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MODELLING THE DISTRIBUTIVE IMPACTS OF CLIMATE MITIGATION AMBITION USING SELECTIVE POWER ENERGY SECTOR FOR KENYA

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DISCLAIMER

All opinions, interpretations and conclusions expressed in this Transforming Social Inequalities through Inclusive Climate Action (TSITICA) Working Paper are entirely those of the authors and do not reflect the views of the research funder UK Research and Innovation (UKRI).

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The Transforming Social Inequalities Through Inclusive Climate Action (TSITICA) project investigates how climate change action can be socially transformative in three contrasting African countries: Ghana, Kenya and South Africa. The research agenda addresses the nexus between climate change, sustainable livelihoods and multidimensional poverty and inequality to tackle the overall question: how can climate actions be deliberately targeted to improve livelihoods and lead to equitable benefits for the most vulnerable and poor – especially for women and youth? With the goal of inspiring climate actions that also reduce poverty and inequality, based on evidence and insights from the research, TSITICA aims to contribute the Agenda 2030 ambition of leaving no one behind.

The full project team comprises researchers from two African Research Universities Alliance (ARUA) Centres of Excellence hosted by the University of Cape Town (UCT); researchers from the centres' regional nodes at universities in Ghana and Kenya; and collaborators from four universities in the United Kingdom:

- African Centre of Excellence for Inequality Research, hosted by UCT's Southern Africa Labour and Development Research Unit, School of Economics
- ARUA Centre of Excellence in Climate and Development, hosted by UCT's African Climate and Development Institute
- ARUA-CD and ACEIR nodes convened respectively by the Institute for Environment and Sanitation Studies and the Institute of Statistical, Social and Economic Research, University of Ghana
- ARUA-CD and ACEIR nodes convened respectively by the Institute for Climate Change and Adaptation and the School of Economics, University of Nairobi
- Grantham Research Institute on the Environment and Climate Change, London School of Economics and Political Science
- Townsend Centre for International Poverty Research, University of Bristol
- International Inequalities Institute, London School of Economics and Political Science
- Tyndall Centre for Climate Change Research, University of East Anglia
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Abstract

Inequality and poverty dimensions in Kenya are affected by climate change policies that target reducing carbon emissions as spelled in Nationally Determined Contribution (NDC) climate action of 2018 for Kenya. This paper aims at testing the impact of such mitigation policy that focuses on energy sector. It seeks to assess the impact of a clean energy policy on poverty and inequality in the context of climate change in Kenya. The study uses Kenya CGE model based on the national 2019 social accounting matrix (SAM), developed by the International Food Policy Research Institute (IFPRI 2021), to inform the underlying structure of the economy in the base year. Other data include power generation and consumption data, and energy statistics for Kenya. Simulations in the model include no-emission constrained and emission constrained scenarios of; forced inclusion of a 3.6Mton LNG terminal in 2028 and a floating Storage regassification unit from 2026.

The results indicate that, in scenario without mitigation, households fare better under the flexible gas scenario than the big gas scenario. Poverty rates are lower in both rural and urban areas, although reductions in urban areas are larger. Incomes are higher in both rural and urban areas in the flexible gas scenario with lower income quintiles experiencing larger increases than households in higher income quintiles. Income increases are also larger in rural areas. With mitigation, relative to the NDC_BigGas scenario, poverty levels are lower, but inequalities increase with in NDC_FlexGas scenario. Real GDP is higher in the NDC_FlexGas scenario than the NDC_BigGas scenario. Further, employment, in line with GDP, is higher in NDC_FlexGas compared to the NDC_BigGas scenarios. Further gains in income sources such as land and enterprise return results lead to higher household incomes and real consumption expenditure. Another key finding is that the cost of power generation will benefit more from global climate financing whose least cost scenario will be diffused to increased sectoral growth hence enhancing poverty reduction in Kenya.

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1. Introduction

Access to and use of clean energy is part of Sustainable Development Goal (SDG) 7, which seeks to deliver energy that is reliable, affordable, sustainable, and modern to everyone by the year 2030. A country's socioeconomic advancement and increased welfare for its citizens are dependent on the achievement of this goal (World Bank, 2013). The attainment of SDG 7 is also crucial in realizing other goals, such as SDG 3 on good health and wellbeing and SDG 13 on climate action. According to the energy progress report of 2021, the globe may fall short of meeting this goal by 2030, as the proportion of the population relying on biomass stands at 2.6 billion, while that lacking electricity connection is approximately 0.76 billion (International Energy Agency (IEA), 2021).

In developing countries, activities related to cooking consume over 90 percent of the energy that is utilized by households (Chattopadhyay et al., 2017), thus the choice of cooking energy is a major consideration for both consumers and decision-makers. Sub-Saharan Africa is more energy poor than the rest of the world from the overdependence on biomass (Sovacool et al., 2012). In addition to their rapid depletion due to unsustainable harvesting and use, overdependence on biomass resources like firewood and charcoal has also resulted in environmental problems (Global Alliance for Clean Cook stove, 2015). A large portion of the population in the area lacks access to electricity and clean fuels because annual population growth is outpacing energy access which is currently estimated at 900 million (IEA, 2020d). According to Subedi et al., (2014), the demand for biomass is directly responsible for about 70% of the current deforestation in Africa. Thus, one of the numerous advantages of practicing clean cooking is the ability to cook in a way that is neither hazardous to the environment nor one's health (Goldenberg, et al., 2018). Despite these challenges, the region, however, has abundant energy resources that can fully satisfy domestic needs but are underutilized and access to modern energy sources is limited (Ahlborg et al., 2015; Ouedraogo.

In Kenya, nearly three- quarters of total primary energy consumption is derived from biomass (Intelligent Energy Europe, 2016). The overreliance on such resources could result in biodiversity loss as well as increasing deforestation, desertification, and land degradation (Dalla Longa & van der Zwaan, 2017; Gonz´alez-Eguino, 2020). The burning of these solid fuels produces harmful emissions that have negative health consequences (Makonese, Ifegbesan & Rampedi, 2018). Further, indoor pollution leads to approximately 15,000 premature deaths in the country (WHO, 2018), with more people anticipated to die each year as a result of respiratory diseases if no action is taken (Mbaka, Gikonyo & Kisaka,2019). From the traditional role of women and girls in cooking tasks and the gathering of cooking fuel, they suffer disproportionately from the time cost of reliance on biomass (Behera, 2015; WHO, 2018).

2. Energy consumption in Kenya

Over 68% of Kenya's total energy consumption is derived from biomass, which has long been recognized as the country's primary energy source. The overreliance on such dirty fuels leads to environmental degradation and has negative health impacts to the population. The challenges associated with unclean cooking disproportionately affect women as they are primarily in charge of cooking tasks. The overreliance on such dirty fuels leads to environmental degradation and has negative health impacts to the population. The challenges associated with unclean cooking disproportionately affect women as they are primarily in charge of cooking tasks.

Kenya's energy industry has been the subject of significant reform initiatives recently. The country's price of electricity increased by 22% between 2017 and 2018 for those using up to 50 kWh per month and 14% for those using up to 200 kWh (KNBS 2018). This places a large proportion of Kenyans especially those in rural areas at a disadvantage as a majority cannot afford grid connectivity while others are not near transmission lines where extending electricity is not cost-effective (Abdullah & Markandya, 2012; Olang, Esteban & Gasparatos, 2018). The high price is a significant barrier to a household's preference for cooking fuel. Overall, the domestic penetration of clean energy sources remains relatively modest (KPLC 2017). This situation is apparent among households that use several energy sources, with consumption intensity for clean energy sources being significantly lower.

Access to clean and reliable energy services products constitutes an important prerequisite for fundamental determinants of human development, contributing, inter alia, to economic activity, income generation, poverty alleviation, health, education, gender equality and environmental safety (Ministry of Energy, 2018).

2.1 Energy consumption by households and key policy in Kenya

Survey on energy consumption patterns by household in Kenya by KIPPRA (2009) revealed that consumers engage in Fuel stacking rather than Fuel switching (KIPPRA, 2009) as opposed to fuel ladder. The fuel stacking model shows that as people become richer, they may be expected to move from traditional biomass fuels to more advanced and less polluting fuels (e.g. from wood to charcoal, kerosene, and then to gas) and the household uses multiple fuels. The households continue to use more than one fuel as income increases. The fuel ladder model postulates that fuel switching is mainly observed when there is significant increase in income and one uses one source of energy fuel.

To move consumers up the energy ladder is the challenge. Biomass, which is at the bottom of the energy ladder, provides 60% of cooking energy needs in Kenya. Apart from price, which is a major influence in the choice taken, other factors that also influence the preferred type of energy include income, fuel quality, convenience, accessibility and availability (Ministry of Energy, 2018). The prices of conventional energy resources, which are subject to structured commercial supply/demand markets, include the cost of production plus profit margins and an array of taxes. Wood fuels which are the traditional energy resources in Kenya are often priced in an informal and less structured market. Thus, prices may only reflect the cost of extraction (labour) and transportation. The cost of the raw material (e.g. tree replacement) is generally not reflected.

Renewable energy, derived from the naturally occurring resources including geothermal, hydro, solar, wind, ocean energy, biomass, biofuels, biogas and municipal waste can supply our energy needs and those of future generations in a sustainable way if effectively harnessed through careful planning and advanced technology. In addition, renewable energy has potential to enhance energy security, mitigate climate change, generate income, create employment and generate foreign exchange savings.

In order to provide affordable and competitive electrical energy to transform Kenya's economy, a roadmap to raise the generation capacity by at least 5,000MW from 1,664MW as of October 2013 to slightly over 6,700 MW by 2024 is proposed. Through this plan the Government will in the medium to long term commit itself to the development of technologies that result to least cost based on power generation.

Sessional Paper No 4 of 2004 identified the need to integrate energy planning with the national economic, social and environmental policies, as energy is a critical input in the social economic progress of any economy. At the sector level, there are close linkages between the various forms of energy, which necessitates integrated planning. The Energy Act, No. 12 of 2006 assigned the responsibility for development of indicative national energy plans to the Energy Regulatory Commission. In 2009, ERC established a committee with responsibility for preparation of the Least Cost Power Development Plan (LCPDP) in the electricity sub-sector.

3. Mitigation and adaptation policy for climate Change in Kenya

Kenya has developed a National Climate Change Response Strategy (NCCRS 2010) National Climate Change Action Plan (NCCAP 2013), and a National Adaptation Plan (NAP) – Kenya is operationalizing these policies and plans through the implementation of climate change actions in various areas such as afforestation and reforestation, geothermal and other clean energy development, energy efficiency, climate smart agriculture, and drought management. Kenya's INDC builds on the participatory multi-stakeholder and cross-sectoral consultative processes during the development of NCCRS and NCCAP at national and county levels. More than 80% of the country's landmass is arid and semi-arid land (ASAL) with poor infrastructure, and other developmental challenges. The country's economy is highly dependent on climate sensitive sectors such as agriculture that is mainly rain-fed, energy, tourism, water and health.

3.1 Policies on mitigation and adaptation of climate change

Kenya's updated Nationally Determined Contribution (NDC) has put in place a number of sectoral measures to help with climate change adaptation and mitigation. The country aims to achieve vision 2030 through low carbon, climate-resilient development pathway. The mitigation goal seeks to abate her GHG emissions by 32% by 2030 relative to BAU scenario of 143 MtCO2eq. Kenya will implement and periodically update the National climate change action plans (NCCAPs) to achieve this target. This will include the promotion and implementation of the following priority mitigation activities:

- Increasing of renewables in the electricity generation mix of the national grid.
- Enhancement of energy and resource efficiency across the different sectors.
- Making progress towards achieving a tree cover of at least 10% of the land area of Kenya.
- Make efforts towards achieving land degradation neutrality.
- Scaling up Nature Based Solutions (NBS) for mitigation
- Enhancement of REED+ activities
- Clean, efficient, and sustainable energy technologies to reduce over-reliance on fossil and non-sustainable biomass fuels.
- Low carbon and efficient transportation systems.
- Climate smart agriculture (CSA) in line with the Kenya CSA strategy with emphasis to efficient livestock management systems.
- Sustainable waste management systems.
- Harness the mitigation benefits of the sustainable blue economy, including coastal carbon payment for Ecosystem Services (PES).

In terms of projects that have addressed climate change issues in Kenya the majority have addressed energy, industrial process and waste management mitigations though they also combine with other goals like livelihood aspects that help to generate income for the households as shown in Figure 1 below.

