LCA guidelines for geothermal installations

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CIRCULAR

ORKUSTOFNUN
National Energy Authority

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GEOENVI Project

Tackling the environmental concerns for deploying geothermal energy in Europe

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2 / *A wide diversity of geothermal energy exploitation impacts*

Acoustic effects (noise pollution during drilling, construction and operations)

Thermal effects (thermal pollution, release of vapor into the air, heating and cooling of the soil due to the extraction or reinjection of fluids)

Visual /surface effects (land use, biodiversity disturbance)

Physical effects (induced seismicity and landslides, micro-seismicity, soil subsidence, geological risk, depletion of groundwater resources, natural radioactivity)

Chemical effects (emissions into the atmosphere, non-condensable gases, reinjection of fluids, discharge of liquid and solid substances)

Click the following link for **more details on environmental risks and impacts** related to geothermal installations:
https://geoenvi.brgm.fr/

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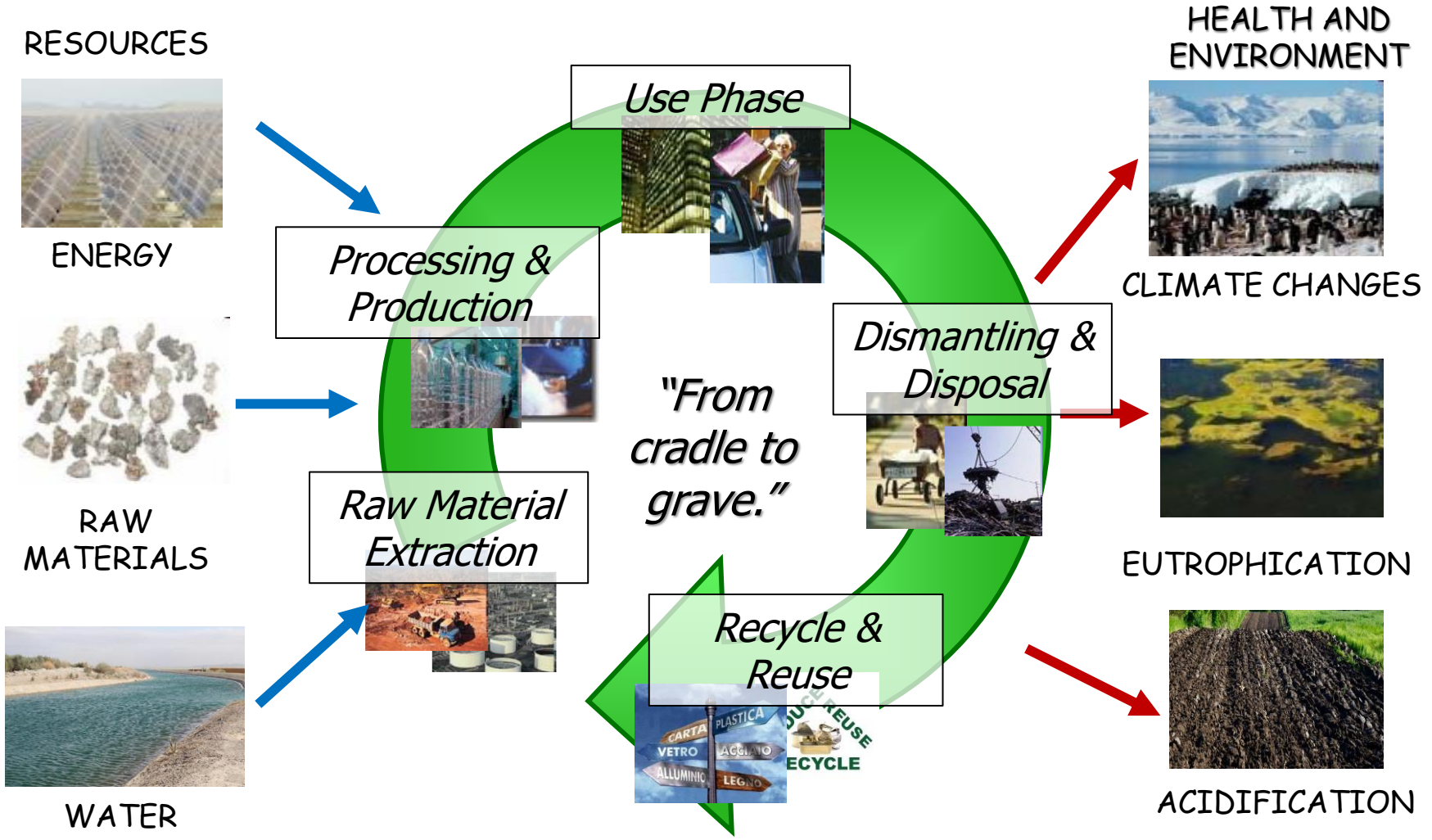
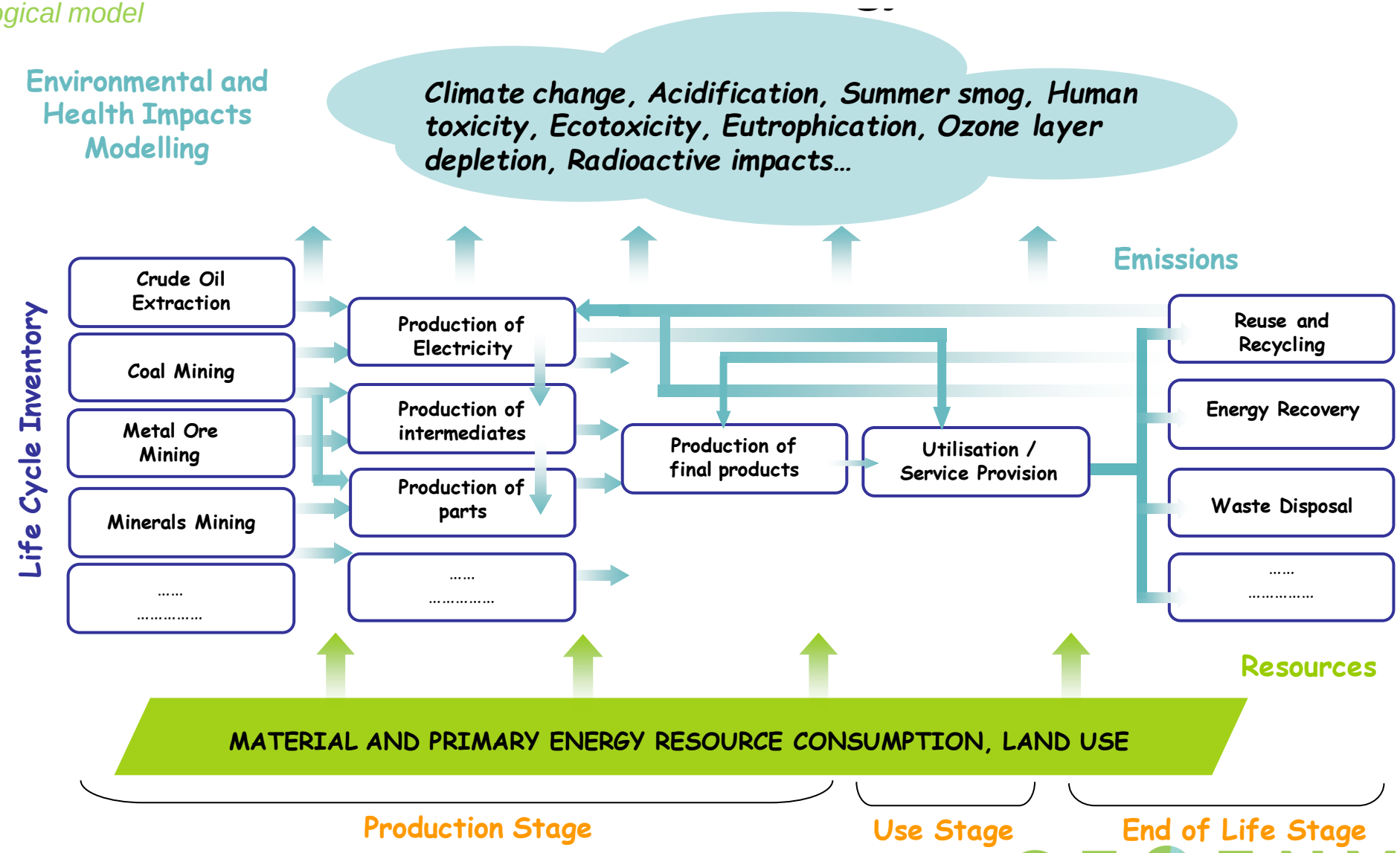
LCA Approach

