International Labour Organization

UNDP

ZIMBABWE GREEN JOBS
ASSESSMENT REPORT

# Measuring the Socioeconomic Impacts of Climate Policies to Guide NDC Enhancement and a Just Transition

## ABOUT UNDP

UNDP's work on climate change spans more than 140 countries and involves US$3.7 billion in investments in climate change adaptation and mitigation measures since 2008. With the goal to foster ambitious progress towards resilient, zero-carbon development, UNDP has also supported implementation of the Paris Agreement on Climate Change by working with countries on achieving their climate commitments, or Nationally Determined Contributions (NDCs).

## THE NDC SUPPORT PROGRAMME

The NDC Support Programme provides technical support for countries to pursue an integrated, whole-of-society approach that strengthens national systems, facilitates climate action and increases access to finance for transformative sustainable development. The programme helps countries address financial barriers by deploying a structured approach to scaling up sectoral investments and putting in place a transparent, enabling investment environment. Beyond direct country support, UNDP facilitates exchanges and learning opportunities on NDC implementation at the global and regional levels by capitalizing on our close collaboration with the UNFCCC and other strategic partners. The programme, which contributes to the NDC Partnership, is generously supported by the German Federal Minister of the Environment, Nature Conservation and Nuclear Safety (BMU), the German Federal Ministry of Economic Cooperation and Development (BMZ), the European Union, and the Government of Spain.

## ILO

ILO is spearheading a global Just Transition agenda through the Climate Action for Jobs Initiative. The Paris Agreement on Climate Change, adopted in 2015, acknowledges the imperatives of a just transition and the creation of decent jobs in a response to climate change. In the same year, ILO constituents adopted Guidelines for a just transition towards environmentally sustainable economies and societies for all.

## ILO GREEN JOBS PROGRAMME

The Green Jobs Programme signals ILO's commitment to act on climate change and promote resource efficient and low-carbon societies. Decent work is a cornerstone for effective policies to green economies for achieving sustainable development. The Green Jobs Programme has, over time, assisted over 30 countries by building relevant ILO expertise and tools.

## ABOUT THIS JOINT INITIATIVE

This is a joint pilot initiative between UNDP's NDC Support Programme and ILO's Green Jobs Programme, assisting countries to measure the socioeconomic impacts of climate policies to guide evidence-based NDC policymaking and support a just transition.

## ACKNOWLEDGEMENTS

**Authors:** Kirsten Svenja Wiebe, SINTEF (kirsten.wiebe@sintef.no)
Tina Andersen, SINTEF
Moana Simas, SINTEF
Marek Harsdorff, ILO

**Technical oversight and guidance / ILO:** Marek Harsdorff (harsdorff@ilo.org)

**Technical oversight and guidance / UNDP:** Sangji Lee (Sangji.lee@undp.org)

**Other contributors to the project/report:** Washington Zhakata, Kudzai Ndidzano and Lawrence Mashungu from the Climate Change Management Department, and Manasa Viriri and Christopher Chinyanya from ZimStat, Gibson Chigumira and colleages at ZEPARU, Tafadzwa Dhlakama and Jeremiah Mushosho from UNDP. Alice Vozza, Tafadzwa Chirinda, Matilda Dahlquist, and Jens Dyring Christensen from ILO.

**Design and Layout:** Jason T Quirk

# Foreword

The 2015 Paris Agreement on climate change is a legally binding international landmark treaty aiming to limit global warming by encouraging all countries to act on climate change through national plans for climate action, known as Nationally Determined Contributions (NDCs). In order to combat climate change, the Paris Agreement seeks to accelerate and intensify the actions and investments needed for a sustainable low carbon future. In other words, it urges us to find the right balance between people's prosperity and taking care of our planet, and actually recognizes that one cannot be achieved without the other.

