Life Cycle Assessment of the Environmental Impacts of the ORCHYD Project

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Background

This work analyzed the environmental impacts of ORCHYD (Novel Drilling Technology Combining Hydro-Jet and Percussion For ROP Improvement In Deep Geothermal Drilling), a Horizon 2020 project, with Life Cycle Assessment (LCA). ORCHYD's objective is to increase the rate of penetration (ROP) of hard rock drilling from the present range of 1 to 2 m/h to a range of 4 to 10 m/h, by combining two previously distinct, mature technologies: High Pressure Water Jetting (HPWJ) and Percussive Drilling.

The effect of the distance of geothermal operations from major urban areas as well as the effect of the drill bit usage lifetime were investigated. The research was rounded up with an Ecological Footprint Assessment (EFA), which further compared the impact of conventional geothermal drilling techniques on the environment with that of the novel drilling technique developed by ORCHYD.

The ORCHYD technique was found to reduce emissions and the average energy required for drilling per meter, improving the sustainability of geothermal drilling operations.

Life Cycle Analysis (LCA)

Eight drilling scenarios were examined. The baseline scenario considered an average ROP of 3.4 m/h, which progressively led to an average ROP of 9.2 m/h in scenario 8. Compared to an ROP of 2 m/h in hard rock formations, scenarios with ROP rates between 4-10 m/h can lead to reductions of:

- Carbon dioxide equivalent by 65.2%;
- Energy consumption (as MJ surplus) by 68.9%;
- CFC equivalent by 3.8%;
- Ozone equivalent by 66.2%;
- Sulfur dioxide equivalent by 66.7%;
- Nitrogen equivalent by 67.1%.

Figure 1. Total impacts of all scenarios for the six examined categories

Effect of distance

This section of the LCA covered the effect of distance that is needed to be covered by project developers for the transportation of materials and equipment. Geothermal operations near cities and remote ones (requiring transportation of 50km) were considered in scenarios 1 and 2 respectively. A total of 50 truckloads of EURO V category freight trucks were assumed for concrete, steel and equipment transport.

Transportation distance had a significant impact on both the MJ surplus category and the carbon footprint of operations. Other categories are expected to have a smaller impact.

ORCHYD

http://www.orchyd.eu

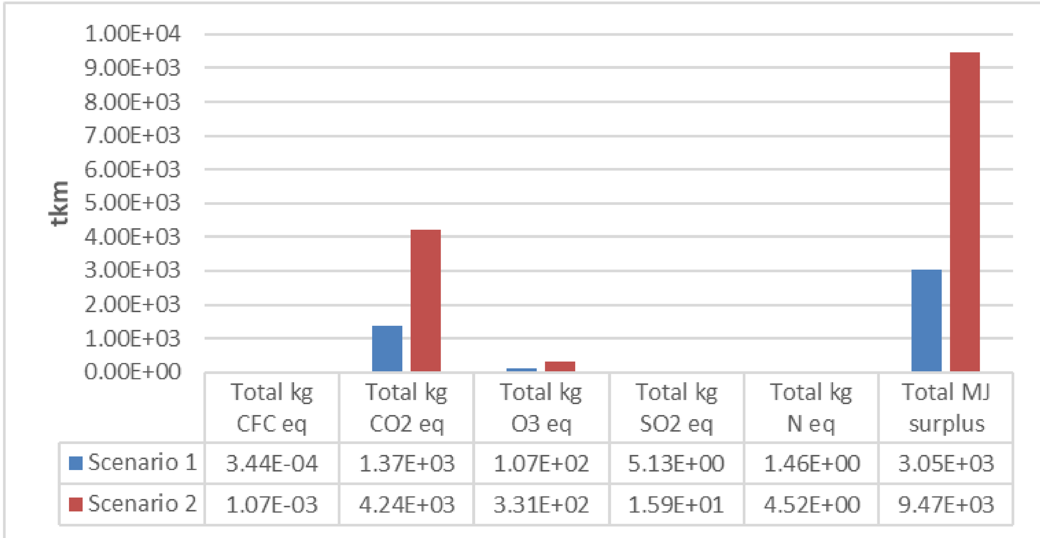

Figure 2. Distance impact on LCA

Effect of drill bit usage

At depths greater than 3000 m, current drilling techniques have a significantly reduced ROP, and the time required to complete the final drilling phases becomes critical (as costs explode).