- ISO Standard
- Comprehensive approach
- Multicriteria assessment
- Life cycle thinking
- International strategy to compare energy pathways




Environmental and Health Impacts Modelling
Climate change, Acidification, Summer smog, Human toxicity, Ecotoxicity, Eutrophication, Ozone layer depletion, Radioactive impacts…
Emissions
Life Cycle Inventory
Crude Oil Extraction
Coal Mining
Metal Ore Mining
Minerals Mining
……
……
Production of Electricity
Production of intermediates
Production of parts
……
……
Production of final products
Utilisation / Service Provision
Reuse and Recycling
Energy Recovery
Waste Disposal
……
……
Resources
MATERIAL AND PRIMARY ENERGY RESOURCE CONSUMPTION, LAND USE
Production Stage
Use Stage
End of Life Stage

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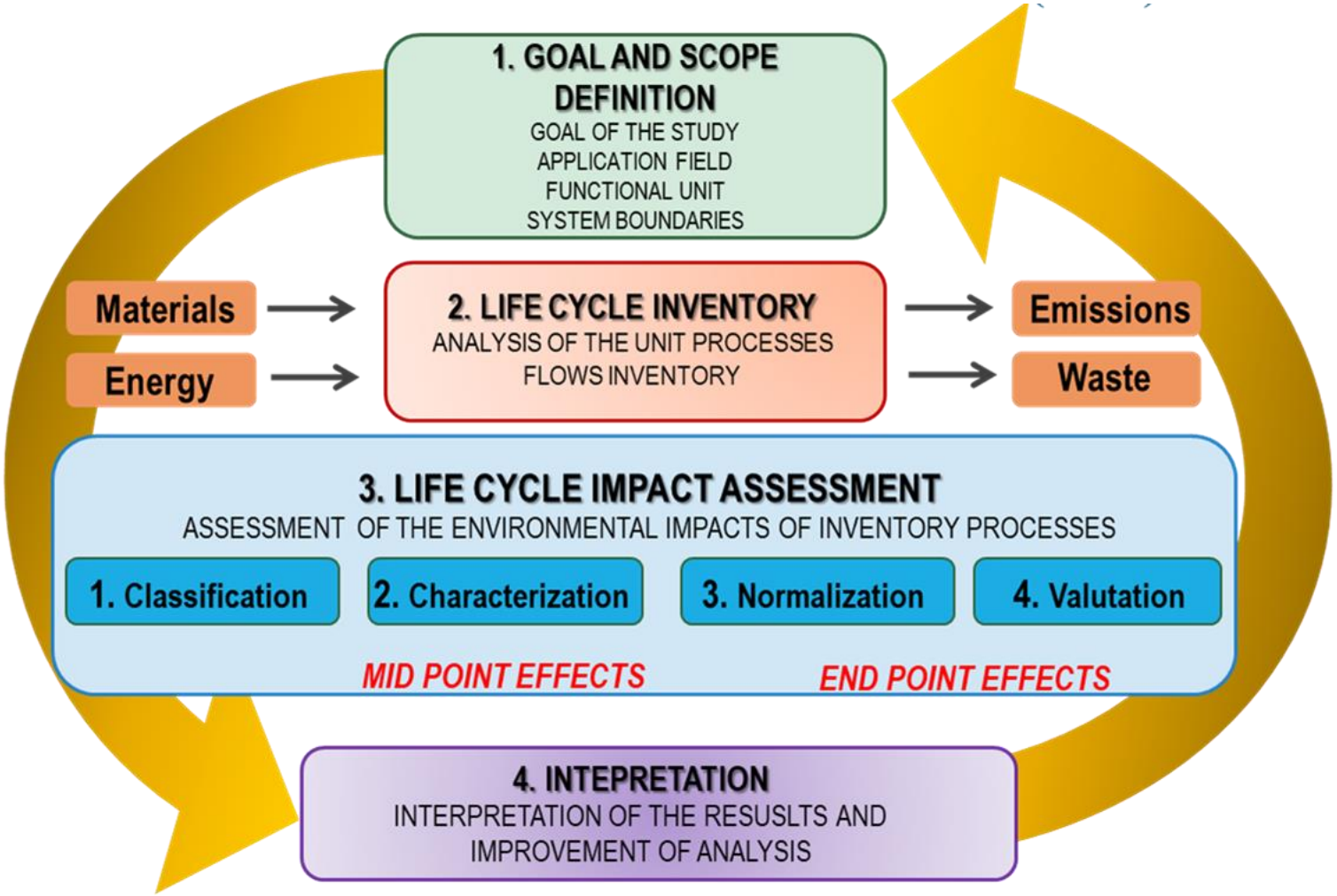
ISO Standard 14040



Goal definition
- Intended application
- Methods, assumptions, limitations
- Reason and decision context

Scope definition
- Functional unit and reference flow
- Life cycle inventory modeling - MULTIFUNCTIONALITY
- System boundaries and cut-off criteria
- Approaches: cradle to grave, cradle to gate, gate to gate, ….

Life cycle inventory
Data collection on elementary flows which are crossing the system boundaries and interacting with the environment (resources taken from nature and emissions to air, water and soil)

Life cycle Impact Analysis
Translation of the LCI elementary flows into impact categories → for geothermal it is important to choose LCIA appropriately as the emissions are not conventional: H_2S, Hg etc..; what type of impact: local or global; where in the cause-effect chain? Midpoint vs endpoint

