Life Cycle Assessment as a tool to determine the environmental impacts of geothermal projects

Virginie Harcouët-Menou (VITO)

Mélanie Douziech (MINES-ParisTech)

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GEOENVI Project

Tackling the environmental concerns for deploying geothermal energy in Europe

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LCA METHODOLOGY

Objective:

Setting an adapted methodology for assessing environment impacts of geothermal projects

Developing and providing tools to assess the environmental performance of geothermal projects

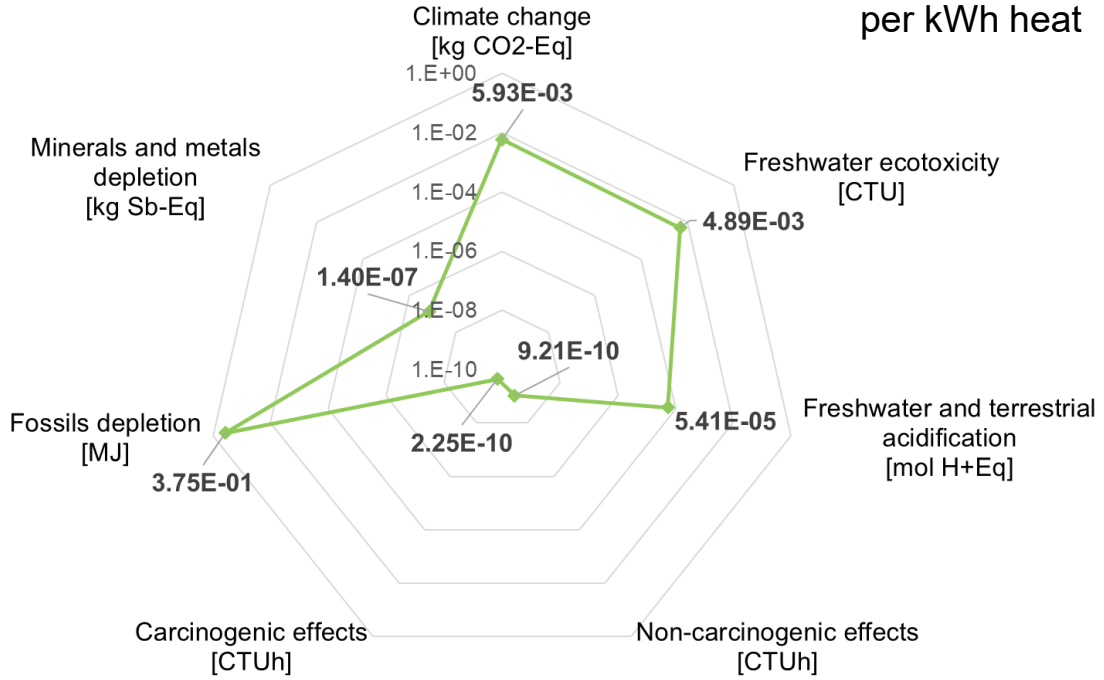
1. A comprehensive analysis of the panorama of studies reporting environmental assessment & sustainability assessment for geothermal systems

2. Elaboration of the **environmental impact and LCA guidelines for geothermal energy** & their application to GEOENVI case studies

3. Development of a **protocol for the generation of simplified LCA models** to assess environmental impacts

4. **Testing the applicability of the guidelines and the protocol** for simplified models with the stakeholders

per kWh heat



Enhanced geothermal system for heat production (FR)

