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Evaluating Policy Options for Transition to Decarbonized Society in Africa

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ABSTRACT

To identify whether African countries can succeed in the transition to a decarbonized society by 2050, this study developed a simulation model creating scenarios with limited data and analyzed the decarbonization potential in Africa. Impact analyses were also conducted to assess effective policy options in industrial, residential, commercial, and transportation sectors for each of the African regions. The types of decarbonization policies that would be effective were also quantitatively evaluated according to each country's degree of economic development. The results showed that under a realistic future assumption, building a decarbonized society by 2050 would be difficult. The results also indicated that the introduction of electric and fuel-cell vehicles and the improvement of cooking stoves in African countries where gross domestic product (GDP) per capita is low would be effective in reducing carbon dioxide emissions relative to the reference scenarios.

1. INTRODUCTION

A global stocktake of greenhouse gas (GHG) emissions was conducted at the 2023 United Nations Climate Change Conference (COP28) to determine the progress towards meeting the goals of the Paris Agreement. The decision document stated that there is a gap between current conditions and the goal of limiting the global temperature increase to 1.5°C, and that action and support are needed to achieve the 1.5°C target. The importance of implementation measures in the decarbonization transition was confirmed.

Africa's GHG emissions were only about 3.8% of total global emissions in 2022 [5]. However, it is expected that GHG emissions will increase in the future because of population growth and increased industrialization. To reduce future emissions, it will be necessary to not only reduce emissions in Asia, North America, and Europe, which are major emitting regions by 2050, but also to reduce the emission growth rate in Africa and other areas [8].

In addition, the energy situation in African countries is a social issue unique to Africa. As of 2016, more than two-thirds of the population of Sub-Saharan Africa (about 600 million people) do not have access to energy sources [2]. The Sharm el-Sheikh Implementation Plan (UNFCCC, 2022) calls for greater support from the state to meet emission goals. In order to implement effective public funding assistance based on the mobilization of private funds, it is necessary to determine what kinds of policies to focus on.

Unfortunately, in developing countries in Africa, there is a lack of data necessary for such evaluations, and data coverage and availability are not uniform in each country. Because of the inadequacy of socioeconomic data, it is quite difficult to compare 2050 GHG scenarios of African countries by region and country. In addition, many African countries do not have enough statistical data for a comprehensive evaluation of policies compared with other regions, but policy and technology options need to be evaluated as a pathway to future decarbonization in the formulation of nationally determined contributions (NDCs) and long-term strategies.

Therefore, in this study, this research aimed to use a simple model to formulate scenarios for the transition to decarbonization in African countries by 2050. Using the scenarios, the differences in the effectiveness of measures by region were compared, so that important policies in African countries could be evaluated from a macro perspective, allowing these countries to adopt effective policy options. It is expected that this analysis and the results will be useful as a reference when considering how to provide effective support to national and international organizations, for example, when African countries requested more financial support at COP29 [11].

2. MODEL

This study developed a simple simulation model that can be used even for countries with insufficient data and applied it to African countries. It is a comparative static simulation model that calculates future energy consumption and GHG emissions. It can be used as a

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tool to integrate future economic, industrial, social, and energy scenarios with GHG emission reduction targets and mitigation measures. The model calculates the energy balance and CO_2 emissions while maintaining consistency across sectors, considering service demand, energy share, and energy improvements by service energy category in the base year and target year [9]. As compared with the computable general equilibrium and Extended SnapShot Tool models [3], this model is more suitable for African countries where the industrial structure is unclear because the activity indicators are set by population and GDP, without conducting an inter-industrial analysis. For all analyses, it is assumed that the industrial structure in the future is the same as the current structure. By using this model, this research created a scenario for a decarbonized society in 2050 in each target country and quantitatively analyzed what kinds of policies would be effective to achieve the target. Although scenarios for 2030, 2040, and 2050 were created for the target countries as they work toward the realization of a decarbonized society, this paper focuses only on the 2050 results and analysis in the following sections.

