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ESTIMATING THE DISTRIBUTIVE IMPACTS OF CLIMATE MITIGATION POLICIES IN THE POWER SECTOR IN GHANA

Monica Lambon-Quayefio, Bruno Merven, Alison Hughes, Faaiqa Hartley, Robert Darko Osei

TSITICA Transforming Social Inequalities Through Inclusive Climate Action
ARUA-CD Centre of Excellence Climate and Development
UK Research and Innovation
ACDI African Climate & Development Initiative
University of East Anglia
ACEIR African Centre of Excellence for Inequality Research

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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

- Tyndall Manchester, University of Manchester

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For more information, please contact:
Project manager: Haajirah Esau (Haajirah.Esau@uct.ac.za)
Communications: Charmaine Smith (Charmaine.Smith@uct.ac.za) and Michelle Blanckenberg (Michelle.Blanckenberg@uct.ac.za)
Research Coordination: Dr Britta Rennkamp (Britta.Rennkamp@uct.ac.za

Abstract

Many developing countries have been encouraged to adopt various mitigation and adaptation strategies to minimize the effects of Climate change in all sectors of the economy. However, there is limited understanding of the full macroeconomic and distributive effects of these strategies that such countries implement. Using an approach which links the power sector economic model with the computable general equilibrium model, the current study compares two mitigation scenarios with the reference case scenario which illustrates the impacts of the existing mitigation strategies. Considering two sources of financing climate mitigation in Ghana; under moderate and ambitious mitigation scenarios, the findings suggest that - climate change significantly reduces GDP and this reduction ranges from 1.5%-8.1% in the long term. However, these reductions are offset significantly when GDP increases between 2.7%-4% in the long term and when the mitigation efforts are financed from foreign sources. Results from the redistributive analyses suggest declines in household incomes with largest impacts on less educated rural farm households. Again, foreign financing significantly minimizes the negative impacts of Climate change on poverty.

Key words: climate change; mitigation, poverty, inequality, Ghana

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1. Introduction

Following global efforts of using mitigation policies to reduce greenhouse emissions, Ghana has recently designed and implemented several climate change mitigation policies relating to renewable energy options, energy efficiency and the implementation of programs to promote afforestation and reafforestation. These policies and programs have been implemented with the aim of reducing the country's carbon footprints and minimising its negative impacts on the economy and the vulnerable population. Although such mitigation policies have generally been considered to be beneficial on the whole, their potential impacts on the macroeconomy and distributive impacts, particularly on the vulnerable population cannot be disregarded as they are disproportionately affected by such policies.

Like many other countries in the sub-Sahara African region, Ghana is vulnerable to climate change (Arndt et al., 2015), due to the structure of its economy. Although Recent data from the World Bank (2021) indicate that the agricultural sector contributes about 18.9 percent of GDP, the sector employs over a third (about 39 percent) of the population. A large proportion of these farmers are small-holder farmers who rely on the weather and traditional technologies and are therefore characterised by low yields (Arndt et al., 2015). Particularly for countries such as Ghana which is characterised by high poverty levels and rising inequality, it is important to understand the potential impacts of these mitigation policies on the economy as well as its distributive effects on the population.

1.1 Climate Change and Agriculture

The direct and biophysical changes caused by climate change directly impacts the agricultural sector. The impact of climate change on agriculture is however mixed. Carbon dioxide ($CO2$) fertilization could lead to an increase in the productivity of some crops while a high atmospheric $CO2$ could as well increase the growth rate of some plants and enhance the efficient use of water in some types of plants. However, climate change could also cause a reduction in yield through – inadequate water levels required for irrigation purposes, modification in weeds and pests, a rise in sea level which may eventually lead to loss of lands and associated salinization which negatively affect agriculture (Aydinalp & Cresser, 2008).

Globally, according to Mendelsohn (2007) the negative effect of temperature and precipitation changes on agriculture were offset by gains from carbon fertilization and therefore, overall agriculture productivity growth increased between 2.6% to 5.4%. The impact of climate change on agricultural growth was relatively higher in mid-high latitude countries than in low latitude countries. However, recent evidence by Ortiz-Bobea et al.,(2021) suggests that the total factor productivity (TFP) of global agriculture has been reduced by about 21% due to anthropogenic climate change. This reduction is higher at 26%-24 % for temperate zones such as Africa, Latin America and the Caribbean.

Due to its location, Ghana may be vulnerable to climate change, especially on the agricultural sector because weather inputs play a major role in agricultural productivity in Ghana. Asante & Amuakwa-Mensah (2014) estimated the future projections of climate change and its impacts on the agriculture sector in Ghana. Their findings projected that the fisheries sub-sector in Ghana will be severely affected by rising sea levels. In the crop sector, the changing climatic conditions in the cocoa growing areas will gradually become unsuitable for the productivity of the cash crop by 2050. Again, the production of other crops such as rice and tubers (especially cassava) will be adversely affected by the projected climate change and variability. A studies by Nutsukpo (2012) and Amponsah et al., (2015) showed similar results as it compared crop yield for the years 2000 and 2050 and found a general declines ranging from 4% to 20% for yields of rainfed maize, rice and groundnut throughout the entire country.

1.2 Climate Change and Industries

The changing climate can have both a direct and indirect impacts on the industrial sector. Climate change mostly affect the industrial sector through the energy sector, infrastructure and the safety risk of people. Climate change is projected to negatively affect the infrastructure systems that support industries, including the energy sector. Also, unsafe weather conditions can affect some industries such as the oil and gas industry. The rising sea levels could adversely impact power plants in coastal zones and risk the transporting of oil and gas through coastal pipelines. Further, electricity grid and the generation of electricity in some critical locations may be poorly affected by high global temperature (Rowbotham, 2014).

Ghana's over reliance on hydropower electricity generation makes the country's industrial sector highly susceptible to climate change and variability. Climate change may affect electricity production which in turn may affect the industry sector (Abokyi et al., 2019); other industries that rely on the national grid as its source of primary electricity source also suffer indirectly from the adverse impact of climate change.

Kabo-Bah et al., (2016) shows that productivity of hydropower at the three main plant stations (Akosombo, Kpong and Bui) in Ghana have been negatively impacted by declining rainfall patterns. Again, Boadi & Owusu (2019) suggest that between 1970 and 1990, 21% of the inter-annual fluctuations in power generation were due to rainfall variability; and 72.4% of the fluctuations in power generation between the years 1991 and 2010 were caused by ENSO and the lake water levels. Also, Kwakwa (2015) found that a 1% increase in carbon emission significantly reduces hydropower generation by 0.4%.

Arndt, et al. (2015) also found that climate change in the global dry scenario severely affects road infrastructure and has a moderate effect on the generation of hydropower in Ghana. Other studies have also associated climate change with deteriorating road infrastructure. Twerefou et al. (2015) suggest that the cumulative cost of such maintenance and repairs of road infrastructures could increase significantly if there are no deliberate actions to adapt or mitigate against climate change.

1.3 Climate Change and Poverty and Inequality

Based on data from the MENA region, Wodon et al. (2014) found that the poorest households suffer greater losses in income, crops, livestock, and fish caught as a result of climate-related changes compared to richer households. Similar findings are documented in other regions, such as Southeast Asia where income losses associated with changing climate is highest among the lowest income households and in some cases, doubling for low-income households compared to richer households (Gentle et al.,2014). Again, similar findings are reported for Uganda by Hill and Mejia-Mantilla (2015). Additionally, more vulnerable groups, such as poor women from rural regions and children from developing nations were particularly affected by the effects of climate change (Pérez-Pea, Jiménez-Garca, Ruiz-Chico & Pea-Sánchez, 2021).

In the Ghanaian context, Adzawla and Kane (2019) showed that climate change/variability had positive significant effect on welfare gap through the explained component and a negative significant effect through the unexplained component. Therefore, observed climate change and variability led to an increase in gender welfare gap by 64.62%. Similar findings were highlighted by Nkegbe and Kuunibe (2014) who showed that, weather-related risks affected rural livelihoods when the changing climate affects both income and non-income components of welfare. Climate change has also been shown to exacerbate existing levels of poverty, inequality and wellbeing. As a result, climate change has been described as a 'threat multiplier'. Nkegbe & Kuunibe, (2014) show the case of this threat multiplier in northern Ghana where the negative impact of climate variability on welfare and agriculture income are found to be worse compared to other regions in the country. Overall, these studies have suggested that climate change would adversely affect Ghana's economic development prospects.

It is, therefore, important for developing countries such as Ghana to estimate the macroeconomic and distributive impacts of climate change mitigation policies given that many developing countries have made considerable commitments through their Nationally Determined Contributions (NDCs) to reduce greenhouse gases. By understanding the impacts of such commitments, governments and policy makers will be better guided to design and consider policy alternatives that may be more effective in achieving the dual goal of reducing greenhouse emissions and ensuring sustainable and equitable growth and development.

The current study builds on previous studies in Ghana, including Asante and Amuakwa-Mensah (2014); Arndt et al. (2015) and Oduro et al. (2020) which have all examined the impacts of climate change mitigation policies on various economic outcomes. This study goes further to focus more on the mitigation policies, particularly in the energy sector and its impacts on the macroeconomy, poverty and inequality. The current study is the first study to consider climate change mitigation strategies in the power sector. By linking the power sector with household data and Ghana's most recent social accounting matrix (SAM, 2015), the paper seeks to show the macroeconomy-wide and distributive impacts of three scenarios of climate change mitigation in Ghana.

2.Literature Review

2.1 Poverty and inequality Trends in Ghana

With a steady and impressive economic growth in the past decade, Ghana attained lower middle-income status in 2010 with GDP growth rates peaking at 14 percent in 2011 with oil revenue contributing significantly to the growth of the economy. Over this period, in its quest to achieve the Millenium Development Goals, Ghana recorded significant declines in poverty, with the poverty rates reducing by half from 42.47 percent to 25.69 percent by 2012. After 2015, a combination of factors such as macroeconomic policies, institutional rigidities, and shocks (IMF Survey, 2016) resulted in significant declines in economic growth rates to about 2.1 in 2015 before rising again to ??? in 2017 and then later to 0.5 percent in 2020 due to the impacts of the Covid-19 pandemic and other macroeconomic policies. By this period, the rate of decline in poverty had slowed down to only about 23.4 percent by 2017. As noted by GSS (2017), with the current rate of poverty decline, the country may not be able to attain the Sustainable Development Goals of eradicating poverty.

Unlike poverty, inequality has been increasing for the past two decades. This indicates that economic growth has not been inclusive. Between 1992 to 2017, inequality, measured by the gini coefficient, has increased steadily from 0.37 to 0.43 respectively. Particularly between 1999 and 2006, the country recorded its highest increase in inequality where the rate increased from 0.39 to 0.42.

With respect to the spatial distribution, based on living standard survey data from 2006 to 2017, Attah-Ankomah et al. (2020) show the regional variation in both poverty and inequality. The data indicate that inequality is highest in regions with the highest prevalence of poverty. The data also suggest that poverty and inequality are largely a rural phenomenon and are highest in the three northern regions (Northern, Upper East and Upper West). These regions also coincide with the ecological zones which are more vulnerable to climate change. Moreover, inequality in Ghana is considered a within phenomenon, where inequality between regions is lower than inequality within regions.

2.2 Energy and emissions in Ghana

Ghana's share of annual CO_2 emissions to global emissions increased from 0.01% in 1950 to 0.04% in 2016(Ritchie et al., 2020). In 2016, emissions reached 48 million metric tons of CO_2 equivalent ($MtCO_2e$), with the forestry and other land use sector accounting for the majority of these emissions at 54.4%. The energy sector contributed 35.6%, followed by the waste sector (7.5%) and Industrial Processes and Product Use (2.5%).