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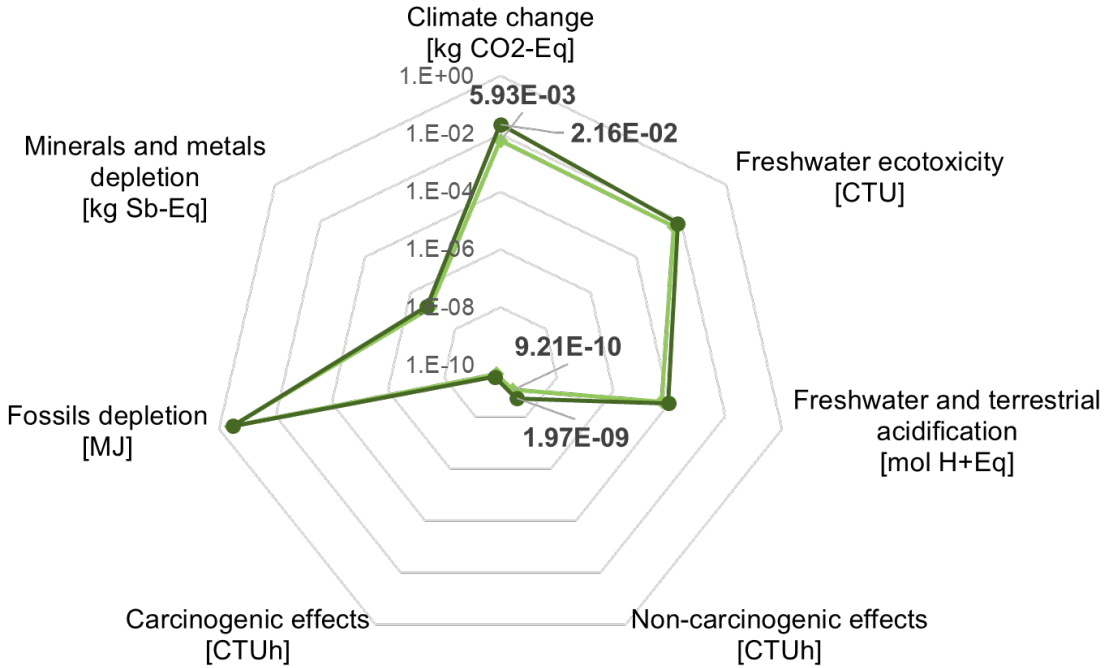
per kWh heat



Enhanced geothermal system for heat production (FR)

Enhanced geothermal system for heat production (DE)

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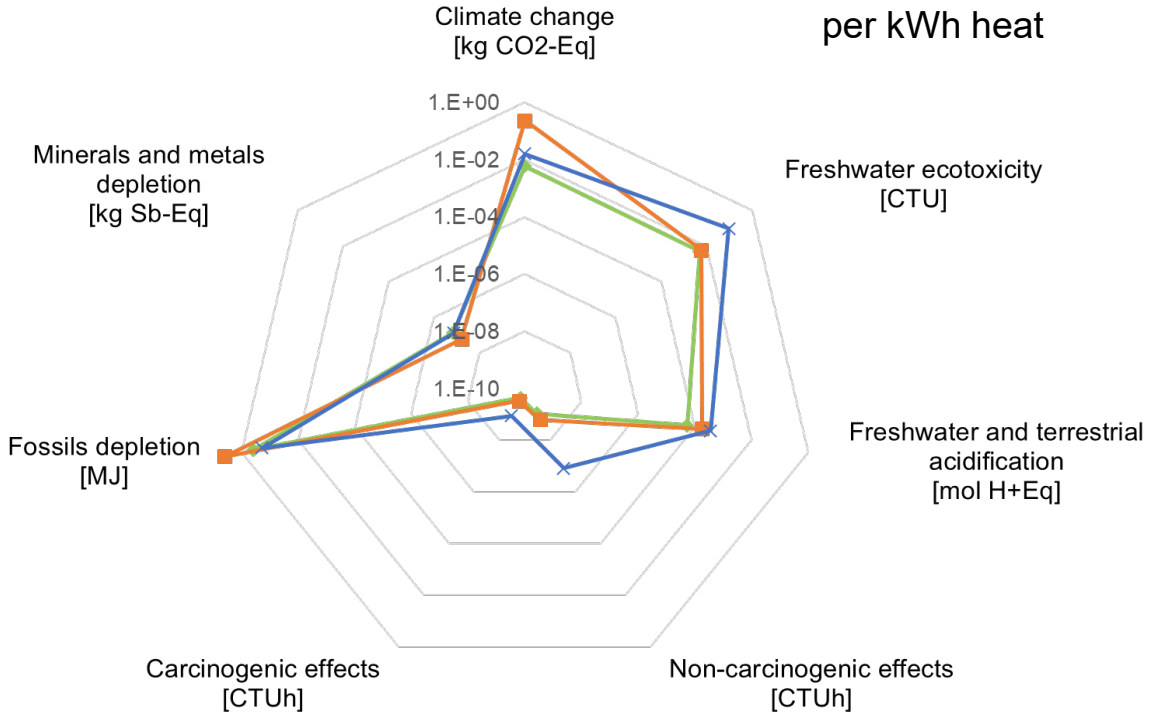
per kWh heat