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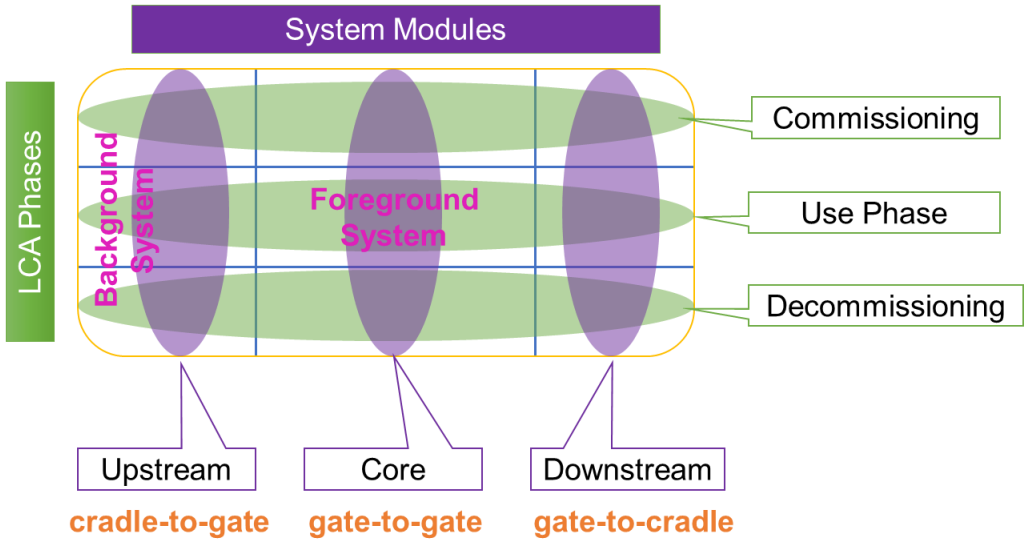
LCA studies literature review: methodological approach representativity

LCA of a geothermal system should be dynamic enough to capture the complexity of the whole system…different methodological approaches



System boundaries
Functional unit
Life Cycle impact methods
Additional indicators
Interpretations
…..

Bayer et al., Review on life cycle environmental effects of geothermal power generation. Renewable and Sustainable Energy Reviews, 2013 , 26, 446-463

Tomasini-Montenergo et al., Life cycle assessment of geothermal power generation technologies: An updated review. Applied Thermal Engineering, 2017, 114, 1119-1136

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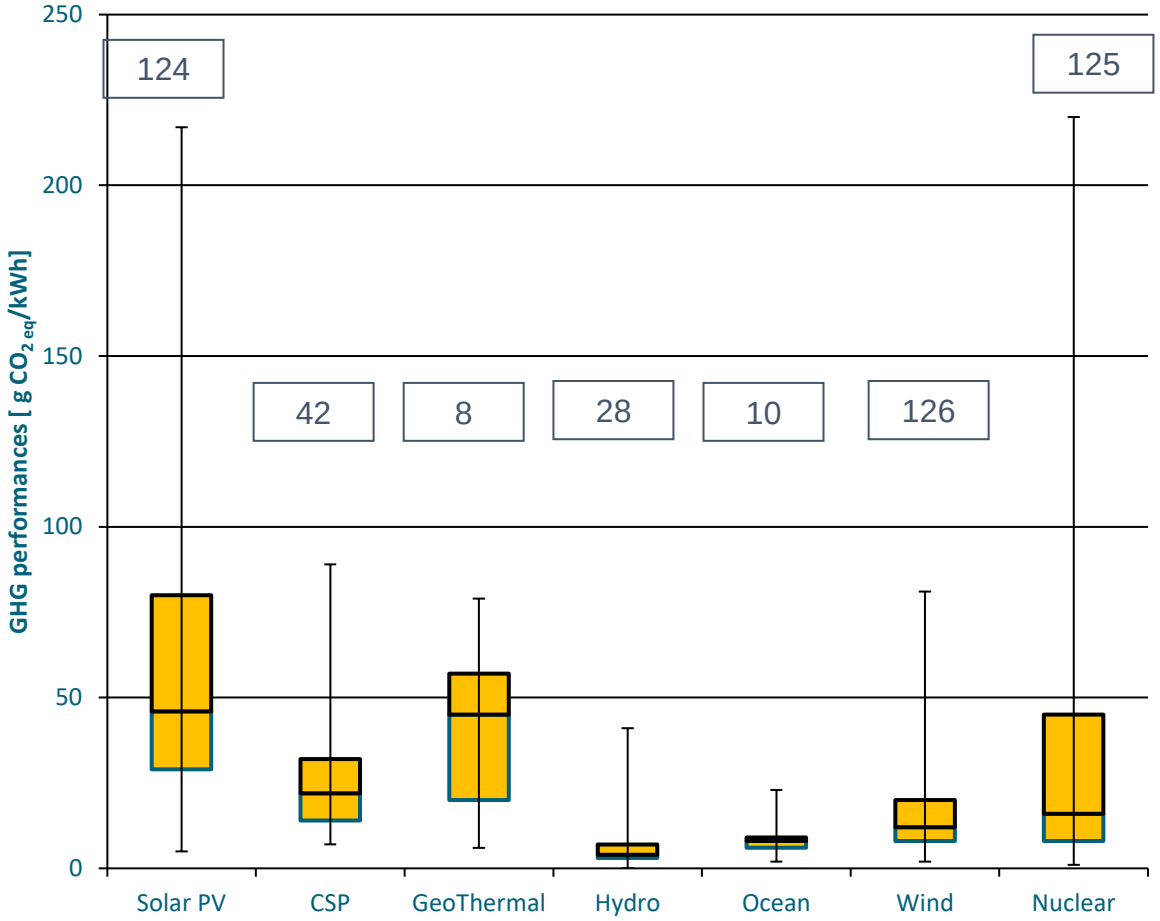
Life Cycle Assessment Review for energy pathways

of publications



IPCC 2011 Source: Moomaw, W., P. Burgherr, G. Heath, M. Lenzen, J. Nyboer, A. Verbruggen, 2011: Annex II: Methodology. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

