Introduction to the Guidelines to perform LCA of geothermal systems

The Italian case study of the Bagnore geothermal power plants as an example of guidelines application.

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GEOENVI

(*) Conceptualized and developed by: **ARMINES** and **CSGI** with contributions from **Electricité Strasbourg** and **VITO** in the framework of the GEOENVI Project

LCA Guidelines for geothermal installations (*)

Motivation

- To offer guidance for **consistency**, **balance** and **quality Life Cycle Assessment** (LCA)
- To enhance the **credibility** of the findings from LCAs on geothermal systems.
- The guidelines cover the **most sensitive aspects** of each step of a LCA applied to geothermal systems.

Beneficiary

- **LCA practitioner** and **geothermal experts**.
- Challenge to produce in **a concise manner** guidelines ready to use for **any type** of geothermal installations fulfilling LCA ISO standards (14040 and 14044).

Objective

- To provide guidance on how to establish the **life cycle inventories (LCI)** of geothermal systems.
- To provide guidance on selection of **life cycle impact assessment (LCIA)** and **impact category indicators**.
- To provide guidance on **how and what to document** regarding the LCA of geothermal energy (electricity, heat or combined systems).

Scope

- LCA results applying these guidelines could contribute to a sustainability assessment of geothermal projects and does not pretend to be exhaustive and exclusive in examining all potential environmental issues.
- LCA could be accompanied by other environmental assessment criteria, which can consider site-dependent matters or whose evaluation involves social or qualitative acceptance.

LCA Guidelines for geothermal installations (30 pages document): table of contents

