(s).
5. Relevant interpreted seismic sections / geosections.
6. Description of faults in and around the area of interest, and assessment of their possible significance regarding the potential yield of the reservoir.
7. Description of the temperature gradient.
8. Description of the pressure gradient of the reservoir.
9. Description and calculation /estimate of the distribution of the reservoir's yield factor.
10. Description of the reservoir and its expected potential.
11. Reservoir risk and possible mitigating activities.
12. The expected life span of the reservoir until its temperature starts dropping.
13. Description of the possibility of a secondary (or tertiary) reservoir existing.
14. Geophysical and/or geological risks and possible mitigating activities.
15. Third party review and assessment of the geological and reservoir data as described in points (2-14) above.
16. Description of the expected composition of the produced water.
17. Description of risks regarding precipitation of salt and other minerals.
18. Description of metallurgic conditions which may require special materials.
19. Description of the concept behind the well design (number and placing of wells).
20. Description of risks related to the drilling activity and possible mitigation actions.
21. An overall technical description of and key data for the planned geothermal plant, including conceptual construction of the surface installations and possible heating pumps, as well as energy technical calculations of the expected yield of heat based on the stated parameters of the reservoir.
22. The expected construction and operation budget for the planned geothermal plant and a calculation of the expected annual production and heating economy in relation to the expected sale to the district heating system.

Parts of the above-mentioned material may be compiled in a preliminary copy of the recovery plan or other documentation submitted to the DEA as a part of the work program permit applied for.

7.2. Required documentation for final approval of participation in the Guarantee Scheme

1. Recovery plan approved by the DEA.
2. General updating of the geological and reservoir-related information incl. the yield factor of the reservoir and its distribution of probability.
3. Decision if EIA is mandatory.
4. Approval related to local and municipal plans.
5. Discharge permit for the drilling phase and when test pumping.
6. Building permit for setting up the necessary installations.
7. Drilling program approved by the DEA.
8. Program for completion and test pumping approved by the DEA.
9. Description of the layout and construction of the drilling site.
10. List of insurances taken.
11. List of contracts signed and their main conditions.
12. Detailed budget for the drilling and test phase.
13. Procedure for test pumping of the geothermal wells.

7.3. Where to find more information?

- Udredning om mulighederne for risikoafdækning i geotermiprojekter
(Memorandum on the possibilities for risk coverage of geothermal projects) (DEA, 2014)
- Drejebog om geotermi
(Script on geothermics) (DEA, 2014)
- Vejledning om strategisk tilgang
(Guideline on strategic approach to Geothermal Projects) (DEA, 2015)
- Vejledning om myndighedsbehandling
(Guideline on Regulatory requirements) (DEA 2015)
- Vejledning om organisering og kompetencer i forbindelse med geotermi
(Guideline on Organisation structure and competences related to geothermics) (DEA, 2015)
- Vejledning om modelkontrakter
(Guideline on Content of standard contracts) (DEA, 2015)
- Vejledning om budget & økonomistyring for geotermiboringer
(Guideline on Budgeting and cost control for geothermal wells) (DEA 2015)

7.4. Use of the guidance

As everybody knows, no two geothermal projects are alike, and the reader's attention is drawn to the fact that this guidance cannot and does not aim at replacing any concrete advice in the relevant area.

Thus, the guidance under all circumstances should be augmented by special advice on the project in question within planning, regulatory procedures, geology and geophysics, reservoir, drilling management and logistics, legal and insurance-related advice as well as any other type of assistance and advice.