GREEN JOBS ASSESSMENT MODEL GHANA

[The social and employment impacts of Ghana's climate and green energy policies]

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0 Executive Summary

In a developing country context such as Ghana, the prime goal of government policy is to foster broad based economic and social development. However, as Climate Change poses an ever-increasing threat to economic and social development, climate and green policy is becoming part of the development objectives. In fact, climate and green policy may even fast track economic and social development and employment creation, while reducing the emission intensity of economic growth.

This study sets out to ascertain the social and employment impacts of Ghana's climate and green policies captured in the updated National Determined Contributions and the National Energy Transition Framework. Compared to a business-as-usual growth scenario, an alternative development path - in which climate and green policies are implemented - is analysed. The alternative climate and green policy scenario demonstrate positive development impacts in terms of economic growth and employment creation while GHG emissions are reduced. It turns out that the climate and green policies are a win-win for social and economic development.

A limited number of three green and climate policies are analysed. Notably, a Solar PV, Biofuels and Cooling Efficiency Policy Scenario. In all three scenarios value-added, GDP and total employment rise over baseline levels up to 2030. A total of close to 100,000 additional jobs may be created by the three policies as compared to a business-as-usual growth scenario.

Interestingly, results indicate that in the green and climate policy scenario, job opportunities for females are higher than for men, close to 60,000 compared to 40,000 job opportunities. This is because in many of the growing industries especially in the retail trade, food and beverage services, manufacture of food products, and in agriculture are traditionally female dominated. Investments into solar PV and cooling appliances would especially expand to employ more females compared to the baseline.

A further disaggregation of employment results shows that new jobs under each green investment option favour people with primary or no education. That is, they offer mostly low-skill jobs and self-employment over the analysis period. This could be explained because of mass employment of low-skilled labour and self-employed in future solar-powered irrigation farming and retail trade. Only the investment into efficient cooling appliances yield significant new jobs for people with tertiary education. Thus, each of the policy scenarios tend to reduce unemployment while redistributing jobs to less skilled labour and the self-employed, opening opportunities for micro-enterprises and private sector growth.

All three climate policies would further reduce GHG emissions by up to 7% below baseline levels by 2030. Whereas there is a steep decline of emissions under the biofuel policy in the near term, the solar PV penetration and efficient cooling appliances investments exhibit a gentle decline up to 2030. The differences in rate of emissions abatement are a result of differences in the turnaround-time of investments into these green policies to have impact on emissions. The steeper the decline, the shorter the turnaround-time of investments.

In conclusion, apart from significantly reducing GHG emissions, all three climate and green policies also generate positive impacts on labour employment over the baseline. Favourable employment variation above the baseline is mostly attributed to direct employment creation in the electricity sub-sectors and induced and supply chain job creation in the agriculture, chemical and pharmaceutical industries, and retail trade. Most of the new jobs to be created would be for vulnerable, less-skilled and for female workers and the self-employed, redistributing jobs to the less privileged with the potential to reduce inequality, foster the creation of miro-enterprises and growth of green businesses.

It is important to highlight that the job and enterprise creation potential can only be realized if just transition policies are enacted which accompany the climate and green policies. Key to enable employment and enterprise creation are skills development, enterprise development and vocational education and training policies. In respect to ensure employment relocation in declining sectors, reskilling, entrepreneurship and social protection measures are of utmost importance. This is required to build the necessary human capital and ensure a frictionless transition is just for all.

In respect to the three analysed policy scenarios, it is important to highlight that deliberate policies towards local manufacturing and value-addition would further elevate the impacts on growth and employment. This is because the current scenarios assume a 100% import share of green technologies, which is a drag on the trade balance and lost opportunity for value addition in country. Deliberate policies to alter the outcome could take the form of industrial policies to incentivize local manufacturers while requiring local content. This would further boost manufacturing jobs and employment creation in supplying and servicing industries.

Finally, it may be inferred that more ambitious climate policies, including in other key sectors of the economy, such as tourism, climate smart agriculture, afforestation and reforestation, would further create job opportunities. In fact, as green and climate policies tend to accelerate positive development across economic sectors, they could become an integral part of Ghana's social and economic development policies.

1 Background

Over the last decades, Ghana has shown tremendous concern over climate change and the protection of the environment from pollution and degradation. As a party to the Paris Agreement on Climate Change, Ghana developed and implemented its Nationally Determined Contributions (GH-NDCs) from 2016 and revised it in 2020. The revised Ghana National Determined Contribution 2020-2030 is hinged on 19 policy options with the objectives of protecting the environment from emissions and pollution as well as to create over one million decent and green jobs.

Estimates from the International Labour Organisation (ILO) and other actors have shown that the emerging green and circular economy presents opportunities for the creation of millions of sustainable and decent jobs. Government is therefore required to institute the necessary mechanisms to ensure that decent job creation within the green and circular economy is maximized across the sectors.

In this regard, the Ministry of Employment and Labour Relations (MELR) in collaboration with partners developed the National Green Jobs Strategy in 2021 and initiated the establishment of an Inter-Sectoral Green Jobs Coordinating Platform to facilitate the coordination of intervention across the sectors for maximized job creation. The National Green Jobs Inter-Sectoral Technical Working Group initiated to undertake a Green Jobs Assessment, to assess green jobs potentials in various sectors of the Ghanaian economy, establish a baseline on green job and green enterprises in Ghana and generate a baseline on green jobs requirements for implementing the revised GH-NDCs. This assessment is carried out using the Green Jobs Assessment Model (GJAM) developed by the ILO to measure how green and climate policies affect job creation, income distribution, and economic growth. More specifically, the GJAM will support evidence-based climate and green policymaking to ensure a Just Transition.

The outcomes of the assessment, and its connected multi-stakeholders dialogue process at country level, will guide evidence-based implementation of National Green Jobs Strategy objectives by providing a baseline on green jobs and green enterprises in Ghana, and assessing the green jobs potential in various sectors in Ghana, to reflect employment and just transition objectives in relevant National Instruments, including the Medium-Term National Development Framework. It will also generate a baseline on green jobs requirements for implementing the revised GH-NDCs.

2 Current state of the Economy, Employment and Emissions

Ghana is a West African country located on the coasts of the Gulf of Guinea and the Atlantic Ocean to the south, Côte d'Ivoire in the west, Burkina Faso in the north, and Togo in the east. Ghana covers an area of 238,535 kilometre square (92,099 square miles), with 30.8 million population (GSS, 2021), the second-most populous country in West Africa, after Nigeria. Ghana has been a rising growth star and a beacon of hope in West Africa, posing strong economic growth over the past two decades, which led to a near doubling of GDP (Gross Domestic Product) per capita, thereby propelling it to a lower middle-income status in 2011 (World Bank, 2021) . Ghana's poverty rates more than halved between 1998 and 2016, and the extreme poverty rate declined from 36.0 percent in 1991 to 8.2 percent in 2016 and grew per capita GDP by an average of 3 percent per year over the past two decades, putting her in the top ten fastest growing countries in Sub-Saharan Africa (SSA).

2.1 Economic Performance

Ghana's rapid growth run (7 percent per year, 2017-2019) took a downturn due to COVID-19 lockdown in March 2020 and its subsequent containment measures. This shock led to a drastic fall in government revenue and expenditure overshoot, and an eventual economic contraction to 0.1 percent average growth by the end of 2020 (GSS 2021). Poverty rate is estimated to have slightly increased from 25 percent in 2019 to 25.5 percent in 2020. Growth, nevertheless, rebounded to 5.4 percent in 2021 by virtue of the dynamic agriculture and services sectors. However, the rebound was short-lived because of soaring global commodity prices, occasioned by the Russian-Ukraine war coupled with the rapid depreciation of the Ghanaian cedi as well as rising public debts by first quarter of 2022.

By the end of the first quarter of 2022, the economy witnessed a significant slowdown in non-oil growth (from 5.3 to 3.7 percent), indicating a decrease in growth rates in agriculture and services sectors than previously recorded in 2021.

Fiscal pressures mounted high and headline inflation had accelerated to a record high of 40.4 percent in October 2022, above the end-period target of 28.5 percent . Additionally, Ghana's overall budget deficit rose to 7.0% of GDP against a programmed deficit target of 6.2% of GDP as of September 2022. Most importantly, at the end of November 2022, the Ghanaian Cedi had lost cumulatively 54.2 percent of its value against the US dollar since the beginning of 2022 compared to the 7 percent average annual depreciation of the cedi between 2017 and 2021. The International Monetary Fund (IMF) projects public debt-to-GDP ratio to reach 90.7 percent by end of 2022.

Given the growing macroeconomic imbalances, in July 2022, the country was classified to be of high debt distress and the government of Ghana began discussions with the IMF on a possible debt-relief programme. Consequently, a number of aggressive economic measures were announced in the 2023 Budget Statement and Economic Policy, with the aim of restoring macro-economic stability and accelerating economic transformation. These include, inter alia, strong support to the production of strategic substitutes and expansion of productive capacity in the real sector of the economy; the encouragement of active consumption of locally produced goods and services; the promotion of exports; aggressive mobilisation of domestic revenue; and expenditure rationalisation (GoG, 2022).

Ghana's economic growth outlook like other Emerging Markets and Developing Economies is expected to deteriorate further in 2023. It is estimated that Sub-Saharan Africa will experience a slowdown in growth to 3.6 percent in 2022 and 3.7 percent in 2023, from 4.7 percent in 2021 due to low investment and a worsening trade balance (IMF, 2023) . Such adverse developments ever recorded in recent history are expected to trickle down to affect food and energy prices, thus impacting the continent's most vulnerable.

2.2 Employment by industry (development over time if data available) (written by local consultant, supported by international consultant)

Employment permeates every public policy Ghana has pursued, especially since the beginning of the millennium. Ghana's huge youth bulge, like in many other African countries, presents enormous opportunities to propel growth with new and energetic millennials. Unfortunately, the

[1] *World Bank. 2021. Ghana Rising: Accelerating Economic Transformation and Creating Jobs. World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/36580 License: CC BY 3.0 IGO.*

[2] Government of Ghana, 2022. The Budget Statement and Economic Policy of the Government of Ghana for the 2023 Financial Year. Ministry of Finance, Accra, Ghana. Retrieved from: https://mofep.gov.gh/sites/default/files/budget-statements/2023-Budget-Statement_v4.pdf

rising unemployment rates among the youth continue to pose serious threats to economic and social stability. As shown in Figure 1, employment among Ghana's labour force (15 years and older) has declined over the last two decades (2000-2022). Employment in agriculture has declined drastically; reduced to about 14 percent as of 2021. Employment in industry, however, has risen, although slowly until between 2019-2021, whereas services sector employment increased steadily from about 31 percent in 2000 to more than half of the labour force (53 %) in 2021.

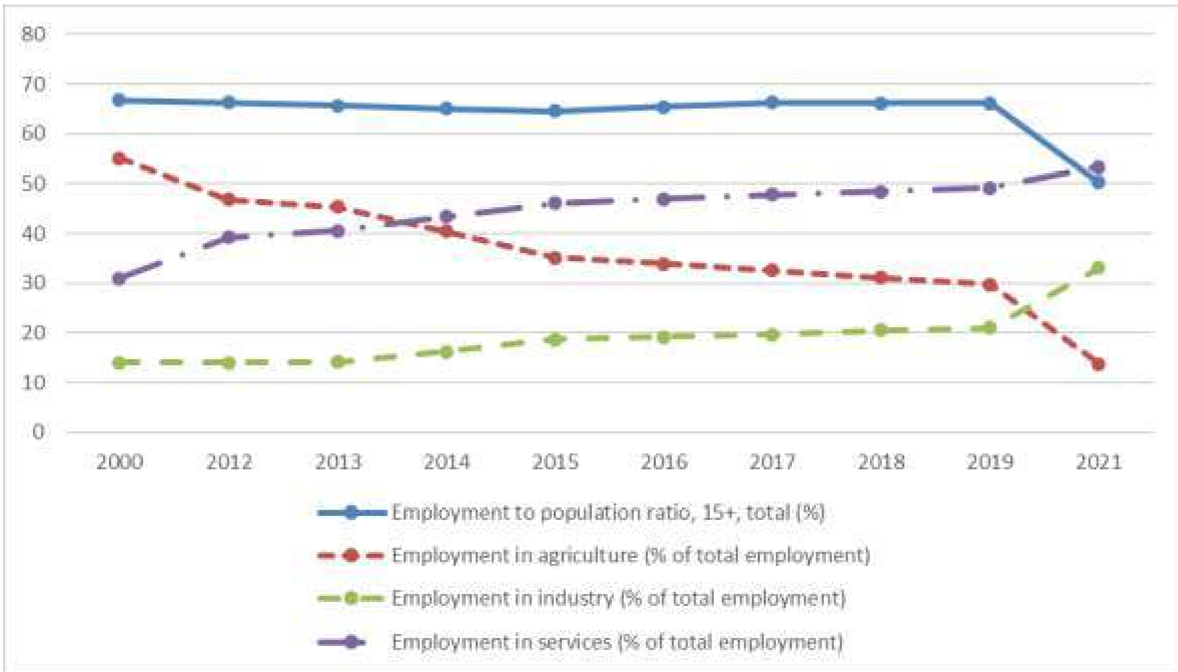

Figure 1: Employment trends in Ghana
Source: World Bank, WDI; Ghana Statistical Service (2022)

2.3 GHG emissions by industry

Ghana as a party to the 2015 Paris Agreement has made a solemn commitment to reduce its carbon footprint in production and consumption systems, in keeping with the global pledge to keep global temperature well below 1.5oC by 2050. Table 1 encapsulates the country’s GHG emissions sources relative to total global emissions of about 33billion tonnes . Despite the country's low emissions, its carbon footprint is increasing from the various emission sources. For instance, national emissions with LULUCF rose by 16.3 percent between 2016 and 2019, while it increased by 139.2 percent since 1990. The observed changes in emissions trend are attributable to the country's heavy reliance on the production, processing, and use of commodities such as hydrocarbons, precious minerals as well as deforestation driven by the use of fuelwood, charcoal and extensive agricultural practices . The most significant emissions are from the mineral and the energy industries, which grew by 5200 percent and 854.5 percent, respectively. Also, rapid urbanisation coupled with improper disposal of wastes has resulted in rising GHG emissions. If the trend is not checked, Ghana's business-as-usual (BAU) emission is expected to reach 73.3 MtCO2e by 2030 (United Nations Development Programme, 2020).

