WellPerform

Guidelines to Geothermal Projects

Budgeting and Cost Control

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CONTENTS

1. Guideline to budgeting and cost control

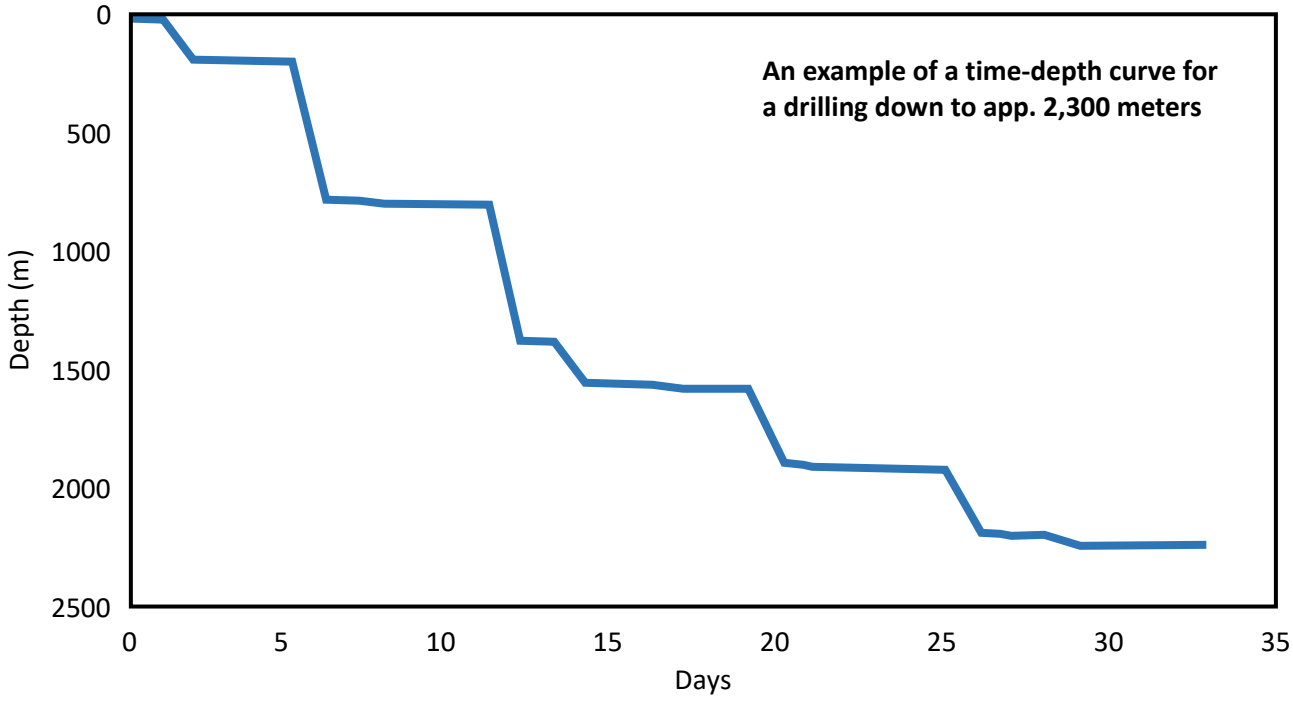
This guideline describes how drilling and test budgets are composed and which elements as a minimum should be included to provide a reliable budget estimate of the operations and thereby a basis for the development of a geothermal project.

The guideline 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 a whole:

2. Estimate of time

A well budget is based on an estimate of time for the drilling and following completion / testing. The estimate of time is based on experience from nearby or similar wells and must include the work planned. As time-related costs amount to some 60% of the costs of the drilling it is important for the time estimate to be correct.

The figure below shows the time-depth curve drawn for relevant drillings. Using such an approach makes it easier to estimate the expected time to be used.



