Presented at "SDG Short Course I on Sustainability and Environmental Management of Geothermal Resource Utilization and the Role of Geothermal in Combating Climate Change", organized by UNU-GTP and LaGeo, in Santa Tecla, El Salvador, September 4-10, 2016.

UNITED NATIONS UNIVERSITY
UNU-GTP
Geothermal Training Programme

LaGeo
GrupoCEL

GEOTHERMAL MITIGATION AND ADAPTATION STRATEGIES IN RESPONSE TO CLIMATE CHANGE

Pacifica Ogola[1)] and Brynhildur Davídsdóttir[2)]
1) Kenya State Department of Environment
Ministry of Environment, Natural Resources and Regional Development
NHIF Building, 12th floor, Ragati Road, Upperhill, Nairobi
KENYA
2) University of Iceland
Saemundargata 1, 101 Reykjavík
ICELAND
bdavids@hi.is

ABSTRACT

In this paper, the role of geothermal energy in mitigation and potential role in adaptation are reviewed. The paper then presents the Geothermal Adaptation-Mitigation (*Geo-AdaM)* conceptual framework. The Geo-AdaM framework can be used in combining mitigation and adaptation linked to geothermal projects, e.g. by introducing adaptation in Clean Development Mechanism or mitigation projects, using geothermal energy in climate vulnerable sectors, combining geothermal development with carbon forestry to improve recharge of geothermal systems in water stressed areas, displacing fossil fuels in heating and cooling, and use of geothermal heat in greenhouses to create carbon sinks and green areas. The framework presented in this paper can cut across most regions, and types of utilisation schemes with mitigation/adaptation co-benefits. The resulting co-benefits come with net positive environmental, economic and social impact.

1. INTRODUCTION

1.1 General

Climate change is one of the most threatening environmental problems globally. The international community reacted to the threat through the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. Binding Greenhouse Gas (GHG) mitigation targets were agreed to in the Kyoto Protocol, adopted in 1997, yet only applied to more affluent countries. Following the 2015 Paris agreement, 180 countries have committed themselves to GHG mitigation with the aim of "a long-term goal of keeping the increase in global average temperature to below 2°C above pre-industrial levels". Governments in addition committed to adaptation action where they agreed to "strengthen societies' ability to deal with the impacts of climate change" and "provide continued and enhanced international support for adaptation to developing countries". Today, simultaneous planning of climate change mitigation and adaptation actions are acknowledged as necessary in building a strategic approach to climate change (IPCC, 2007; Ogola et al., 2012a and 2012b). Treating them separately as done in the past, may undermine the effectiveness as mitigation actions, may limit adaptation capacity and adaptation may lead to less effective mitigation. Harmonized planning may minimize risks of such conflicts, enabling capitalizing on synergies between the two.

Investment in low-carbon energy resources such as geothermal power is a powerful climate change mitigation action. At the same time, given its potential to have direct and indirect positive socioeconomic impacts, it may also significantly contribute to adaptation. This paper addresses the importance of geothermal energy in the context of adaptation and mitigation, and then presents a framework for a harmonized approach in the context of geothermal development. The materials in this paper are largely derived from Ogola et al. (2012a and 2012b).

2. DEFINING MITIGATION AND ADAPTATION

The Intergovernmental Panel on Climate Change (IPCC, 2001a; Appendix II Glossary) defines mitigation as, "Anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases." The aim of mitigation is therefore to prevent climate change through reducing GHG emissions by man-made interventions and through enhancing sequestration for example in forests and other vegetation.

The IPCC (2001b; Appendix II Glossary) defines adaptation as, "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation" (IPCC, 2001b; Annex B Glossary of Terms). According to the IPCC, adaptation therefore includes actions that moderate harm as well a actions that enable taking advantage of the opportunities offered by climate change or climate change mitigation.

As stated in the introduction, up until now, the two strategies, mitigation and adaptation were largely viewed separately (IPCC, 2007). The third assessment report (AR3) of the IPCC clearly distinguished mitigation and adaptation, but for the first time in the fourth assessment report a chapter on the interrelationships, the synergies and tradeoffs between the two was introduced (IPCC, 2007). The fifth assessment report (AR5) even further considered integration, however the structure of the IPCC working groups still maintains the divide.