Enhanced geothermal system for heat production (FR)

Heat from natural gas

Heat from wood logs

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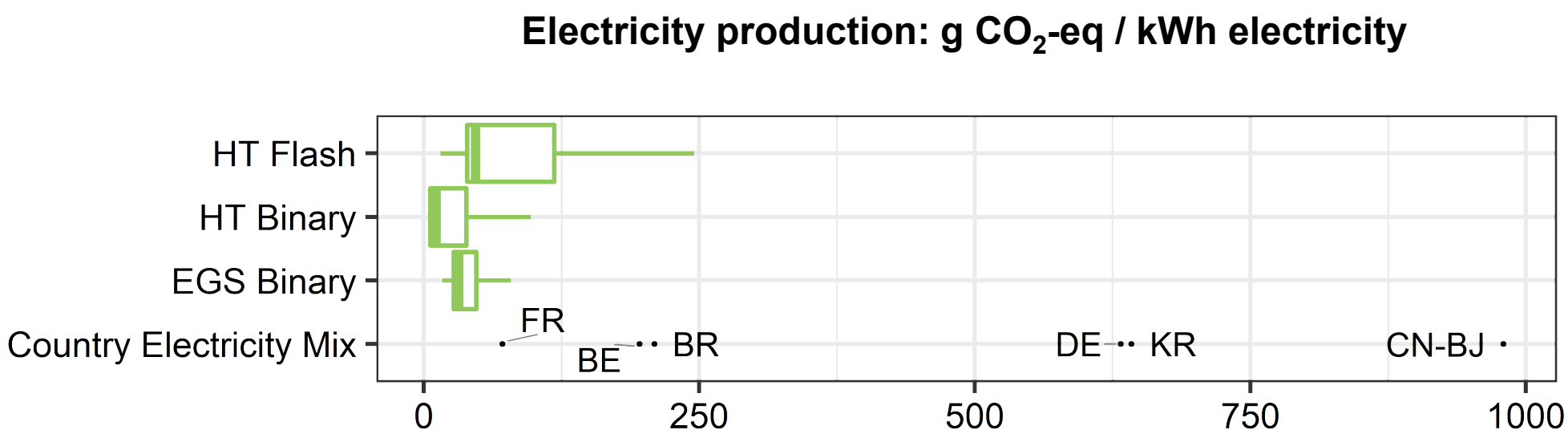
Example of CO2 eq emissions for electricity production