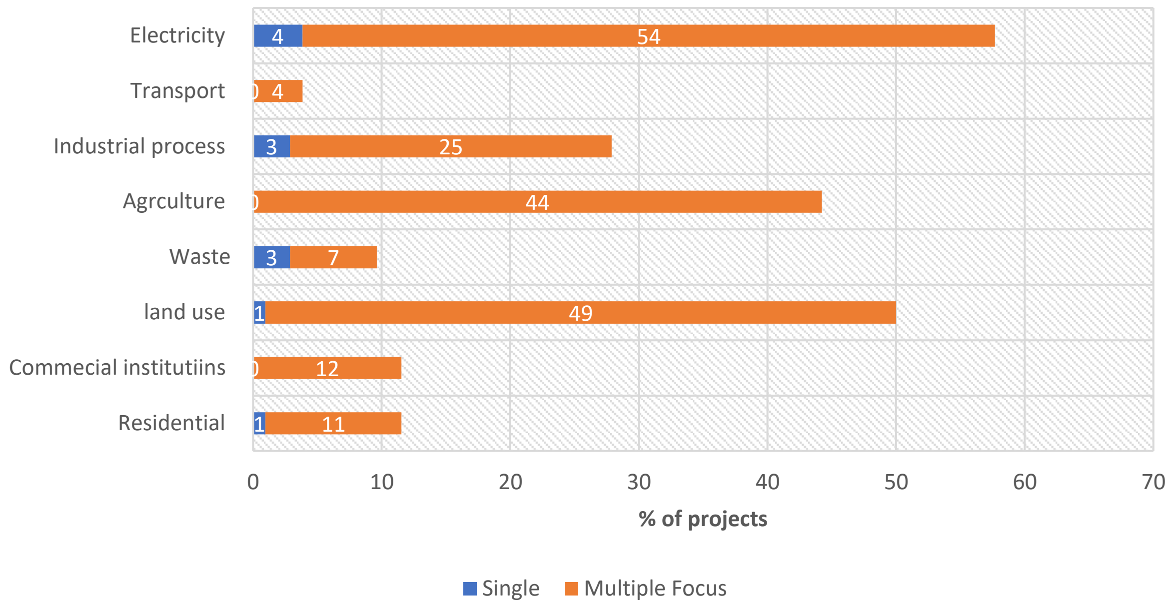

Figure 1: [Moses include title please]

Source: Country Report: Systematic mapping of reported climate change projects in Kenya: STISTICA project 2022

Figure 1 shows that only 4% of projects that focused on electricity generation as a mitigation issue while 3% focused on industrial process and waste. The results indicate that out of 109 projects focusing on mitigation or both mitigation and adaptation are mostly cross-sector. This implies that they cut across more than one sector. The results indicate that the bulk (58%) of mitigation or both addresses electricity alongside other mitigation issues while 44% addressed agriculture alongside other mitigation issues. This implies that each of the mapped projects addressed more than one mitigation issue.

3.2 Research question

How has Climate change policy on energy affected inequality and poverty in Kenya?

3.3 Objective

The key objective of this paper is to assess how the impact of a clean energy policy can affect poverty and inequality in Kenya.

4. Perspective of inequality and poverty in Kenya

The definition of inequality focuses on differences between individuals in terms of opportunities, processes and outcomes. Some of the easily observed inequality outcomes include wealth, employment and education differentials. Some inequality outcomes may arise from the normal functioning of the market economy while others may arise from differences in where people live, parental circumstances and gender, among others.

In contrast, poverty refers to the proportion of people whose standard of living falls below a defined poverty line. Poverty, too, has many dimensions that go beyond income, such as sickness, chronic pain, exhaustion, exclusion, insecurity, powerlessness, lack of access to information and institutions, lack of self-confidence and voice, and psychological suffering (Narayan et al., 2000).

Inequality trend and diagnostic in Kenya (KNBS 2020a) used data set drawn from three decades that is 1994 2005 and 2006 to assess the trends of inequality in Kenya. The report shows that; urban dwellers had higher real mean annual expenditure than rural residents over the study period, 2005/06-2015/16. A larger decline in inequality was recorded for male-headed households than for female-headed, and in urban, than in rural areas at county level, inequality declined in most counties but rose in a few others: Nairobi had the highest decline in Gini & Turkana had highest increase. The within-group inequality contributes more to overall inequality, than between-groups inequality. Individuals in male-headed households contributed more to within-group inequality. Rural areas contributed more to within-group inequality than urban areas.

Using CEQ approach to estimate impact of fiscal policy on inequality and poverty in Kenya, KNBS (2020b) the following finding were reported; Government fiscal actions (taxation and transfers) lead to a reduction in inequality, they also lead to increases in both the headcount poverty (the proportion of the population below the poverty line) and the poverty gap (the income amount by which mean household income falls below the poverty line, expressed as a fraction of that line).

Moses Ikiara, Samuel Mwakubo, Godfrey Olukoye, (2009) indicated that poverty and inequality in Kenya have been on the increase over the years and the trend seems to be getting worse. The proportion of people living below the poverty line and who predominantly subsist on natural resources increased from 48 per cent in 1994 to 52 per cent in 1997 and 57 per cent in 2003.

Poverty in Kenya has many dimensions that vary substantially across space, time and various socio-economic groups (Government of Kenya, 2005). Poverty estimates by Mwabu et al. (2002) show that rural poverty is higher than urban poverty.

Using multidimensional energy poverty (MEP) framework of analysis, Cohen Ang'u et.al. (2023) found that energy poverty is relatively high in the North Eastern parts of Kenya, with multidimensional energy poverty (MEP) index of 0.62 with 87.5% of households classified as acute energy poor. On the other hand, regions like Rift valley, Western, Nyanza, Eastern, Coast and Central had MEP values of 0.56, 0.55, 0.54, 0.52, 0.50 and 0.43, respectively. Nairobi region recorded the least MEP at 0.21, though with 72.9% of households classified in the low energy poor category. As expected, the MEP index for rural areas was high compared to urban areas.

Another study done by Christine. W. et.al. (2018) in Kirinyaga which is part of central Kenya, shows that residents, experience energy poverty as indicated by low electricity access and reliance on traditional cooking fuels. This Energy poverty has a negative impact on indicators of standards of living, calorific intake, life expectancy, and literacy levels.

4.1 Poverty, inequality and natural resources in Kenya

The major sources of energy in Kenya are wood fuel, petroleum and electricity, which account for 70 per cent, 21 per cent and 9 per cent respectively, of total energy consumption (KIPPRA 2009). The present power generation system has an effective capacity of about 1,300 MW with a peak demand of 1,070 MW. The use of energy resources differs in the rural and urban areas. About 89 per cent of the rural and 7 per cent of urban households regularly use firewood. For urban areas, it is households with the lowest incomes that depend on firewood the most. Firewood is obtained mainly from agro-forestry or on-farm sources (84%), trust lands (8%) and gazetted forests (8%) ((Kamfor, 2002).

KIPPRA (2009) showed that the rich were able to use modern forms of energy that have very little negative health impacts, if any, thereby increasing inequality. Scarcity of appropriate forms of energy increases poverty and slows down growth thereby increasing inequality due to differential impact to the poor and rich. Due to diminishing biomass energy supplies, women and children in some parts of the country are spending increasing amounts of time fetching firewood and other biomass fuels, implying limited study-time and little time for other productive activities for women. This reduces labour productivity, thereby worsening poverty especially for women-headed households

The production of electricity from hydro sources, although environmentally sound, also causes inequality. The generation of hydro power has perverse negative externalities in the sense that the benefits are mainly enjoyed by the cities and industries that receive electricity (World Bank, 2005), while population living in the areas involved in the projects suffer displacement, loss of fishing and productive agricultural land due to flooding, and salinization.

The inequality of access to energy resources is caused by inadequate capacity in the supply of clean forms of energy, poverty, inappropriate legal and regulatory framework and the prevailing social structures. Social structures such as the land tenure system in some situations inhibit access to biomass fuels by women.

Kenya has a total land area of 56.9 million hectares, about 17.5 per cent of which is either high or medium potential. Only about 8 per cent of the total land area is arable.

The amount of land available to each person in Kenya has decreased from 9.6 ha in 1950 to 1.7 ha in 2005. It is projected that available land will further decline to 0.3ha per person by 2050 (UNEP, 2009). The sub-division of land into smaller units encourages overuse and degradation and has led to low agricultural productivity and decline in land investments (Syagga, 2006). There is high inequality in the ownership of the arable land in the country. According to Kenya Rural Development Strategy (2002), 3,600 large landowners' control 39 per cent of all arable land in the country, while 3.5 million smallholders share less than 50 per cent of the arable land, giving them an average of 1.2 ha per household.

The status of land and its management contribute to inequality in Kenya. The poor are the most vulnerable from degradation of land as they hardly invest in agricultural inputs such as fertilizers8 and soil and water conservation measures (Kabubo-Mariara et al., 2006). The results are lower crop output, lower incomes and increased food insecurity.

Inequality also leads to land degradation. Inequality of access to land has wrought many land conflicts. The land clashes in Njoro, Kuresoi and Mt Elgon are clear examples. Moreover, the post-election violence in the country (early 2008) has been attributed to inequalities in land ownership (Government of Kenya, 2008).

Distribution of land contributes to gender inequality in the country. Women are disadvantaged as they do not inherit land. Despite providing the bulk of labour in agriculture, women only hold 1 per cent of registered land titles in their names and about 5-6 per cent of registered titles in joint names (KLA and FIDA-Kenya, 2006).

Another key natural resource attributable to poverty and inequality is water resources. According to the Kenya Integrated Household Budget Survey 2005/6 (KIHBS), access to water supply is poor with only about 57 per cent of households using water from sources considered safe. In most rural parts of the country, people obtain their drinking water from untreated surface and ground water. The dependence on surface water is most prevalent along permanent streams and other fresh water bodies (Kenya Integrated Household Budget Survey, 2005/06). Households relying exclusively on surface water are the most vulnerable to flow interruptions and water contaminations as those with piped water can protect themselves from these impacts.

Women also suffer disproportionately from scarcity and degradation of water resources. In many areas, women have the responsibility of fetching water especially for domestic purposes, yet they are also the key source of labour for agricultural production. The amount of time they spend collecting water, which is estimated at about 15 per cent, affects the amount of time they have for education and paid work. Whittington et al. (1990) estimated the value of time spent collecting water for households in Ukunda, Kenya, at nearly equal in value to the wage rate for unskilled labour. This means that ecosystem degradation that leads to drying of streams or pollution of available water bodies worsens gender inequality by reducing the time available for women to earn wages.

4.2 Impact of Climate change on livelihood

Climate change brings about droughts, floods, migration, diseases and human-wildlife conflict. Some particular areas and groups people are at a greater risk than others, but the ways in which climate change aggravates inequality have been largely overlooked.

Sherwood (2013) carried out a study on community adaptation to climate change in Gituamba location and found that drought created poverty traps and disproportionately affected women. They used semi structured interviews and participatory research methods to determine the effects of 2008-2009 drought on women. Due to crop failure women were forced to seek off farm work while maintaining their household obligations without receiving help from men. Climate sensitive duties like fetching water and firewood lead to poverty of time and energy to the women. The study recommends comprehensive policies that involve relief, recovery, and long-term adaptation strategies especially for the most vulnerable in society.

In a study to examine the economic impact of climate on crops in Kenya by Kabubo-Mariara & Karanja (2007) found that global warming is harmful for crop productivity. The study applied the Ricardian model to assess the impact of climate on net crop revenue per acre using cross-sectional data from 816 households. The results show that a small increase in global warming would have immediate significant effects on crop revenue in arid and semi-arid areas. In contrast, increased precipitation increases net crop revenue. Additionally, the study revealed through temperature elasticities that global warming has a negative effect on agricultural productivity.

Oluoko-Odingo (2011) conducted a study on the vulnerability and adaptation to food insecurity and poverty in Kenya. The researcher used both primary and secondary data to investigate the connections between food insecurity and poverty, as well as their implications for livelihoods and vulnerability in Nyando district. The findings indicate that poverty was the leading cause of food insecurity although climate related disasters further exacerbated the situation.

Marigi (2017) conducted a study on climate change vulnerability and impacts analysis in Kenya. He utilized point rainfall data from 1960-2014 and countrywide socio-economic data from the Commission of Revenue Allocation. The data was analysed to develop adaptive parameters, sensitivity as well as the spatial patterns of exposure. The results indicate that most vulnerable areas to climate induced hazards were the Northern part and the Southern strip of the coastal region. In addition, drought and floods had a significant adverse effect on the country.

Le et al. (2019) investigated the direct and indirect impacts of climate change on malaria in coastal Kenya using stochastic lattice-based malaria (SLIM) model with Malaria incidence data collected from 2008 to 2013 in rural Kilifi County. The purpose of the research was to look into the multiple effects of climate change on malaria transmission dynamics. The main findings indicate that vegetation acclimation triggered by elevated [CO2] under climate change increases the risk of malaria transmission throughout the year. It recommends for future malaria prediction and management, the indirect effects of temperature change on soil moisture dynamics should be weighed alongside the direct effects of temperature change on mosquito and parasite life cycles.