3. GEOTHERMAL ENERGY AND MITIGATION

3.1 Mitigation in the Paris Agreement

The Paris agreement of 2015 ends the differentiation between developed and developing countries in the context of mitigation actions that characterized earlier efforts. These are replaced with a common framework that commits all countries to put forward their best efforts and to strengthen them in the years ahead. This includes, for the first time, for example requirements that all parties report regularly on their emissions and implementation efforts, and undergo international review.

The main features of the Paris agreement relating to mitigation include (C2ES, 2015):

- *Reaffirm the goal of limiting global temperature increase well below 2 degrees Celsius, while urging efforts to limit the increase to 1.5 degrees;*
- *Establish binding mitigation commitments by all parties to make "nationally determined contributions" (NDCs), and to pursue domestic measures of mitigation aimed at achieving them;*
- *Commit all countries to report regularly on their emissions and "progress made in implementing and achieving" their NDCs, and to undergo international review;*

- *Commit all countries to submit new NDCs every five years, with the clear expectation that they will "represent a progression" beyond previous ones;*
- *Reaffirm the binding obligations of developed countries under the UNFCCC to support the efforts of developing countries, while for the first time encouraging voluntary contributions by developing countries too;*
- *Extend the current goal of mobilizing $100 billion a year in support by 2020 through 2025, with a new, higher goal to be set for the period after 2025; and*
- *Call for a new mechanism, similar to the Clean Development Mechanism under the Kyoto Protocol, enabling emission reductions in one country to be counted toward another country's NDC.*

3.2 GHG emissions and mitigation opportunities from geothermal industry

Emissions per kilowatt-hour of electricity derived from high-temperature geothermal fields are significantly lower than derived from fossil fuel resources. According to data derived from 85 geothermal plants in 11 countries, emissions of GHG measured in grams per kilowatt hour range from 4 to 740 g, with a weighted average of 122 g kWh^{-1} (Fridleifsson et al., 2008). As high-temperature geothermal power for electricity generation is mainly limited to geologically active regions, the regions most promising with respect to reduced GHG emissions from development of high temperature geothermal resources are located in Central America and in the East African Rift Valley. Fridleifsson et al. (2008) illustrate that in these areas 39 countries have the potential to produce close to 100% of their electricity needs from geothermal resources. Given the global potential and reasonable rate of investment, Fridleifsson et al. (2008) also illustrate that by 2050 approximately 8.3% of the total world electricity demand could be met with geothermal resources. Assuming that this investment would replace coal-fired power plants this investment could mitigate slightly less than 1 billion tons of CO_2 emissions in 2050. Ogola et al. (2012b) illustrate an even larger potential or a range between 1 to 5 billion tons of mitigated GHG´s in 2050.

Direct use of geothermal power from low-temperature areas, such as for space and water heating in various contexts also provide mitigation benefits and the same applies to heat pumps. Emissions due to direct use are minimal as they on average do not exceed normal natural background emissions. For example the district heating system in Reykjavík emits about 0.5 mg CO_2 kWh^{-1} Fridleifsson et al. (2008). The mitigation benefits therefore can be significant. Fridleifsson et al. (2008) assessed the mitigation potential for heat pumps to be over 200 million tons CO_2/yr for heat pumps, given that the heat pumps are replacing older units that are driven by fossil fuels. Abatement potential for other direct use amounted to over 90 million tons CO_2/yr.

Adding together mitigation potential due to indirect use for electricity generation and from heat pumps, the total mitigation potential amounts to approximately 12% of total GHG emissions by 2050, when compared to IEA reference scenario, assuming no carbon capture and storage (IEA, 2015).

3.3 CCS and CCU

Carbon capture and storage (CCS), is the process of capturing CO_2 from significant point sources such as power plants, transporting it to a storage site, and depositing it, normally in an underground geological formation such as deep aquifers. The aim is to ensure that CO_2 will not enter the atmosphere. The geothermal industry has participated in the development of CCS. A new method called Carbfix, developed by researchers at University of Iceland, Columbia University and Reykjavik Energy was recently scientifically confirmed to work. The Carbfix project "fixes" carbon by dissolving CO_2 in water and then re-injected deep into the ground into volcanic basaltic rocks. Once that happens, the CO_2 turns into a solid mineral (calcite), which can then be stored for a long time. Recent observations confirm that this method is effective as 95% of the carbon injected is calcified within 2 years (Matter et al., 2016). The method however has its limitations as large amount of water is required for the process and it is site specific, as it requires basaltic rock. It does however complement other CCS methods that most depend on re-injection to sedimentary rock.

