Ghana LEDs Country Report

Environmental Protection Agency

EU - UNEP Africa Low Emissions Development Strategies

Africa LEDs (http://www.africaleds.org)

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Chapter 1: Development context

1.1 Climate change issues in Ghana

Africa bears the severest brunt of the ravages of climate change. Africa is the hardest hit because it has little capacity to withstand climate shocks. Seven of the ten countries most at risk of climate change are in Africa. The severity of climate change in Ghana is not markedly different from the rest of Africa. Climate change has the potential to erode Ghana's past economic gains and can undermine our efforts to become a fully-fledged middle-income country by 2056. Ghana has crucial development challenges to deal with now and future such as rising urban population; rising public debt; youth joblessness; high prevalence of poverty; widening technological gap and depletion of natural resources. Climate change can multiplier the magnitude of the development challenges facing Ghana.

According to recent a study by the Environmental Protection Agency (EPA), temperatures have risen by an average of 1.1 ^{O}C over the last 3 decades and are projected to get warmer by at least 3 ^{O}C by 2080 nation-wide. The study also indicated that the observed rainfall variabilities are likely to continue over the next 50 years. The study further points out that, the occurrence of extreme weather events will go high. Majority of the natural-resource dependent sectors of Ghana's economy (Agriculture, Water, Energy etc.) are prone and already experiencing climate change impacts. Geographically, the northern drylands and transition zones of the country are the most vulnerable parts of the country (Figure 1). In the two ecological zones, there nearly 2 million smallholder farmers who are confronted with the harsh realities of climate change daily.

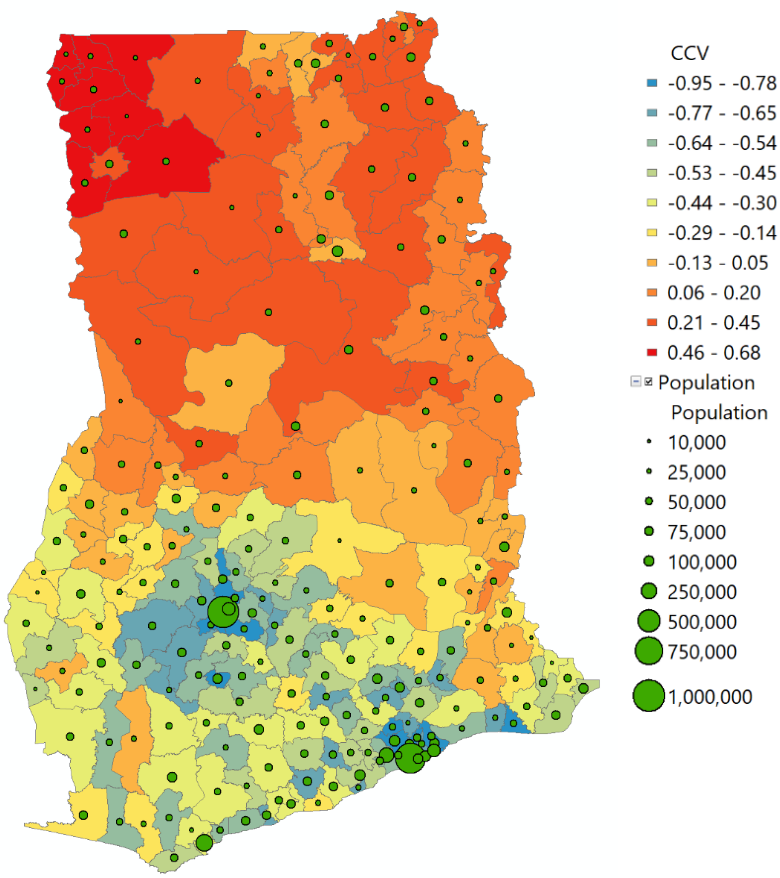

Figure 1: Climate change vulnerability scores for Ghana's 216 districts

Considering this, the negative impacts of the changing climate have the potential to exacerbate Ghana's development challenges if swift and sustained actions are not taken to address them. Regarding greenhouse gas emissions, even though African countries contribute less than 10% of the global GHG emissions, the rate at which the emission levels are rising on the continent is a source of concern. Ghana is a good example. Between 1990-2016, the total national GHG emissions increased by 66% to 42.2 million tonnes carbon dioxides equivalent. The emission increase was due to the expanding the economy through export revenues from natural-resource base commodities like timber, gold, oil and gas and cocoa. Indications are that the rising trend of the GHG emissions is likely to continue in the future if concrete measures are not taken to reverse it.

The emission per capita decreased from 1.7 tCO_2e per person in 1990 to 1.5 tCO_2e in 2016 representing a drop of 13.7% over the period. Similarly, the emissions intensity of GDP, the emission per unit GDP output (at constant 2010 US$) has dropped from 2.1 kg/ per GDP (constant 2010 US$) to 0.87 kg per GDP (constant 2010 US$) which is 59.3% reduction in the same period. The overall decreases in the emission per capita and GDP intensity suggest positive effects of the growth-focus and economic diversification policies Ghana pursued in the last two decades. What it means is that the economy and population are expanding at a faster rate than the GHG emission growth rate. The Ghanaian population has more than doubled from 14.6 million in 1990 to 28 million in 2016 at a 2.7% annual growth rate. In the same vein, the GDP recorded a consistent growth of 12 US billion to 48.2 billion US dollars for the same period with an annual growth rate of 5.7%. Within the same period, the GHG emissions grew from 25.3 $MtCO_2e$ to 42.2 $MtCO_2e$ at a 2.1% annual rate (Figure 2).

For the GHG emissions and GDP comparison, it is particularly important to highlight the kink from 2010 onwards when the proceeds from the commercial oil production were added to the GDP basket. Between 2011 and 2016, GDP increased by 31.4% with a corresponding GHG emissions rise of 11.7%

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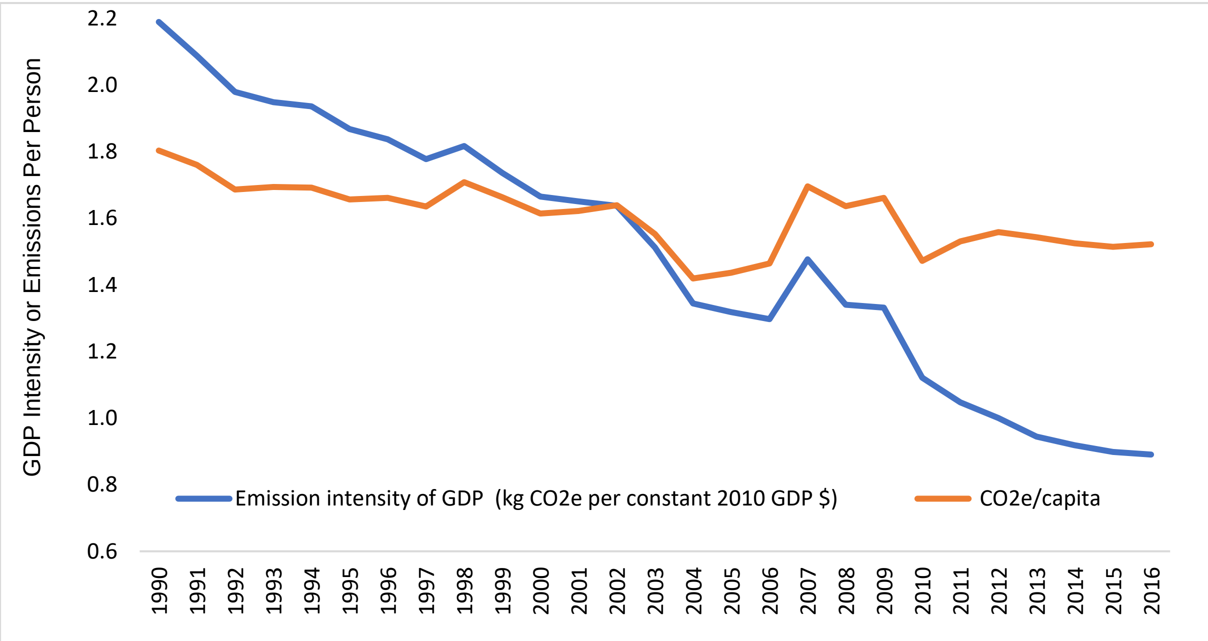

Figure 2: Trends of Emission intensity of GDP and emission per capita

Ghana is of the view that the policies it has adopted to tackle climate change can at the same time make the economy more resilient and put it on a sustainable path in the long run. This is the reason the current national development plan outlines climate change as one of the priority areas that need concrete policy interventions The Government's latest Coordinated Programme of Economic and Social Policies [1] demonstrates Ghana's commitment to respond to climate change. The strategy is to adopt development policies that can deliver growth-focus, people-centered and climate-proof outcomes. The strategy has been articulated in its recent medium-term development policy framework, the national climate change policy and the recent nationally determined contributions (NDCs)[2] under the Paris Agreement.

In 2015, Ghana put forward NDCs made up of 31 actions cutting across seven priority areas (energy, transport, agriculture and forestry, water, gender, industry, disaster management, and climate services). The implementation spans up to 2030 with the possibility for revision at the midway. The 31 mitigation and adaptation actions require $22.6 billion investments. Of US$ 22.6 billion, US$ 6.4 billion[3] is being mobilised from domestic sources, while 16.2 billion are to come from international support. In all, 56% of the overall investment needs will go into adaptation and the remaining 44% has been allocated to mitigation actions. The breakdown of the investment requirements are as follows:

- national budget (6.2%)
- corporate social responsibility budget (7.5%)
- commercial facilities (14.2%)
- Green climate fund (22.1%)
- multilateral funds (4.9%); bilateral arrangement (12.4%)
- private capital investment (16.8%) and
- international carbon market (15.9%).

The implementation of Ghana's NDCs is already underway and is on course to achieve the emission reduction and adaptation goals. Since 2016, attention has been on mobilising financial resources for the NDC implementation. As of 2018, Ghana has cumulatively invested more than US$14 billion in the NDCs in areas like natural gas available for low carbon electricity supply; forest plantation development and clean cooking, renewable energy and vulnerable agricultural landscapes. The investments in the NDCs have led to 2 million of tonnes carbon dioxide emission reductions every year as against its 2.2 million tonnes annual commitments[4]. Besides the NDC specific actions, the current government has also introduced several policies that have development and climate protection imperatives. The flagship policies include on planting for food and jobs, one-village-one-dam, one district one warehouse and the one district-one factory are all geared towards boosting industrialisation and rural development as well as building resilience to the impacts of climate change[5].

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[1] http://www.ghana.gov.gh/index.php/media-center/news/4561-co-ordinated-programme-of-economic-and-social-development-policies-2017-2024-launched-in-accra

[2] https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Ghana%20First/GH_INDC_2392015.pdf

[3] This also included existing public-sector investments that the central government mobilise to support green investments.

[4] https://unfccc.int/process/transparency-and-reporting/reporting-and-review-under-convention/biennial-update-reports-0

[5] http://www.ghana.gov.gh/index.php/media-center/news/4561-co-ordinated-programme-of-economic-and-social-development-policies-2017-2024-launched-in-accra

The one-village-one-dam (1V1D)[6] policy focuses on vulnerable communities in the northern savannah-dryland. It is aimed at ensuring all year-round agriculture in the three regions of the north, through the construction of irrigation dams in every village in that part of the country. So far, 570 small dams and dugout (Northern 310, Upper East 150, Upper West 110) have been constructed. The government one district one warehouse also relates to the post-harvest loses under the agriculture NDCs. This initiative is targeted at reducing post-harvest loses among smallholder farmers across the country. In all, fifty-one 1,000 metric tonnes prefabricated grains warehouses have been completed throughout the country[7].

In the 2019 national budget, the Ministries of Energy and Finance were tasked to come up with a special incentive package for electric cars[8] to give a boost to green mobility in the country. The government also announced a major policy to boost distributed renewable energy to reinvigorate the solar rooftop programme. For instance, there are plans to fully power the seat of Government with solar energy. In the same vein, Ghana has taken decisive steps to fight illegal mining which is a major driver of deforestation. In this regard, more than 20,000 youth have been recruited to plant over 10 million trees to restore degraded lands.

1.2 Low- emission development planning in Ghana

The success of implementing Ghana's NDCs depends on effective planning, coherent policies and capable institutions. Thus, integrating the NDCs into the national development plan is an important first step to ensure broad governmental support. The National Development Planning Commission (NDPC) has the mandate to coordinate the formulation of medium-term development plans with inputs from the ministries and the district assemblies. Although development planning takes place at the local government level, it is usually informed on the needs of the communities within the jurisdiction of the district assembly. Nevertheless, whatever the district assemblies prioritise must feed into the broad development agenda in the medium-term development plan prepared by the NDPC on behalf of the government.

Regarding climate change issues, and for that matter, low emissions development, the Ministry of Environment, Science Technology and Innovation (MESTI) has the oversight responsibility for coordination with the technical backstop from the EPA. In 2014, MESTI led the preparation of the National Climate Change Policy[9] and the National Low Carbon Development Strategy[10]. All these national processes rely on credible analytical work that underpins it. For example, to justify the inclusion of low emission development issues into national planning, NDPC, MMDAs[11] and the MDAs[12] must have convincing and robust data to support their arguments.

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[6] This initiative is led by the Ministry of Special initiative (http://www.msdi.gov.gh/1D1A.html) in collaboration with the Ministry of Food and Agriculture and Ghana Irrigation Development Authority.

[7] http://www.msdi.gov.gh/1D1W.html

[8] https://www.mofep.gov.gh/sites/default/files/budget-statements/2019-Budget-Statement-and-Economic-Policy.pdf

[9] https://www.pef.org.gh/documents/climate-change/national-climate-change-policy.pdf

[10] https://www.modernghana.com/news/490055/ghanas-low-carbon-strategy-aims-to-identify-emission-reduct.html

[11] Metropolitan, Municipal and District Assemblies

[12] Ministries, Departments and Agencies

However, analytical data on low emission development are not adequately utilised in the decision-making and policy formulation processes. Lack of capacity, poor data systems, wrong messaging, institutional inertia, limited political will and the inability to articulate the full climate and sustainable benefits of climate actions, are some of the factors that explain the low policy assimilation. The quality of technical information to guide low emission development planning has been a source of concern for many stakeholders. Many actors have raised questions about the rigor and credibility of the modelling data used in low emission development planning and back the call for robust data. Inadequate modelling capacity is considered as an additional barrier. The wrong messaging aspects relate to the question is about how to cut through the technically complex modelling exercise and make it meaningful to decision-makers.