Especially for developing countries, the shift to resilient, low-carbon economies must come hand-in-hand with inclusive and sustainable growth through identifying new and green employment opportunities, while also addressing climate change in line with national development priorities. Zimbabwe's National Development Strategy 2021-2025 is the first economic blueprint to set the country on a trajectory of becoming a Prosperous and Empowered Upper Middle-Income Society by 2030. For this to happen, at least 760,000 new climate-sensitive jobs must be created.

The Department of Climate Change and the Zimbabwe Economic Policy Analysis and Research Unit (ZEPARU) with technical and financial support from the United Nations Development Program (UNDP) and the International Labour Organization (ILO) undertook an assessment to measure the projected impact of Zimbabwe's climate policies on on employment, Gross Domestic Product and emissions. This economic model, known as the Green Jobs Assessment, allows the Government of Zimbabwe to examine the potential impact of its climate policies on economic growth, employment creation, skills and education needs, gender equality and income levels. In other words, it allows policy makers to make the right choices for a Just Transition to a low carbon and prosperous economy.

This Green Jobs Assessment is done at a time when Zimbabwe is in the process of revising its NDCs, thereby presenting an opportunity to embed just transition principles in the country's long-term national climate action commitments. Twelve scenarios were developed for the key NDC sectors, namely Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Other Land Use (AFOLU), and Transport and Waste as prioritised by the Government. The proposed scenarios along with the key recommendations may stimulate employment impacts of mitigation and adaptation actions and offer a net creation of green and decent jobs in the coming years.

We want to stress that the climate change mitigation and adaptation strategies provided by the model should be carefully considered and, ultimately, adopted by the Government of Zimbabwe in order to guide the NDC revisions and set the country on a low carbon and sustainable development path. UNDP and the ILO assure the Government of Zimbabwe of our continued support in the implementation of the NDCs. We look forward to a continued fruitful partnership towards achieving Vision 2030 and the Sustainable Development Goals while leaving no one behind.

