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Life-Cycle Environmental Impacts of Individual and District Geothermal Heating and Cooling in Geneva

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In 2017, the energy delivered for heating purposes of buildings in the State of Geneva in Switzerland came from oil- and gas-fired boilers, which led to negative impacts on air pollution and global warming. The 2035 target of the State of Geneva is therefore to reduce the annual heat consumption to 29 GJ/capita, from which 34% should come from renewable energy or waste heat recovery. The State has identified geothermal energy as one of the most prominent sources of renewable energy. Since 2014, GEothermie 2020 program responds to this finding by carrying out projects to characterize Geneva's subsurface and to develop new geothermal projects. Exploration wells between 700 m and 1500 m are planned and being implemented. These projects are organized together with the district heating expansion program. As GEothermie 2020 program has environmental goals at its core, the geothermal developments are accompanied by Life Cycle Assessment (LCA) for evaluating the environmental sustainability.

Concerning geothermal heating and cooling applications, the available state-of-the-art LCA studies were systematically reviewed. Existing studies mostly cover ground-source heat pumps (GSHP), whereas the research on groundwater extraction from medium depth is still very scarce, despite the widespread deployment of such systems in Europe. The environmental impacts of GSHP highly depend on the energetic performance of the heat pump and the electricity mix of the country in question. As a result, the impacts of GSHP are not necessarily lower as compared to those of oil boilers. In contrast, the impacts of groundwater extraction systems are reported in the literature to be lower than those of oil boilers. More LCA results are yet to be obtained to conclude this finding.

Two LCA studies were carried out for a residential building and an office building in Geneva, benefiting from a shallow aquifer at a depth of 10 m and 30 m. The results of LCA with a lifetime of 30 years show that the operation phase contributes the most towards the environmental impacts. Geothermal energy from a shallow aquifer in Geneva reduces, among others, the global warming potential and air pollution (PM10) by 95% and 63% respectively, as compared to an individual oil boiler. It reduces the consumption of fossil fuel by over 95%. However, the impact on water depletion is higher on average by 45 times, owing to the consumption of electricity produced by Swiss hydropower. The use of heat pumps, heat exchangers, and piping leads to high depletion of abiotic resources.

LCA studies are also carried out to evaluate the environmental performance of geothermal energy applications in the context of district heating in Geneva. Concorde and Satigny projects are two of the GEothermie 2020's projects in the development phase. Concorde project aims to incorporate geothermal energy from the aquifer at a depth of 60 m into the district heating that supplies heat to eight buildings. The successfully drilled Geo-01well in Satigny (744 m) could be valorized to supply a district with heating and cooling. An LCA study is performed on a hypothetical installation based on the known parameters of this well.

Sensitivity analyses are performed to identify the parameters that influence the impacts the most. The results of Concorde's and Satigny's LCA study are to be compared with the impacts of conventional oil boilers and the impacts of previously analyzed individual geothermal energy systems. Recommendations of environmentally optimized configurations are to be constructed in order to support the implementation of GEothermie 2020 goals.

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