Another important challenge is that, because there is no one single model window that can accommodate the dynamics of all the sectors, we are forced to use a different set of tools in each sector. The challenge that arises is the difficulty in putting individual model results together to construct a coherent narrative, in addition to the fact that, managing uncertainties in using multiple model can be a serious constraint. Furthermore, access to good quality data is a major challenge. The problem is that, in most instances, the datasets are either missing or incomplete.

1.3 LEDs-related modelling exercises in Ghana

The emerging global climate architecture requires countries to regularly plan and implement NDCs in the long-term. For countries to comply to this emerging trend, they must put in place durable national systems and capacities to undertake low emission planning. In Ghana, some capacity exists in several organisations, more need to be done to improve upon them. The capacity levels vary from sector to sector. Generally, there more low emission development at the national level than the local government.

At the national level, some key planning and research institutions have in-house advance capacity on general dynamic models. The NDPC and Institute for Statistical Social and Economic Research (ISSER) received on Threshold 21 integrated model from the Millennium Institute. The skills they acquired from the T21 training enriched green economy assessment exercise and guided the formulation of national development plans. The major setback of the capacity building approach that since it was one-off, there was not enough time to internalise the capacity within the organisations that benefited from the training. More recently, the International Labour Organisation (ILO) and the (EPA) also collaborated to train key stakeholders on Green Jobs Assessment Model (GJAM)[13].

In the energy sector, the Energy Commission uses the LEAP model for the preparation and updates of the Strategic National Energy Plan (SNEP). There are significant capacity and experience in using the LEAP tool over the last 15 years. The Energy Commission has consistently improved on the use of the LEAP model through pieces of training and updates of the LEAP database. They have a dedicated team responsible to regularly update the LEAP database. When the LEAP data is finalised, the EPA then introduces the requisite environmental loading factors to the energy demand projections and scenarios to estimate the GHG emissions and co-benefits. The LEAP results are then used as input in the mitigation assessment section of the national communications and the NDCs. In addition, Ghana has one of the highest

[13] https://www.ilo.org/global/topics/green-jobs/publications/assessments/lang--en/index.htm

LEAP users (360 users[14]) in the sub-region from researchers, students, CSOs and the private sector. Recently, under the CCAC initiative on SNAP, Ghana has developed a new customised LEAP template coupled with integrated benefit calculator (LEAP-IBC). The LEAP-IBC has the capability to depict the emission implications on health, crop and long-term climate change. Apart from the baseline emissions and projections, mitigation scenarios can also be visualised through multi-criteria analysis. The EPA has adopted the COPERT V transport mode to estimate vehicular emissions. The results of the COPERT model was used as input in the preparation of the fuel-economy action plan for the country.

The Africa LEDs Project is one of the major NDC support initiatives. Its overall goal is to help support evidence-based low emission development planning in Africa. Ghana joined the Africa LEDs initiative to support the on-going implementation of its NDCs and generate new perspectives to inform the revision of the NDCs in 2020. Ghana is participating in the Africa LEDs Project with the view to strengthen institutional capacities especially of those organisations that are involved in low emission development planning. In this regard, the EPA is collaborating with the Energy Centre of Kwame Nkrumah University of Science and Technology to implement Ghana's EC-UNEP LEDs project.

[14] https://www.energycommunity.org/default.asp?action=members

Chapter 2: Project Context

2.1 Project objectives

Ghana is part of the eight Africa LEDs project countries. The aim of the project is to establish an analytical framework to facilitate long-term LEDs policy decision making and implementation in line with Ghana's NDCs and its socio-economic development priorities. The rationale of this project is to position LEDs modelling as a direct enabler of socio-economic development.

It was agreed that actions will be targeted at sectors that can unlock socio-economic development opportunities alongside offsetting carbon. Accordingly, clean energy and supply of renewable wood fuel were selected for the energy and forestry sectors. It was also agreed that the modelling will build on progress established in the NDCs, NAMAs and other climate actions.

3.2 Terms of Reference of the LEDs Project

When Ghana was selected to join the project, a scoping workshop were held for key national stakeholders at the EPA Conference room in 2017. A representative of ECN and UNEP Africa Region Office participated in the workshop. During the meeting, the UNEP team and the ECN consultant introduced the project to the key sectors and initiated focus-group discussions (FGD) on potential project level priorities and the formation of policy and technical teams.

To this end, the stakeholders of Ghana narrowed down the priorities to target those most aligned to the country's socio-economic development agenda. Accordingly, clean energy and renewable wood fuel supply were prioritised. Hence, the modelling support will complement developments in these areas by providing the analytical framework to forecast carbon offset vis-a-vis jobs created and economic expansion actualised by alternate investment decisions in each of these sectors as well as an amalgamation of the two.

The end objective was to inform optimal policy decisions as Ghana progresses in implementing NDCs and its vision 2020. It was also agreed that the modelling will build on progress established in the NDCs, NAMAs and other climate actions. And, technically build on the tools that the GHG inventory & NDCs team, is already working on, including sectorial level progress e.g. by the Energy Commission. The outcomes from the country stakeholder discussions were captured to inform the terms of reference of the Ghana LEDs project and has been regurgitated in Table 1.

Table 1: Scope of work of Ghana's LEDs Project

LEDS modelling support	Deliverable	Next steps	Responsible	Timeline
	Deliverable 1	Establish in-country technical modelling team. The team that participated in the Focus Group Discussions to oversee establishment of Ghana's modelling team. Team will build on the greenhouse gas inventory & NDCs teams already in place by adding technical persons drawn from energy and agriculture to capture the socio-economic dimension. The team will also include policy persons to establish an inter-governmental policy framework to integrate modelling into policy processes. This team is the one that will work with the technical team from NREL and partners to ensure its capacity is built.	UNFCCC National focal point and team.	March 2017
		Organise short course / training workshop for country modelling team on LEDS modelling, GHG inventories, establishing reference baselines and development of monitoring indicators and reporting framework	NREL and Partners - AfLP, LEDS GP in coordination with UN Environment	April 2017
		Support Ghanaian counterparts in establishing Ghana's project level baseline for clean biogas cook stoves and agroforestry as well as their amalgamation as expounded earlier as reference for extrapolating future options, developing monitoring indicators and a reporting framework	NREL and Partners - AfLP, LEDS GP in coordination with UN Environment	May-Aug 2017
	Deliverable 2	In-country modelling team to work with project technical partners in selecting relevant models for adapting and testing to inform long-term socio-economic policies in the priority areas of clean biogas cook stoves, agroforestry and their amalgamation as expounded earlier.	Country technical modelling team with technical backstopping from NREL and Partners - AfLP, LEDS GP in coordination with UN Environment	Sept-Nov 2017
		- Work with country modelling team to adapt and test above model options and document results of different scenarios to demonstrate effectiveness of adapted models. Adapted models should provide data on carbon offset; percentage of GDP added; jobs created by alternative levels of investment at project level on clean biogas cook stoves, agroforestry and their amalgamation as expounded earlier.	Country technical modelling team with technical backstopping from NREL and Partners - AfLP, LEDS GP in coordination with UN Environment	Dec 2017 – Feb 2018
		- Organise a 3-day training workshop for modelling team on use of the adapted models.	NREL and partners - AfLP, LEDS GP, in coordination with country technical modelling team and UN Environment	March 2018
		- Transfer and installation of relevant software and hardware technologies of adapted model(s) into decision frameworks of technical and policy departments in relevant line Ministries as well as to technical, research, academic and other institutional members of the country modelling team.	NREL and partners-AfLP, LEDS GP, will provide technical support in coordination with UN Environment, to Country technical modelling team.	April-June 2018

Chapter 3: Achievement and Accomplishment

3.1 Establishment of inter-agency taskforce

Ghana adopted a national working group to undertake the climate and socio-economic assessment of two technologies for incorporation into key sector strategies. In line with the project, two inter-agency teams formed and grouped into modelling team and the policy team. The modelling team focused on the development of technical analysis of two climate technologies whiles the policy team was to discuss the strategies for policy uptake of the modelling results. The modelling team was further grouped into energy task team and the forestry/agriculture task team. The LEDs project team had the option to form a new inter-agency taskforce or use an existing national working group to perform the LEDs task.

Upon deliberations, the team decided to use the existing national working group for the NDCs as its inter-Agency taskforce for the Africa LEDs Project in Ghana. Using the existing working group was the rationale choice because it was in line with the practice of not proliferating parallel groups to work on a similar subject matter. This decision was also consistent with the effort to avoid needless fragmentation of the existing structures and add value to the overall climate change institutional governance in the country. Nevertheless, existing groups did not prevent the LEDs team from adding extra hands where necessary. The general approach was to use national working group, add on to the institutional representation, and expand their mandate to cover the LEDs.

The membership of the inter-agency taskforce was made up of 18 representatives from line ministries, agencies, academia and the civil society organisations. The members were carefully chosen with the view to ensure balanced representations of different key stakeholders. When choosing the membership of the two teams, there was preference for those who were actively engaged in the forest plantation and cookstove planning and markets. Also, the selected team members had working knowledge in NDCs, LEDs modelling and national policies. The NDC team was established in 2015 and tasked to prepare and facilitate its implementation. Since the NDCs and LEDs project had similar objectives it was easy to align both work streams.

After the decision to use the existing national teams for the LEDs assignment, the EPA and MESTI issued official letters[15] to inform the members of the modelling and the policy team. The team members and their institutional affiliation are provided below in Table 2:

Table 2: Membership of Ghana's policy taskforce and their institutional affiliation

Name of Member	Institution	Technology Type
Dr. J. Y Essandoh	Energy Commission	Woodstove
Mr. Joe Baffoe	Environmental Protection Agency	
Mr. Charles Kurugu	Centre for Energy and Climate Policy	
Dr. Daniel Twerefou	University of Ghana, Economics Dept.	
Mr. Kennedy Amankwa	Energy Commission	
Mr.Simpson Attieku	Energy Commission	

[15] Refer to annex 1 for reference to official letter nomination for the technical and policy teams.

Mr. Salifu Addo	Energy Commission	
Kingsley A Amoako	Ministry of Food and Agriculture	Plantation
Kwame Agyei	Forestry Commission	
Dr. Daniel Benefoh	Environmental Protection Agency	
Dr. Raymond Kasei	University of Development studies	
Kyekyeku Y. Oppong-Boadi	Environmental Protection Agency	
Mr. Felix Kofi Debrah	Ghana Statistical Service	
Dr. Felix Addo-Yobo	National Development Planning Commission	Policy team
Mr. Peter Dery	Ministry of Environment	
Mrs. Gifty Tetteh	Ministry of Energy	
Mr. Kingsley A Amoako	Ministry of Food and Agriculture	
Dr. J. Y Essandoh	Energy Commission	

When the processes for having the inter-agency task force was finalised, the team started to work on the agreed LED activities. Series of informal meetings were held to discuss strategies for data collection and operational matters. In the first two meetings, the team discussed the terms of reference for the team and the work plan. The team deliberated on the selection of sectors and technologies to focus on in the LEDs project. Ghana EPA as the national implementing entity of the LEDs project coordinated the activities of the task force and acted as the liaison with the working group and UNEP.

3.2 Selection of LEDs sectors and technologies

The modelling team held its first meeting to go over the terms of reference and work plan for adoption. They also selected the chairman and the facilitators for the technical teams. One staff from EPA was attached to each of the teams. They were tasked to provide backstop by facilitating access to data and make technical inputs where necessary. The energy task team was led by the Energy Commission played whereas the Forestry Commission and the Ministry of Food and Agriculture led the agroforestry work. The EPA facilitated the soft linking of the results of the technical assessment of cookstove and forest plantation technologies. Each task team was responsible for: (a) data collection and processing, model selection; (b) ex-ante assessment of climate and non-climate benefits of low emission development interventions, (c) soft-linking of the results from the cookstove and plantation assessment results into an amalgamated model.

The second major assignment of the task force performed was the selection and prioritisation of LED technologies. After extensive consultation, the technical team settled on focus on the Energy and Forestry Sectors. The selected sectors were aligned to the NDCs and the national economic development priority areas. Within two selected sectors, technical team settled on cookstove and the agroforestry technologies to focus on. The selection of the two technologies was preceded by a consultative process involving key line ministries through focus group discussion (FGD) in-country.

Under cookstove technology, discussion narrowed on to the increasing adoption of improved cookstoves as priority project areas. The socio-economic impacts (job creation potential, investment decisions etc.) and carbon offsetting potential of adoption of improved cookstoves technology will be assessed. In the same vein, under the Agric/forestry even though the team initially selected agroforestry, after reviewing available in-country data, the team decided to focus rather on the forest/woodfuel plantations in the restoration of grassland in the transition and transitional zones of the country.

3.3 Selection of LEDs modelling tools

3.3.1 Model selection process

The modelling team selected two independent tools to model the climate and socio-economic benefits of the cookstove and plantation NDC measures. And followed up with an excel spreadsheet for the soft-linking of the two model results. The selected models were LEAP (developed by SEI) for cookstove and ABACUS (developed by ICRAF) for the renewable wood fuel plantation. Both were settled on after series of discussions by among stakeholders on the pros and cons. The summary of the justification for selecting the LEAP and ABACUS model are provided below.

A. Justification for selecting LEAP model for the cookstove technology

The energy task team selected the LEAP tool for the integrated LEDs assessment for cookstove. LEAP, the Long-range Energy Alternatives Planning System, is a widely-used software tool for energy policy analysis and climate change mitigation assessment developed at the Stockholm Environment Institute. It has been used by several organisations in more than 190 countries worldwide. Its users include government agencies, academics, non-governmental organisations, consulting companies, and energy utilities. It has been used at many different scales ranging from cities and states to national, regional and global applications.

LEAP[16] is popular in countries undertaking integrated resource planning, greenhouse gas (GHG) mitigation assessments, and Low Emission Development Strategies (LEDS) especially in the developing world, and many countries have also chosen to use LEAP as part of their commitment to reporting to the UN Framework Convention on Climate Change (UNFCCC). At least 32 countries used LEAP to create energy and emissions scenarios that were the basis for their NDCs. LEAP is an integrated, scenario-based modelling tool that can be used to track energy consumption, production and resource extraction in all sectors of an economy. It can be used to account for both energy sector and non-energy sector greenhouse gas (GHG) emission sources and sinks. In addition to tracking GHGs, LEAP can also be used to analyse emissions of local and regional air pollutants, and short-lived climate pollutants (SLCPs) making it well-suited to studies of the climate co-benefits of local air pollution reduction.

The model considered suitable for the exercise because of its unique flexibility to allow for the structuring of the mode to reflect the country's economic structure. Though the tool is data intensive and complex, it is possible to adapt to suit the data situation of the country. Below are the reasons for selecting LEAP as the right choice for the LEDs exercise:

- There is considerable amount of experience in the country in the use of LEAP.
- It is the officially adopt tool for long-term energy planning process in Ghana and mitigation assessment under the national communication process.
- The new LEAP has incorporated non-energy sector into existing energy template.

