Environmental aspects of geothermal utilization

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General

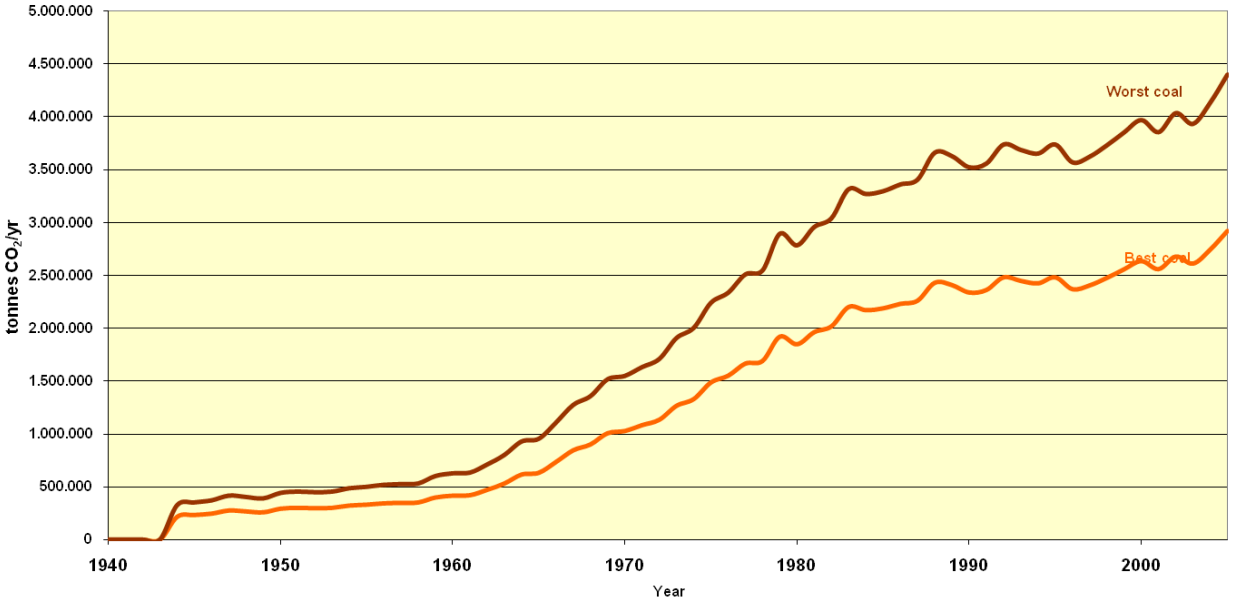
- All use of energy has some influence on the environment
- Modern communities demand large energy sources
- The energy sources have to be selected not only from economical point of view but also from the environmental impact
- Geothermal energy is environmental friendly energy source but its utilization can also have influence on the environment

Benefits of geothermal development

- One of the cleanest energy source
- In all cases domestic energy and used locally
  - Reduces import of other energy sources such as fossil fuels

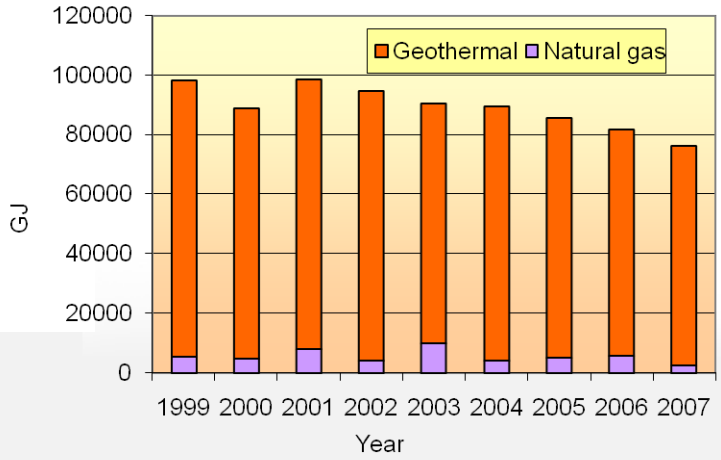
CO_2 saving using geothermal water for house heating

- 90% of all houses in Iceland are heated with geothermal water
- Comparison with other alternatives such as using fossil fuels
- Total saving of CO_2 emission in the Reykjavík area is about 100 million tonnes
- Saving about 2-4 million tonnes annually similar as annual release from Iceland

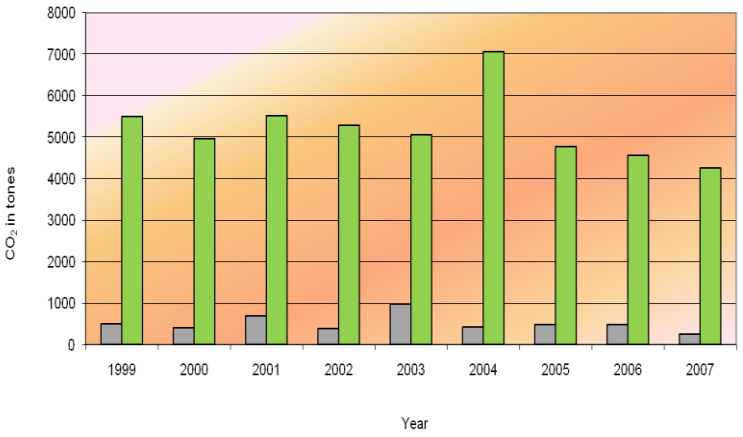


Example from Slovakia

- In Galanta in Slovakia geothermal water was used to replace natural gas
- 9,000 GJ/year heat production was modified
- Natural gas replaced by carbonate rich geothermal water
- Although the water is rich in carbonate its CO_2 emission is negligible – about 0.3 g CO_2/kWh
- Reduction of about 5,000 tonnes of CO_2 emission annually