Allen et al. (2021) carried out a study on Kenyan women bearing the cost of climate change with the aim of examining trends in intimate partner violence (IPV) and severe weather conditions. They utilized Integrated Public Use Microdata Series-Demographic Health Survey (IPUMS-DHS) data and Emergency Events Database (EM-DAT) data in their analysis. The study shows that women are susceptible to violence if their partner worked in the agricultural sector. Further, there was an increased probability of reporting IPV in counties that experienced severe weather conditions as opposed to other counties.

Njiru (2012) conducted research on climate change, resource competition, and conflict amongst pastoral communities in Kenya. They used key informant, focus group discussions and in-depth interviews to collect data from Namanga and Matuu locations. The study found out that climatic conditions such as drought caused pastoralists to migrate in search for pasture resources which resulted in disputes over pasture from the host area.

Liru & Heinecken (2021) did a study on the gendered effect of climate change on food security and sovereignty in Kakamega, Kenya. They employed focus group discussions and key informant interviews on 138 participants in the period September 2017 and January 2018. The aim was to investigate the claim that while women have developed ways to adapt to the consequences of climate change on their livelihoods, gender inequality and patriarchy in society are said to be impeding their ability to apply revolutionary strategies. The results showed that due to over-reliance on rain-fed crops incidences of drought and floods affected food security especially for the rural women who constituted as majority of the small-scale farmers in Kakamega.

Mulwa et al., 2016 investigated climate change's effects on agricultural household welfare in Kenya. The study applied the trade-off analysis multi-dimensional impact assessment tool on data obtained from 441 households. Seasonal changes are being brought about by climate variability and change in weather patterns. As a result of these varying weather patterns and seasonal shifts, agricultural ecosystems are put under duress, which compromises the production of agricultural products and services and lowers farm yields, household incomes, and increases poverty rates.

5. Framework for quantitatively assessing climate action impacts

The distributional impacts of climate actions in Kenya are assessed using a linked power sector-economic model for the country with outputs linked to an accounting-based microsimulation module for poverty and inequality estimations (see Figure 2). The linked model, referred to as KENTIM-GE, is a modelling framework in which two individual models, namely the Kenya TIMES (KENTIM) model and an energy extended version of the Kenya General Equilibrium model, are hard-linked through the iterative exchange of information. Such an approach is well placed for climate action analysis as the combination of the detailed models ensures that the physical properties of the power system are accounted for and thus that the appropriate costs and constraints are considered, but also that the economic impact of changes in the power system are assessed and their implications for power demand are fed back into the planning of power capacity.

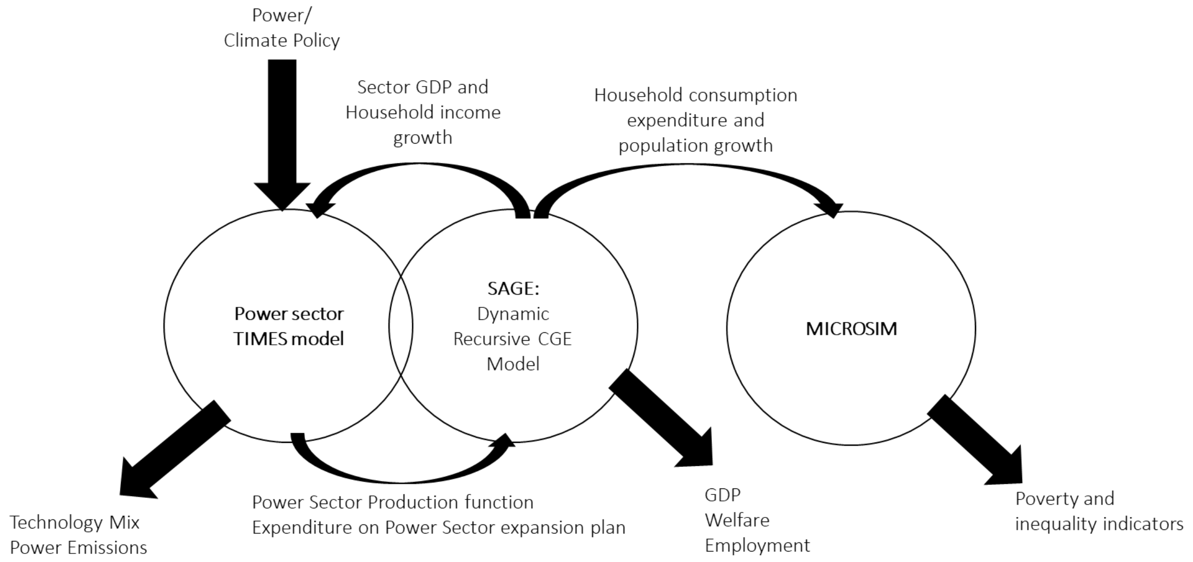

Figure 2: Illustration of modelling framework

Source: Authors

5.1 Kenya TIMES model (KENTIM)

TIMES is a technology rich, bottom-up model which optimizes based on least cost. The Kenya TIMES model is a power sector model. The model represents the power sector in terms of resources and fuels, transformation technologies and the temporal demand for electricity. Within the model power plants are represented in terms of the fuels they use, their capital and operating costs, along with other technology characteristics such as the efficiency and availability of the power plants and the GHG emissions that are associated with fuel use by the plants. The model base year is 2020 and electricity demand and the capacity of power plants within the model are calibrated to match demand and capacity in Kenya in 2020.

Demand for electricity in 2020 is assumed to be 10 450GWh. Demand is represented temporally in three demand sectors, namely industry, residential and an “other” sector. The Industrial sector is the largest consumer using 7 314GWh, followed by the residential sector which used 2 090GWh. Each of the three demand sectors has a demand profile which depicts the variation in electricity demand in that sector over the course of a "typical" day in three seasons. The daily demand profile has 10 timeslices, nine two hourly timeslices during the day between six am and midnight, and one longer timeslice period overnight between midnight and six am when demand is lowest. The use of sector specific demand profiles in the model allows the summed profile of demand to change over time as the sectors grow and their respective share of total demand changes.

The capacity of power plants in 2022 is 3.02GW. The majority of generation capacity is in Geothermal plants (0.899 GW) and Hydro plants (0.8575 GW). An additional 0.7 GW of capacity lies in thermal power plants using HFO or diesel, 0.4255 in wind plants, 0.09GW in solar PV plants and 0.036GW are thermal plants using bagasse. The majority of these plants are modelled individually allowing the expected retirement date and technology characteristics of plants to be taken into account at a more granular level when determining future capacity needs. Appendix C provides a list of the plants that were operational in 2022 along with their capacity and assumed date of decommissioning.

New capacity additions in geothermal, hydro, wind, solar, batteries, gas (OCGT and CCGT) and diesel/HFO OCGT plants are considered. At the end of their life geothermal plants are allowed to be refurbished and continue operating at an assumed refurbishment cost. Along with the technology characteristics and costs, new power plants are also assigned a first year in which they can be commissioned. The first year in which the model can generate electricity from new capacity depends on the complexity of building the power plants, for example hydro plants are given a much longer lead time compared to PV which are modular and can be built more quickly.

Where the availability of power plants is variable and uncertain, such as wind, solar and run of river hydro plants the daily and seasonal availability of the plants follows an anticipated daily and seasonal profile. The availability of run of river hydro plants follows the seasonal variability of river flow. Where hydro plants follow a dam, seasonal and interannual storage is possible up to the individual dam capacities. Similarly, the availability of solar and wind plants is location specific and follows the variation in renewable resources over the day and seasons. Solar plants can therefore only generate electricity during the day. The annual capacity factor of solar plants ranges from 0.2 to 0.23. Annual wind capacity factors in the model range from 0.43 to 0.63, depending on the location.

Constraints are applied to the speed at which new capacity of a particular technology can be added in a given year., These are consistent across the scenarios. The build limits applied to new plants are shown in the plant list in appendix A.

5.2 Kenya economy-wide model

A dynamic recursive, economy-wide computable general equilibrium (CGE) model based on the framework of Diao and Thurlow (2012) is developed for Kenya. CGE models are useful simulation tools for distributional policy analysis as they capture the functioning of a market economy in which the interactions of economic agents are mediated via prices and markets, with macroeconomic and resource constraints respected. Economy-wide models include detailed information on sector production and intermediate use including production factor use. Detailed information on household income and expenditure is also included with linkages to the production sector represented by returns to households for factors of production provided to the market; and expenditure of households on goods and services produced and provided to the market. The general equilibrium framework of the model adjusts prices such that demand and supply markets are balanced. These price changes inform the level of household consumption expenditure. The Kenya CGE model includes representative household quintiles for rural and urban regions.

The Kenya CGE is based on a version of the national 2019 social accounting matrix (SAM), developed by the International Food Policy Research Institute (IFPRI 2021), to inform the underlying structure of the economy in the base year. The SAM is enhanced by matching the power generation and consumption data to the energy statistics for Kenya to ensure that the models are consistent. Appendix A presents the SAM accounts.

While the Kenya CGE model allows for some household distributional analysis through the inclusion of the disaggregated household sector, the household groups in the model are still representative households (i.e., households are an aggregate group of households and not an average household). To extend the distributional analysis of climate actions on households, a top-down micro-accounting approach following Pauw and Thurlow (2011) is taken (see Appendix C). Under this approach economic outcomes from the KENTIM-GE modelling framework are soft-linked to a microsimulation module to calculate expenditure-based inequality and poverty estimates. The 2015/16 Kenya Integrated Household Budget Survey is used to calibrate the microsimulation module. The same data set is also used to disaggregate household income and consumption vectors in the 2019 SAM. Each of the households in the survey is linked to the corresponding household representative group in the Kenya CGE model. For each scenario considered, growth in household per capita consumption by commodity from the CGE model is used to project household consumption in the microsimulation module. This updated information is then used to recalculate inequality and poverty indicators. This approach allows for a refined interpretation of the effects on poverty and inequality although within-group income distributions remain constant (Pauw and Thurlow, 2011). The methodology is unable to account for the dynamics related to persistent poverty and poverty traps. While no behavioural changes are directly modelled in the microsimulation module, behavioural changes from the Kenya CGE model are passed through via relative differences in consumption expenditure growth across commodity groups.

5.3 2019 Kenya social accounting matrix structure of the economy

Table 1 below shows the general structure of the Kenyan economy according to the 2019 SAM. The service sector is the main driver in the economy accounting for more than 40% of total GDP and employment. Within the services sector, the largest contributing sectors to GDP are transport, trade, and real estate. Trade is also the largest employer within services. Agriculture, particularly crop agriculture, is an important economic activity accounting for nearly a third of total GDP and nearly as large of an employer as the services sector. The sector is also an important source of foreign revenues accounting for a third of total exports. Kenya is fairly self-sufficient in terms of food with agriculture crop imports accounting for less than 5% of demand and processed food imports accounting for a little over 10%. Other manufacturing, particularly machinery and chemicals, make up the bulk of imports with more than 80% of domestic demand for these goods being met by foreign products. The top 20 electricity-intensive sectors account for a third of GDP and employment, and a quarter of export revenues. These sectors include mining, non-metallic minerals, fisheries, hotels and accommodation and transport.[1] A large share of energy intensive sector outputs is also imported.

Table 1: Economic structure of the Kenyan economy, 2019

	Share of total (%)					Intensity (%)	
	GDP (factor cost)	Output	Employment	Exports	Imports	Exports	Imports
Total GDP	100.0	100.0	100.0	100.0	100.0	7.3	13.4
Agriculture	37.0	29.6	42.6	32.5	4.4	8.0	2.7
- Crops	30.3	20.8	41.0	32.4	4.3	11.7	3.9
Mining	0.8	0.7	0.7	2.3	0.9	21.5	16.0
Manufacturing	8.3	18.1	5.9	23.0	82.0	8.3	38.9
- Food	3.5	9.8	1.9	6.2	8.2	4.0	11.4
- Other	4.8	8.3	4.0	16.8	73.8	13.4	57.3
Other industry	8.7	9.9	6.3	0.0	2.3	0.0	2.9
Services	45.2	41.6	44.4	42.1	10.3	7.9	3.2
Energy intensive	32.0	31.9	33.9	25.5	47.4	5.6	18.6

Figure 3, in the left panel, illustrates the composition of activity expenditure on intermediate inputs and factors of production (i.e., land, labour and capital). These shares provide an indication of the linkages of sectors with the rest of the economy, including households who receive returns from the provision of production factors. The

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[1] The top 20 electricity intensive sectors are Mining, Non-metal minerals, Fisheries, Accommodation and food services, Transportation and storage, Other manufacturing, Construction, Machinery, equipment and vehicles, Wood and paper products, Public administration, Textiles, clothing and footwear, Metals and metal products, Wholesale and retail trade, Education, Water supply and sewage, Poultry and eggs, Cotton and fibres, Business services, Coffee, tea and, and Other services.

right panel provides a breakdown of the key employers for different types of labour. When combined with Figure 4 (left panel), we get a better understanding of the linkages between production and household incomes in the Kenyan economy. Several key observations can be made:

- Returns on land and capital are important contributors to rural household income making up between 35% and 41% of total income in rural household quintiles. Enterprise income, which is also returns from capital paid to households, contribute a larger share of urban household income. In terms of total capital returns, 80% go to enterprises. The share of enterprise income in total incomes is larger for higher income household quintiles.
- Returns to land is particularly important for low-income rural households, making up a third of their total income. Land is only used in crop agriculture production, thus changes in production would significantly affect rural households.
- Other manufacturing, energy, mining, and food manufacturing are the most capital-intensive sectors. Changes in returns to capital will thus have large impacts on urban households.
- A larger share of urban household income is also linked to labour, particularly primary and secondary educated labour. Secondary labour employment is concentrated in the services sector while primary educated labour is largely employed in crop agriculture and to a lesser extent services. Rural households receive most labour income from the supply of primary educated labour.
- Uneducated labour returns primarily contribute to low-income household quintiles, more so in rural than urban areas. These skills are mostly employed in the crop agriculture sector.