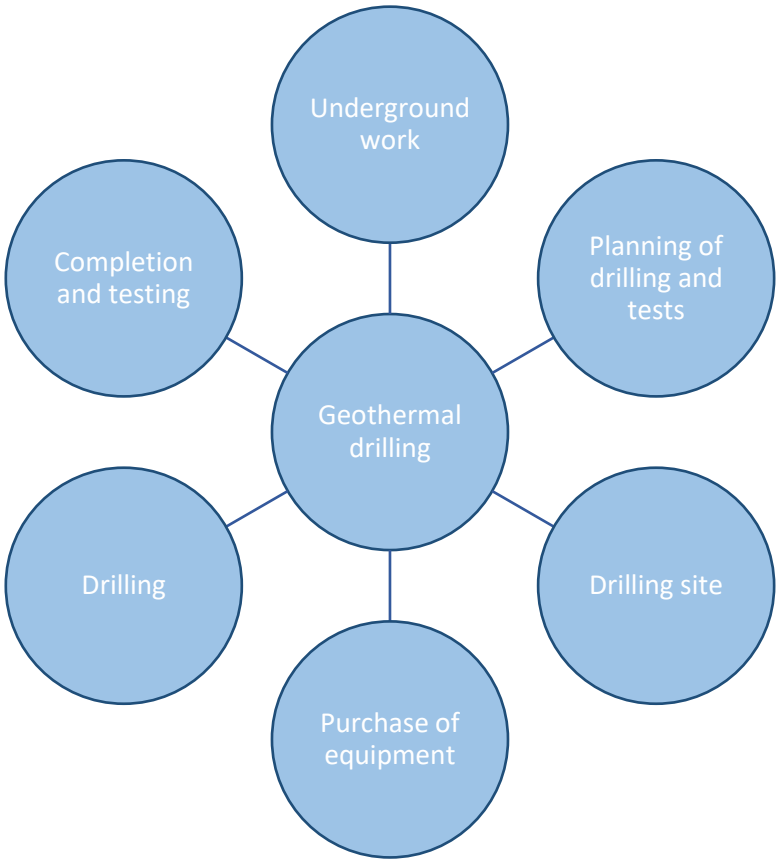
3. Budgeting

The drilling budget must be composed in compliance with good practise for geothermal projects. The Danish Geothermal Guarantee Scheme requires a well budget for each well, in which the mean value of the individual entries of the budget will act as the basis for the drilling budget to be used for the Guarantee Scheme.

The drilling budget is to be based on the costs stated in the concession holder's offered, negotiated and conditional contracts for the most important contracting activities and covering the rates for equipment necessary for drilling the well. It should be possible to sign such contracts of agreed prices if the concession holder is granted covering under the Guarantee Scheme.

When accepting tenders for work, equipment etc. related to the drilling project, lists of tenders, prices etc. shall be split in such a way that to the highest possible degree it is possible to carry out the subsequent identification of entries to be included in the drilling project, and entries not being relevant. If doubt may arise as to the distribution an estimate shall be made by the Advisory Board.

Drilling of a thermal well typically will comprise the following major element each calling for costs:



4. Underground work

During this early phase the geophysical, geological and reservoir studies are performed as they will form the foundation for the position and design of the geothermal wells.

Costs concerning underground work will vary depending on the complexity of the underground and the amount of information being available at the start-up. Typically, they will be related to man-hours, seismic (if needed) and specific analyses.

As a minimum, the budget for the underground work should comprise:

- Geophysical and geological interpretation of the information
- Reservoir evaluation and potential
- Regulatory requirements
- Third party review

If further seismic lines are to be acquired the following should be included:

- Planning of seismic acquisition
- Calling for tenders for seismic
- Gathering of seismic material, coordination with authorities and neighbours, meetings and reporting
- Interpretation of seismic data and reporting

5. Planning of drilling & testing

In general, planning of the first standard geothermal well will be a process lasting 6-12 months. The following wells may be planned while the first drilling takes place, so the first well will be costlier than the subsequent ones.

Budgeting and planning as a minimum should cover:

- Regulatory requirements
- Contract strategy & call for tenders
- Drilling engineer and operational geologist
- Safety organisation

Direct planning costs will depend on the chosen contract strategy. If a total delivery has been selected, the technical planning will be undertaken by the contractor, and the costs will then be part of the total contract.

6. Drilling site

A typical drilling rig will require a site consisting of an area for building the foundation for the rig, digging water pools and laying drain pipes, providing water, setting up fences, offices, etc.

The requirements for the drilling site primarily will be defined by the state and the municipality and partly by the drilling contractor.