Within the energy sector, stationary combustion, and transport mobile combustion account for over 95% of the emissions. However, the highest increase in emissions was seen in the fugitive emissions category, which rose by 101.3% from 0.012 $MtCO_2e$ to 0.024 $MtCO_2e$ between 2012 and 2016. This was due to the commencement of the commercial production of oil and gas during this period. Within that same period, stationary and transport mobile combustion both recorded increases of 22.7% and 7.2% respectively. The rise in stationary combustion emissions was due to the expansion of electricity power plants and increased fuel use in the manufacturing industry, as well as changes in household energy consumption patterns. The growth in transport emissions was driven by the increasing number of vehicles and the rise in diesel and petrol consumption. Between 2012 and 2016, stationery combustion emissions decreased from 8.65 to 7.83 $MtCO_2$. On the other hand, transport mobile combustion increased slightly, from 6.68 to 7.1 $MtCO_2$. The highest increase in emissions was seen in the fugitive emissions category, which rose from 0.012 to 0.024 $MtCO_2$, representing a 100% increase.

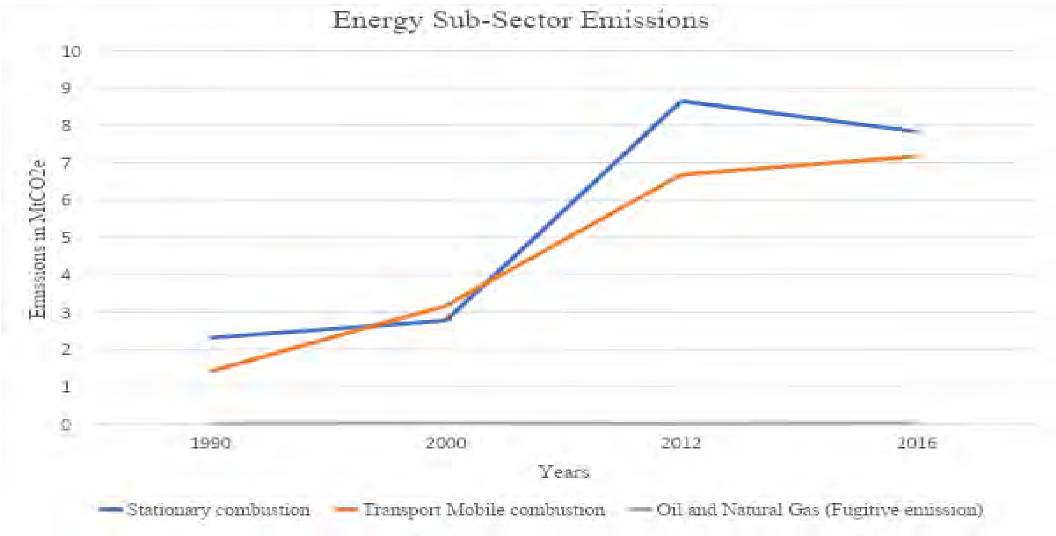


Figure 1: Emissions from energy sub-sector over time

Source: Authors' own construction of data from the Environmental Protection Agency

3. Policy Context

The Nationally Determined Contributions (NDC) are essential to Ghana's efforts to mitigate and adapt to the effects of climate change. These contributions demonstrate the government's commitment to lowering greenhouse gas emissions and strengthening resilience to climate change's effects. Ghana's NDC is a comprehensive plan that aims to reduce the country's carbon footprint, ensure a more resilient future for its population, and improve socioeconomic outcomes. The NDC emphasizes both adaptation and mitigation actions to cut emissions and boost resilience.

The NDCs of Ghana aim to reduce emissions by 64 million tons of CO2 equivalent by 2030 through the implementation of 34 mitigation initiatives. These techniques promote energy efficiency in households, businesses, and industries, as well as in refrigeration and air conditioning. The NDCs also prioritize the development of sustainable and clean energy solutions, including the expansion of renewable energy penetration, the generation of low-carbon electricity, and the adoption of market-based cleaner cooking alternatives. In addition, the NDC aspires to encourage sustainable and responsible production in industry and forest management, as well as improve water resource management and increase climate services.

Ghana focuses on growing the adoption of market-based cleaner cooking options, encouraging sustainable charcoal production, scaling up the penetration of renewable energy, decarbonizing oil and gas production, and embracing alternative solid waste management in terms of mitigating climate change. In addition to acknowledging the significance of inter- and intra-city transportation, the NDCs contain initiatives to enhance sustainable mobility.

Ghana places major emphasis on adaption strategies, such as citywide resilient infrastructure planning, integrated water resource management, and the improvement of early warning and disaster risk management systems, in addition to mitigation. Also, the country acknowledges the significance of fostering resilience and livelihood opportunities for youth and women in agricultural landscapes and food systems that are fragile. In addition to supporting gender-responsive sustainable forest management, the NDC includes measures to increase the climate resilience of women and other vulnerable groups. Ghana is also implementing adaption measures, including the development of early warning systems for extreme weather events, the improvement of agricultural techniques, and the protection of coastal habitats.

However, Ghana has considerable obstacles in attaining its NDC. These include funding constraints, lack of technical expertise, and infrastructure, as well as its reliance on oil and natural gas (Nyasapoh et al., 2022). Ghana remains dedicated to decreasing its carbon emissions and boosting its usage of renewable energy sources to provide a sustainable future for its citizens despite these obstacles (MESTI, 2021). The nation acknowledges the urgency of addressing climate change and is taking initiatives to assure its inhabitants' sustainable future.

In summary, the NDCs of Ghana demonstrate the country's commitment to addressing the issues posed by climate change through an integrated approach that includes both adaptation and mitigation measures. The NDCs aim not merely to cut emissions, but also to provide positive socioeconomic outcomes for the people of Ghana, especially for vulnerable groups.

4. Framework for assessing Climate Action Impacts

The distributional impacts of climate actions in Ghana 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 GHATIM-GE, is a modelling framework in which two individual models, namely the Ghana TIMES (SATIM) model and an energy extended version of the Ghana General Equilibrium model, are hard-linked through the iterative exchange of information. Not only is such an approach 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 the appropriate costs and constraints are considered; but in addition the economic impacts of changes in the power system are assessed and their implications for power demand are fed back into the planning of power capacity.

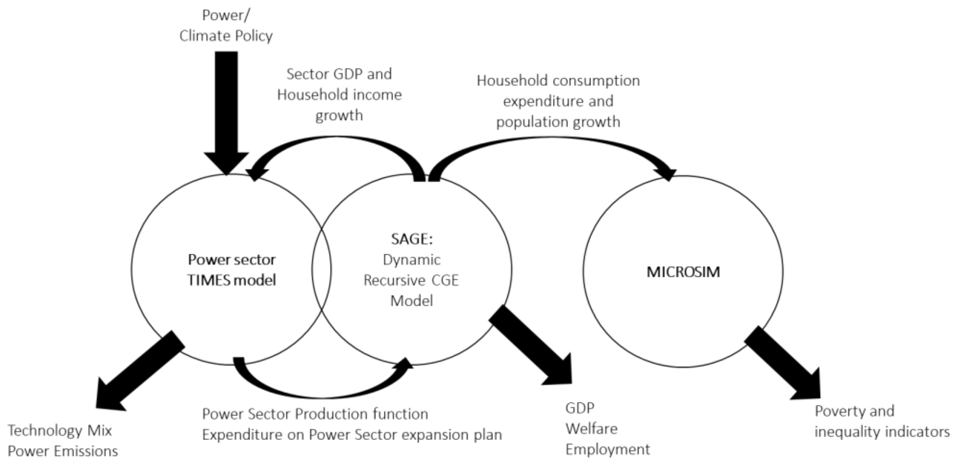


Figure 2: illustrative diagram of the modelling framework

Source: Author's illustration

4.1 Discussion of power sector model

The TIMES model of the power sector in Ghana is a technology rich, partial equilibrium optimisation model. Within the model, power plants are represented in terms of the fuels they use, their capital and operating costs, 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. Demand for electricity in the model is disaggregated into household, industry and other demand, and represented in terms of a daily load profile for each of these sectors. The profile allows the changes in demand over the course of a day or season to be captured. These changes are represented in 10 daily timeslices to depict a "typical" day, and over 3 seasons to capture seasonal variations in demand. The model is calibrated to a base year of 2020 for the demand sectors. Demand for electricity in 2020 is 16 531GWh. The residential sector is the largest consumer using 7 765GWh, followed by industry which used 5 499 GWh.

All the power plants that were operating in 2021, and those that were under development, are represented individually in the model. The model therefore includes, 4.8 GW of dependable capacity in 2021, of which 3.31GW are thermal plants, 1.4GW are hydro and 84MW are renewables. A further 225MW of wind at the Ayitepa wind farm is committed to come online in 2023.

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 follow 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 of solar plants ranges from 0.17 to 0.19 . Annual wind capacity factors in the model range from 0.25 to 0.39, depending on the location.

There are several power purchase agreements that are concluded as take-or-pay contracts. These contracts are predominantly associated with thermal power plants. Where it was known that a plant was under a take-or-pay contract these plants are modelled so that they incur a minimum operating cost regardless of whether electricity is being generated or not. To allow the model to choose whether or not to run the plants, and at the same time capture the full cost of these contracts, the cost of running the plant up to the level of supply falling under the take or pay contract is modelled as a fixed operating cost; if the plant is generating electricity above the level of the take-or-pay contracts, fuel costs and variable operation and maintenance costs reflect the actual cost of running the plant.

Battery storage is included as an option in all scenarios. Batteries are able to store electricity generated by plants, and then discharge the energy as needed. Unlike dam storage which can store water in one season for use in another, batteries are only able to store energy over a day. Storing energy in batteries is associated with a small loss of energy.

In the system optimisation, the cost of fuels, capital and O&M costs, expected plant life, efficiency and availability factors of individual plant options all inform the optimised model results for new capacity additions. Any constraints imposed, such as: the speed at which new capacity of a particular generation technology can be added; the total capacity that can or must be added to the solution for different generation types; environmental constraints etc will be reflected in the results. All plants have an assumed lead time, which varies according to the technology. New capacity investments are possible for wind and solar plants, hydro plants and generic oil, gas and coal plants. The capital costs and maintenance costs of new wind and solar plants decrease over time to reflect technology learning, making these plants more attractive from a cost perspective in future years. In the Ghana model, constraints are imposed on the amount of new capacity additions that can occur for a particular technology, for example, solar capacity additions are capped at 0.5GW per year throughout the model period, whereas additional wind capacity is capped at 0.5GW in 2023, increasing to 5GW by 2050.

Fuel use generates GHG emissions. These emissions can be constrained to a maximum at a certain point in time, or constrained at a cumulative amount between certain years.

The combination of plants, fuels, emissions, demand sector disaggregation and temporal representation provide a least cost technology mix that can meet the total demand, including transmission losses at the temporal resolution specified over the modelling period.

4.2 A Computable General Equilibrium (CGE) model for Ghana

The CGE model for Ghana is a dynamic recursive, economywide computable general equilibrium (CGE) model built on the framework from Diao and Thurlow (2012). 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. The model includes detailed information on sector production and intermediate use including 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 markets are clear. These price changes inform the level of household consumption expenditure. The Ghana CGE model includes representative household quintiles by rural farm, rural non-farm and urban region.

The Ghana CGE uses an enhanced version 2015 social accounting matrix (SAM) for Ghana, developed by the International Food Policy Research Institute (IFPRI, 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 Ghana to ensure that the models are consistent. Appendix Table 2 presents the SAM accounts.

A key feature of the Ghana CGE model used in GHATIM-GE is the behaviour of household consumption over time. Most CGE models assume a Linear Expenditure System for household expenditure. The Ghana CGE model uses a Cobb-Douglas approach, changing consumption shares over time in line with changes in household incomes to account for changes in living standards. For example, if incomes in the poorest 20% of households increase to the level of the poorest 40%, the consumption shares are adjusted to reflect the profile of households in the poorest 40%. Such an evolution in household consumption is better suited for long term analysis as it better captures the “welfare-enhancing feature of modern economic development” (Chai, 2018). Such an approach is also important for understanding household energy needs as fuel type demands evolve with lifestyle changes. More detail on this approach can be found in Merven, Hartley and Schers (2020).

