

Sustainable Approach to Emission Reduction through Carbon Credits in Geothermal Production

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ABSTRACT

Geothermal energy, renowned for its low greenhouse gas emissions, presents a promising avenue for reducing emissions by providing an alternative green and renewable energy source. Currently, most of the global emissions come from power sector where the energy generated substantially by fossil fuels is used to power industries and buildings. Substituting these power sources with geothermal energy could significantly reduce their emissions signature. However, currently geothermal potential is largely underexploited meaning the proportion of geothermal energy fed into national or regional power-grids is still way too low to make meaningful impact on emissions reductions due to the power sector. High costs of resource development, costly technology, seismic risks and existing power purchase agreements are some of the impediments to the wide adoption of the technology. This means unless these challenges are mitigated it will take considerable time to wean the power sector from fossil fuels. This study, therefore, examines how the integration of carbon credits within the geothermal energy sector can be used as a strategic incentive for increased adoption of geothermal energy. The paper investigates the potential benefits, challenges and regulatory frameworks associated with leveraging carbon credits in geothermal projects. Through a comprehensive analysis, it sheds light on how this energy can encourage traditional energy investors to diversify into clean energy projects and also how the carbon credits used as a derivative can help offset development costs, hence, increasing development and feeding of geothermal energy into national and subnational power grids. The study, recommends that there is need for developing carbon trading markets for the developing world markets to enhance the appropriation of carbon credits for investors in the geothermal energy and related sectors.

1. INTRODUCTION

Climate change is one of the most pressing threats to development today. Addressing climate change requires that countries transform their economies and grow in a different way — climate and development planning must be integrated so that policies and actions across multiple sectors and scales lower greenhouse gas emissions, reduce vulnerability to climate shocks and deliver poverty reduction gains. The last 100 years have seen an exponential rise in anthropometric climate change at a scale never witnessed in the history of the earth and that puts the future of the planet and its inhabitants at risk. The main driver of this human induced climate change, which is mainly characterized by global warming and erratic climatic patterns, is carbon emissions due to megatons of carbon emissions annually from the rapid industrialization and massive energy consumption from fossil fuels (Koubi, 2019).

Global climate change is inextricably linked with the enhanced build-up of greenhouse gases. The Intergovernmental Panel on Climate Change (IPCC, 1990) reported for the first time in 1990 that greenhouse gas (GHG) concentrations in the global atmosphere were rising as a result of human GHG emissions, principally from fossil-fuel burning. Since industrialization, the impact of human fossil fuel burning has raised GHG concentration level in the atmosphere by 30%. Scientists have found that the four most important variable greenhouse gases, whose atmospheric concentrations can be influenced by human activities, are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and chlorofluorocarbons (CFCs). The principal greenhouse gases that enter the atmosphere as a result of human activities are: carbon dioxide, methane, nitrous oxide and fluorinated gases. Common GHGs include water vapor, carbon dioxide, methane, nitrous oxides, chlorofluorocarbons, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, ozone, and aerosols. Natural processes and human activities emit GHGs. The accumulation of GHG in the atmosphere regulates the earth's temperature.

Earth's temperature has risen by an average of 0.11° Fahrenheit (0.06° Celsius) per decade since 1850, or about 2° F in total. The rate of warming since 1982 is more than three times as fast: 0.36° F (0.20° C) per decade (Lindsey & Dahlman, 2020). Global temperature is projected to warm by about 1.5 degrees Celsius (2.7° degrees Fahrenheit) by 2050 and 2-4 degrees Celsius (3.6-7.2 degrees Fahrenheit) by 2100 (Huber et al., 2022). Holding temperatures at 2°C or to be precise 1.5°C above pre-industrial levels will require a transformation in production and consumption processes across all countries (Bodnar et al., 2018). It will also necessitate significant support, especially to the poorest and vulnerable people in developing countries, to strengthen adaptation measures and improve community adaptive capacity.

Warmer temperatures over time are changing weather patterns and disrupting the usual balance of nature. This poses many risks to human beings and all other forms of life on Earth (AghaKouchak et al., 2020). Changes in temperature cause changes in rainfall. This results in more severe and frequent storms. They cause flooding and landslides, destroying homes and communities, and costing billions of pounds (Huang et al., 2013). Water is becoming scarcer in more regions. Droughts can stir destructive sand and dust storms that can move billions of tons of sand across continents. Deserts are expanding, reducing land for growing food. Many people now face the threat of not having enough water on a regular basis (Stringer et al., 2021). Nearly all land areas are seeing more hot days and heat waves; 2020 was one of the hottest years on record. Higher temperatures increase heat-related illnesses and can make it more difficult to work and move around. Hot temperatures increase the ozone concentration, which can damage people's lung tissue and cause complications for asthma patients and those with lung diseases (Ćurić et al., 2022).