Eberle et al., 2017
https://doi.org/10.2172/1398245

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

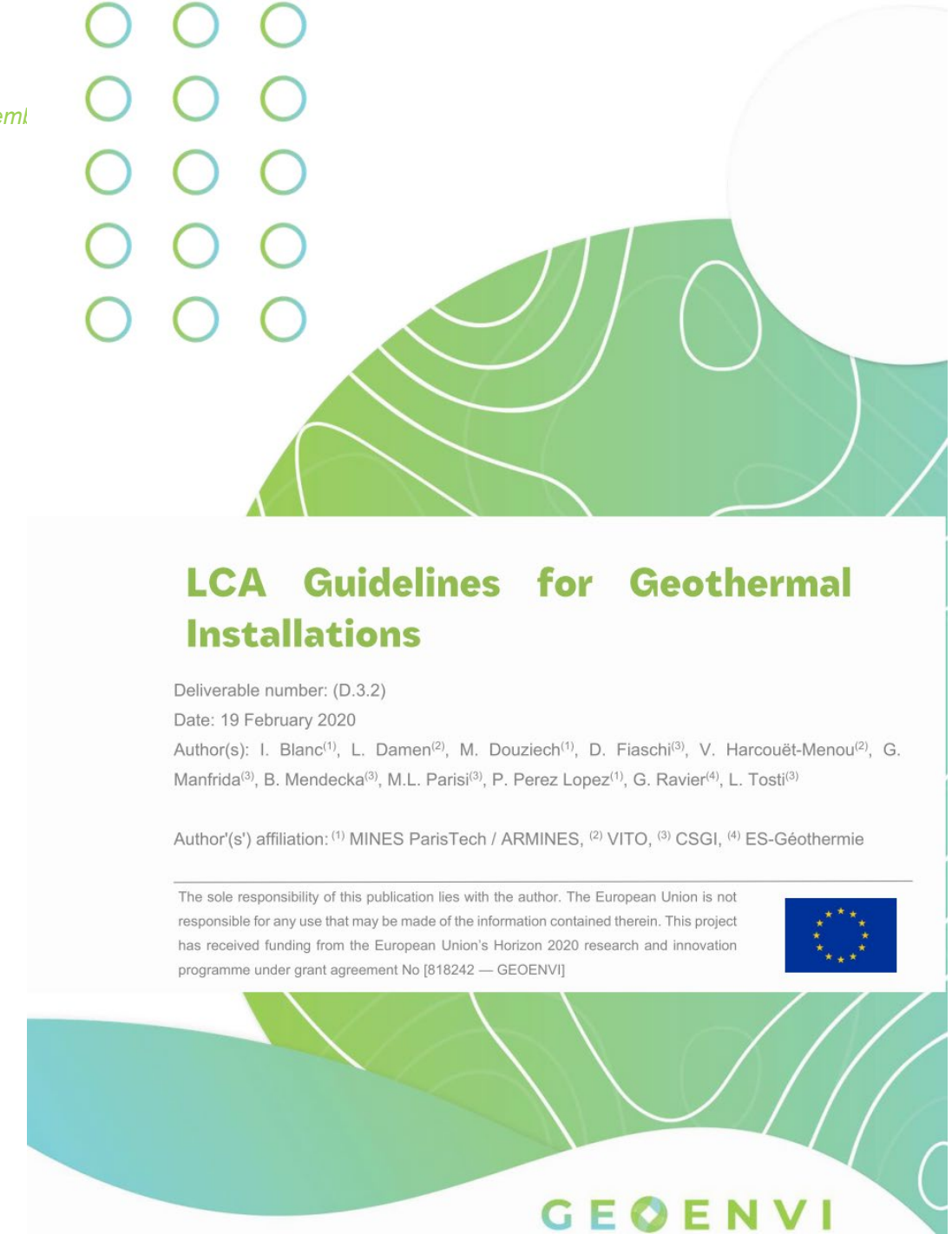
- **LCA practitioner** and **geothermal experts**.
- Challenge to produce in **a concise manner** guidelines ready to use for **any type** of geothermal installations fulfilling LCA ISO standards (14040 and 14044).

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

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Date: 19 February 2020

Author(s): I. Blanc[1], L. Damen[2], M. Douziech[1], D. Fiaschi[3], V. Harcouët-Menou[2], G. Manfrida[3], B. Mendecka[3], M.L. Parisi[3], P. Perez Lopez[1], G. Ravier[4], L. Tosti[3]

Author'(s') affiliation: [1] MINES ParisTech / ARMINES, [2] VITO, [3] CSGI, [4] ES-Géothermie