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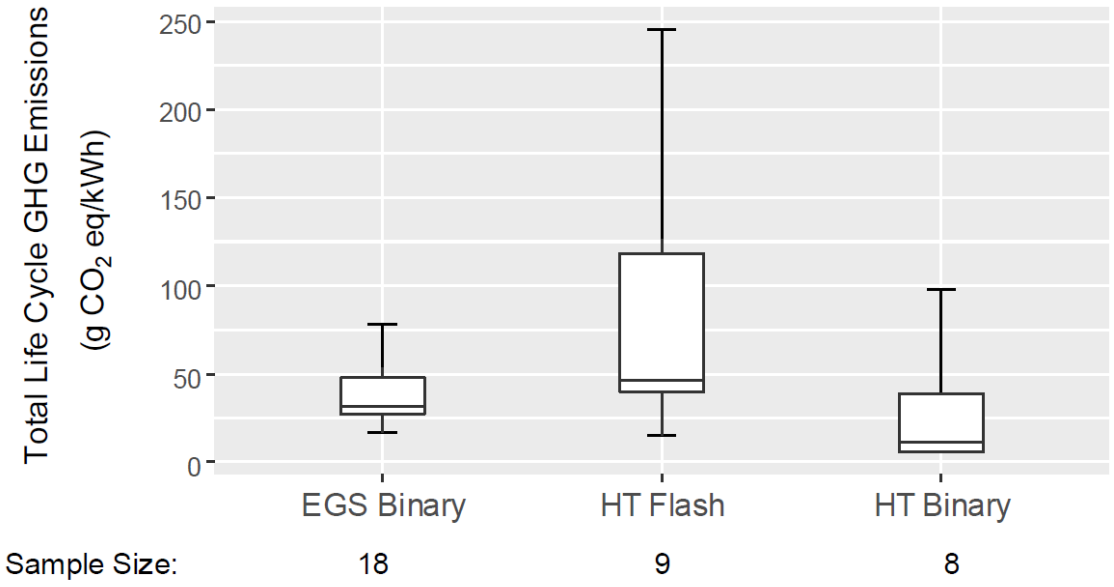
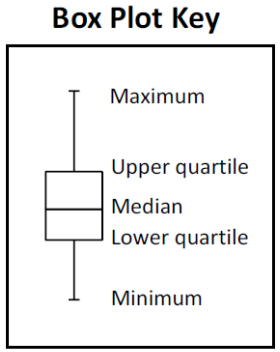
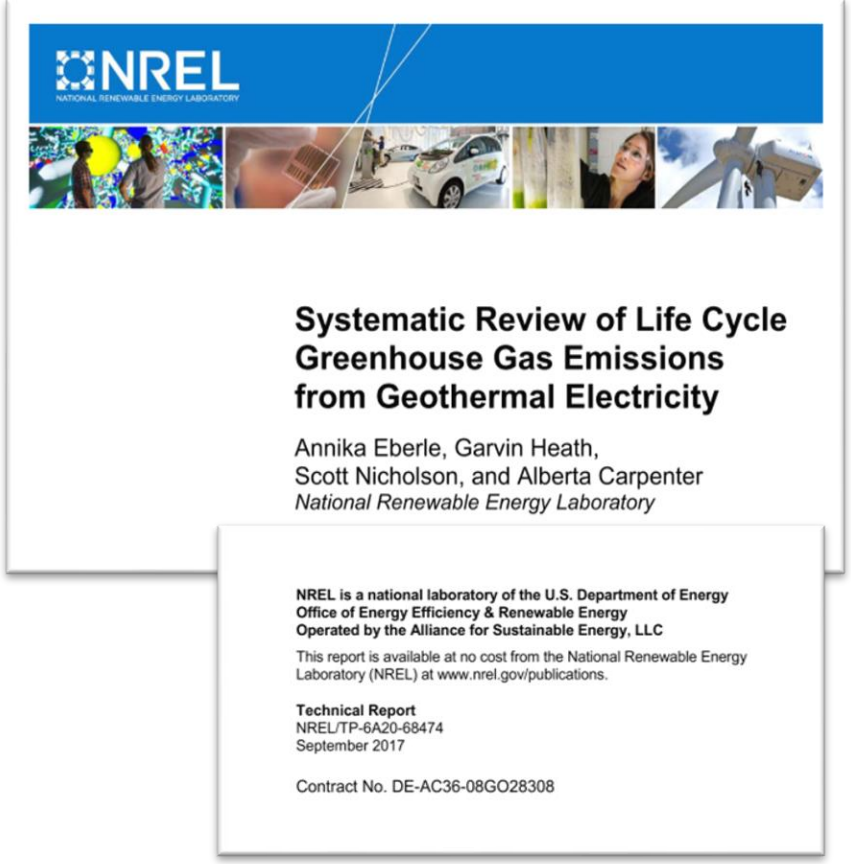
LCA studies literature review: technology representativity