The budget for the establishing of the drilling site as a minimum should comprise costs in connection with constructing the site, but also decommission and removal of the parts which are not to remain after the completion of the drilling operation.

The following are some examples of items to consider:

- Geotechnical work and samples of soil
- Regulatory requirements
- Digging pools for drainage and test pumping
- Drilling for water (if necessary)

- Fencing around the site and its pools
- Well cellars (8 pcs.) and their covers to be removed
- Concrete foundation for the drilling rig
- Paving of the site (part of the site is to have a watertight membrane)
- Drainage, sand filters, sludge tanks and separators

The price of a drilling site to a great extent depends on the drilling rig to be used. A small rig means less costs than for a large one. As a guideline, the cost will be in the DKK 2-6 million range.

7. Purchase of equipment

Some 20% of the costs of a typical drilling operation will be purchase of equipment like casing, wellhead, chemicals, drilling equipment etc.

When considering the contract strategy, it will be necessary to define equipment having a long delivery time as well as equipment of significant influence on the budget in order for the decisions on the project to include financial consequences.

The budget for equipment should as a minimum contain:

- Casing (often some 10-15% more casing than necessary for the drilling are purchased)
- Wellhead (one wellhead per well should be purchased, but access to back-up equipment should be available)
- Drilling mud and completion liquids
- Cement and chemicals
- Drilling and core bits
- Diesel
- Drilling pipes and other drilling equipment
- Liner hanger
- Completion
- Test equipment and pump

8. Drilling rig

The drilling rig accounts for 20-30% of the total well budget, so it is important for this contract to have clearly defined areas of responsibility and deliveries from drilling contractor and contractor.

If the project is not planned as a total delivery the drilling rig will typically be hired on a standard contract having a cost structure as follows:

Mobilizing to the drilling site and setting up:	Fixed price
Drilling operation:	DKK per day
De-mobilizing from the drilling site:	Fixed price

Mobilizing and de-mobilizing depends on where the drilling rig is situated. In Europe, this may amount to between DKK 1-6 million.

The drilling operation may be differentiated if the rig develops technical problems or the weather turns adverse. In such a case, the rate will be reduced (90-98% of the normal rate).

The price of the drilling rig will depend, too, of the general demand for rigs. As the rigs are the same as the ones used for drilling for oil and gas, the rate to a large extend will depend on the market price of oil and gas.

9. The drilling operation

Drilling, itself, requires a broad range of services (something like 10-20 depending on the selected contract strategy and organisation) which are called in during the operation. This means that the time-related costs are running high during the drilling proper and the testing, and it may amount to some 70% of the total cost.

A typical drilling operation will cost between DKK 300,000 and 500,000 per day while the rig is working. This underlines how important it is to optimise the drilling process.

The budget for the drilling operation as a minimum should comprise:

- Daily rate for the drilling rig and service personnel specialized in:
- Drilling mud (fluid)
- Well head
- Cement
- Logging (wireline, LWD / MWD)
- Directional drilling
- Coring
- Running of casing
- Running of liner hanger
- Depositing of cuttings
- Rented drilling equipment
- Well testing

10. Completion & testing

Drilling is finished when the last casing has been installed. Then the Completion phase starts up. This phase includes installation of production pipes, pumps, flushing and production tests.

The budget should comprise the following elements for completion & testing:

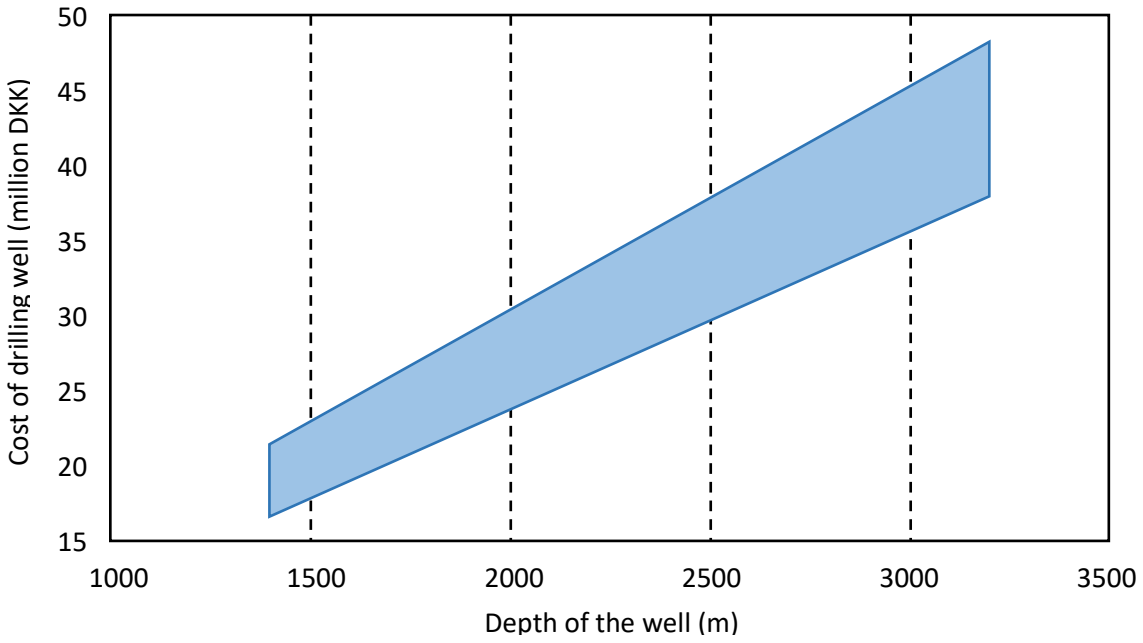
- Production pipes
- Production pump
- Test equipment, personnel & analyses

11. Use of key figures for drillings

In the early phase of a geothermal project it may be useful to have some key figures for budgeting, calculation, estimate of time etc. Such key figures are based on a number of geothermal and oil/gas projects carried out in Europe, so naturally they may offer a broad idea only, and they cannot be used uncritically for budgeting. All key figures are based on a standard rig for deep wells complying with the requirements of the Danish authorities. Today, several projects have been launched looking at cheaper solutions, but they are not yet commercial, so they have not been included in this guideline.

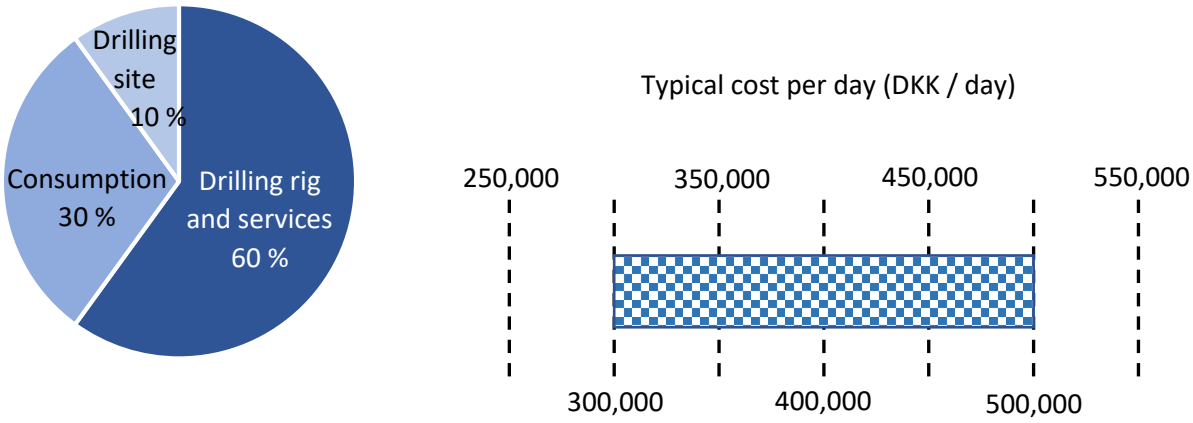
12. Cost of drilling a well

Based on a succession of wells drilled in Denmark, Germany and the Netherlands an approximate cost can be calculated for drilling a deep geothermal well. The figure below shows the relation between depth and costs. A 2,500 m well, thus, may cost between DKK 30 and 38 million, depending on geology etc. Added to this price will be costs of the start-up phase (geological reports, proposals for projects, seismic etc.) and construction of the drilling site.