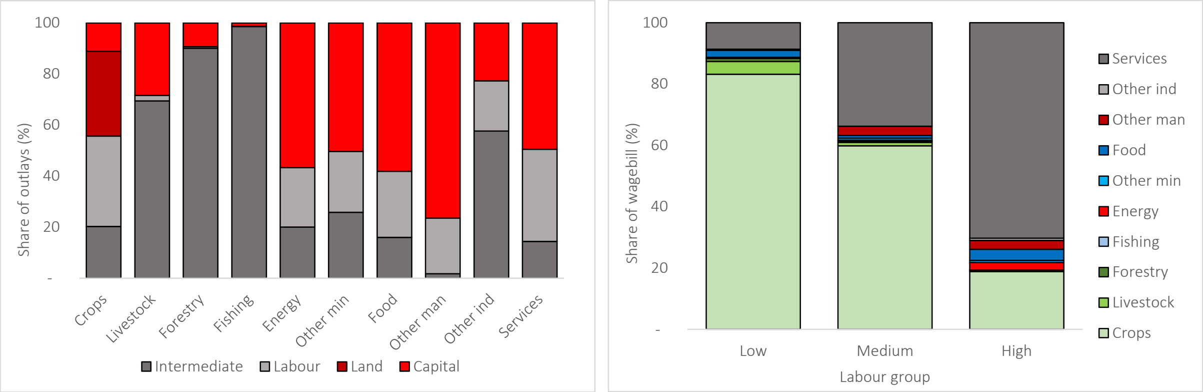

Figure 3: Factor use by sectors

The right panel in Figure 4 presents consumption expenditure by commodity group by household quintile in rural and urban areas. A substantial proportion of consumption expenditure in both rural and urban areas is on agriculture crop and processed food. In urban areas, average food consumption expenditure makes up over 50% of total consumption and in rural areas this is slightly higher at over 60%. Lower income household quintiles spend a larger share of their incomes on food, particularly crop agriculture, than higher income households. Consumption spending on services is higher in higher income quintiles as is non-food manufacturing. Electricity consumption makes up a small share of spending, although shares in urban areas are higher than rural areas; and higher income household group shares are higher than lower income household group shares. Figure 5 (right panel) presents the volume of total and per capita electricity consumed by the different household groups.

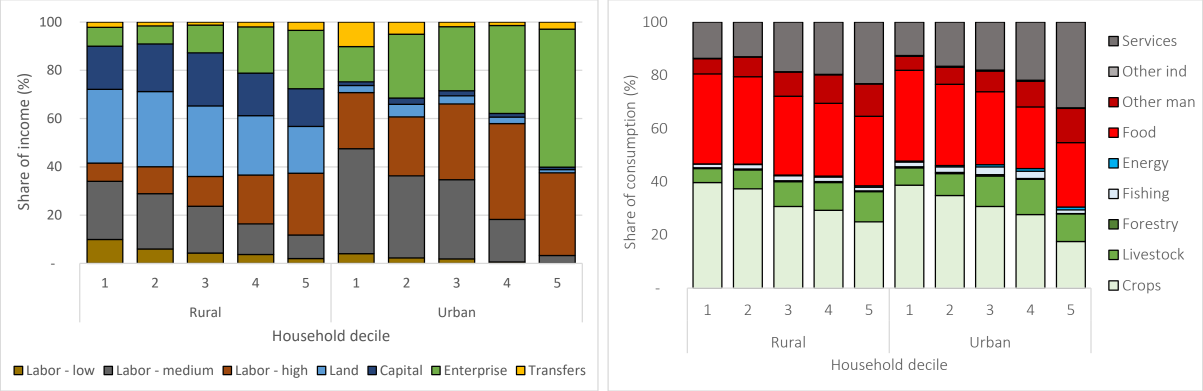

Figure 4: Sources of household income and consumption expenditure

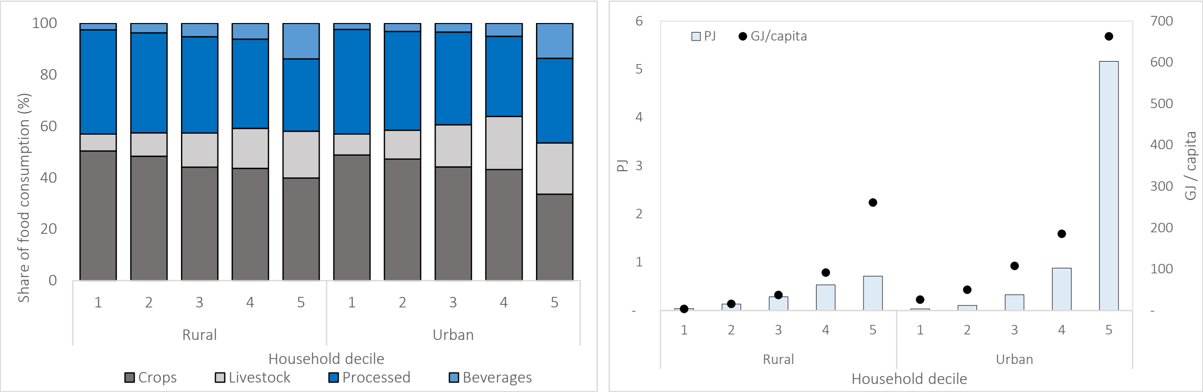

Figure 5: Household food and electricity consumption

6. Scenarios and assumptions

Kenya has significant potential for renewable energy and in existing plans such as the 2021-2030 Least Cost Power Development Plan (Ministry of Energy, 2021) these resources make up the bulk of new power generation capacity. The optimised case from the Least Cost Power Development Plan shows that a technology mix comprising solar PV, wind, gas cogeneration, imports, hydropower and geothermal is optimal for power generation in Kenya. The drive within the country to diversify power generation capacity and improve energy security has led to liquified natural gas being explored as a technology option to accomplish this. A feasibility study is currently underway to assess the impacts of the development and operation of infrastructure for the importation of LNG which will be used by converting existing HFO (MSD) power plants to LNG plants.

There are two likely options for the introduction of such capacity, namely a large land-based LNG terminal with take or pay contracts or a more flexible option via a floating storage regasification unit (FSRU) with no take or pay contracts. Gas imported via the larger land-based LNG terminal would potentially have a lower unit cost per GJ of gas compared to the FSRU terminal depending on capacity utilization. At lower utilization levels, potentially driven by mitigation goals, this would not be the case, with a potential risk of stranding of the asset. In this paper we consider the impacts on the economy of both options for LNG inclusion with and without a mitigation constraint. There are therefore four scenarios that are considered, two reference scenarios where either a large land-based LNG terminal (called Reference_BigGas) or the flexible floating storage regasification terminal (called Reference_FlexGas) is forced in, and two additional scenarios where a mitigation constraint is included with the FlexGas and BigGas scenarios. The power details related to both of these scenarios is discussed in section 9 below and summarised in Table 2.

The economic assumptions underlying the Reference_BigGas scenario are as follows. A moderate growth rate of 6% is assumed from 2020 to 2050 (see Figure 6). This growth path is based on a combination of actual growth rates for 2020-2022, short-term forecasts from the IMF (2022) and long-term forecasts from the EIU (2022). The IMF forecasts growth of 5.1% in 2023 and 5.5% for 2024 to 2027. The EIU projects average growth of 5.4% between 2022-2030 and 6.7% between 2031-2050. It is important to note that CGE models are not forecasting tools, the growth projections therefore aim to capture these trends in growth. Exogenous assumptions informing growth are kept in line with historical trends and sector total factor productivity is adjusted to reach the targeted growth path. As the analysis takes place over the longer term, we assume an upward sloping labour supply curve. Capital is updated in a dynamic recursive manner in the Kenya CGE model as such it is dependent on the level of investment made in the previous period. Investment in the Kenya model is assumed to be a fixed share of absorption which in 2019 was roughly 17%. The government balance is fixed, sales taxes adjust to maintain revenues. In line with the stylised facts for Kenya, the exchange rate is assumed to be flexible. No mitigation or climate impacts are included.

Employment increases at an average annual rate of 2.7% over the period. Sector employment gains are in line with sector GDP gains – services and agriculture remain the largest employers although the share of agriculture does decrease marginally as does the contribution of agriculture to overall GDP. Real household income and expenditure increases over time. Larger gains in income are experienced in rural and lower income household quintiles, while households in quintiles 3 and 4 experience larger gains in real consumption. Poverty improves over the period with fewer people falling below the upper and food poverty lines, and inequality measured by real expenditure also decreases over the period. The rise in economic activity and household incomes results in an increased demand for electricity which increases at an average annual growth rate of 6%.

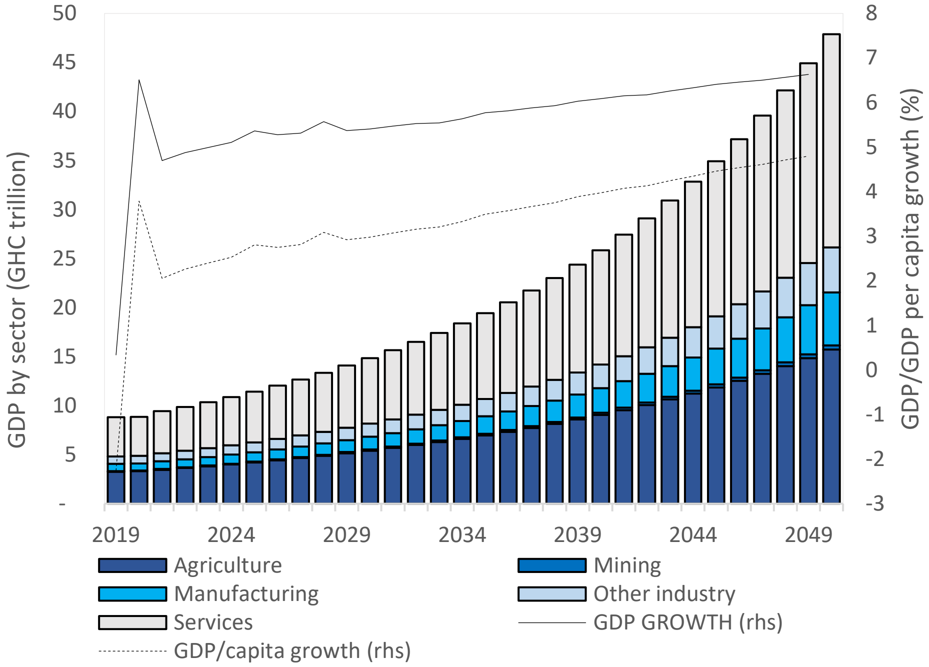

Figure 6: Reference_BigGas GDP growth projection

To assess the impacts of mitigation we compare the Reference_BigGas and Reference_FlexGas to scenarios (i.e., NDC_BigGas and NDC_FlexGas) in which emissions in the power sector are capped to 500CO_2eq (just below 2022 levels) by 2035. The updated NDC does not specify an emissions target for the power sector specifically. A summary of the scenario considered in this study is provided in the table below. The underlying economic assumptions are held constant across the different scenarios such that the impact of power systems on the economy can be assessed.

Table 2: Modelled scenarios

Scenario	**Description**
Reference_BigGas	Forced inclusion of 3.6 Mton per annum land-based LNG terminal installed in 2028; Take or pay contract with 25% utilization rate of LNG terminal; No emissions constraint
Reference_FlexGas	Forced inclusion of small 1Mton per annum Floating Storage Regasification Unit (FSRU) available from 2026; No take or pay contract; No emissions constraint

NDC_BigGas	Same as Reference_BigGas but with mitigation. Emissions constrained to reach 0.5Mton CO_2eq per annum from 2035.
NDC_FlexGas	Same as Reference_FlexGas but with mitigation. Emissions constrained to reach 0.5Mton CO_2eq per annum from 2035.