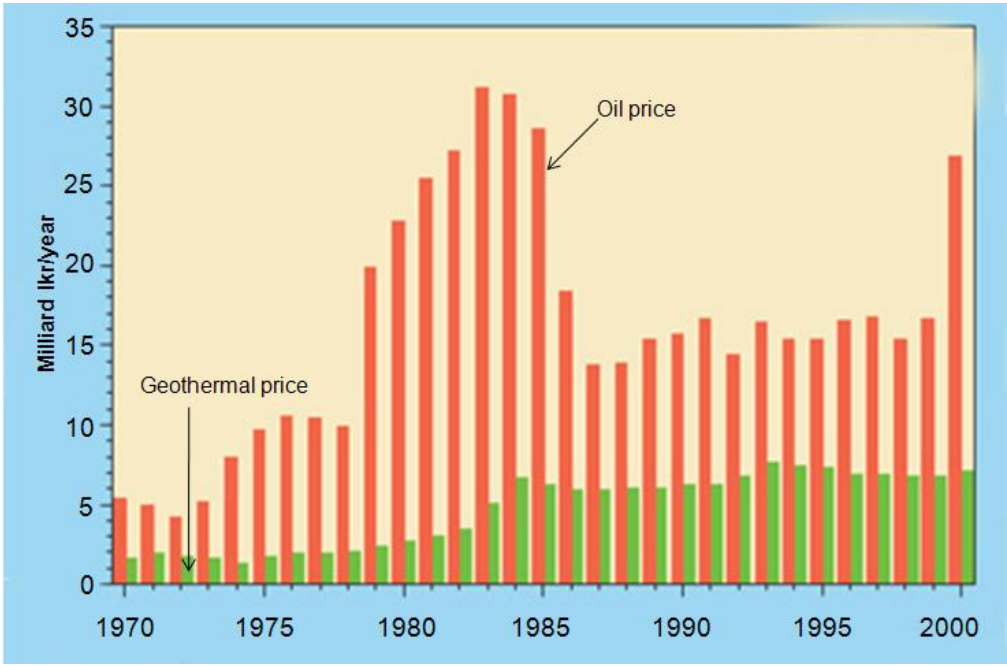


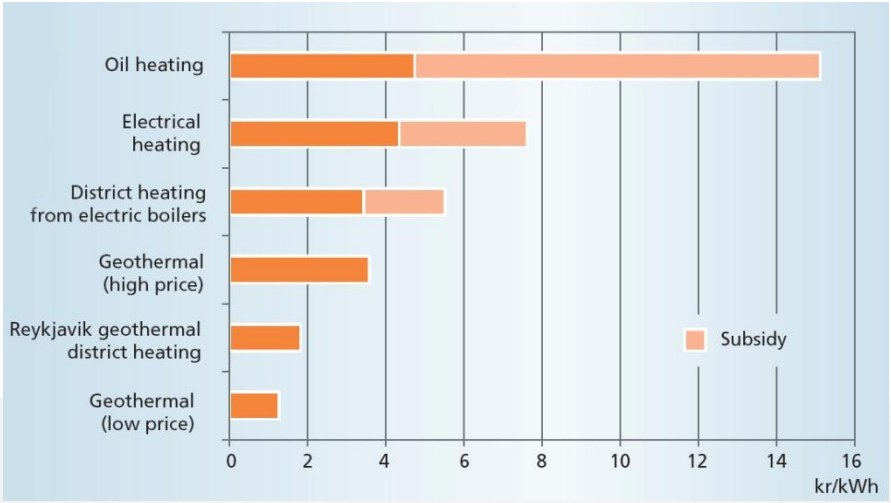
Production of heat from geothermal water and gas in the period 1999 - 2007



Economics for house heating

- Comparison of oil price and geothermal price
- The saving in 1983 was 26 milliard Iskr
- Total saving from 1970-2000 is about 356 milliard Iskr



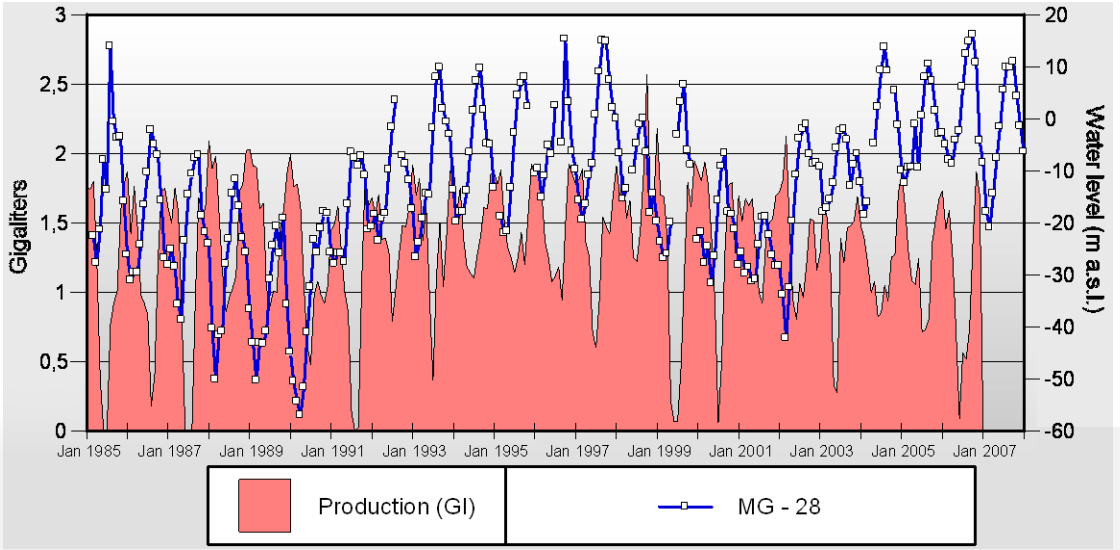


Environmental impact

- Effect of mass withdrawal
  - Changes in surface manifestations
  - Subsidence
  - Induced seismicity
- Visual impact
- Disposal of fluid
  - Water
  - Gas
  - Thermal effect
  - Biological effects
- Noise

Thermal manifestations may disappear

- Surface manifestations may change significantly even though there is no exploitation
- Information on environmental factors in geothermal areas should be available prior to exploitation
- Utilization of geothermal energy call upon monitoring of physical changes
- The thermal springs in Reykjavík have disappeared due to exploitation also the springs at Reykir



Levelling survey

- At the Hengill area levelling survey last 15-20 years
- Prior to 1994 some subsidence could be seen
- Last years increase in land elevation