[3] International Monetary Fund (IMF) (2023). *Managing Exchange Rate Pressures in Sub-Saharan Africa—Adapting to New Realities.* In Regional Economic Outlook: Sub-Saharan Africa—The Big Funding Squeeze, Washington, DC, April

Table 1: Emission sources and trends

Sectors/ Categories	Total Emissions ($MtCO_2e$)					Percentage Change	
	1990	2000	2012	2016	2019	2016-2019	1990-2019
National Emissions with LULUCF	**25.0**	**26.2**	**42.6**	**51.4**	**59.8**	**16.3**	**139.2**
National Emissions without LULUCF	**10.7**	**12.8**	**29.1**	**38.0**	**45.3**	**19.2**	**323.4**
Energy	**2.86**	**4.07**	**14.9**	**22.4**	**27.3**	**21.9**	**854.5**
Stationery combustion)	1.2	1.7	6.1	7.6	10.0	31.6	733.3
Transport (Mobile combustion)	1.7	2.3	7.5	6.3	9.2	46	441.2
Oil and Natural Gas (Fugitive emission from fuels)	-	-	1.3	8.4	8.1	-3.6	-
Industrial Processes and Product Use	**1.96**	**0.90**	**2.01**	**1.68**	**1.73**	**3.0**	**-15**
Mineral Industry	0.01	0.04	0.52	0.35	0.53	51.4	5200
Metal Industry	1.95	0.86	0.73	0.75	0.60	-20	-69.2
Non-Energy Products from Fuels and Solvent Use	-	0.0	0.0	0.0	0.0	-1.3	-
Product Uses as Substitutes for ODS	-	-	0.75	0.58	0.59	1.7	-
Agriculture, Forestry, and Other Land Use	**19.0**	**19.53**	**22.6**	**23.73**	**26.64**	**12.3**	**40.2**
Livestock	1.94	2.37	3.28	3.93	4.44	13.0%	128.9
Land	14.3	13.3	13.52	13.37	14.52	8.6	1.5
Aggregate sources and Non-CO_2 emissions sources on land	2.75	3.85	5.80	6.43	7.68	19.4	179.3
Waste	**1.1**	**1.6**	**3.1**	**3.6**	**4.1**	**14**	**265.1**
Solid Waste Disposal	0.31	0.57	1.18	1.38	1.57	13.8	406.5
Biological Treatment of Solid Waste	0.10	0.07	0.07	0.10	0.09	-10	-10
Incineration and Open Burning of Waste	0.03	0.04	0.08	0.09	0.17	88.9	466.7
Wastewater Treatment and Discharge	0.69	0.97	1.78	2.06	2.29	11.2	231.9

Source: Ghana Environmental Protection Agency (2022)

[4] IEA (2020), Global Energy Review 2019, IEA, Paris https://www.iea.org/reports/global-energy-review-2019, License: CC BY 4.0

[5] United Nations Development Programme (2020). Engaging private sector in NDC implementation - Assessment of private sector investment potential in the energy sector - Ghana, UNDP, New York

3 Method and data

3.1 Existing economic scenario models in Ghana

Economic models are powerful tools that are essential in providing real-world analysis of complex economic systems at the sub-national, national, regional, and global levels. Deployed by state and non-state actors for performing policy scenarios and economic forecasting, they provide simplified reality to comprehend economic principles and guide policies. Models for scenario building are mostly based on input-output/social accounting matrix and computable general equilibrium (CGE) models, whereas economic forecasting models often based on vector autoregressive (VAR) and cointegration models. Currently, existing macro models used in Ghanaian state agencies are based on VAR and cointegration purposely for economic and financial forecasting (Economic Commission for Africa, 2020) . Examples include the Quarterly Projection Model (QPM) which underlies the Bank of Ghana Forecasting and Policy Analysis System (FPAS). Another example is the Ghana Macroeconomic Model (GMM) hosted by the National Development Planning Commission (NDPC) used for forecasting medium-to-long-term national development policies. The country does not maintain IO/SAM based models like the GJAM of the Green Jobs Assessment Institutions Network (GAIN) network. The GAIN approach provides for a macro-econometric structural simulation model which allows for a What-if analysis of policy scenarios for a given macroeconomic structure in lieu of economic forecasting as pertains to the VAR and cointegration models.

3.2 Using supply-and-use tables for policy analysis

Policies have effects throughout the economy. A climate or energy policy that affects one industry directly – for example, coal power plants – causes ripple effects throughout the economy. The decrease in the demand of coal will impact the demand for products from the coal mining industry. The decrease in the demand for coal will also affect the demand for machinery and financial services related to coal mining. The reduced demand in machinery will, in turn, affect the demand for metals and components, which will affect the demand for iron ore. The substitution of the coal power plants for solar energy for production of electricity will lead to an increase the demand for photovoltaic panels and for electric inverters. Those will then increase the demand for electronic components, for products from copper mining and refining, and other industries that provide goods and services for these new products. The direct effects of the policies – decrease of coal electricity, increase of solar electricity – will therefore have indirect economic effects on different industries due to the changes in the demand of goods and services from the industries directly affected - which will also impact their suppliers, and the suppliers of their suppliers, and so on.

The increase or decrease of economic activity will impact jobs. With any policy, there will be industries which will increase their economic output and therefore increase the demand for workers, but there will also be industries that will have a decrease in their economic output, leading to job losses. Assessing the positive and negative impacts of policies is, therefore, necessary to maximise the potential benefits and minimise potential negative economic, social, and environmental implications.

[6] Economic Commission for Africa (2020). Theoretical foundation for the macroeconomic model. United Nations Economic Commission for Africa; Addis Ababa, Ethiopia

[7] This section in based on the GJAM report for Turkey(Moana Simas et al., 2022)

GJAMs are built to quantify these ripple effects of climate policies and green structural change. GJAMs are macro-economic models based on IOTs or SUTs that integrate economic data with data on jobs and GHG emissions. The starting point are the economic SUTs, compiled by statistical offices. These tables give a picture of the total supply and the total use of goods and services in the economy, quantifying the transactions in products between industries, purchases by final consumers, and to and from international trade. Supply tables describe what industries produce and how much of each product is imported. It also includes the trade and transport margins and taxes less subsidies on products, which represent the difference between the production (basic) prices and the final consumer (purchase) prices. Use tables describe all products used by industries in the country, as well as products purchased by final consumers and exported, and gross value added (VA) generated by industries.

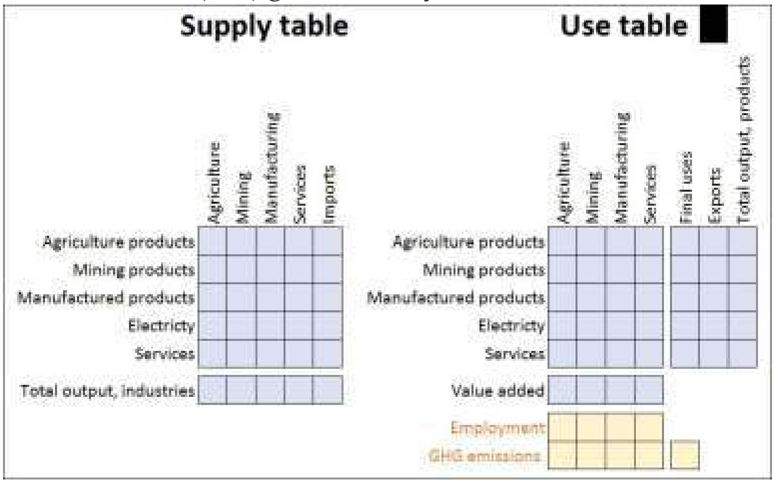

Figure 2 Simplified illustration of a supply table (left) and a use table (right), extended with employment and GHG emissions data per industry.

Models based on SUT can simulate the direct and indirect effects of different policies on the economic output of the different industries. Not only that, but supply-and-use and input-output tables can be linked with social and environmental indicators (called extensions) that describe direct impacts of each industry on workers and on the environment. A simplified supply-and-use table is illustrated in Figure 1. Note that we do not model inflation. The only price changes that can be modelled are those due to changing technology of production in the scenarios, which are reported in constant prices.

The Green Jobs Assessment Models (GJAMs) quantify impacts of policies on:

- The economy. Gross value added correspond to the GDP by industry, giving insights on the effects of climate policies to national GDP growth, and on the growth or decrease of each industry's economic activity
- Greenhouse gas emissions. Besides direct changes due to, for example, decrease of coal electricity, it also considers the net changes in emissions including increased emissions from infrastructure investments, and from increased or decreased economic activities in other industries.
- Employment. The model gives insights of the potential increase or decrease of the demand for workers in different industries. By including information on the structure of workers in each industry – per gender, skill level, and formality status – it can measure how the

demand for skills will change in the economy, and how it can affect workers in disadvantaged groups.

It is important to note that GJAMs are not economic forecasting models. Rather, these models are a tool to inform about possible effects of "what-if" scenarios on emissions and labour demand by industries, given that the remaining structure of the economy remains as is. The results show how changes in individual economic activities influence the economic structure and reflect on direct, indirect, and induced effects. A technical description of the model is available in section A.1 in the appendix.

How do Green Jobs Assessment Models work?

Green Jobs Assessment Models are built to answer one main question: How do climate and other green policies affect employment and the labour market?

Here is how it works:

First, policies questions are translated into scenarios, describing these policies in values such as:

- Which are the industries directly affected? For example, electricity generation industries when shifting from coal to solar and wind electricity
- How fast and by how much do green industries grow? For example, how does the electricity mix changes year by year, by increasing green electricity and decreasing in coal shares?
- What are the investments needed for this transition? Investments include, for example, goods, services, research, and training.

Next, these scenarios are implemented in the model:

- A baseline scenario for economic growth is built using macro-econometric parameters for economic and population growth
- New green industries are added to the supply-and-use table
- Annual changes in the market shares of green and traditional industries supplying products according to green industries' growth
- Annual investments in green industries distributed in products as additional investments to the economy or replacing investments in traditional (such as coal) industries.

Finally, the model quantifies direct impacts on the industries affected, and how these changes affect the demand for goods and services from other industries (and how increase or decrease of economic output from these other industries affect the demand from other industries, and so on).

The results of the GJAM model, then, comprise all (direct and indirect) impacts of the modelled policies on the economic output of every industry in the national economy, and how these affect employment and greenhouse gas emissions in each industry. In turn, induced effects are also quantified. For example, as workers lose or gain income, their increased or decreased spending on final goods and services has economic, employment and emission effects in those industries. Those effects are called induced effects.

3.3 Data used for the Green Jobs Assessment Model

This section describes the data sources needed to develop the GJAM:

- Supply-and-use table for the most recent year available, here 2013 updated to 2017
- Macro-economic time series
- Labour data
- Greenhouse gas emissions
- Data for splitting electricity industry

Supply-and-use table for the most recent year available

In this report, we used the most recent SUT available from Ghana Statistical Service (2021) , which describes the economy in 2013 for 101 products and 90 industries, and updated the SUT to 2017, based on macro-economic data also available from Ghana Statistical Service (2021) (see Table 4 and Table 5 in the appendix for the full industry and product detail). It is important to mention that the authors obtained a highly disaggregated (101 products from 90 industries) SUT from the Ghana Statistical Service (GSS) than the publicly available SUT (20 products from 20 industries), which is published on its website. The base year for the analysis in this report is the same year as the updated SUT, that is 2017, and all economic growth is estimated based on constant-2017-prices. The method and data used for estimating the estimating SUT are detailed in section A.2.1 in the appendix.

Macro-economic time series

The model considers the past and current state of the economy as described by data from the System of National Accounts (UNSD, 2022), that is the macro-economic values for final household and government consumption expenditure, gross fixed capital formation, imports, and exports, as well as value added with as much industry and component (e.g., net taxes on production, compensation of employees, net operating surplus) as possible. The SUT should adhere to these macro-economic key indicator values.

For the econometric estimations (if applicable), we use a historical time series of data from the UN System of National Accounts (UNSD, 2022). Please see Section A.1 for a detailed description of the econometric model. The estimated parameters together with exogenous information on the development of investments and exports from the IMF (IMF, 2022), and global economic (Guillemette & Turner, 2018) and population (UN, 2019) growth, are the main parameters defining the baseline scenario pathway. For more information the reader is referred to Section 4.1.

Labour data

[8] Ghana Statistical Service (2021). Supply and Use Tables for 2013. Ghana Statistical Service; Accra: Ghana. Accessible online at https://statsghana.gov.gh/nationalaccount_macros.php?Stats=Mjc5NzQ5MDU1OS45MDk=/webstats/5r4pq59s09

[9] Ghana Statistical Service (2021). Supply and Use Tables for 2013. Ghana Statistical Service; Accra: Ghana. Accessible online at https://statsghana.gov.gh/nationalaccount_macros.php?Stats=Mjc5NzQ5MDU1OS45MDk=/webstats/5r4pq59s09

[10] Environmental Protection Agency (2019). Ghana's Fourth National Greenhouse Gas Inventory Report. EPA, Accra. Available online at https://unfccc.int/sites/default/files/resource/gh_nir4-1.pdf

The labour data used comprise Ghana Living Standard Survey 2017 (GLSS 7) data from the GSS processed and harmonized by the Institute of Statistical, Social and Economic Research (ISSER). It is available in the same industry classification as the SUT but a different year from that of the SUT. It contains extensive details of indicators of labour force composition, employment by gender, residential location, education level and employment status. The employment indicators available are presented in Table 11 in the appendix.

Greenhouse gas emissions

The GHG emissions data used are the official Greenhouse Gas Inventory for the year 2016 (EPA, 2019) . The GHG inventory provides information on emissions of CO2, CH4 and N2O (including HFCs, PGCs and SF6) according to broad and detailed activities described in the IPCC guidelines (IPCC, 2006) for GHG inventories. However, the IPCC sector classification does not match the SUT ISIC classification so that a reallocation of the emissions to the SUT industries is necessary using a concordance table.

Data for splitting electricity industry

Modelling the effect of the growth of green electricity requires the split of the original electricity generation industry into wind electricity, solar electricity, and the remaining electricity generation technologies. For this, data on the use of inputs to produce electricity (Castillo-Ramírez et al., 2017; Committee on Climate Change, 2011; MacDonald, 2011) (here we focus on the operation of the power plants, not counting construction and investments, those are part of the scenario calculations) from wind and solar is used to estimate the industry structure of the green electricity in the use table, and the split of the supply of electricity in the supply table obeys the share of wind and solar electricity in the total electricity generation in the base year 2017. These shares come from the Energy Commission (2018) , , which describes the electricity production from each source. Table 2 shows the share of electricity by source for 2017, and the allocation to the split electricity industries in the model. In addition, the shares of output from the new electricity industries were corrected for the share of electricity supply from the original " Electricity, gas, steam and air conditioning supply". Based on the estimates of final consumption of energy by source from the International Energy Agency (Ghana - Countries & Regions - IEA, n.d.), electricity was estimated to represent 97.5% of the output of the industry for 2017.