7. Implications for the power sector

This section presents the power sector results for all four scenarios. Figure 7 shows the capacity of power plants (GW) needed to supply demand in all scenarios between 2020 and 2050 whilst Figure 8 shows the production of electricity from these power plants. In all scenarios there is a sharp increase in capacity to supply the production shown in Figure 8 and meet the rising electricity demand driven by the growth in GDP over the period. Production differs slightly between the scenarios due to the economy responding to the investment needed in that scenario to expand capacity (shown in Figure 9) and the price of electricity in that scenario which incorporates both the cost of new capacity as well as fuel and maintenance costs (shown in Figure 10).

The effect of the forced development of the land-based LNG terminal versus the Floating Storage Regasification Unit, and the emissions cap can be clearly seen in the results. In the case where the large LNG land-based terminal is forced in with a take or pay contract (Reference_BigGas), gas capacity is the highest, and production of electricity with gas is higher than in the other scenarios. When the emissions constraint is forced on the BigGas scenario (NDC_BigGas), even though the LNG terminal is in place, less gas generation capacity is built, and production of electricity by gas fired plants reduces to meet the emissions constraint, with production from oil stopping entirely. Forcing the terminal build, which is not fully utilised when an emissions constraint is imposed, increases the price of electricity in the NDC_BigGas scenario, and forces the model to switch away from gas towards batteries, wind and solar effectively stranding some of the gas supply capacity.

In the Reference_FlexGas scenario a smaller terminal is forced in and there is a smaller investment in gas production capacity resulting in far less electricity being produced by gas plants in the Reference_FlexGas scenario compared to the Reference_BigGas scenario. The Reference_FlexGas scenario has both slightly higher investment requirements and a slightly higher price of electricity compared to the Reference_BigGas scenario. This is due to the higher unit cost of gas in this scenario.

Due to the lower investment in terminal capacity, there is a smaller difference in both gas use and the investment needs and electricity price between the Reference_FlexGas and the emissions constrained NDC_FlexGas scenario compared to the Reference_BigGas and NDC_BigGas scenarios. Production from oil is higher in the

Reference and NDC BigGas scenarios due to the earlier availability of gas in the FlexGas scenarios. The FSRU plant is available from 2026, whereas the land-based LNG terminal, which is larger, is only available two years later in 2028.

There is a high penetration of flexible renewables in all scenarios by 2050. In the scenarios where gas capacity and production are lower, battery storage increases. As batteries are storing and not generating electricity, battery storage does not show in Figure 8. Towards the end of the period wind and solar plants reach the limit of the capacity available to be built, in the model, and geothermal capacity increases slightly to meet demand.

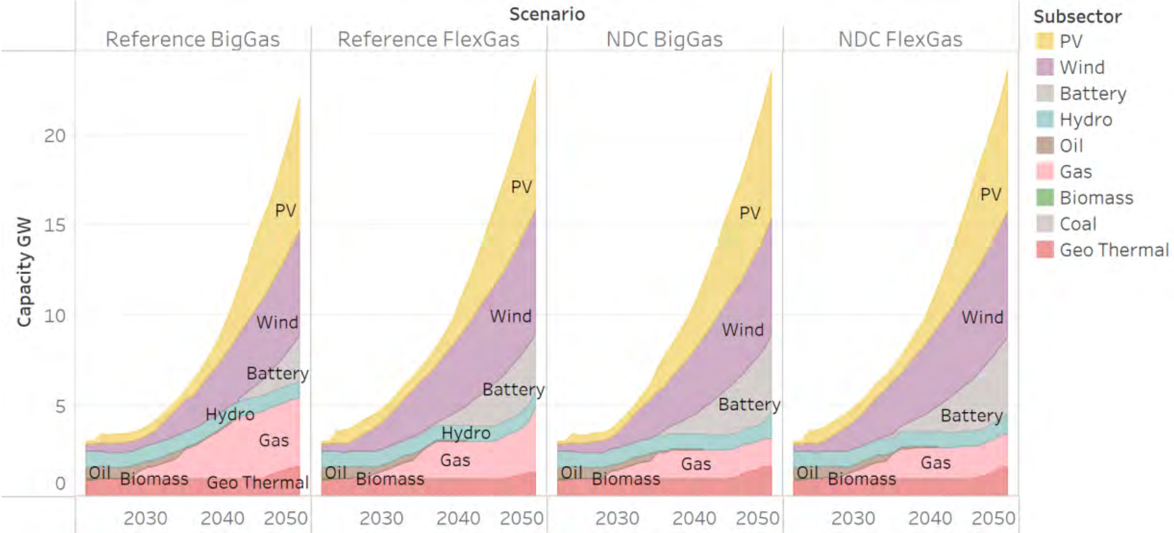

Figure 7: Electricity capacity by plant type (GW)

Source: KENTIM-GE

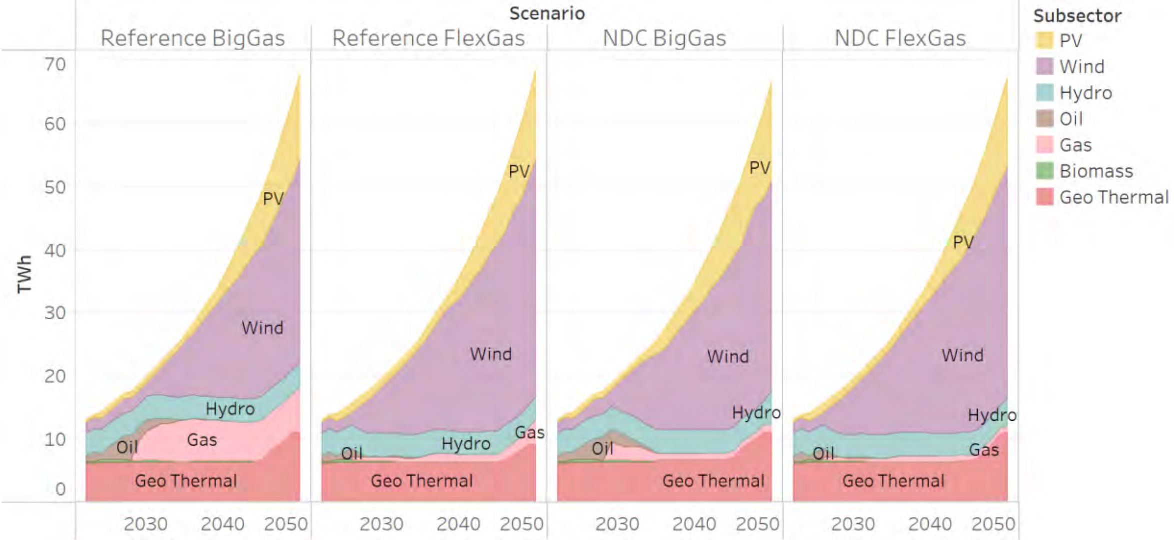

Figure 8: Electricity production by plant type (TWh)

Source: KENTIM-GE

Figure 9 shows the cumulative investment required to meet the increase in capacity needed in all scenarios. The plant builds under the NDC_BigGas scenario, requires additional power sector investment compared to the Reference_BigGas scenario. Similarly, NDC_Flexgas requires more investment compared to the Reference_Flexgas scenario. This is partly due to the investment in the gas supply terminals not being fully utilised. The Reference_BigGas scenario has the lowest investment cost.

In all cases the electricity price is able to decrease over time, primarily due to technology learning in renewable energy plants, where it is assumed that wind and solar costs will continue decrease over time.

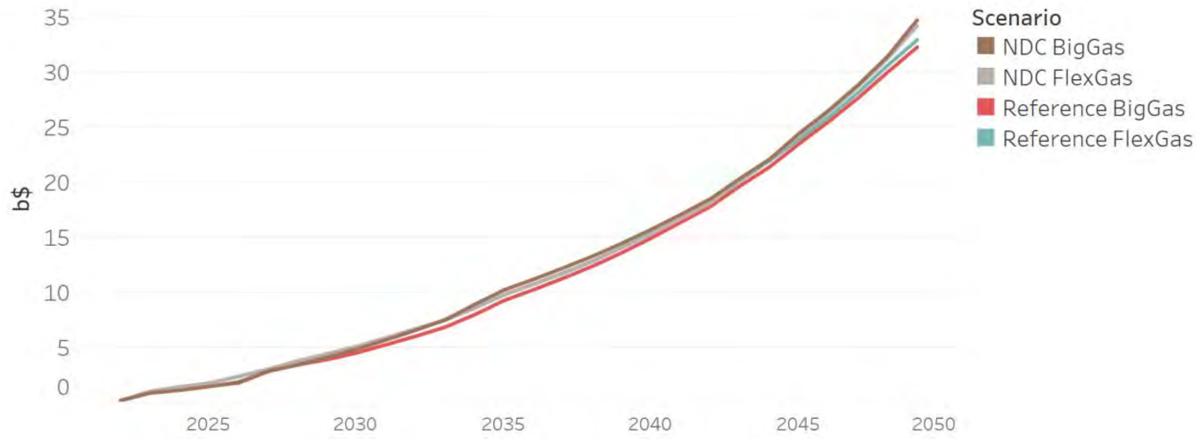

Figure 9: Cumulative investment

Source: KENTIM-GE

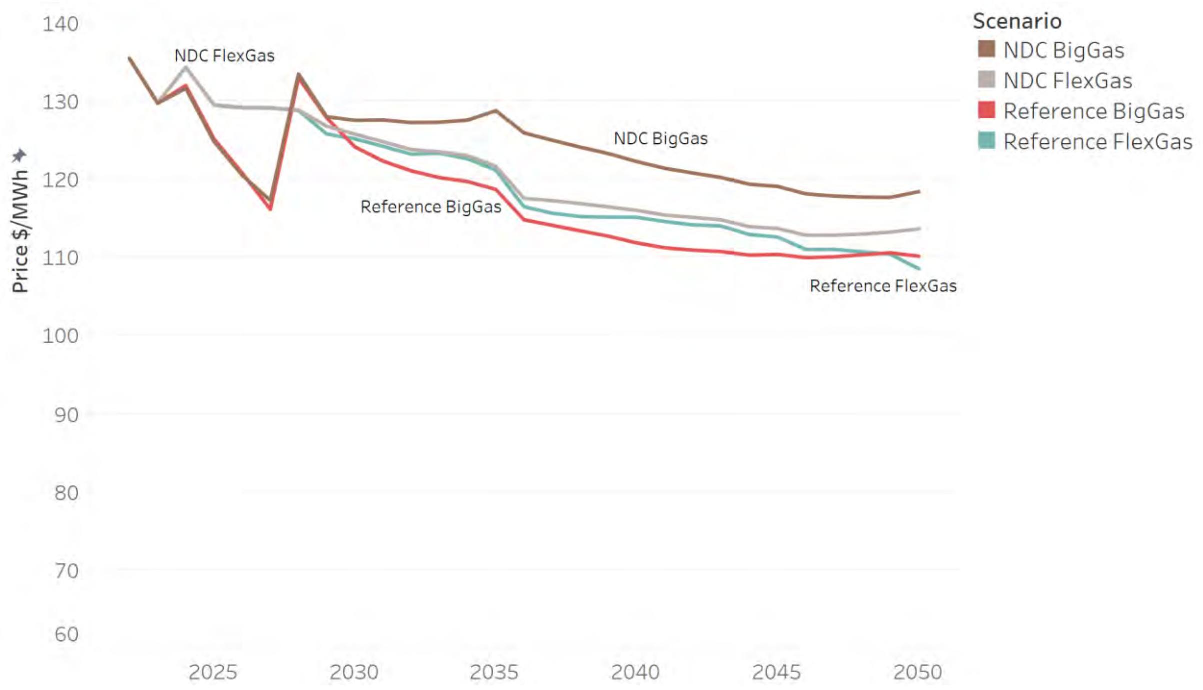

Figure 10: Price ($/MWh)

Source: KENTIM-GE

The emissions constraint-imposed caps CO2eq from the power sector at 500kton per annum from 2035 onwards. In the unconstrained Reference_BigGas scenario, emissions increase with the initial investment and increased production from the gas plants, however, this plateaus once the take or pay contracts are fully utilized. More gas capacity is added but annual utilization drops.