[16] https://www.energycommunity.org/default.asp?action=introduction

- It has the utility to evaluate emission and socio-economic benefits of mitigation actions in an integrated manner. For example, it is possible to assess the climate and health benefits of selected mitigation action for a different level of implementation.
- It is also possible to depict modelling variables for two or more chosen technologies or policy options.

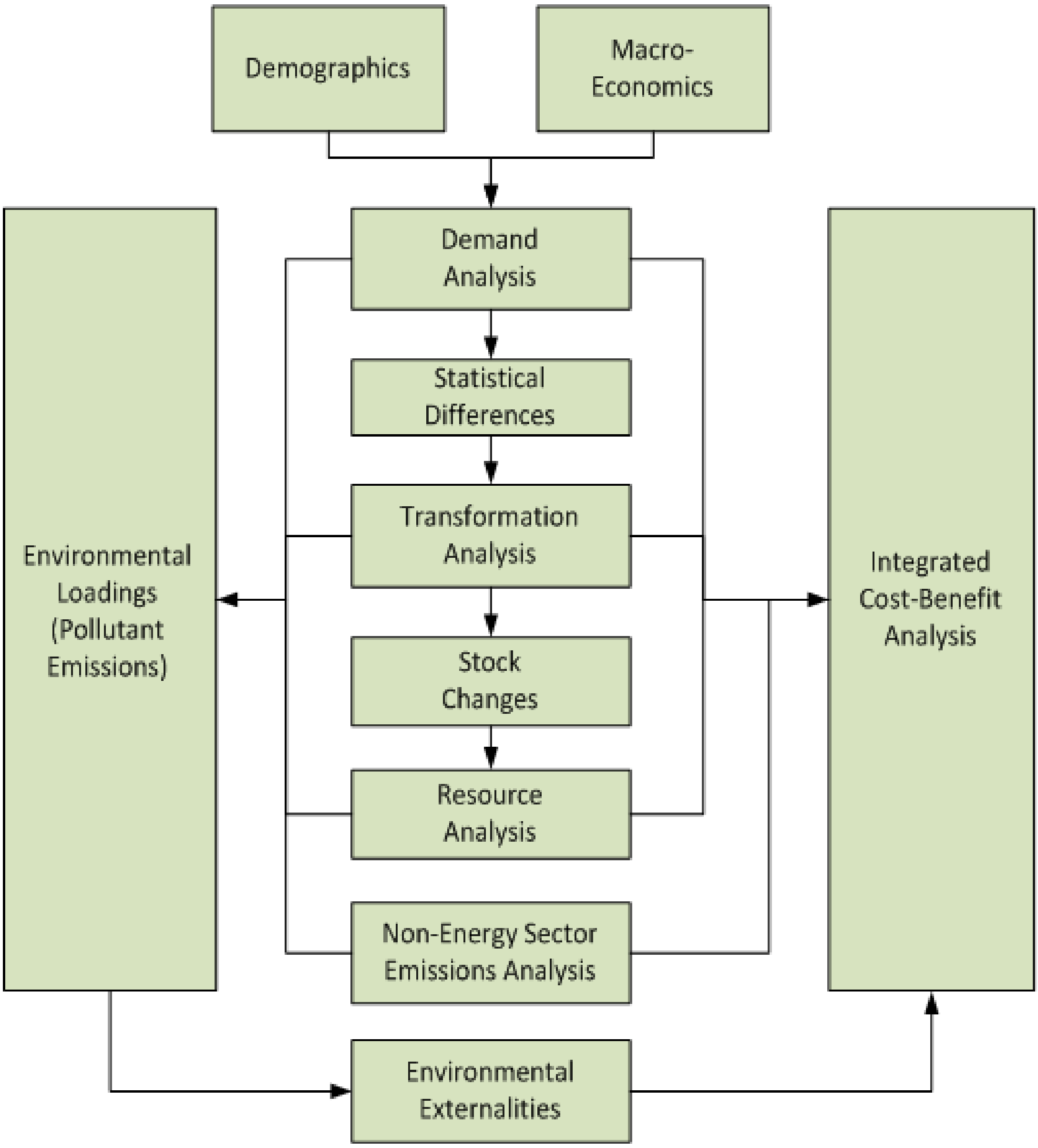

Figure 3: Structure of LEAP's Calculations

The model relied on time series data on the economy, demography, technology, household, electricity, energy resource, fuels and environmental pollutants (Figure 3). With these datasets, the emissions associated with traditional stoves and the alternative scenario of improved stoves were calculated. Emissions and health benefits of the improved cookstove NDC action was evaluated. The major limitation with the LED exercise was the inability to gather data on socio-economic indicators (cost/investment and employment variables) across the value chain of the selected technology to populate the LEAP tool. So, the team decided to use available cost and jobs data for the cookstove manufacturing segment of the value chain and incorporated in the soft-linking analysis. It is also important to stress that it was not possible to disaggregate the results by different gender and demographic groups.

B. Justification for selecting ABACUS model for the forest/woodfuel plantation technology

REDD ABACUS model[17] was used to evaluate the climate and socio-economic impacts of forest/woodfuel plantation as an alternative to converting open forest to grassland for grazing. REDD Abacus is a public domain software developed by the World Agroforestry Centre (ICRAF) to:

- Estimate emission from land use and land cover changes allowing for dynamic heterogeneity of soil types, elevations, climate and other biophysical characteristics in the landscapes
- Analyse trade-offs between emissions and financial gain (opportunity cost analysis) and produce abatement cost curves Project ex-ante emissions and financial gain of business-as-usual scenarios for setting Reference Emission Level (REL)
- Simulate zone-specific policies and other emission reduction scenarios within the landscapes and estimate the potential emission reductions and opportunity costs of them (Figure 4).

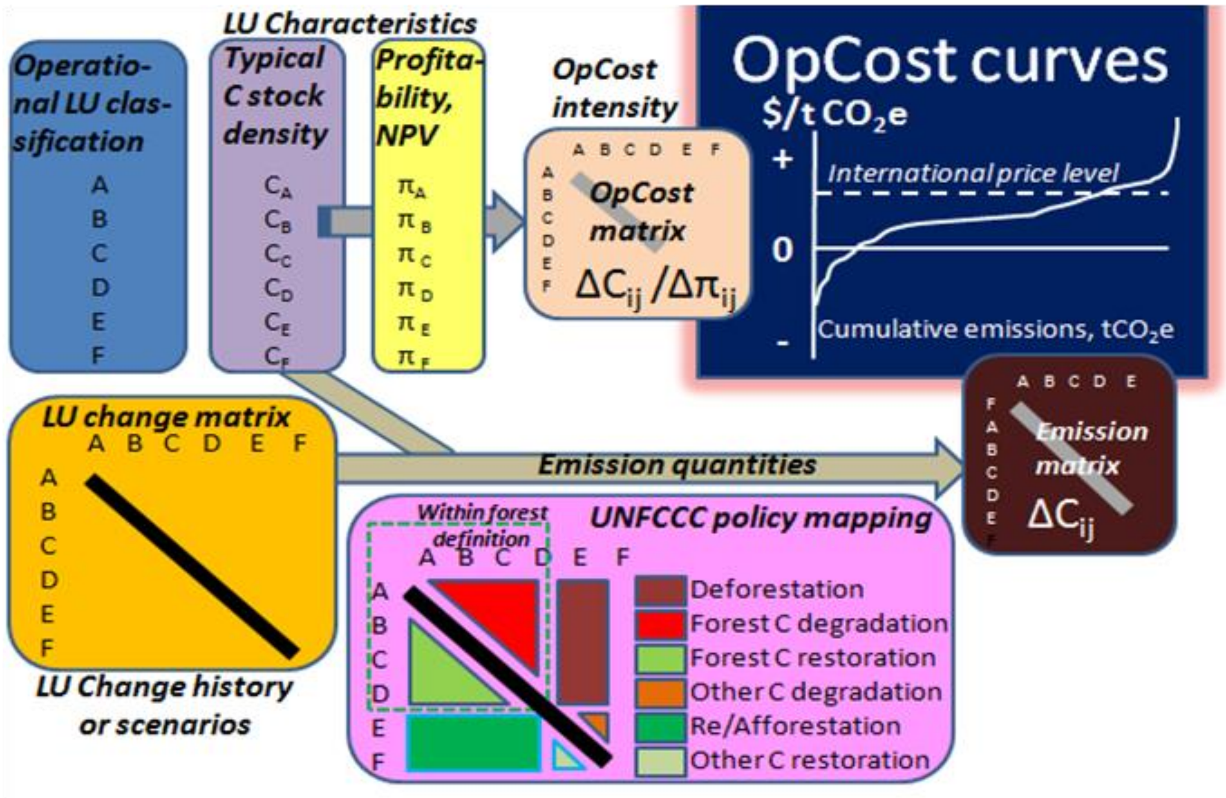

Figure 4: Steps in deriving an opportunity cost (OpCost) curve

[17] http://www.worldagroforestry.org/output/tools/redd-abacus-sp-more

Since REDD ABACUS was new to the forestry/agriculture team, a series of meetings were organised for the members to familiarise themselves with the model and the data requirements. The familiarisation exercise was important because it afforded the members to have real hands-on experience on the ABACUS for the first time.

Following the formalisation with the REDD ABACUS, the team designed the data flow for the wood fuel plantation model and used it to build a test model to see how the actual one will look like. The trial model also helped the team to deal with unresolved data issues. After the initial testing with the available data, the team was convinced the ABACUS would be the right choice for modelling the climate and non-climate effects of wood fuel plantations. The main reason for picking the REDD ABCUS model was its high analytical rigor and the fact existing country data can be used for the model without incurring extra cost to obtain additional data. All the basic data inputs like land-use matrix, corresponding carbon stocks and NPV are available. Another advantage of the REDD ABACUS was the transparent logical sequence of the work flow. Besides the results from the ABACUS, model would be easy to integrate into the cookstove model at the soft—linking stage.

C. Soft-linking of LEAP and REDD ABACUS Model results

One important feature the Africa LEDs project pushed for in the project is the need to explore additional cross-sector climate and socio-economic benefits of the two selected technologies. Ordinarily, the Impacts assessment of the cookstove and wood fuel plantation would have ended at the sector level without looking into the potential extra impacts when the two results are brought together. The soft-linking of the two model results was done using an excel spreadsheet. The results of the LEAP and ABACUS model were pooled for the soft-linking analysis (Figure 5).

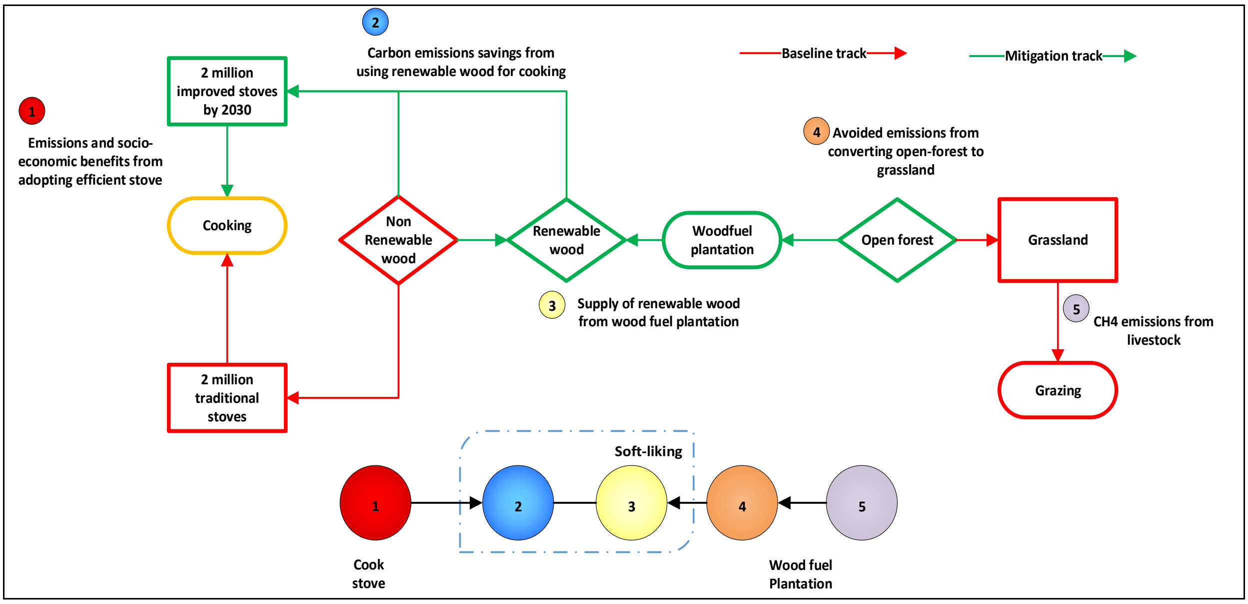

Figure 5: Diagram illustrating the soft-liking steps

3.3.2 Scoping out for suitable model

Before the two teams settled on the LEAP and ABACUS tools as the suitable models for the LEDs assignment, they conducted a review of existing tools being used within the country. In this regard, the team made an inventory to come up with a list of tools/model of past and existing emission tools. For the organisations that had used or still using a model, the team assessed the strength and the challenges of the model in question. The team also identified the capacity levels within the modelling institution, gaps and their needs. Overall, many of the identified LED-related models are applied at the project scale. Most of the reviewed LED models were applied for specific technologies or sectors. Hardly did the team find any of the model designed to depict a comprehensive climate and socio-economic benefits at a go. Different models are in use at the project level in the forest and agriculture sector. Some of the identified models include:

- Agriculture and Land use national GHG inventory software (ALU)[18] developed by Colorado State University.
- Ex-Ante carbon balance tool (EX-ACT)19developed by FAO
- Wood fuel Integrated Supply/Demand Overview Mapping model (WISDOM)20
- Comprehensive Mitigation Assessment Process (COMAP)

The models in the energy sector vary widely, but since the focus was on cookstove, the team listed the applicable tools:

- RETScreen clean energy management software[21];
- GACMO developed by UNEP DTU[22];
- Approved CDM methodology[23] and
- LEAP[24].

For integrated tools with the economy-wide scale, two models were identified as appropriate. LEAP was considered suitable because it has the flexibility to combine energy and non-energy sectors and evaluate emissions and non-emission benefits of climate measures. Another integrated tool the team identified was the Threshold 21 (T21) model[25]. T21 is a dynamic simulation tool designed to support comprehensive, integrated long-term national development planning by comparing different policy options across a wide range of sectors and identifying those leading towards the desired goal. The T21 model was once used by the national development planning commission to provide an analytical basis for the long-term development planning and green economy assessment for the country with support from UNDP[26].