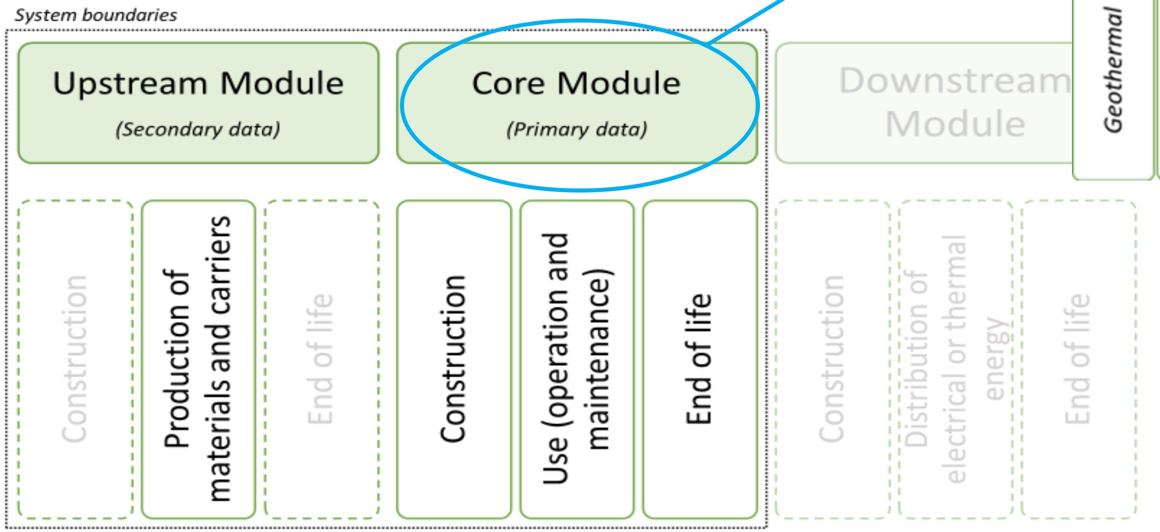
Goal and scope definition

Functional unit

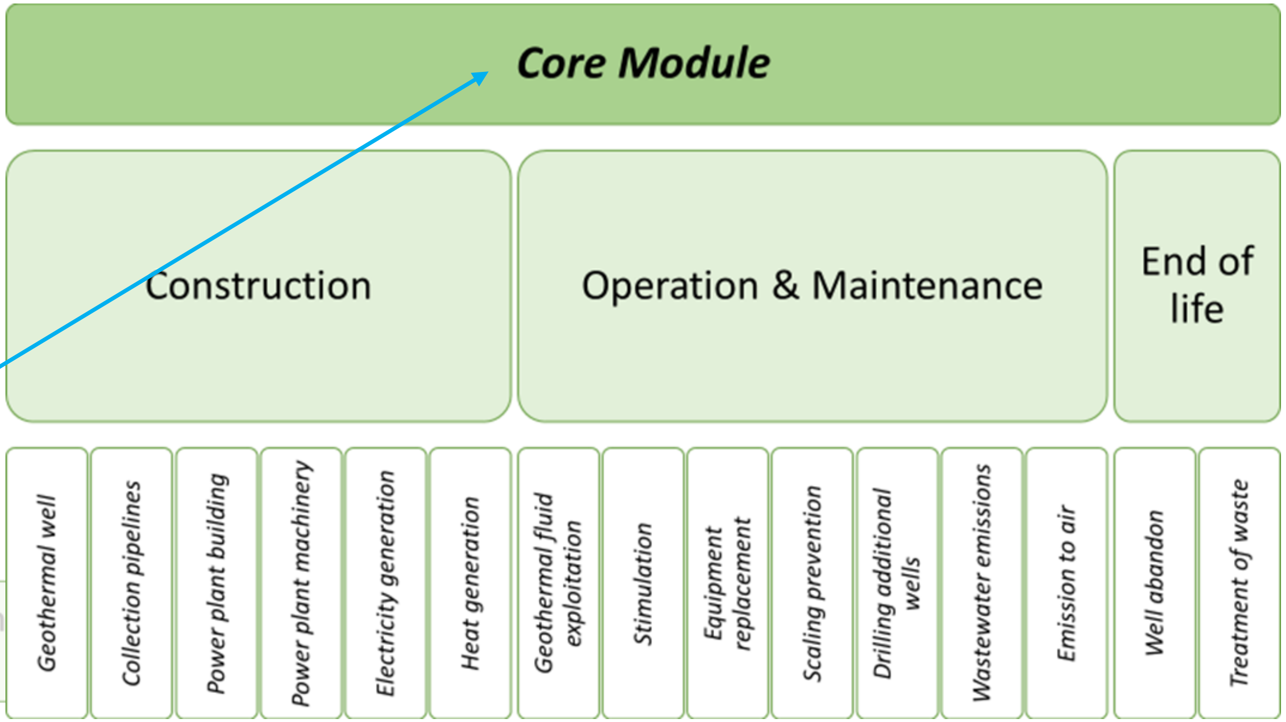
1) Power production only
   - *kWh of electricity delivered to the grid or a user k(Whel)*

2) Heating/cooling production only
   - *kWh of heat delivered to the grid or a user (kWhth)*

3) Multifunctional approach



System boundaries



Lifetime: 30 years (activity of the plant)

Multi-functionality: selection of an appropriate allocation procedure

LCA often deals with multi-purpose processes, having multiple products. In the case of geothermal plants, there is a wide variability among the installations and their power production. Two different allocation schemes can be applied to the wide diversity of geothermal installations

Share between the co-products > 75%

system expansion with a substitution model for the co-products

Share between the co-products < 75%

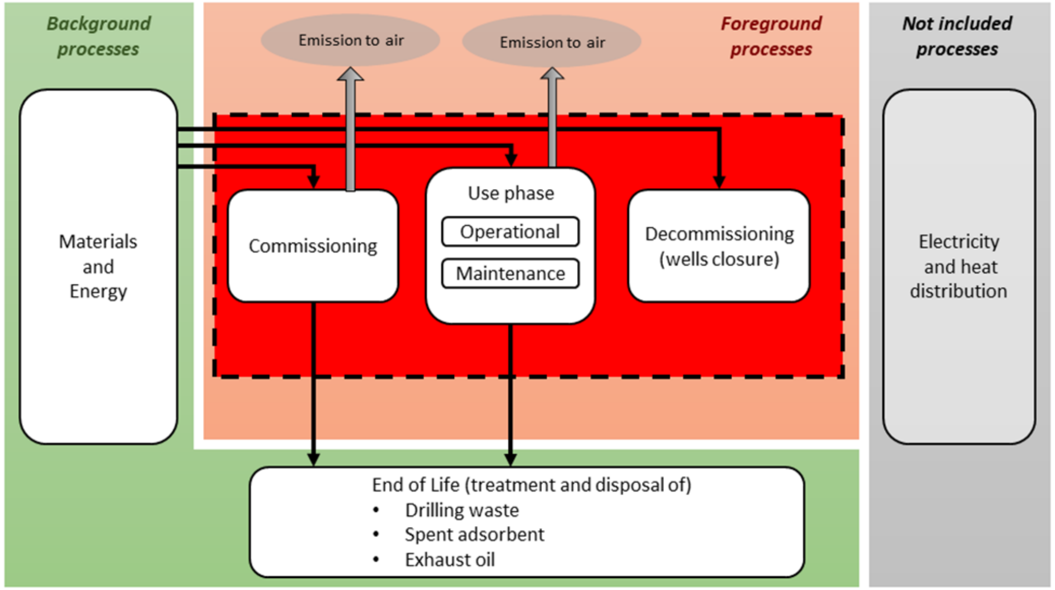
Exergy content (Appendix 1).