**Georges van Montfort**
Resident Representative
United Nations Development Program, Zimbabwe

**Hopolang Phororo**
Director
ILO Country Office for Zimbabwe and Namibia

# Table of Contents

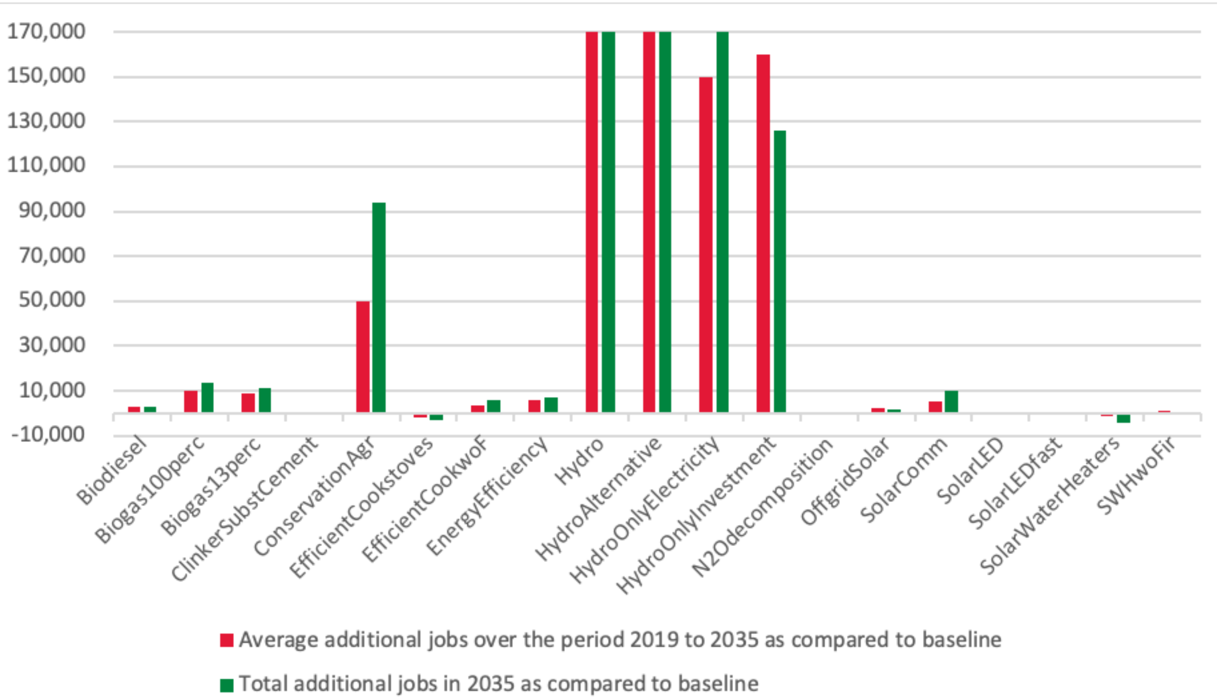
# Executive Summary

Policymakers' many concerns in addressing climate change include its impact on economic growth, job creation and social development. This is evident from Zimbabwe's Vision 2030 to become an upper-middle income country and its 2021-2025 development strategy prioritizing "new wealth creation and expanding horizons of economic opportunities for all Zimbabweans, with no one left behind." It is thus of utmost importance to assess the potential development effects of climate policies ex-ante so as to design a climate strategy that maximizes job creation, economic and social development, while minimizing negative effects and leaving no one behind.

The purpose of this study is to assess the social, employment and economic impacts of Zimbabwe's climate policies. To do so, the 12 leading policies were selected from Zimbabwe's Nationally Determined Contributions (NDCs). They are analysed in terms of their immediate, short- and medium-term effects (primary), as well as their long-term effects (secondary). Impacts on the labour market, employment, economic growth and emissions are also assessed.

Energy policies dominate Zimbabwe's climate policies. Most investments planned for new generation capacity are in renewable energy, specifically, hydro power and solar. The study's analysis takes this into account. In terms of total number of jobs created, policies to increase electricity generation from the Batoka hydro plant have the greatest impact. By 2035, it is estimated that around 300,000 net additional jobs will be added to the economy annually, on average, compared to a baseline scenario. The significant increase in employment (see left panel of Figure ES1) should be interpreted in light of the significant capital investment requirements. The investment amount ($5.4 billion) represents a quarter of the Zimbabwean economy's current total capital investments, with a planned installed capacity of 1200 MW, double that of the current Kariba Dam.

**ES Figure 1: Total net jobs created by selected climate policies (NDCs) in 2035**




The commercial solar and biogas policy is expected to create approximately 10,000 jobs in each area. The biodiesel, solar water heater (SWH) and off-grid solar policy is projected to create approximately 5,000 additional jobs. As the initial investments are rather small, particularly compared to the hydro dam, total employment effects are also small, consistent with the low level of investment and the small structural changes. The LED streetlight and $NO_2$ policies have very small to no employment effects. This is due to the very small initial investment (primary effect) and because the structural change effects (secondary) on the economy are marginal in the long term. For example, conventional streetlights are no different in terms of operation and maintenance than light-emitting diodes (LEDs). Also, forward linkages in terms of the productive use of the light emitted does not depend on the type of light used.

Comparing the total impact of the commercial solar policy to the biogas policy, it is important to note that while their effect is similar - around 10,000 additional jobs each in 2035 - total investments in biogas are only one-quarter of those in commercial solar.