3. TRANSITION SCENARIOS

The International Energy Agency (IEA) has published energy balance tables for 35 African countries, which were the countries targeted in this analysis. In setting expected future conditions for 2050, the scenario used the World Bank's database [13] to set the future population of each country. In addition, as no forecasts for the average annual growth rate of gross domestic product (GDP) were available for the study countries, it was set at 4.1% [12]. The energy consumption settings are shown in Table 1, and the power supply mix for each region was set as shown in Table 2, on the basis of the power supply configuration estimated in a technical report to be required to reach the 1.5°C target by 2065 [2]. Carbon capture and storage (CCS) was set by referring to the IEA [4]; the installation rate was assumed to be 3% for fossil fuel-derived power plants and 0% for biomass power generation.

Although scenarios were developed for all 35 countries, the focus is on the five regional groups listed in Table 2. Under the reference scenario, CO_2 emissions from combustion in all five regions in 2050 are at least double those of the base year, whereas estimated emissions in the countermeasure scenario under the assumption (Table 1) are less than those of the base year, except in the Eastern region. Eastern countries are supposed to still relatively depend on coal as part of their energy structure in 2050 (Figure 1 and Table 2). The expected emissions in central, northern and western countries in 2050 are 35.4 million tons (Mt), 265.5 Mt and 99.5 Mt, respectively, from consumption of fossil fuels (mainly oil and gas) (Figures 2, 3, and 5). In the central region, the current power source composition is dependent on biomass and oil, but a shift to renewable energy, hydropower, and gas power is envisioned to meet growing energy demand, with great expectations for hydropower, for which Africa has abundant resources [2]. The current power supply mix in northern Africa is dependent on gas and oil, but a shift from fossil fuels to renewable energy is envisioned (Figure 3 and Table 2). The current power source mix in western Africa is expected to shift from biomass, gas, and oil to renewable energy, mainly hydropower (Figure 5 and Table 2). The southern region could achieve zero energy-related CO_2 emissions (Figure 4) because it is projected to make a drastic energy transition from coal to zero emission resources [2].

Table 1. Assumptions about measures in 2050.

Sector	Model assumptions about measures in 2050
Industry	Improvements in the efficiency of industrial machinery such as boilers (7%–33% improvement)
Transport	Progress in penetration of EVs (50%) and fuel cell vehicle (FCV) passenger cars (50%); electrification of railroads (100% penetration); improving fuel efficiency of airplanes (20%)
Residential and Commerce	Electrification and improvements in the efficiency of air- conditioning (100% penetration, 200% improvements)

Table 2. Energy source in each African region in 2050.

(Region) Countries	Energy source in 2050 (%)					
	Coal	Oil	Gas	Biomass	Nuclear	Renewable
(Eastern) Cameroon, Central African, Congo Democratic Rep. of Congo, Equatorial Guinea, Gabon.	3	2	5	45	6	39
(Central) Eritrea, Ethiopia, Kenya, Rwanda, Sudan, South Sudan, Tanzania, Uganda, Egypt, Democratic Republic, of Congo, Libya.	0	3	2	45	6	44
(Northern) Algeria, Egypt, Libya, Morocco, Tunisia.	1	4	8	34	12	41
(Southern) Angola, Botswana, Mozambique, Namibia, South Africa, Swaziland, Zambia, Zimbabwe, Democratic Republic of Congo, Tanzania.	1	1	5	30	40	23
(Western) Benin, Cote d'Ivoire, Gambia, Ghana, Guinea, Liberia, Niger, Nigeria, Senegal, Togo.	1	2	5	38	23	31

