December 2017

Knowledge centre

Guideline

Geothermal energy power plant project phases

Material developed by:
Koen Broess
Kees van den Ende
Tom Geurink
Bart in ’t Groen
Rianne ’t Hoen
Nynke Verhaegh

Table of contents



Project phases: 1. 2. 3. 4. 5. 6. 7.

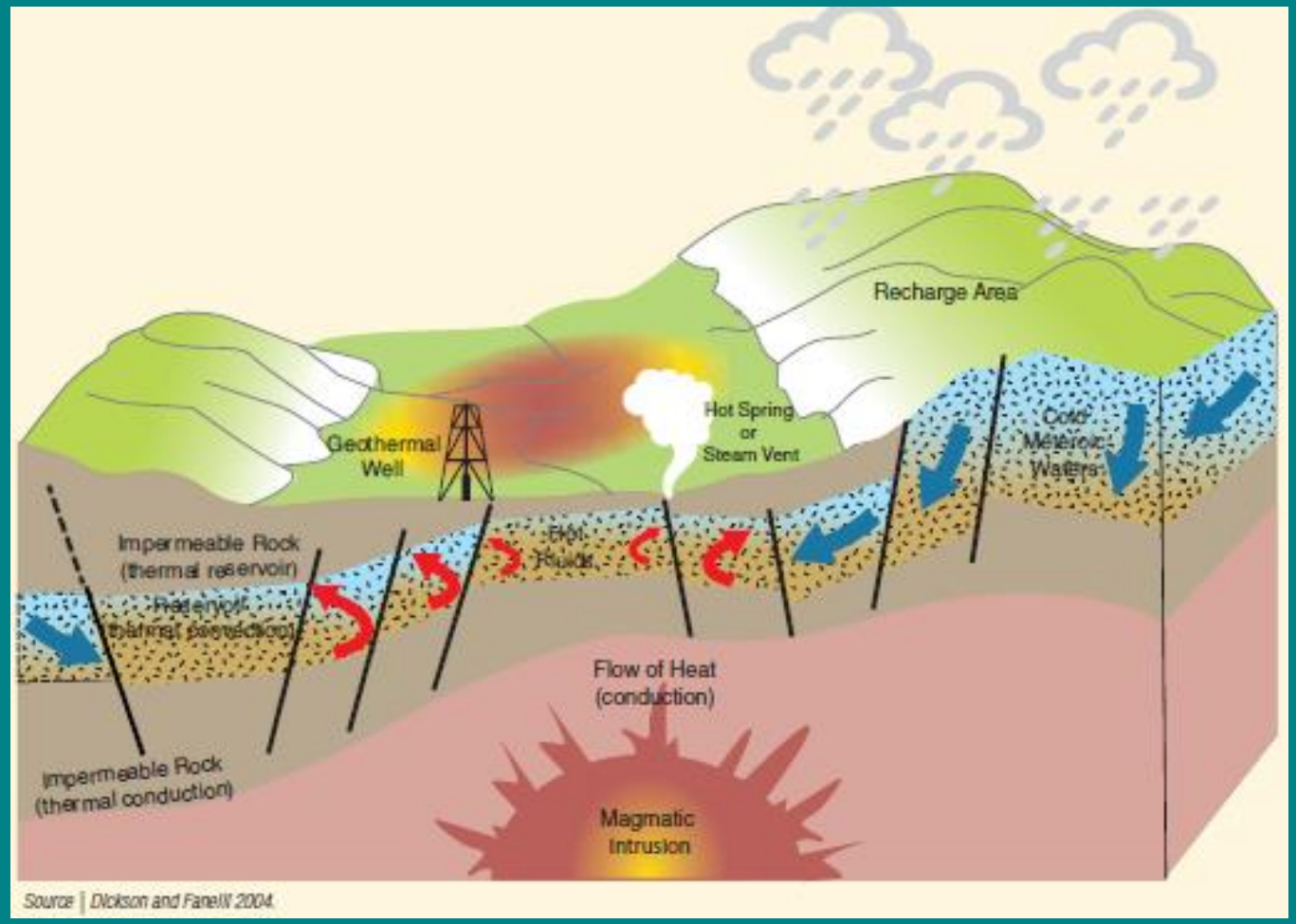
Geothermal energy plant development phases