While the Ghana CGE model allows for some household distributional analysis through the inclusion of a 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 B). Under this approach economic outcomes from the GHATIM-GE modelling framework are soft-linked to a microsimulation module to calculate expenditure-based inequality and poverty estimates. The Ghana Living Standards Survey (GLSS) 6 used to calibrate the household development of the 2015 SAM, it used to inform the base year calculations. Each of the households in the survey is linked to the corresponding household group in the Ghana CGE model through growth in household consumption by commodity group and population resulting in a different per capita level of expenditure per household across time and scenario. 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, behavioural changes from the Ghana CGE model are passed through via relative differences in consumption expenditure growth across commodity groups. Domestic poverty lines are used in the modelling framework. Specifically, the 2013 food and upper poverty lines of GHC 792 and GHC 1314, as reported by the GSS (2014) are included. A lower poverty line, the average of the food and upper are also added to the analysis. Because we are assessing real changes in households' consumption, the poverty lines remain unchanged in the microsimulation module although they are increased to reflect the values in 2015 prices.

2015 Ghana SAM Economic Structure

The 2015 SAM shows that Ghana's economy is largely driven by the services sector, which contributes about half (49.6%) of the country's GDP and accounts for about 44% of total employment. As shown in table 1 the services sector employs more than half of lower skilled workers with a significant proportion of workers having primary and secondary or middle level education. The manufacturing and mining sectors together contribute less than a fifth of the total GDP.

Table 1: Sectoral Contribution to GDP

	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	14.9	24.1
Agriculture	19.9	12.0	38.3	13.6	2.3	12.2	5.2
- Crops	15.6	8.5	34.5	13.5	2.1	18.4	7.5
Mining	6.7	12.4	1.5	60.6	2.3	75.9	14.1
Manufacturing	5.5	11.1	11.9	11.2	78.1	14.4	67.2

- Food	1.5	3.8	3.7	2.6	10.2	9.1	49.2
- Other	3.9	7.2	8.2	8.6	67.8	16.7	72.2
Other industry	18.3	16.5	4.8	0.0	0.0	0.0	0.0
Services	49.6	48.0	43.6	14.6	17.3	5.0	7.6
Energy intensive	35.4	50.1	44.1	70.5	41.7	21.9	22.6

Source: 2015 Ghana SAM

The top 20 sectors that are considered to be energy intensive in its activities, contribute about 35.4% of GDP. These sectors include services, mining, manufacturing and industry. In total, these energy intensive sectors also employ about 44.1% of the country's labour.

Figure 3 shows that most sectors make use of intermediate goods, with the highest being the fishing sector where about 98% of its inputs consist of intermediate goods followed by the livestock sector whose intermediate inputs constitute about 84% of its total inputs. The sectors with the highest capital inputs are the food and services sectors where capital inputs make up 62% and 52% of their total input outlays respectively. As expected, the crops sector is the only sector that makes use of land in significant proportions as an input of production.

Figure 3: Sector outlays, 2015

Source: 2015 Ghana SAM

For a significant proportion of households in the rural areas, particularly for uneducated labour, crop and livestock are the main sources of income (see figure 4). For both rural and urban areas, we note that as education increases, the contribution of household income from agriculture (crop and livestock) production declines while the contribution of services increases. This may serve as a signal to the increasing returns to higher education in the economy. For rural households with primary education, energy and other manufacturing sectors serve as significant contributions to household wages compared to other households in both urban and rural localities.

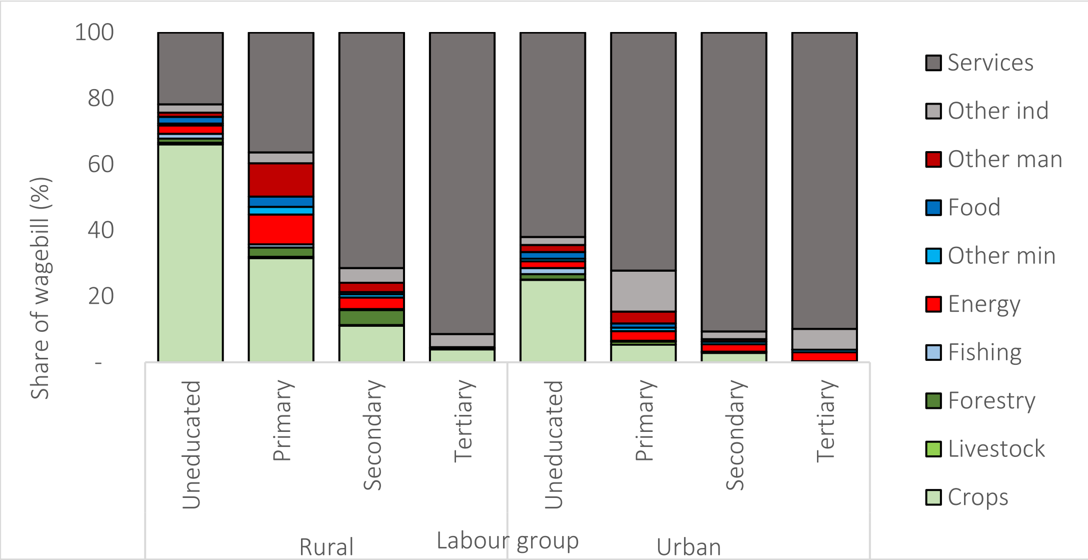


Figure 4: Labour expenditure by sector, 2015

Source: 2015 Ghana SAM

More than a third (39% ,36% and 33%) of household income for rural farm households in the lower three quintiles come from agricultural crop production. although this declines with higher income levels. Also, we note that the share of household income from capital ownership reduces with higher income quintiles, from 21% of household income from the lowest quintile to 9% in the highest quintile. However, income from capital ownership does not contribute to household income from non-farm households irrespective of the wealth quintile. Consistently across the three household types, we note that ownership of enterprises is the main source of income and its contribution to household income increases with higher wealth quintiles (see figure 5). For rural farm households, the contribution of enterprise ownership increases from 3% for the lowest wealth quintile to 37% for the highest wealth quintile. For non-farm households, it increases from 12% to 50% while in urban households, it increases from 23% to 68%. For both farm and non-farm households in rural areas, income from uneducated labour form a significant proportion of household income while income from labour with primary education are most prominent in the urban areas.

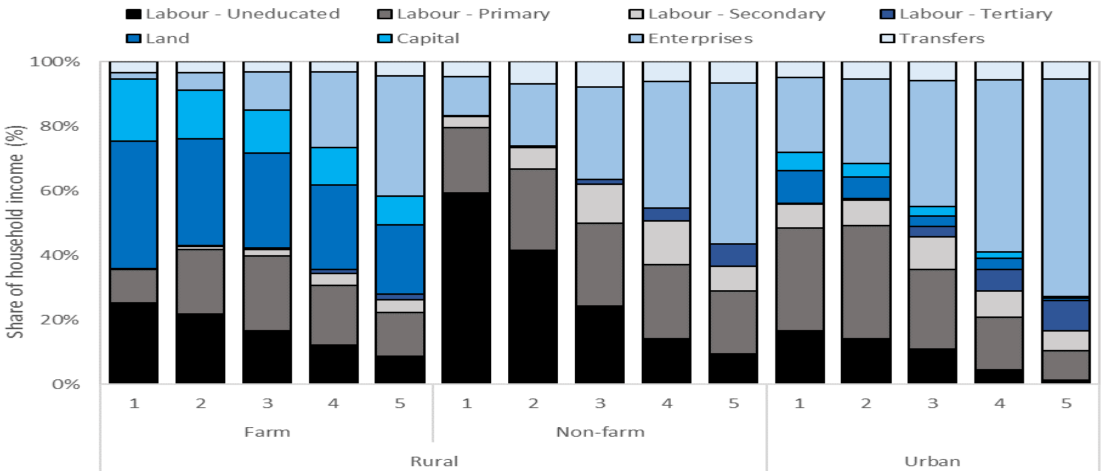


Figure 5: Household income by source, 2015

Source: 2015 Ghana SAM

For all household types, the data shows that households in the lowest quintiles spend a larger proportion of their income on food items compared to households in higher quintiles. In farm households, the consumption of manufactured goods is associated with higher income households. Compared to farm and non-farm households, urban households appear to spend a larger proportion of their incomes on energy. We also note that all households spend about a third of their incomes and various services, although the proportions are higher for urban households, especially for higher quintile households. (See figure 6)

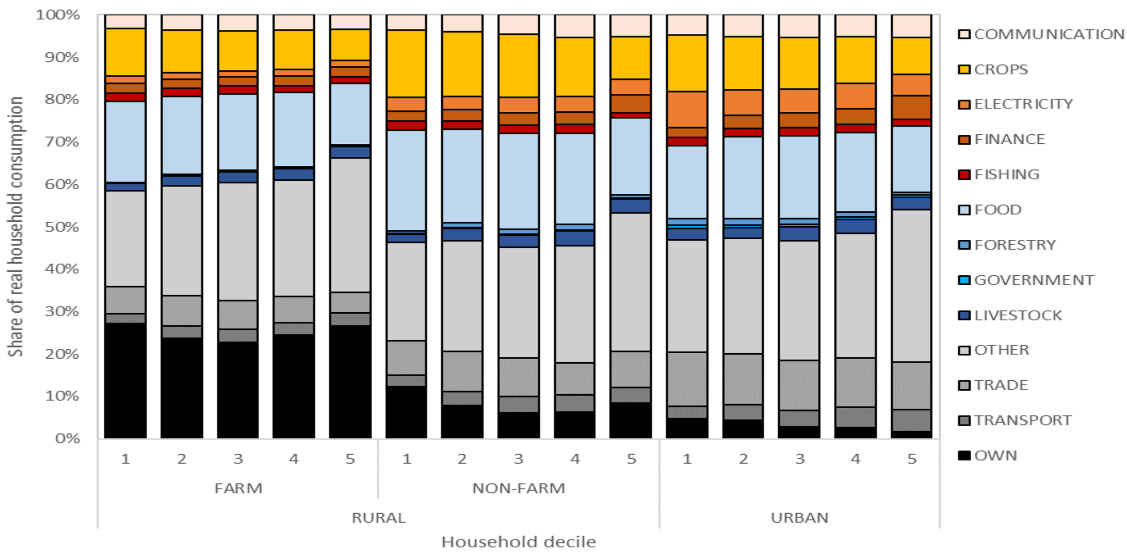


Figure 6: Household consumption expenditure by commodity, 2015

Source: 2015 Ghana SAM

6. Reference case

The reference case scenario is the business-as-usual scenario for the Ghanaian economy under which no mitigation action is taken. The reference case is used as the counterfactual scenario to which mitigation scenarios are compared to assess their impact on the economy. In this scenario we assume that the economy grows at an average annual rate of 5.8% per annum between 2015 and 2050. The growth rate is based on actual historical growth and projections. Figure 7 presents the economic projection.

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 and as such it is dependent on the level of investment made in the previous period. Investment is assumed to be a fixed share of absorption which in 2015 was roughly 26%. The government balance can adjust to finance shortfalls in expenditures or save surplus funds. In line with the stylised facts for Ghana, the exchange rate is assumed to be flexible. No mitigation or climate impacts are included in the Reference case. The underlying assumptions included in the reference case are kept consistent across scenarios to ensure that the differences in outcomes are the result of the climate actions taken.