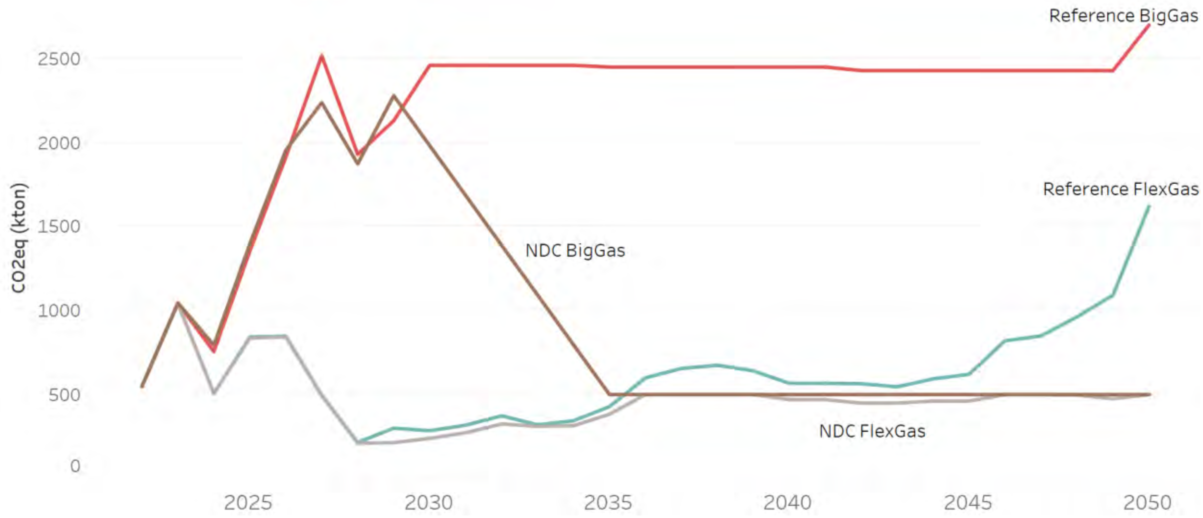

Figure 11: Emissions (C02eq)

Source: KENTIM-GE

8. Implications for the economy and households

8.2 Big versus flexible gas: unconstrained power emissions

As discussed in section 5, more investment and a higher electricity price is experienced in the flexible gas scenario (Reference_FlexGas) relative to the big gas scenario (Reference_BigGas). This is particularly the case in the short- to medium-term, while the difference decreases by 2050. Despite this high-power sector investment cost, total real GDP and employment in both 2030 and 2050 is higher in the flexible gas scenario. This result is driven by lower gas imports and thus a smaller leakage from economy. The macroeconomic impacts of a flexible gas scenario relative to a big gas scenario (with no emissions constraints) is presented in Table 3. For the most part, the implementation of flexible gas capacity is more positive across the economy. The only exception is the mining and services (primarily transport) over the short-term. The higher investment needs in the power sector under the flexible gas scenario reduces the pool of investment available for capital expansion in other sectors. The mining and transport services sectors are largely affected by this because in they are either more capital intensive or more exposed to export markets for demand. Exports of goods and services are lower in the flexible scenario due to a slightly stronger exchange rate as imports are lower.

Table 3: Macroeconomic changes in Reference_FlexGas relative to Reference_BigGas

Flexible Gas relative to Big Gas				
	% change in real GVA level		Level change in employment (000s)	
	2030	2050	2030	2050
Total GDP	**0.01**	**0.18**	**11.7**	**61.17**
Agriculture	0.12	0.14	5.01	30.46
Mining	-0.68	0.30	-1.51	1.42
Manufacturing	0.03	0.18	0.84	1.86
Other industry	0.38	0.37	9.40	6.40
Services	-0.14	0.16	-2.02	21.03

On aggregate, households are also better off under the flexible gas scenario than the big gas scenario. Poverty rates are lower in both rural and urban areas, although reductions in urban areas are larger. Incomes are higher in both rural and urban areas in the flexible gas scenario with lower income quintiles experiencing larger increases than households in higher income quintiles. Income increases are also larger in rural areas. The higher level of income in rural households are the result of both higher labour income as well as higher returns for land capital. Primary and skilled labour contribute more to the changes in rural income than uneducated labour. In urban areas, skilled labour is the driver of higher income levels. Enterprise income is lower in the flexible gas scenario –

this affects urban areas more than rural areas, and higher income household quintiles more than lower income quintiles.

Table 4: Household income changes (%) in Reference_FlexGas relative to Reference_BigGas

FlexGas relative to BigGas						
	2030			2050		
	Urban	Rural	Total	Urban	Rural	Total
Total	**0.43**	**0.49**	**0.46**	**0.2**	**0.30**	**0.24**
Quintile 1	0.46	0.51	0.50	0.31	0.32	0.32
Quintile 2	0.46	0.51	0.50	0.27	0.32	0.31
Quintile 3	0.45	0.50	0.49	0.28	0.30	0.30
Quintile 4	0.44	0.48	0.47	0.26	0.29	0.28
Quintile 5	0.43	0.47	0.44	0.16	0.27	0.19

In terms of welfare, measured by changes in real household expenditure which accounts for the impact of both income and price changes, welfare is higher in both rural and urban areas but urban areas, and higher income household quintiles, experience larger gains. This is because overall price increases faced by these households, due to their consumption baskets, are smaller than those experienced by rural and low incomes households. Based on real consumption expenditure, inequality does increase although very marginally. Appendix D presents the price indexes for different household groups under the different scenarios.

Household food poverty is also lower in the flexible gas scenario. The number of people falling below the food poverty line is 60,000 and 43,000 less by 2030 and 2050 than in the big gas scenario. Larger declines in food poverty are experienced in urban areas.

Table 5: Total household consumption changes (%) in Reference_FlexGas relative to Reference_BigGas

FlexGas relative to BigGas						
	2030			2050		
	Urban	Rural	Total	Urban	Rural	Total
Total	**0.59**	**0.54**	**0.57**	**0.51**	**0.50**	**0.51**
Market	***0.61***	***0.63***	***0.62***	***0.52***	***0.54***	***0.53***
Quintile 1	0.54	0.58	0.58	0.51	0.51	0.51
Quintile 2	0.55	0.62	0.61	0.52	0.53	0.53
Quintile 3	0.59	0.63	0.62	0.56	0.56	0.56
Quintile 4	0.59	0.63	0.62	0.56	0.55	0.56
Quintile 5	0.62	0.64	0.62	0.51	0.56	0.52

Own	***0.04***	***0.09***	***0.08***	***0.18***	***0.25***	***0.24***
Quintile 1	-0.05	0.09	0.08	0.20	0.27	0.26
Quintile 2	0.01	0.08	0.08	0.20	0.26	0.26
Quintile 3	0.03	0.08	0.08	0.22	0.25	0.25
Quintile 4	0.05	0.08	0.08	0.21	0.25	0.24
Quintile 5	0.06	0.11	0.10	0.14	0.26	0.23

Table 6: Change in poverty levels in Reference_FlexGas relative to Reference_BigGas

FlexGas relative to BigGas						
	2030			2050		
	Urban	Rural	Total	Urban	Rural	Total
Upper poverty line	-53,105	-68,812	-121,917	-135,367	-14,754	-150,121
Food poverty line	-36,571	-23,761	-60,332	-41,930	-1,609	-43,540

Table 7: Inequality indicators, Reference_BigGas and Reference_FlexGas

	2030		2050	
	Reference_BigGas	Reference_FlexGas	Reference_BigGas	Reference_FlexGas
Gini	0.4527	0.4529	0.4416	0.4416
Palma ratio	2.4549	2.4599	2.2972	2.2977
Household income shares				
Decile 1	2.0256	2.0235	2.0339	2.0337
Decile 2	3.2106	3.2079	3.3904	3.3903
Decile 3	4.1430	4.1404	4.3893	4.3891
Decile 4	5.1116	5.1089	5.3495	5.3492
Decile 5	6.2028	6.2007	6.3277	6.3270
Decile 6	7.4698	7.4685	7.4746	7.4739
Decile 7	9.0431	9.0429	9.0708	9.0701
Decile 8	11.4073	11.4071	11.4734	11.4724
Decile 9	15.7688	15.7718	15.6318	15.6310
Decile 10	35.6173	35.6284	34.8586	34.8635

8.2 Mitigation impacts with inclusion of big gas

Under the NDC_BigGas scenario, additional power sector investment is required relative to Reference_BigGas to move to cleaner power generation. This rise in power sector investment, along with the higher electricity price has a negative impact on the level of real GDP in Kenya. Interestingly, employment however is higher under the NDC_BigGas scenario than the Reference_BigGas scenario. In terms of sector impacts, changes in the power sector to reduce emissions has a negative impact across most sectors, although in the longer-run production in the food manufacturing and agriculture sector does increase. Within agriculture, production in crops (specifically coffee, tobacco, and fruit) and livestock is particularly positively affected. The increase in production experienced in these sectors is the result of inelastic demand for these commodities and/or because they are tradable goods. These sectors also create more jobs than those lost in other sectors resulting in the positive net employment impact.

Table 8: Macroeconomic changes in NDC_BigGas relative to Reference_BigGas

NDC_BigGas relative to Reference_BigGas				
	% change in real GVA level		Level change in employment (000s)	
	2030	2050	2030	2050
Total GDP	**-0.08**	**-0.34**	**0.45**	**35.83**
Agriculture	-0.03	0.01	1.14	50.62
Mining	-0.30	-0.98	-1.32	-3.08
Manufacturing	-0.07	-0.30	1.27	3.78
Other industry	-0.20	-0.78	3.30	-4.88
Services	-0.10	-0.50	-3.94	-10.60

The total impact on household incomes in the short run is negative, although declines are smaller in urban and higher income households. In the long run the impact on households is positive but small. Lower income households are more positively affected in rural areas due to the rise in agriculture production which positively affects returns to land and contributes to higher labour income. In urban areas the impacts are concentrated in lower income households but also at households in the upper income quintile. Higher income urban household incomes are largely affected by higher enterprise returns while lower income urban households experience increases in labour income, particularly primary educated labour.

Table 9: Household income changes (%) in NDC_BigGas relative to Reference_BigGas

NDC_BigGas relative to Reference_BigGas						
	2030			2050		
	Urban	Rural	Total	Urban	Rural	Total
Total	**-0.02**	**-0.08**	**-0.05**	**0.10**	**0.09**	**0.07**
Quintile 1	-0.11	-0.10	-0.10	0.05	0.11	0.11
Quintile 2	-0.08	-0.10	-0.10	0.06	0.10	0.10

Quintile 3	-0.09	-0.08	-0.08	0.05	0.10	0.09
Quintile 4	-0.07	-0.08	-0.07	0.03	0.08	0.07
Quintile 5	0.00	-0.07	-0.02	0.06	0.07	0.06

There is generally a decrease in household welfare, although welfare in rural households does increase in the longer term with larger gains in low-income households. In rural areas, market commodity increases while own consumption declines. While poverty is higher by 2030, by 2050 poverty levels (including the number of people living in food poverty) decrease under the mitigation scenario. Larger poverty decreases are experienced in urban areas. Similarly, inequality is marginally higher in the short-term and lower in the longer term. Tables 10 to 12 presents these results.

Table 10: Total household consumption changes (%) in NDC_BigGas relative to Reference_BigGas

NDC_BigGas relative to Reference_BigGas						
	2030			2050		
	Urban	Rural	Total	Urban	Rural	Total
Total	**-0.22**	**-0.22**	**-0.22**	**-0.03**	**0.04**	**0.00**
Market	***-0.22***	***-0.23***	***-0.23***	***-0.03***	***0.05***	***0.01***
Quintile 1	-0.23	-0.21	-0.22	0.01	0.09	0.08
Quintile 2	-0.24	-0.22	-0.23	0.00	0.08	0.07
Quintile 3	-0.27	-0.24	-0.25	-0.03	0.06	0.04
Quintile 4	-0.26	-0.24	-0.25	-0.05	0.04	0.00
Quintile 5	-0.21	-0.23	-0.21	-0.03	0.03	-0.02
Own	***-0.12***	***-0.16***	***-0.15***	***-0.10***	***-0.06***	***-0.06***
Quintile 1	-0.12	-0.17	-0.16	-0.09	-0.04	-0.04
Quintile 2	-0.12	-0.16	-0.15	-0.08	-0.04	-0.05
Quintile 3	-0.14	-0.15	-0.15	-0.10	-0.05	-0.05
Quintile 4	-0.14	-0.15	-0.15	-0.11	-0.06	-0.07
Quintile 5	-0.09	-0.18	-0.15	-0.09	-0.08	-0.08

Table 11: Change in poverty levels in NDC_BigGas relative to Reference_BigGas

NDC_BigGas relative to Reference_BigGas						
	2030			2050		
	Urban	Rural	Total	Urban	Rural	Total
Poverty						
Upper poverty line	34,768	30,887	65,654	-30,509	-2,627	-33,137

Food poverty line	4,163	16,157	20,319	-10,107	0	-10,107

Table 12: Inequality indicators, Reference_BigGas and NDC_FlexGas

	2030		2050	
	Reference_BigGas	NDC_BigGas	Reference_BigGas	NDC_BigGas
Gini	0.4527	0.4528	0.4416	0.4415
Palma ratio	2.4549	2.4585	2.2972	2.2965
Household income shares				
Decile 1	2.0256	2.0250	2.0339	2.0340
Decile 2	3.2106	3.2098	3.3904	3.3902
Decile 3	4.1430	4.1419	4.3893	4.3892
Decile 4	5.1116	5.1102	5.3495	5.3496
Decile 5	6.2028	6.2016	6.3277	6.3286
Decile 6	7.4698	7.4689	7.4746	7.4758
Decile 7	9.0431	9.0428	9.0708	9.0725
Decile 8	11.4073	11.4072	11.4734	11.4756
Decile 9	15.7688	15.7701	15.6318	15.6335
Decile 10	35.6173	35.6225	34.8586	34.8509

8.3 Mitigation impacts: comparing flexible and big gas

Tables 13 and 14 illustrate the impact on the economy when mitigation occurs with flexible versus big gas. Appendix D presents the results for household incomes and consumption levels as well as inequality indicators. Real and sector GDP is higher in the NDC_FlexGas scenario than the NDC_BigGas scenario. This is because less investment is needed in the power system with flexible gas and the electricity price is lower. Less imports are also needed in the NDC_FlexGas scenario. In the short term, the level of GDP in mining and services (largely transport) is lower than in NDC_BigGas due to the stronger exchange rate. Employment, in line with GDP, is higher in NDC_FlexGas. The largest number of jobs are created in agriculture followed by services. Higher employment, along with gains in other income sources such as land and enterprise return results in higher household incomes and increased real consumption expenditure. Relative to the NDC_BigGas scenario, poverty levels are lower in NDC_FlexGas. Inequality levels are marginally higher in NDC_FlexGas as consumption expenditure differences are larger for higher than lower income households.