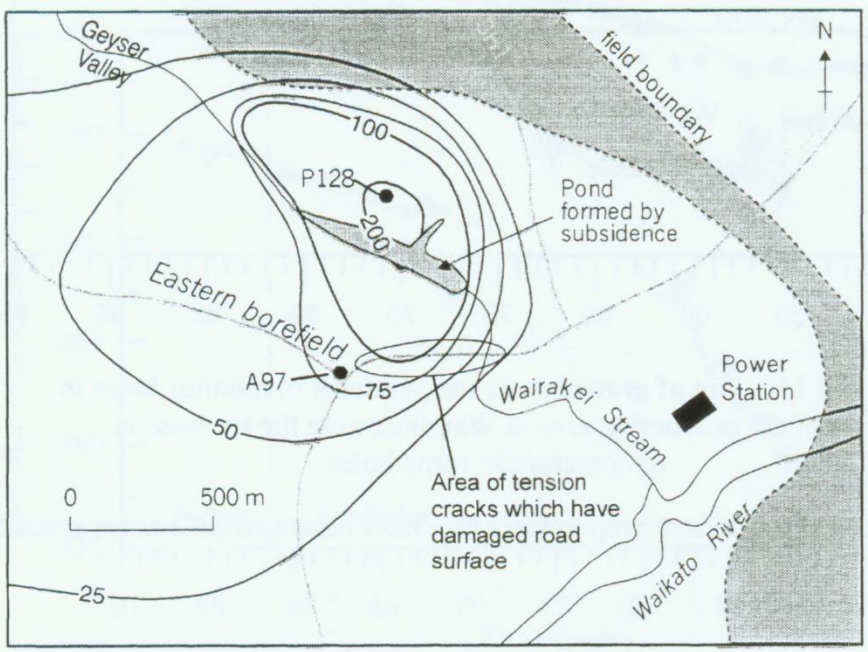
Seismicity

- Increased flow can increase seismic activity
- Injection can cause seismicity
- Seismicity can locate fractures and faults

Distinguish between natural seismicity and seismicity caused by exploitation

Subsidence in Wairakei

- Detected 1956
- Now about 16 m
- In 2050 predicted 20 m
- 6 m deep pound formed
- Tree have been flooded
- Damage of casings
- Damage of pipelines
- Damage of nearby highway



Increased steam flow

Water dominated geothermal systems that rely on the flow of steam - characterized by steaming ground, acid sulphate springs and fumaroles often show:

- Increasing activity
- Decreasing pressure in the reservoir cause increase of steam flow which has high mobility
  - Increased steam pressure may led to hydrothermal explosion - forming large craters
- Further exploitation steam reaching the surface slowly declines

Visual impact

- All energy plants have some visual effect
- Drill holes, pipelines and power plants are the most significant signs of geothermal energy production
- The area of activity is relatively small
  - design of pipelines follow landscape
  - power plants can have an architectural form that has low effect on landscape or can be hidden in the landscape
  - Reduce drill platform

Strategic planning

- To minimize visual effect

- Drilling platforms
- Pipes
- Roads
- Buildings
- Land reconstruction

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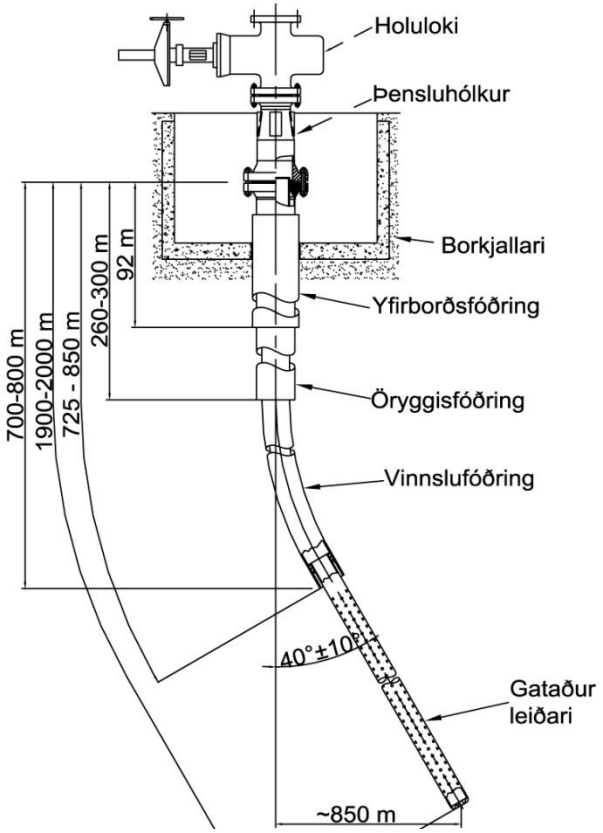

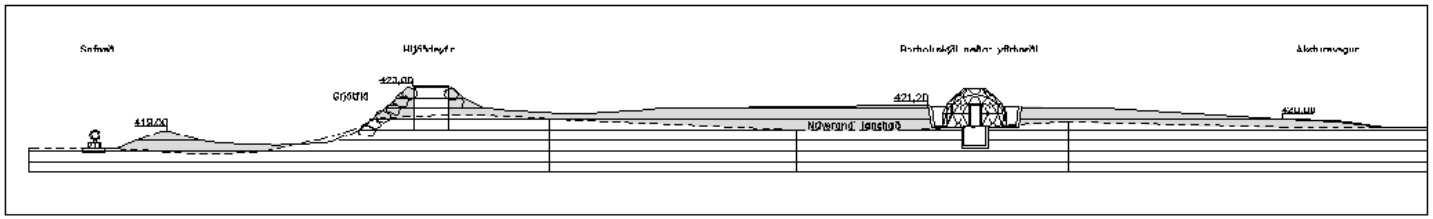

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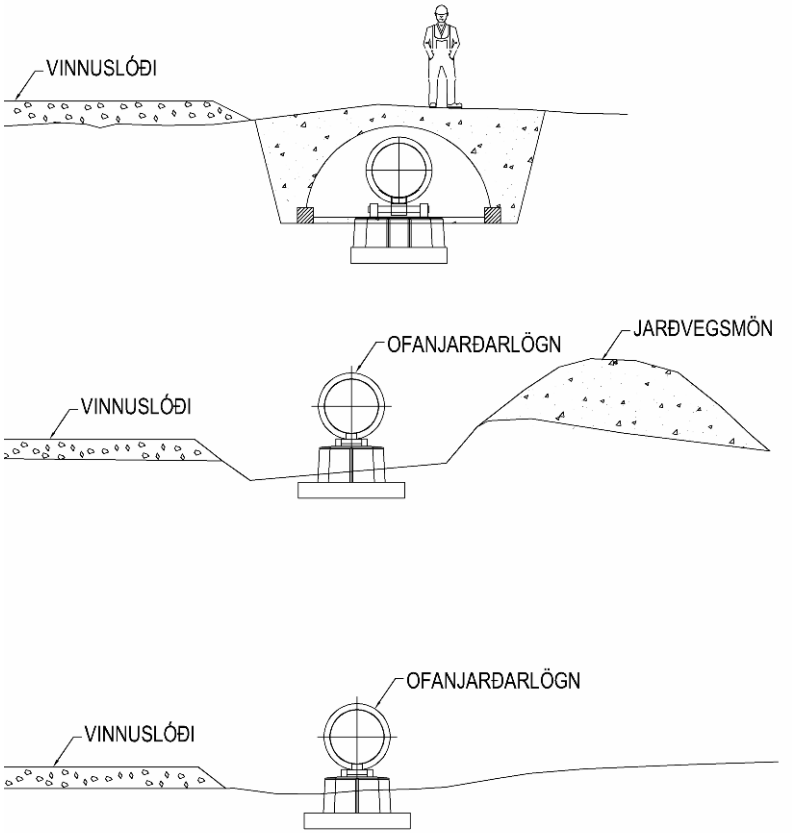