Type of geothermal systems	GHG in gCO_2eq/kWh Mediane estimate
Enhanced Geothermal Systems (EGS) Binary	32
Hydrothermal (HT) Flash	47
Hydrothermal (HT) Binary	11

<u>26 LCA studies elligible</u>
among 180 studies
(Harmonized method, Heath and Man, NREL, 2012)

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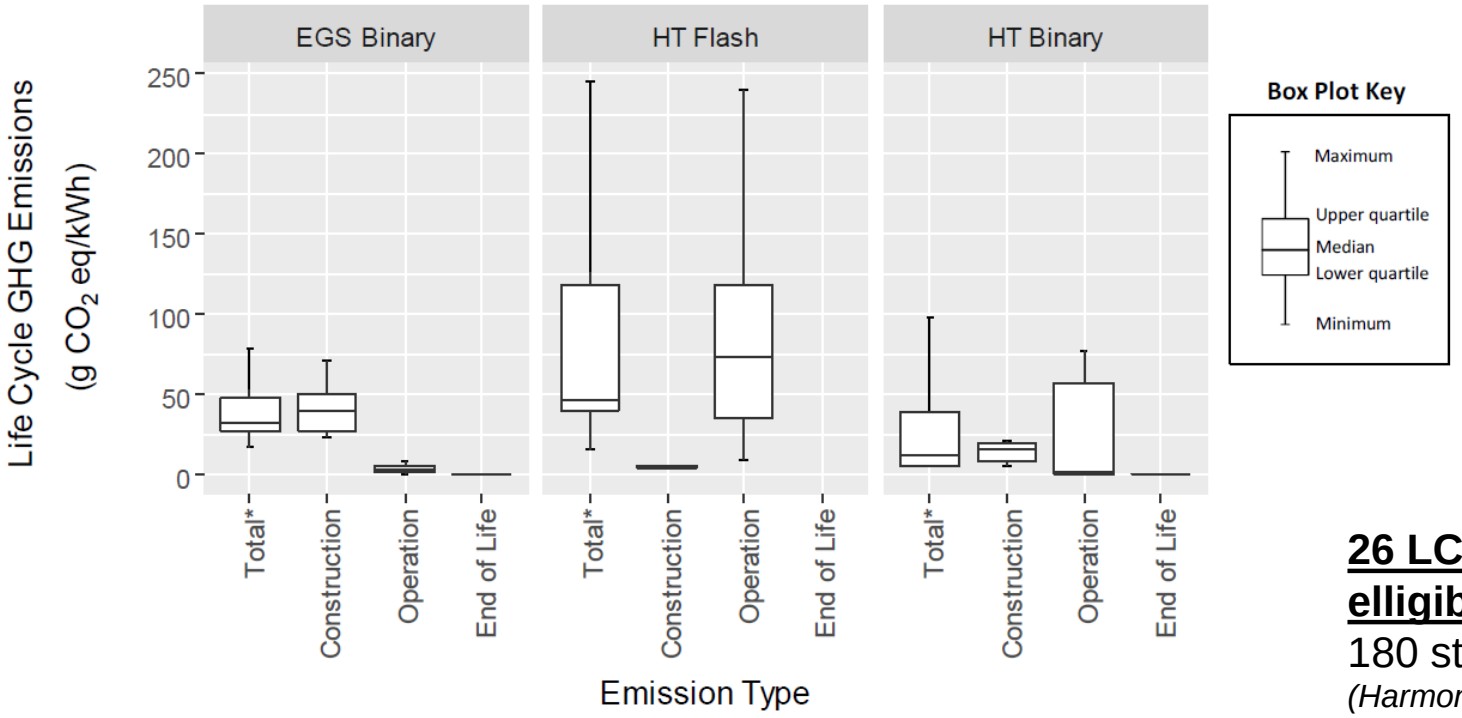
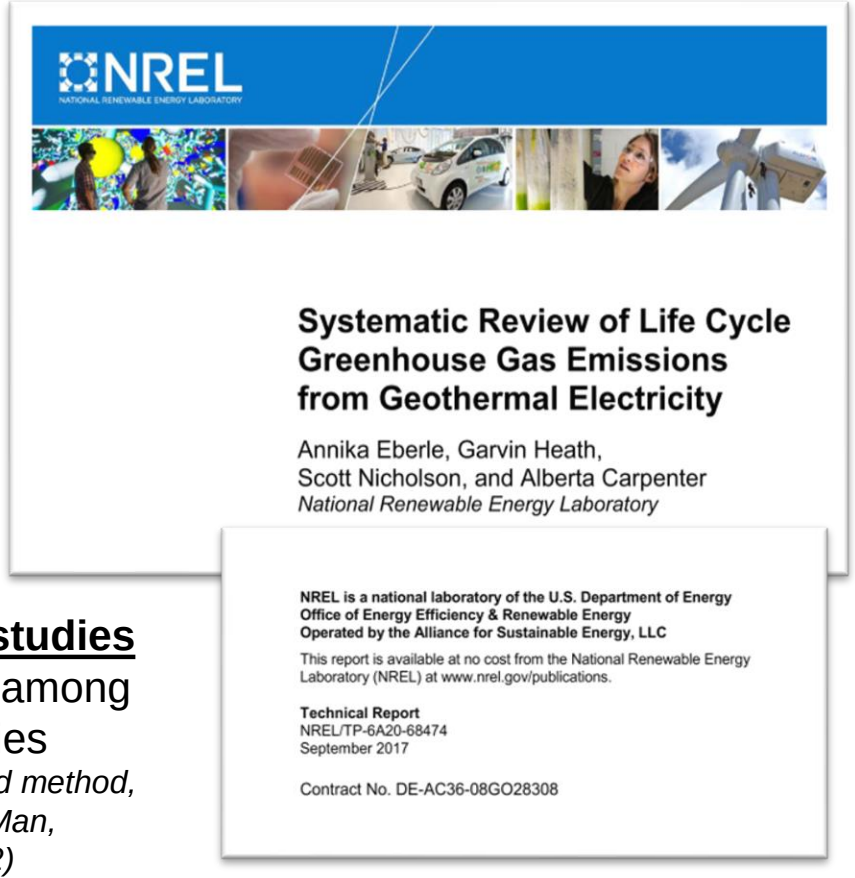
LCA studies literature review: technology representativity