1	*Pre-phase Reconnaissance*	Collect & analyze data to estimate the existence of geothermal resources
2	*Preliminary research*	Collect & analyze data to predict location and potential of geothermal resources Prepare for exploration drilling, including secure funding, licenses and permits
3	*Exploration*	Exploration drilling to confirm the existence, size, temperature, exact location, and potential of the reservoir
4	*Feasibility study*	-To create a business plan (including technical, economic and environmental assessment) -To develop design and operation plan of the power plant
5	*Field development & construction*	Drilling of the production and injection wells, construction of the power plant, testing and commissioning
6	*Operation & maintenance*	Direct and indirect utilization of geothermal energy. Operation and Maintenance of the geothermal energy plant
7	*Decommissioning*	Well abandoning

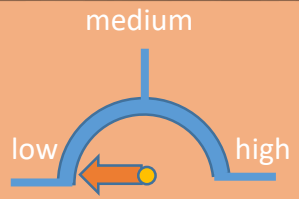
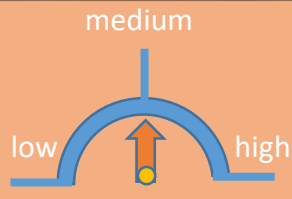
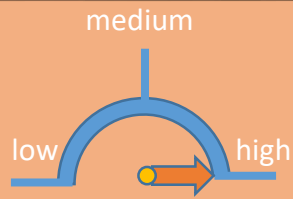
Geothermal energy definitions

Geothermal Resource refers to a geothermal system with sufficient heat and permeability which may be exploited

Geothermal Reserve refers to a geothermal system which can be economically exploited (determined by technical, physical or commercial criteria)



Geothermal Resources

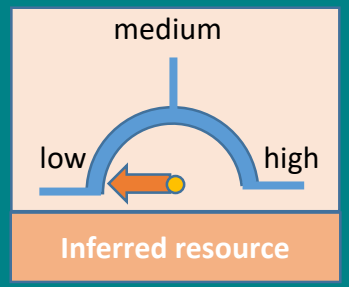
Knowledge	Indirect measurements & extrapolated data	Direct measurements	Direct measurements by drilling & fluid analysis
Level of confidence	 **Inferred**	 **Indicated**	 **Measured**

Geothermal Reserves

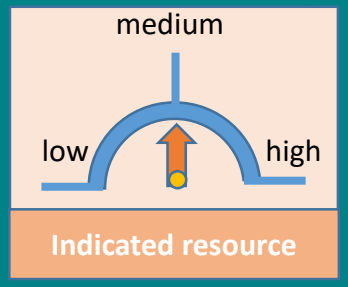
	Probable	Accurate	Proven
Economical potential	**>50%**	**>90%**	**>100%**
Next steps	Exploration drilling	Drilling	During operation & maintenance
	Analysis of business case	Business case finalized	
	Assessment of legal, environmental, social and stakeholder aspects	Final settlement of legal, environmental, social and stakeholder aspects	

Geothermal energy plant development phases

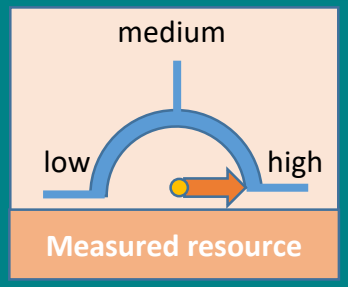
1. Pre-phase Reconnaissance
2. Preliminary research
3. Exploration
4. Feasibility study
5. Field development & construction
6. Operation & maintenance
7. De-commissioning



Inferred resource



Indicated resource



Measured resource

Probable reserve

Accurate reserve

Typical time schedule

	Project Phase	year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year n	year n+1
1	Pre-phase Reconnaissance										
2	Preliminary research										
3	Exploration										
4	Feasibility study										
5	Field development & construction										
6	Operation & maintenance										
7	Decommissioning										

1. Pre-phase Reconnaissance | 2. Preliminary research | 3. Exploration | 4. Feasibility study | 5. Field development & construction | 6. Operation & maintenance | 7. De-commissioning

Aim

Collect and analyze data to estimate the existence of geothermal resources

Key actions:

Data collection and analysis:
- geothermal resources and best location
- best possible market for geothermal energy

Visit geothermal site

Stakeholder involvement

Secure financing for next project phase

Control questions:

Are there indications of the presence of a geothermal resource?

