# Environmental issues
# WP4 D4.2

| | |
|---|---|
| N° of work package: 4 | Regulatory, social and environmental conditions |
| WP leader | BRGM |

**4.2 Environmental issues, emissions**

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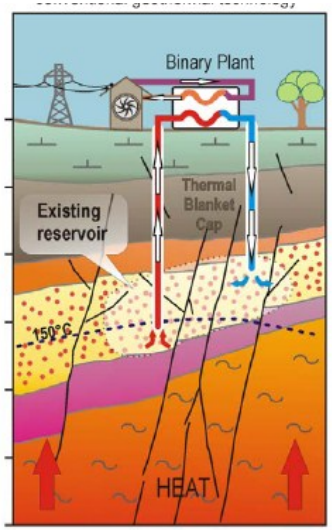
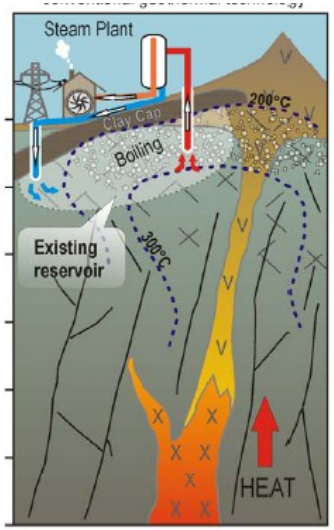
# Geothermal systems-three types

- Geothermal facilities using flash-steam techniques for exploiting high enthalpy resources
- Geothermal facilities using binary cycles
- Enhanced Geothermal Systems (EGS)

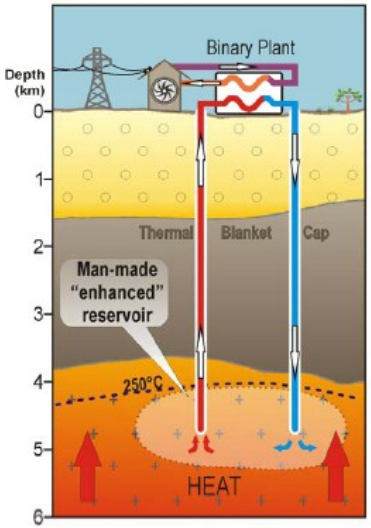
hot sedimentary aquifer




Magmatic play




hot rock play

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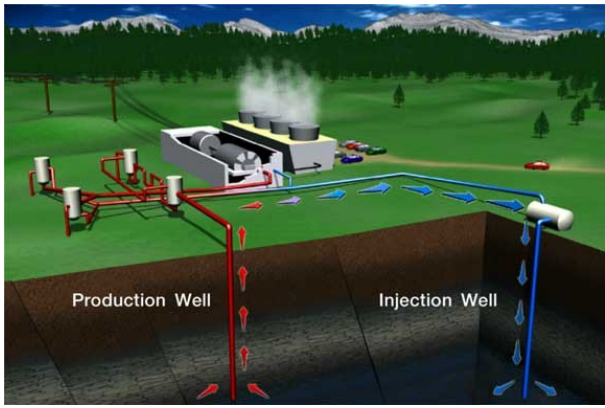
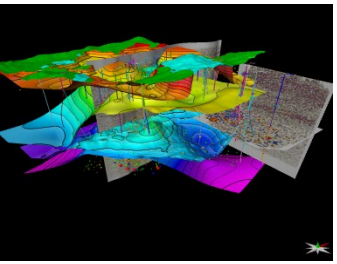
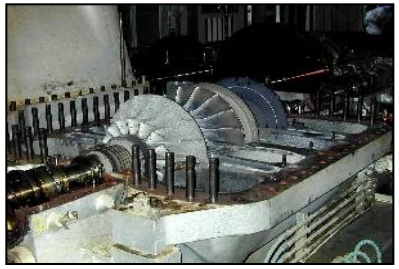
# EIA - ENVIRONMENTAL IMPACT ASSESSMENT

**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.




**RESOURCE ASSESSMENT** → **WELL DRILLING AND TESTING** → **POWER SYSTEM DESISGN AND CONSTRUCTION** → **OPERATION AND MAINTENENCE** → **DECOMMISIONING**




**Environmental impact assessment, mitigation and monitoring**

Each stage of geothermal development might generate environmental effects, especially with regard to air and water pollution, noise, land use, and impacts on the aesthetic qualities of the landscape.