Sample Size:	18	8	8	4	9	7	8	0	8	6	6	4

Figure 2. Greenhouse gas (GHG) emissions disaggregated by phase of the life cycle (i.e., total, construction, operation, and end of life) for three geothermal electricity generation technologies: enhanced geothermal systems (EGS) binary, hydrothermal (HT) flash, and HT binary.



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(*) 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 available on
https://www.geoenvi.eu/publications/lca-guidelines-for-geothermal-installations/

Table of contents

3 Technical Appendixes:

- Short guide to the use of Exergy as an allocation scheme in geothermal installations
- Reference average values as a support for modelling the inventory (based on GEOENVI case studies)
- Primary Energy Saving (PES)
- Additional Appendix in the next version : Renewable Energies: Geothermal Heat and Power versus PV and Wind – A case study using exergy and PES

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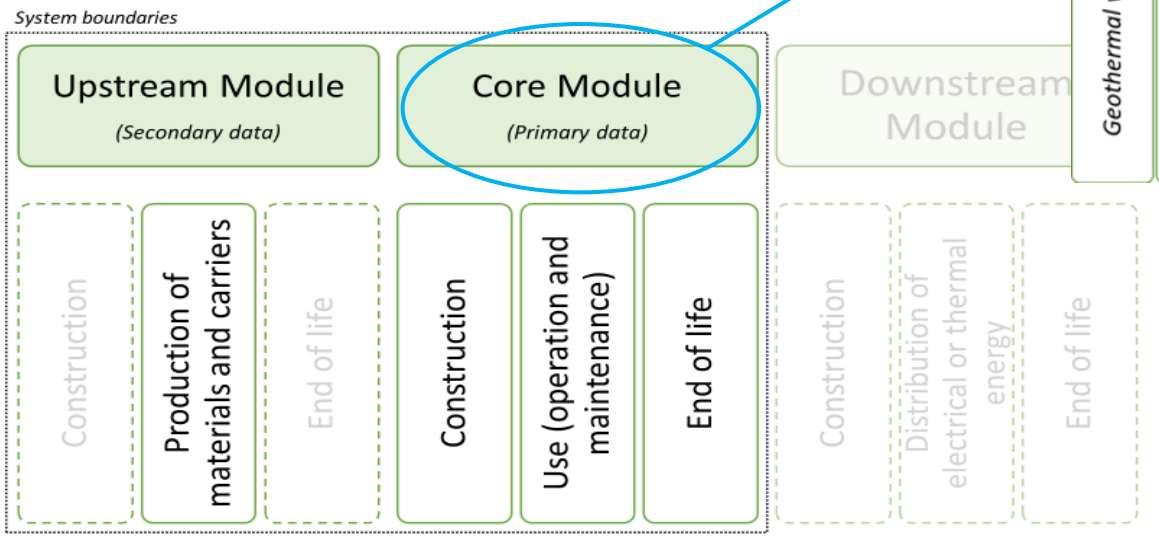
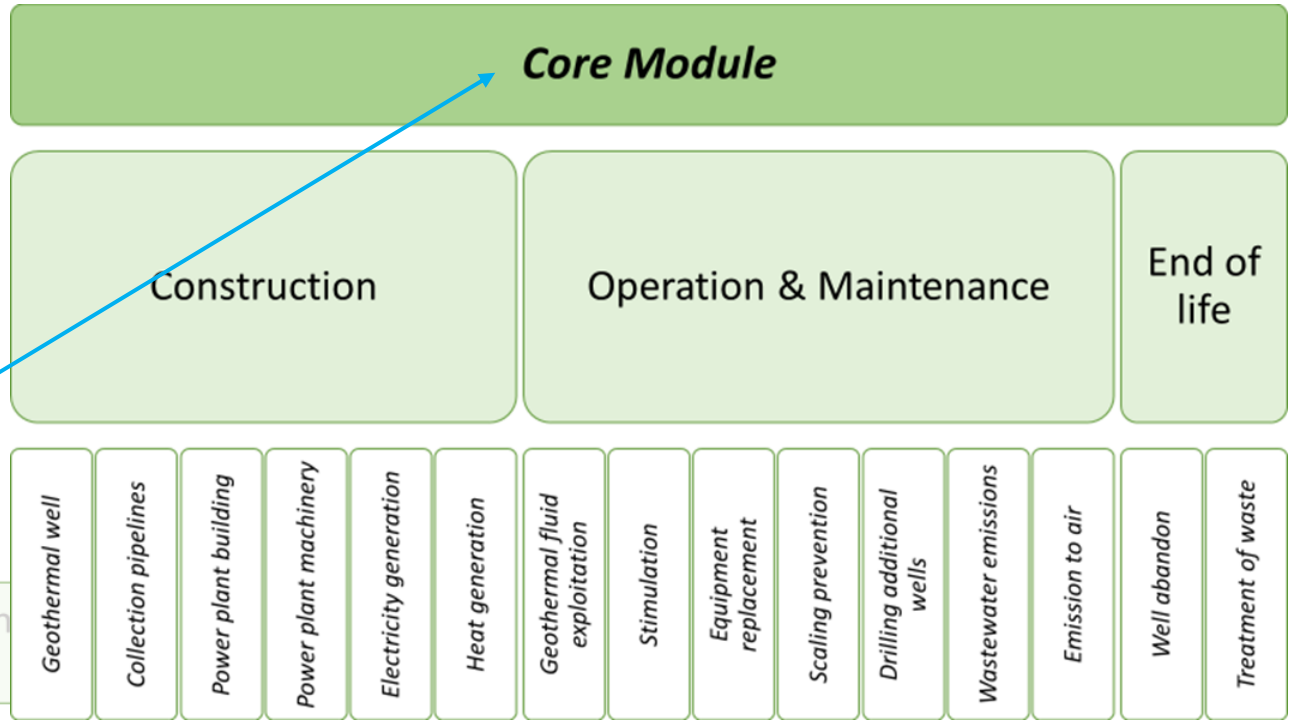
Goal and scope definition

Functional unit

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

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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).

Representative geothermal Systems (RGS) in GEOENVI

	Bagnore	Rittershoffen	Hellisheidi	Balmatt	Hungary	Dora-II
Geothermal source type	Liquid - hydrothermal	Liquid- EGS	Liquid/Vapour-hydrothermal	Liquid	Liquid	Liquid
Energy generation technology	Flash	Direct heat use	Single and double flash	Direct use + ORC	ORC	ORC
Final energy use	Electricity + Heat	Industrial heat use	Electricity + Heat	Heat + Electricity (self-consumption)	Electricity	Electricity
Installed capacity	61 MWe 21.1 MWth	27 MWth	303.3 MWe 133 MWth	8 MWth 0.25 MWe	3.75 MWe	9.5 MWe