13. Distribution of drilling costs

Typically, cost of drilling a well may be split into consumption, drilling site and time-related expenses. They normally are distributed as shown in the figure below. As can be seen the time-related costs amount to app. 60% meaning that the estimates of time are of major influence on the total cost.



As seen above total cost may amount to DKK 300,000-500,000 per day depending on the stage of the drilling phase being calculated – and, naturally, which drilling rig has been contracted.

As a part of the drilling budget consideration should be paid to the infrastructure if several drilling sites are being planned. Such plans will call for more drilling sites and consequent construction costs and cost of moving drilling rig and its equipment.

14. Duration of the drilling operation

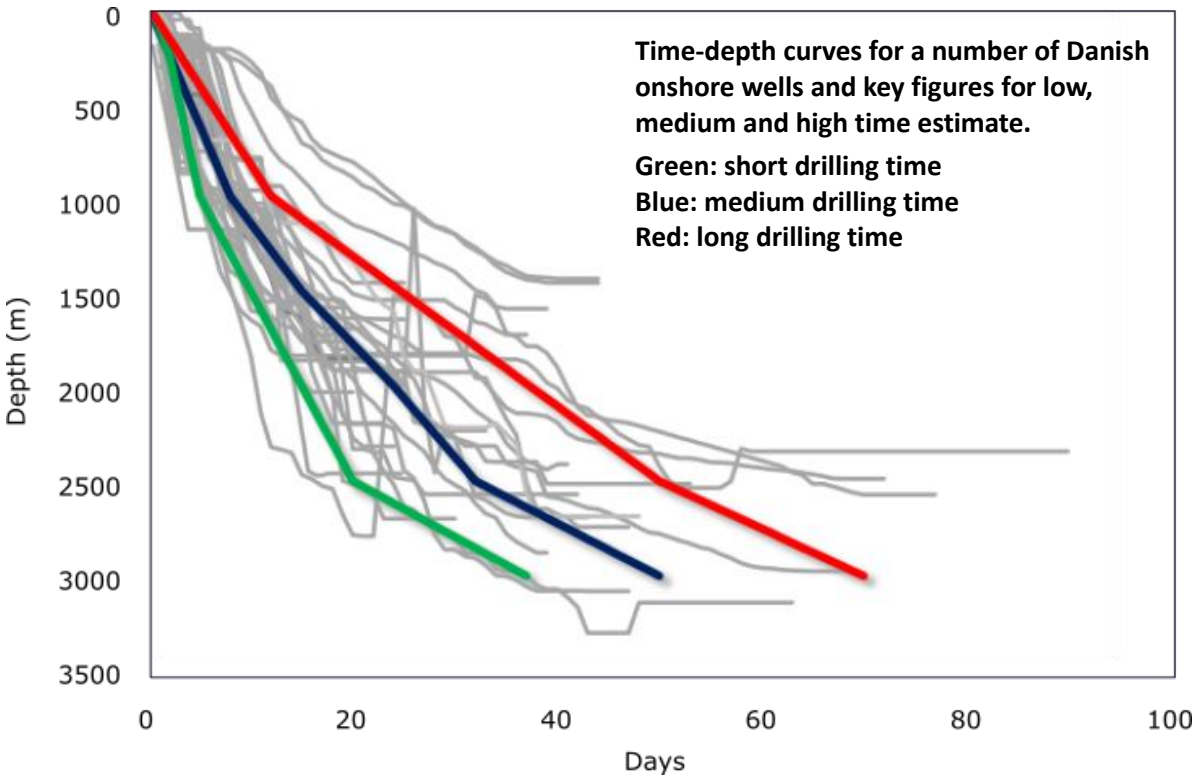
Typically, the duration of a drilling operation is shown as a time-depth curve. The figure below shows a number of Danish onshore wells having been drilled during the latest 30 years.

This plot may help in giving an idea of the duration of drilling a well. The three coloured curves (green, blue and red) are low, medium and high, respectively, estimates of the time it takes to drill to the final depth. Added to the time shown should be time for logging, completion and test of the well.

As an example, drilling a 2,500 m well may take:

- low estimate: 20 days
- medium estimate: 32 days
- high estimate: 50 days

The days only state the drilling phase and not the completion / test period.