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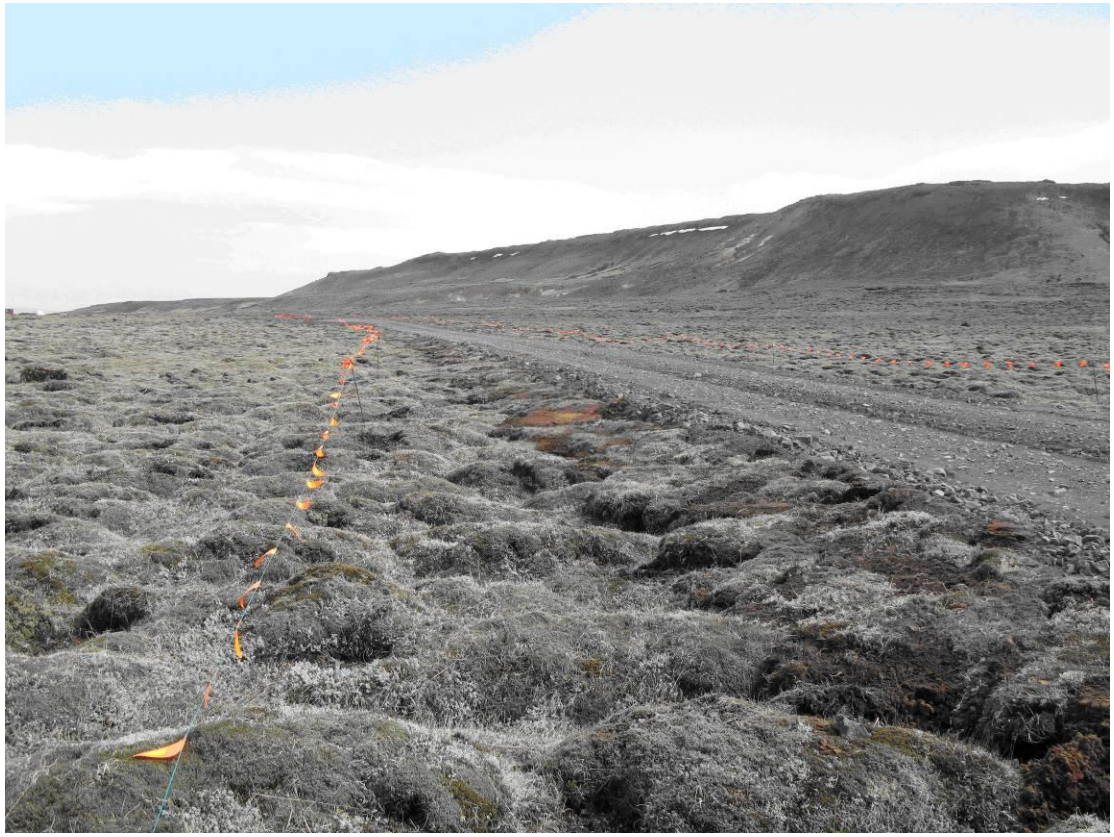

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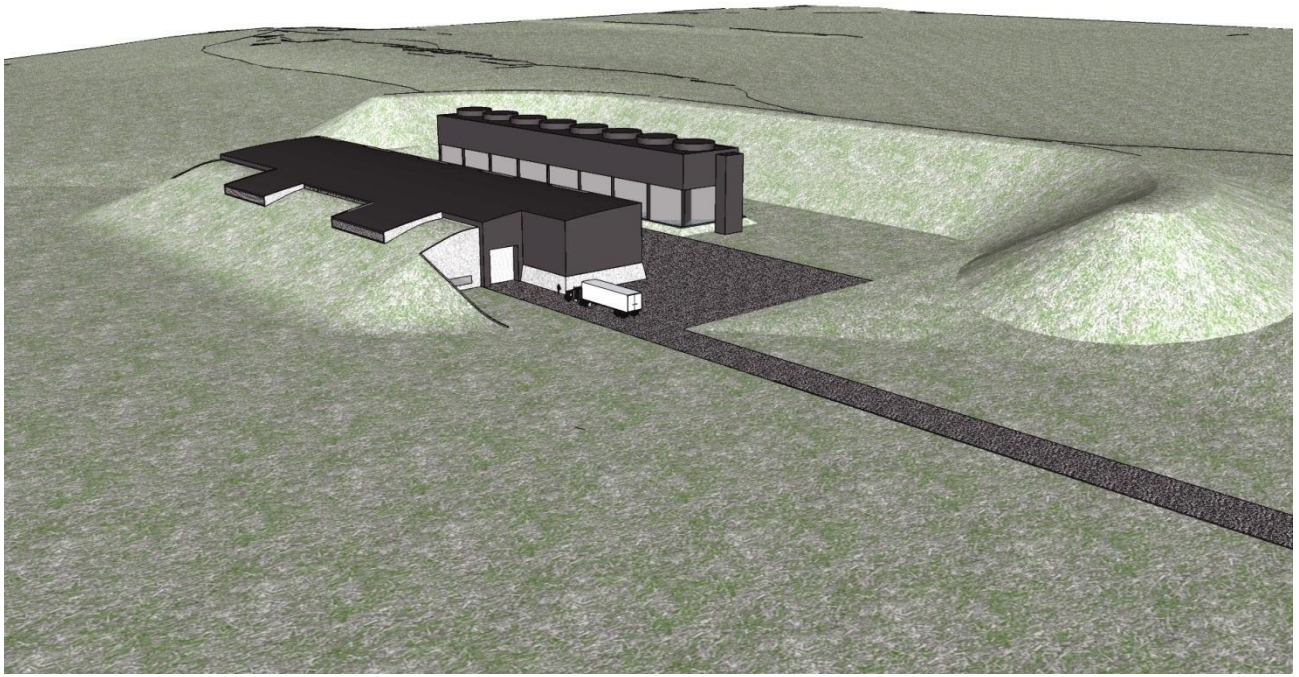

