D 3.2: LCA Guidelines for Geothermal installations

ARMINES(*) + CSGI / University of Florence / University of Siena + Electricité Strasbourg + VITO

(*) Isabelle Blanc

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• LCA Guidelines for geothermal installations:

**MOTIVATION**

⇒ These guidelines were developed to offer guidance for **consistency**, balance and quality 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.
• LCA Guidelines for geothermal installations: WHO is going to use?

1. LCA practitioners
2. 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)
• Objectives of the LCA Guidelines for geothermal installations

1. To provide guidance on how to establish the life cycle inventories (LCI) of geothermal systems
2. To provide guidance on which environmental impacts to address in life cycle impact assessment (LCIA) and which impact category indicators to use
3. To provide guidance on how and what to document regarding the LCA of geothermal energy (electricity, heat or combined systems)
SCOPE OF THE GUIDELINES

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 environmental assessment criteria, which can consider site-dependent matters (such as micro-seismicity, subsidence, noise, ...) or whose evaluation involves social or qualitative acceptance (preservation of landscape, cultural heritage, effects on occupation and economics, ...).
LCA Guidelines for geothermal installations: FORMAT AND METHODOLOGY

- Synthetic guidelines in 30 pages
- 4 technical Appendixes based on outcomes/data issued from GEOENVI Case studies, EU project (RINA-VITO) and Specificities of CHP installations
## GEOENVI Case studies

<table>
<thead>
<tr>
<th></th>
<th>Rittershoffen</th>
<th>Bagnore</th>
<th>Hellisheidi</th>
<th>Balmatt</th>
<th>Dora II</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Geothermal source type</strong></td>
<td>Liquid</td>
<td>Liquid</td>
<td>Liquid/Vapour</td>
<td>Liquid</td>
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<tr>
<td><strong>Energy generation technology</strong></td>
<td>Direct heat use - EGS</td>
<td>Flash - hydrothermal</td>
<td>Single and double flash - hydrothermal</td>
<td>ORC - EGS</td>
<td>ORC</td>
</tr>
<tr>
<td><strong>Final energy use</strong></td>
<td>Industrial heat use</td>
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</tr>
<tr>
<td><strong>Installed capacity</strong></td>
<td>27 MWth</td>
<td>61 MWe</td>
<td>303.3 MWe</td>
<td>0.25 MWe</td>
<td>9.5 MWe</td>
</tr>
<tr>
<td></td>
<td>21.1 MWth</td>
<td></td>
<td>133 MWth</td>
<td>8 MWth</td>
<td></td>
</tr>
<tr>
<td><strong>ID used in Annex 2</strong></td>
<td>RT</td>
<td>BG</td>
<td>HL</td>
<td>BA</td>
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</table>
Rittershoffen heat plant project

- Project started in 2015
- 3 shareholders (Electricité de Strasbourg, Roquette Frères and Caisse des dépôts)
- 1 heat user: Roquette Frères starch plant at Beinheim, France, on the Rheine river
- 2,000 t of corn and wheat daily transformed
- Total heat demand of the starch plant: 80 MW
- Use of local geothermal energy to supply 24 MW of the heat of the Beinheim Starch plant and 180 GWh/year
Rittershoffen heat plant

Reservoir, brine and wells

- Reservoir depth: 2500m
- Fractured sandstone and Carboniferous granite
- 2 wells in operation
- 1 production well: GRT-2 (drilled in 2014)
- 1 injection well: GRT-1 (drilled in 2012)
- Bottom hole temperature: 177°C
- Na-Ca-K-Cl dominated brine

(Baujard et al., 2017)

Fluid geochemistry and gas composition of Rittershoffen geothermal fluid (Mouchot et al., 2018)
• Table of Content (30 pages)

- Introduction
- Motivation and Objective
- Methodological Guidelines
- Specific aspects of geothermal energy production
- Goal and scope definition
- Life Cycle Inventory (LCI)
- Life Cycle Impact Assessment (LCIA)
- Reporting and communication
- References
• 4 Appendixes

1. Short guide to the use of Exergy as an allocation scheme in geothermal installations
2. Reference average values as a support for modelling the inventory (based on GEOENVI case studies and EC Project)
3. Primary Energy Saving (PES)
• **Goal and Scope definition**

- **Goal of the study**
- **Functional Unit:** Power production only: kWh of electricity delivered to the grid or a user \( k\text{Wh}_{\text{el}} \); Heating/cooling production only: kWh of heat delivered to the grid or a user \( k\text{Wh}_{\text{th}} \) & Multifunctional approach
- **System boundaries**
- **Life time = 30 years**
- **Comparability**
• Goal and Scope definition / System boundaries
• Goal and Scope definition / stems boundaries
• LCI : example for the Inventory of the construction phase

- 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 in priority otherwise reference/average values given in Appendix 2
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- Default values available in Appendix 2 (Example for wellhead construction)