Africa is the most vulnerable continent to climate change impacts under all climate scenarios above 1.5 degrees Celsius. Despite having contributed the least to global warming and having the lowest emissions (AfDB, 2021a). Seven of the 10 countries that are most vulnerable to climate change are in Africa (Bol & van Niekerk, 2023). Most scientists studying the potential impact of climate change have predicted that Africa is likely to experience higher temperatures, rising sea levels, changing rainfall patterns and increased climate variability, all of which could affect much of its population. Africa faces exponential collateral damage, posing systemic risks to its economies, infrastructure investments, water and food systems, public health, agriculture, and livelihoods, threatening to undo its modest development gains and slip into higher levels of extreme poverty (AfDB, 2021b). More than 110 million people on the continent were directly affected by weather, climate and water-related hazards in 2022, causing more than US\$ 8.5 billion in economic damages. There were a reported 5 000 fatalities, of which 48% were associated with drought and 43% were associated with flooding (ReliefWeb, 2023; Nwokolo et al., 2023). But the true toll is likely to be much higher because of under-reporting.

Climate change in Kenya and across Eastern Africa has led to more frequent droughts. From 2008 to 2011, drought caused economic losses equivalent to 3.9 percent of Djibouti's GDP per annum (AfDB, 2021a). With the largest economy in East Africa and a population of 54 million, Kenya serves as the region's financial, trade, and communications hub. The country's economy is largely dependent on rainfed agriculture, tourism, and natural resources, sectors that are susceptible to climate variability and change and extreme weather events. Climate risks pose serious threats to Kenya's sustainable development goals and development gains despite the fact that the country contributes less than 0.1 percent of global greenhouse gas (GHG) emissions annually. Climate Change has led to more frequent extreme weather events like droughts which last longer than usual, irregular and unpredictable rainfall, flooding and increasing temperatures. For instance, a 2018 by Kenya National Bureau of Statistics study showed Kenya loses 2.0–2.4% of its gross domestic product per year due to the effects of climate change, such as drought and floods (KNBS, 2018).

2. Sustainable Approach

There has been a concerted effort by international stakeholders to reduce the carbon emissions and gradually shift towards green energy. However, this shift requires solid policy initiatives, financing, technological interventions and stakeholder support among other things. Countries now have new and expanded opportunities to finance climate change actions to reduce their vulnerability to the effects of climate change and also mitigate emissions. Two-thirds of the world's greenhouse gas emission reduction potential through 2030 is located in developing countries. More than half of that is in forestry, including reduction of emissions from deforestation and forest degradation (REDD), a top priority for near-term reductions. Beyond REDD, achieving the full potential of emission reduction in developing countries requires investment of hundreds of billions of dollars in renewable energy, transport, and other sectors (O'Sullivan et al., 2010).

Sustainable energy development is an emerging paradigm to combat climate change through the reduction of emissions. A sustainable energy system may be regarded as a cost-efficient, reliable, and environmentally friendly system that effectively utilizes local resources and networks. A sustainable energy system has the potential reducing negative health and environmental impacts, whilst simultaneously increasing energy access, affordability, security and the efficiency of energy use. The renewability concept and sustained yield of energy resources is generally agreed to be a necessary but not a sufficient requirement for sustainable energy development. Renewable energy is energy from sources that are cyclic and naturally replenished on a human time scale. The most common renewable energy sources are: solar, wind, hydro, geothermal, and biomass. The sustainability perspective requires a much broader assessment of energy development. This implies that there is a need to monitor all of the environmental, social and economic impacts associated with renewable energy developments.

Geothermal energy has emerged as one of the most promising sources of renewable energy with vast potential. Geothermal energy is renewable because its source is natural heat generated and stored deep within the Earth's core. The Earth's core contains an incredibly vast amount of thermal energy and some of this energy is accessible near the crust. Geothermal energy is heat that flows continuously from the Earth's interior to the surface—and has been doing so for about 4.5 billion years. The temperature at the center of the Earth is about the same as the surface of the sun (nearly 6,000°C, or about 10,800°F). Geothermal energy has several applications including heating buildings and for generating electricity. Geothermal systems eliminate the combustion of fossil fuels on site and dramatically lower the need to generate power - significantly reducing the emission of greenhouse gasses and the environmental damage associated with nonrenewable resource extraction.