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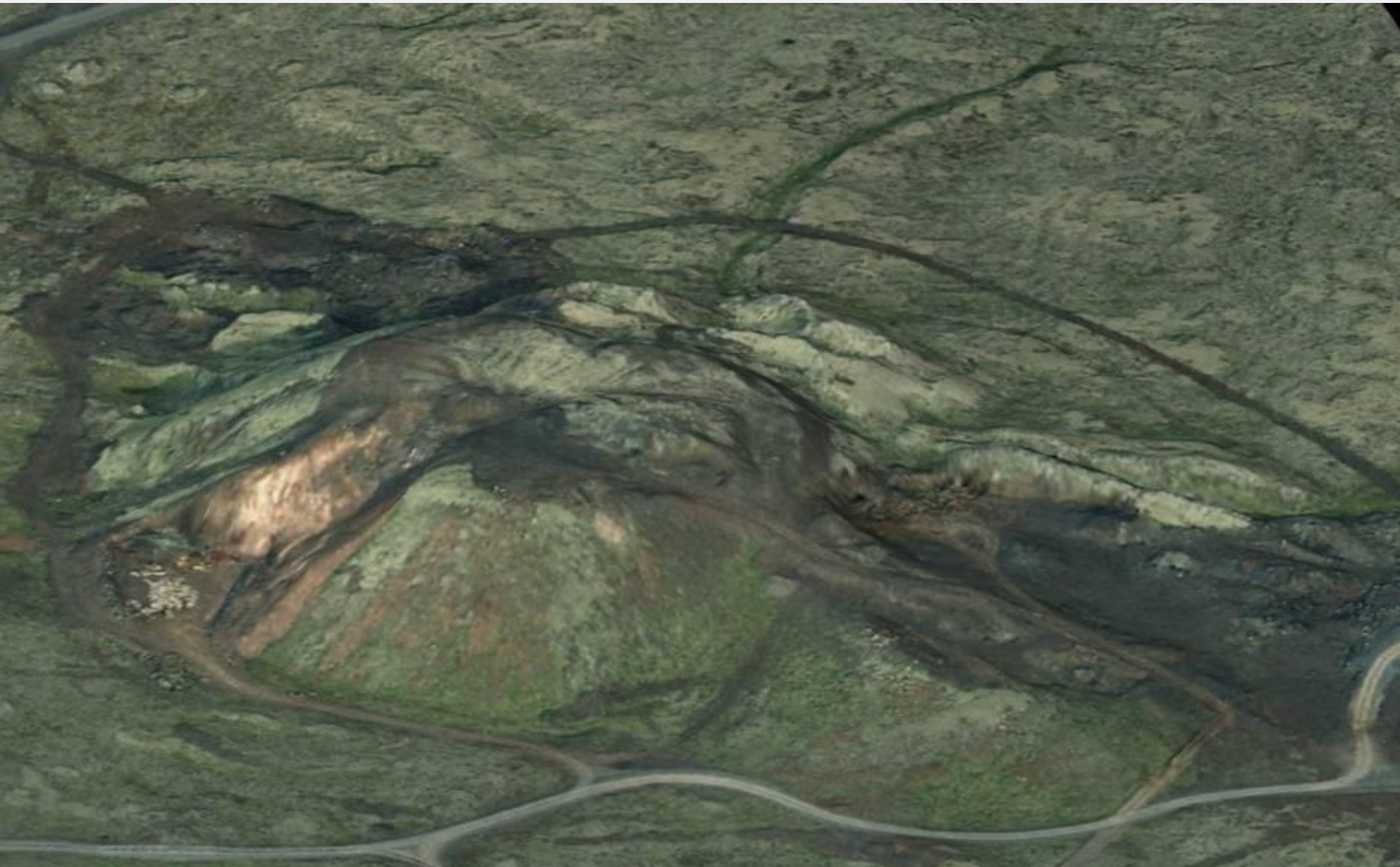
Gígahnjúkur