Carbon capture and use (CCU), is the process of capturing CO_2 from industries but rather than storing the carbon deep underground, the carbon is used in industrial applications and in horticulture applications for example (Ogola et al., 2012a). Horticulture applications include use in greenhouses and industrial applications include transforming CO_2 using chemical processes into methanol that can be used for example for transportation (Ogola et al., 2012a and 2012b).

4. GEOTHERMAL ENERGY AND ADAPTATION

Geothermal energy using high and low temperature resources has a significant role to play in enhancing adaptive capacity to climate change. This potential can be realized by identifying climate vulnerable sectors such as, agriculture, energy (hydropower, biomass), fisheries, livestock, health, water, as well as heating and cooling requirements among others and using geothermal energy to enhance their adaptive capacity (Ogola et al., 2012a and 2012b).

Ogola et al. (2012a) assessed the potential role of geothermal utilisation in drought vulnerable sectors using local resources within a radius of 50 km in the Eastern Baringo lowlands in Kenya. This area suffers from high poverty levels, poor infrastructure, recurrent droughts, limited natural resources, high vulnerability to diseases and food insecurity, among other factors. The population largely depends upon wood fuel, kerosene and candles for lighting. Artisanal industry is not yet developed. Ogola et al. (2012a) illustrate that the development of geothermal resources in the region will improve physical access to electricity and therefore improve energy services such as lighting in homes and institutions, in addition to have the potential to enhance diverse rural micro enterprises through cascading use of the geothermal resource. The positive socioeconomic impact will then enhance adaptive capacity of the affected population to climate change. The observations made by Ogola et al. (2011; 2012a) in Kenya apply to other regions, illustrating the importance of geothermal energy in climate change adaptation.

Similar adaptation opportunities exist, in the utilization of low temperature resources in for example irrigation projects and greenhouses. Application of geothermal water for irrigation for example, is practiced in Tunisia where about 31,500 ha of oasis is irrigated with cooled geothermal water (Mohamed, 2010). This type of application can save limited fresh water resources and boost agricultural production, but its consumptive use can reduce reservoir recharge and thus needs to be planned carefully. Geothermal energy through this type of utilization schemes can create livelihoods that are resistant to drought, lead to higher and diversified agricultural production, provide cooling and heating requirements needed in extreme temperatures, among other benefits (Ogola et al., 2012a).

5. THE FRAMEWORK FOR ADAPTATION AND MITIGATION: THE GEO-ADAM MODEL

As stated above, geothermal projects contribute to mitigation by replacing fossil fuel based sources for power generation or heat. They also contribute to adaptation e.g. through cascading utilisation in climate sensitive sectors enhancing adaptive capacity. The possibility of developing geothermal utilization schemes in a cascaded system, grid based, or in an off-grid mini-grid thus gives simultaneous mitigation and adaptation co-benefits. Figure 1 illustrates the co-benefits derived from geothermal adaptation-mitigation projects. Co-benefits are shown at the intersection between the two inner circles (Ogola et al., 2012b).

The outer circle embraces both adaptation and mitigation of geothermal development, and shows how the two can be derived from a single geothermal project, using either high or low temperature resources. Not all geothermal utilization schemes should qualify as direct adaptation projects. Only projects that