[11] Energy Commission (2022). 2022 Energy Statistics. Energy Commission; Accra: Ghana. Available online at https://www.energycom.gov.gh/files/2022%20Energy%20Statistics.pdf

[12] Energy Commission, et al (2017). Electricity Supply Plan for the Ghana Power System. Energy Commission; Accra: Ghana. Available online at https://www.energycom.gov.gh/files/2017%20Electricity%20Supply%20Plan%20-%20Final%20Report.pdf

Table 2: Data for splitting electricity industry

	Original electricity generation industry, share in electricity production	Industry in the GJAM
Natural Gas	25.2%	Other electricity, gas, steam and air conditioning supply
Light Crude Oil	20.2%	
Heavy Fuel Oil/Diesel	17.6%	
Coal	0.5%	
Hydro	39.8%	Hydro electricity
Small hydro	0%	
Solar PV	0.2%	Solar PV electricity
Biogas	0.002%	Biogas electricity

4 Policy scenarios and scenario assumptions

4.1 Baseline development

The purpose of having this reference scenario is to have an economic development which can serve as a baseline to which the development in the green scenario can be compared. Here, we assume that the economy grows (as specified in the following paragraphs), but that the structure of the economy does not change. That is, industries are continuing to produce with the same production technology and the import shares of products remains stable.

In the reference scenario, we set the exogenous export growth rate to follow the trends from the UN SNA(UNSD, 2022) (green cells) and IMF WEO(IMF, 2022) (yellow cells) data, the values for 2021 and 2022 are used to calibrate the model to follow the observed GDP growth rate, as displayed in Table 2.

Table 3 Growth rates for exogenous variables 2018-2027

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Volume of exports of goods and services[1)]	3.3 %	6.4 %	-2.1 %	0.0 %	2.0 %	4.0 %	2.0 %	5.9 %	3.3 %	4.6 %

1) Note that we use UNSSNA data(UNSD, 2022) until 2020, and the IMF forecast(IMF, 2022) from 2023 to 2026. For 2021 and 2022 we set the growth rate to 0 for model stability. As the 2027 growth rate was set to 17%, we replaced it by the average of 2025 and 2026. From 2028 to 2035, we use the development of global GDP as described in the OECD LongView, but correct for the difference in 2027.

The other macro-economic demand side components are modelled as follows:

- Government consumption grows (exogenous to the model) as a function of population (econometrically estimated)
- Gross fixed capital formation (exogenous to the model for the current year) grows with the average GDP growth rate of the previous four years and investments into electricity generation capacity are given exogenously (see below for more information)
- Changes in inventories (exogenous to the model) decrease by 1% annually.

The product shares for these variables in the total are constant.

Household consumption is endogenous to the model, as is GDP (the sum over all industries' value added). The household consumption model utilises income elasticities from USDA international food comparison programme (Meade et al., 2014; Muhammad et al., 2015) for nine consumption categories, see Table 2. The change in household income for the consumption model is approximated by the change in GDP.

Table 4 Income elasticities for broad consumption categories for Ghana from the USDA international food comparison programme(Meade et al., 2014; Muhammad et al., 2015)

Food, beverages & tobacco	Clothing & footwear	Housing	House furnishing	Medical & health	Transport & communication	Recreation	Education	Other
0.799	0.968	1.076	1.055	1.795	1.221	3.022	0.931	1.817

The purpose of having this reference scenario is to have an economic development which can serve as a baseline to which the development in the green scenario can be compared. When interpreting the results, we will not look at the absolute values of the growth rates of GDP, emissions, and employment, but we will analyse the difference between the green scenarios and the baseline scenario. It is therefore not vital that national or international IMF forecasts are met for the model.

In this reference scenario we assume constant labour productivity (persons employed per unit industry output). To estimate the employment requirements, we thus multiply the (constant) number of per unit of industry output with the projected output by industry in monetary terms. The same procedure is used for GHG emissions. Note that the model (akin to other macro-economic models (Rosendahl et al., 2021)) does not include land use, land use change and forestry (LULUCF) emissions.

[13] Based on the description of the baseline scenario used for GJAM Turkey, but adapted to the model for Ghana.

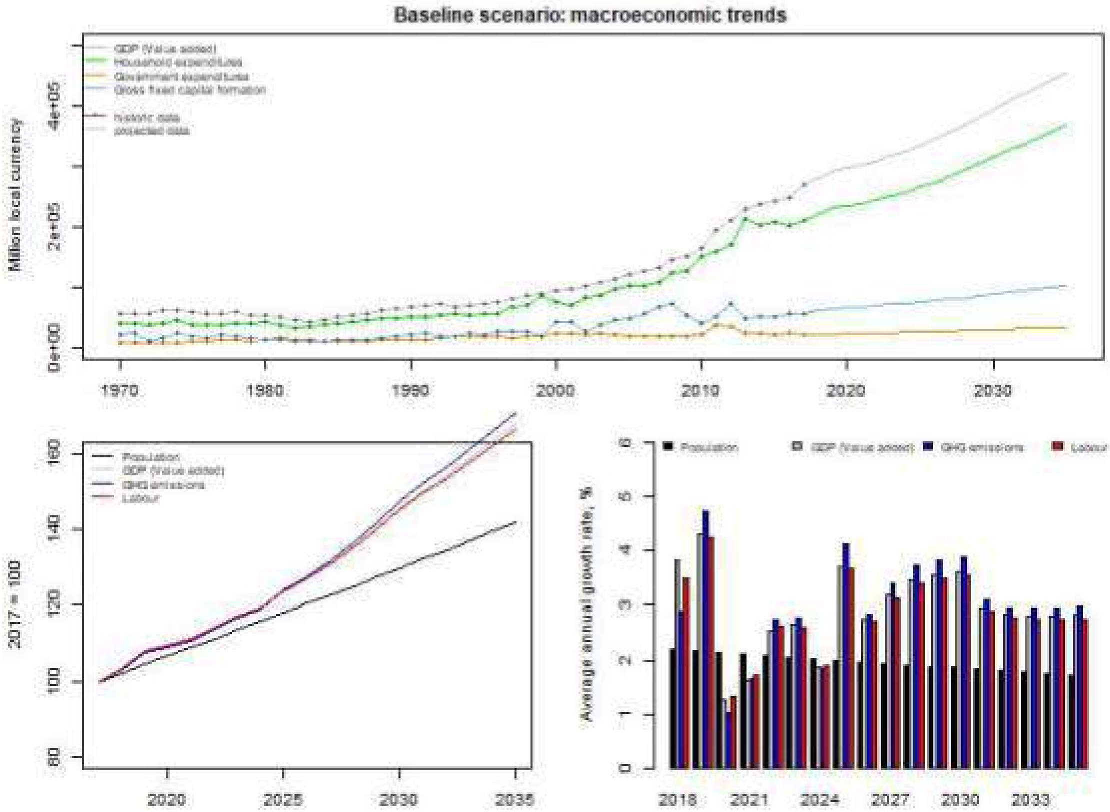

Figure 3 Macroeconomic trends as per GJAM Ghana for the Baseline scenario

4.2 Assumption and Expected Economic, Employment and Emission impacts of Solar PV scenario

Key reforms aimed at decarbonising Ghana's economy largely hinges on the energy sector as enshrined in the updated GH_NDCs ending 2030 and the energy sector's broader transition framework (i.e., National Energy Transition Framework) ending 2070. The energy sector is the most important GHG source with potentially huge mitigation effects on the overall national decarbonation goals by 2030. This is rightly so because by the end of 2019 the energy sector emissions had surpassed LULUCF emission sectors to become the highest emitter of greenhouse gases, when it was about 15 percent of GHG emissions from the LULUCF the highest GHG emitter some three decades ago (see, EPA, 2022). This change also reflects the high deforestation rate in the past and the small remaining forest cover which account for fewer and fewer emissions. Despite the declining emissions share, deforestation led to significant negative effects on agricultural productivity and high degraded land and soil quality.

Ghana's energy transition in the energy sector specially targets production and consumption reforms in the electricity and petroleum sub-sectors that result in less pollution to the environment.

One important of such reforms in the electricity sub-sector is to raise renewable energy penetration to a minimum of 10 percent grid-electricity by 2030. This policy scenario targets electricity generation through additional investments in solar PV, wind turbines, biogas and small hydro (i.e., less than 100MWh capacity) (see, Ghana Energy Commission, 2019).

However, the policy scenarios implemented in this analysis only take into account investment in solar PV to fill the gap in renewable electricity penetration by 2030 since large portion of Ghana's current renewable grid-electricity is from solar PVs and makes sense, experience-wise, to accelerate additional investments in utility scale solar PV plants till 2030. The scenario consists of two sets of assumptions, first, regarding the share of solar PV in electricity consumption (demand-side), and, second, regarding the necessary investment in increasing the solar PV capacity installed (supply-side).

It is important to mention that the Government of Ghana's has momentarily placed a moratorium on additional installed capacity in electricity generation in the electricity sub-sector which arose from the several power purchase agreements (PPAs) the government entered with Independent Power Producers (IPPs) between 2013-2015 in peak of the country's power generation crises. Thus, the analysis of additional investments in utility scale solar PV plants acknowledges that additional generation capacity is not needed due to the present excess capacity. That is, for renewable electricity penetration to increase of on-grid generation, production using other technologies need to be reduced to maintain the current installed capacity. To this end and as the first assumption for this analysis, the share of electricity production from natural gas (natural gas is expected to be the only fuel for thermal electricity generation over the transition period) is reduced from current share of 61.5% to 54%, while at the same time the share of Solar PV rises from about 2.5% to 10%.

Notwithstanding the constraints on additional generation capacity, gains from an additional solar PV investment could be enormous. In the first place, where grid interconnections allow the country could export displaced excess electricity from thermal sources to neighbouring West African countries for foreign currencies to boost its revenue and foreign reserves. Moreover, the surplus domestic gas available for electricity generation could be repurposed towards Ghana's industrialisation drive to provide energy for manufacturing in heavy industries, and as a feedstock to its petrochemical industry.

The second assumption under this scenario project installed capacity to increase from current (2021) 144 MW to 576 MW in 2030. We assume a linear increase with 54 additional MW per year. According to IEA, the capital/investment costs for utility scale solar PV in South Africa was 1321 USD/kW in 2019. We use an exchange rate of about 5 Ghana Cedi / USD from 2019, in contrast to the 2022 exchange rate of 12 Cedis to 1 USD. This yields an annual investment of 356 million Cedi per year for 2023 to 2030. Investing into solar PV plants leaves less budget among public and private investors to invest in other projects. We therefore calculate the scenario in which all investments in inputs but the investments in construction are reduced accordingly.

Another assumption, though implicit, in the foregoing analysis is 100% import share of solar PV panels. Although, an assembling plant for solar PV panels exists in the country, it does not have enough capacity to produce the required quantity of panels to for the realisation of the 10% renewable electricity generation target by 2030. An interesting additional future policy scenario and option is to look into an industrial policy to match the solar PV policy, which is likely to have significant employment and industrial growth impacts.

The impact of upscaling investment in utility scale solar PV is understood by measuring the deviation of GHG emissions, value-added and employment from 2022 -2030 compared to the baseline case (solid line preceding 2022 where no policy intervention is implemented) as shown in Figure 4. First, GHG emissions decline by nearly 3% relative to the baseline scenario by 2030, by replacing with electricity output from fossil fuels with clean electricity from solar PV in the electricity, gas, steam, and air conditioning supply industry.

Also, value-added GDP increases sharply by about 0.2% above the baseline GDP after the first year of investment in 2023 and continuous to increase marginally till 2030. Similarly, employment also increases above the baseline level and continues with marginal increases till 2030 before marginally declining in 2031 and flattens out afterwards. The rise in jobs as a result of solar PV investment could be attributed to new jobs in construction, installation, and related activities in the initial year. This new level of employment would be maintained till 2030. An additional solar PV industrial policy like local manufacturing and assembling of major components of the PV panels may be required by 2030 to keep employment gains in the long term.

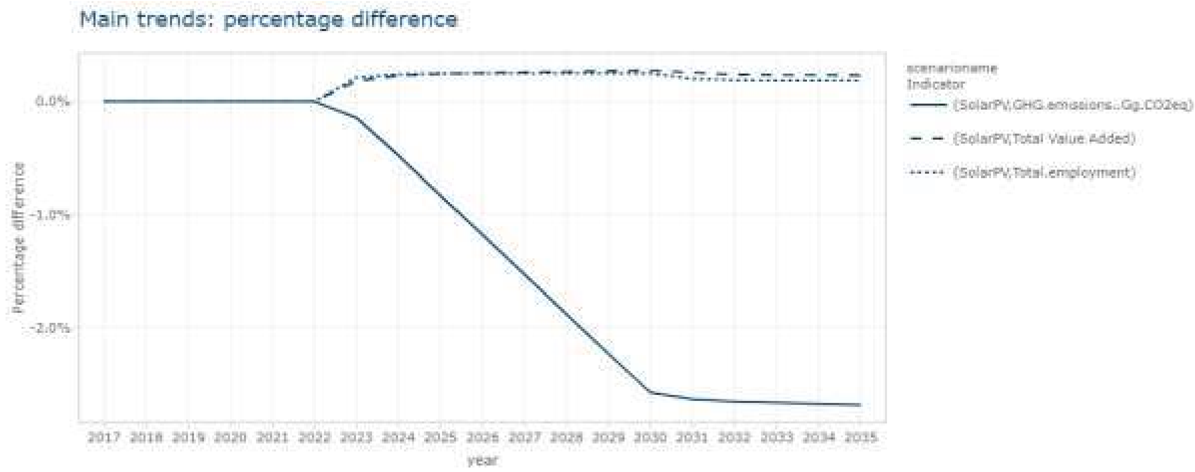

Figure 4: Trends of impacts of solar PV investment scenario

New jobs in the solar electricity sub-industry will rise to about 25% from baseline levels by 2025 as shown in Figure 5. Importantly, employment creation will happen across industries, notably in the rural areas where the PV systems are built. This will benefit employment creation in related sectors such as construction, wholesale, retail and transport where some 15,000 net jobs can be created. The boost to the rural economy would also promote growth in value addition and employment in agriculture, husbandry and food processing where some 20,000 jobs would be added. However, the scenario will also lead to a decline in jobs in other industries, significant among them being the fossil fuel-based electricity, gas, steam, and air conditioning industry. The cumulative employment gains in solar electricity and other significant industries over the baseline case will, nonetheless, outstrip cumulative job losses. Overall, solar PV investment will yield positive returns by significantly reducing GHG emissions, boost economic growth through value-addition to produce green electricity. Such investments will also generate net gains in employment by shifting labour from fossil-based activities in the electricity industry, and adding on new jobs.