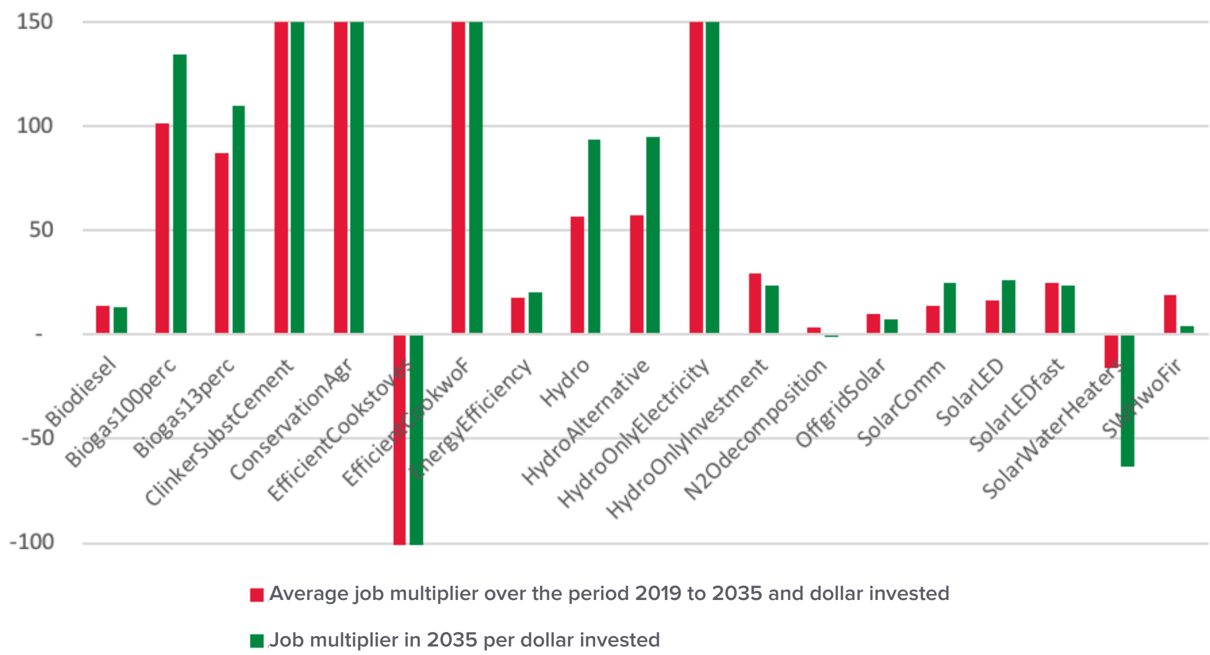
This finding is important: the total *size* of the investment matters, but the *type* of investment is crucial. The structural economic change that the investment produces will determine the resulting number of jobs, amount of GDP and volume of emissions – whether larger or smaller.

This reveals a third dimension of the policy effects (in addition to the *primary* and *secondary* effects) that is important to the findings. The total number of jobs created or lost in 2035 per dollar invested should be considered, as should the effects on GDP and emissions per unit of investment.

In the case of biogas, $1 million invested will stimulate the creation of around 130 jobs economy-wide in 2035. This compares to only 25 jobs for commercial solar and some 100 jobs for the Batoka hydro dam. This is because operating and maintaining biogas plants is more labour intensive than running the hydro dam or operating commercial solar plants. The supply chain effects extend further and are more closely linked to the national economy through the collection, transport and management of local manure and agricultural residues. Operating commercial solar and building the hydro dam also involve significant imports, which have little employment effect (due to leakage out of the economy).

It is important to note that the biogas scenario described above assumes 100 percent capacity utilization once the plants are built. However, studies show that the current utilization rate is only around 13 percent, which would result in much lower employment multipliers. The comparison between these two capacity utilization rate scenarios is relevant to all other scenarios: just transition policies should accompany climate policies to ensure that capital investments are serviced, maintained and used productively.