<table>
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<tr>
<th>Materials</th>
<th>Unit</th>
<th>Reference value MIN-MAX (Average)</th>
</tr>
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<tbody>
<tr>
<td>Steel, unalloyed</td>
<td>kg/well</td>
<td>7 428 (RT)– 17 660 (DO) (13 221)</td>
</tr>
<tr>
<td>Steel, stainless INOX 316 L</td>
<td>kg/well</td>
<td>16 (HL)</td>
</tr>
<tr>
<td>Concrete</td>
<td>kg/well</td>
<td>18 (HL) – 18 520 (BG) (9 269)</td>
</tr>
<tr>
<td>Portland cement</td>
<td>kg/well</td>
<td>13771 (RT) – 259286 (BG) (117686)</td>
</tr>
<tr>
<td>Aluminium</td>
<td>kg/well</td>
<td>1 218 (HL) – 1500 (DO) (1359)</td>
</tr>
<tr>
<td>Iron</td>
<td>kg/well</td>
<td>4 000 (DO) – 8 568 (BG) (6284)</td>
</tr>
<tr>
<td>Excavation</td>
<td>m³/well</td>
<td>250 (DO) – 6851 (RT) (1940)</td>
</tr>
<tr>
<td>Filling</td>
<td>m³/well</td>
<td>250 (DO) – 3135 (RT) (1723)</td>
</tr>
</tbody>
</table>
• General guidelines: accounting for multiple outputs

• Systems producing only electricity;
• Combined heat and power CHP (or even heat, cold and power);
• The production of heat alone for direct utilization;
• The production of other by-products (e.g.: natural gas, Lithium, Boron, …) is also possible.
• Specific allocation schemes based on co-products shares

(1) If the share between the co-products > 75%
=> the system allocation scheme = system expansion with a substitution model for the co-products

(2) If the share between the co-products < 75%
=> the system allocation scheme = exergy content (Appendix 1).

For systems producing large amounts of heat = Primary Energy Saving (PES) Appendix 3 & 4.
CHP: system with 2 co-products

CASE where ELECTRICITY > 75% HEAT
=> System expansion with a substitution model
System expansion with a substitution model

System (A & B)

INPUTS (A+B)

ELECTRICITY (A)

HEAT (B)

OUTPUTS (A+B)

System (B’ = EU Natural gas process)

INPUTS (B’)

OUTPUTS (B’)

ENERGY (B’)
System expansion with a substitution model

INPUTS (A+B) → OUTPUTS (A+B) → INPUTS (B') → OUTPUTS (B')

System (A & B)

ELECTRICITY (A)

HEAT (B)

System (B') = EU Natural gas process

ENERGY (B')
System expansion with a substitution model

System (A & B)

INPUTS (A+B)

ELECTRICITY (A)

HEAT (B)

OUTPUTS (A+B)

System (A ‘) = Country Electricity Mix

INPUTS (B’)

ENERGY (A’)

OUTPUTS (B’)

INPUTS (A+B)
### Life Cycle Impact Assessment based on EF V3.0 = examples

<table>
<thead>
<tr>
<th>Impact Category</th>
<th>Unit</th>
<th>Indicator/Method</th>
<th>Version LCIA method</th>
<th>Source LCIA method</th>
<th>Level of priority</th>
<th>Level of robustness*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change</td>
<td>kg CO₂ eq</td>
<td>Radiative forcing as Global Warming Potential (GWP100)</td>
<td>1.0.5 (land use, land use change, biogenic), 1.0.8 (fossil), 4.0.16</td>
<td>IPCC 2013</td>
<td>High</td>
<td>I</td>
</tr>
<tr>
<td>Ozone depletion</td>
<td>kg CFC-11 eq</td>
<td>Steady-state ozone depletion potential</td>
<td>2.0.12</td>
<td>WMO 1999</td>
<td>Low</td>
<td>I</td>
</tr>
<tr>
<td>Human toxicity cancer effects</td>
<td>CTUh</td>
<td>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.</td>
<td>1.0.3</td>
<td>Rosenbaum et al., 2008</td>
<td>High</td>
<td>III</td>
</tr>
</tbody>
</table>

**LEVEL OF PRIORITY (specific to Geothermal installations) & LEVEL OF ROBUSTNESS (scientifically ground)**
• Reporting Inorganic emission with toxicity impacts
  ➢ H$_2$S, NH$_3$, As, B, Ar, Hg, Rn, Sb

In most of the currently available methods for the characterization of impacts there is no characterization factor associated to H$_2$S emission to air. It is recommended to multiply H$_2$S emitted mass by a 1.88 factor which corresponds to an equivalent mass of SO$_2$ emitted.

Additionnal indicators : PES , Energy PayBack Time
• Reporting & Communication

Life cycle stages included (e.g., end of life stage included or not)
Explicit goal of the study
System boundaries (including excluded processes)
Assumptions related to the production of major input materials
LCA approach used
Characteristics of the geothermal resource
List of inorganic and metal emissions (See section “Modelling of the operation phase”)
LCI database(s) used (e.g. ecoinvent, GaBi, ELCD, Franklin, other) including the version #
Data quality
Allocation method used
Impact category indicators used with versions #
LCA software used
Contributions of "background" and "foreground" recommended.
Geothermal plant description (next slide)
All figure captions should specify:

1. Geothermal technology (Hydrothermal with or without stimulation)
2. Type of energy conversion technology (e.g., direct or ORC)
3. Expected annual electricity/heat production or load factor (hours/year) and energy output decay
4. Lifetime of installation (years)
5. Plant size (MW)
6. Number of wells (production and reinjection) and depth of the wells
7. Characteristics related to the products:
   - Steam: The distribution system pressure, feed and return temperature and flow rate
   - Hot water: The distribution system feed and return temperature and flow rate
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=> V1 End February 2020 under GEOENVI review

=> V2 June 2020 after testing Case studies applications

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