When the two techniques were compared, it was suggested that 26 drill bits are used with the rotary drilling technique for the crystalline zone, while 13 are used with the percussive and HPWJ techniques for the same zone. Scenario 1 (rotary drilling) required 2,334.6 kg of steel for the drill bits, while scenario 2 (percussive and HPWJ drilling) required 1,196.8 kg of steel.

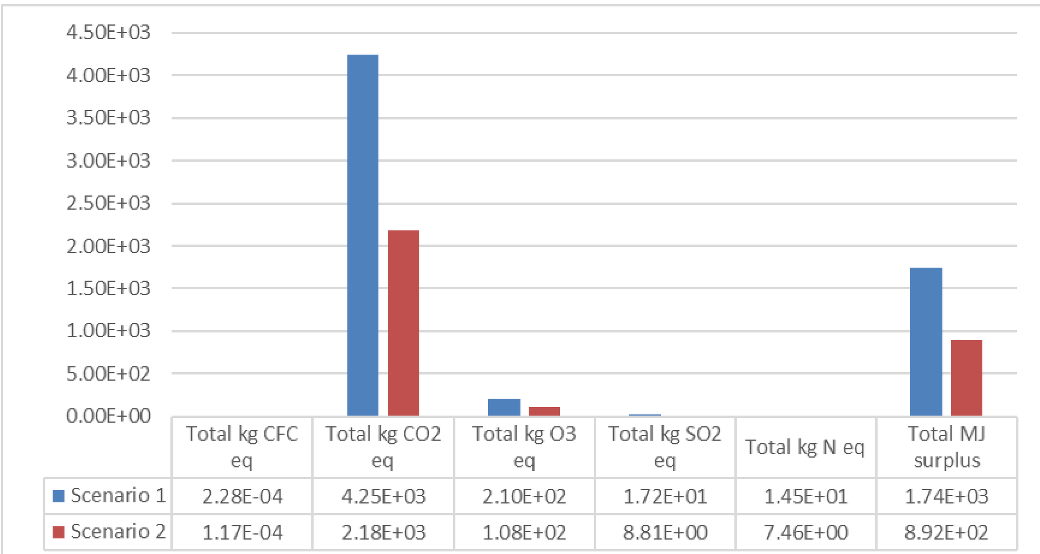

Figure 3. Life cycle emission equivalent and energy surplus vs rotary and percussive/HPWJ of drill bit usage

Effect of bit replacement

Drill bit replacement is an expensive and time-consuming process that can take anywhere from one to three days, depending on the depth of the drill bit at the time of replacement.

Scenarios 1 and 2 were used as a basis for examining how replacement time affects the LCA for the granite drill zone. It was assumed that the average time for replacing a drill bit is 48 hours.