**ES Figure 2: Total economy-wide job multiplier/dollar invested of selected climate policies (NDCs)**



Burning of biomass, deforestation and agriculture are the largest sources of Zimbabwe's emissions. This underscores the importance of climate policies that address the agriculture, forestry and land use (AFOLU) sector. Improved cookstoves offer a low-cost solution. A $1 million investment in the production of energy efficient cookstoves would create more than 850 jobs. This is based on the assumption that time spent collecting firewood is not considered employment and that that time would be used for other household activities, without loss of income. However, the effect changes to negative (job losses) when firewood collection is assumed to be employment (and income generating). Approximately 450 full-time equivalent jobs net per $1 million invested would thus be lost in firewood collection.

Here, too, any climate policy designed to reduce firewood collection should be paired with social and labour market policies to ensure that any income losses in the firewood industry are addressed. Just transition policies should accompany the energy and AFOLU sector policies.

The agricultural conservation scenario offers great promise in the context of climate policies that do not directly target the energy sector. Agriculture is Zimbabwe's largest sector and employer. A policy that encourages a shift to climate-smart and conservation farming entails several significant labour market effects. It requires increased organic fertilizer use and production, which creates jobs in supplying industries) and less use of chemical fertilizer, which reduces imports, and calls for some 10 percent additional direct agriculture-related jobs in soil preparation, management, harvesting and post-harvest activities.

The policy's net effect is estimated at close to 100,000 additional full-time equivalent jobs in 2035. And because the investment requirements are very small - and relate more to training and upskilling for farmers than actual capital - the job multiplier is the highest of all the scenarios. A $1 million investment in conservation and climate-smart agriculture is expected to create some 30,000 jobs in 2035.

The industrial processes and product use (IPPU) policy has little effect on total jobs created, as both the policy and the investments are very modest. However, the job multiplier per $1 million invested is very high, with around 300 total jobs created in 2035 because the cost to the cement industry of substituting clinker with fly ash is marginal. At the same time, the use of fly ash, compared to clinker, creates a significant number of jobs in fly ash collection and transport.

The above assessment concludes that if climate policies are to be effective, they should be accompanied by just transition policies. Four important dimensions of just transition policymaking are highlighted below. They require a sequenced and balanced inter-ministerial approach.

First, failing to address social consequences may lead to non-implementation and failure of the climate policies. This could occur because of social protest (for example, mass protests against fossil fuel subsidy reform), non-compliance (failure to comply with bans on charcoal production because of lack of alternatives) and/or economic and social hardship, which prevents any shift from harmful economic activities (such as firewood production). To ensure buy-in throughout the society and ensure that no one is left behind, social protection measures should be designed in parallel with climate policies to address and signal the concerned populations that the government will buffer any negative impacts of the prioritized policies. Social policies include, but are not limited to, extending social protection floors, insurance, public employment programmes, unemployment guarantees and or conditional cash transfer programmes.

Second, the type of climate policy has significant and very different effects on social, labour market and economic outcomes. The type of climate policies and investments to focus on should be assessed and prioritized initially. The national development strategy should guide this process. Integrating just transition policy analysis in the design stage could maximize social inclusion, pro-poor growth and job creation. For example, climate policies that involve investing in conservation agriculture have very high job creation potential per million dollars invested compared to high capital-intensive investments in, for example, hydro or commercial solar plants. However, the productive forward linkages of new electricity generation have long-term structural change effects on manufacturing capacity. While the low-skilled and rural poor would benefit most from a well-designed agricultural conservation policy, the urban population would gain from large-scale electricity generation plants in the short term. In the long term, economic development depends on sustainable energy capacity to power economic growth. Policymakers thus need to consider the short- and long-term effects of the climate policy on inequality, income distribution and urban-versus-rural development, as well as potential effects on industrial, agro-processing and aggregate long-term GDP growth. Government and policymakers need to consider these effects to make informed decisions regarding the Vision 2030 development strategy.