The potential of untapped geothermal energy is substantial, with significant resources waiting to be developed around the world. Geothermal energy remains largely underutilized despite its vast potential due to various factors, including technological limitations, economic considerations, and

regulatory challenges. Based on current geologic knowledge and technology the Geothermal Energy Association (GEA) publicly discloses, the GEA estimates that only 6.9% of total global potential has been tapped so far, while the IPCC reported geothermal power potential to be in the range of 35 GW to 2 TW. International markets grew at an average annual rate of 5 percent over the three years to 2015, and global geothermal power capacity was expected to reach 14.5–17.6 GW by 2020 (Craig & Gavin, 2018). As of 2019, worldwide geothermal power capacity amounts to 15.4 GW, of which 23.9% (3.68 GW) are installed in the US (Ritcher, 2020).

Africa is well known for Geothermal Energy associated with the East African Rift System (EARS) extending through Tanzania, Burundi, Rwanda, Uganda, Kenya, Ethiopia, Djibouti, and Eritrea, but there are other potential locations for low and medium enthalpy Geothermal resources. Geothermal power has contributed to Africa's energy sector since the 1950s. The continent has vast geothermal potential but had an installed geothermal capacity of about of 1 gigawatt (GW) in 2023. Kenya and Ethiopia lead the growth of Africa's geothermal sector, accounting for close to 90% of total capacity. This is due to their rich geothermal resources and the need to diversify Ethiopia's power mix. The power supply in the two countries is expected to increase six-fold from 2023 to 2050, rising from 34 terawatt-hours (TWh) to 222 TWh. However, this will require significant investment. A UNEP-commissioned research, for instance, estimates that the cost of adapting to climate change across Africa could reach \$50 billion a year by 2050, if the global temperature increase is kept within 2°C above preindustrial levels. This financing can be achieved substantially through access to internationally agreed carbon funds specifically through carbon credits.

3. Carbon Credits

Climate finance is critical for helping low-income countries to pursue climate-resilient and low carbon development. It has been an integral part of international climate change negotiations since the start of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 (Dupuy, Lundsgaarde & Persson, 2018). Since 2009 developed countries have reiterated a commitment to mobilize USD 100 billion a year in publicly – and privately – sourced finance to assist poor countries with their societal transformations in response to climate challenges (Amerasinghe, Thwaites, Larsen & Ballesteros, 2017). This agenda covers a wide range of possible actions including support for agricultural extension or infrastructure development to manage the consequences of rising global temperatures, and investment in renewable energies and sustainable transport to limit greenhouse gas emissions (Yoshino & Taghizadeh-Hesary, 2018).

Financial instrumentation and the eventual monetization of carbon finance is, therefore, crucial in driving the sustainability agenda. The Kyoto Protocol proposes a Clean Development Mechanism (CDM) under Article 12 that permits industrialized countries to be able to meet part of their emission reduction targets by investing in emission reduction projects in developing countries (Protocol, 1997). Through CDM projects, the investing entity earns Certified Emission Reduction (CER) credits while stimulating sustainable development in the host country. CDM projects are registered with a CDM registry, a standardized electronic database that ensures accurate accounting of the issuance, holding, and acquisition of CERs (Mwania, 2020).

Carbon credit is a tradable permit or certificate that provides the holder of the credit the right to emit one ton of carbon dioxide or an equivalent of another greenhouse gas – it's essentially an offset for producers of such gases. Therefore, they can purchase carbon credits to comply with the emission cap. Carbon markets is a system for buying and selling carbon credits, which are instruments that allow companies, governments, and other organizations to address their greenhouse gas emissions by funding projects that reduce or remove carbon dioxide from the atmosphere.

Carbon credits cap how much CO₂ can be emitted by an entity. This cap on emissions can be gradually reduced over time, leading to less and less overall emissions. In the early 2010s, when renewable energy sources were cost prohibitive, revenue from carbon credits aided the development

of renewable energy projects in countries like China, India, Brazil, and Turkey. Renewable energy sources (RES) carbon credits generated large issuances and have historically made up a significant portion of available credits in voluntary carbon markets (VCMs). RECs create new energy from lower or zero-carbon sources, rather than from traditional fossil fuels (Ozcan, 2022). RES projects are a type of avoidance carbon credit measured in metric tons of carbon dioxide (tCO₂). These emissions reductions credits are based on displacing greenhouse gas emissions from fossil fuel power plants with renewable electricity beyond a grid baseline (Downey & Ellis, 2022).