Table 13: Macroeconomic changes in NDC_FlexGas relative to NDC_BigGas

NDC_FlexGas relative to NDC_BigGas

	% change in real GDP level		Level change in employment (000s)	
	2030	2050	2030	2050
Total GDP	**0.08**	**0.32**	**11.81**	**63.95**
Agriculture	0.14	0.10	5.78	47.87
Mining	-0.44	0.74	-1.66	-1.18
Manufacturing	0.09	0.27	0.72	2.21
Other industry	0.54	0.68	9.33	4.00
Services	-0.05	0.41	-2.36	11.04

Table 14: Change in poverty levels in NDC_BigGas relative to Reference_BigGas

NDC_FlexGas relative to NDC_BigGas						
	2030			2050		
	Urban	Rural	Total	Urban	Rural	Total
Poverty						
Upper poverty line	-87,872	-99,699	-187,571	-113,819	-15,998	-129,817
Food poverty line	-40,734	-39,918	-80,651	-31,823	-1,871	-33,694

9. Global climate financing

Climate financing reduces the impact of mitigation as it decreases the domestic cost of funding power sector investment from domestic funds. Table 15 presents the difference in real GDP and employment levels in 2030 and 2050 between the NDC_BigGas scenario with climate financing and the Reference_BigGas scenario. Compared with Table 8, the results show an increase in real GDP and employment, particularly by 2050 when mitigation efforts are financed through foreign investment. Households are also better off under a scenario with foreign financed mitigation with poverty levels lower than in the NDC_BigGas scenario. Food poverty is also lower (see Table 16).

Table 15: Macroeconomic changes in NDC_BigGas with climate financing relative to NDC_BigGas

NDC_BigGas with climate financing relative to Reference_BigGas		
	% change in real GDP level	Level change in employment (000s)

	2030	2050	2030	2050
Total GDP	**0.06**	**0.09**	**-1.58**	**54.76**
Agriculture	0.12	0.11	5.78	47.87
Mining	-0.74	-0.24	-1.66	-1.18
Manufacturing	0.02	-0.03	0.72	2.21
Other industry	0.34	-0.11	9.33	4.00
Services	-0.15	-0.09	-2.36	11.04

Table 16: Change in poverty levels in NDC_BigGas with climate financing relative to NDC_BigGas

NDC_BigGas with climate financing relative to Reference_BigGas						
	2030			2050		
	Urban	Rural	Total	Urban	Rural	Total
Poverty						
Upper poverty line	-56,396	-117,686	-174,082	-199,874	-34,435	-234,309
Food poverty line	-36,012	-36,388	-72,399	-85,526	-6,826	-92,352

10. Conclusion and Future Work

Modelling framework provides a useful tool for informing power sector planning and mitigation policy, including future global mitigation commitments. While not illustrated here, can also be used to look at the impact of climate change. This modelling scenario has been built based on the available pronouncement of mitigation prospects in Kenya where NDC flexible gas is proposed.

What came out from the scenario assessment is that the impacts of reducing emissions in the Kenya power sector does not have a large impact on economic development and welfare. This is because of the large renewable resources available in the country and the relatively low cost of renewable energy technology costs relative to other technologies. Alternative options such as gas, which is more emissions intensive, also requires the importing of gas making it more costly to the economy. To that end flexible gas is a better option, if want to include gas in the power system as it has a less negative impact on the economy and also leads to lower emissions even in an unconstrained scenario

The result also indicates that having flexible gas also makes it less costly to transition to lower emissions in the power sector. The impact of the flexGas which was found to have poverty reducing effect over long term while pushing inequality slightly higher among household depending on area of residence also improved welfare. There is generally a decrease in household welfare, although welfare in rural households does increase in the longer term with larger gains in low-income households. In rural areas, market commodity increases while own consumption declines under these mitigating scenarios.

Agriculture and food manufacturing are important sectors in the transition toward cleaner electricity as illustrated capital shifts toward these sectors due to continued household and export demand. These sectors also aid in poverty reduction. The domestic financing of these mitigation options is found to cost more compared to foreign financing. Under global financing the effect of change in exchange rate will not have a major cost implication and that is why the sector is registering a higher growth as opposed to domestic financing. In the event of trying to make mitigation work cost containment measure is a key aspect to consider if climate actions are to work towards having sectoral impact that would have impacts on inequality and poverty.

This paper did not take consideration of issues like positive externalities of cleaner energy on health and labour productivity, the potential impacts of climate change on power technology options such as hydropower, potential trade partner punitive emissions from insufficient emissions and migration effects of changing power system it is assumed that labour is able to efficiently move between sectors which is a very strong assumption. In line with the current finding, it would be important to look at the impact of changes in electricity production under climate change with the reasoning that if agriculture is very negatively affected by lower yields, would capital still move toward these sectors? How would transition in agriculture and food consumption over time and how this affects this result. An improvement could be made in the CGE model to look at changes in consumption preferences as household incomes change. Again, if there is a change in export demand, will there be a rise or decline in demand over time under climate change? In this paper we have assumed that global agriculture prices do not change

We feel that these are areas that can be revisited once the microsimulation model is well enhanced. Other future work that this study propose is an expansion of the power system model, particularly to include the transport and industrial sectors in order to understanding the impacts of mitigation on the Kenyan economy as these are the key producers of emissions. We also suggest expanding models to account for sub-national impacts to inform more targeted policy since most of the policies on climate change would target what is happening at the county level and the fact that different sub-nationals would require different climate actions due to their heterogenous nature of climate impact.

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Appendices

Appendix A

A1: 2019 Kenya Social Accounting Matrix Accounts

Sectors	**Sectors**	**Commodities**
Agriculture: Maize	Education	Accommodation and food services
Agriculture: Rice	Health and social work	Information and communication
Agriculture: Other cereals	Other services	Finance and insurance
Agriculture: Pulses	**Commodities**	Real estate activities
Agriculture: Oilseeds	Agriculture: Maize	Business services
Agriculture: Roots	Agriculture: Rice	Public administration
Agriculture: Vegetables	Agriculture: Other cereals	Education
Agriculture: Sugarcane	Agriculture: Pulses	Health and social work
Agriculture: Tobacco	Agriculture: Oilseeds	Other services
Agriculture: Cotton and fibres	Agriculture: Roots	**Other**
Agriculture: Fruits and nuts	Agriculture: Vegetables	Labor - Uneducated (incomplete primary)
Agriculture: Coffee, tea and cocoa	Agriculture: Sugarcane	Labor - Primary (complete primary, incomplete secondary)
Agriculture: Other crops	Agriculture: Tobacco	Labor - Secondary (complete secondary and/or tertiary)
Agriculture: Cattle and raw milk	Agriculture: Cotton and fibres	Land - agricultural crops
Agriculture: Poultry and eggs	Agriculture: Fruits and nuts	Capital - other
Agriculture: Other livestock	Agriculture: Coffee, tea and cocoa	Capital - energy
Forestry	Agriculture: Other crops	Households: Rural - quintile 1
Fisheries	Agriculture: Cattle and raw milk	Households: Rural - quintile 2
Mining	Agriculture: Poultry and eggs	Households: Rural - quintile 3
Processed foods	Agriculture: Other livestock	Households: Rural - quintile 4
Beverage and tobacco	Forestry	Households: Rural - quintile 5
Textiles, clothing and footwear	Fisheries	Households: Urban - quintile 1
Wood and paper products	Mining: other	Households: Urban - quintile 2
Chemicals and petroleum	Mining: Natural gas	Households: Urban - quintile 3
Non-metal minerals	Processed foods	Households: Urban - quintile 4
Metals and metal products	Beverage and tobacco	Households: Urban - quintile 5
Machinery, equipment and vehicles	Textiles, clothing and footwear	Domestic transaction costs
Other manufacturing	Wood and paper products	Export transaction costs
Electricity, gas and steam	Petroleum (for use in power)	Import transaction costs
Water supply and sewage	Chemicals and petroleum	Enterprises
Construction	Non-metal minerals	Direct taxes
Wholesale and retail trade	Metals and metal products	Import tariffs
Transportation and storage	Machinery, equipment and vehicles	Sales taxes
Accommodation and food services	Other manufacturing	Energy price differentials
Information and communication	Electricity, gas and steam	Government
Finance and insurance	Water supply and sewage	Savings and investment
Real estate activities	Construction	Changes in stocks
Business services	Wholesale and retail trade	Rest of world

Public administration	Transportation and storage	

Appendix B:

B1: Microsimulation module

The approach, while simple, provides improved measurement of inequality and poverty metrics as it includes a finer resolution of households as opposed to the representative households provided in the eSAGE. The use of the microsimulation module also enables an analysis of inequality and poverty metrics for different household characteristics (e.g., spatial location, race, and gender) which is not included in the CGE model.

In the standard TD-MA, information on household income and prices are applied to the household survey data. This influences expenditure which is used to measure changes in welfare. The changes are generally passed on as percent deviations from baseline as the survey and national accounts data are often not aligned in level terms. In building the SAM only the shares of expenditure and income from the household survey is used.

Pauw and Thurlow (2011) uses the TD-MA approach in RIAPA for the assessment of poverty in Tanzania. Instead of passing income and commodity price changes from the CGE model to the survey data, the authors pass along information on household expenditure changes by commodity. By doing so, behavioural adjustments from the CGE model are accounted for in the microsimulation group for households corresponding to representative households in the CGE model. This is an improvement to the standard TD-MA approach which otherwise would include no behavioural change.

The microsimulation module used in the TSITICA project follows the approach of Pauw and Thurlow (2018). The argument for doing so is that eSAGE includes behavioural change for households based on their income changes over time. Specifically, household consumption patterns begin to resemble those of the neighbouring representative household groups as their incomes increase. This important as it accounts for changes in the consumer price baskets faced by different household groups and the impact of policies on these baskets. For example, households in the 10th percentile of the income distribution (decile 1) may not consume a lot of electricity and may instead consume other fuels such as wood or paraffin to meet energy needs. As incomes in these households increase, an increase in the use of electricity may rise as these households are now able to afford electrical appliances. Changes in electricity prices thus now become a feature of their consumer baskets where they were not before. Mitigation actions affect the price of electricity as it often requires the build of new low/no mitigation technologies for power generation. Not accounting for the change in consumer preferences for electricity would miss the impact of changing electricity prices on the welfare of these households.