Third, well-intended climate policies and capital investments in the low-carbon economy require that managers, workers, enterprises and entrepreneurs have the right skills to finance, manage, construct, operate and maintain the capital asset – and use it productively in the long term. A lack of skilled managers and workers may hinder climate projects and investments; a skills development strategy should thus be developed for each priority sector. A systems approach, rather than an *ad hoc* one, is recommended. This requires integrating the required skills and professions into the country's education and training systems. It also involves creating a mechanism by which government, employers and workers discuss and decide on skills requirements, develop and update curricula, train teachers and trainers, integrate curricula in schools, technical vocational education and training (TVET) institutions and universities, and roll out the skills strategy. Apprenticeship systems and on-the-job training programmes may complement the skills strategy. This strategy would ensure that skilled workers will be available for future occupations. Enterprise development, an enabling business environment, and entrepreneurship training and support are critically important to achieve and implement the capital investments and drive the productive use of newly installed energy capacity.

Fourth, accompanying fiscal, macroeconomic, sectoral and industry policies have the potential to support structural economic change and enhance economic growth and social development. A main instrument is a fiscally-neutral policy reform with a double dividend: tax carbon while lowering labour costs. This could shift economic growth to low-carbon activities and industries and, simultaneously, reduce the cost of employment, thereby enhancing overall national employment creation. A well-designed local content, foreign direct investment and sustainable procurement policy, in combination with policies that support green infant industry, such as tax breaks, special economic zones or research and development support, would strengthen employment creation and long-term structural change.

# 1. Objective of the Green Jobs Assessment Model

Zimbabwe is defining its climate strategies and policies, in response to the risks, ever more present, associated with climate change. Similar to the other 180 countries party to the Paris Agreement, the objective is to set targets for the country's total emissions and adaptation needs to comply with the international agreement [1]. However, Zimbabwe has inherent geographic, social and economic characteristics that must be taken into account when developing adequate mitigation and adaptation strategies. For instance, its climate susceptibility and the country's social and economic structure will have a strong influence on the effects of climate strategy on GDP, employment, income, skills and emissions, as well as gender.

The overall objective of this project is to develop a Green Jobs Assessment Model (GJAM) for Zimbabwe in order to assess possible employment, social, GDP and emission impacts of climate change mitigation and adaptations strategies, as laid out in the NDCs. The related policies are developed as part of the Paris Agreement and Zimbabwe's Long-term Low Greenhouse Gas Emission Development Strategy (LEDS) [2].

The GJAM is based on detailed national data on the Zimbabwean economy (supply and use table, SUT). It thus reflects, in depth, the structural changes generated by the implementing climate policies, as envisioned in the NDCs and LEDS. The model captures the direct effects of the policies and the indirect impacts on supply industries that will be affected by those changes. These results aim to inform the policy design for the revised NDC. They will make it possible to develop inherent and accompanying just transition policies with the goal of maximizing employment gains and minimizing and developing social and employment policies that address potential losses.

The model is also based on the modelling approach described in the International Labour Organization's (ILO) GAIN Training Guidebook [3], developed further to incorporate intertemporal dynamics and price effects.

The next section provides an overview of the policy scenarios as described in the NDC and LEDS and outlines the main policy effects on employment, GDP and emissions. Section 3 introduces the modelling approach and the data used. Section 4 describes each scenario in detail - assumptions, implementation and results. It discusses accompanying just transition policies intended to maximize positive and minimize negative outcomes. Section 5 summarizes the policy implications.

# 2. Policy scenarios and policy implications

This section briefly describes the main policy scenarios and discusses the general policy implications of Zimbabwe's LEDS. The policy analysis follows the sector structure of the NDCs. The four NDC sectors cover energy, IPPU, AFOLU and waste. The impacts on employment, GDP and emissions are also assessed.

## 2.1 Overview

Energy policies are central to Zimbabwe's NDCs and LEDS energy policies. Taking that into account, the scenario analysis thus also focuses on the energy system. Of the 12 policy scenarios modelled here, nine relate directly or indirectly to the energy sector, while three relate to chemical processes in industry and to agriculture production systems.