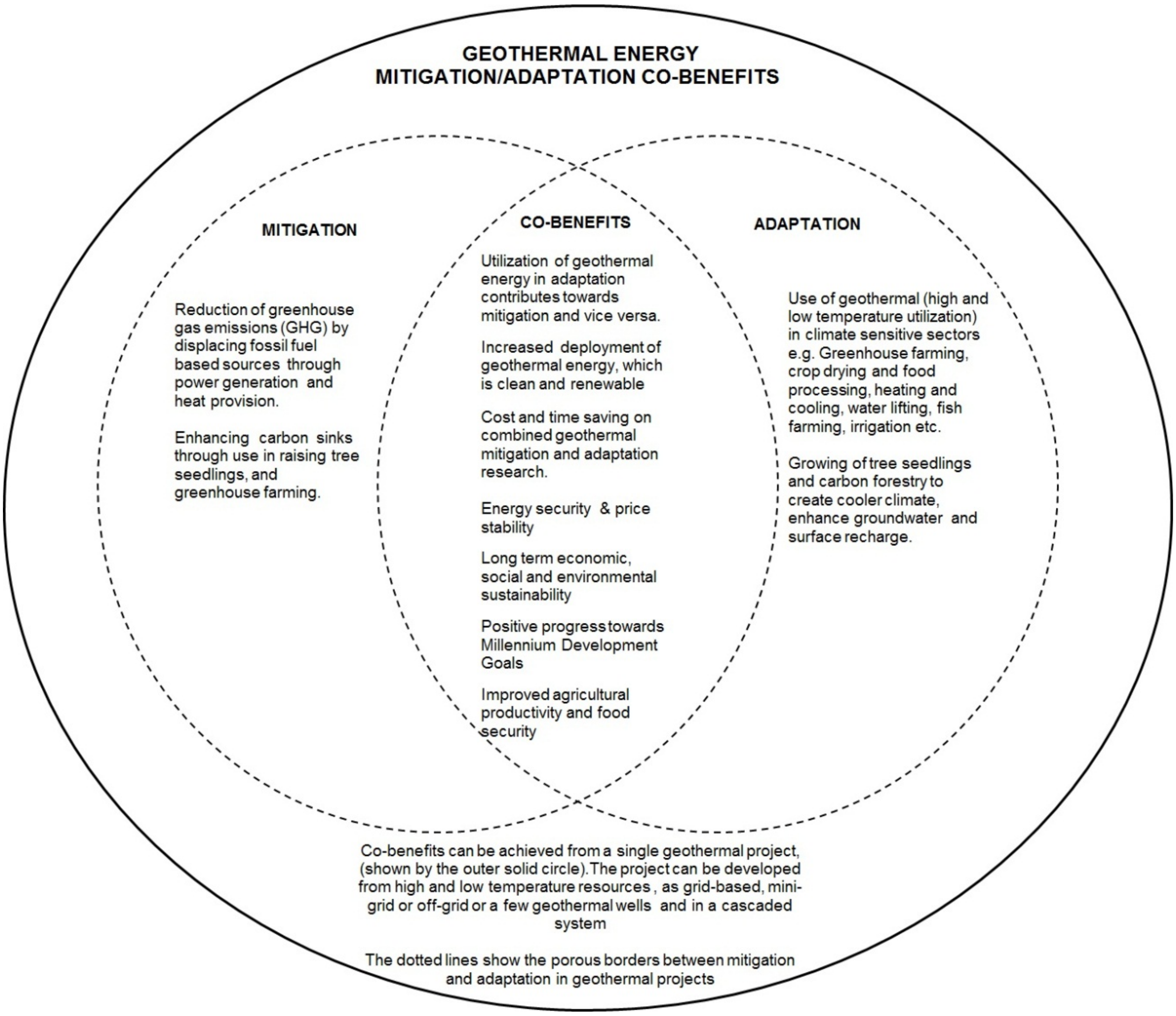

FIGURE 1: Mitigation and adaptation co-benefits in geothermal projects
(Ogola et al., 2012b)

are targeted towards a specific climate change impact, with clear adaptation benefits can qualify as such. To reveal such direct impacts an adaptation additionality assessment is needed as is required for mitigation projects in CDM (Ogola et al., 2012b).

Derived from Ogola et al. (2012b) a conceptual framework explaining the processes involved in creating and strengthening adaptation-mitigation synergies in geothermal projects is presented in Figure 2, below. Based on this framework the potential a geothermal development has to significantly contribute to climate change resilient societies, is revealed.