GDP per capita increases from GHC 4,445 in 2015 to GHC 17,932 in 2050 (real 2015 prices; 2040: GHC 11,044). The increase in per capita GDP is driven by the faster growth in GDP relative to population growth. Annual population projections are taken from the UN. A distinction is made between rural and urban population growth with rural areas expected to grow at the slower pace of 0.2% per annum relative to urban areas which grow at 2.7%. Rural population growth starts at 0.5% in 2023 and reaches -0.3% by 2050. Urban population growth starts at 3.1% and falls to 2% by 2050. As illustrated in Figure 7, all sectors continue to grow in the Reference case, although the shares of mining and other industry to overall GDP decreases. Manufacturing and services become a larger part of the economy and agriculture remains relatively the same. Employment increases as the economy expands although employment intensity does increase due to the more prominent roles of manufacturing and services which are the largest employers per unit of output following agriculture. In terms of types of employment, more jobs are created for low skilled workers with slightly more than half of all new jobs being created for urban workers. Poverty (using an upper poverty line) decreases over the period from an estimated headcount rate of 23% in 2015 to 3.1% in 2040 and 0.7% in 2050 with the level of people living below the poverty line decreasing to 1.4 million in 2040 and 0.4 million in 2050 from an estimated 6.7 million in 2015. This may be considered ambitious but as highlighted before, the microsimulation module does not account for the persistence of poverty. Inequality also decreases over the period with the Gini decreasing from an estimated 0.45 in 2015 to 0.44 in 2050.

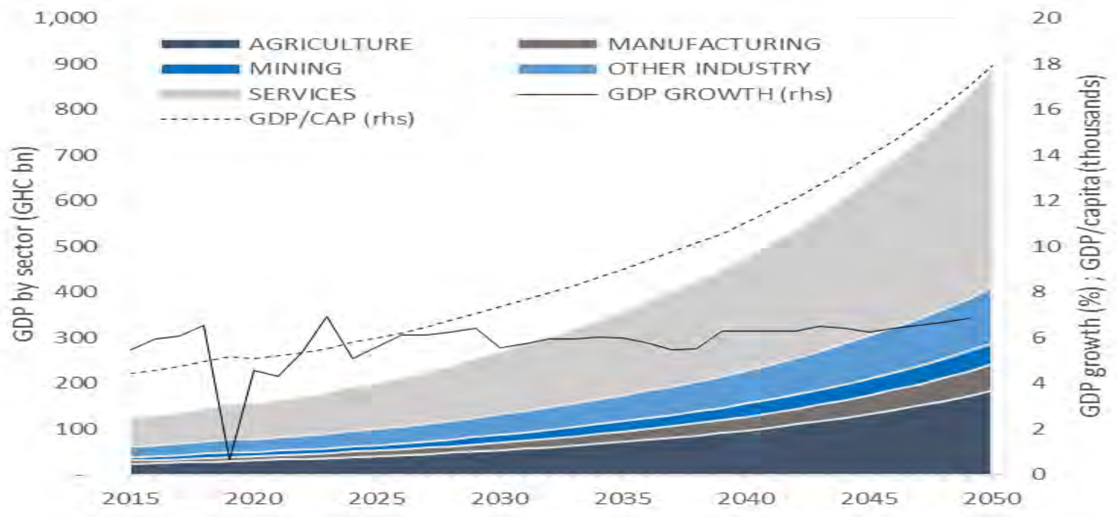


Figure 7: Reference case economic projections

Source: GHATIM-GE

7. Mitigation scenarios

We consider two mitigation scenarios, i.e., a moderate mitigation ambition in line with the Updated NDCs in which emission levels in the power sector are constrained to those of 2015 from 2035 onward, and an ambitious mitigation scenario under which power sector emissions are reduced to half of those produced in 2015 from 2035 onward. All assumptions are held the same as in the reference case.

Figure 8 presents the annual power sector emissions under the reference case, moderate mitigation ambition, and ambitious mitigation ambition scenarios. In the reference case, emissions initially rise due to the continued use of oil. As oil-based power generation is replaced by gas with some solar PV and wind, emissions stabilise between 2026 and 2035. Higher growth post this, however requires an increase in power supply which is largely met by increased gas use. By 2050, power sector emissions are near zero in the Ambitious scenario and 88% lower than in the reference case. Under the Moderate scenario emissions are 76% lower than in the reference in 2050. The changes in the energy system resulting in these changes are discussed next.

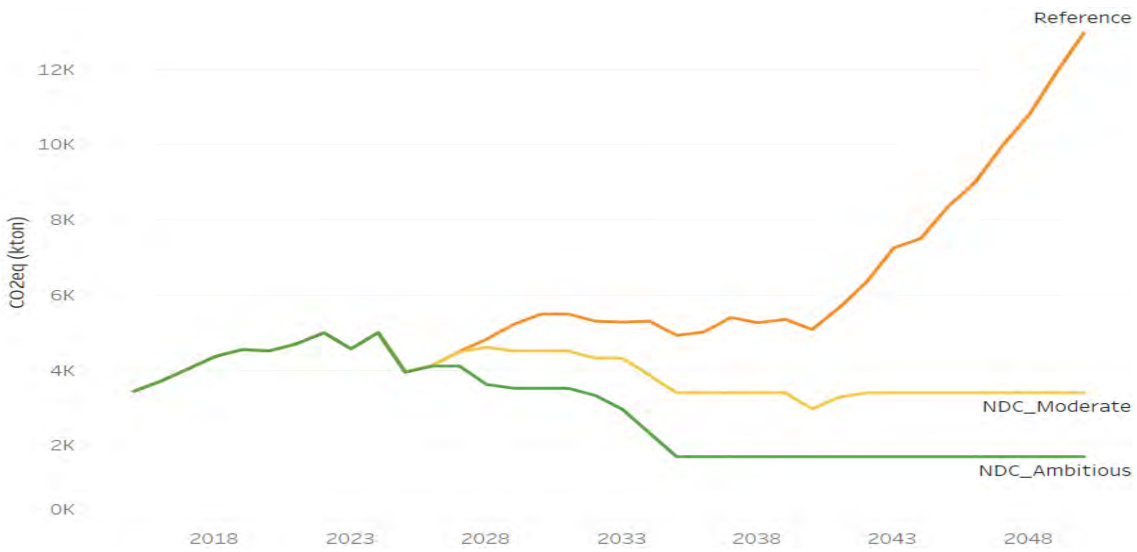


Figure 8: Annual power sector emissions by scenario, 2015-2050

Source: GHATIMGE

In the scenarios above, mitigation in the power sector is funded through existing investment resources in the economy. Many countries' NDCs are however dependent on the receipt of foreign assistance to achieve their necessary mitigation goals. Ghana's Updated NDC reflects potential mitigation of 64MtCO2eq by 2030 (relative to a baseline cumulative 2020-2030 emissions). However only about a third of this commitment is unconditional on international or private investment (MESTI, 2021). We therefore consider two additional scenarios in our analysis - Moderate+CF and Ambitious+CF - these scenarios are the same as the Moderate and Ambitious scenarios discussed above except that all renewable energy power sector projects are funded from foreign funding sources. These scenarios provide a lower bound to cost of mitigation with the previous two scenarios indicating a potential upper bound.

8. Changes in the power sector

Figure 9 shows the electricity produced by different plant types in each of the scenarios. Production of electricity increases to meet the demand for electricity in the scenarios. Throughout the period, the demand for electricity is lower in the NDC scenarios, reflecting the impact on demand of the investment in new generation capacity and the cost of production from this capacity in each scenario captured in the linked model. The most striking difference between the scenarios is the ratio of generation from gas seen in the reference case compared to the generation from wind and solar PV in the NDC scenarios. In the NDC scenarios, in response to the emissions constraints imposed in the model, there is an increase in production from PV and wind plants. Due to the availability constraints imposed on these intermittent renewables to reflect the intermittency of generation from these plants, the supply of electricity from these plants needs to be matched with some investment in battery storage capacity or alternative supply technologies that can generate electricity on demand as needed. In the NDC scenarios, in order to supply electricity when RE supply is constrained and emissions reductions limit investment in gas, the model invests in large amounts of battery storage by the end of the period (shown in Figure 10). The demand seen in the NDC scenarios includes the additional electricity needed to cover losses that occur as the battery storage technologies are charged and discharged.

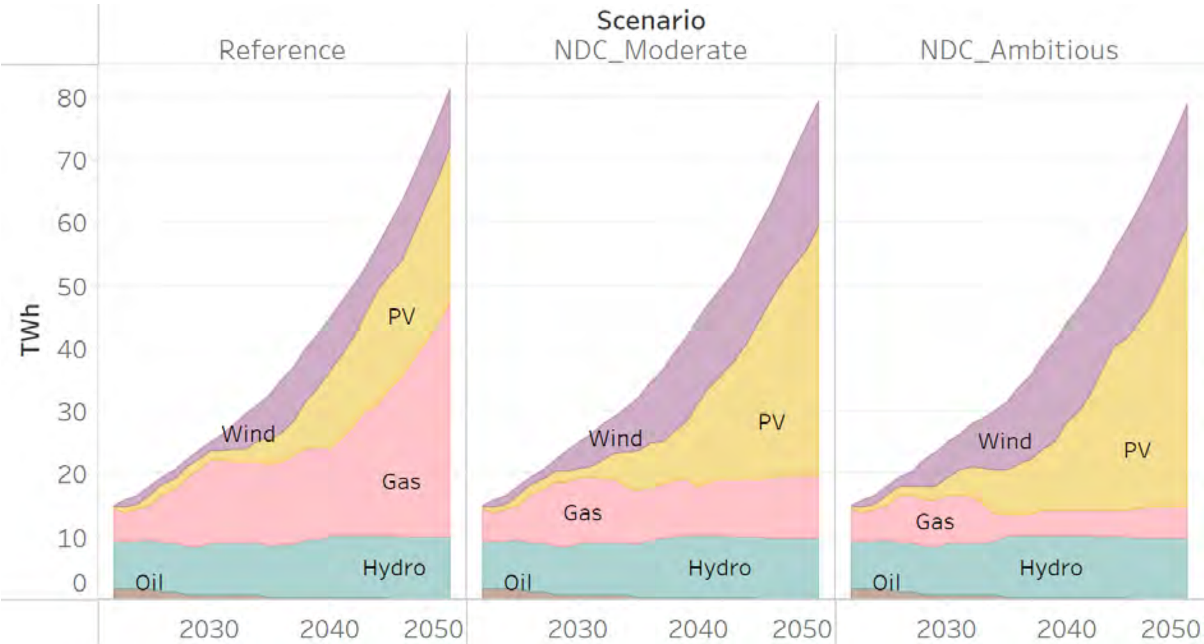


Figure 9: Electricity production by plant type (TWh)

Source: GHATIM-GE

New capacity investments in the NDC scenarios are driven by investment in solar power, wind and batteries, replacing the investment in gas in the reference scenario. A tightening of the emissions constraint raises investment in these technologies. Liquid fuel plants are phased out over the period in all scenarios. Although demand is similar in the NDC scenarios the additional capacity needed to replace gas in these scenarios is large. This is primarily due to the assumptions around the availability of solar and wind plants compared to the gas plants in the reference scenario and the battery storage capacity needed.