Of the 10 energy policies, four scenarios assess electricity policies' impacts on the labour market, the economy and emissions. They include *additional electricity generation* from investments in hydro, biogas, commercial solar and off-grid solar plants.

Three policies relate to *energy efficiency* investments into SWH, LED street lights and the manufacturing industry. Industry policies play an important role here as efficiency improvements are to be achieved in the manufacturing industry. However, they also directly relate to energy policies through management to reduce energy demand, often labelled as the 'hidden fuel'.

Two scenarios investigate energy policies related to *fuel energy*, specifically the production and use of firewood and biodiesel. As they address deforestation, land use and alternative cookstoves, they are at the intersection of energy, agriculture, forestry and transport sector policies.Finally, two policies on chemical processes focuses on the cement and chemical industry. The agricultural policy targets small farmers as well as commercial and large-scale agro-industries to shift to climate smart and conservation agricultural production systems.

Finally, two policies addressing chemical processes focus on the cement and chemical industry. The agricultural policy targets small farmers and commercial and large-scale agro-industries to shift to climate-smart and conservation agricultural production systems.

Similar to the implications of other development policies, climate and energy policies generate several rounds of primary, secondary, short-, medium- and long-term effects on GDP, income, jobs and emissions (among others). The GJAM is well suited to capture those effects, as will be described in the next section.

The policy analysis aggregates the impacts into two types of effects: short to medium term (primary) and medium to longer term (secondary). This simplified distinction facilitates policy discussion and allows for concise conclusions.

The initial short- to medium-term effect (primary) derives from the investment itself. Any additional investment in an economy (green or conventional) creates demand for labour to manufacture, build, purchase, transport, sell and/or install the asset or provide a service (if, for example, the investment is in a school or hospital). Through supply chain effects, jobs are created, income is generated, GDP grows and emissions rise (initially). The direction of the effect is in one-way only: growth.

The growth effect on employment, GDP and emissions is based on the assumption that investments up to 2030 are additional to the current capital investment trend, that they do not crowd-out private investment and are fiscally neutral in the long term. Funding is assumed to come from a combination of budgetary review (such as reallocation of military spending), increased tax collection and fiscally-neutral tax reform that increases the cost of pollution (via a carbon tax) while lowering labour costs, and channelling a portion of carbon tax revenues into climate investments and/or a national climate fund. Revenues may also be generated by issuing green government bonds or green credits and funds may come from international development grants and loans. Policymakers will need to assess and discuss further the issue of financing the investments and the potential implications. However, that is outside the scope of this analysis.

The medium- to long-term effects (secondary) result from a (green) structural change to the economy; specifically, the operation, maintenance or productive use of the assets created and their potential implications for other economic activities. A structural change may replace some activities, which may decrease over time, while others may increase.

Investment in biogas for generating electricity and/or cooking provides an example from Zimbabwe's climate policies. After the investment and construction activity is completed, technicians' services and transport for cow dung and agricultural residues will be required. At the same time, the increase in biogas production may reduce the import and/or production of conventional gas and related sales services, as well as demand for firewood collection and sales.

The additional income available to workers and their households to buy goods and services also generates secondary impacts, as do price changes, which in turn affect consumer and investment decisions. For example, biogas technicians may spend their additional income on food, heath and schooling. These services typically increase most when earnings rise. However, the jobs and income lost in conventional gas and fuelwood production, transport, and sales may lead to decreased spending by households engaged in those activities.

It thus follows that the direction of the secondary effect on emissions, GDP and employment is less clear than that of the primary investment effect. Because some economic sectors may shrink and jobs and income may be lost, the net effect should be assessed carefully, which this report will do.

The same logic (regarding secondary economic effects) applies in terms of emissions. If polluting assets are replaced in the medium to long term, emissions may turn negative after an initial rise (as a result of the first round of investments). Take, for example, the planned investment in the hydro-power Batoka dam. The initial investment stimulates economic activity in the cement and construction industry and, thus, will increase emissions in the short term. In the medium to long term, when (emissions-free) hydroelectricity is produced, and when it replaces fossil fuel electricity, overall emissions may decline.