Figure 2 is broken to two parts. The first part of shows the **geothermal resource assessment stage**, while the second part depicts **implementation** and thereby the cycle of activities required when linking adaptation to mitigation. The two parts are described below (fully based on Ogola et al. (2012b).

a) Assessment stage (screening and scoping)
At this stage, climate variability and community vulnerability assessments have been carried out. Based on the vulnerability assessment, various adaptation need assessments that can be enhanced through geothermal utilisation are performed, including finding out the availability of raw materials and natural resources such as, agricultural produce, fisheries etc, within a predefined radius. At this stage, screening and scoping for vulnerability, adaptation needs and geothermal resource availability should be completed and the relevant sectors/activities, and their contribution to adaptation clearly listed. After

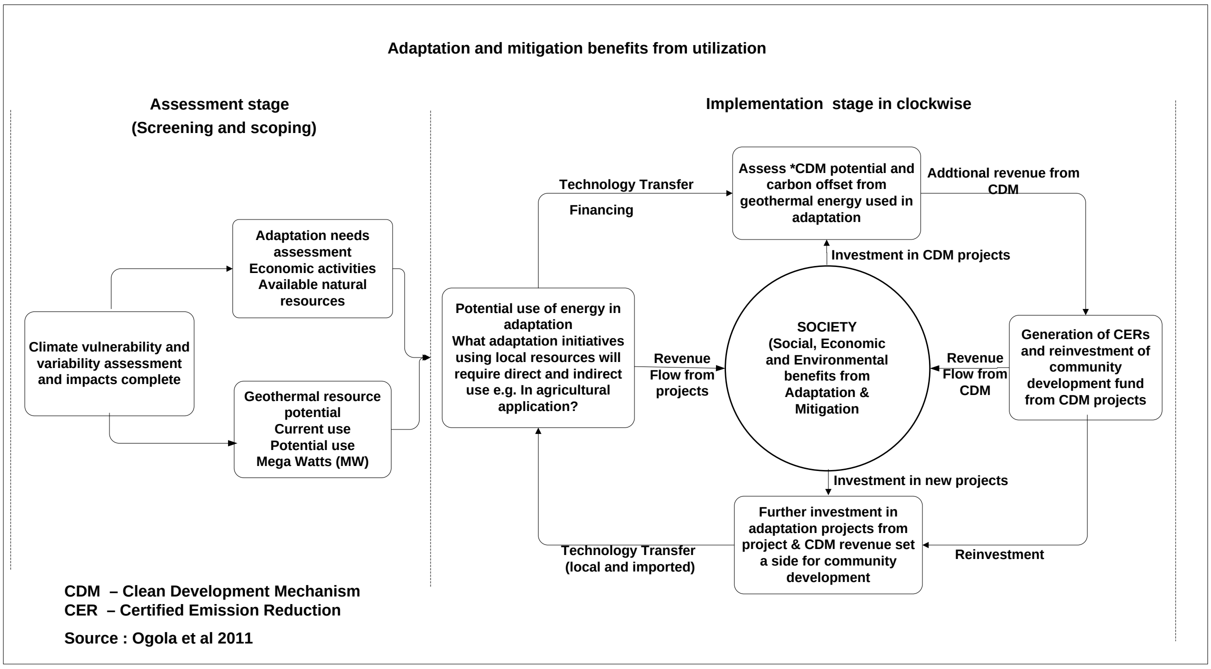

FIGURE 2: The Geo-AdaM conceptual framework showing the assessment, implementation and benefits of mitigation adaptation synergy from geothermal projects (Ogola et al., 2012b)

scoping, various options for utilisation can be assessed based on technical (e.g. cascaded system, capacity MW etc), economic (e.g. investment costs, tariff, operation and maintenance costs), social (e.g. improvement in social well being, resilient livelihoods etc) and environmental aspects (e.g. expected CO_2 –eq emission reduction, and other co-benefits). Adaptation additionality and benefits, must be clear at the end of the assessment stage. Expected synergies and tradeoffs must also be clear (Ogola et al., 2012b).

b) Implementation stage

Once the screening and scoping assessment is complete, various geothermal utilization projects are developed to enhance local adaptation in climate vulnerable sectors such as, agriculture, provision of water, livestock and fisheries development and others. Application of geothermal energy in these sectors will generate revenue streams into society. Since geothermal energy projects qualify as mitigation projects, the adaptation projects utilizing geothermal energy can be registered as CDM projects with an adaptation component. The CDM projects will generate additional revenue streams through Certified Emission Reductions (CERs). Some of the revenue from CDM can go to the community as income or be reinvested in more adaptation projects using more geothermal energy, while attracting local and international technology transfer and increasing production of local raw materials (Ogola et al., 2012b). In the Paris agreement a new mechanism will replace CDM but its structure is not known at this point.