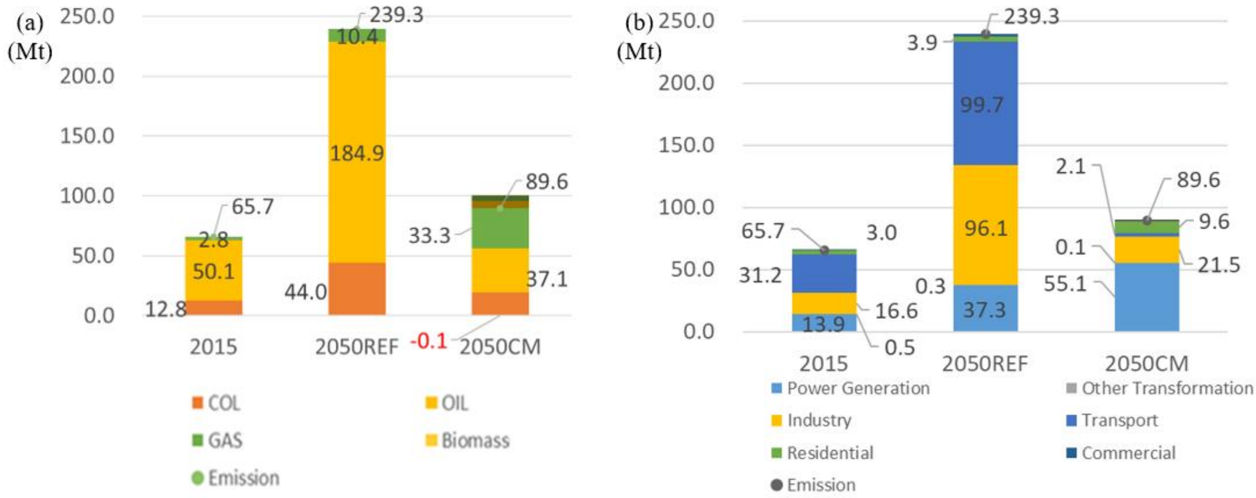

Fig. 1. Energy-related CO_2 emissions in the Eastern region by energy (a) and sector (b).

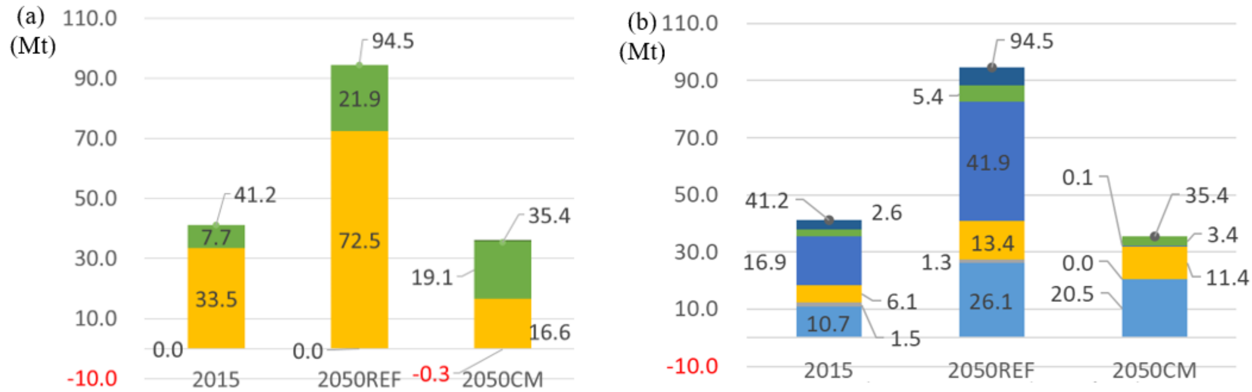

Fig. 2. Energy-related CO_2 emissions in Central region by energy (a) and sector (b).

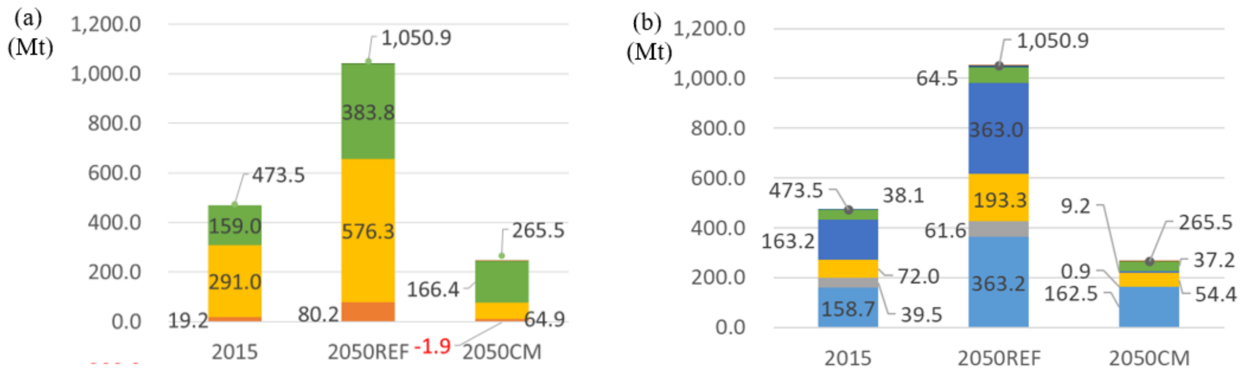

Fig. 3. Energy-related CO_2 emissions in the Northern region by energy (a) and sector (b).