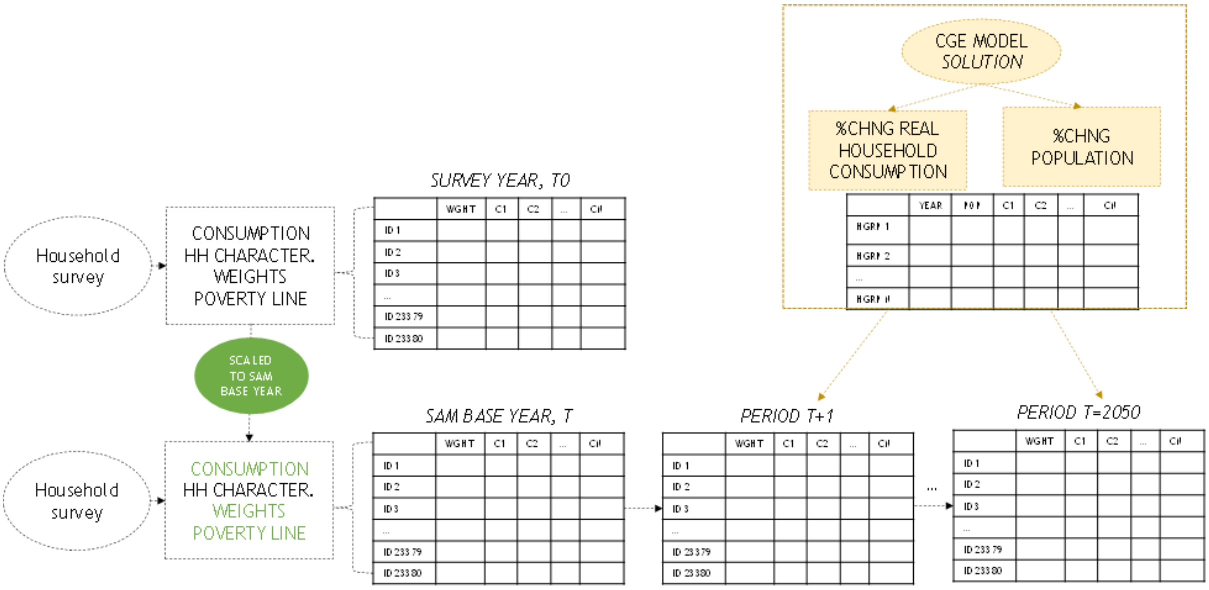
As an expenditure approach is taken in the microsimulation module, metrics for inequality and poverty are calculated based on expenditure per capita. This opens the potential measure of inequality and poverty at different levels of consumption including food and energy.

A key assumption informing these metrics would be the change in population and number of households. The CGE model does not directly use population as an input to its solution. Population (by household representative group) is used to calculate per capita metrics for welfare analysis. As a first pass at improved inequality and poverty assessment in the linked energy-economic modelling framework, and to keep the model input assumption simplistic, we assume that changes in population are uniform across households and as a result do not impact the inequality metric. While this assumption does have implications for poverty analysis (for example if higher population growth is experienced in low-income households relative to wealthier households, the poverty incidence rate may be underestimated), the uncertainty of changes in population growth by income group lends it to be a fair assumption. Future research could consider different specifications.

Future work to enhance the CGE model and microsimulation module included in the TSITICA project could include but are not limited to the estimation of an education transition matrix to inform labour supply growth assumptions, shifting household labour income source shares in relation to the education matrix, adjustment of other income shares, including changes in household characteristics, accounting for non-uniform changes in population, inclusion of new households with different incomes which may change the household mapping to deciles, and accounting for migration.

Linking income with behavioural changes with regards to employment status: in this case the microsimulation module would include information on changes in incomes, commodity prices and consumption shares from the CGE model.

The figure below illustrates how the microsimulation module works.



Appendix C:

C1: Installed Capacity of Power plants 2022

	Description	Installed capacity (GW) 2022		Decommissioning
Diesel	Kipevu_I	0.0735		2024
Diesel	Tsavo_Muhoroni	0.13	0.2035	2021
HFO	Triumph/GULF/THIKA	0.25032		2034
HFO	Iberafrica_IPP/Iberafrica_3_IPP	0.0525		2034
HFO	Kipevu_II/Rabai	0.205	0.50782	2028
Wind	Lake Turkana	0.3		2035
Wind	Ngong_phase1-3	0.0255		2040
Wind	Kipeto	0.1	0.4255	2046
Solar PV	Garissa/Selankei Solar	0.09	0.09	2038
Geothermal	Orpower4-plant1and4	0.0928		2043
Geothermal	ORPower4-plant2and3	0.0572		2043
Geothermal	OLKWH2	0.03		2033
Geothermal	OLKWH1	0.0506		2033
Geothermal	Olkarai_V	0.158		2044
Geothermal	Eburru	0.0024		2032
Geothermal	Olkaria_1and4and6	0.407		2039
Geothermal	Olkaria_2	0.101	0.899	2028
Bagasse	Kwala	0.01		2045
Bagasse	Mumias	0.026	0.036	2031
Hydro	Kamburu/Masinga	0.13		2053
Hydro	Turkwell	0.105		2050
Hydro	Kiambere	0.164		2050

Hydro	Kindaruma_opt	0.048		2050
Hydro	Tana	0.02		2050
Hydro	Sangoro	0.021		2062
Hydro	Kindaruma	0.0705		2050
Hydro	Sondu_Miriu	0.06		2058
Hydro	Gitaru	0.216		2050
Hydro	KY_Small_hydro_and_IPP	0.023	0.8575	2060
			3.01932	

Appendix D:

D1: Additional tables

Price indexes

		Reference _BigGas	Reference _FlexGas	NDC _BigGas	NDC _FlexGas	NDC_BigGas with climate financing
		Total price index				
Rural, 2030	1	100.61	100.77	100.65	100.77	100.69
	2	100.45	100.60	100.48	100.60	100.52
	3	100.32	100.47	100.36	100.47	100.39
	4	100.30	100.44	100.34	100.44	100.36
	5	100.17	100.26	100.20	100.26	100.21
Urban, 2030	1	100.41	100.52	100.43	100.52	100.46
	2	100.26	100.36	100.28	100.36	100.31
	3	100.08	100.15	100.10	100.15	100.12
	4	99.98	100.01	99.99	100.01	100.00
	5	100.01	99.99	100.00	99.99	99.98
Rural, 2050	1	103.87	103.90	103.93	103.93	104.02
	2	103.17	103.20	103.23	103.23	103.30
	3	102.55	102.57	102.60	102.60	102.65
	4	102.31	102.33	102.36	102.36	102.41
	5	101.26	101.27	101.29	101.29	101.31
Urban, 2050	1	102.73	102.75	102.77	102.77	102.84
	2	102.07	102.09	102.10	102.11	102.16
	3	101.12	101.13	101.14	101.14	101.17
	4	100.15	100.15	100.15	100.16	100.16
	5	99.45	99.45	99.44	99.44	99.40
Food price index						
Rural, 2030	1	100.61	100.77	100.65	100.77	100.69
	2	100.45	100.60	100.48	100.60	100.52
	3	100.32	100.47	100.36	100.47	100.39
	4	100.30	100.44	100.34	100.44	100.36
	5	100.17	100.26	100.20	100.26	100.21
Urban, 2030	1	100.41	100.52	100.43	100.52	100.46
	2	100.26	100.36	100.28	100.36	100.31
	3	100.08	100.15	100.10	100.15	100.12
	4	99.98	100.01	99.99	100.01	100.00
	5	100.01	99.99	100.00	99.99	99.98
Rural, 2050	1	103.87	103.90	103.93	103.93	104.02
	2	103.17	103.20	103.23	103.23	103.30
	3	102.55	102.57	102.60	102.60	102.65
	4	102.31	102.33	102.36	102.36	102.41
	5	101.26	101.27	101.29	101.29	101.31
Urban, 2050	1	102.73	102.75	102.77	102.77	102.84
	2	102.07	102.09	102.10	102.11	102.16
	3	101.12	101.13	101.14	101.14	101.17
	4	100.15	100.15	100.15	100.16	100.16
	5	99.45	99.45	99.44	99.44	99.40

Mitigation impacts: comparing flexible and big gas – Additional Tables

Household income changes (%) in NDC_FlexGas relative to NDC_BigGas

NDC_FlexGas relative to NDC_BigGas						
	2030			2050		
	Urban	Rural	Total	Urban	Rural	Total
Total	**0.46**	**0.58**	**0.51**	**0.20**	**0.25**	**0.20**
Quintile 1	0.58	0.61	0.61	0.29	0.26	0.26
Quintile 2	0.54	0.61	0.60	0.24	0.27	0.26
Quintile 3	0.54	0.59	0.58	0.26	0.25	0.25
Quintile 4	0.51	0.57	0.55	0.25	0.24	0.24
Quintile 5	0.43	0.54	0.46	0.13	0.24	0.16

Total household consumption changes (%) in NDC_FlexGas relative to NDC_BigGas

NDC_FlexGas relative to NDC_BigGas						
	2030			2050		
	Urban	Rural	Total	Urban	Rural	Total
Total	**0.82**	**0.77**	**0.80**	**0.56**	**0.50**	**0.53**
Market	***0.84***	***0.87***	***0.85***	***0.57***	***0.53***	***0.55***
Quintile 1	0.78	0.81	0.80	0.53	0.47	0.48
Quintile 2	0.80	0.86	0.85	0.54	0.50	0.50
Quintile 3	0.86	0.89	0.88	0.60	0.54	0.56
Quintile 4	0.86	0.88	0.87	0.62	0.55	0.58
Quintile 5	0.83	0.88	0.84	0.55	0.56	0.56
Own	***0.16***	***0.25***	***0.23***	***0.25***	***0.29***	***0.29***
Quintile 1	0.07	0.25	0.24	0.26	0.30	0.29
Quintile 2	0.13	0.24	0.23	0.25	0.29	0.29
Quintile 3	0.17	0.23	0.23	0.29	0.28	0.28
Quintile 4	0.18	0.24	0.23	0.29	0.29	0.29
Quintile 5	0.15	0.28	0.25	0.20	0.31	0.28

Inequality indicators, NDC_BigGas and NDC_FlexGas

	2030		2050	
	NDC_BigGas	NDC_FlexGas	NDC_BigGas	NDC_FlexGas
Gini	0.4528	0.4529	0.4415	0.4416
Palma ratio	2.4585	2.4599	2.2965	2.2953
Household income shares				
Decile 1	2.0250	2.0234	2.0340	2.0336
Decile 2	3.2098	3.2079	3.3902	3.3900
Decile 3	4.1419	4.1404	4.3892	4.3888
Decile 4	5.1102	5.1088	5.3496	5.3490
Decile 5	6.2016	6.2007	6.3286	6.3274
Decile 6	7.4689	7.4685	7.4758	7.4745
Decile 7	9.0428	9.0429	9.0725	9.0709
Decile 8	11.4072	11.4071	11.4756	11.4737
Decile 9	15.7701	15.7719	15.6335	15.6319
Decile 10	35.6225	35.6283	34.8509	34.8603

Global climate financing – Additional Tables

Household income changes (%) in NDC_BigGas with climate financing relative to NDC_BigGas

NDC_BigGas with climate financing relative to Reference_BigGas						
	2030			2050		
	Urban	Rural	Total	Urban	Rural	Total
Total	**0.46**	**0.58**	**0.51**	**0.2**	**0.25**	**0.20**
Quintile 1	0.58	0.61	0.61	0.29	0.26	0.26
Quintile 2	0.54	0.61	0.60	0.24	0.27	0.26
Quintile 3	0.54	0.59	0.58	0.26	0.25	0.25
Quintile 4	0.51	0.57	0.55	0.25	0.24	0.24
Quintile 5	0.43	0.54	0.46	0.13	0.24	0.16

Total household consumption changes (%) in NDC_BigGas with climate financing relative to NDC_BigGas

NDC_BigGas with climate financing relative to Reference_BigGas						
	2030			2050		
	Urban	Rural	Total	Urban	Rural	Total
Total	**0.82**	**0.77**	**0.80**	**0.56**	**0.50**	**0.53**
Market	***0.84***	***0.87***	***0.85***	***0.57***	***0.53***	***0.55***
Quintile 1	0.78	0.81	0.80	0.53	0.47	0.48
Quintile 2	0.80	0.86	0.85	0.54	0.50	0.50
Quintile 3	0.86	0.89	0.88	0.60	0.54	0.56
Quintile 4	0.86	0.88	0.87	0.62	0.55	0.58
Quintile 5	0.83	0.88	0.84	0.55	0.56	0.56
Own	***0.16***	***0.25***	***0.23***	***0.25***	***0.29***	***0.29***
Quintile 1	0.07	0.25	0.24	0.26	0.30	0.29
Quintile 2	0.13	0.24	0.23	0.25	0.29	0.29
Quintile 3	0.17	0.23	0.23	0.29	0.28	0.28
Quintile 4	0.18	0.24	0.23	0.29	0.29	0.29
Quintile 5	0.15	0.28	0.25	0.20	0.31	0.28

Inequality indicators, NDC_BigGas with climate financing relative to NDC_BigGas

	2030		2050	
	NDC_BigGas with climate financing	NDC_BigGas	NDC_BigGas with climate financing	NDC_BigGas
Gini	0.4528	0.4529	0.4415	0.4416
Palma ratio	2.4585	2.4599	2.2965	2.2953
Household income shares				
Decile 1	2.0250	2.0234	2.0340	2.0336
Decile 2	3.2098	3.2079	3.3902	3.3900
Decile 3	4.1419	4.1404	4.3892	4.3888
Decile 4	5.1102	5.1088	5.3496	5.3490
Decile 5	6.2016	6.2007	6.3286	6.3274
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Decile 7	9.0428	9.0429	9.0725	9.0709
Decile 8	11.4072	11.4071	11.4756	11.4737
Decile 9	15.7701	15.7719	15.6335	15.6319
Decile 10	35.6225	35.6283	34.8509	34.8603