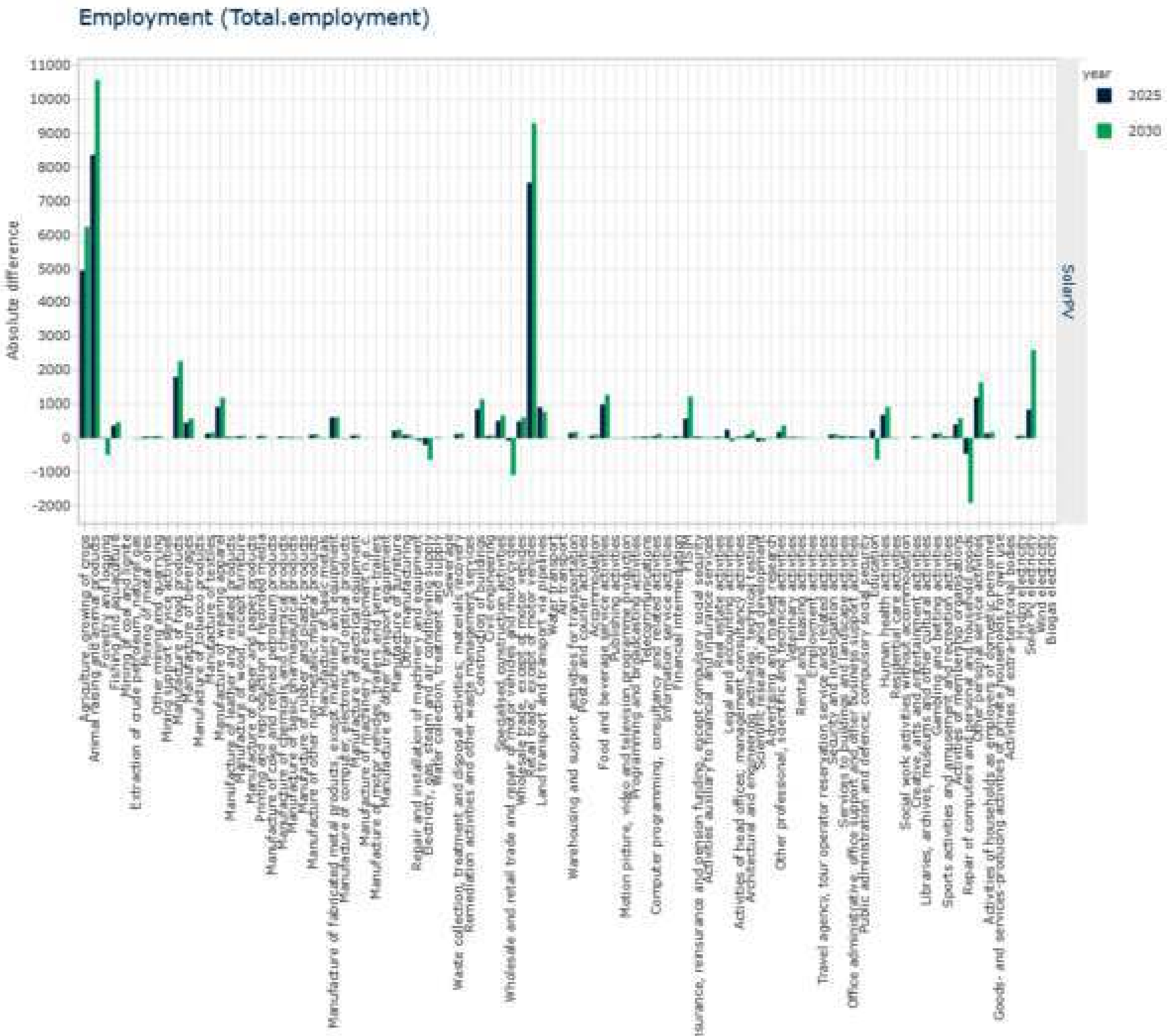

Figure 5: Impact of Solar PV scenario on total employment

4.3 Assumption and Expected Economic, Employment and Emission impacts of Biofuel/Ethanol scenario

In pursuant of a low-carbon development trajectory per the country's energy transition framework (MoE, 2022) , seeks to introduce alcohol (ethanol) blend into the major petroleum products (gasoline and diesel). The target is to reach 10% ethanol blend in gasoline (E10) and diesel (B10) by 2030 and completely phase-out off-road fossil-fuelled internal combustion engines (ICEs) 10 years later.

This is not new in Ghana's policy space. In her Strategic National Energy Plan 2006-2020, Ghana sought to achieve 10% penetration of liquid fuels by ethanol and biodiesel fuel complementation by 2015 and expanding to 20% by 2020. Also, the Energy Sector Strategy and Development Plan (2010) sought to support development of biofuels as a transportation fuel as well as job creation initiative by creating appropriate financial and tax incentives. Furthermore, the Renewable Energy Act, 2011 (Act 832), also sought to achieve the same. All these plans were, however, not achieved as initial attempts at commercial production of biodiesel from jatropha curcas plant were plagued by land litigations among others. Hence, going forward, the Government of Ghana has resolved to achieve the E10/B10 targets wholly through ethanol penetration.

Investment demand for ethanol is calculated using demand projections (kilo tons) for gasoline and diesel in the Strategic National Energy Plan 2021-2030 (see Table 5). In this strategic plan, total diesel and gasoline demand under the accelerated economic growth scenario are projected to be 8,111kt and 2,258kt, respectively. These translate into about 9,599 and 2,990 million litres of diesel and gasoline demand, respectively, by 2030. Therefore, 10% penetration of ethanol will yield 960 and 299 million litres of diesel and gasoline, respectively, and total production volume of 1,259 million litres by 2030.

Recent studies by Iddrisu and Bhattacharyya (2015) and Pelizan, Lickteig and Alavi (2019) on Ghana's ethanol potential from selected agricultural feedstocks including cassava, maize, sugarcane and palm oil concluded that cassava provides the best option for producing ethanol in Ghana, given the current level of production. Pelizan, Lickteig and Alavi (2019) estimated the cost of investment of ethanol to be between USD 0.5 – USD 1.28 per liter. Therefore, the total cost of investment to achieve E10 and B10 target is about USD 775 million (see Table 5). This amount is spread equally over three investment years (2022-2024).

Table 5: Demand and Investment cost projections for ethanol in Ghana

Ethanol Demand projections up to 2030				
	Demand under Accelerated Economic Growth scenario, 2030 (Kilo tons)	Number of Liters per metric ton	Million liters (ML)	Ethanol penetration at 10% (ML)
Diesel	8111	1183.43	9598.80073	960
Gasoline	2258	1324.5	2990.721	299
Total	10369	2508	12589.52173	1259
Investment cost				
Product	Capacity (Million liters/year)	Minimum cost USD mill (at US$0.54/litre)	Maximum cost in USD mill (at US$1.28/litre)	Average cost
Diesel	960	518.40	663.55	590.98
Gasoline	299	161.46	206.67	184.06
Total	1259	679.86	870.22	775.04

We assume full domestic production of ethanol to meet demand through to 2030 and, also, assume that the special-purpose machinery used in ethanol production are 100% imported (see Table 6), which consumes the largest share (20%) of the capital investment. The other input shares are shown in Table 6.

[14] Ministry of Energy (MoE), 2022. National Energy Transition Framework/Abridged – Ghana (2022-2070).

Table 6: Investment goods used for domestic production of ethanol

Investment goods	Import share	Share of investment
Rubber and plastics products		7.5%
Glass and glass products and other non-metallic products n.e.c.		5.0%
Fabricated metal products, except machinery and equipment		10.0%
General-purpose machinery		10.0%
Special-purpose machinery	100%	20.0%
Office, accounting and computing machinery		5.0%
Electrical machinery and apparatus		10.0%
Transport equipment		10.0%
Constructions		15.0%
Construction services		2.5%
Freight transport services		4.0%
FISIM		5.0%
Other financial service activities		5.0%

On-top of inducing clean air through less-pollution from diesel and gasoline combustion, the policy also has a potential for monetary savings through price differentials between original 100% fossil fuels and final 10% ethanol fuels. Using global prices (US$ per litre) of diesel and gasoline, the country stands to gain up to 5% reduction in prices of petroleum products, as shown in Table 7.

Table 7: Savings from 10% ethanol blend

Savings from Ethanol use						
	Price per litre (US$), 2022	**90% fossil fuel**	**10% ethanol**	**10% blend (E10/B10)**	**Savings**	**% Savings**
Diesel	1.59	1.431	0.111	1.542	0.048	3 %
Gasoline	1.321	1.1889	0.111	1.2999	0.0211	2 %
Ethanol	1.11					
Total savings						5%

The implications of this policy on the national economy are shown in Figure 6. Total GHG emissions (solid line preceding 2022) increase initially over the first year of investment, that is 2022-2023, and then fall steeply downward to about 7% below baseline emissions by 2026, and stabilizes thereafter. Most industries will record between 5%-10% drop in GHG emissions below baseline levels. Notable among them are the agricultural industries and the extraction of crude petroleum and natural gas.

Both GDP and labour employment increase marginally over the baseline scenario. The marginal rise in GDP and labour, however, ceases and flattens out beyond 2027.

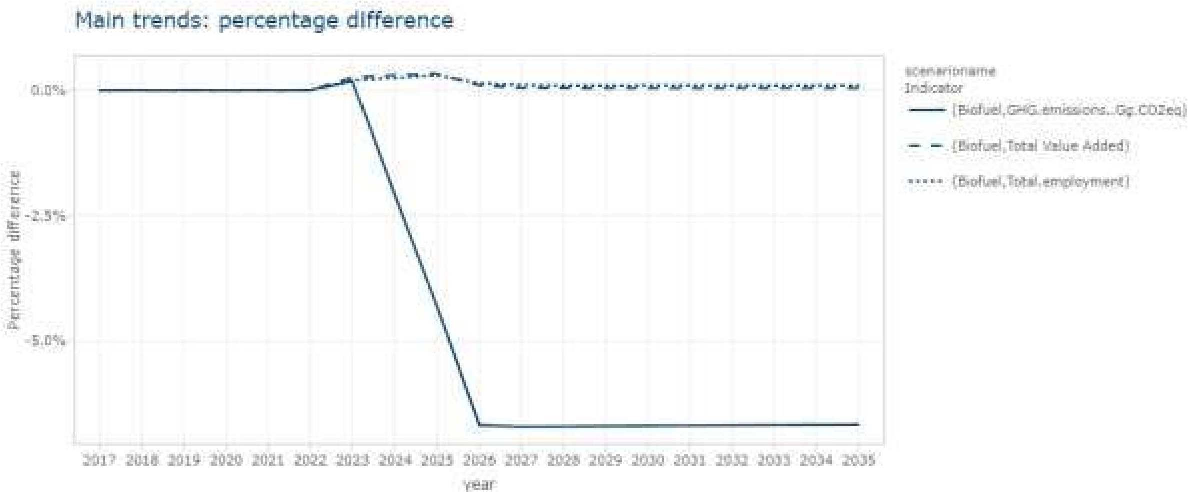

Figure 6: Impact of Biofuel scenario compared to baseline

Nonetheless, there are few other industries, especially chemicals, and pharmaceutical manufacturing industries whose GHG emissions would rise significantly above the baseline levels (7). The rising trend of emissions from these industries is not surprising because they are the resident industries to produce ethanol for the biofuel. Hence to minimize net emissions in the biofuel policy, there ought to be additional steps to reinforce energy efficiency within the chemical, and pharmaceutical industries to minimize and sequestrate carbon emissions in their production processes.

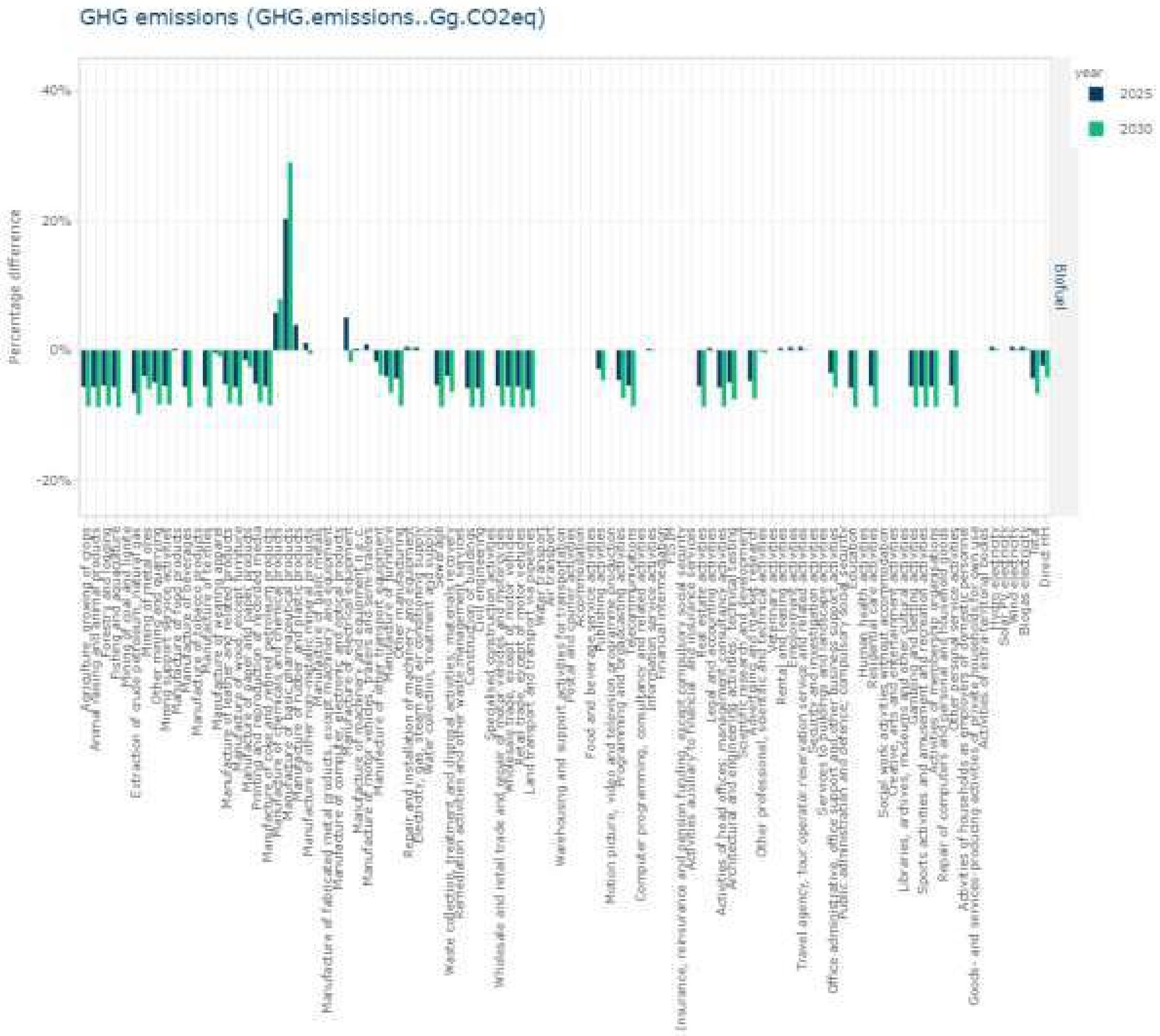

Figure 7: GHG emissions from industries in the Biofuel scenario

Labour and employment outcomes under the biofuel scenario decrease in the manufacture of coke and refining of petreleum products by nearly 5% and 10% by 2025 and 2030, respectively, as a result of the reduction in volumes of refined petroleum products (mainly gasoline and gasoil) that are replaced by ethanol. Nevertheless, the rise in labour employments in the chemical and basic pharmceutical manufacturing, in particular, cummulatively far exceeds job losses in the refined petroleum industry, orcherstrated by the blend with ethanol.