Application to the Italian case study

- ***Goal of the study:*** Assessment of the potential environmental impacts associated with the production of electricity from the Italian geothermal power plants of Bagnore 3 and Bagnore 4

- ***Functional unit:*** kWh of net electricity produced over the entire life cycle (30 years).

- ***System boundaries:***
    - LCA phases modelled by Background processes
    - LCA phases modelled by Foreground processes
    - LCA phases not included



Application to the Italian case study

- ***Allocation procedure:*** the exergy takes into account the quality of the two energy products (i.e., electricity and heat) generated by the power plant.

- ***Data representativeness and quality:*** site-specific data have always been used when possible, whereas background data were retrieved from the Ecoinvent database with a preference for specific Italian dataset when available (i.e. for the electricity mix). When not available, average European or global dataset where selected instead.

- ***Main assumptions***
  - All the drilled wells will undergo a closure process when the plant runs out its lifetime.
  - During maintenance a 10% of the steel content of the steam turbine rotor was assumed to be substituted with new steel every four years.
  - Drilling wastes spent mineral oil and sorbent are sent to landfill with no additional treatment.

BAGNORE - EXERGY ALLOCATION FACTORS

Source

EPD UN CPC 171 AND 173

https://www.environdec.com/PCR/Detail/?Pcr=5802

E	5.4E+08	KWh	T_Q	180.3030221
Q	3.2E+07	KWh	*t*	0.861344531
T_s	100	°C		
T_r	60	°C	**αQ**	**0.05**
T_{ref}	25	°C	**αE**	**0.95**

E = electricity produced by the CHP system

Q = heat produced by the CHP system

T_s = supply temperature

T_r = return temperature

T_{ref} = reference temperature

T_Q =mean logaritmich temperature of the heat produced by the CHP

t = exergetic temperature factor

αQ = allocation factor for heat

αE = allocation factor for electricity

Life Cycle Inventory

- Materials and energy requirements to build subsurface, surface infrastructures and equipment/components & drilling of the wells.
- Recommendations on the reporting of the type of direct emissions and receiving compartment (e.g. atmospheric emissions, effluents) are provided for each of these sub-systems.
- Use of primary data is priority, otherwise reference/average values as given in Appendix 2

Materials	Unit	Reference value MIN-MAX (Average)
Steel, unalloyed	*kg/well*	*7 428 (RT)– 17 660 (DO) (13 221)*
Steel, stainless INOX 316 L	*kg/well*	*16 (HL)*
Concrete	*kg/well*	*18 (HL) – 18 520 (BG) (9 269)*
Portland cement	*kg/well*	*13771 (RT) – 259286 (BG) (117686)*
Aluminium	*kg/well*	*1 218 (HL) – 1500 (DO) (1359)*
Iron	*kg/well*	*4 000 (DO) – 8 568 (BG) (6284)*
Excavation	*m^3/well*	*250 (DO) – 6851 (RT) (1940)*
Filling	*m^3/well*	*250 (DO) – 3135 (RT) (1723)*

Default values available in Appendix 2 (Example for wellhead construction)

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Life Cycle Impact Assessment method based on EF V3.0

Impact Category	Unit	Indicator/Method	Version LCIA method	Source LCIA method	Level of priority	Level of robustness
Climate change	*kg CO_2 eq*	*Radiative forcing as Global Warming Potential (GWP100)*	*1.0.5 (land use, land use change, biogenic), 1.0.8 (fossil), 4.0.16*	*IPCC 2013*	*High*	*I*
Ozone depletion	*kg CFC-11 eq*	*Steady-state ozone depletion potential*	*2.0.12*	*WMO 1999*	*Low* *Looking at the study by Chiavetta et al 2011*	*I*
Human toxicity cancer effects	*CTUh*	*Comparative toxic unit for humans as provided in the USEtox 2.1. Factors have been applied on inorganics and metals to account for the fact that USEtox has been designed for organic substances.*	*1.0.3*	*Rosenbaum et al., 2008*	*High* *Interesting to know even though potentially very uncertain*	*III*

LEVEL OF PRIORITY (specific to Geothermal installations) & LEVEL OF ROBUSTNESS (scientifically ground)

Additionally covered aspects in the Guidelines

Reporting Inorganic emission with toxicity impacts

- *As, B, Ar, Hg, Rn, Sb, H_2S*

Additional indicators PES , Energy Pay-Back Time

Reporting & Communication section

- *Methodological setting*
- *Parameter choices*
- *LCI details and assumptions*
- *Indication on what should be reported in figure and table captures*
- *…..*

Thank you for your attention

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