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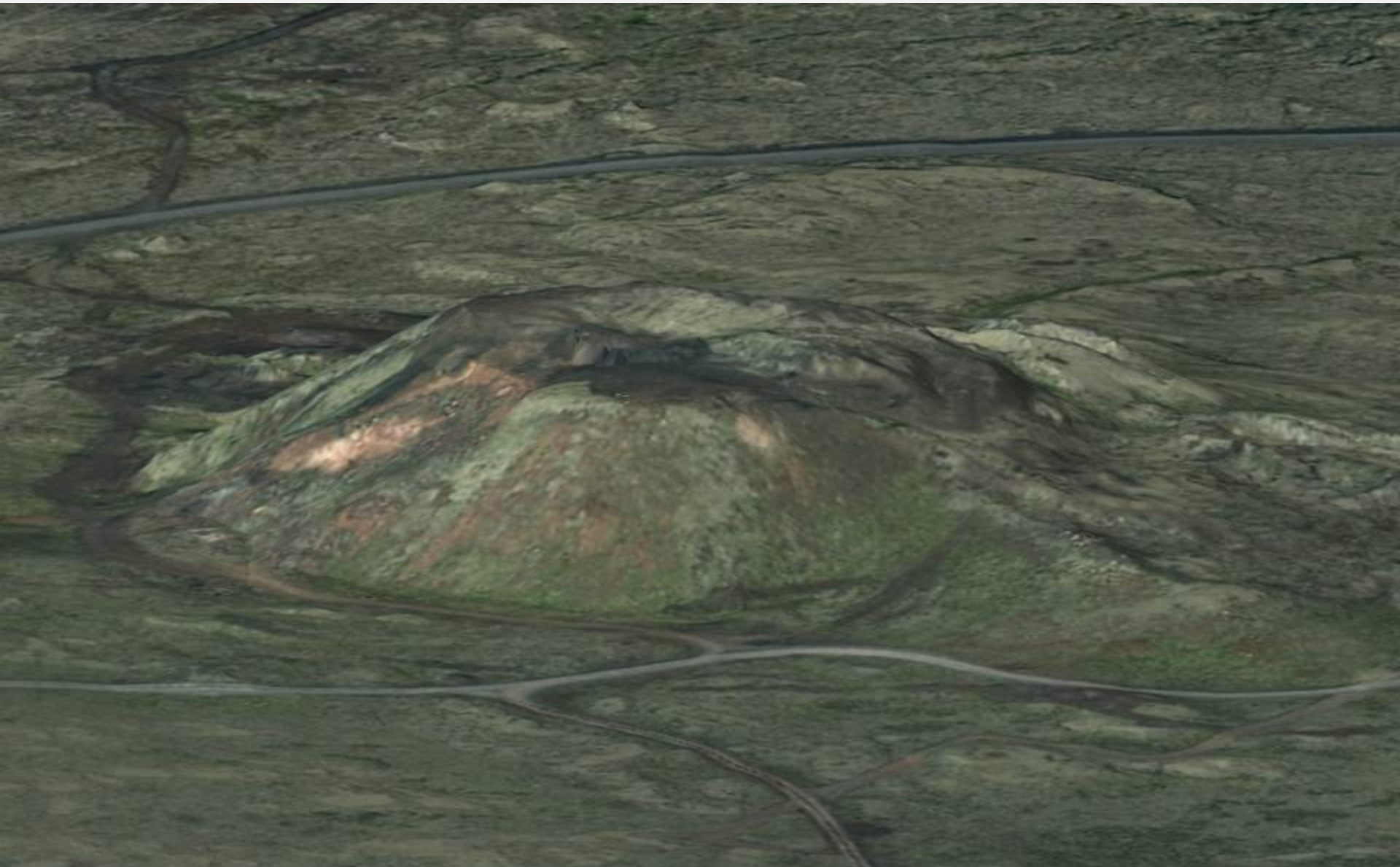
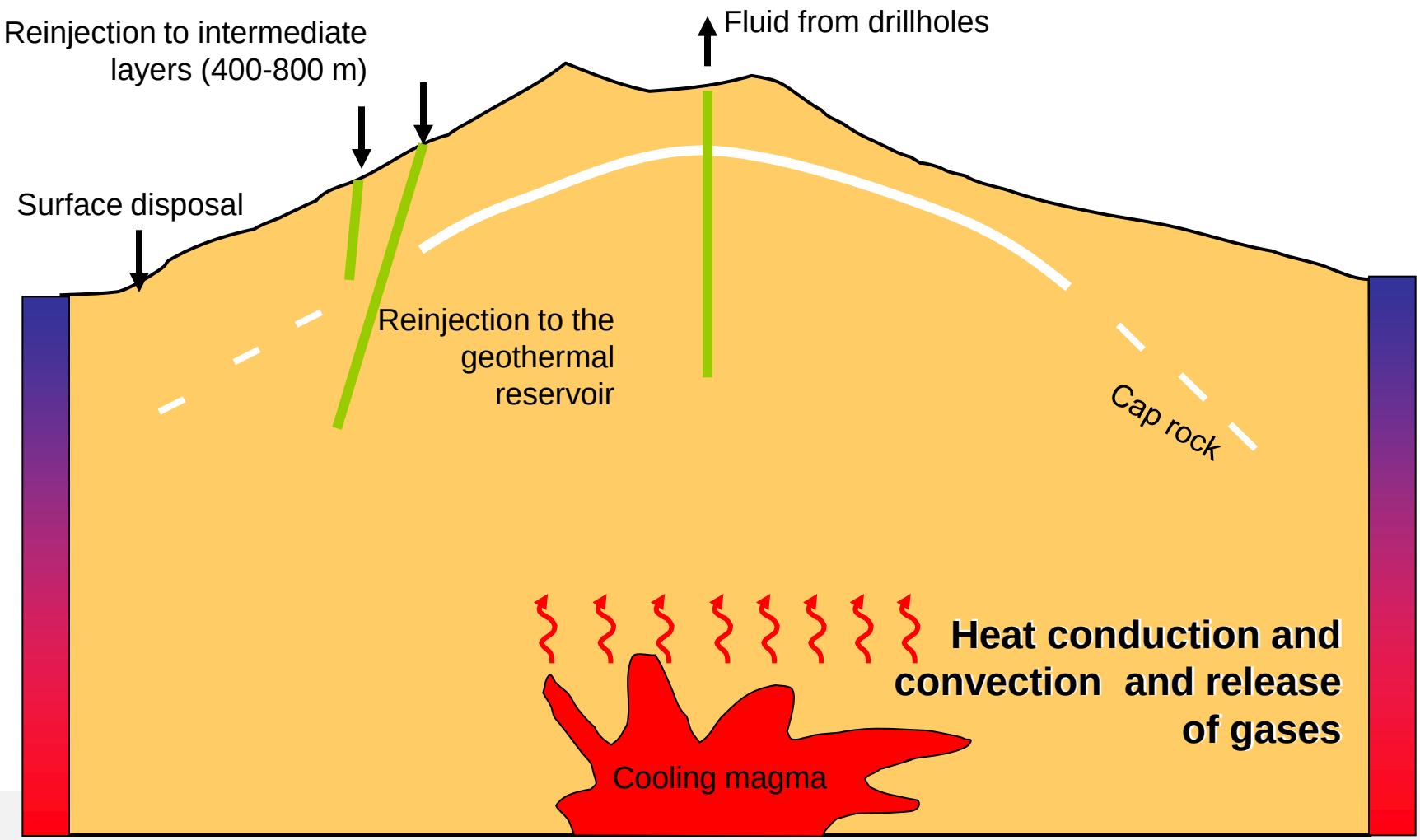