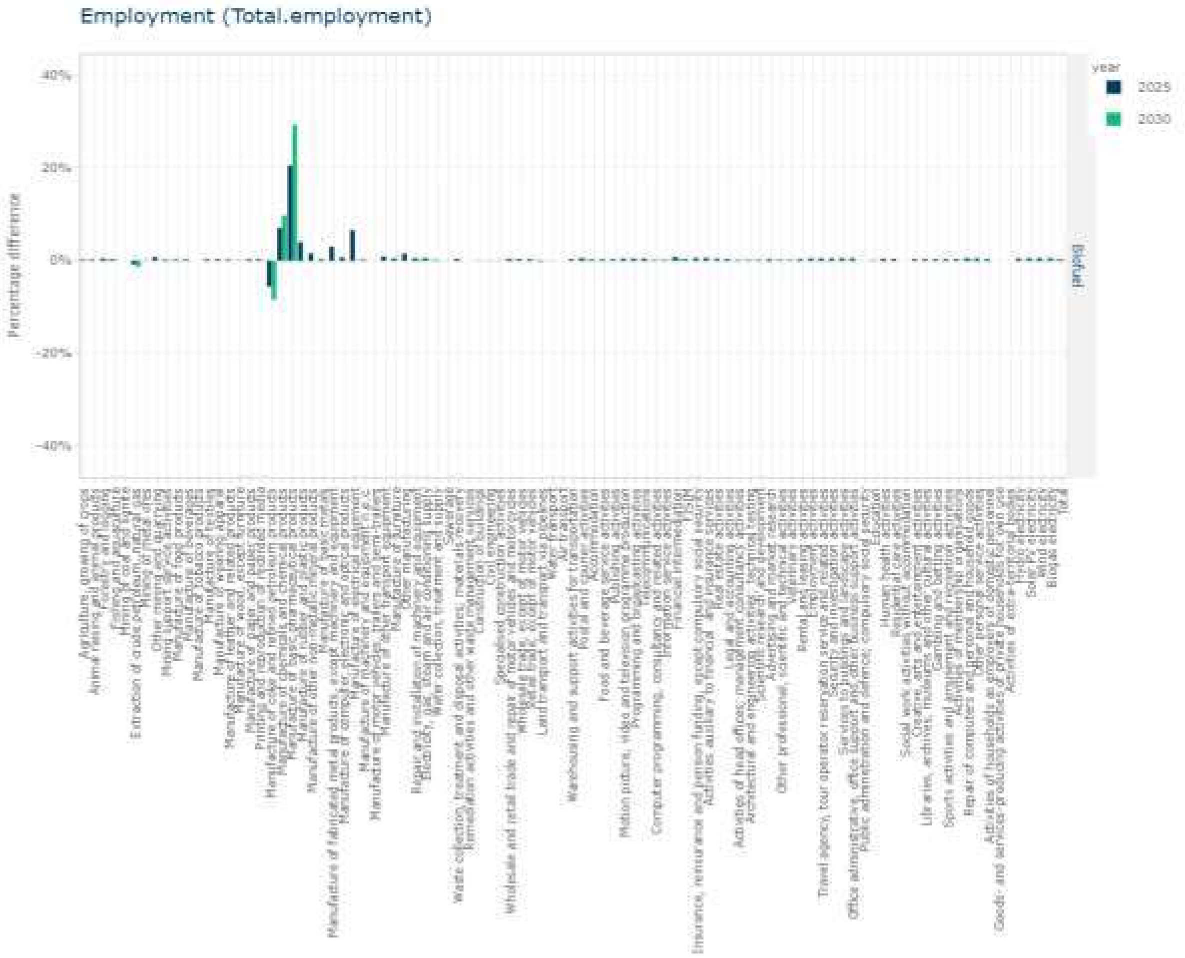

Figure 8: Labour employment difference of Biofuel to baseline in %

4.4 Assumption and Expected Economic, Employment and Emission impacts of Cooling efficiency scenario

Energy consumption efficiency is at the core of global emissions control. In Ghana, efficiency in electricity consumption occupies a prominent position in Ghana's updated GH-NDC and the National Energy Transition Framework. The residential sector in Ghana accounts for 47% of the total final energy consumption. Used and inefficient cooling appliances (refrigerators/freezers and air conditioners) have been identified as electricity intensive appliances in the residential sector. Whilst refrigerators/freezers consume between 25% - 30% of the total electricity in the residential sector, air conditioners account for 6.5%. The used and inefficient refrigerators and air conditioners consume, on average, 1,200 kWh and 4,200 kWh per unit per year respectively.

The potential of cooling appliances (refrigerators and air conditioners) towards significant energy efficiency improvements, have often been targets for regulation in the residential sector. Hence, Ghana's policy to achieve more than 60% of best-in-class cooling appliances and systems. The scenario analysis set forth in this regard considers achieving the set target by replacing old and inefficient refrigerators/freezers and air conditioners in the residential sector since about

85% of these cooling systems are used by households. A study by the Centre for Energy, Environment, and Sustainable Development (CEESD) (2020) for the Ghana Energy Commission estimates the total number of old and second-hand refrigerators at 1.79 million units countrywide as of 2019 and puts the total cost of replacement at US$ 600 while the cost of replacing Air conditioners is estimated at US$ 46

Thus, a total investment cost of US$ 646 is needed to achieve 100% replacement of refrigerators and ACs (cooling appliances), for the best-in-class Ghana national energy transition framework projects at least 60% cooling appliances to be in the best-in-class by 2030 and 98% by 2070. It is also assumed that 30% additional cost (the most likely situation) for installation of new cooling appliances. This is broken down in Table 8.

Table 8: Distribution of cost of installing new cooling appliances

Electrical machinery and apparatus	10%
Construction services	15%
Freight transport services	4%
FISIM	1%

We, however, estimate 65% (5% more than the threshold) replacement of all sub-standard fridges and ACs by the end of 2030. Hence, 65% of the total investment cost is spread across the 7 years from 2023.

We estimate 5% of the total investment cost to be made in each of the first 3 years (2023 -2025). This is due to the assumption that Ghana will be under strict IMF debt relief programme for the next 3 years, hence investment is projected to be low. We estimate 10% of investment to be made in 2026 -2027 as Ghana exits the IMF programme, investment will pick up but slowly. Finally, in 2028-2029 we estimate 15% of the total investment. This marks the time the country expects to bounce back to the once buoyant economy pre-COVID-19.

The study by CEESD (2020) also estimates 50% savings in the electricity consumption for households if all investments are made. However, because we estimate to achieve 65% by 2030, the savings in electricity consumption is estimated to be 32.5% (i.e., 65% of 50% savings). The savings in succeeding years of investments are therefore computed as a share of committed investments per year.

As presented in Figure 9, there is a stepwise decline in GHG emissions below baseline levels in accordance with investment patterns discussed in preceding paragraphs. That is, GHG emissions decelerate as investments into efficient cooling appliances increase. Cumulatively, emissions dip close to 2% below baseline emissions by 2030. Value-added GDP, on the other hand, is not significantly impacted until 2030 and beyond. This could be due to overdependence on imports of cooling appliances with little to no local value addition. Although total employment would be gently rising over baseline levels until 2030, high cost of imports and general lack of local content promotion including manufacturing or assembling of cooling appliances would diminish the impacts on overall GDP growth. Hence, with necessary industrial policy to promote local value addition in efficient cooling appliances, the country is likely to experience significant economic and employment growth, notably in the manufacturing and supplying industries.

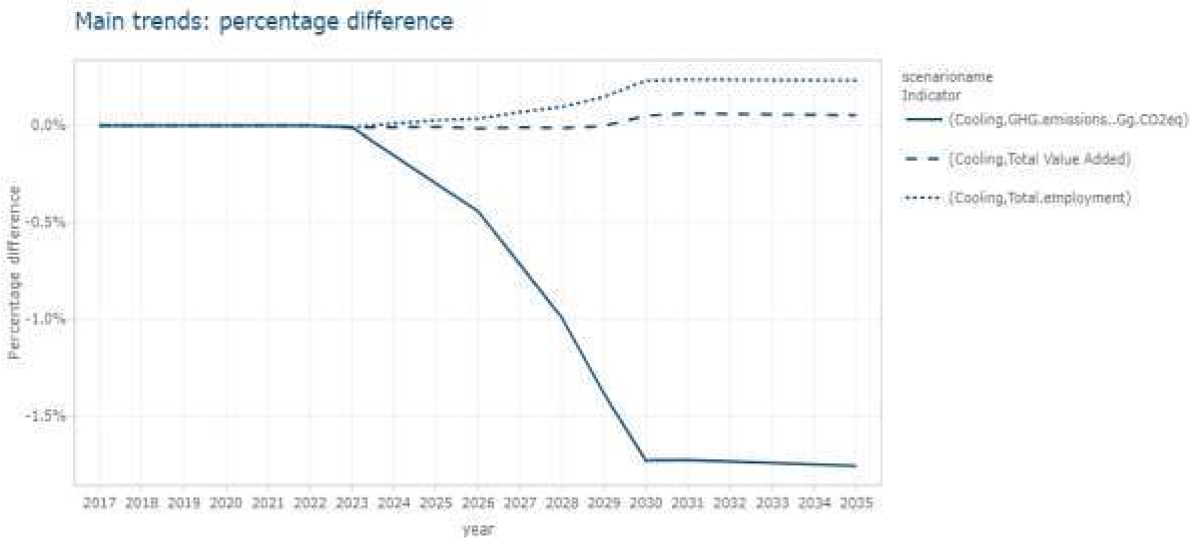

Figure 9: Impact of Cooling scenario compared to baseline

Moving on, in Figure 10 it is clear that GHG emissions fall significantly in both fossil-fuel-based electricity industry by 2030. Noticeably, there is a about 100 gigagram decline in carbon dioxide equivalent emissions by 2025 which is far less compared to about 700 gigagram below the baseline level by 2030. In other words, much of the impact of the cooling scenario on emissions will not be felt in the near term. However, in the medium to long-term, GHG emissions fall significantly in the electricity, gas, and air conditioning industry. The reason the impacts on GHG emissions will be experienced after 2025 is the fact that investment is assumed to be slow in the first three years, 2023-2025, but rises thereafter, due to the potential financial constraints Ghana is likely to face under an IMF bailout in the medium-to-long-term. That said, however, if adequate funds are readily available and invested, the GHS emissions would also be immediate (see Figure 10).

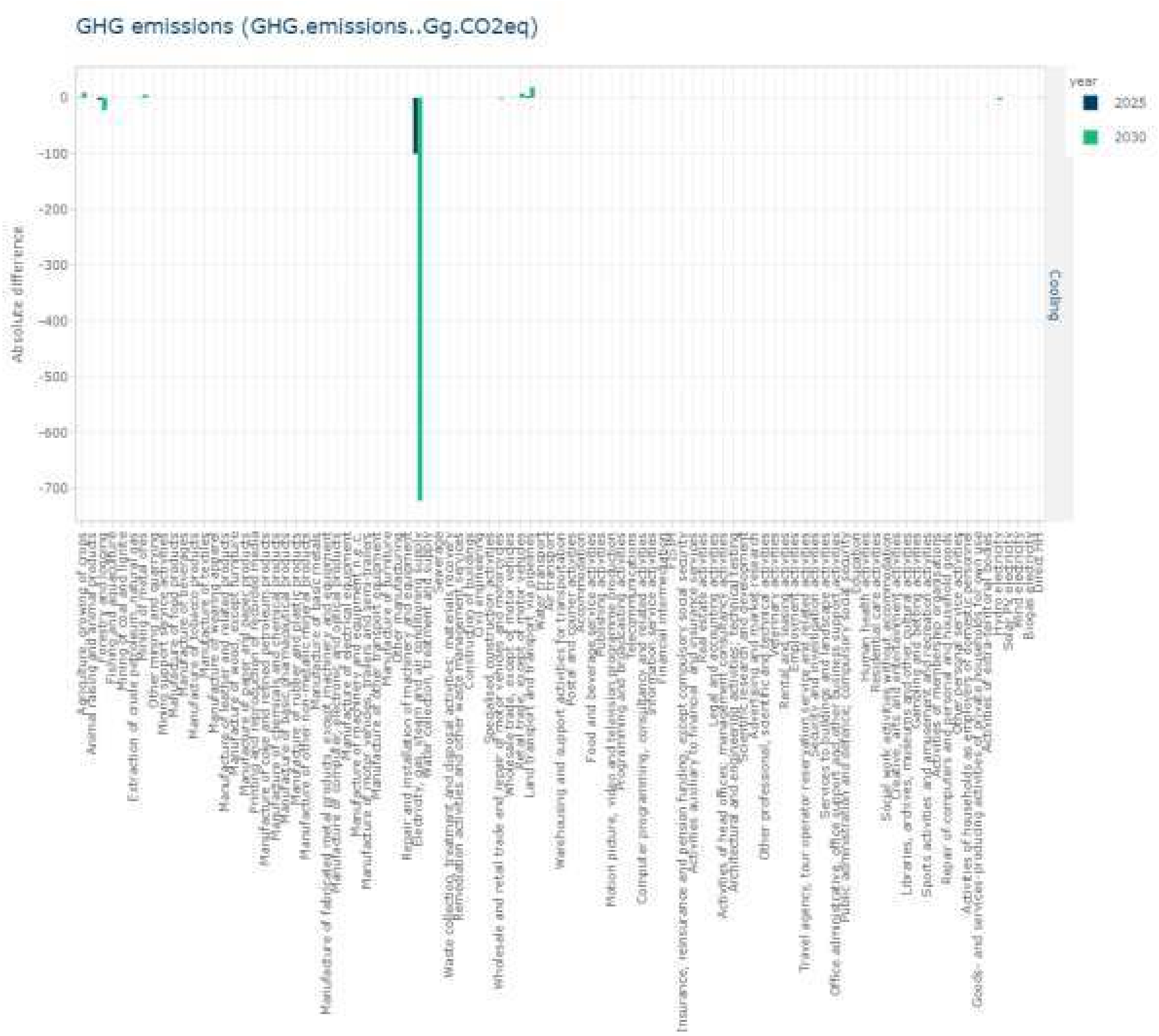

Figure 10: GHG emissions difference of cooling to baseline in %

Similarly, Figure 11 shows that labour employment is largely positive in the cooling scenario across all sectors of the national economy. Yet, as noted previously, most significant increases would be witnessed after 2025 when adequate investments have been made. Also, it is obvious that there is a rise in employment created in forwardly linked industries in the services sectors especially in education, health services, personal care, retail trade, and food and beverage services, as a result of installing cooling appliances to induce long labour-hours. For instance, the education sector could witness nearly 10,000 new jobs compared to the baseline as a result of cooling (low temperature) and conducive environmental factors that promote longer contact hours. This argument also applies in the health, and food and beverages services sectors. On the other hand, however, there is a decrease in jobs within the hydroelectricity sub-sector due to a decline in consumer demand for electricity, and repair of computers and electronic appliances due to installation of efficient cooling appliances.

