Geothermal environmental factors and mitigation

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Synthesis of environmental factors: Objectives

- An up-to-date critical review on how environmental factors influence public's support on implementation of geothermal project.
- The review has identified relevant sources from:
  - academic literature
  - ongoing and previous projects and
  - online sources and reports
  - industry and innovation reports
- Overall potential environmental risks in deep/shallow geothermal systems – it is not implied that a geothermal project shall present all these risks!

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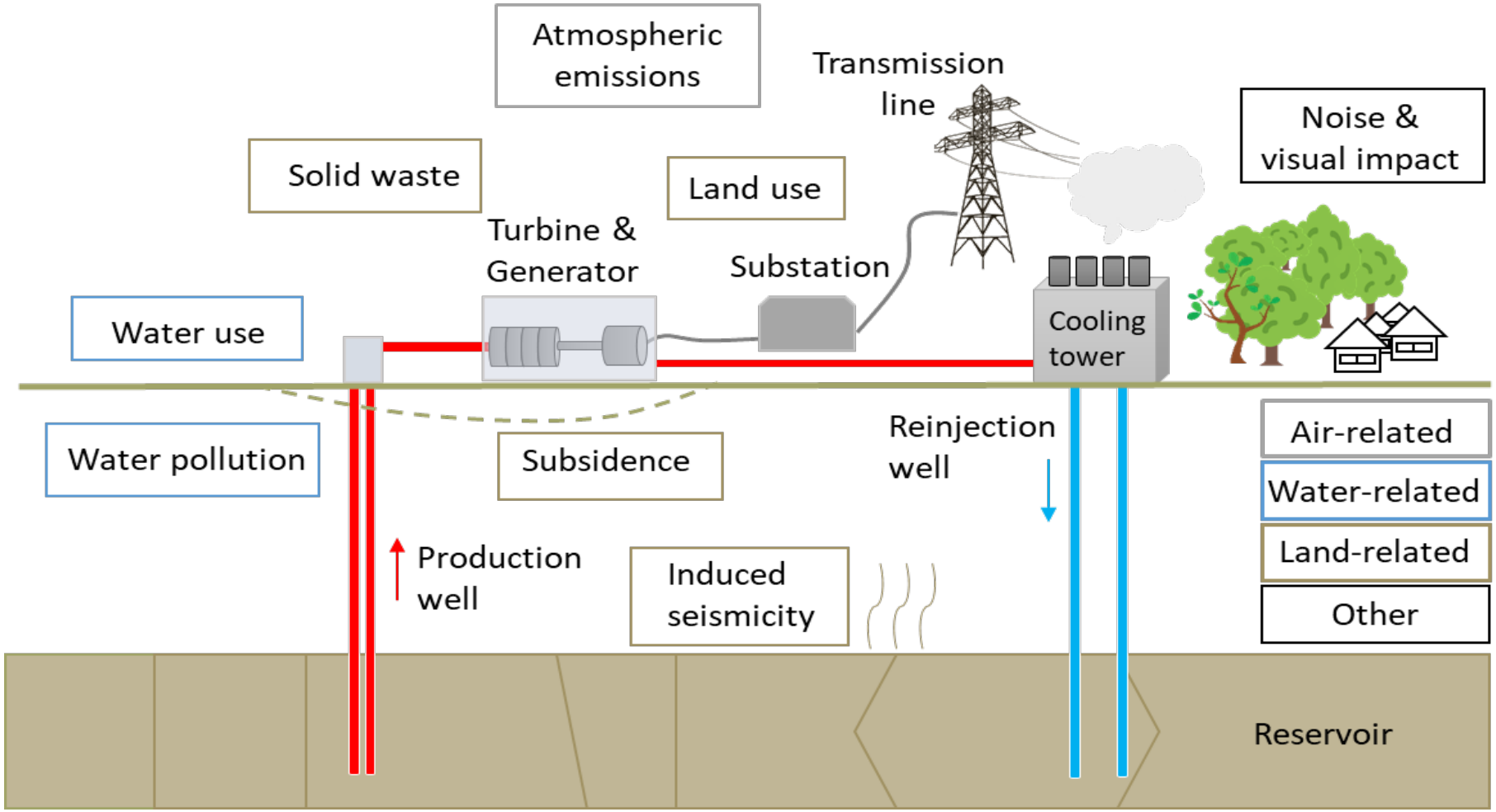
Overview of environmental risks