**In regions with geothermal potential can be also considered social and economic effects**

# Environmental impacts-main categories

1. Surface disturbances
   - Landscape, surface water
2. Physical effects
   - Land subsidence, induced seismicity, visual effect
3. Noise
4. Thermal pollution
   - Hot liquid and steam release
5. Chemical pollution
   - Solid waste, gaseous emission to the atmosphere
6. Ecological protection
   - Flora and fauna

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# Activities causing environmental impacts

- Building of access roads and drilling pads
- Well drilling, repairs, stimulation and testing phase
- Laying of pipelines, electric power transformation and transmission lines
- Plant construction and equipment installation
- Power plant commissioning and operation
- Decommissioning of facilities

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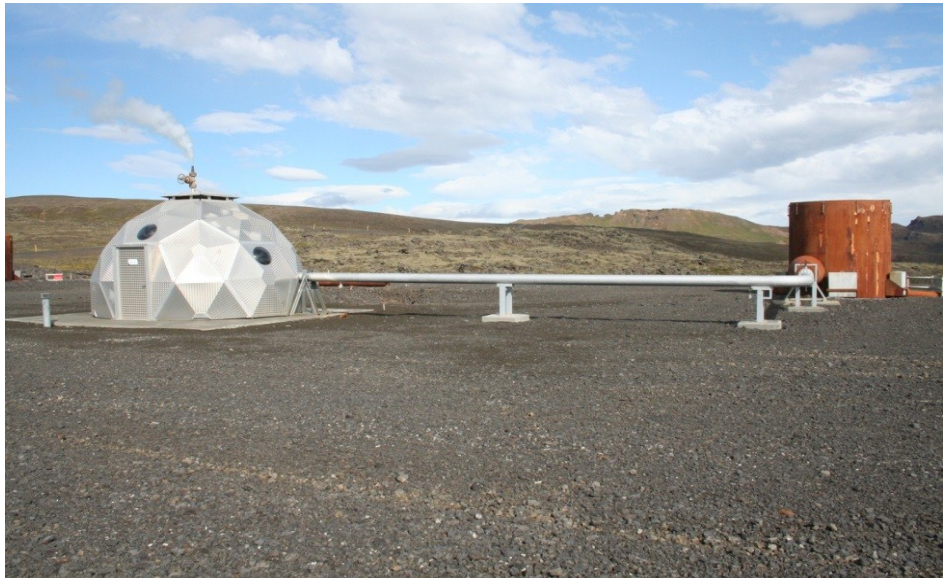
# Access roads, pipe laying

**Predominant environmental concerns:**

- Surface disturbance
- Visual impact
- Disposal of waste



Enclosed wellhead connected to a muffler

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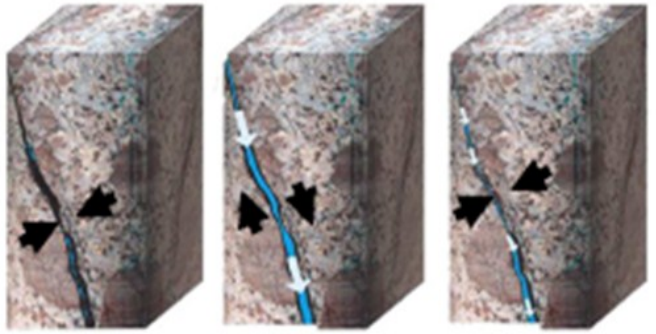
# Well drilling, repair, stimulation and testing phases

**Predominant environmental concerns:**

- Liquid and liquid carried pollutant release
- Environmental impact of stimulation
- Noise and vibration
- Induced seismicity and seismic hazards
- Surface release of geothermal fluid
- Surface disturbances
- Visual impact

**Holding pond in Hungary**

**Hydraulic stimulation**



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# Plant construction and equipment installation

**Predominant environmental concerns:**

- Surface disturbances
- Noise
- Visual impact
- Disposal of waste

**Nesjavellir flash power plant in Iceland**

**Bruchsal binary cycle power plant in Germany**


Ref.: Google Maps 2011

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# Power plant commissioning and operation

## Predominant environmental concerns are:

- Emission and injection of geothermal fluids
- Emission of geothermal gases
- Noise

Gaseous emission from various power plants

| Plant type | $CO_2$ Kg/MWh | $SO_2$ kg/MWh | $NO_x$ kg/MWh | Particulates kg/MWh |
|---|---|---|---|---|
| Coal-fired | 994 | 4.71 | 1.955 | 1.012 |
| Oil-fired | 758 | 5.44 | 1.814 | N.A |
| Gas-fired | 550 | 0.0998 | 1.343 | 0.0635 |
| Geothermal-flash steam, liquid dominated (USA) | 27.2 | 0.1588 | 0 | 0 |
| Geothermal-The Geysers dry steam field (USA) | 40.3 | 0.000098 | 0.000458 | negligible |
| Geothermal-closed binary/EGS | 0 | 0 | 0 | negligible |
| Geothermal-flash steam Hellisheidi-(Iceland) | 21.6 | 17.6 | 0 | 0 |
| Geothermal-flash steam – Tuscany (Italy) | 324 | 1.65 | - | - |
| Average. All European plants | 369.7 | 1.1 | 0.5 | 0.1 |

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# Example of landscaping

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# Decommissioning of facilities

**Predominant environmental concerns:**

- Chemical pollution and disposal of hazardous and other waste
- Surface disruption