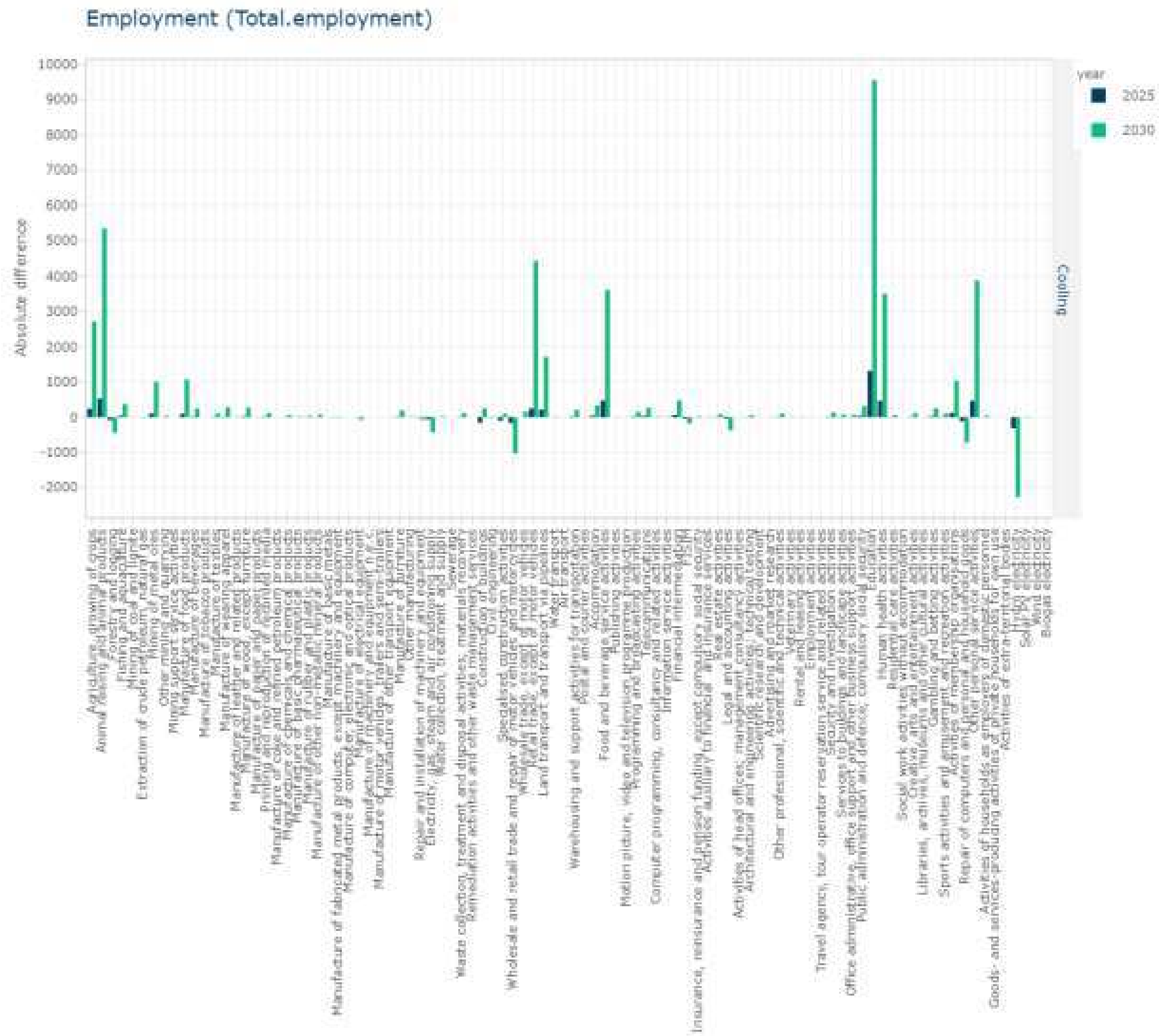

Figure 11: Percentage changes in Labour employment in the Cooling scenario

5 Policy implications and analysis

The prime goal of climate and green policy in a developing country context such as Ghana is to promote growth and employment while reducing the emission intensity of economic growth. In this instance, the analysis of climate and green policies captured in the updated GH-NDCs and the National Energy Transition Framework has so far demonstrated possible significant impacts on GHG emissions, economic growth, and employment.

Value-added, GDP and total employment rise over baseline levels among all three analysed policy scenarios, notably the solar PV, biofuels and cooling efficiency policy. It is important to highlight that deliberate policies towards local manufacturing or value-addition other than import dependency would further elevate the impacts on growth and employment than shown in this analysis.

All three policies would further reduce GHG emissions by 2% to 7% below baseline levels by 2030. As specifically shown in Figure 12, all three policies, relative to the baseline, demonstrate drastic reduction in CO2 emissions from the energy sector. The policy introducing 10% ethanol blend in major petroleum products (i.e., biofuel) has the greatest impact, up to about 7% decline in GHG emissions consistent with the volume of pollution in transportation sub-sector. It thus has far-reaching implications on GHG emissions reduction than the combined effects of the cooling appliances and solar PV policies. This is followed by the policy to upscale solar PV to 10% penetration by 2030 since it is also able to reduce up to about 2.5% less of baseline emissions by 2030. In the solar PV scenario, the industry for coke and refined petroleum as well as manufacturing industries including basic pharmaceutical products, and other non-metallic mineral products accommodate the highest share (between 10% to 22%) of fall in GHG emissions in relative terms. The cumulative deficit in emissions relative to the baseline by 2030 is approximately 2% of emissions from the implementation of the 60% best-in-class cooling appliances policy.

Whereas there is a steep decline of emissions under the biofuel policy in the near term by 2026, the solar PV penetration and efficient cooling appliances investments exhibit a gentle decline up to 2030. The differences in rate of emissions abatement are a result of differences in the turnaround-time of investments into these green policies to have impact on emissions. The steeper the decline, the shorter the turnaround-time of investments.

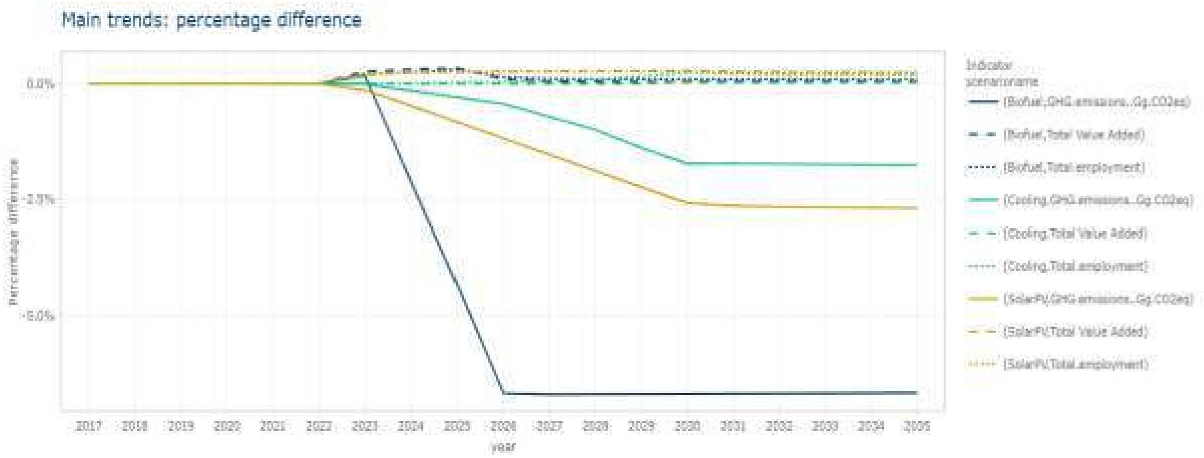

Figure 12: Main trends of emissions abatement scenarios

Moving into industry-specific employment, Figure 13 shows the rural-urban distribution of jobs under each policy experiment. In each of the green investment options, new jobs in rural agriculture increase significantly, especially under the solar PV scenario where about 15,000 new jobs are altogether created in crops-growing and animal-raising agriculture. This could be due to the choice of location for the construction of a utility-scale solar PV station. Since urban centres are in most cases congested, siting a new utility solar PV farm is most likely to be in the rural areas which would boost local employment in the construction, installation and maintenance of the PV farm. Added to that are secondary jobs like irrigation farming emanating from the installed power, as well as other indirect jobs creation on the basis of increased demand for food and other agricultural products from workers on the solar PV farms Urban jobs, on the other hand, are largely in the services industries like retail trade in solar PV installation components and sale of efficient cooling appliances.

The chart shows two panels of potential distribution of employment according to education level and location of gender. It is evident from Figure 13 that both cooling and solar PV scenarios have the potential of generating higher number of jobs across urban-rural locations compared to the baseline.

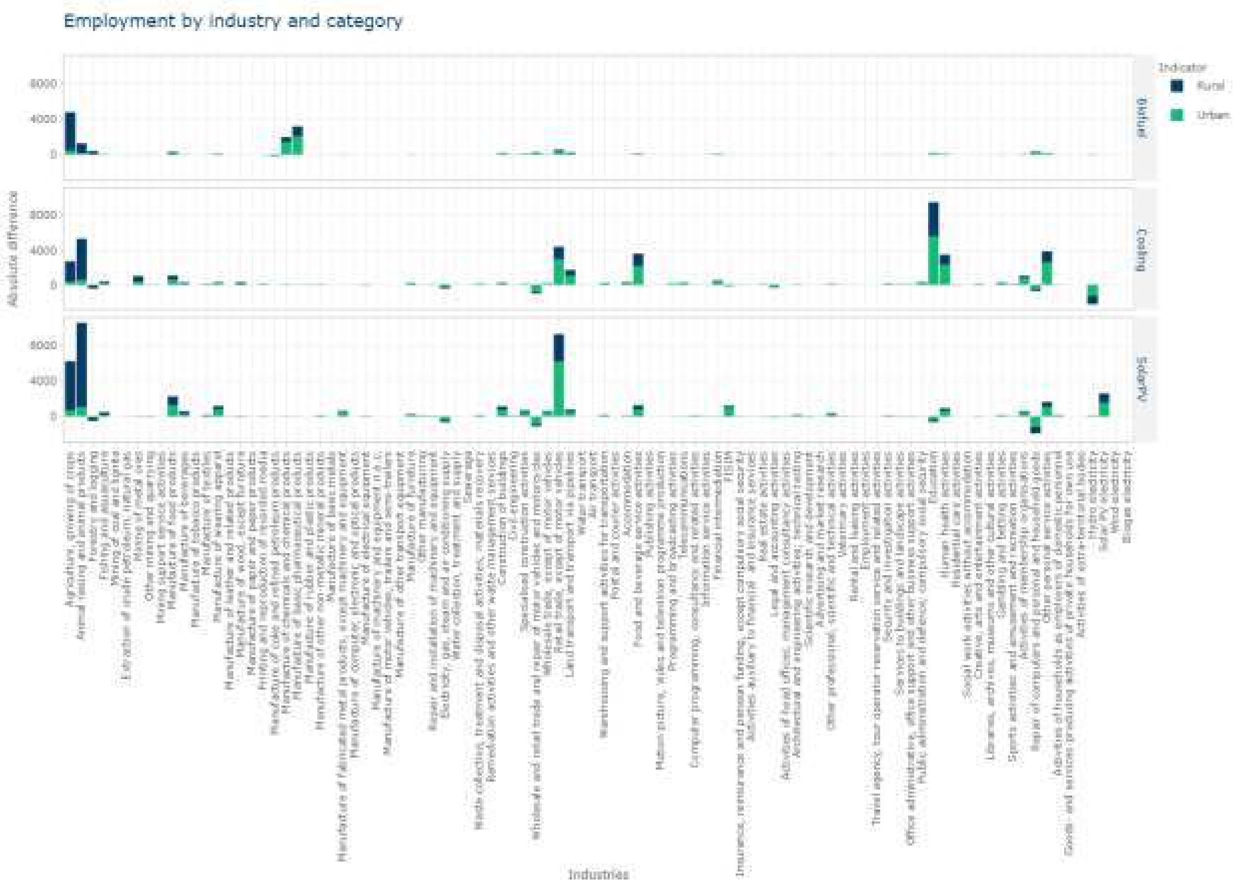

Figure 13: Employment by location, industry and policy scenario

A further disaggregation of employment (Figure 14) also shows that new jobs under each green investment option favour people with primary or no education. That is, they offer to a great extent low-skill jobs over the analysis period. This could be explained as a result of mass employment of mostly low-skilled labour in solar-powered irrigation farming and retail trade; only the investment into efficient cooling appliances yield significant new jobs for people with tertiary education. Thus, each of the policy scenarios tend to reduce unemployment while redistributing jobs to less skilled labour.

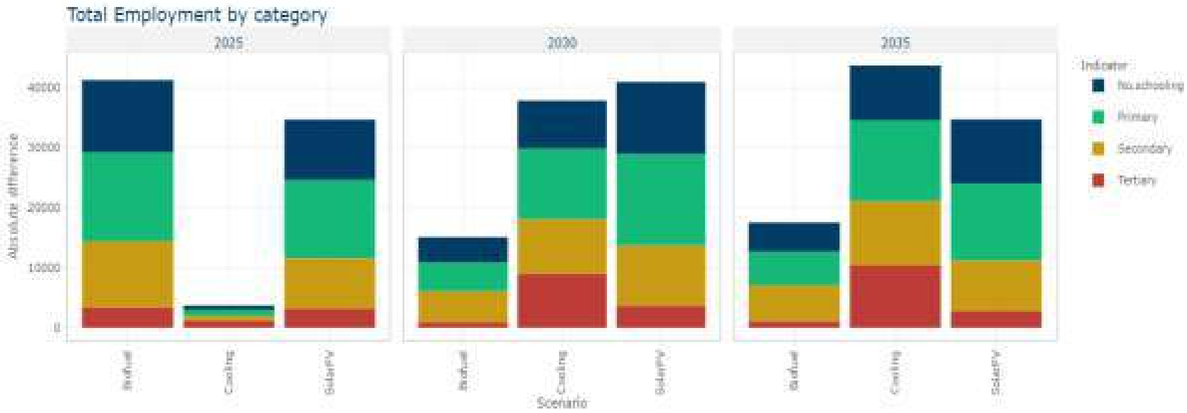

Figure 14: Total employment by education level and policy scenario

In another breadth, Figure 15 indicates that job opportunities for females are highest in many industries especially in the retail trade, food and beverage services, manufacture of food products, and in agricuture. Cooling and solar PV scenarios tend to be gender sensitive since both males and females are catered for, with many more jobs likely to be created for female workers. The overall policy impact on female employment is some thousands of jobs more than their male counterparts since many of the affected industries (e.g., agriculture, food processing, retail trade, and food and beverage services) are traditionally female-dominated. Investments into solar PV and cooling appliances would especially expand to employ more females compared to the baseline.