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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*	*13 771 (RT) – 259 286 (BG) (117 686)*
Aluminium	*kg/well*	*1 218 (HL) – 1 500 (DO) (1 359)*
Iron	*kg/well*	*4 000 (DO) – 8 568 (BG) (6284)*
Excavation	*m^3/well*	*250 (DO) – 6 851 (RT) (1 940)*
Filling	*m^3/well*	*250 (DO) – 3 135 (RT) (1 723)*

Default values available in Appendix 2 : Example for wellhead construction

RT	Rittershoffen
HL	Hellisheidi
DO	DORA II
BG	Bagnore

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Life Cycle Impact Assessment method based on EF V3.0 (example for 3 impact indicators)

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 (scientifical ground)

List of impact categories identified as high priority for geothermal installations

climate change total
freshwater ecotoxicity
freshwater and terrestrial acidification
mineral and metal resource depletion
fossil resource depletion
human non-carcinogenic effects
human carcinogenic effects

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Additionally covered aspects in the Guidelines

Reporting Inorganic emission with toxicity impacts in addition to the recommended impact categories

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

Additional metrics

PES (Primary Energy Saving) & 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 captions*
- *…..*

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Thank You

Blanc I., Damen L., Douziech M., Fiaschi D., Harcouët-Menou V., Manfrida G., Mendecka B., Parisi M.L.,
Perez Lopez P., Ravier G., Tosti L., 2020. First version of harmonized guidelines to perform environmental assessment for geothermal systems based on LCA and non LCA impact indicators: LCA Guidelines for Geothermal Installations.
D3-2. GEOENVI Project # 818242.

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