3.3 Modelling

3.3.1 Scope of Ghana LEDs Models

The approach for the LEDs exercise was innovative compared to traditional modelling. The LEDs approach had a broader scope in the evaluation of potential “full effects” of climate actions. In the case of Ghana, climate and sustainable development benefits of cookstove and wood fuel plantation were first assessed using the LEAP and ABACUS models respectively then followed by soft-linking (Figure 6). For climate

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18 https://www.nrel.colostate.edu/projects/alusoftware/software-design/

19 http://www.fao.org/tc/exact/ex-act-home/en/

20 http://www.wisdomprojects.net/global/

21 https://www.nrcan.gc.ca/energy/software-tools/7465

22 http://www.cdmpipeline.org/

23 https://cdm.unfccc.int/methodologies/index.html

24 https://www.sei.org/projects-and-tools/tools/leap-long-range-energy-alternatives-planning-system/

25 https://openei.org/wiki/File:T21.JPG

26 https://www.millennium-institute.org/projects

benefits, CO_2 savings was used as the indicator whereas jobs creation, cost savings, health benefits (avoided death) were used to estimate the sustainable development benefits. This approach was useful because pointed out additional benefits of the measures that would otherwise not be considered in the analysis. Reflecting the combined local and global benefits of climate actions in terms of CO_2 savings, jobs creation, cost savings and health benefits will give a better justification for the implementation of climate actions. Furthermore, the cross-sectoral benefits of the two actions have been calculated at the soft-linking stage. This involves the estimation of additional benefits by linking them together. For cookstoves and wood fuel plantation, 2016 is the baseline with 2030 as the target year. As much as possible, data from national institutions were used.

3.3.2 Model conceptualisation

The LED modelling was in three stages. At stage 1 and 2, climate and sustainable development benefits of the cookstoves and plantation were evaluated using LEAP and the ABACUS models. Stage 3 was on the amalgamation of the two model results. In stage 1, the LEAP tool was used to evaluate the long-term impacts of the government policy to replace 2 million traditional cookstoves with improved cookstove in the energy sector by 2030. Similarly, the REDD ABACUS tool was used to estimate the potential benefits of establishing 9,450 ha of wood fuel plantation as part of the government annual forest plantation of target 25,000 ha up to 2030. The aim of the forest intervention is to convert 12,000 ha of grassland in the transitional ecological zone to wood fuel plantation to produce renewable biomass for the cooking market. In the third stage, the quantities of renewable biomass produced from the wood fuel plantation would replace the corresponding non-renewable wood fuel for domestic and commercial cooking (Figure 5). The 2 million improved cookstoves and the annual 12,000 ha wood fuel plantation are government policies that are captured in the sustainable energy for all action agenda (SEforALL) and the national plantation development strategy documents (FC, 2018). The implementation of the SEforALL and plantation development is led by the Energy and Forestry Commissions respectively.

3.3.3 Model run and results

3.3.3.1 Overview of the Two million improve cookstove strategy

In Ghana, wood biomass still constitutes 67% of total primary energy consumption. More than 70% of households in Ghana still use on wood biomass for cooking which stood at 2,440.1 ktoe in 2016[27]. Seventy-five of rural households use firewood. This translate to about 2.2 million total available rural woodstove market[28]. Besides, majority of the traditional stoves used in households and commercials cooking is known to grossly efficient. This

Figure 6: Traditional cooking stoves

[27] http://energycom.gov.gh/files/ENEERGY_STATISTICS_2017_Revised.pdf

[28] http://www.snv.org/public/cms/sites/default/files/explore/download/20171217_snv_ghana_rural_woodstove_study.pdf

implies that the traditional burn more non-renewable wood to produce less heat for cooking. Replacing the traditional stove with efficient stoves for cooking the performance differ widely depending on the type of stove from 5-20% thermal efficiency. The traditional cookstoves are made locally from mud or metal, are slightly more fuel-efficient than the three-stone fire, yielding as much as 15 fuel saving (Figure 7). The use of wood fuel for cooking is still dominant and continue to be part of cooking technologies mix in the years for come even though it has serious health and environmental consequences. Wood fuel harvesting and its use for cooking exert pressure on forest resources, indoor air pollution and global warming. Modernising cooking is a major government intervention to promote access to alternative fuels and improved stoves. In the past three decades, the government’s LPG promotion policy has helped access to LPG for cooking. The current focus on rural areas where the use of wood fuel for cooking is still on the high side. There are additional efforts to facilitate greater adoption of the improved stove instead of the low-quality stoves.

Figure 7: Man, and Man Improved stoves

The promotion of access to clean fuel and the adoption of efficient stove underpin Ghana’s NDCs strategy on clean cooking. The clean cooking NDC targets the distribution of 2 million improved cookstoves by 2030 and the 50 of the household adopting for cooking in the same period. Under this study, the focus is on the assessment of the emissions and sustainable development benefits for disseminating the 2 million improved cookstoves (Figure 8). The dissemination and use of the 2 million improved cookstoves are expected to reduce the total wood fuel consumption in the country. It will also help reduce the pressure on forest resources, cut down greenhouse emissions and indoor pollution. The manufacture and distribution of the 2 million improved stoves are also expected to increase investments in the country, create jobs and increase incomes of those involved in the stoves market.

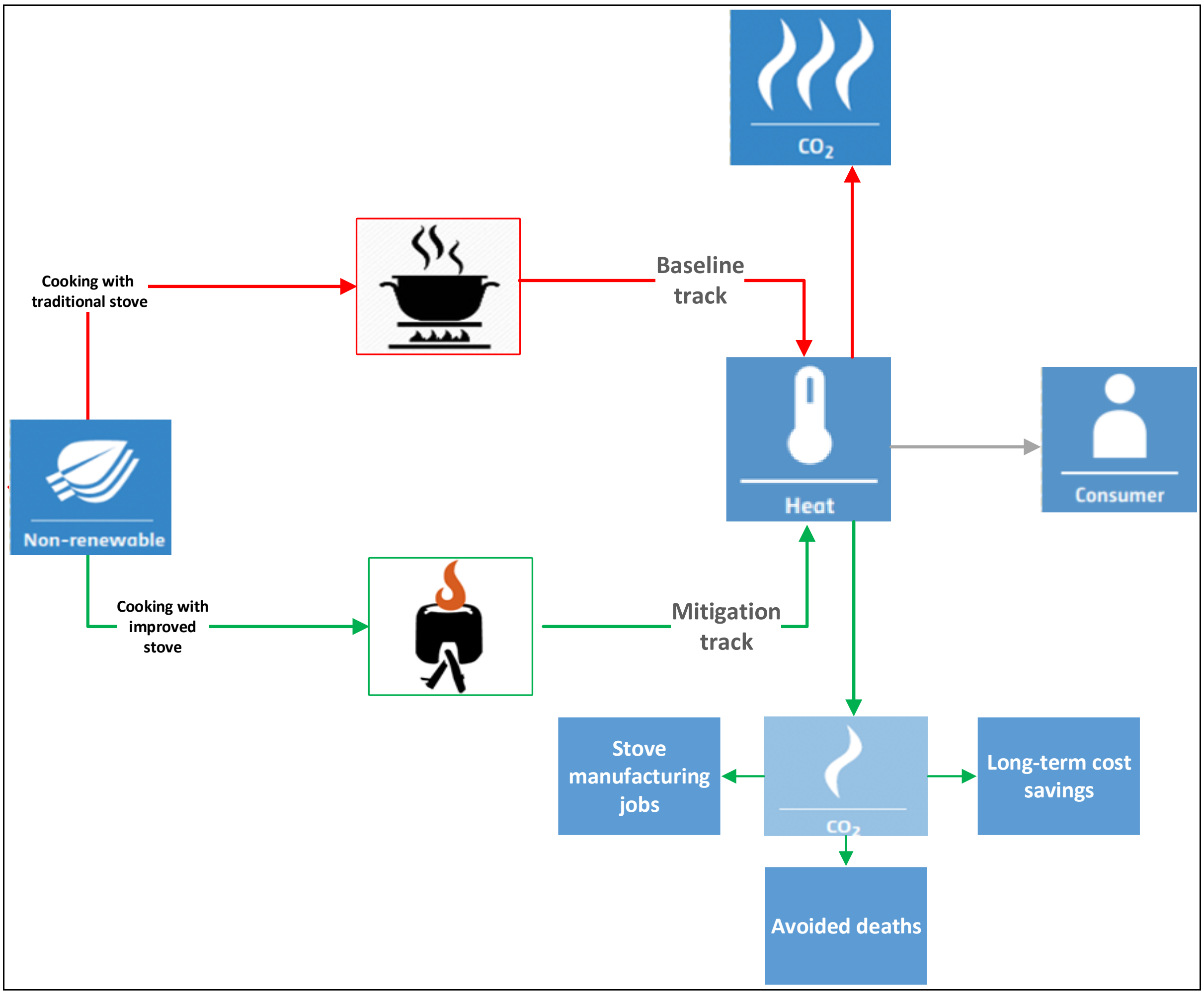

Figure 8: Emissions and socio-economic benefits for adopting improve cook stoves

3.3.3.2 Summary of LEAP Model and results of the two million improve cookstove strategy

The LEAP tool uses a wide range of dataset from macroeconomic indicators, household and services data, cookstove technology penetration and market information and their environmental loadings (Figure 9). The data were obtained from a national database managed by the team working on strategic national energy planning at the Energy Commission. The Energy Commission's data covered stocks for different energy resources, demand projections, electricity supply and transmission, energy intensities etc. Macroeconomic, households and demographic data were collected from the Ghana Statistical Service (GSS). GSS regularly publishes demographic and household data through the census and living standard surveys. The idea of using the already existing national data for the LED was to ensure consistency across the figures in the energy statistics, NDCs baselines and the national communications. In additional statistics on the cost profile (technology deployment and maintenance cost, fuel cost, depreciation, replacement cost and discount rate etc.) and "lifetime" net job creation were collected from the Energy Commission to enrich the analysis. The model baseline was set to 2016 upon which the business-as-usual (BAU) and alternative technology adoption was projected up to 2030. The emissions for the baseline, BAU and future alternative scenarios were derived using the technology activity, fuel intensity and the IPCC emission factors of selected gases (CO_2, CH_4, N_2O, $PM_{2.5}$ etc).

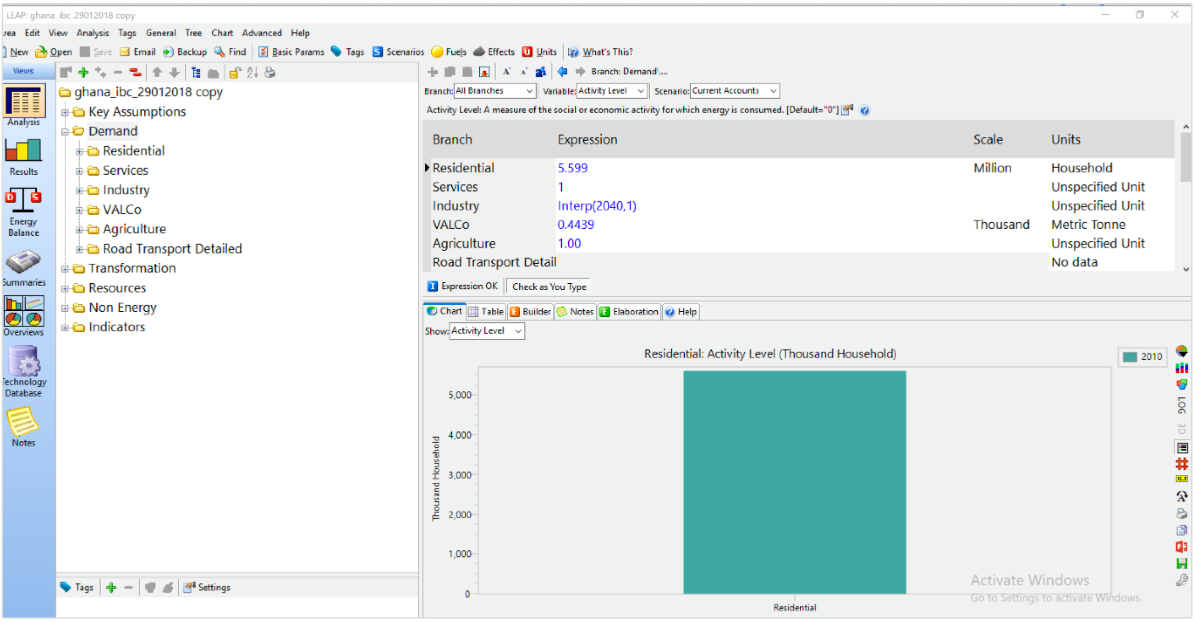

Figure 9: Screenshot of the LEAP model showing the broad data inputs

The alternative scenario referred to as the improved cookstove strategy scenario. The improves cookstoves was pegged at equal annual rates over 14 years until the 2 million stoves are achieved in 2030. The potential climate and socio-economic benefits (avoided mortality, cost savings and job creation) were estimated generated for cookstove and combined as the aggregate effects. The Business-as-Usual scenario (BaU) depicted cooking with traditional stoves using non-renewable wood with very limited adoption of improved cookstoves (Table 3). The improved cookstove policy depicted an alternative scenario with the increased adoption of improved cookstoves for cooking. The potential effects of the improved cookstove policy on the baseline are calculated as the differences between the BAU traditional cookstove scenario and alternative 2 million improved cookstoves by scenario by 2030.