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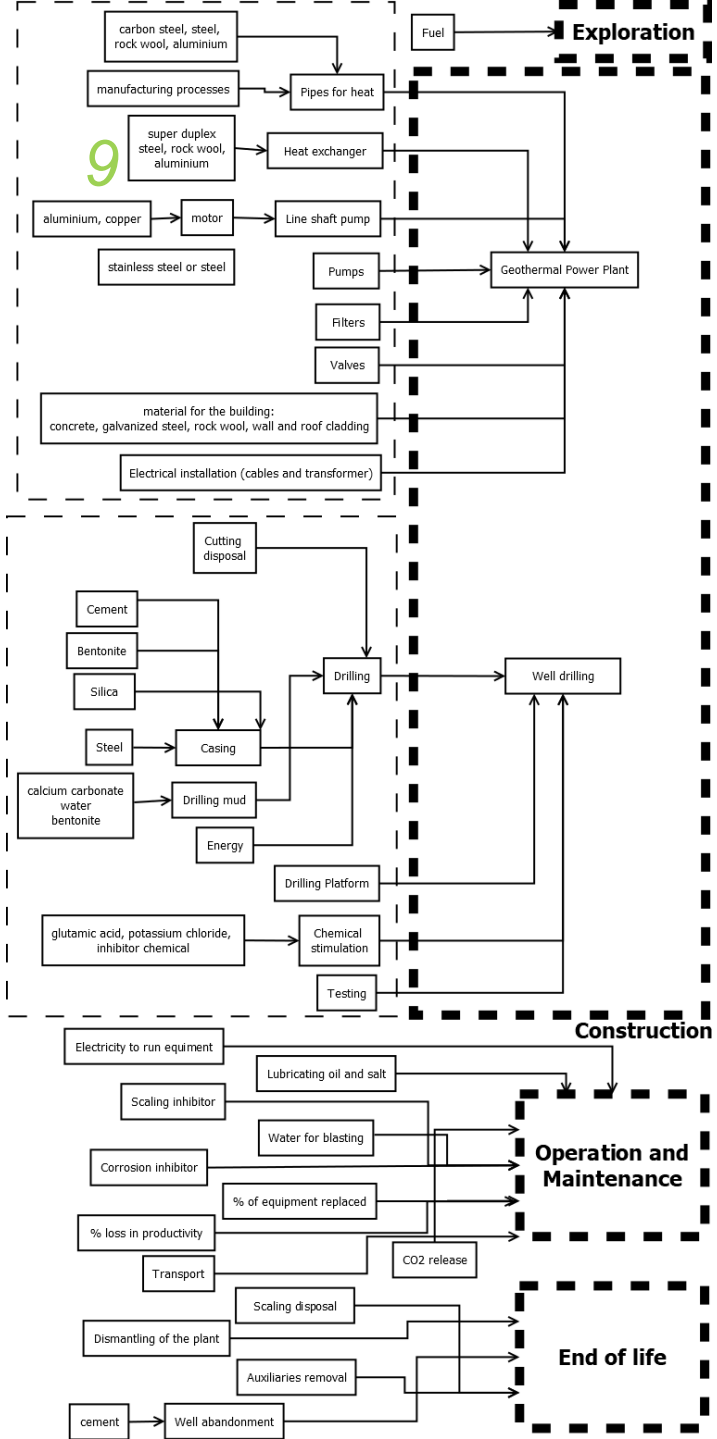

EXPLORATION

$Energy_{exploration}$

CONSTRUCTION

POWER PLANT

Heat exchanger (HE)

$L_{freshwater\ pipe}$

$L_{groundwater\ pipe}$

M_{HE}

Pumps

$P_{production\ pump}$

$P_{injection\ pump}$

Building

$A_{Powerplant}$

WELL DRILLING

Drilling

$km_{cuttings}$

L_{well}

$Ratio_{Meters\ drilled,well}$

$N_{injection}$

$N_{production}$

Drilling Platform

$A_{Platform}$

Stimulation

$V_{chemical\ stimulation}$

$V_{hydraulic\ stimulation}$

Testing

CO_2 testing

OPERATION AND MAINTENANCE

$f_{direct\ emission}$, $f_{CO_2\ in\ direct}$, $f_{CH_4\ in\ direct}$

$M_{scaling}$, Q, $LifeTime$, $h_{operating}$,

$P_{thermal}$, km_{OM}

ELECTRICITY MIX

END OF LIFE

$Energy_{abd}$, $M_{Cement,Abd}$

The reference LCA model relies on 35 variable parameters for the EGS example (among which, 8 describe the tailor-made electricity mix)

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Simplified LCA models

Motivation

- To offer very simple tools to facilitate and speed access to life cycle assessment for geothermal installations
- To enlarge the simple vision of a single carbon footprint assessment for a multicriteria vision

Beneficiary

- Decision makers
- Non LCA practitioners

Objective

- To provide life cycle environmental impact indicators with a very limited number of input variables (< 10)
- To provide environmental assessment for a selection of Representative Geothermal System (RGS)

Scope

- These simplified models can only be used in accordance to the scope for which they have been designed for.
- They are valid for specific technological ranges