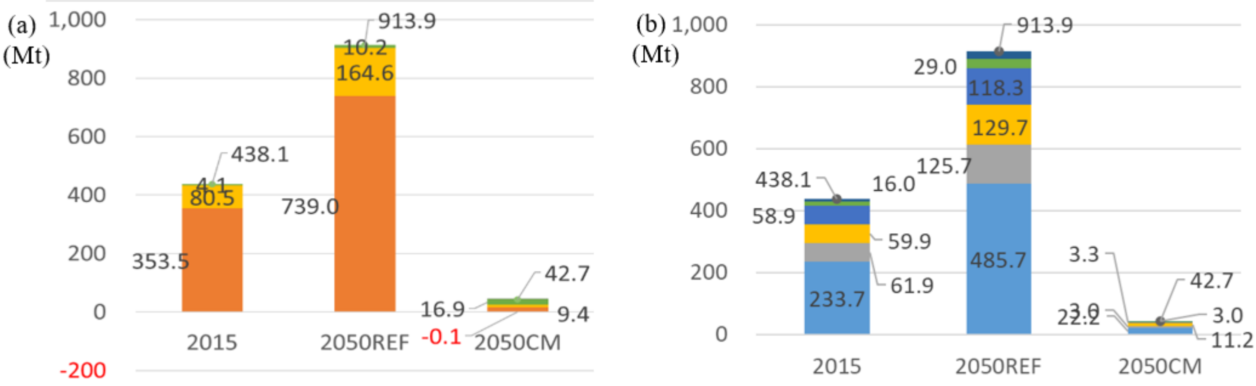

Fig. 4. Energy-related CO_2 emissions in the Southern region by energy (a) and sector (b).

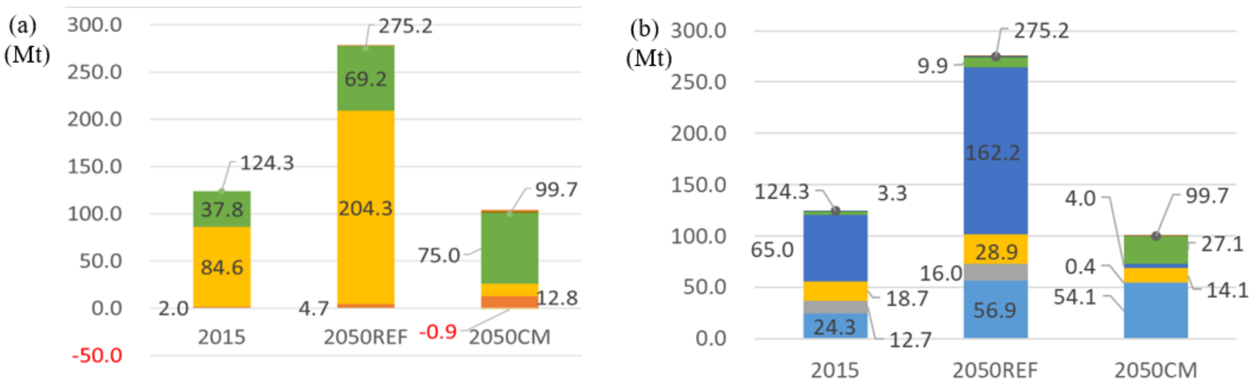

Fig 5. Energy-related CO_2 emissions in the Western region by energy (a) and sector (b).

4. IMPACT ANALYSIS

The analysis used scenario analysis applied to the 35 African countries to analyze the effects of policy introduction in housing, transportation, and industry, as well as the change in emissions depending on the ratio of renewable energy introduction in each country. However, this paper focuses on the effect from the energy demand side.