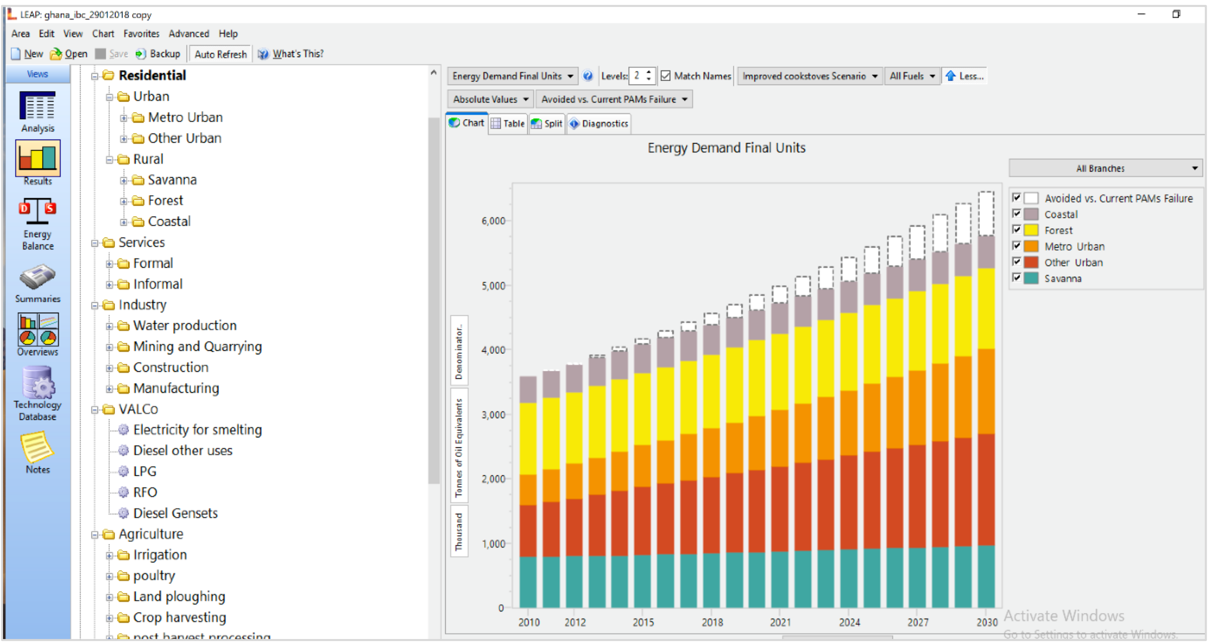

Figure 10: The differences in final energy demand in residential sector for BAU and the improved cookstove scenario

The total carbon emissions associated with the BAU scenario Is most likely to increase from 49,181.5 t in 2016 to 75,253.92 t. Carbon dioxide will consistently makes 72% of the projected 2030 emissions for traditional stoves. This will be followed by methane and nitrous oxide emissions.

Table 3: Business as usual greenhouse gas emissions associated with traditional stoves

Year	No. of traditional stoves	Wood consumption per stove (t)	Carbon content of wood (t/yr)	fNR* Wood	EF (kg CH_4/kt)	EF (kg N_2O/kt)	CO_2 emissions (tCO_2e)	CH_4 emissions (tCO_2e)	N_2O emissions (tCO_2e)	Total emissions (tCO_2e)
2016	98,426	0.445	0.22	99%	12.5	0.17	35,375.9	11,497.409	2,308.242	49,181.535
2017	120,554	0.445	0.22	99%	12.5	0.17	43,329.1	14,082.255	2,827.180	60,238.520
2018	122,723	0.445	0.22	99%	12.5	0.17	44,108.6	14,335.602	2,878.043	61,322.245
2019	124,933	0.445	0.22	99%	12.5	0.17	44,902.9	14,593.762	2,929.871	62,426.553
2020	127,185	0.445	0.22	99%	12.5	0.17	45,712.2	14,856.792	2,982.678	63,551.697
2021	129,394	0.445	0.22	99%	12.5	0.17	46,506.1	15,114.796	3,034.475	64,655.338
2022	131,638	0.445	0.22	99%	12.5	0.17	47,312.7	15,376.962	3,087.108	65,776.785
2023	133,918	0.445	0.22	99%	12.5	0.17	48,132.2	15,643.313	3,140.581	66,916.133
2024	136,234	0.445	0.22	99%	12.5	0.17	48,964.7	15,913.869	3,194.899	68,073.469
2025	138,587	0.445	0.22	99%	12.5	0.17	49,810.2	16,188.649	3,250.064	69,248.873
2026	140,924	0.445	0.22	99%	12.5	0.17	50,650.1	16,461.631	3,304.868	70,416.584
2027	143,294	0.445	0.22	99%	12.5	0.17	51,502.0	16,738.501	3,360.453	71,600.931
2028	145,697	0.445	0.22	99%	12.5	0.17	52,365.8	17,019.264	3,416.820	72,801.930
2029	148,134	0.445	0.22	99%	12.5	0.17	53,241.7	17,303.923	3,473.969	74,019.592
2030	150,604	0.445	0.22	99%	12.5	0.17	54,129.5	17,592.479	3,531.900	75,253.922

* fNR – fraction of non-renewable wood, Calorific value of wood (MJ/kg) = 15

Using an average cost of US$5.5 per traditional stove, the total average annual investment of US$ 730.49 million would be required to disseminate 132,816 stoves. Likewise, at annual average US $0.53 per kg of wood fuel, a total of US$ 31.31 million would be required to invest in fuel cost up to 2030. Annual average levelized investment of US$ 85.8 thousand would be required. This brings the total projected average investment to US$ 32.14 million for the 14-year period.

Table 4: Investment analysis associated with the traditional stoves

Year	Number of traditional stoves	Average Cost of traditional stove	Wood fuel cost	Efficiency of traditional fuel	Total investment	Annual fuel cost	Stove life	Discount rate	Levelised investment	Total annual cost	Total cost
		(US$ @ 5 GhS)	(US$ @ 5 GhS/kg)	%	US$ ('000)	US$ (million)	Years	%	$ ('000)	$ (million)	$ (million)
2016	98,426	5.5	0.53	10	541.34	23.21	20	10	63.59	23.28	23.82
2017	120,554	5.5	0.53	10	663.05	28.43	20	10	77.88	28.51	29.17
2018	122,723	5.5	0.53	10	674.98	28.94	20	10	79.28	29.02	29.70
2019	124,933	5.5	0.53	10	687.13	29.47	20	10	80.71	29.55	30.23
2020	127,185	5.5	0.53	10	699.52	30.00	20	10	82.17	30.08	30.78
2021	129,394	5.5	0.53	10	711.67	30.52	20	10	83.59	30.60	31.31
2022	131,638	5.5	0.53	10	724.01	31.05	20	10	85.04	31.13	31.86
2023	133,918	5.5	0.53	10	736.55	31.58	20	10	86.51	31.67	32.41
2024	136,234	5.5	0.53	10	749.29	32.13	20	10	88.01	32.22	32.97
2025	138,587	5.5	0.53	10	762.23	32.69	20	10	89.53	32.78	33.54

2026	140,924	5.5	0.53	10	775.08	33.24	20	10	91.04	33.33	34.10
2027	143,294	5.5	0.53	10	788.12	33.80	20	10	92.57	33.89	34.68
2028	145,697	5.5	0.53	10	801.34	34.36	20	10	94.12	34.46	35.26
2029	148,134	5.5	0.53	10	814.74	34.94	20	10	95.70	35.03	35.85
2030	150,604	5.5	0.53	10	828.32	35.52	20	10	97.29	35.62	36.45

The improved cookstove strategy is the alternative scenario with 2 million improved cookstoves replacing traditional stoves by 2030. This policy is expected to generate multiple outcomes in the areas of climate changes, jobs, investments and health. The resultants positive impacts will occur the policy is fully implemented. First, the results showed an ambitious carbon emission reduction with this policy. A total of 50% carbon emissions cut compared to the BAU emission are expected by 2030 (Table 5). Table 5 further reveals that the annual average emissions are likely to decline from 66,365.61 t CO_2eq for BAU scenario to 32,873.479 t CO_2eq for the improve cookstove strategy.

Table 5: Greenhouse gas emissions associated with the improve cookstove strategy

Year	No. of improved stoves	Wood consumption per stove (t)	Carbon content of wood (t/yr)	fNR* Wood	EF (kg CH_4/kt)	EF (kg N_2O/ kt)	CO_2 emissions (tCO_2e)	CH_4 emissions (tCO_2e)	N_2O emissions (tCO_2e)	Total emissions (tCO_2e)
2016	98,426	0.2981	0.149	99%	12.5	0.17	15,872.8	7,701.455	1,546.159	25,120.393
2017	120,554	0.2973	0.149	99%	12.5	0.17	19,343.6	9,409.161	1,889.001	30,641.747
2018	122,723	0.2966	0.148	99%	12.5	0.17	19,591	9,553.954	1,918.070	31,063.073
2019	124,933	0.2958	0.148	99%	12.5	0.17	19,843.1	9,701.408	1,947.673	31,492.186
2020	127,185	0.2951	0.148	99%	12.5	0.17	20,098.5	9,851.222	1,977.750	31,927.417
2021	129,394	0.2943	0.147	99%	12.5	0.17	20,342.3	9,996.484	2,006.913	32,345.678
2022	131,638	0.2936	0.147	99%	12.5	0.17	20,589.8	10,143.957	2,036.520	32,770.252
2023	133,918	0.2928	0.146	99%	12.5	0.17	20,839.6	10,293.300	2,066.502	33,199.329
2024	136,234	0.2921	0.146	99%	12.5	0.17	21,090.5	10,444.147	2,096.787	33,630.979
2025	138,587	0.2913	0.146	99%	12.5	0.17	21,344.2	10,597.199	2,127.514	34,068.863
2026	140,924	0.2906	0.145	99%	12.5	0.17	21,592.5	10,748.150	2,157.819	34,498.419
2027	143,294	0.2898	0.145	99%	12.5	0.17	21,840.9	10,900.338	2,188.373	34,929.617
2028	145,697	0.2890	0.145	99%	12.5	0.17	22,092.5	11,054.490	2,219.321	35,366.267
2029	148,134	0.2883	0.144	99%	12.5	0.17	22,345.6	11,210.220	2,250.585	35,806.356
2030	150,604	0.2875	0.144	99%	12.5	0.17	22,593.8	11,365.927	2,281.845	36,241.612

The total investments required to adopt 2 million will rise by 71% from a cumulative total of US$ 10,957,352 over the 14-year period (Table 6). The growth in the investment cost is attributed to the high-cost improved cookstove pegged at the unit price of US$ 17 as against US$ 5.5 for traditional stoves. The annual cost will cover fuel and levelised cost. Table 6 shows a slightly low fuel cost for the policy scenario. The slum in the cost will be driven lower fuel cost for in improved stoves relative to the traditional stoves. The annual variable cost will also be determined relatively short-lifetime and the discount rate which will be comparatively 5 years lower than traditional stoves. General, the total cost (investment and annual cost) of the improved stove strategy will be 39% lower than the traditional stoves (Table 6). Additionally, the improves stoves strategy is likely to create an average of 618 jobs per year and a total of 9,266 job over the 14 years.

Table 6: Investment analysis associated with the improved cookstove strategy

Year	No. of improved stoves	Average Cost	Wood fuel cost	Efficiency of traditional fuel	Total investment	Annual fuel cost	Stove life	Discount rate	Levelized investment	Total annual cost	Total cost	Jobs created
		(US$ @ 5 GhS)	(US$ @ 5 GhS/kg)	%	US$ ('000)	US$ (million)	Years	%	$ ('000)	$ (million)	$ (million)	Number
2016	98,426	17	0.53	30	1,673.25	15,549.60	15	10	219.99	15,769.6	17,442.84	457.80
2017	120,554	17	0.53	30	2,049.42	18,997.54	15	10	269.45	19,266.9	21,316.41	560.72
2018	122,723	17	0.53	30	2,086.29	19,289.89	15	10	274.29	19,564.2	21,650.48	570.81
2019	124,933	17	0.53	30	2,123.86	19,587.60	15	10	279.23	19,866.8	21,990.70	581.08
2020	127,185	17	0.53	30	2,162.14	19,890.09	15	10	284.27	20,174.4	22,336.50	591.56
2021	129,394	17	0.53	30	2,199.69	20,183.38	15	10	289.20	20,472.6	22,672.27	601.83
2022	131,638	17	0.53	30	2,237.85	20,481.13	15	10	294.22	20,775.4	23,013.20	612.27
2023	133,918	17	0.53	30	2,276.61	20,782.66	15	10	299.31	21,081.9	23,358.59	622.88
2024	136,234	17	0.53	30	2,315.98	21,087.23	15	10	304.49	21,391.7	23,707.70	633.65
2025	138,587	17	0.53	30	2,355.97	21,396.25	15	10	309.75	21,706	24,061.97	644.59
2026	140,924	17	0.53	30	2,395.70	21,701.03	15	10	314.97	22,016.0	24,411.70	655.46
2027	143,294	17	0.53	30	2,435.99	22,008.30	15	10	320.27	22,328.6	24,764.56	666.48
2028	145,697	17	0.53	30	2,476.85	22,319.54	15	10	325.64	22,645.2	25,122.04	677.66
2029	148,134	17	0.53	30	2,518.28	22,633.97	15	10	331.09	22,965.1	25,483.34	689.00
2030	150,604	17	0.53	30	2,560.28	22,948.35	15	10	336.61	23,284.9	25,845.23	700.49

The improved cookstove strategy has multiple benefits. It is expected to produce a cumulative total greenhouse emission of 77,225.6 t CO_2eq by 2030 (Table 7). Similarly, a total of US $134.94 million would be saved in the long run from the improve cookstove strategy. In terms of jobs, 9,266 stove manufacturing jobs will be created over the period.

Table 7: CO_2 Savings, investment savings, number of jobs created for the improved cookstove strategy

Year	Total emissions savings (tCO_2e)	Total savings (US$ million)	Av. No. of persons required to produce improved stove per year @215 stoves/person	US$/t CO_2
2016	24,061.14	6.38	457.80	264.99
2017	29,596.77	7.86	560.72	265.48
2018	30,259.17	8.05	570.81	265.97
2019	30,934.37	8.24	581.08	266.46
2020	31,624.28	8.44	591.56	266.94
2021	32,309.66	8.64	601.83	267.43
2022	33,006.53	8.84	612.27	267.91
2023	33,716.80	9.05	622.88	268.38
2024	34,442.49	9.26	633.65	268.87
2025	35,180.01	9.48	644.59	269.34
2026	35,918.17	9.69	655.46	269.81
2027	36,671.31	9.91	666.48	270.29
2028	37,435.66	10.14	677.66	270.76
2029	38,213.24	10.36	689.00	271.23
2030	39,012.31	10.60	700.49	271.72

The 2 million improved cookstove strategy is expected to reduce indoor pollution and the corresponding health impacts. Apart from the benefits of reducing emissions from the adoption of improved cookstove, there are additional health benefits (Figure 11).