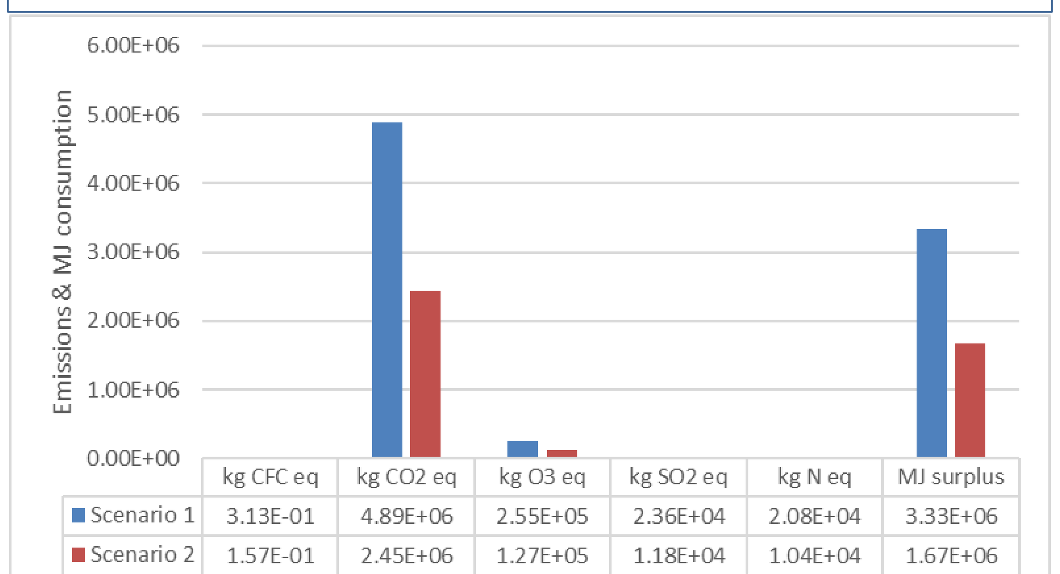

Figure 4. Life cycle emission equivalent and energy surplus vs rotary and percussive/HPWJ of drill bit replacement

Ecological Footprint Assessment (EFA)

The carbon footprint results of the LCA were used for the determination of the ecological footprint of drilling operations using the proposed technique by ORCHYD. All calculations were based on carbon sequestration of forest areas. Different forest areas presented different carbon absorption values.

A weighted average world carbon absorption value was calculated to be 1.3 tons of carbon per hectare. The percentage of carbon absorbed by the oceans was considered 30.8%. The footprint of 1 ton of CO_2 in global hectares was 3.737929 tCO2/gha/yr.

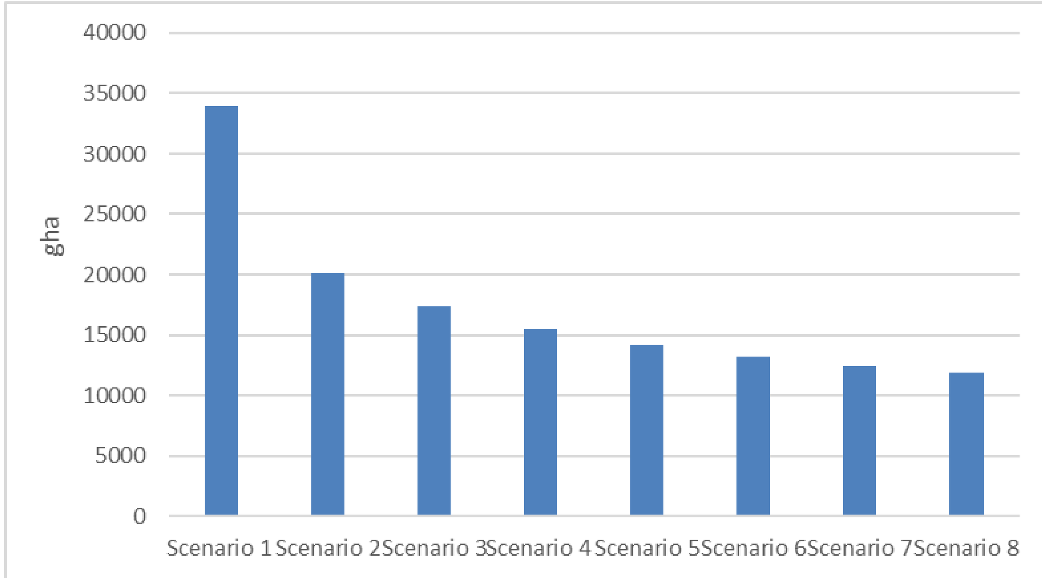

Figure 5. Life cycle emission equivalent and energy surplus vs rotary and percussive/HPWJ of drill bit usage

Discussion & conclusions

The LCA conducted in the different scenarios gave important results concerning the impact of ROP on the emissions and energy consumption of drilling operations. These are summarized as follows:

- There was an inversely proportional relation between ROP and the emission categories examined.
- ROP rates over the 3.5 m/h value of ROP (which was considered in scenario 1), yielded significantly lower carbon footprint and energy consumption during drilling operations (scenarios 2 to 8). Smog was reduced significantly, while minor reductions occurred in the rest of the examined categories as well.
- Drill bit usage and drill bit replacement times were significantly reduced.
- The Ecological Footprint (in global hectares) was reduced by 65.2%.

The results underscore the favorable environmental impacts of higher ROP and highlight the importance of ORCHYD in the path towards sustainable geothermal drilling.

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