15. Cost of mobilizing

The cost of mobilizing the drilling rig depends on where it is to be mobilized from and to. Mobilized from far away will mean high costs – up to DKK 2-6 million – and typically a bit less for demobilizing. For budgeting in the early phase, a mobilizing cost of DKK 4 million is recommended.

16. Deposit of cuttings

The cost of depositing of cuttings depends on the amount of cuttings. The table below provides a guideline as to the amount of cuttings generated by the individual sections of the bore hole.

	26” hole	17-1/2” hole	16” hole	12-1/4” hole	8-1/2” hole
Tons of cuttings per meter drilled	1.22	0.57	0.48	0.29	0.15
Typical waste of drilling mud (m^3 per meter drilled)	1.48	0.35	0.15	0.09	0.09

17. Minimum requirements to drilling budget and service contracts

A drilling budget under the Guarantee Scheme should show relevant costs corresponding to points 1-7 in below table, and as a minimum they should be split into the levels shown:

Minimum requirements to drilling budget for projects to be eligible for the Guarantee Scheme			
	Activity	**Remarks**	**Checklist**
0	Time schedule	Based on offset wells and previous experience. This estimate should be the basis of pricing services. For rental equipment time for mobilizing and demobilizing of equipment and personnel should be included.	
1. Consumption:			
1.1	Casing, liner production pipes	Based on well design +10% extra.	
1.2	Wellhead	Include one wellhead.	
1.3	Mud and chemicals	Based on technical proposal. Must include mud approved for use in Denmark and having the technical qualities required.	
1.4	Cement and chemicals	Based on technical proposal. Must include all cement jobs required for the well.	
1.5	Fuel	Based on actual market price.	
1.6	Drill bits	Based on technical proposal.	
1.7	Coring equipment (if required)	Based on technical proposal.	
1.8	Testing equipment (if required)	Based on technical proposal.	
1.9	Top hole	If the top hole is drilled by a professional water well driller this entry includes placing and cementing of the surface casing. Normally it is done at a fixed price.	
1.10	Drilling of water wells (if required)	Based on the technical proposal from the water well driller if water wells are required. Normally it is done at a fixed price.	
1.11	Other consumables	Any other costs. 5% of the total cost of consumables may be spent before such costs can finally be assessed.	
2. Drilling site			
2.1	Geotechnical surveys	Not included as a part of the drilling budget of the Guarantee Scheme.	
2.2	Drilling site	Not included as a part of the drilling budget of the Guarantee Scheme.	
3. Mobilization			
3.1	Mobilizing of the drilling rig	Budget estimate to be submitted as a fixed price by the drilling contractor as a part of the drilling contract.	
3.2	De-mobilizing of the drilling rig	Budget estimate to be submitted as a fixed price by the drilling contractor as a part of the drilling contract.	
4. Services			
4.1	Drilling rig	The drilling budget for the Guarantee Scheme must include costs based on an actual conditional contract.	
4.2	Electric logging equipment	Based on the technical proposal. Must include the logging program as stated in the drilling program.	
4.3	Mud logging	Must include the logging program as stated in the drilling program.	

4.4	LWD & MWD services	Based on technical proposal.	
4.5	Transport	Budget assessment including logistics in connection with the drilling operation. To be based on technical proposal as well as actual offers / conditional contracts.	
4.6	Mud personnel	Including the daily rates for mud personnel / equipment and will be part of the technical proposal.	
4.7	Cement personnel	Including the daily rates for mud personnel / equipment and will be part of the technical proposal.	
4.8	Wellhead personnel	Including the daily rate for wellhead service / equipment and will be part of the technical proposal.	
4.9	Installation of casing – equipment and personnel	Budget assessment from technical proposal including personnel and equipment.	
4.10	Safety equipment and personnel	Budget assessment including safety personnel, equipment and safety courses required for the drilling operation.	
4.11	Misc. drilling equipment	Budget assessment including all drilling equipment except for equipment for directional drilling and LWD and MWD. Based on actual offers / conditional contracts.	
4.12	Depositing of cuttings and other waste	Based on technical proposal. Cutting are to be deposited in a responsible way approved by the authorities.	
4.13	Directional drilling – services	This includes the day-rate for directional drilling – service / equipment and will be based on the technical proposal.	
4.14	Coring - services	This includes the day-rate for coring service / equipment, and will be based on the technical proposal.	
5. Workforce			
5.1	Workforce for planning	Not included as a part of the drilling budget for the Guarantee Scheme.	
5.2	Workforce for drilling	Budget assessment including day-rates for personnel during the drilling operation based on actual offers / conditional contracts. This only comprises services to be invoices and not internal costs for concession holder.	
5.3	Workforce for reporting	Not included as a part of the drilling budget for the Guarantee Scheme.	
6. Other costs			
6.1	Travels	Budget assessment for travels necessary during the drilling operation.	
6.2	Communication	Including telephones, other communication equipment and computers.	
6.3	Insurance	Budget assessment + own contribution to the Guarantee Scheme.	
6.4	Reports and analyses	Budget assessment. Only reports necessary for the drilling and / or test phase are to be included.	
7. Well Testing			
7.1	Test planning	Not included as a part of the drilling budget for the Guarantee Scheme.	
7.2	Testing of well	Including daily costs caused by the test pumping as stated in actual offers / conditional contracts. Estimate is to be based on the expected duration of the well test and technical requirements.	