As alternative financing instruments incentivizing the development of renewable energy capacity, RES carbon credits and RECs play an important role in the energy transition and co-exist in the renewables landscape. Some renewables projects on the market that have revenue streams from both the sale of carbon credits and RECs, and both can help companies achieve their net-zero goals. However, RES carbon credits and RECs have material differences buyers need to be aware of when making claims about renewables usage in their value chain and their offset strategy.

Carbon credit schemes in Kenya fall under two categories: those under the compliance market—primarily the Clean Development Mechanism (CDM) — and those under the Voluntary Carbon Market (VCM). The present study will focus on Clean Development Mechanism Projects. As of 2021, some 20 CDM projects could be cited to have been successfully registered in Kenya with others in the pipeline (NEMA, 2021). These projects varied greatly ranging from geothermal, wind, hydro and biogas power projects, bio residue briquettes, to small-scale afforestation and reforestation programs (Nyambura & Nhamo, 2014; NEMA, 2021). Over \$2.1 billion has been invested in these projects, which are estimated to produce cumulative emissions savings in excess of 135 million tons of carbon dioxide offsets (million tCO₂e) (Mwania, 2020).

4. Geothermal Production and Carbon Credits

Carbon finance in the form of carbon credits can provide the geothermal field with a crucial economic incentive encouraging further investment and development in this renewable energy source. Now that the instrumentation of climate finance through carbon credit system is gaining traction, the geothermal sector could greatly leverage carbon credits to provide funding for further development in the sector (Pan et al., 2019). Carbon credits enhance the financial viability of geothermal projects by creating additional revenue streams. This integration and carbon markets strengthens the position of geothermal energy within the broader renewable energy landscape. The use of carbon credits in geothermal projects could facilitate significant reduction of greenhouse gas emissions, contributing to global efforts in mitigating climate change and promoting cleaner energy transition.

Further, the availability of carbon credits can stimulate innovation in geothermal technologies, fostering the development of more efficient and sustainable practices that align with emission reduction goals. Carbon credits enable international collaboration by providing a standardized metric for emissions reduction, encouraging cooperation among nations to achieve sustainable geothermal development on a global scale. The adoption of carbon credit mechanisms fosters community and stakeholder engagement as local populations witness the positive environmental impact of the geothermal projects and share in the economic benefits through the carbon credit revenue. Carbon credits serve as a risk mitigation tool, providing a predictable revenue stream for geothermal projects and attracting investment by offering a hedge against regulatory uncertainties and market fluctuations. The utilization of carbon credits align geothermal energy projects with broader sustainable development goal creating a win-win scenario where economic growth is coupled with environmental stewardship.

However, the carbon trading system still faces challenges which could impede the sales of carbon credits and the subsequent appropriation of carbon finance for geothermal development. Challenges include market volatility, regulatory complexity, fraud risks, equity concerns, and over-reliance on

offsets rather than direct emission reduction. Effective in combating climate change, carbon credits necessitate stringent regulation and transparency for optimal impact (Rhodes, Scott & Jaccard, 2021). Further, there is no global marketplace for carbon trading, several regional jurisdictions have created their own markets for the exchange of carbon credits (Keohane, Peterson & Hanafi, 2017).

According to Sovacool (2011) in a critique of global carbon markets and trading, with a special focus on the Clean Development Mechanism of the Kyoto Protocol, problems with the use of tradable permits to address climate change revolve around four areas: homogeneity, justice, gaming, and information. Homogeneity problems arise from the non-linear nature of climate change and sensitivity of emissions, which complicate attempts to calculate carbon offsets. Justice problems involve issues of dependency and the concentration of wealth among the rich, meaning carbon trading often counteracts attempts to reduce poverty. Gaming problems include pressures to promote high-volume, least-cost projects and the consequences of emissions leakage. Information problems encompass transaction costs related to carbon trading and market participation and the comparatively weak institutional capacity of project evaluators.

5. Conclusions

In conclusion, this research advocates for a holistic and sustainable approach to emission reduction in geothermal production fields, inform policy makers, efficient resource management, encompassing technological advancements, waste heat utilization, industry stakeholders, environmental enthusiasts and community involvement. By adopting such a comprehensive strategy, geothermal energy can evolve into a more environmentally friendly and socially responsible energy source. Therefore, as a recommendation, there is need for developing carbon trading markets for the developing world markets to enhance the appropriation of carbon credits for investors in the geothermal energy and related sectors.

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