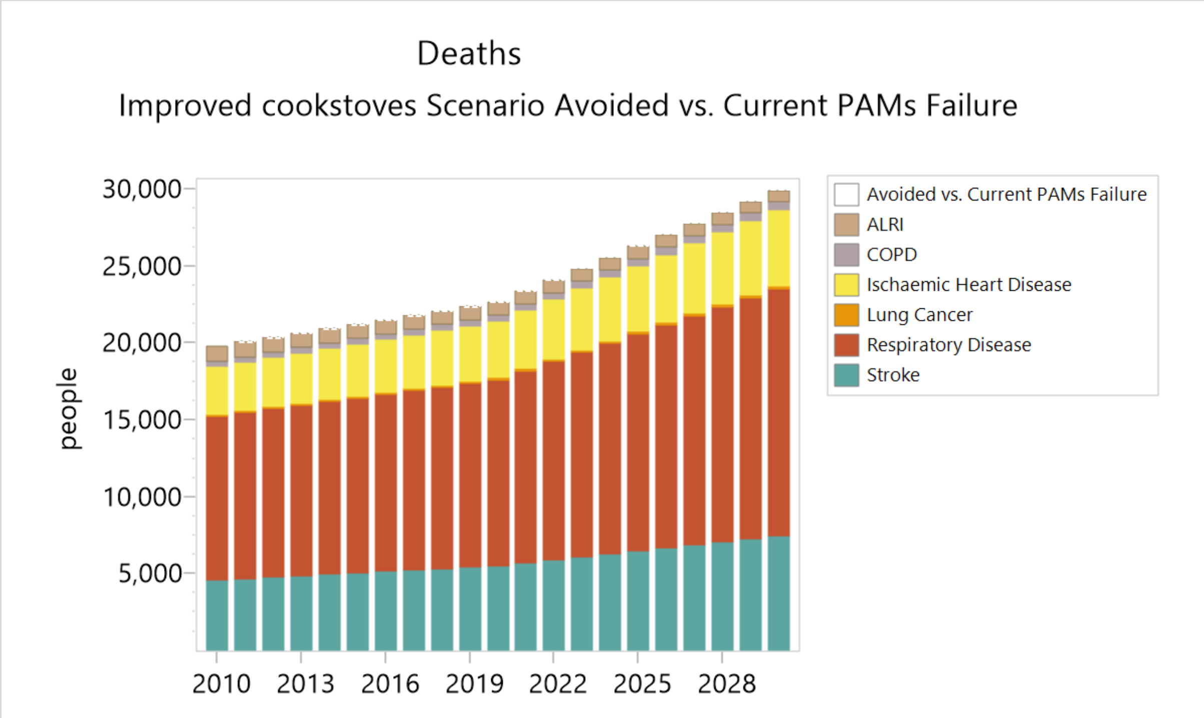

Figure 11: Potential avoided death effects of the improved cookstove strategy

The model results further revealed additional health benefits expressed in terms of avoided mortality due to exposure to the concentration of polluted air (mainly black soot emissions). In all, a total estimated 599 lives are to be saved from death due to the exposure black soot if the cookstove/biogas technologies were to be adopted for household cooking especially in rural Ghana (Figure 11). Most of the ambient pollutants that are likely to remain in the atmosphere would mainly be an ozone precursor and those of natural background.

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3.3.3.3 Summary of REDD ABACUS Model and results of the wood fuel plantation strategy

The ABACUS model was originally developed to evaluate REDD+ project potentials and has been adapted to suit the wood fuel plantation strategy. It relies on data such as land-use, carbon stocks and Net Present Value (NPV) to assess the effects of land use change on net carbon emissions and the opportunity cost thereof. In this assessment, two individual decade land-use maps for 2000 and 2015 (used for 2016) were generated for the whole country using Landsat images. Both land-use maps originally had eight land representation but were subsequently reclassified to align with the wood fuel plantation strategy (Figure 12).

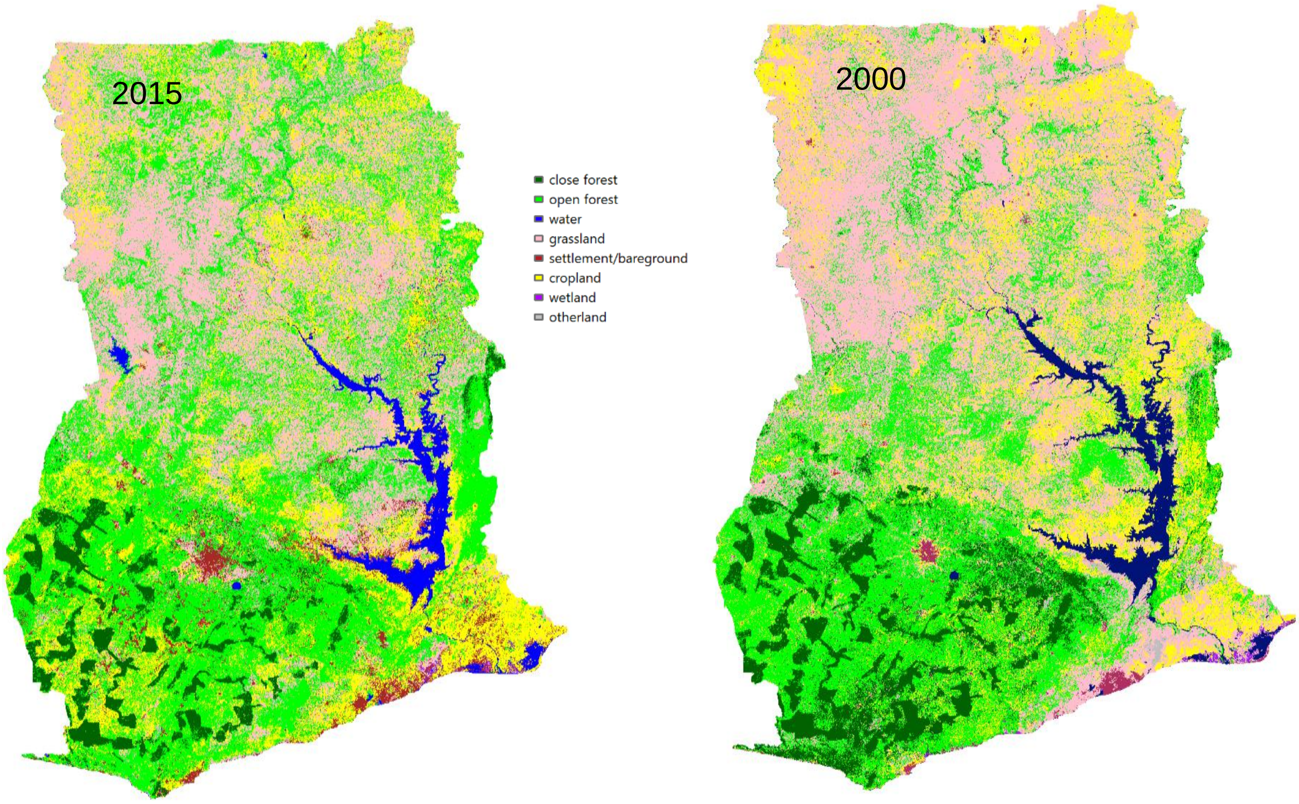

Figure 12: 2000 and 2015 land cover maps used in the ABACUS Model

The wood fuel plantation strategy targeted degraded areas in the transitional ecological zone. The degraded areas were open-forest and grasslands. Therefore, both land-use maps were clipped to fit the geographic borders of the savanna, semi-deciduous inner zone and semi-deciduous fire zone totalling 16,754,733.1 ha (Figure 13). After the clipping, the initial land categories were further reclassified close forest, open forest, grassland, cropland, forest plantation, wood fuel plantation, settlement and others[29]. Though the forest plantation class was not originally isolated in the land-use maps, it was they were classified as part of the open-forest category. The reason being that the technology to map the landscape was not capable to delineate the plantation nationwide. So, the open-forest areas were adjusted to first separate the forest plantation from it out of which wood fuel plantation area was estimated.

[29] “Others” category included areas originally labelled as wetlands, water, other lands.

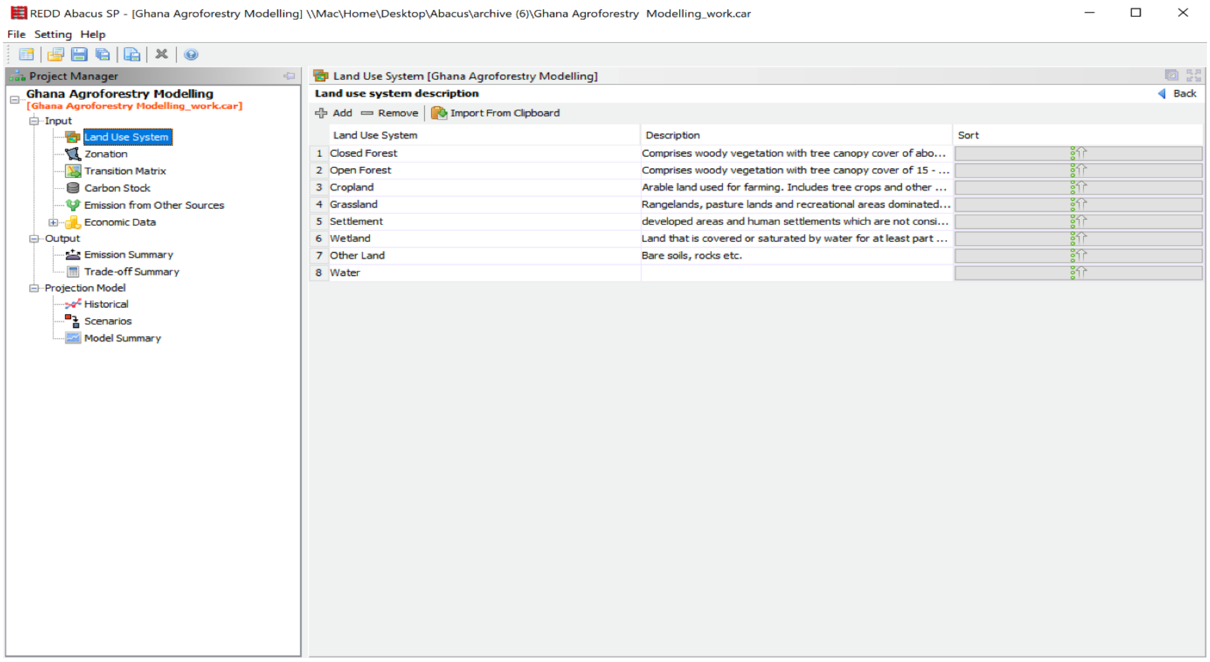

Figure 13: REDD ABACUS Interface

Another critical input is data carbon stocks. It requires each of the land-cover types to have a corresponding reference carbon stock both in the reference/BAU scenario and the mitigation/wood plantation scenario. The carbon stocks figures used in this exercise was obtained from the Forestry Commission's Forest Preservation Programmes study. Similarly, each of the land-cover types was assigned unique NPV values derived from national reports and expert judgement.

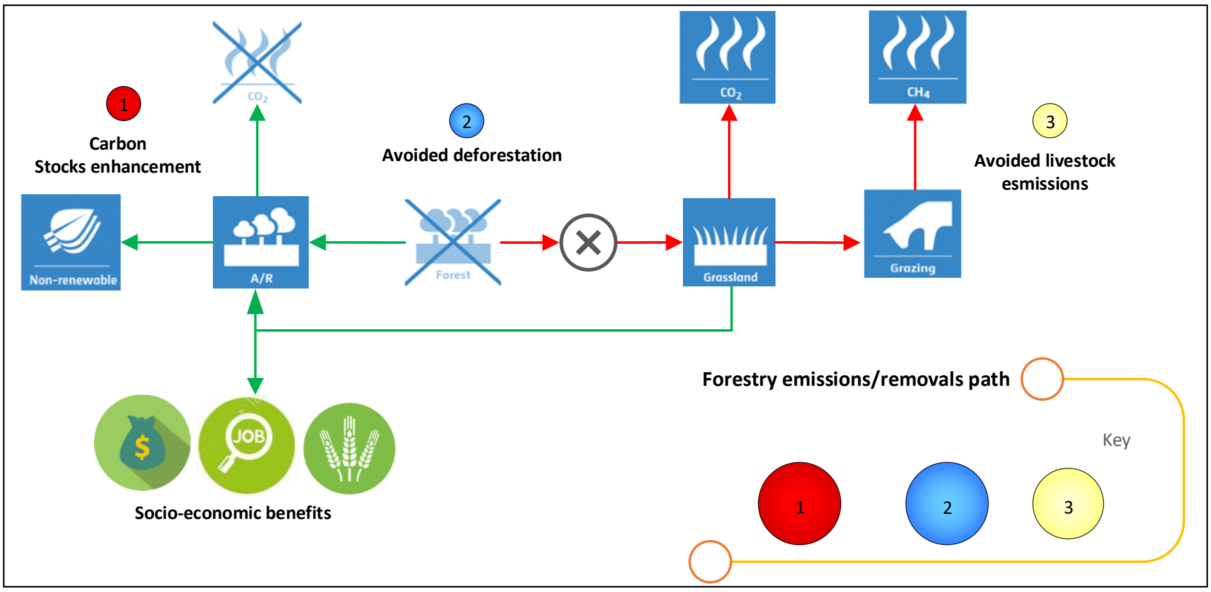

Figure 14: Schematic of the impacts of the wood fuel plantation strategy

With this dataset, ABACUS made it possible to evaluate the emissions/removals and opportunity cost associated with land-cover change matrix for each period. The reference scenario and the alternative wood fuel plantation strategy were modelled for the period was for the period 2016-2030. The scope of the strategy was to convert 12,000 ha per annum of degraded areas (mainly grassland or avoided open-forest areas) in the selected ecological zones to product renewable woodfuel for the cookstove market.

A. Reference scenario

A.1. Land-use classification

Table 8 presents the various land-use categories identified in the transitional zone as potential wood fuel plantation areas for 2016. Table 8 also shows that the total forest and wood fuel plantation areas as of 2016 were estimated at 5,116.5 ha, making up 0.03% of the total area. On the other hand, grassland constitutes 53% of the entire area (Table 8). In terms of carbon stocks, while wood fuel plantation had an average of 128.57 tCO_2/ha and that of grassland was 65.6 tCO_2/ha. In terms of economic figures, the wood fuel plantation had a positive NPV of 28,570 compared to the grassland of -476.64. The NPV figures were retrieved from the cost outlay data usually published by the Forestry Commission as part of the annual progress report of the plantation development project. The NPVs values for the rest of the land-use classes such as forest, cropland, grassland and settlement were based on the expert judgement of the forest/agriculture team.

Table 8: Land-cover types and the corresponding carbon stocks and NPV values in the reference scenario

Land use class	**Area at assessment period start (ha)**	**Carbon stock data Total carbon (tCO_2/ha)**	**Total carbon (tCO_2/ha)**	**NPV Economic data**
close forest	244,051.83	578.76	157.87	3,855.27
open forest	3,483,746.05	320.85	87.52	-988.51
grassland	8,959,531.50	240.50	65.60	-476.64
cropland	3,193,212.33	302.98	82.65	3,875.81
forest plantation	13,833.50	358.20	97.71	28,570
woodfuel plantation	5,116.50	471.32	128.57	28,570
settlements	75,508.02	157.00	42.83	3,288.00
all others	779,733.36	202.10	55.13	-98.92
Total	16,754,733.09			

A.2. Land-use matrix of the reference scenario

Table 9 presents the land-use transitions projected to occur in the study area for the period 2016 and 2030 under the reference scenario[30]. It is worthy to note that during the period, the different transition pathways and intensities among the various land-use classes are have been projected to happen. But of key interest to this study is the conversion of 46,792ha of grassland to wood fuel plantation. As a result, the total area of wood fuel plantation will increase from 5,116.5ha in 2016 to 51,908.5ha in 2030. This translates into a conversion rate of 3,342.3 ha per annum which sufficiently inadequate compared to the national target of 12,000 ha.