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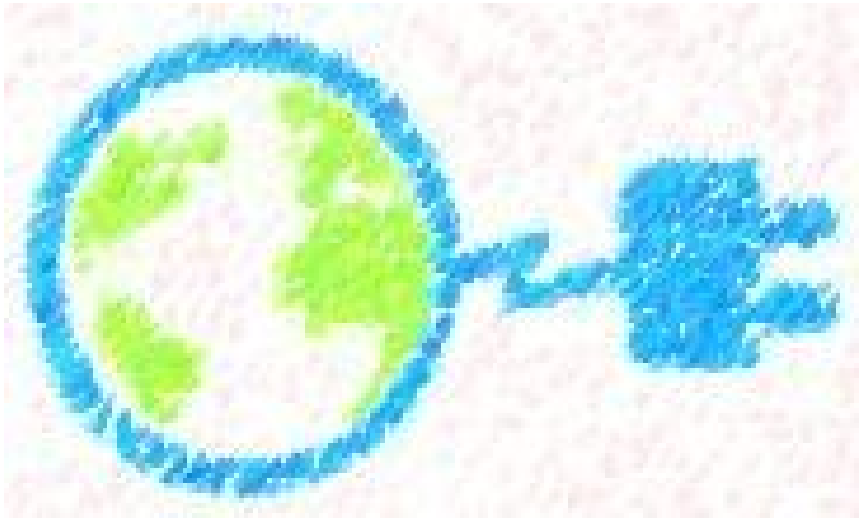
# Environmental impacts and mitigation measures

| Development stages | Impacts to be considered | Possible mitigation measures |
|---|---|---|
| **Access roads, pipe laying** | **Surface disturbance, disposal of waste and visual impact.**<br><br>**Except for the visual impact, these effects are mostly temporary** | **To avoid ecologically sensitive areas, locations of historical value and natural beauty**.<br><br>**To minimize visual impact of the wellheads, it is recommended that each wellhead should be enclosed in a small building of a design that falls well in with the surroundings.** |
| **Well repair, well stimulation, well drilling and testing phase** | **Liquid and liquid carried pollutant release noise and vibration, induced seismicity, solid waste, surface release of geothermal fluid, surface disturbance and visual impact.** | **To select only contractor(s) that have good environmental record. State in contract requirements on special waste ponds**.<br><br>**To apply hearing protections. Noise barriers will need to be erected if residential areas are being affected**.<br><br>**To avoid ecologically sensitive areas where possible**.<br><br>Prior to EGS activities, the Project Owner will need **to implement the Protocol for Induced Seismicity Associated with Geothermal Systems.** |

# Environmental impacts and mitigation measures

| | | |
|---|---|---|
| **Plant construction and equipment installation** | **Surface disturbance**, **noise**, **visual impact and disposal of waste**. | The impact can be minimized through **careful siting of the plant, avoiding ecologically and historically sensitive areas**.<br><br>To minimize visual impact it is important **to apply good architectural principles in the design and layout of facilities.** |
| **Power plant commissioning and operation** | **Emission and injection of geothermal fluids, gases and noise.**<br>Air emission from binary plants is minimal but flash plants for conventional use, emit some amount of hydrogen sulfide ($H_2S$) and carbon dioxide ($CO_2$). | To minimize the number of hazardous substances in the geothermal fluid return stream **it is recommended to consider thermodynamic scaling control rather than inhibitors where possible**.<br><br>For mitigation of emission of $H_2S$ from flash geothermal power plants it is important **to monitor the release and apply appropriate measures if emission numbers are above environmental limits.**<br><br>**Ventilation** should be applied to avoid gases in confined spaces.<br><br>In terms of mitigation for noise, adequate **ear protectors** should always be made available to the staff. |
| **Decommissioning of facilities** | The predominant environmental concerns encountered during the decommissioning phase are **chemical pollution and disposal of hazardous and other waste** and **surface disruption**. | **In general proper care should be taken when disposing of chemicals, during cleaning up of equipment and in landscaping during this project phase.** |



**Thank You!**

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# Geothermal systems-three types

***Geothermal facilities using flash--steam techniques for exploiting high enthalpy resources***: relying on natural aquifer and fracture permeability. These facilities generally produce from very high temperatures at shallow depth (150°--300°) and release geothermal steam to the atmosphere.

***Geothermal facilities using binary cycles:*** relying on natural aquifer and fracture permeability. It is generally used for lower enthalpy and can operate in a closed system where the geothermal fluid is injected into the ground.

***Enhanced Geothermal Systems (EGS):*** an Enhanced Geothermal System is an underground reservoir that has been created or improved artificially. EGS are mainly located in regions of elevated temperatures (caused by radiogenic heat production, elevated tectonic heat flow, or vertical heat advection through deep fault zones). EGS is typically situated in basement rock marked by relatively low natural permeability. The specific characteristics of the EGS are mainly connected to the enhancement of natural permeability. EGS geothermal power plants operating in a closed system where the geothermal fluid is reinjected into the ground have minimal emissions.

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