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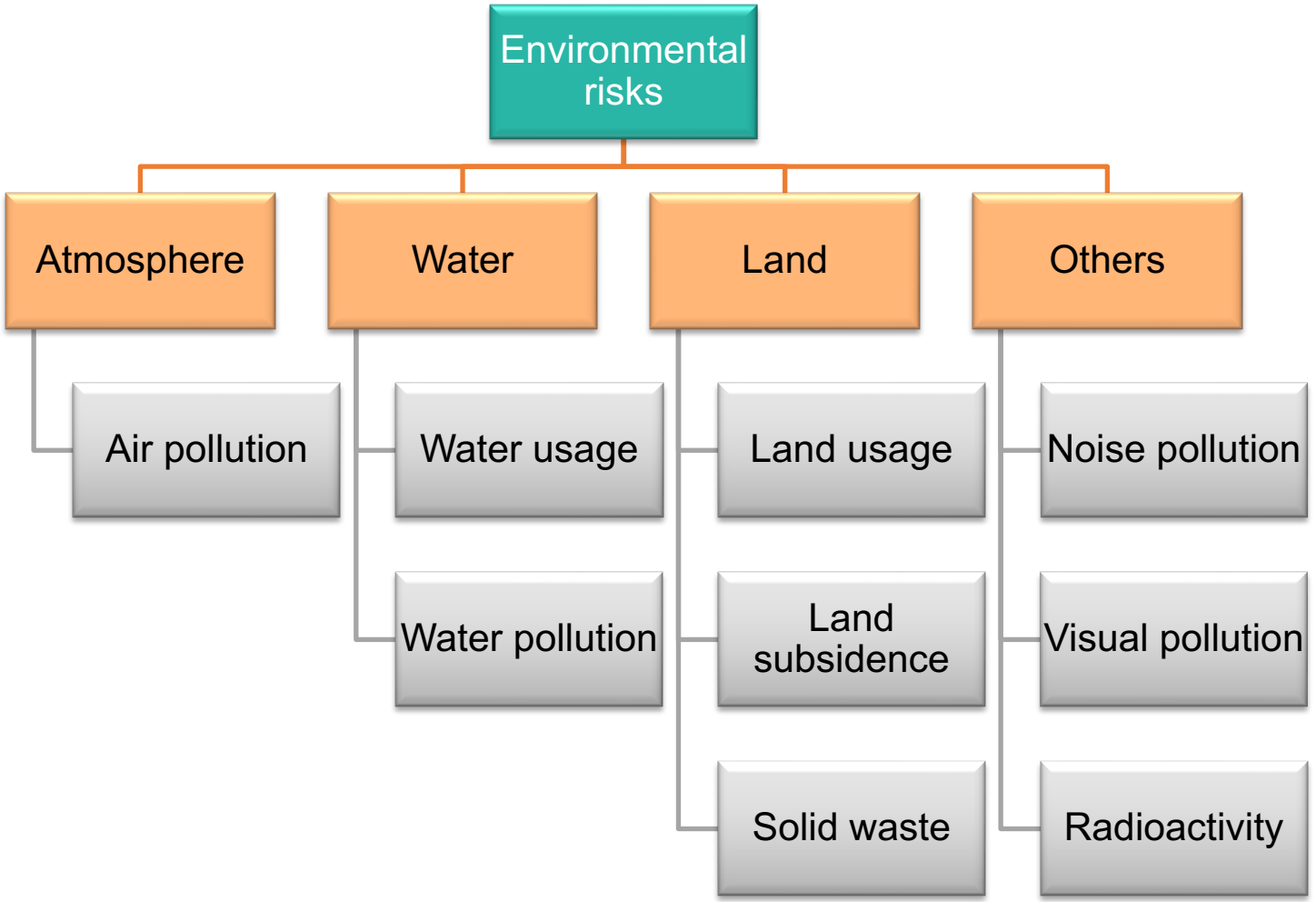
Classification of environmental factors



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Most relevant project phases

Drilling

- Construction of the 1st full-size production/ injection well
- subsequent resource development (i.e. drilling of the second well in case of a doublet)

Construction

- Building the actual geothermal plant, facilities and wells
- connection to the grid or district heating system
- testing the well

Operation

- Commissioning and operation of the plant
- electricity generation/ heating/ cooling
- maintenance & monitoring

Decommissioning & Post-Closure

- Field rehabilitation
- site closure, well plugging
- monitoring for potential releases from abandoned wells

*introduced in ANNEX I of the CROWTHERMAL D5.1 Case Study Assessment Protocol

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Results: Deep geothermal systems