Table 9: Land-use change matrix for the reference scenario for 2016

Initial (change from initial land cover) / Final (change to final stage/latest land cover classification) (ha)									
Land-cover types	close forest	open forest	grassland	cropland	forest plantation	woodfuel plantation	settlement	all others	Total (ha) - 2016
close forest	17,291.9	155,012.6	40,068.1	25,755.6	-	-	3,669.48	2,254.00	244,051.7
open forest	43,911.7	1,385,061.7	1,323,401.3	497,259.5	126,511.	46,792	53,825.85	6,982.83	3,483,745.9
grassland	28,767.6	2,633,587.9	4,697,737	1,459,179.1	-	-	114,261.66	25,998.21	8,959,531.5

[30] The reference scenario represents the status quo where open-forest-grassland conversion is the main driver of deforestation

cropland	14,749.7	972,310.3	1,271,833.2	847,120.7	-	-	81,177.84	6,020.55	3,193,212.3
forest plantation	-	-	-	-	13,833.	-	-	-	13,833.5
woodfuel plantation	-	-	-	-	-	5,116.5	-	-	5,116.5
settlement	74.97	10,278.7	17,527.8	24,594	-	-	22,832.82	200.00	75,508.3
all others	1,006.2	48,159.72	90,128.1	76,312.5	-	-	39,375.36	524,751.00	779,732.9
Total (ha) - 2030	105,802.2	5,204,410.96	7,440,695.1	2,930,221.4	140,344.5	51,908.5	315,143.01	566,206.59	16,754,732.6

Table 10 and 11 show the implications of the land-use transition for the period 2016 and 2030 on net CO_2 emission and the resultant opportunity cost.

A.3. Net GHG emission matrix for the reference scenario

The results in Table 10, reveals that grassland as the largest land-use category totalling 7,440,695.1 ha 2030. With this, the largest gain of 1,323,401.3 ha to grassland will come from open-forest in a status-quo scenario. This large transfer of open-forest to grassland will lead to emissions of 106,335,295.3 tCO_2 over the 14-year period. If this conversion rate continues the same trajectory in the future, it can become the largest source of emissions in the country. Conversely, there is a great opportunity to restore 46,792 ha of grassland to wood fuel plantation with the potential to accumulate a total of 7,040,792.2 tCO_2 over the 14 years. This level of carbon accumulation would not be as much as the quantities of net emissions that will be lost through open-forest to grassland should it occur with that level of magnitude. However, if the wood plantation is logged according to the laid down plan, the total carbon removal would not be much as in areas where logging damage is high. The collateral impact would be far lower than the figure reported in Table 10.

Table 10: Total net GHG emissions from land-cover change between 2016 and 2030 under reference scenario

Initial/Final	close forest	open forest	grassland	cropland	forest plantation	woodfuel plantation	settlement	all others
close forest	-	(39,979,294.5)	(13,553,432.1)	(7,102,871.1)	-	-	(1,547,639.9)	(848,991.6)
open forest	11,325,271.7	-	(106,335,295.3)	(8,886,026.4)	4,724,806.3	7,040,792.2	(8,819,365.5)	(829,211.1)
grassland	9,730,928.4	211,608,789.4	-	91,169,509.5	-	-	(9,540,848.6)	(998,331.3)
cropland	4,067,683.3	17,375,185.4	(79,464,138.3)	-	-	-	(11,850,341.1)	(607,353.1)
forest plantation	-	-	-	-	-	-	-	-
Woodfuel plantation	-	-	-	-	-	-	-	-
settlements	31,619.4	1,684,168.3	1,463,568.8	3,590,236.5	-	-	-	9,020
all others	378,995.3	5,718,966.8	3,460,917.9	7,698,408.0	-	-	(1,775,828.7)	-

A.4. Opportunity cost matrix for the reference scenario

Generally, grassland-plantation conversions present a negative opportunity cost, though the areas would be not as large as the open-forest to grassland. This suggests converting open-forest to wood fuel plantation regardless of the scale would be a far greater good than the alternative to grassland. The conversion can lead to a total saving of US$ 1,383.1 million monetary equivalents for the period 2016-2030 (Table 11).

Table 11:Opportunity costs per tCO_2 in US$ between 2016 and 2030 under reference scenario

Initial/Final	close forest	open forest	grassland	cropland	forest plantation	woodfuel plantation	settlement	all others
close forest	-	(18.78)	(12.81)	0.07	-	-	(1.35)	(10.50)
open forest	(18.78)	-	6.37	272.21	(791.46)	(196.44)	26.10	7.49
grassland	(12.81)	6.37	-	(69.66)	-	-	45.09	9.84
cropland	0.07	272.21	(69.66)	-	-	-	(4.03)	(39.40)
forest plantation	-	-	-	-	-	-	-	-
woodfuel plantation	-	-	-	-	-	-	-	-
settlements	(1.35)	26.10	45.09	(4.03)	-	-	-	75.10
all others	(10.50)	7.49	9.84	(39.40)	-	-	75.10	-

B. Impacts of the wood fuel plantation strategy

The wood fuel plantation strategy aims at converting portions of the grassland areas in the transitional zone into productive wood fuel plantation. The programme is part of the national plantation development strategy. It is also one of the unconditional NDCs mitigation action being coordinated by the Forestry Commission. The implementation of the strategy is expected to the establishment of 168,000 ha wood fuel plantation on open-forest (degraded land). The plantation will able to produce 19,035,000 tonnes of renewable wood fuel and bring in investments, foods and estimated jobs of 3,628,800. The conversion of more grassland to wood fuel plantation would enhance the carbon stocks far more than otherwise becoming grassland. In the nutshell, instead of allowing 162,000 ha of the open-forest to be converted to grassland to produce emissions, the wood fuel planation strategy provide alternative to turn the grassland to biomass plantation.

B.1. Land-use classification for the wood fuel plantation strategy

The land-cover classification inputs for the wood fuel plantation strategy is the same as the reference scenario. Refer to Table 12 for the dataset on land cover, carbon stocks and NPV for the start year of the wood fuel plantation strategy.

B.2. Land-cover matrix of wood fuel plantation strategy

Under the wood fuel plantation strategy, the wood fuel plantation area is expected to increase by 98% from 5,116.5 ha in 2016 to 219,908.5 in 2030 as a result of converting 168,000 ha of grassland as part of the national forest plantation development programme (Table 13)

Table 13: Land-use change matrix for the woodfuel plantation scenario

Initial (change from initial land cover) / Final (change to final stage/latest land cover classification) (ha)									
Land-cover classes	close forest	open forest	grassland	cropland	forest plantation	woodfuel plantation	settlement	all others	Total -2016 (ha)
close forest	17,291.9	155,012.6	40,068.1	25,755.6	-	-	3,669.5	2,254	244,051.7
open forest	43,911.7	1,385,061.7	1,323,401.3	497,259.5	126,511	46,792	53,825.9	6,982.8	3,483,745.9
grassland	28,767.6	2,633,587.9	4,072,737.0	1,459,179	457,000	168,000	114,261.7	25,998.2	8,959,531.5
cropland	14,749.7	972,310.3	1,271,833.2	847,120.7	-	-	81,177.8	6,020.6	3,193,212.3
forest plantation	-	-	-	-	13,833.5	-	-	-	13,833.5
Woodfuel plantation	-	-	-	-	-	5,116.5	-	-	5,116.5
settlement	74.97	10,278.7	17,527.8	24,594	-	-	22,832.8	200	75,508.3
all others	1,006.2	48,159.7	90,128.1	76,312.5	-	-	39,375.4	524,751	779,732.9
Total 2030 (ha)	105,802.2 0	5,204,410.9	6,815,695.5	2,930,221 .3	597,344.5	219,908.5	315,143	566,206. 6	16,754,732.6

In the same vein, 457,000 ha of forest plantation would be added to the original area of 13,833.5 ha in 2016. Even though forest plantation strategy is not part of the wood fuel plantation, it is important to note that both are driven by national forest plantation development strategy. Besides, the benefits would be an add-on to the wood fuel plantation. The difference between the two end-use. While the forest plantation will have wide economic and ecological utility the wood fuel plantation is to specifically cultivate preferred tree species that ate fast-grow and of high-calorific for energy use.

B.3. Net GHG emission matrix for the wood fuel planation scenario

In the wood fuel plantation, net emission savings will increase by 85% 7,040,792.24 tCO_2 from 45,818,552.24 tCO_2 (Table 14). The expansion wood fuel plantation to 168,000 ha from previously classified grassland would lead to 38,777,760 tCO_2 carbon dioxide accumulation of the same period. This level of emission savings translates into annual saving carbon dioxide of 3,272,753.73 tonnes which will be more than the total national emission target of 2.2 million tonne annually.

Table 14: Total net GHG emissions (tCO_2) from land-cover change between 2016 and 2030 under woodfuel plantation scenario

Initial/Final	close forest	open forest	grassland	cropland	forest plantation	woodfuel plantation	settlements	all others
close forest	-	(39,979,294.5)	(13,553,432.1)	(7,102,871.1)	-	-	(1,547,639.9)	(848,991.6)
open forest	11,325,271.7	-	(106,335,295.6)	(8,886,026.4)	4,724,806.3	7,040,792.24	(8,819,365.5)	(829,211.1)
grassland	9,730,928.4	211,608,789.4	-	91,169,509.5	53,787,529	38,777,760	(9,540,848.6)	(998,331.2)
cropland	4,067,683.3	17,375,185.4	(79,464,138.3)	-	-	-	(11,850,341.1)	(607,353.1)
forest plantation	-	-	-	-	-	-	-	-
woodfuel plantation	-	-	-	-	-	-	-	-
settlements	31,619.4	1,684,168.2	1,463,568.8	3,590,236.5	-	-	-	9,020.0
all others	378,995.3	5,718,966.8	3,460,917.9	7,698,408	-	-	(1,775,828.7)	-

B.4. Opportunity cost matrix for the wood fuel plantation scenario

Overall, the conversion of grassland to the wood fuel plantation is expected to have a negative opportunity cost. The conversion can lead to an additional saving of US$ 4.8 billion over the period (Table 15)

Table 15: Opportunity costs per tCO_2 in US$ between 2016 and 2030 under woodfuel plantation scenario

Initial/Final	close forest	open forest	grassland	cropland	forest plantation	woodfuel plantation	settlement	all others
close forest	-	(18.78)	(11.69)	0.07	-	-	(1.35)	(10.50)
open forest	(18.78)	-	11.07	272.21	(791.46)	(196.44)	26.10	7.49
grassland	(11.69)	11.07	-	(63.62)	(243.58)	(124.20)	40.56	-
cropland	0.07	272.21	(63.62)	-	-	-	(4.03)	(39.40)
forest plantation	-	-	-	-	-	-	-	-
woodfuel plantation	-	-	-	-	-	-	-	-
settlement	(1.35)	26.10	40.56	(4.03)	-	-	-	75.10
all others	-10.49	7.49	0	-39.40	0	0	75.09	0

3.3.3.4 Soft-linking of improved cookstove and wood fuel plantation strategies

There are additional potential benefits if the renewable wood from the wood fuel plantation are utilised by the 2 million improved cookstoves (Figure 15). This is because the renewable wood would replace the wood fuel obtained from non-renewable sources.

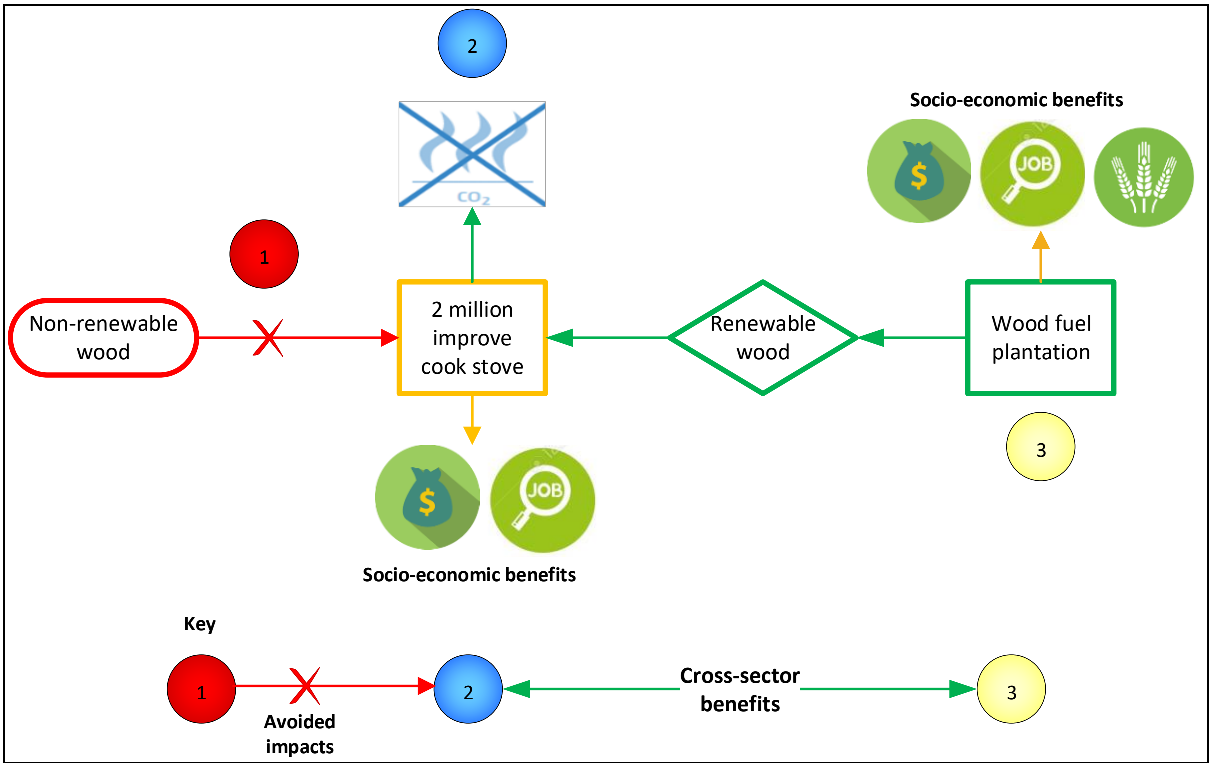

Figure 15: Conceptualisation of the soft-linking of the cookstove and wood fuel plantation strategies

The following steps were followed in the soft-linking:

C.1. Estimate quantities of renewable wood from wood fuel plantation and job creation.