The actual drilling costs are to be stated for each day during the drilling operation in order to compare them to the entries of the drilling budget. Thus, only costs within the above stated limits are to be included in the drilling budget and entered as drilling costs. Drilling costs must be based on documented expenses.

18. Example of a budget

Below is shown an example of a drilling budget including the elements from sections 1 and 3.

Drilling budget for <well name>					
Name of project	:	**<name of project>**	**Drilling**	:	**x days**
Name of well	:	**<name of well>**	**Completion and testing**	:	**y days**
Date of spudding	:	**dd.mm.yyyy**	**Total days**	:	**x + y days**
Drilling rig rate	:	**__.___ EUR / day**	**EUR / DKK**	:	**__.___**
Total depth (mMD)	:	**____**	**USD / DKK**	:	**__.___**
Total vertical depth (mTVD)	:	**____**	**GBP / DKK**	:	**__.___**

Budget details			DKK
Activity		**Description**	
Consumption			0
	1.1	Casing	
	1.2	Wellhead	
	1.3	Mud chemicals	
	1.4	Cement and chemicals	
	1.5	Fuel	
	1.6	Drill bits and other equipment	
	1.7	Coring equipment	
	1.8	Other purchases	
	1.9	Completion	
	1.10	Test equipment and pump	
Drilling site			0
	2.1	Geotechnical analysis	
	2.2	Water wells	
	2.3	Construction of drilling site	
	2.4	Drilling of top hole	
	2.5	Re-establishment of drilling site	
Mobilization and de-mobilization of drilling rig			0
	3.1	Mobilization of drilling rig	
	3.2	De-mobilization of drilling rig	
Service contracts			0
	4.1	Drilling rig	
	4.2	Directional drilling	
	4.3	Electric logging	
	4.4	Mud logging	
	4.5	L/MWD service	
	4.6	Coring	
	4.7	Misc. drilling equipment	
	4.8	Drilling mud and related jobs	
	4.9	Cement	
	4.10	Running of casing	
	4.11	Wellhead	
	4.12	Transport	
	4.13	Transport and deposit of cuttings	
	4.14	Deposit of waste	
	4.15	Safety related expenses	
	4.16	Well test	
	4.17	Testing equipment incl. pump	
	4.18	Miscellaneous	
Personnel			0
	5.1	Planning	
	5.2	Drilling operation	
	5.3	Well test	
	5.4	Reporting	
Other expenses			0
	6.1	Travel	
	6.2	Communication	
	6.3	Insurance	
	6.4	Reports and analyses	
Unexpected expenses		XX%	0
Total cost of well			0

19. 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 verifikationsprocesser i geotermiprojekter
  (Guideline on verification process for Geothermal Projects) (DEA 2015)
- Vejledning om myndighedsbehandling
  (Guideline on Regulatory requirements) (DEA 2015)
- Vejledning om organisering og kompetencer i forbindelse med geotermi
  (Guideline on Organisational structure and competences) (DEA 2015)
- Vejledning om modelkontrakter
  (Guideline on the content of Standard Contracts) (DEA 2015)

20. 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 advise in the relevant area.

Thus, the guidance under all circumstances should be augmented by special advise 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 advise.