Type	Drilling	Construction	Operation	Decommissioning & Post-Closure	Indicative mitigation measures
Deep geothermal systems	- Degassing (NCGs: CO_2, H_2S, NH_3, CH_4) - Blow-outs - Water use during well drilling - Water use for hydraulic stimulation - Induced seismicity from well stimulation - Land subsidence - Land use for well pads and plant facilities - Production of drilling mud - High noise levels - Visual intrusion - Radioactive scales	- Degassing - Fugitive emissions - Water use for concrete production - Land use for installation of geothermal plant - Normal construction waste (lubricant spill, metallic waste, cement) - Blowing/ air pumping of the well to clean it from cuttings, or other remains - Temporary typical construction noise	- Leakage of organic working fluid from binary plants - Water use in cooling tower - Release of vapour from cooling towers or holding ponds - Intersection of several aquifers, connection of aquifers to surface - Make-up water requirements - Impacts from geothermal energy utilisation (e.g. disappearance of geysers) - Land subsidence/occupation - Hazardous solid waste produced by scaling in the system - Leaks of fluids from tanks temporary storing waste - Visual impact - Noise from cooling towers and generator	- Soil degassing in case the well is not sealed correctly - Chemical pollution from working fluid of binary power plant (risk to egress into the ground). - Ground water contamination due to corrosion of the wells - Unlikely to recover the amount of occupied land to its original form - Disposal of additives - Permanent visual impacts from surface disruptions	- Monitoring amount of gases released from the soil (accumulation chamber method, snowmelt tracks and thermal infrared imagery) - Blowout preventers/expansion vessels - NCG abatement technology - Installation of wells casing and grouting to prevent the groundwater contamination. - Prior to EGS activities, the Project Owner will need to implement the Protocol for Induced Seismicity, traffic light systems - Contractor(s) with good environmental records - Thermodynamic scaling control instead of inhibitors to minimize hazardous substances - Careful sitting to avoid ecologically and historically sensitive areas - Landscape planning - Sound barriers (plantation of trees) - Use of inhibitors to keep the radioactive nuclides in solution
	Atmosphere	Water	Land	Solid waste	Other (noise, radioactivity, noise)

Results: Shallow geothermal systems

Type	Drilling	Construction	Operation	Decommissioning & Post-Closure	Indicative mitigation measures
Shallow Geothermal Systems	- Fugitive emissions - Connection of different aquifer layers or connecting aquifers to surface - Drilling into artesian water leading to flooding of buildings and infrastructure - Land subsidence from drilling and grouting of BHE. - Land use during the drilling process - Uplift of the ground surface due to swelling processes - Well drilling mud and cuttings - High noise levels - Visual intrusion - Radioactive scales	- Water use for concrete production - Land clearance and use - Normal contractor's construction waste - Temporary standard construction noise	- Risk from potential leakage of antifreeze and other compounds could cause groundwater contamination - Changes of soil temperature leading to concentration of microbes to ground water resources - GSHP system leads to local temperature changes in the ground affecting the ecological balance - Solid waste from O&M activities - Urban waste from the personnel - Minor visual pollution	- Corrosion may damage the wells and allow leakage of pollutants into the groundwater - Waste materials: chemical inhibitors, tracer materials, chemical reagents	- Grouting the Borehole Heat Exchangers (BHE), sealing of annulus to avoid contamination /connection of overlapped aquifers - Legislation for installation of geothermal (esp. open loop) systems in drinking water areas - Drill rigs equipped with adequate safety equipment to detect, gas and artesian water outflows, GIS data to assess the risk of artesian groundwater - Proper sealing of the boreholes, through a cement-based backfill to avoid swelling of anhydrites - Important to select only contractor(s) that have good environmental record. State in contract requirements on special waste ponds - Noise barriers to avoid disturbances of residential areas - Careful landscaping during operation - Avoid ecologically sensitive areas

Atmosphere Water Land Solid waste Other (noise, radioactivity, noise)

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Conclusions

- Environmental factors can affect public acceptance of geothermal energy. Distinguishing between actual and perceived environmental risks is challenging in the communication with the public.
- In Europe shallow geothermal systems (mostly GSHP) 66.5%, direct use 26.2% and electricity 7.3% (installed capacity).
- Shallow (and low-enthalpy deep) geothermal systems environmental factors:
  - risk of groundwater contamination
  - land subsidence and deformation
- Deep high-enthalpy geothermal systems
  - Emissions (degassing and blow-out) of NCGs (CO_2, H_2S, NH_3, etc.)
  - Induced seismicity and land subsidence among the major negative acceptance factors
  - Visual impact and increased noise levels
- Future goal of this study is the dissemination of key findings, through the development of the publication on the decision tree.

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Thank you for your attention!

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