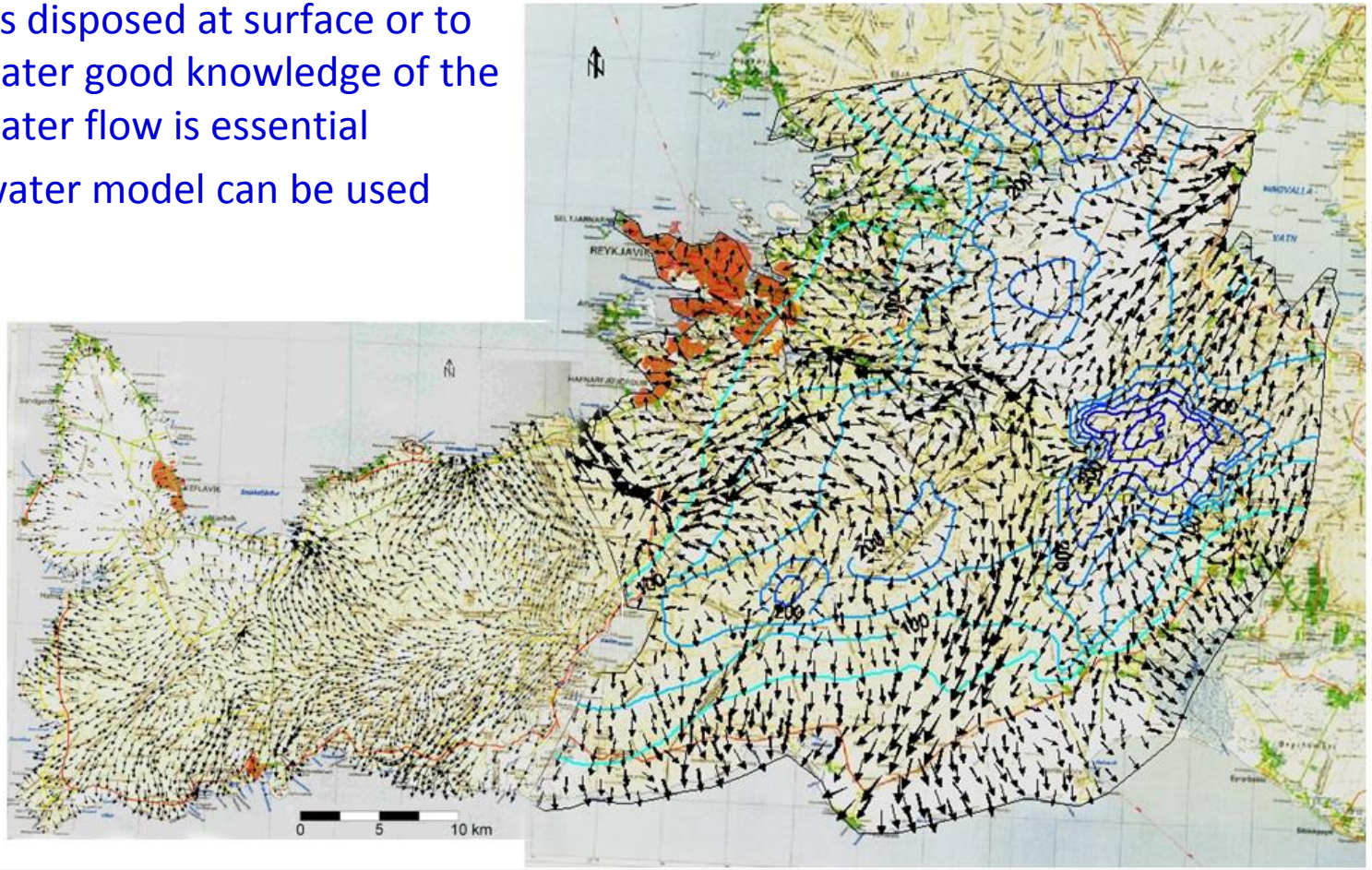
Re-vegetation

Disposal of water



Disposal to the groundwater

- If water is disposed at surface or to groundwater good knowledge of the groundwater flow is essential
- Groundwater model can be used



Biology

Important to collect “baseline biological data”

- The impact depends on
  - dilution of contaminant
  - dispersion
  - chemical speciation
  - heat

Monitoring should preferably be performed at the same time of the year, and under similar physical and chemical conditions

Heat

- Utilization of geothermal energy may led to waste of heat through the effluent - affects local biota.
- In vapour dominated geothermal fields waste heat can be discharged to the atmosphere - affect local climate.
- Many countries have regulations on changes in temperature during development.

Air pollution

High temperature geothermal steam does contain gases such as

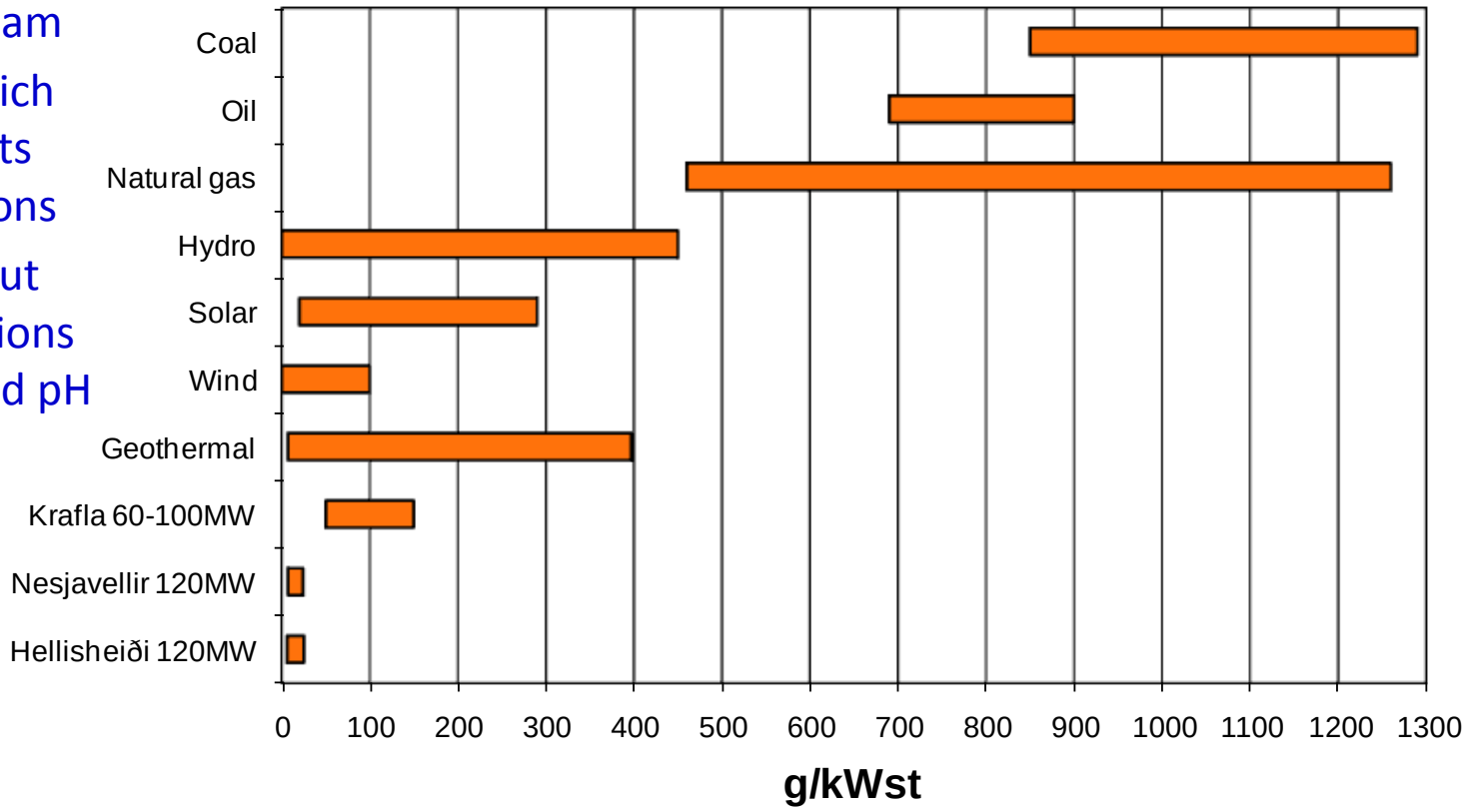
- Carbon dioxide CO_2
- Hydrogen sulphide H_2S
- Methane CH_4
- Hydrogen H_2
- Nitrogen N_2