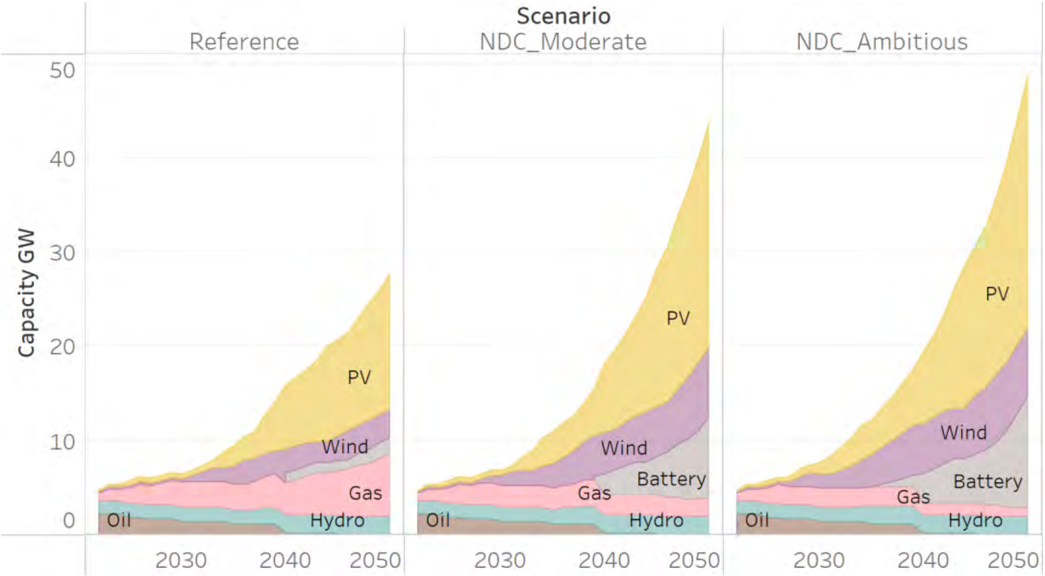


Figure 10: Electricity capacity by plant type (GW)

Source: GHATIM-GE

The cumulative investment needed (billions of US dollars) to acquire the additional capacity shown in Figure 10, is shown in Figure 11. Although electricity generated is lower in the NDC scenarios, the investment needs of the power sector are far higher, although doubling the level of mitigation ambition does not increase investment needs proportionally.

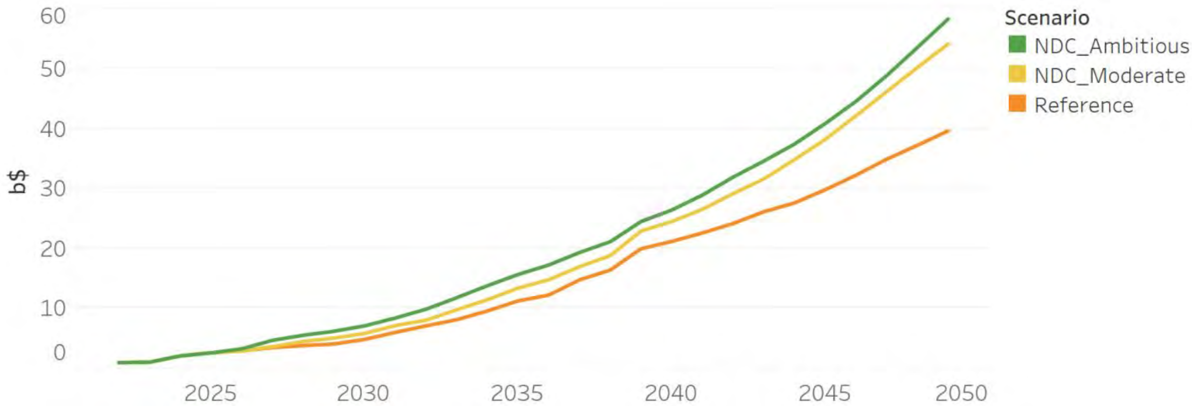


Figure 11: Cumulative investment in Power Sector

Source: GHATIM-GE

Figure 12 shows the impact of the investment and production decisions on the electricity price ($/MWh). The cost of producing a unit of electricity drops initially as capacity is more fully utilised and take-or-pay contracts are replaced with lower cost alternatives. It is assumed in all scenarios that take-or-pay contracts are not renewed but that these plants can continue to run until the end of their plant life. The impact of the additional investment needed in the NDC scenarios can be seen in the higher price of electricity in these scenarios, increasing towards the end of the period, although it is worth noting that even in the most ambitious scenario, the price remains well below the price in 2020.

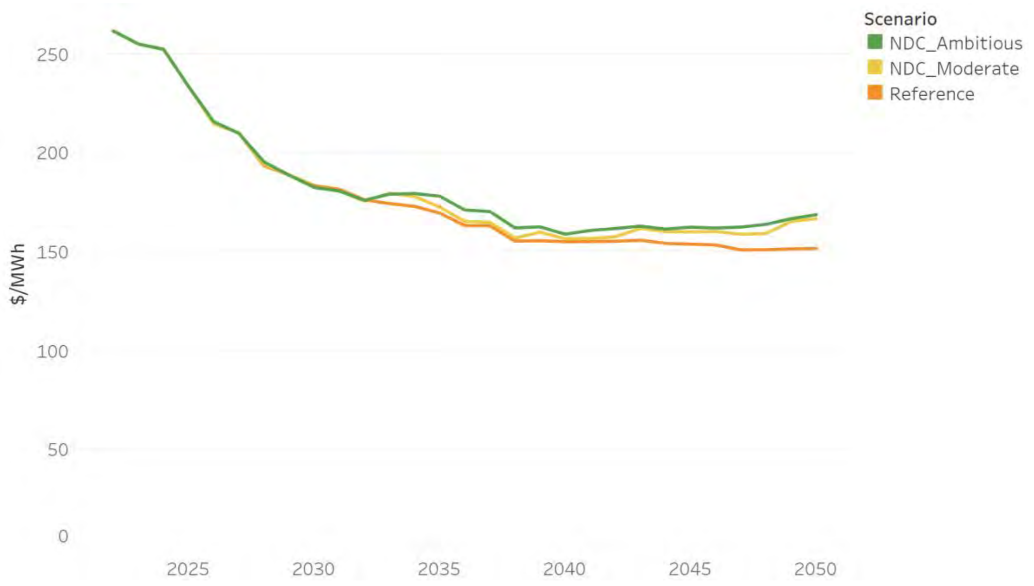


Figure 12: Price ($/MWh)

Source: GHATIM-GE

Figure 13 shows the hourly dispatch of electricity from each plant type for two years, namely 2025 and 2040 in the reference scenario compared to the Ambitious NDC scenario. The demand profile is also shown by the red line in the figures. The figure reflects the restriction in seasonal and daily availability of PV, wind, and hydro plants. For example, it shows that generation of electricity using PV is restricted to daylight hours, and is lower in winter. In the reference scenario, there is very little battery use, which reflects as both a demand for electricity and the subsequent dispatch of electricity over the course of the day.

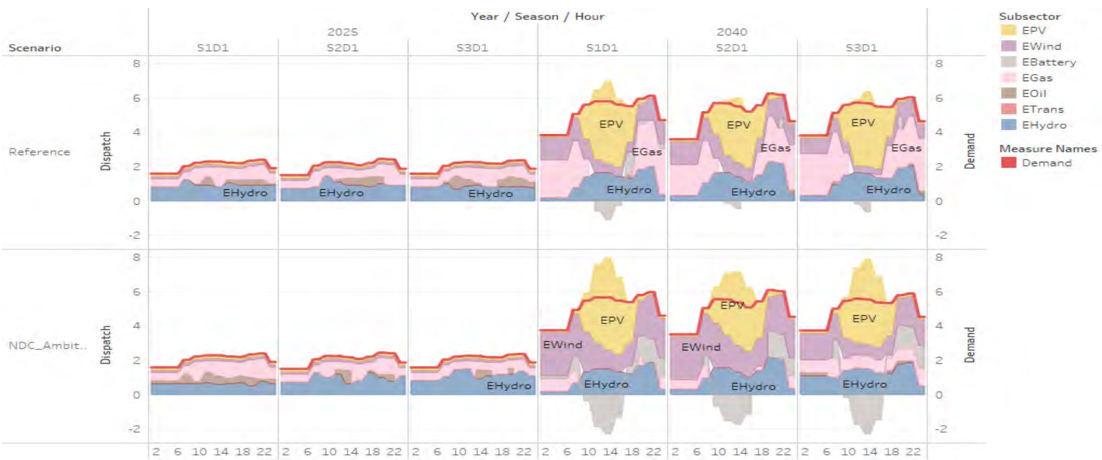


Figure 13: Hourly Dispatch in 2025 and 2040 for Reference and NDC_Ambitious Scenarios

9. Implications for the macroeconomy

Mitigation in the power sector results in a decrease in the level of real GDP. The decrease is driven by the increase in power sector investment required to transform the sector from being primarily gas based to being renewables based as discussed above. The rise in investment needed for power generation reduces available funds for other sectors in the economy. We assume that investment in the power sector is funded domestically. This raises the cost of non-energy capital and limits the expansion of non-electricity production. By 2030 and 2040, the level of real GVA in the Moderate scenario is 1.5% and 4.9% below the level of the Reference case. The growth rate is 0.4 and 0.6 percentage points lower. Costs to the economy increase with more ambitious power sector mitigation as illustrated by the Ambitious scenario - real GDP losses, relative to the reference case, rise to 2.5% and 8.1% by 2030 and 2040 respectively. By 2040, the level of GDP relative to the Reference case lags by less than 1 and less than 2 years under the Moderate and Ambitious scenarios, respectively.

The negative impacts of power sector mitigation are experienced across sectors, although the mining and manufacturing sectors are worse affected. Declines in the mining sector are driven by decreased natural gas and crude oil production which falls by 20% and 11% in the Moderate scenario, and 30% and 16% by 2040 in the Ambitious scenario relative to the Reference case. The natural gas sector contributes less than 1% to overall GDP by 2050 in the reference case. Declines in the manufacturing sector are driven by lower production in food manufacturing particularly in the meat sub-sector. Meat is primarily consumed domestically by households. In food production, the fruit and vegetable sub-sector is the least affected. This sector is a key food manufacturing export sector, exporting more than 90% of its output. Other manufacturing sub-sectors also decreases. While declines are similar by 2030, decreases in these sectors are smaller than in the food processing sector by 2050.

Table 2: Percent change in Gross Value Added relative to Reference case

	2030		2040	
	NDC Moderate	NDC Ambitious	NDC Moderate	NDC Ambitious
Total GDP	-1.5	-2.5	-4.9	-8.1
Agriculture	-1.2	-2.0	-3.9	-6.3
Crops	-0.9	-1.5	-2.8	-4.5
Mining	-3.6	-5.7	-11.5	-17.4
Manufacturing	-2.8	-4.4	-7.9	-12.4
Food	-2.7	-4.4	-9.2	-14.6
Other	-2.8	-4.5	-7.1	-11.1
Other industry	-1.3	-2.1	-3.7	-6.6
Services	-1.3	-2.2	-4.6	-7.6

Source: GHATIM-GE

Employment declines presented in Table 3 reflect the declines in GDP. By 2030 and 2050, total employment is 87,000 and 146,000 less than the Reference case in the Moderate scenario. Under the Ambitious scenario jobs losses are larger reaching just over 1 million by 2050. Employment decreases relative to GDP are larger by 2050 because the economy is more employment intensive than it was in 2030 as manufacturing and services become larger parts of the economy. Manufacturing and services are the second and third largest employers per unit of output after agriculture. This also explains the larger job losses in the agriculture sector despite the smaller change in GDP relative to mining, manufacturing, and services.

Table 3: Change in level of employment relative to Reference case (thousands)

	2030		2040	
	NDC Moderate	NDC Ambitious	NDC Moderate	NDC Ambitious
Total GDP	-87	-146	-775	-1,181
Agriculture	-57	-94	-376	-567
Crops	-62	-102	-357	-544
Mining	-9	-14	-45	-66
Manufacturing	-28	-43	-190	-303
Food	-22	-35	-163	-257
Other	-5	-9	-27	-46
Other industry	19	29	21	46
Services	-12	-23	-185	-292

Source: GHATIM-GE

In terms of employment sub-categories, the bulk of job losses are experienced in rural areas (more than 60% by 2040). Agriculture, mining, and manufacturing employs more than 50% of its workers from these regions. Job losses are concentrated in workers with primary school or less education (i.e., uneducated and primary) with more than 80% of total job losses coming from these two labour groups. This trend is reflected in both the rural and urban areas, although in rural areas uneducated and primary educated job losses account for just over 90%. Wages also decrease due to the decline in production. Wage declines are largest for lower skilled workers in the urban areas.