4.1 Residential Sector (Demand Side)

This research examined how improvements in the housing sector (specifically, replacing cookstoves) would affect the emission pathways of each country because improvement of cookstoves has been the subject of many reports and projects in terms of human health impacts (*e.g.*, IEA, [6]). For cookstoves, this research analyzed (a) the case where the energy source of cookstoves in the residential sector is 100% electrified and (b) the case where 50% charcoal and 50% biomass fuel are used. The reduction rate was set at 100% × ((b) emissions – (a) emissions)/(2050 emissions (no measures)).

As shown in Figure 6 for countries with a low GDP per capita (*e.g.*, Ethiopia), the reduction effect of introducing clean cooking stoves is large, whereas it is much smaller in countries with a high GDP per capita (*e.g.*, Gabon). The contribution of emissions from cookstoves in countries with a low GDP per capita is higher than that in countries with a high GDP per capita (IEA, [7]); therefore, the reduction effect of improved cookstoves is greater in countries with a lower per capita GDP.

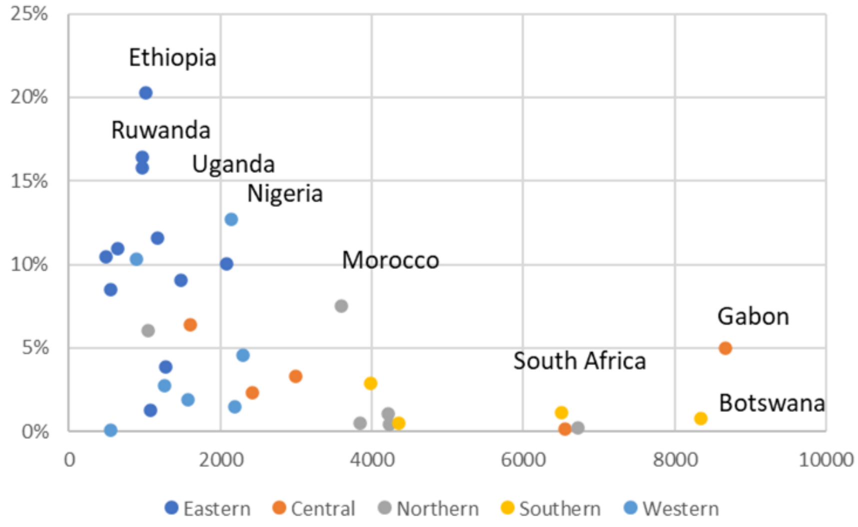

Fig 6. Analysis of the reduction effects of introducing clean cooking stoves (horizontal axis: GDP per capita, vertical axis: reduction rate).

4.2 Commercial Sector (Demand Side)

Here, this research examined the extent to which the introduction of energy-saving equipment in the private sector would contribute to the reduction of the economy as a whole. Specifically, this analysis compared the reduction in the case where the coefficient of performance (COP) of electrical equipment in the commercial sector is twice that of the base year. The reduction rate was set at 100% × (emissions when COP remains unchanged – emissions when COP is doubled)/(emissions in 2050 (no measures)). Although there was a large variation and no particular overall trend, some countries with a low GDP per capita (*e.g.*, Niger and Cameron) had a relatively large reduction effect (Figure 7). One reason may be that high GDP per capita countries have a larger degree of industrial development [1]; thus, the contribution to emission reductions from measures in the commercial sector is relatively small:

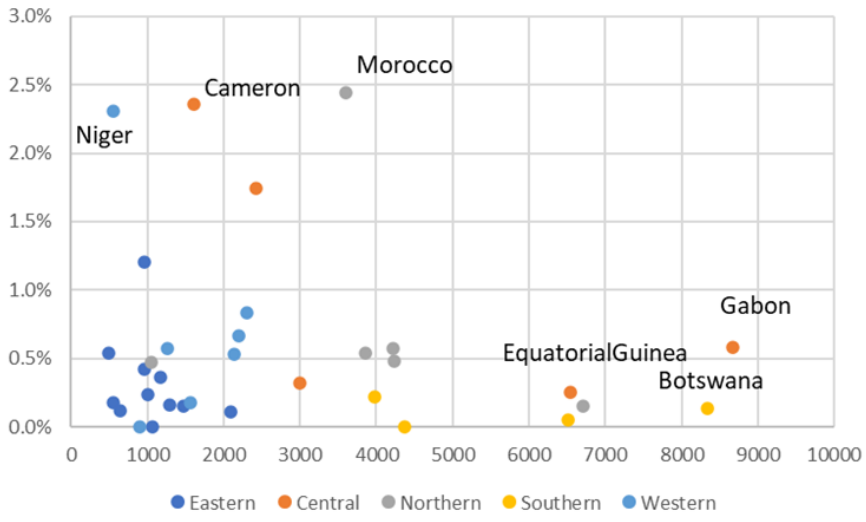

Fig. 7. Analysis of the reduction effects of introducing of energy-saving equipment (horizontal axis: GDP per capita, vertical axis: reduction rate).

4.3 Transport Sector (Demand Side)

This research examined how emissions are affected by the degree of introduction of electric vehicles (EVs) and fuel-cell vehicles (FCVs). Specifically, the research analyzed (a) the case where the introduction rate of EVs and FCVs was 50% and (b) the case where the introduction rate of gasoline-powered vehicles was 50% and the introduction rate of EVs and FCVs was 25%. The reduction rate was set at 100% × ((b) emissions – (a) emissions)/(2050 emissions (no countermeasures)). The results are shown in Fig. VIII. As a trend, it was suggested that countries with a relatively low GDP per capita, such as Benin, Nigeria, and Democratic Republic of Congo, had a large reduction effect by introducing EVs and FCVs. This can be attributed to the fact that countries with a low GDP per capita are often more dependent on automobiles. In fact, based on the base year emission profiles, the transportation sector accounts for a relatively large share of total energy-related CO_2 emissions in those countries (IEA, [7]).

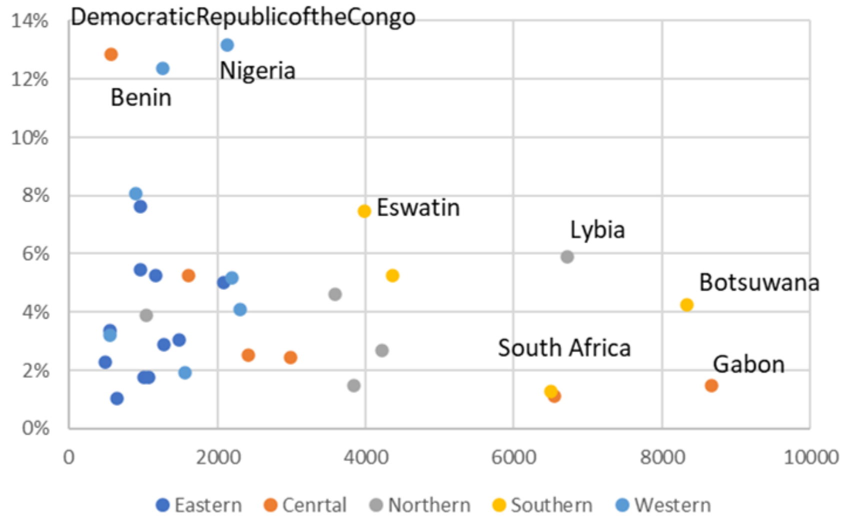

Fig. 8. Analysis of the reduction effects of introducing EV and FCV (horizontal axis: GDP per capita, vertical axis: reduction rate).

5. CONCLUSION

By comparing the reduction effects of various policies in the African region, this research quantitatively showed the kinds of policies that may be effective, depending on the degree of economic development. In countries where GDP per capita is low, the introduction of EVs and FCVs and the improvement of cooking stoves should be effective in reducing emissions.

The scenarios in African regions imply that zero emissions of energy-related CO_2 in 2050 may be difficult to achieve. As is the case with the national strategies of many Asian countries, it might be more effective to use a later year (*e.g.*, 2065) as the target year for realistic pathways towards a decarbonized society.
These results imply that the model could contribute to quantitative analysis for making emission pathways and projections. International organizations and donor countries could use this model with the aim of finding effective approaches and funding schemes in their partner countries.

In the future, it is expected that the development of information on the future vision of each country will lead to progress in the scenario analysis in each country. In addition, it is desirable to analyze the future energy supply in countries, especially Sub-Saharan Africa, where many people do not currently have access to energy because it may affect the future amount of CO_2 emissions in Africa.

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