The potential wood volume from the wood fuel plantation was calculated using the area (ha), the rotation period and the coefficient of Mean Annual Increment (MAI). The volume of wood from the plantation was converted to mass unit using average wood density (Table 16). The projected yearly 12,000 ha of wood fuel plantation will be required 53,750 jobs to plant and manage them over the rotation cycle.

Table 16: Potential wood volume from the woodfuel plantation

Year	Annual woodfuel plantation areas (ha)	Cumulative woodfuel plantation areas (ha)	Rotation cycle years	Jobs required	Wood volume	Average wood density	Wood Quantity	
				Number	(MAI = 10 m3/ha)	kg/m3	kt	tonnes
2016	12000	12000	5	53,750	600,000	470	282	282,000
2017	12000	24000	5	107,500	1,200,000	470	564	564,000
2018	12000	36000	5	161,250	1,800,000	470	846	846,000
2019	12000	48000	5	215,000	2,400,000	470	1,128	1,128,000
2020	12000	60000	5	268,750	3,000,000	470	1,410	1,410,000
2021	12000	72000	5	322,500	3,600,000	470	1,692	1,692,000
2022	12000	84000	5	376,250	4,200,000	470	1,974	1,974,000
2023	12000	96000	5	430,000	4,800,000	470	2,256	2,256,000

2024	12000	108000	5	483,750	5,400,000	470	2,538	2,538,000
2025	12000	120000	5	537,500	6,000,000	470	2,820	2,820,000
2026	12000	132000	5	591,250	6,600,000	470	3,102	3,102,000
2027	12000	144000	5	645,000	7,200,000	470	3,384	3,384,000
2028	12000	156000	5	698,750	7,800,000	470	3,666	3,666,000
2029	12000	168000	5	752,500	8,400,000	470	3,948	3,948,000
2030	12000	180000	5	806,250	9,000,000	470	4,230	4,230,000

C 2. Calculate the number improved stoves needed to consume the quantity of renewable wood supply

With an average wood consumption of 0.29 tonnes/year for each unit of improved cookstove, and an annual average renewable wood supply 2,256,000 tonnes/year, nearly 7.7 million improved stoves would be required nation-wide to consume over the 14-year period. (Table 17).

Table 17: Calculation of the number of improved stoves need to consume the projected wood supply

Year	Wood consumption/stove/yr	Wood supply from renewable plantation	Number stoves available use to renewable biomass
	t/yr	t/yr	No
2016	0.29808	282,000.00	946,054.75
2017	0.29733	564,000.00	1,896,882.25
2018	0.29657	846,000.00	2,852,614.90
2019	0.29582	1,128,000.00	3,813,129.61
2020	0.29507	1,410,000.00	4,778,527.13
2021	0.29431	1,692,000.00	5,749,040.13
2022	0.29356	1,974,000.00	6,724,349.37
2023	0.29281	2,256,000.00	7,704,654.90
2024	0.29205	2,538,000.00	8,690,292.76
2025	0.2913	2,820,000.00	9,680,741.50
2026	0.29055	3,102,000.00	10,676,303.56
2027	0.28979	3,384,000.00	11,677,421.58
2028	0.28904	3,666,000.00	12,683,365.62
2029	0.28829	3,948,000.00	13,694,543.69
2030	0.2875	4,230,000.00	14,713,043.48

C 3. GHG Savings for consuming renewable wood fuel

t is possible to save an additional cumulative of 17.7 million tonnes of CO_2 emissions from the consumption of 2,256,000 tonnes renewable biomass by 14 million stoves in the country by 2030 (Table 18). This level of emission reduction would be achieved by consuming biomass from a renewable source. The assumption is that carbon emissions from renewable biomass would eventually be compensated for through the natural or assisted regeneration of the tree stumps after harvesting. The natural regeneration or replanting of harvest areas would balance out the carbon loss from harvesting.

Table 18: GHG emissions from consuming renewable biomass

Year	Wood consumption/ improved stove	Wood supply from renewable plantation	Number stoves available use to renewable biomass	Carbon content of wood	fNR* Wood (%)		CO_2 emissions (tCO_2e)/yr - non-renewable biomass	CO_2 emissions (tCO_2e)/yr - Renewable biomass	Emissions Savings
	t/yr	t/yr	No	(t c/yr)	Non-renewable wood	Renewable wood			tCO_2e
2016	0.29808	282,000	946,054.75	0.14904	99%	1%	152,566.29	1,541.07	151,025.21
2017	0.29733	564,000	1,896,882.25	0.148665	99%	1%	304,364.83	3,074.39	301,290.44
2018	0.29657	846,000	2,852,614.90	0.148285	99%	1%	455,380.27	4,599.80	450,780.47
2019	0.29582	1,128,000	3,813,129.61	0.14791	99%	1%	605,638.20	6,117.56	599,520.64
2020	0.29507	1,410,000	4,778,527.13	0.147535	99%	1%	755,128.39	7,627.56	747,500.83
2021	0.29431	1,692,000	5,749,040.13	0.147155	99%	1%	903,820.12	9,129.50	894,690.63
2022	0.29356	1,974,000	6,724,349.37	0.14678	99%	1%	1,051,769.70	10,623.94	1,041,145.77
2023	0.29281	2,256,000	7,704,654.90	0.146405	99%	1%	1,198,951.54	12,110.62	1,186,840.92
2024	0.29205	2,538,000	8,690,292.76	0.146025	99%	1%	1,345,319.56	13,589.09	1,331,730.48
2025	0.2913	2,820,000	9,680,741.50	0.14565	99%	1%	1,490,960.79	15,060.21	1,475,900.58
2026	0.29055	3,102,000	10,676,303.56	0.145275	99%	1%	1,635,834.27	16,523.58	1,619,310.69
2027	0.28979	3,384,000	11,677,421.58	0.144895	99%	1%	1,779,878.59	17,978.57	1,761,900.02
2028	0.28904	3,666,000	12,683,365.62	0.14452	99%	1%	1,923,211.46	19,426.38	1,903,785.08
2029	0.28829	3,948,000	13,694,543.69	0.144145	99%	1%	2,065,776.59	20,866.43	2,044,910.16
2030	0.2875	4,230,000	14,713,043.48	0.14375	99%	1%	2,207,266.88	22,295.63	2,184,971.25

* fFN – fraction of non-renewable biomass

Since the wood fuel plantation will be managed on a sustainable basis, harvesting will be done according to the guidance in the forest management plans. In this regard, the quantity of wood and technology to harvest the wood will comply with the approved standards which facilitates faster coppicing. In addition to the natural regeneration, their substantial amount of the carbon stock would be put back through replanting. All these silvicultural practices including a measure to reduce fire risk are expected to ensure a sustainable supply of renewable biomass to the cookstove market. With the 5-year rotation cycle, the harvesting and replanting will be phased out in a way to avoid significant net loss in the biomass stocks.

C.4. Estimate the overall emission and development impacts of improved cookstoves and wood fuel plantation mitigation strategies

When the two NDCs mitigation policies are put together, the impacts are more than the expected emission reductions. Often, the other development benefits of the GHG emission mitigation measures are not assessed. Presently the emission reduction alone is an unfair way of evaluated the full effects of the implementation of the climate action. This is the reason why most climate mitigation measures are an additional cost to the economy. They are typically second rated over competing measures that results are perceived as more tangible. So, the idea to evaluate the emission reduction potential and the sustainable development benefits of the individual mitigation measures and later link them to maximise potential additional benefits are the way to go. For both measures, carbon saving, job creation, investments revenues and health benefits have been evaluated (Table 19).

Table 19: Emissions and development impacts of improve cookstoves and wood fuel plantation strategy

Year	GHG emissions				Jobs creation		Investments	Health
	Improved cookstove replacement	Establishment of biomass plantation on grassland	Renewable biomass for cooking	Totals	Cookstove replacement	Establishment of biomass plantation		Cookstove replacement
	CO_2e	CO_2	CO_2e	CO_2e	Numbers		Savings ($)	Avoided death
2016	24,061.14	2,769,840.00	151,025.21	2,944,926.35	457.80	53,750	6,375,908	32.40
2017	29,596.77	2,769,840.00	301,290.44	3,100,727.21	560.72	107,500	7,857,259	37.81
2018	30,259.17	2,769,840.00	450,780.47	3,250,879.64	570.81	161,250	8,048,048	43.21
2019	30,934.37	2,769,840.00	599,520.64	3,400,295.01	581.08	215,000	8,242,641	48.61
2020	31,624.28	2,769,840.00	747,500.83	3,548,965.11	591.56	268,750	8,441,758	54.01
2021	32,309.66	2,769,840.00	894,690.63	3,696,840.29	601.83	322,500	8,640,478	66.13
2022	33,006.53	2,769,840.00	1,041,145.77	3,843,992.30	612.27	376,250	8,842,673	78.25
2023	33,716.80	2,769,840.00	1,186,840.92	3,990,397.72	622.88	430,000	9,049,073	90.37
2024	34,442.49	2,769,840.00	1,331,730.48	4,136,012.97	633.65	483,750	9,260,455	102.49
2025	35,180.01	2,769,840.00	1,475,900.58	4,280,920.59	644.59	537,500	9,475,440	114.61
2026	35,918.17	2,769,840.00	1,619,310.69	4,425,068.86	655.46	591,250	9,691,237	126.73
2027	36,671.31	2,769,840.00	1,761,900.02	4,568,411.33	666.48	645,000	9,911,954	138.85
2028	37,435.66	2,769,840.00	1,903,785.08	4,711,060.75	677.66	698,750	10,136,127	150.98
2029	38,213.24	2,769,840.00	2,044,910.16	4,852,963.40	689.00	752,500	10,364,544	163.10
2030	39,012.31	2,769,840.00	2,184,971.25	4,993,823.56	700.49	806,250	10,600,439	175.22

The total emissions reduction potential of the two policies amounted to 59.75 million tonnes CO_2eq by 2030. Of this, 55 are expected to come from the establishment of renewable wood fuel plantations on previously occupied grasslands. The remaining 45 per cent is likely to generate from the replacement of 2 million improved cookstoves and the use of renewable biomass for cooking. Both policies are likely to generate investment revenues US$ 134.94 million at US$ 9 million annual average. In terms of employment, a total 6,459,266 direct job will be created from the manufacture of the improved cookstoves and the establishment and the management of the wood fuel plantations. On average, an average 430,618 direct jobs are expected to be generated from the two policies with the majority coming from the wood fuel plantation. The adoption of the improved cookstove is expected to reduce indoor pollution PM2.5 and ozone. In all 1,422.76 deaths will be avoided from the reduction of PM2.5 emissions and ozone.

3.4 Integrating models into policy decision frameworks through the NDCs working group

The integrated models showed impressive results, there would be additional value when it is incorporated into policy and investment decisions. But this does not come easy. It requires a carefully thought through strategy to drive the assimilation process. First, the results from the integrated model must be credible and must ultimately enhance the quality of decisions. Secondly, there must a clear channel for adoption for further use. In this case, the focus is on using the model results to improve on the analytical underpinning the second generation NDCs in Ghana. As already indicated, Ghana plans to use both model results and methodology to improve on its next NDCs. In this regard, the role of the working group would be extremely useful. Since the same NDC group acted as the inter-agency taskforce under the LED project, it would be far easier for them to use the result and methodology in the NDC2. One way to do this is to ensure that the LEDs report is added to the list review document when the team starts the stock taking exercise. Adding the LEDs report in the literature would facilitate the review of the findings and methods. The lessons and the key messages from the review will inform the scope and ambition level of the clean cooking and tree plantation measures in the NDCs.It is also important to note that, when it gets to the point to prioritise the NDCs action, the clean cookstove and tree plantation stand chance, it has more compelling details decision-maker will rely on to make a choice. This is crucial because it provides a fresh approach to evaluate mitigation action to come up with emission and non-emission benefits.

Chapter 4: Conclusion & way forward

4.1 Conclusion

In totality, the LEDs analysis approach has been largely insightful and achieved the purpose it was originally intended for in terms of; contribute to improving the analytical precision behind the NDCs, strengthening capacity and awareness and facilitating policy assimilation of LEDs assessments. The integrated approach not new though but it added value to the project design to satisfy Ghana's needs. This reflected in the idea of having technical and policy team. The main reason was that the results of the analytical work would feed into various policy discourses at the level of the ministries. In a nutshell, the integrated modelling approach and consultation within the in-country team contribute to making the LEDs project a success. It has been a useful learning curve for the Ghanaian team. Above all, the LEDs project has offered us a viable alternative to evaluate the full effects NDC actions which hitherto focussed more on projecting the emission reduction benefits.

The modelling exercise did not only make it possible to assess the socio-economic benefits of climate actions beyond emission reductions, but the soft-linking utility of the model was also great value addition. With this, the additional cross-sectoral benefits among the two technologies were estimated, which hitherto would not have been highlighted. This new way to evaluate climate actions will be adopted as the best practice when Ghana start to revise the current NDCs next year. It will enhance the analytical rigor of the data that will underpin Ghana's revised NDCs. Another important value-addition from this exercise is the learn-by-doing way of building capacities within the key government, academic organisations and CSOs within the country. With the fresh analytical perspective and the enhanced capacities, Ghana will be in the position to conduct the comprehensive assessment of its climate actions regularly.

In another important lesson from this exercise is about the need to beef up communication aspects. Most times, the socio-economic benefits of the NDCs are neglected in communication. This is a great disservice that needs to be addressed. At least the results from the integrated model show far more additional benefits of NDC actions that really to be highlighted to policymakers. Especially the multiple benefits of the NDCs must be emphasised during in the communication materials. At least the LED study has demonstrated that the real socio-economics of the NDCs. The general public will relate to the economic benefits of the NDCs than the sole unattractive emission-led communication.

This is crucial when it comes to making a compelling case to decision-makers in the finance and planning ministries for more allocation of financial resources to support the NDCs. With the LEDs results, it is possible to articulate the emission reduction potential and the socio-economic benefits (investment savings, job creation, health benefits for specific NDC interventions. Even the results from the LEDs work can also be useful for public awareness programme in the country. The general public will relate better to the socio-economic benefits of climate measure than the global perspective. Once the general public starts to support the NDCs it enhances the chance to get them implemented. The main reason for having modelling and policy groups was to facilitate policy uptake of the results. The plan is to adequately brief the policy team on the practical ways to assimilate the results into policy discussions.

4.2 Way forward

After this report is finalised, the following activities will be pursued:

- Synthesise the key results into key messages for dissemination among the key ministries and the general public.
- Produce short interview clips of the key experts who were involved in the LEDs process.
- Continue to improve on the data quality for further improvements in the model in future.
- Use the experience and results from the LEDs to inform revision of Ghana's NDC for submission next year.