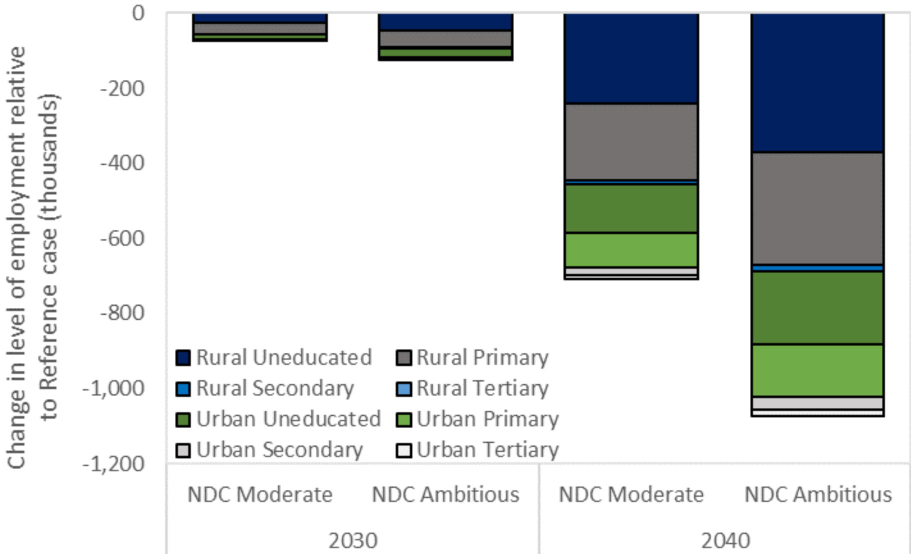
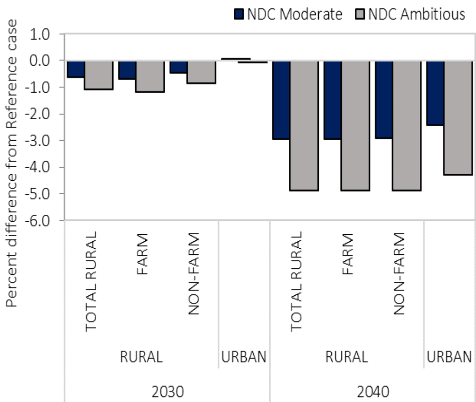


Figure 14: Change in employment level relative to Reference case by education group and geolocation (thousands)

Source: GHATIM-GE

10. Distributional impacts

Figure 15 presents the change in household income by representative group. The change in income shown is for returns to production factors and enterprise income - transfers do not change between modelled scenarios. Mitigation in the power sector has a larger negative impact on rural household income than urban, although by 2040 all households experience a decrease in income. Farm households are more negatively affected than non-farm households with lower income households experiencing larger losses in incomes. Declines in incomes are larger under the Ambitious scenario.



			GHATIM_NDCAmbitious 2030	GHATIM_NDCAmbitious 2040	GHATIM_NDCModerate 2030	GHATIM_NDCModerate 2040
RURAL	FARM	1	-1.40	-5.02	-0.84	-3.07
		2	-1.38	-4.98	-0.83	-3.05
		3	-1.29	-4.93	-0.77	-3.01
		4	-1.08	-4.83	-0.62	-2.91
		5	-0.83	-4.73	-0.45	-2.79
	NON-FARM	1	-0.87	-4.87	-0.47	-2.91
		2	-1.45	-5.33	-0.87	-3.27
		3	-1.30	-5.18	-0.77	-3.16
		4	-1.06	-4.98	-0.61	-3.01
		5	-0.82	-4.80	-0.44	-2.86
URBAN		1	-0.59	-4.68	-0.28	-2.74
		2	-0.07	-4.30	0.08	-2.43
		3	-0.60	-4.56	-0.32	-2.76
		4	-0.49	-4.45	-0.24	-2.69
		5	-0.32	-4.43	-0.11	-2.61

Figure 15: Percent change in household income relative to Reference case

Source: GHATIM-GE

Figure 16 shows the contributions of different sources of household income to the overall change experienced relative to the Reference case. A negative value shows a positive contribution to the change in income levels. For example, in 2030,in the fourth and fifth household quintiles in urban areas, the overall increase in income relative to the Reference case is driven by increases in enterprise incomes as income from labour and capital declines. Enterprise income also increases for other households, but this is presented as a negative because overall income decreases. Loss of labour income is the primary contributor to lower household income in 2030, but by 2040 enterprise income's contribution increases across households. Rural farm households are also negatively affected by loss in income from land and capital returns.

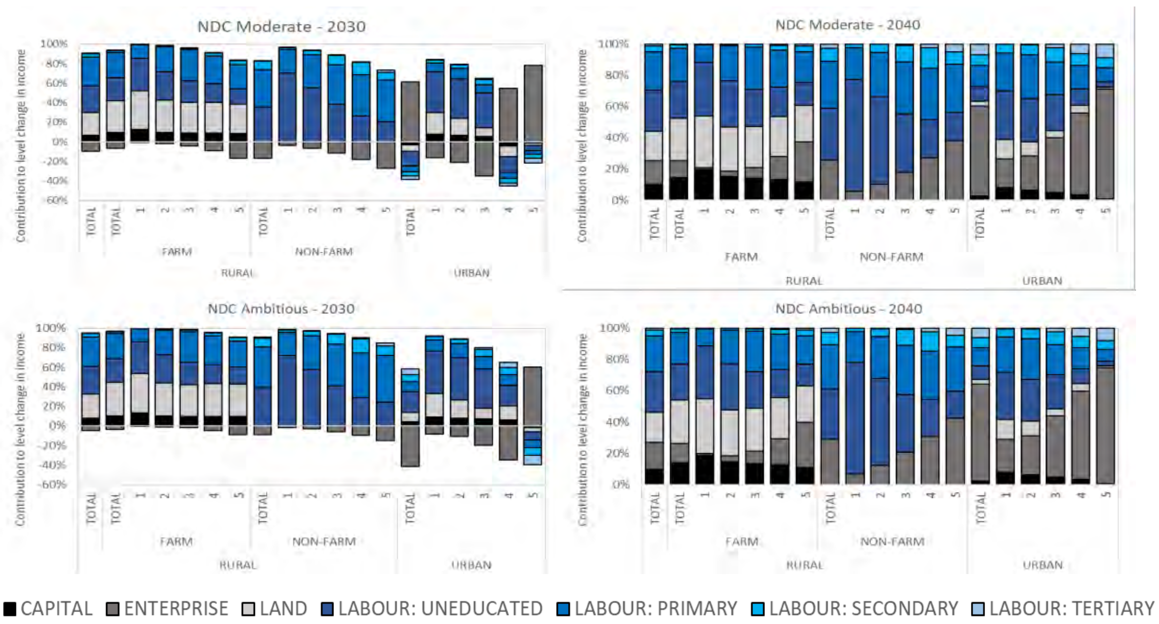
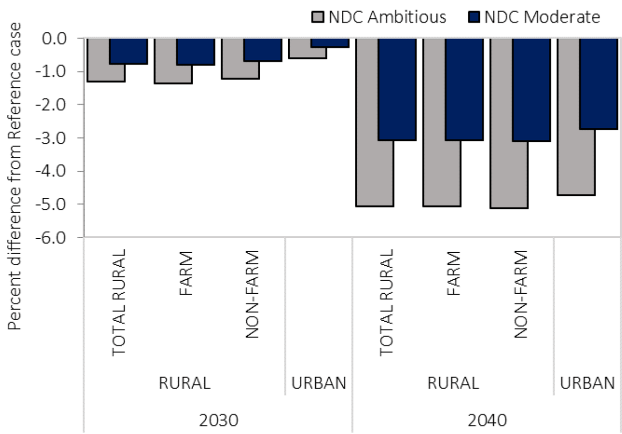


Figure 16: Contribution to level change in household factor income

Source: GHATIM-GE

Declines in household incomes translate into decreases in real household expenditure as illustrated in Figure 17. As with incomes, rural areas are more negatively affected than urban, while non-farm households in rural areas experience larger expenditure declines than farm households. Expenditure decreases are also found to be larger in lower income households than higher income households.



			GHATIM_NDCAmbitious		GHATIM_NDCModerate	
			2030	2040	2030	2040
RURAL	FARM	1	-1.52	-5.10	-0.92	-3.13
		2	-1.53	-5.11	-0.93	-3.14
		3	-1.49	-5.10	-0.90	-3.13
		4	-1.31	-5.04	-0.78	-3.05
		5	-1.07	-4.93	-0.61	-2.94
	NON-FARM	1	-1.21	-5.13	-0.70	-3.09
		2	-1.56	-5.40	-0.95	-3.32
		3	-1.41	-5.22	-0.85	-3.20
		4	-1.25	-5.07	-0.74	-3.09
		5	-1.22	-5.13	-0.71	-3.10
URBAN		1	-1.04	-5.04	-0.58	-3.00
		2	-0.59	-4.72	-0.28	-2.74
		3	-0.77	-4.64	-0.43	-2.83
		4	-0.69	-4.56	-0.38	-2.77
		5	-0.62	-4.63	-0.32	-2.76

Figure 17: Percent change in total real household expenditure relative to Reference case

Source: GHATIM-GE

Under both the Moderate and Ambitious scenarios, poverty increases. In the short-term, by 2030, the rise in poverty is concentrated in rural areas while in the longer run, by 2040, poverty increases are larger in urban regions. The severity of poverty also increases under mitigation with both the poverty gap index and squared poverty gap index increasing in 2030 and 2040. The level of inequality remains relatively unchanged across the scenarios.

Table 4: Change in number of people living below the Food, Lower and Upper poverty lines

	Poverty line	Total		Rural		Urban	
		2030	2040	2030	2040	2030	2040
Moderate	Food	17,360	17,794	10,688	20,349	6,672	7,405
	Lower	20,200	46,751	11,738	27,649	8,462	61,955
	Upper	39,405	140,912	29,994	75,186	9,412	188,469
Ambitious	Food	43,645	27,754	10,688	20,349	6,672	7,405
	Lower	59,106	89,605	11,738	27,649	8,462	61,955
	Upper	59,811	263,655	29,994	75,186	9,412	188,469

Source: GHATIM-GE

11. Impact of climate financing

In this section, we consider the impacts of climate change under conditions where investments in climate mitigation efforts are financed through foreign sources . Specifically, we compare changes in the impacts on GDP growth, employment and on poverty and inequality to previous scenarios where mitigation was predominantly financed from domestic sources.

Overall, we see a reverse effect of foreign financing on the macroeconomy under both moderate and ambitious scenarios and in the short and long term. At a disaggregated level, all sectors record positive impacts except for the mining and manufacturing sectors, and particularly for the mining sector which carries over its negative growth even in the long term. Compared to the reference case, GDP increases by 2.7% in the short term to 4.6% in the long term under the moderate scenario. We observe similar growth in GDP from 2.4% to 4% under the more ambitious scenario (see table 5)

Table 1: Impacts of Foreign climate financing on macroeconomy

Percent change in level of GVA relative to Reference case				
	2030		2050	
	NDC Moderate	NDC Ambitious	NDC Moderate	NDC Ambitious
Total GDP	**2.7**	**2.4**	**4.6**	**4.0**
Agriculture	1.7	1.5	3.8	3.7
Crops	1.5	1.4	2.6	2.6
Mining	-9.9	-11.8	-1.5	-3.7
Manufacturing	-4.2	-5.4	2.7	1.5
Food	1.0	0.6	6.8	6.8
Other	-5.8	-7.2	1.1	-0.6
Other industry	8.7	8.9	6.9	6.6
Services	4.0	3.8	5.5	5.1

Source: GHATIM-GE

The general improvement recorded in GDP growth have mixed impacts on employment in the various sectors. While employment in the services and manufacturing sector improve compared to the reference case discussed earlier, the agriculture and crop sectors as well as the mining sector record higher declines in employment relative to the reference case and this is observed for both the moderate and ambitious case in the short to medium term. However, the trends reverse in the long term for almost all the sectors. The projections suggest that employment gains from foreign financing pick up significantly for all sectors only in the long term under both moderate and ambitious scenarios.