EXPLORATION

$Energy_{exploration}$

CONSTRUCTION

POWER PLANT	WELL DRILLING
Heat exchanger (HE)	**Drilling**
$L_{freshwater\ pipe}$	$km_{cuttings}$
$L_{groundwater\ pipe}$	L_{well}
M_{HE}	$Ratio_{Meters\ drilled,well}$
	$N_{injection}$
Pumps	$N_{production}$
$P_{production\ pump}$	
$P_{injection\ pump}$	**Drilling Platform**
	$A_{Platform}$
Building	
$A_{Powerplant}$	**Stimulation**
	$V_{chemical\ stimulation}$
	$V_{hydraulic\ stimulation}$
	Testing
	CO_2 testing

OPERATION AND MAINTENANCE

$f_{direct\ emission}$, $f_{CO_2\ in\ direct}$, $f_{CH_4\ in\ direct}$
$M_{scaling}$, Q, $LifeTime$, $h_{operating}$,
$P_{thermal}$, km_{OM}

ELECTRICITY MIX

END OF LIFE

$Energy_{abd}$, $M_{Cement,Abd}$

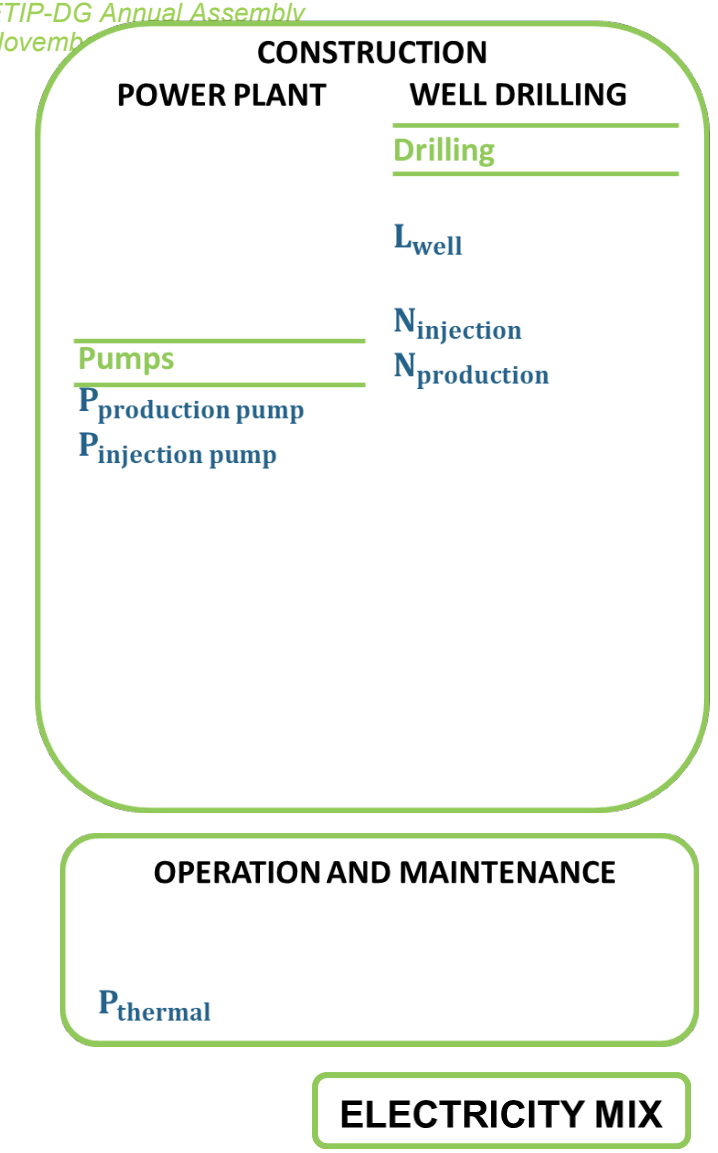
Simplified models for seven impact categories

$$\text{kg CO2-eq / kWh} = \frac{\begin{aligned}&0.00113(N_{in}\cdot P_{inj}+N_{prod}\cdot P_{prod})\cdot[0.0588f_{biomass}\\&+1.28f_{coal}+0.434f_{NG}+0.917f_{oil}+0.0624f_{solar}]\\&+5.06\cdot10^{-9}[3.28\cdot10^{3}N_{prod}\cdot P_{prod}\\&+(N_{in}+N_{prod})\cdot\left(\begin{matrix}790.0\cdot10^{0.000397\cdot L_W+2.04}+276.0L_W\\+28.2L_W^{1.05}+58.5L_W^{1.22}+25.9L_W^{1.23}\end{matrix}\right)\\&+7.27\cdot10^{6}]\end{aligned}}{P_{th}}$$

