

## Integrating Circular Economy Framework into Life Cycle Analysis: An Exploratory Study Applied to Geothermal Power Generation Technologies

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**Abstract :** Renewable electricity has become an indispensable contributor to achieving net-zero by the mid-century to tackle climate change. Unlike solar, wind, or hydro, geothermal was stagnant in its electricity production development for decades. However, with the significant breakthrough made in recent years, especially the implementation of enhanced geothermal systems (EGS) in various regions globally, geothermal electricity could play a pivotal role in alleviating greenhouse gas emissions. Life cycle assessment has been applied to analyze specific geothermal power generation technologies, which proposed suggestions to optimize its environmental performance. For instance, selecting a high heat gradient region enables a higher flow rate from the production well and extends the technical lifespan. Although such process-level improvements have been made, the significance of geothermal power generation technologies so far has not explicitly displayed its competitiveness on a broader horizon. Therefore, this review-based study integrates a circular economy framework into life cycle assessment, clarifying the underlying added values for geothermal power plants to complete the sustainability profile. The derived results have provided an enlarged platform to discuss geothermal power generation technologies: (i) recover the heat and electricity from the process to reduce the fossil fuel requirements; (ii) recycle the construction materials, such as copper, steel, and aluminum for future projects; (iii) extract the lithium ions from geothermal brine and make geothermal reservoir become a potential supplier of the lithium battery industry; (iv) repurpose the abandoned oil and gas wells to build geothermal power plants; (v) integrate geothermal energy with other available renewable energies (e.g., solar and wind) to provide heat and electricity as a hybrid system at different weather; (vi) rethink the fluids used in stimulation process (EGS only), replace water with CO<sub>2</sub> to achieve negative emissions from the system. These results provided a new perspective to the researchers, investors, and policymakers to rethink the role of geothermal in the energy supply network.

**Keywords :** climate, renewable energy, R strategies, sustainability

**Conference Title :** ICLCT 2022 : International Conference on Low Carbon Technologies

**Conference Location :** Toronto, Canada

**Conference Dates :** September 20-21, 2022