Table 6: Impacts of Foreign climate financing on macroeconomy

Change in level of employment relative to Reference case (thousands)					
		2030		2050	
		NDC Moderate	NDC Ambitious	NDC Moderate	NDC Ambitious
Total	Total GDP	206	218	1,435	1,463
AGRICULTURE	Agriculture	-70	-83	482	520
CROPS	Crops	-92	-109	402	433
MINING	Mining	-29	-33	-7	-18
MANUFACTURING	Manufacturing	61	65	367	377
FOOD	Food	-12	-11	229	245
OTHER	Other	73	76	138	132
OTHER INDUSTRY	Other industry	51	61	102	114
SERVICES	Services	193	207	491	469

Source: GHATIM-GE

In the short to medium term, we observe employment gains concentrated in the urban areas and among the people with primary education. This could be explained by the growth in employment in the manufacturing and services sectors which are found mostly in urban areas. Modest gains in employment are seen for workers in the rural areas who are uneducated although workers in rural areas and with primary education experience job losses. This may also be explained by the overall decline in employment in the agriculture and crop sectors which is predominantly in the rural areas. In line with the significant increases in employment under the moderate and ambitious scenarios in 2050, employment gains are recorded for all categories of labour. In the long term, jobs increase for workers in both urban and rural areas, with workers with no education and primary education experiencing the highest gains in employment. Workers in rural areas with secondary education experience the least gains in jobs.

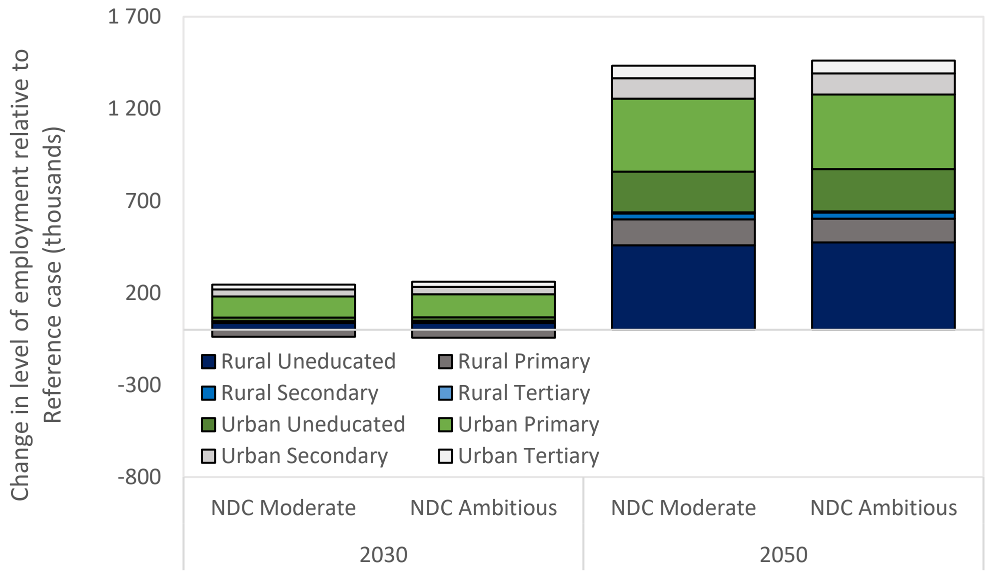


Figure 18: Percent change in total real household expenditure relative to Reference case

Source: GHATIM-GE

In terms of the welfare and distributive impacts, the projections show significant declines in poverty with significant declines in all three categories of poverty considered and the highest declines observed for the upper poverty line. There is however a slowdown in the rate of declines by 2050 (see table 7). Inequality rises moderately in both the moderate and ambitious scenarios even in the long term. See figure (19)

Table 7: Reductions in the number people living below the Food, Lower and Upper poverty lines

	Poverty line	**Total**		**Rural**		**Urban**	
		2030	**2050**	**2030**	**2050**	**2030**	**2050**
Moderate	Food	(1,367,533)	(206,818)	(650,016)	(47,833)	(717,517)	(158,986)
	Lower	(1,370,089)	(206,818)	(651,753)	(47,833)	(718,336)	(158,986)
	Upper	(1,581,180)	(301,742)	(721,439)	(69,871)	(859,741)	(231,870)
Ambitious	Food	(2,291,047)	(316,249)	(1,193,244)	(74,126)	(1,097,803)	(242,123)
	Lower	(2,323,503)	(316,249)	(1,205,768)	(74,126)	(1,117,736)	(242,123)

Upper	(2,772,631)	(449,257)	(1,376,252)	(104,260)	(1,396,379)	(344,996)

Source: GHATIM-GE

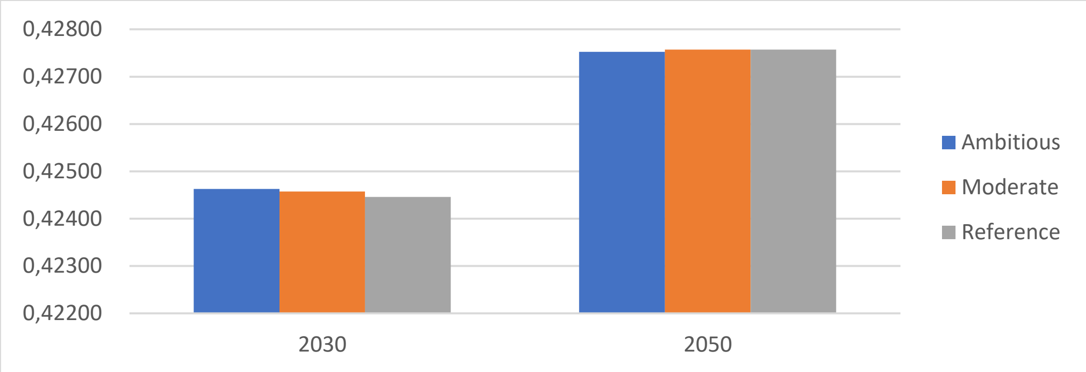


Figure 19: Inequality levels for the ambitious mitigation, moderate mitigation and the reference case.

Source: GHATIM-GE

12. Discussions and Future Work

The study highlights the macroeconomic implications and distributive effects of the mitigation strategies that Ghana currently has in place which constitutes the reference case. The reference is then compared to the moderate and ambitious scenarios which aims to further reduce emissions from the power sector. The moderate and ambitious scenarios are also considered under two different financing options.

Overall, reducing emissions in the power sector negatively impacts economic growth. The reduction in GDP below the reference case ranges from 1.5%-4.9% under the moderate case to 2.5%-8.1% in the ambitious case in the long run. These significant reductions observed are driven by the crowding out of funding for the real sector due to the diversion of domestic funds to the power generation sector to provide the required investment in the power generation sector. The most affected sectors of the economy are the mining and manufacturing sectors mainly driven by significant declines in the production of natural gas and crude oil production and declines in the manufacturing of food, particularly in the meat sector. However, with funding from foreign sources, the GDP losses are offset with GDP increasing between 2.7% to 4.6% under the moderate emission reduction scenario and from 2.4%-4% in the long term under the ambitious scenarios. At the sectoral level, we observe that manufacturing and mining sectors recover although the mining sector is slower to recover in the long-run. These findings suggest that financing mitigation activities in the power sector using foreign sources of funding makes it less costly for Ghana to transition to low emissions.

The negative impacts of mitigation on GDP is reflected in the job losses with larger declines in employment in 2050 where the economy becomes more employment intensive than in 2030 due to the increased contribution of manufacturing and services in the country's GDP. By 2040, rural areas experience majority of the job losses due to their involvement in the agricultural sector which also experiences a significant decline in growth. The employment declines are particularly high among workers with less education in both rural and urban areas, resulting in wage declines for lower skilled workers, particularly for those in the urban areas. Similar to the reversal in the GPD growth under the foreign financing, we observe significant gains in employment with concentrations in the urban areas. This is explained by the large employment in the manufacturing and services sectors, although by 2050 we find significant employment in the rural areas as well with workers with relatively less education experiencing these gains.

With respect to distributive impacts, findings suggest that mitigation in the power sector are associated with larger negative impacts on rural households, particularly for farm households than non-farm households. In the long term, however, both rural and urban household experience declines in incomes as a result of the ambitious mitigation efforts. The results show that climate change mitigation are associated with increases in poverty with large concentrations in the rural areas by 2030 and large concentrations in urban areas in 2040. There is no change in inequality across the moderate and ambitious scenarios considered when mitigation is financed through domestic resources. Poverty reduces significantly under foreign financing although inequality rises marginally under all scenarios considered.

In interpreting these results, it is important to acknowledge some of the limitations of the study. First, in the economic analysis, the current study does not account for any other benefits associated with the decreased emissions, such as improvement in air quality which may have health benefits and therefore reduced medical expenditure for households and the government and ultimately have positive impacts on productivity. In addition, it is important to note the costs of mitigation may be lower if other sectors are also considered. For instance, cheaper mitigation options may exist in other sectors which may then reduce the need for such significant reductions in the emissions from the power sector. Given that this current work considers only mitigation strategies as a way of reducing emissions, future work could consider a combination of adaptation and mitigation strategies. An expansion of the models could be considered to account for impacts of mitigation strategies at a more disaggregated level, such as the district level to guide more effective policy making. Also, in this current study, we consider two extreme financing options- either domestic or foreign. Future studies could explore the financing options that combines both sources of financing to find the most optimal option that is feasible for the country.

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APPENDICES

Appendix A:

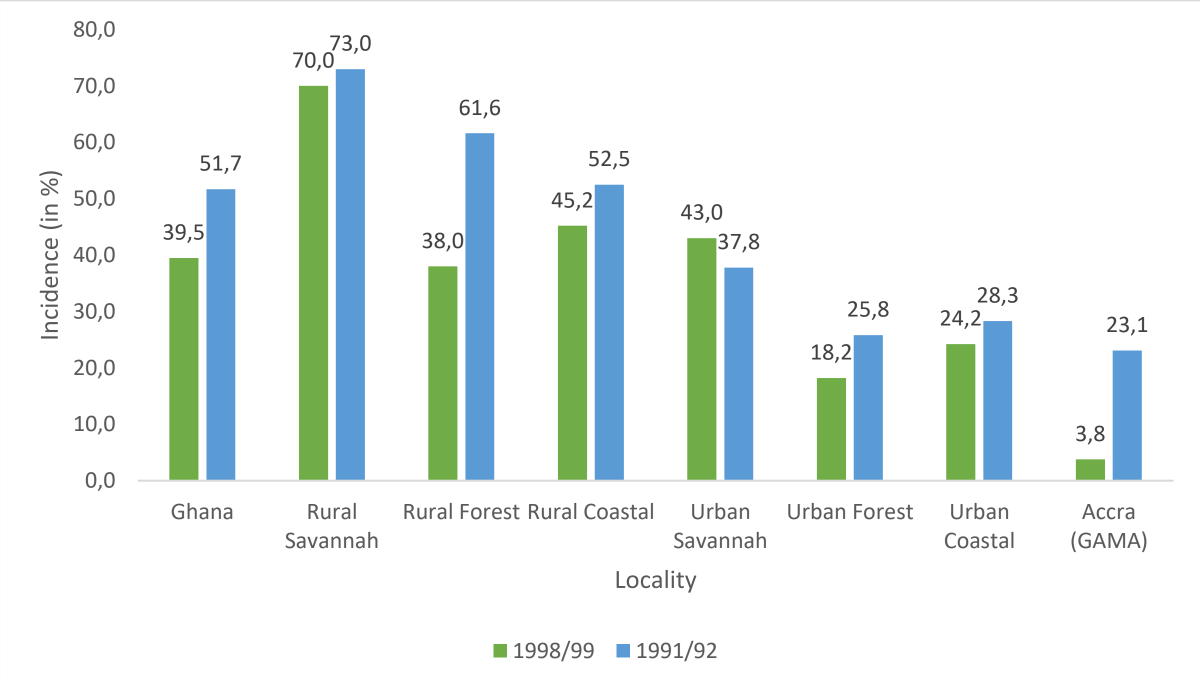

Figure 1.1: Poverty incidence by locality (Poverty line=900,000.00 cedis)