$$\text{CTU/kWh} = \frac{\begin{aligned}&0.00113(N_{in}\cdot P_{inj}+N_{prod}\cdot P_{prod})\cdot[0.309f_{biomass}+0.0891f_{coal}\\&+0.0114f_{NG}+0.0251f_{nuclear}+0.671f_{oil}+0.0937f_{solar}+0.0374f_{wind}]\\&+5.13\cdot10^{-9}[8.09\cdot10^{5}N_{in}+7.92\cdot10^{3}N_{prod}\cdot P_{prod}\\&+(N_{in}+N_{prod})\cdot\left(\begin{matrix}131.0\cdot10^{0.000395\cdot L_W+2.04}+328.0L_W\\+202.0L_W^{1.05}+66.4L_W^{1.22}+2.76L_W^{1.23}\end{matrix}\right)+5.53\cdot10^{6}]\end{aligned}}{P_{th}}$$

and four geothermal installation types

- Enhanced geothermal systems for heat generation with very low direct emissions
- Flash power plant for electricity production with moderate to high non-condensable gas content
- Combined heat and power plant with low direct emissions
- Heat production with demonstration Organic Rankine Cycle with very low direct emissions



Simplified models for seven impact categories

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and four geothermal installation types

- Enhanced geothermal systems for heat generation with very low direct emissions
- Flash power plant for electricity production with moderate to high non-condensable gas content
- Combined heat and power plant with low direct emissions
- Heat production with demonstration Organic Rankine Cycle with very low direct emissions

Generation of simplified parametrised models for a selection of GEOENVI geothermal installations categories

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Author(s): M. Douziech(1), I. Blanc(1), L. Damen(2), K. Dillman(3), V. Eggertsson(4), N. Ferrara(5), S.R. Guðjónsdóttir(3), V. Harcouët-Menou(2), M.L. Parisi(5), P. Pérez-López(1), G. Ravier(6), H. Sigurjónsson(3) , L. Tosti(5)

Author'(s') affiliation: (1) MINES ParisTech/ARMINES, (2) VITO, (3) Circular Solutions, (4) OS, (5) CSGI, (6) ES-Géothermie

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Simplified model

Application

- Different case studies
- Create your own simplified model?
  - Stay tuned for training seminar
  - Tutorial to generate LCA simplified models for geothermal systems - GEOENVI project

Description/Links to worksheets	EGS	Flash	CHP	HeatORC
Geothermal source	Liquid	Vapour	Liquid/Vapour	Liquid
Production technology	Downhole pumps	Self-flowing	Self-flowing	Downhole pumps
Power/heat generation unit	Heat exchanger	Flash steam plant	Double flash CHP	Binary / heat exchanger
Cooling system	None	Wet cooling tower	Wet cooling tower	Air cooling tower
Gas control system	None	NCG abatement	None	None
Stimulation	Hydraulic-Thermal-Chemical	None	None	Chemical
Final energy use	Industrial heat	Electricity + industrial heat	Electricity + space heat	Heat + electricity for self consumption

Simplified model

Application

- Web platform for simplified LCA assessment by stakeholders
  - Very easy online tool
  - Fill in key parameters → get LCA results per 1 kWh heat/electricity produced
- Not yet public : Testing phase by committed stakeholders with data of their geothermal projects until **the end of January 2021**.
- Feedback will be gathered before the final version is released in 2021

SUMMARY

Environmental concerns are a major barrier for the development of the deep geothermal market. Life Cycle Assessment (LCA) is the best answer to assess potential environmental impacts. But the methods to perform LCA can vary widely, take a long time and are not tailored to energy systems.

The GEOENVI research project proposes guidelines to harmonize current LCA practices applied to geothermal plants in different geological settings throughout their lifetime.

GEOENVI has also developed newly integrated simplified models for non-LCA experts to assess the potential environmental impacts of geothermal energy systems.

Visit https://www.geoenvi.eu/lca-for-geothermal/

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Thank You

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