Is the site accessible?

Have stakeholders been identified?

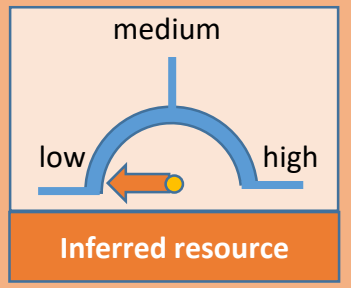
Have supporting (policy & regulatory & financial) instruments been identified?

Output

Selection of location

Preliminary budgeting

Indicative feasibility of the geothermal project



1. Pre-phase Reconnaissance
2. Preliminary research
3. Exploration
4. Feasibility study
5. Field development & construction
6. Operation & maintenance
7. De-commissioning

Aim

- Collect & analyze data to predict location and potential of geothermal resources
- Prepare for exploration drilling, including secure funding, licenses and permits

Key actions:

Project & resource assessment
- surface exploration
- development of conceptual reservoir model

Business models and project financing

Technical feasibility
- drilling plan & conceptual design power plant
- grid connection requirements and regulations

Control questions:

Is there sufficient evidence for an indicated geothermal resource?

Have financial & political means been secured for exploration drilling?

Have the required research permits and licenses been arranged?

Has a preliminary Environmental & Social Impact Assessment been prepared?

Has a risk assessment been performed?

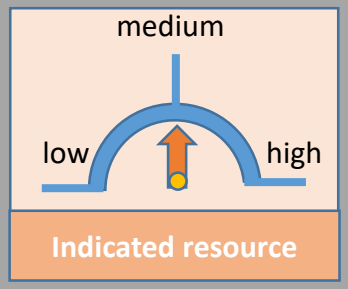
Is there sufficient evidence for a probable geothermal reserve?

Output

Conceptual model of reservoir

Secured funding and signed agreements for exploration drilling

Preliminary ESIA report



Probable reserve

1. Pre-phase Reconnaissance
2. Preliminary research
3. Exploration
4. Feasibility study
5. Field development & construction
6. Operation & maintenance
7. De-commissioning

Aim

To confirm the size of the geothermal resource by drilling exploration wells

Key actions:

Process and timelines for exploration drilling
- Set up local office for project management and related staff

Managing a drilling operation
- Contract a qualified drilling company

Secure owners' engineer

Control questions:

Has exploration drilling been successful (size, temperature, sub surface information)?

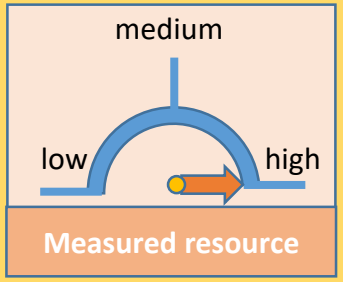
Has the reservoir model been improved?

Has infrastructure on-site been arranged (well pads, roads, water supply)?

Have tendering documents been prepared for EPC contractor (including drilling capabilities)?

Output

Improved model of reservoir



Is there sufficient evidence for a measured geothermal resource?

1. Pre-phase Reconnaissance
2. Preliminary research
3. Exploration
4. Feasibility study
5. Field development & construction
6. Operation & maintenance
7. De-commissioning

Aim

-To create a business plan (including technical, economic and environmental assessment)

-To develop design and operation plan for the power plant

Key actions:

Create a conceptual design of Power Plant and Steam Field

Finding drilling contractor and EPC tendering of power plant

Assessment optimal size of power plant and finalize design criteria

ESIA report for the geothermal project

Detailed budget plan and update financial model,secure financing from investors and financial institutes.