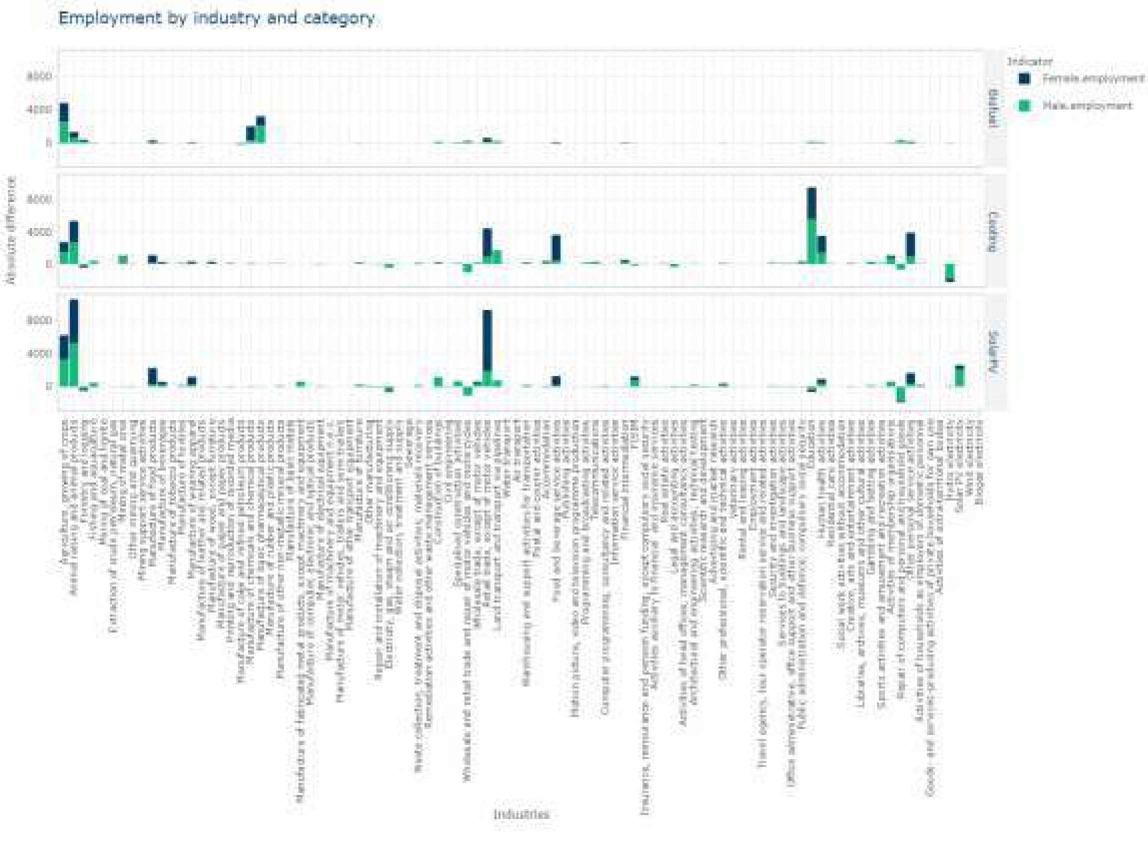

Figure 15: Employment by sex, industry and policy scenario

Lastly, in Figure 16, entrepreneurship and micro and small-scale enterprises under the three policy scenarios measured by own-account jobs (i.e., self-employment) without employees account contribute the largest shares of new jobs by both sexes. This is true for both agriculture and non-agricultural industries by 2025 and 2030. New jobs for females in sole-proprietor, non-agricultural businesses dominate all new employments in biofuel, cooling and solar PV investment scenarios by 2030. As already pointed out in Figure 14, employment under the biofuel scenario generally declines between 2025 and 2030. Notwithstanding, self-employment businesses in non-agricultural industries provide the needed haven for jobs and incomes for households. In like manner, micro and sole-proprietor agricultural businesses witness significant jump over the baseline case. Nevertheless, absolute employment generally shrinks between 2025 to 2030 for both females and males, except for the solar PV scenario. Generally speaking, except for the cooling scenario where wage-employment in the form of paid employees contributes significant number of new jobs, the informal sector dominated by micro and small businesses stand to gain a greater share of jobs in the investment scenarios.

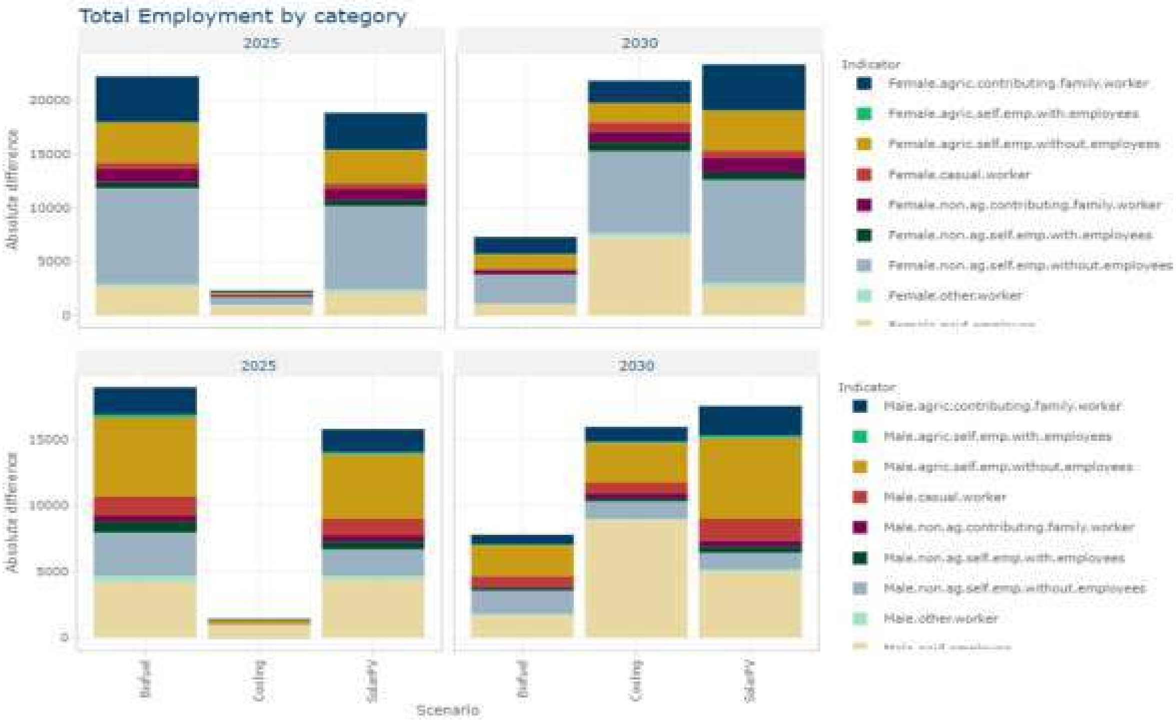

Figure 16: Employment by sex, job-status and policy scenario

In conclusion, apart from significantly reducing GHG emissions, all three emissions-abatement scenarios also generate positive impacts on labour employment over the baseline case in the short-to-medium term. Favourable employment variation above the baseline is mostly attributed to direct employment variations in the electricity sub-sectors and induced variations in the agriculture, chemical and pharmaceutical industries, and retail trade. Most of the new jobs to be created would be for vulnerable and less-skilled workers, the self-employed and for female workers, redistributing jobs to the less privileged and closing the inequality gaps in the labour market and opening up opportunities for micro- and small enterprise creation. Positive outcomes for the less privileged labour market participants strongly hinges on accompanying and supporting Just Transition policies, notably skills and enterprise development, entrepreneurship and social protection.

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Annex

A.1 The Green Jobs Assessment Model (general description)

The GJAM we develop for Ghana applies the same philosophy and modelling approach as taken for MEIO Norway(Aponte et al., 2021; Wiebe et al., 2022), GJAM Nigeria(ILO & UNDP, 2021a), GJAM Zimbabwe(ILO & UNDP, 2021b) and GJAM Turkey(Moana Simas et al., 2022). It is based on the model suggested in the International Labour Organizations GAIN Training Guidebook(ILO, 2017), adapted to the use of supply-and-use tables. We have further introduced endogeneity of some macro-economic key variables to capture dynamic development paths over time. To this end we follow ideas put forward by the Interindustry Forecasting Project at the University of Maryland(Clopper, 2012). We embed the supply-use-model into a set of linear macro-economic equations, see Figure A1. Population and exports are exogenous drivers of the model, while investments (gross capital formation), household demand and GDP (and value added) are endogenous. The model is dynamic-recursive and can be classified as a simple macro-econometric input-output (MEIO) model(Lewney et al., 2018; West, 1995). While similar to computable general equilibrium (CGE) models, the most important differences are that MEIO models are more empirically based (estimation of behavioural parameters), assume myopic foresight of all agents, and have a Leontief production function(Pollitt et al., 2018) in contrast to e.g. a constant elasticity of substitution (CES) production function. Although some price effects are considered in the GJAM model family, these models are to date simpler than other MEIO models such as E3MG(Mercure et al., 2018) and related models or models from the INFORUM family, such as INFORGE(Maier et al., 2015; Mönnig et al., 2019) for Germany.

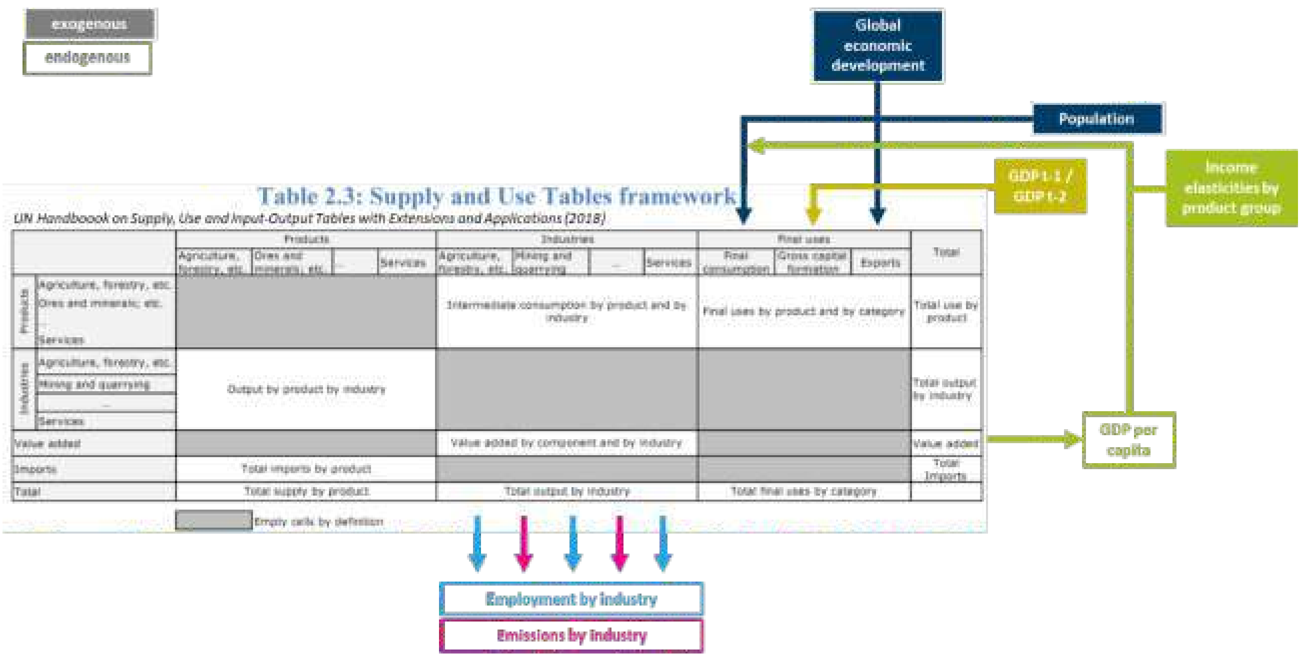

Figure A1 Schematic representation of the supply-and-use table based model

The Green Jobs Assessment Model GJAM for Ghana is a dynamic-recursive model combining macro-economic equations with a supply-and-use table system. The model is set up in constant 2017 prices. The macro-economic equations are:

- Exports, which grow with an exogenously assumed global GDP growth rate.
- Gross capital formation (investments), which grow with last four year's average growth rate. This stabilises the model by exogenising investments when finding the solution for the current year, while still allowing for different growth paths across scenarios.
- Government consumption, which depends on population growth and is estimated econometrically based on time series data from the system of national accounts.
- Population is assumed to follow the medium fertility scenario from UN DESA's world population prospects(UN, 2019)

We assume that the share of each product in total exports, total investments and total government consumption remains constant in the reference scenario, while these can be exogenously changed in the green transition scenarios.

Household consumption expenditures are modelled using a demand system where household consumption by product prod depends on total income (GDP) and income (eI), own-price (eop) and cross-price (ecp) elasticities, with grX denoting the growth (in %) in variable X:

$$HHEprod_t = HHEprod_{t-1} + (eI \times grGDP) + (eop \times grOwnPrice) + (ecp \times grOtherPrices)$$

Here, income, own-price and cross-price elasticities are taken from the USDA international food comparison programme(Meade et al., 2014; Muhammad et al., 2015), but can be estimated econometrically if time series with a sufficient number of observations are available. Product price changes are determined in the input-output core, using the Leontief price model. Note that we do not model inflation. The only price changes that can be modelled are those due to changing technology of production in the scenarios. Prices in the reference and the current green scenario are constant.

Figure A1 shows the circular flow between final demand by product, value added by industry, which considering taxes and other flows determines GDP per capita, which is used to model final demand. In mathematical terms, the use matrix is denoted U and the supply matrix is the transpose of the make matrix, VT. The industry-by-commodity commodity-demand-driven SUT model(Miller & Blair, 2009) is

$$g = D\,(I - BD)^{-1}\,y$$

Where y is the final demand by product (obtained by summing the individual final demand vectors), and B is the use coefficient matrix:

$$B = U\,diag\,(g)^{-1}$$

where g is the vector of industry output. D is the market share matrix:

$$D = V\,diag(q)^{-1}$$

where *q* is the vector of product output.

The model iterates in every year until the change in final household demand from one iteration to the next is below a given threshold. The next year is then initialised with endogenous variables being set to the current year solution and exogenous variables as well as scenario inputs taking the next year's value.

For the scenarios it is possible to model

- additional investment by product
- changes in the structure of household and government demand
- changes in the use coefficient matrix, i.e. the technology with which an industry produces
- changes in the market share matrix, i.e. which industries produce which share of a product
- changes in the import shares by products
- changes in emission intensities of industries

Production and value added are always endogenous. From this we can estimate changes in employment by using a constant labour intensity (that is, a fixed number of workers by skill and gender per unit of value added by industry) multiplied with the new value added by industry.