Sometime tracers of:

- Mercury
- Ammonia
- Arsenic
- Boron

Carbon dioxide CO_2

- Carbon dioxide is the main gas component in geothermal steam
- It is heavy gas which accumulates in pits and low depressions
- Not highly toxic but larger concentrations will alter the blood pH

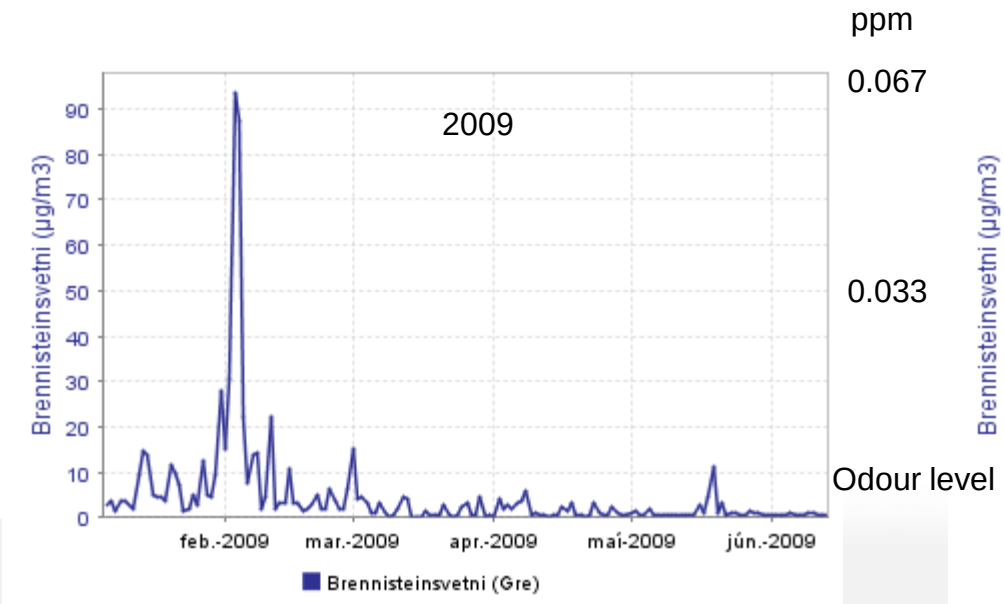


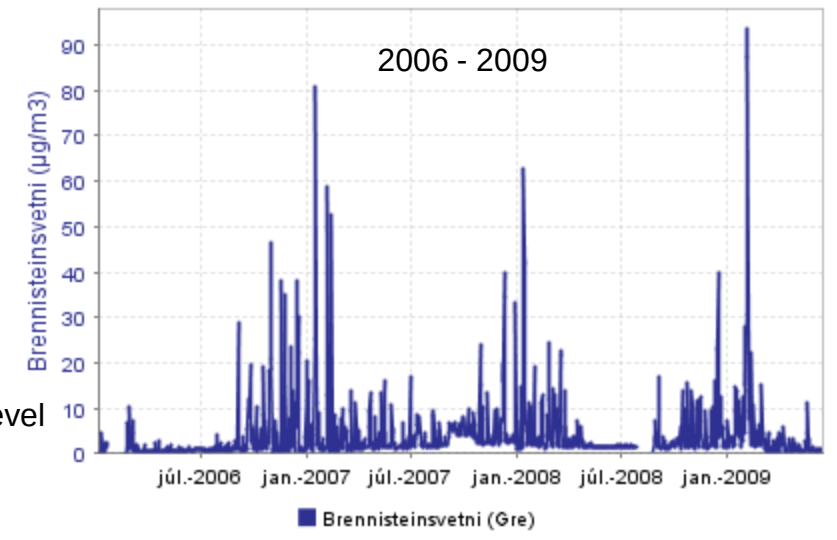
Hydrogen sulphide in the atmosphere

- Measurements in geothermal areas 0-0.5 ppm
- Detection of odour
  - in general 0.005 ppm
- Odour sensitivity decrease at 0.07 to 0.7 ppm

- Human level is 10 ppm for 8 hour working day
- Maximum 15 ppm on average in 15 minutes.

Smell of H_2S from geothermal power plants is easily found in Reykjavík during calm cold weather conditions





Noise levels

130	Jet takeoff at 60 m	Intolerable
125	Well discharge	
120	Threshold of pain at 1000 Hz Free venting well at 8 m	
110	Drilling with air 8 m	Very noisy
100	Unmuffled diesel truck at 15 m	
95	Loud motorcycle at 15 m	
90	Construction site Well vented to rock muffler	
85	Office with typewriter Bleed line not muffled	Noisy
80	Office with geologist Mud drilling	
70	Loud radio Outside generation building 8 m	
65	Normal speech at 3 m	
60	Accounting office	
45	Office with reservoir engineers	Quiet
40	Residential area at night	
30		
25	Broadcasting studio	Very quiet
5		
0	Threshold of hearing	

Noise

- Noise specific to geothermal development
  - drilling noise - rarely exceeds 90 db
  - noise from discharge of drill hole may exceed 120 db, the pain threshold at 2-4000 Hz
- Using cylindrical type silencers the noise can by brought down to about 85 db.

Summary

- One of the cleanest energy sources
- CO_2 saving in Reykjavík about 100,000,000 tonnes, yearly similar as total CO_2 emission from Iceland
- Geothermal utilization may:
  - Change natural thermal activity
- Design has to take into account:
  - Visual impact
  - Disposal of water and gas
  - Noise

Thank you