Control questions:

Has the conceptual design and operation plan of power plant been developed?

Have the finances been secured?

Has the environmental feasibility been demonstrated in the ESIA?

Has the risk assessment been updated?

Have the required contracts, permits and licenses been arranged?

Is there sufficient evidence for an accurate geothermal reserve?

Output

Conceptual design and operation plan

Business plan

Financial close

Accurate reserve

1. Pre-phase Reconnaissance
2. Preliminary research
3. Exploration
4. Feasibility study
5. Field development & construction
6. Operation & maintenance
7. De-commissioning

Aim

-Drilling of the production and injection wells

-Construction of the power plant

-Testing and commissioning

Key actions:

Drilling and construction of the production and re-injection wells.

Construction of the power plant and infrastructure

Connection to electricity grid/ heat network (surrounding infrastructure)

Testing & commissioning

Recruiting and training of personnel

Control questions:

Are additional production wells and re-injection wells needed?

Have trained employees been selected for the power plant?

Are contracts with vendors and service providers in place?

Is the risk assessment updated?

Is the power plant successfully tested and commissioned?

Output

Commercially operational power plant

Proven reserve

1. Pre-phase Reconnaissance
2. Preliminary research
3. Exploration
4. Feasibility study
5. Field development & construction
6. Operation & maintenance
7. De-commissioning

Aim

- Direct and indirect utilization of geothermal energy
- Operation and Maintenance of the geothermal energy plant

Key actions:

Direct and indirect utilization of geothermal energy. O&M of the plant. Selling electricity, usually via PPA.

Reservoir management: Additional/ replacement drilling, to compensate for drawdown of the reservoir.

Reservoir numerical modelling: Calibration and revision of the reservoir engineering model

Environmental monitoring

Control questions:

Is the power plant operating commercially, reliably and sustainably?

Are O&M activities of the geothermal wells and plants well planned and executed?

Are all contractual guarantees for supplying energy being met?

Is the reservoir model continuously updated and working correctly?

Is the risk assessment regularly updated?

Output

A geothermal power plant operating commercially, reliably and sustainably

1. Pre-phase Reconnaissance
2. Preliminary research
3. Exploration
4. Feasibility study
5. Field development & construction
6. Operation and maintenance
7. De-commissioning

Aim

Well abandoning and returning plant site in original state

Key actions:

Investigate the possibilities for reuse of the plant (lower electricity production, heat/ cold production) or recycling of equipment.

Well abandoning: bring plant site as close to original state as possible
- Radio activity check
- Government check
- Approval decommissioning properly performed

Control questions:

Are the possibilities of repurposing been investigated?

Has proper recycling of equipment been safeguarded?

In case of final closing of the plant; have local regulations according well plugging and abandoning been followed?

Output

Possibilities for reuse of the plant or parts

Final closing of the plant

References

- AGEA, *Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves*, Nov 2010, http://www.pir.sa.gov.au/__data/assets/pdf_file/0005/147875/The_Geothermal_Reporting_Code_Ed_2.pdf
- Canadian Geothermal Energy Association, *The Canadian Geothermal Code for Public Reporting,* 2010, http://www.cangea.ca/geothermal-code-for-public-reporting.html
- R. DiPippo, *Geothermal Power Plants, principles, applications, case studies and environmental impact*, 2012, Elsevier Ltd.
- M. Gehringer & V. Loksha, *Geothermal Handbook: Planning and financing power generation*, 2012, Washington DC: Energy Sector Management Assistance Programm (ESMAP), https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/FINAL_Geothermal%20Handbook_TR002-12_Reduced.pdf
- IFC World Bank Group, *Success of Geothermal Wells: A Global Study,* 2013
- International Geothermal Association, *Geothermal exploration – Global Strategies and Applications*, 2016, https://www.geothermal-energy.org/iga-shop.html
- IRENA Project Navigator Geothermal – Technical Concept Guidelines, 2017, https://navigator.irena.org/inside/pn/learn/Pages/geothermal/home.aspx