General limitations and strengths of the modelling approach

Excerpt from general documentation of the software for the economic core model (SUT_core)

SUT based macro-econom(etr)ic IO models / GAIN type Green Jobs Assessment Models are not economic forecasting models. Rather, these models are a tool to inform about possible effects of "what-if" scenarios on emissions and labour demand by industries, given that the remaining structure of the economy remains as is.

The results should be assessed relative to the reference scenario. They indicate the direction and possible size of the effects but should be taken as indicative estimates.

The results show how changes in individual economic activities influence the economic structure. Direct, indirect, and induced effects of technological change and changes in household, government and investment structure are reflected.

A(n imperfect) list of limitations to the modelling approach

- The model is based on historic relation between economic activity, income and consumption and the production structure of the base year (currently last year available at TurkStat is 2012), which in turn might be estimated based on older supply-and-use tables. For some countries, the most recent available SUT might be from 2010 or 2012, while other countries might have tables as recent as 2019. Extrapolating data over the next decade based on such data will not necessarily give a complete picture, but it constitutes a valuable starting point for assessing effects of climate change mitigation and adaptation and other sustainability policies through "what-if" analyses.

- While the option for price changes is given, there is no adjustment of production structure or investments based on price changes. Household demand for different product groups, however, is modelled using own- and cross-price elasticities.
- Investments grow with the previous year's growth rate, and the structure of the investment remains the same, with one exception: the exogenously given investment for individual scenarios, which comes in addition to the general investments. This entails that the additional investments in the scenarios are not crowding out other investments but come as an additional economic stimulus.
- The results show which industries are likely to have an increased demand for labour, and which industries might contract. The actual labour market outcomes also depend on other factors as well as dynamic labour market adjustments such as wage adjustments, labour availability, labour productivity changes etc, that are not considered here.
- The current modelling of international trade is very simplified. Import shares by product are based on the supply table from the base year. Exports grow with global GDP projections from the IMF or OECD.

Once these limitations are well understood, they contribute to the **main strength of the model: simplicity and transparency**. These are reinforced by the other strengths:

- The model depends on very few types of data, which can be combined into one consistent framework with few equations.
- The model is data-driven and reflects country-specific characteristics very well.
- Scenarios are implemented using one Excel sheet and the model runs in only a few seconds, which allows to calculate a large number of scenarios and thereby assessing the validity of different scenario assumptions.
- For every single result, we can find an explanation that is in the data or one of the very few assumptions underlying the model.

The Baseline scenario is calibrated as follows:The economic structure (described by the market share matrix D, calculated from the 2017 supply table) and the technology coefficient matrix B (calculated from the 2017 use table) are kept constant for the years 2018-2035. This entails that the economy is assumed to have a static Leontief production function without technological change or any economies of scale or price effects. Import shares per product are constant. As there is no technological change or changes in the structure of primary inputs (value added components), prices are constant.

Production by industry g is calculated using the industry-by-commodity commodity-demand-driven SUT model(Miller & Blair, 2009) $g = D\,(I - BD)^{-1}\,y$. In this demand-driven model, this results in for example electricity production growing with electricity demand in monetary terms.

Since the technology coefficient matrix B is constant, the share of value added in total industry output is also constant. Value added per industry is then determined endogenously, by multiplying the value added in output shares with output per industry. Total GDP equals the sum over all industries' value added, and is then used to determine the development of household consumption expenditures. Since both total value added/GDP and household consumption expenditures are endogenous to the model, they cannot be completely equal to any existing forecast. Figure 2 displays the macro-economic trends of the model in the baseline scenario. The fluctuations in the growth rate of GDP, and also emissions and employment, (lower right panel of the figure) up to 2022 are introduced into the model through the calibration with the exogenous variables exports and investments (gross fixed capital formation). The IMF WEO data estimates the GDP growth rate to be about 6% in 2018 and 2019, slightly higher than the growth rate of about 5% in the model, and about 0.5% in 2020 (approximately the same in the model). For 2021 and 2022 the IMF estimates are significantly higher than what we see in the model (5 and 3.5-4% compared to about 1-1.5% in the model), while thereafter, the model with about 3% annually is only slightly lower than the IMF forecast (fluctuates between 3 and 5% annually).

A.2 Ghana's supply and use table

1	Products of agriculture, horticulture and market gardening	52	Rubber and plastics products
2	Maize	53	Glass and glass products and other non-metallic products n.e.c.
3	Rice (Paddy)	54	Furniture
4	Sorghum	55	Wastes or scraps
5	Millet	56	Basic metals
6	Pepper	57	Fabricated metal products, except machinery and equipment
7	Garden eggs	58	General-purpose machinery
8	Tomato	59	Special-purpose machinery
9	Onions	60	Office, accounting and computing machinery
10	Okro	61	Electrical machinery and apparatus
11	Banana	62	Radio, television and communication equipment and apparatus
12	Plantain	63	Medical appliances, precision and optical instruments, watches and clocks
13	Mango	64	Transport equipment
14	Pineapple	65	Constructions
15	Pawpaw	66	Construction services
16	Citrus	67	Wholesale trade services
17	Cashew	68	Retail trade services
18	Soybean	69	Accommodation
19	Groundnuts	70	Passenger transport services
20	Shea nut	71	Freight transport services
21	Coconut	72	Rental services of transport vehicles with operators
22	Oil palm	73	Supporting transport services
23	Cassava	74	Postal and courier services
24	Yam	75	Electricity, gas and water distribution (on own account)
25	Cocoa	76	Central banking service
26	Cowpea	77	Deposit Services
27	Live animals and animal products (excluding meat)	78	FISIM
28	Forestry and logging products	79	Other financial service activities
29	Fish and other fishing products	80	Life insurance
30	Coal and peat	81	No-life Insurance
31	Crude petroleum and natural gas	82	Real estate services
32	Uranium and thorium ores and concentrates	83	Imputed rent
33	Metal ores	84	Leasing or rental services without operator
34	Stone, sand and clay	85	Research and development services
35	Other minerals	86	Legal and accounting services
36	Electricity, town gas, steam and hot water	87	Professional, scientific and technical activities
37	Natural water	88	Telecommunications, broadcasting and information supply services
38	Meat,fish, fruits, vegetables, oils and fats	89	Support services
39	Dairy products and egg products	90	Support and operation services to agriculture, hunting, forestry, fishing, mining and utilities
40	Grain mill products, starch and other food products	91	Maintenance, repair and installation (except construction) services
41	Beverages	92	Manufacturing services on physical inputs owned by others
42	Tobacco products	93	Other manufacturing services; publishing, printing and reproduction services; materials recovery services
43	Yarn and thread; woven and tufted textile fabrics	94	Public administration and other services provided to the community as a whole; compulsory social security services
44	Textile articles other than apparel		
45	Knitted or crocheted fabrics; wearing apparel	95	Education services
46	Leather and leather products; footwear	96	Human health and social care services
47	Products of wood, cork, straw and plaiting materials	97	Sewage and waste collection, treatment and disposal and other environmental protection services
48	Pulp, paper and paper products; printed matter and related articles	98	Services of membership organizations
49	Coke oven products; refined petroleum products; nuclear fuel	99	Recreational, cultural and sporting services
50	Basic chemicals	100	Other services
51	Other chemical products; man-made fibres	101	Domestic services

Table 10 List of 90 SUT Industries

1	Agriculture, growing of crops	46	Water transport
2	Animal raising and animal products	47	Air transport
3	Forestry and logging	48	Warehousing and support activities for transportation
4	Fishing and aquaculture	49	Postal and courier activities
5	Mining of coal and lignite	50	Accommodation
6	Extraction of crude petroleum, natural gas	51	Food and beverage service activities
7	Mining of metal ores	52	Publishing activities
8	Other mining and quarrying	53	Motion picture, video and television programme production
9	Mining support service activities	54	Programming and broadcasting activities
10	Manufacture of food products	55	Telecommunications
11	Manufacture of beverages	56	Computer programming, consultancy and related activities
12	Manufacture of tobacco products	57	Information service activities
13	Manufacture of textiles	58	Financial intermediation
14	Manufacture of wearing apparel	59	FISIM
15	Manufacture of leather and related products	60	Insurance, reinsurance and pension funding, except compulsory social security
16	Manufacture of wood, except furniture	61	Activities auxiliary to financial and insurance services
17	Manufacture of paper and paper products	62	Real estate activities
18	Printing and reproduction of recorded media	63	Legal and accounting activities
19	Manufacture of coke and refined petroleum products	64	Activities of head offices; management consultancy activities
20	Manufacture of chemicals and chemical products	65	Architectural and engineering activities; technical testing
21	Manufacture of basic pharmaceutical products	66	Scientific research and development
22	Manufacture of rubber and plastic products	67	Advertising and market research
23	Manufacture of other non-metallic mineral products	68	Other professional, scientific and technical activities
24	Manufacture of basic metals	69	Veterinary activities
25	Manufacture of fabricated metal products, except machinery and equipment	70	Rental and leasing activities
26	Manufacture of computer, electronic and optical products	71	Employment activities
27	Manufacture of electrical equipment	72	Travel agency, tour operator reservation service and related activities
28	Manufacture of machinery and equipment n.e.c.	73	Security and investigation activities
29	Manufacture of motor vehicles, trailers and semi-trailers	74	Services to buildings and landscape activities
30	Manufacture of other transport equipment	75	Office administrative, office support and other business support activities
31	Manufacture of furniture	76	Public administration and defence; compulsory social security
32	Other manufacturing	77	Education
33	Repair and installation of machinery and equipment	78	Human health activities
34	Electricity, gas, steam and air conditioning supply	79	Residential care activities
35	Water collection, treatment and supply	80	Social work activities without accommodation
36	Sewerage	81	Creative, arts and entertainment activities
37	Waste collection, treatment and disposal activities; materials recovery	82	Libraries, archives, museums and other cultural activities
38	Remediation activities and other waste management services	83	Gambling and betting activities
39	Construction of buildings	84	Sports activities and amusement and recreation activities
40	Civil engineering	85	Activities of membership organisations
41	Specialised construction activities	86	Repair of computers and personal and household goods
42	Wholesale and retail trade and repair of motor vehicles and motorcycles	87	Other personal service activities
43	Wholesale trade, except of motor vehicles	88	Activities of households as employers of domestic personnel
44	Retail trade, except of motor vehicles	89	Goods- and services-producing activities of private households for own use
45	Land transport and transport via pipelines	90	Activities of extra-territorial bodies

Table 11 Employment Indicators

1 - Dimension	2 - Dimensions	3 - Dimensions
Gender	**Gender & Location**	**Gender, Location & Education Level**
Male	Male-rural	Male-rural-no education
Female	Male-urban	Male-rural-primary
	Female-rural	Male-rural-secondary
Residential Location	Female-urban	Male-rural-tertiary
Rural		Male-urban-no education
Urban	**Gender & Education level**	Male-urban-primary
	Male-no education	Male-urban-secondary
Level of Education	Male-primary	Male-urban-tertiary
No schooling	Male-secondary	Female-rural-no education
Primary	Male-tertiary	Female-rural-primary
Secondary	Female-no education	Female-rural-secondary
Tertiary	Female-primary	Female-rural-tertiary
	Female-secondary	Female-urban-no education
Employment Status	Female-tertiary	Female-urban-primary
Paid employee		Female-urban-secondary
Casual worker	**Location & Education Level**	Female-urban-tertiary
Non-agric self-employed with employees	Rural-no education	
Non-agric self-employed without employees	Rural-primary	
Non-agric contributing family worker	Rural-secondary	
Agric self-employed with employees	Rural-tertiary	
Agric self-employed without employees	Urban-no education	
Agric contributing family worker	Urban-primary	
Other worker	Urban-secondary	
	Urban-tertiary	

A.2.1 Updating the 2013 SUT to the base year of the model, 2017

The most recent supply-and-use table available for Ghana is from 2013, while the most recent data for GHG emissions and labour force are available for 2017. The base year for the model was therefore set to 2017, and the SUT was updated from 2013 to 2017, using detailed data on the final demand components (household and government consumption, gross fixed capital formation, exports) and imports by 101 products and value added by 90 industries. To obtain total industry output, the assumption of constant value-added shares was used. That is, the share of value added in total output of each industry is assumed to be the same in 2017 as in 2013. The procedure for the update is a imple RAS algorithm, scaling and rebalancing the intermediate product in the supply and use matrices until the column sums correspond to total output by industry and row sums then consider the new final demand structure. Data for value-added for 2017 was sourced from Ghana Statistical Service (2021) annual GDP using the product approach.

Similarly, data for final demand for 2017 were obtained from Ghana Statistical Service (2021) on annual GDP using consumption expenditure on final goods and services by economic institutions including households, government, investment and stock, and rest of the world. The mapped aggregated demand was then disaggregated using constant consumption shares between 2013 and 2017. That means, the share of final consumption expenditure by the economic institutions remained unchanged between 2013 and 2017.

A.2.2 GHG extensions note on LULUCF emissions

While agricultural emissions can be easily related to economic activity, emissions from Land Use, Land-Use Change and Forestry (LULUCF) cannot be allocated to the GJAM. This emissions category describes carbon emissions and sinks per land type and per change of use in land type between years. These include, for example, changes in forest and other woody biomass stocks; forest and grasslands conversions: abandonment of croplands, pastures, or other managed lands; changes in carbon content of soils; or natural disturbances such as forest fires in managed lands or in unmanaged lands when those disturbances are followed by land-use changes.

The emissions and sinks associated to land use and land-use change do not depend directly on economic activity, but on many different factors. The GJAM assumes direct relationship between economic output and emissions. While this relationship can be assumed for the emission categories accounted in the model (for example, higher output from animal husbandry would lead to higher emissions from manure management and from enteric fermentation), the relationship between economic output and land-use change is not direct. Increased agricultural output comes, often, from increased productivity, and not necessarily from increased land use. For this reason, it cannot be established a direct correlation between increased economic activity of different industries to changes in carbon emissions or sinks in the LULUCF accounts.

An approximation for reflecting emissions from land degradation and/or deforestation is by accounting for emissions from the burning of firewood and charcoal for cooking and heating. In countries with a large consumption of traditional biomass by households and in economic activities, and where there are established links between collection of fuel wood and deforestation or land degradation, these emissions can be used as a proxy for covering parts of LULUCF emissions. The main assumption, in this case, is that the fuel wood comes from unmanaged lands and contributed to reduced carbon stock in forests, since managed forestry is not considered to represent net emissions.

[15] Ghana Statistical Service (2021). Annual GDP by Production Approach. Ghana Statistical Service, Accra. Available online at https://statsghana.gov.gh/nationalaccount_macros.php?Stats=MzE2Njk3MDQ0LjUxOA==/webstats/q4q76srp20

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