The new projects are then further assessed for their carbon offset potential bringing in additional financing and technology transfer and continuing the cycle while building community resilience. The concept promotes sustainable development, and illustrates how geothermal energy can enhance both adaptation and mitigation.

A non-exhaustive list of indicators that can be used in monitoring the mitigation-adaptation geothermal projects under the *Geo-AdaM* framework in comparison to the baseline include (Ogola et al., 2012b):

- tCO_2-eq reduced per year;
- Number of megawatts going towards adaptation and contributing towards mitigation;

- Number of projects depending on geothermal energy and their impact on adaptation and mitigation;
- Percentage of population benefiting from development and their adaptive capacity including income, and improved access to water;
- Reduction in economic losses due to extreme weather events;
- Improved agricultural yield in geothermally heated greenhouses, agricultural drying, and food preservation etc.;
- Number of people with improved health, and reduction in number of vulnerable people as well;
- Reduction in human and animal loss where drought is recurrent.

5. CONCLUSION

This paper has illustrated how geothermal projects implemented as mitigation projects can also contribute towards local adaptation, when used to respond to a particular adaptation need. Similarly, application of geothermal utilization aimed at adaptation can also contribute towards GHG emission reduction. However, not all geothermal utilization schemes can qualify as direct adaptation projects and only projects that are targeted towards a specific climate change impact, with clear adaptation benefits qualify. It is however clear that the use of geothermal energy in combined mitigation and adaptation actions have greater co-benefits and larger socioeconomic implications than when used for mitigation alone. As a result, the Geo-AdaM conceptual framework is useful when realizing the full societal potential of geothermal development.

REFERENCES

C2ES, 2015: *Outcomes of the U.N. climate change conference in Paris*. Center for Climate and Energy Solutions, Arlington, Virginia, United States, 5 pp.

Fridleifsson, I.B., Bertani, R., Huenges, E., Lund, J.W., Ragnarsson, Á., and Rybach, L., 2008: The possible role and contribution of geothermal energy to the mitigation of climate change. In: Hohmeyer, O. and Trittin, T. (editors), *Proceedings of IPCC Scoping Meeting on Renewable Energy Sources*, Luebeck, Germany, 59-80.

IEA, 2015: *Energy technology perspectives 2015*. Organization for Economic Cooperation and Development (OECD) / International Energy Agency (IEA), Paris, France, 418 pp.

IPCC, 2001a: *Climate change 2001: Mitigation. Contribution of Working Group III to the third assessment report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, New York, United States, 677 pp.

IPCC, 2001b: *Climate change 2001: Impacts, adaptation and vulnerability. Contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, New York, United States, 1023 pp.

IPCC, 2007: Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, New York, United States, 976 pp.

Mohamed, B.M. 2010: Geothermal direct application and its development in Tunisia. *Proceedings of the World Geothermal Congress 2010*, Bali, Indonesia, 8 pp.

Matter, J.M., Stute, M., Snaebjörnsdóttir, S.Ó., Oelkers, E.H. Gíslason, S.R., Aradóttir, E., Sigfússon, B., Gunnarsson, I., Sigurdardóttir, H., Gunnlaugsson, E., Axelsson, G., Alfredsson, H.A., Wolff-

Boenisch, D., Mesfin, K., de la Reguera Taya, D.F., Hall, J., Dideriksen, K., and Broecker, W.S., 2016: Rapid carbon mineralization for permanent disposal of anthropogenic carbon dioxide emissions. *Science, 352*, 1312-1314.

Ogola, P.F.A., Davídsdóttir, B., and Fridleifsson, I.B., 2011: Lighting villages at the end of the line with geothermal energy in Eastern Baringo lowlands, Kenya: Steps towards reaching the Millennium Development Goals (MDGs). *Renewable and Sustainable Energy Reviews, 15*, 4067–4079.

Ogola, P.F.A., Davídsdóttir, B., and Fridleifsson, I.B., 2012a: Potential contribution of geothermal energy in climate change adaptation. A case study of arid and semi-arid eastern Baringo lowlands, Kenya. *Renewable and Sustainable Energy Reviews, 16*, 4222–4246.

Ogola, P.F.A, Davídsdóttir B, and Fridleifsson, I.B., 2012b: Opportunities for adaptation–mitigation synergies in geothermal energy utilization – Initial conceptual frameworks. *Mitigation and Adaptation Strategies for Global Change, 17*, 507-536.