Source: Authors' construct, Poverty Profile Report; 1991-2017

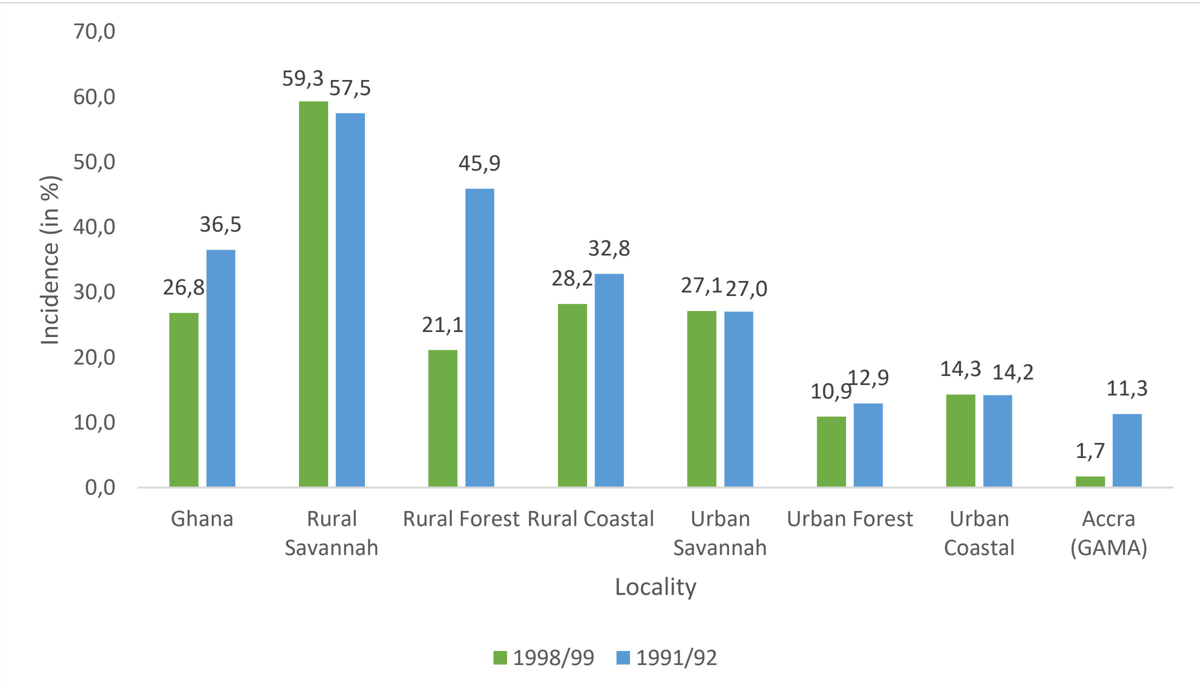

Figure 2.1: Extreme poverty incidence by locality (Poverty line=700,000.00 cedis)

Source: Authors' construct, Poverty Profile Report; 1991-2017

Table 1: Existing and committed power plants 2021

Power Plant	Fuel Type	Installed Capacity (Nameplate)	% Share	Dependable Capacity
Hydro Power Plants				
Akosombo	Hydro	1,020		900
Bui	Hydro	400		360
Kpong	Hydro	160		140
	Sub-total	*1,580*	*30.8*	*1400*
Thermal Power Plants				
Takoradi Power Company (TAPCO)	Oil/NG	330		300
Takoradi International Company (TICO)	Oil/NG	340		320
Sunon–Asogli Power (SAPP)	NG	560		520
Tema Thermal Plant1 (TT1P)	Oil/NG	110		100
Tema Thermal Plant2 (TT2P)	Oil/NG	87		70
CENIT Energy Ltd (CEL)	Oil/NG	110		100
KTPP	Oil	220		200
AMERI	NG	250		230
Karpower (power rental)	HFO	470		450
AKSA	HFO	370		350
Cenpower	Oil/DFO	360		340
Amandi*	Oil/NG	203		190
Early Power*	Gas/LPG	144		140
	Sub-total	**3,554**	**69.2**	**3310**
Genser	NG/LPG	95		85
	Sub – total (incl. embedded gen.)	*3,649*	*68.5*	*3395*
Renewables *(excl. large hydro)*				
VRA Solar (Navrongo)	Solar	2.5		2
Meinergy Solar	Solar	20		16
BXC Solar	Solar	20		16
VRA Solar (Lawra)	Solar	6.5		4.5
Tsatsadu Hydro	Hydro	0.045		0.045
Bui Solar	Solar	50		45
Safisana Biogas	Biogas	0.1		0.1
	Sub – total	*99.145*	*1.9*	*83.645*
Total (incl embedded gen.)		**5,328.1**		**4,878.6**
*Completed and undergoing test-run for commissioning sometime in 2021				

Table 2: 2015 SAM Accounts

Sectors	Sectors	Commodities	Other
Agriculture: Maize	Machinery and equipment	Mining: Natural gas	Labor - rural uneducated
Agriculture: Sorghum and millet	Other manufacturing	Mining: Other mining	Labor - rural primary
Agriculture: Rice	Electricity, gas and steam	Processed: Meat, fish and dairy	Labor - rural secondary
Agriculture: Pulses	Water supply and sewage	Processed: Fruit and vegetable processing	Labor - rural tertiary
Agriculture: Groundnuts	Construction	Processed: Fats and oils	Labor - urban uneducated
Agriculture: Other oilseeds	Wholesale and retail trade	Processed: Grain milling	Labor - urban primary
Agriculture: Cassava	Transportation and storage	Processed: Sugar refining	Labor - urban secondary
Agriculture: Other roots	Accommodation and food services	Processed: Other foods	Labor - urban tertiary
Agriculture: Vegetables	Information and communication	Processed: Beverages	Land - agricultural crops
Agriculture: Sugar cane	Finance and insurance	Processed: Tobacco processing	Capital - other
Agriculture: Tobacco	Real estate activities	Textiles	Capital - energy
Agriculture: Cotton and fibers	Business services	Clothing	Households:Rural farm - quintile 1
Agriculture: Fruits and nuts	Public administration	Leather and footwear	Households:Rural farm - quintile 2
Agriculture: Cocoa	Education	Wood and paper	Households:Rural farm - quintile 3
Agriculture: Other crops	Health and social work	Petroleum	Households:Rural farm - quintile 4
Agriculture: Cattle	Other services	Chemicals	Households:Rural farm - quintile 5
Agriculture: Poultry	**Commodities**	Non-metal minerals	Households:Rural nonfarm - quintile 1
Agriculture: Other livestock	Agriculture: Maize	Metals and metal products	Households:Rural nonfarm - quintile 2
Forestry	Agriculture: Sorghum and millet	Machinery and equipment	Households:Rural nonfarm - quintile 3
Fishing	Agriculture: Rice	Other manufacturing	Households:Rural nonfarm - quintile 4
Mining: Crude oil	Agriculture: Other cereals	Electricity, gas and steam	Households:Rural nonfarm - quintile 5
Mining: Natural gas	Agriculture: Pulses	Water supply and sewage	Households:Urban - quintile 1
Mining: Other mining	Agriculture: Groundnuts	Construction	Households:Urban - quintile 2
Processed: Meat, fish and dairy	Agriculture: Other oilseeds	Wholesale and retail trade	Households:Urban - quintile 3
Processed: Fruit and vegetable processing	Agriculture: Cassava	Transportation and storage	Households:Urban - quintile 4
Processed: Fats and oils	Agriculture: Other roots	Accommodation and food services	Households:Urban - quintile 5
Processed: Grain milling	Agriculture: Vegetables	Information and communication	Domestic transaction costs
Processed: Sugar refining	Agriculture: Sugar cane	Finance and insurance	Export transaction costs
Processed: Other foods	Agriculture: Tobacco	Real estate activities	Import transaction costs
Processed: Beverages	Agriculture: Cotton and fibers	Business services	Enterprises

Processed: Tobacco processing	Agriculture: Fruits and nuts	Public administration	Direct taxes
Textiles	Agriculture: Cocoa	Education	Export taxes
Clothing	Agriculture: Other crops	Health and social work	Import tariffs
Leather and footwear	Agriculture: Cattle	Other services	Sales taxes
Wood and paper	Agriculture: Poultry		Energy price differentials
Petroleum	Agriculture: Other livestock		Government
Chemicals	Forestry		Savings and investment
Non-metal minerals	Fishing		Changes in stocks
Metals and metal products	Mining: Crude oil		Rest of world

Appendix B:

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 incomes 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.

Thurlow et al. (2018) 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 Thurlow et al. (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 is 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.

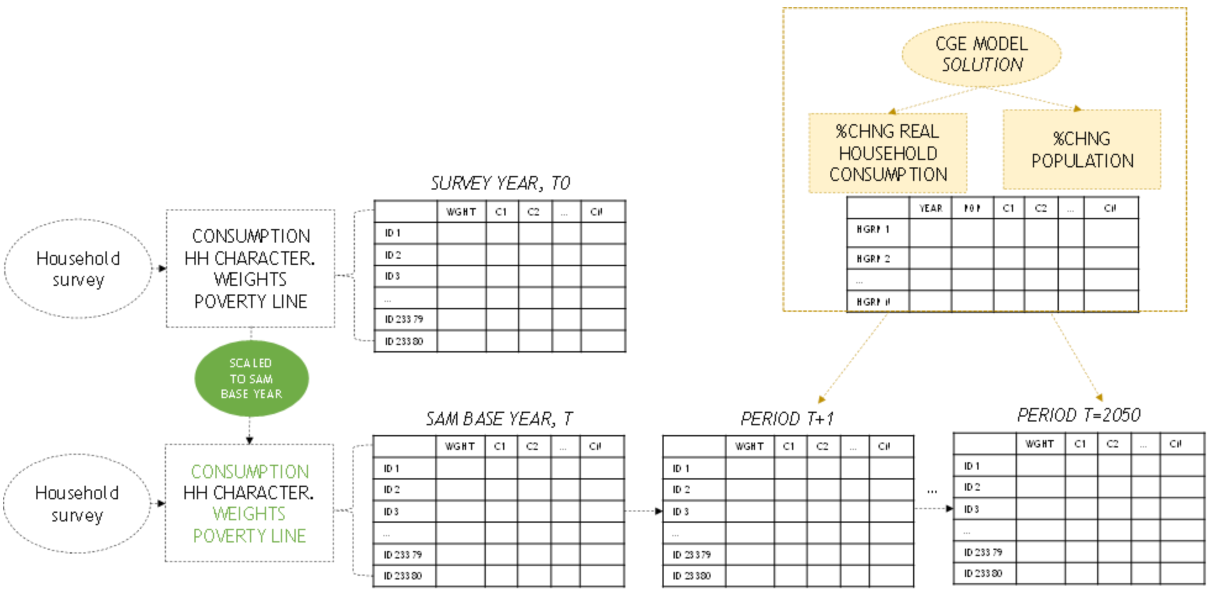

Figure 3.1: Microsimulation Module