## 2.2 NDC sectors and detailed policy scenarios

Policies to *increase electricity generation* include building the Batoka mega-dam. It would increase electricity supply by a massive amount (5000 GWh per year). The planned 1200 MW generators are close to double the current installed capacity at the Kariba Dam (750 MW). Other power plant investments are planned in commercial solar (1233 GWh), off-grid solar (760GWh) and biogas (10GWh).

In terms of *energy efficiency* policies, investments in LED streetlights and 250,000 SWH are modelled. Those will primarily *reduce demand for electricity* (and, to a lesser extent, firewood) as the technologies are more energy efficient than their conventional counterparts (conventional streetlights, electric geysers or heating water with firewood). The report assesses the manufacturing industry, economy-wide job and emission impacts of 30 percent energy efficiency improvements by 2030.

Policies to reduce deforestation and firewood use are modelled through the roll out of energy efficient cookstoves. Such policies operate at the intersection of the agriculture, forestry and energy sectors. Finally, a cross-cutting energy/agriculture/transport policy is modelled to achieve a 2 percent share of domestic biodiesel production in 2030.

Table 1 lists the detailed NDC policy scenario specifications. As indicated, five policy scenarios relate to renewable electricity generation (Electricity.xlsx, Energy), three to other energy efficiency measures (OtherEnergy.xlsx, Energy), one to IPPU, and one to conservation agriculture. As the use of firewood includes the reduction of prescribed burning and, thus, the provision of more efficient cookstoves, this policy operates at the intersection of energy and AFOLU. Table 1 also lists alternative policy options for some of the 12 scenarios, such as an additional increase in biogas capacity utilization. This is explained further in subsequent sections.

**Table 1: List of scenarios**

| SCENARIO | ALTERNATIVES | DESCRIPTION |
|---|---|---|
| Hydro | Historic electricity mix, Electricity addition only, investments only | 5,000 GWh dam; $5.4 billion investments between 2021–2030; operations starting from 2027; additional 37% electricity; increasing hydro share to 2/3 of total electricity. |
| Biogas | 100 percent biogas | About 50 GWh (13% utilization on farms)/160 GWh (100% utilization on farms) additional elec-tricity, investments of $99 million |
| Commercial solar | | 1,233 GWh additional electricity; $407 million in-vestments between 2021-2030; 5% current share in electricity production commercial & off-grid solar 5% increasing to 25% in 2030; commercial solar larger in 2030. |
| Offgrid solar | | 760 GWh additional electricity; $243 million in-vestments between 2021-2030, current solar mar-ket share of 5% (3.7% off- grid) increasing to 25% in 2030. |
| Solar LED | Faster investment rate | Gradual investments over the coming decade; re-duced government spending on electricity; savings to reinforce grid infrastructure |
| Solar water heaters | Without firewood | Assumed that 6% (=250k/3.94 mill households) will benefit from SWH and 18% reduction in ener-gy consumption reduction. |
| Energy efficiency | | All manufacturing industries use 30% less energy inputs by 2030; total investment of $341 million between 2021-2030. |
| Biodiesel | | 2% domestically produced biodiesel in diesel by 2030; $299 million investments between 2021-2030; chemical industry produces biodiesel. |
| $N_2O$ decomposition | | Emission abatement technology installed at chemi-cal plants. |
| ClinkerSubstitution | | Clinker substituted with fly ash in cement produc-tion. |
| Conservation agriculture | Includes reduced prescribed burning | Increasing share of conservation agriculture in total agricultural production from 5% currently to 60% in 2030; $3.1 million investments |
| Efficient cookstoves | | Very hypothetical; not in LEDS; assumes about 0.5% of households will obtain a more efficient cookstove per year until 2030; reduced petroleum and firewood use. |

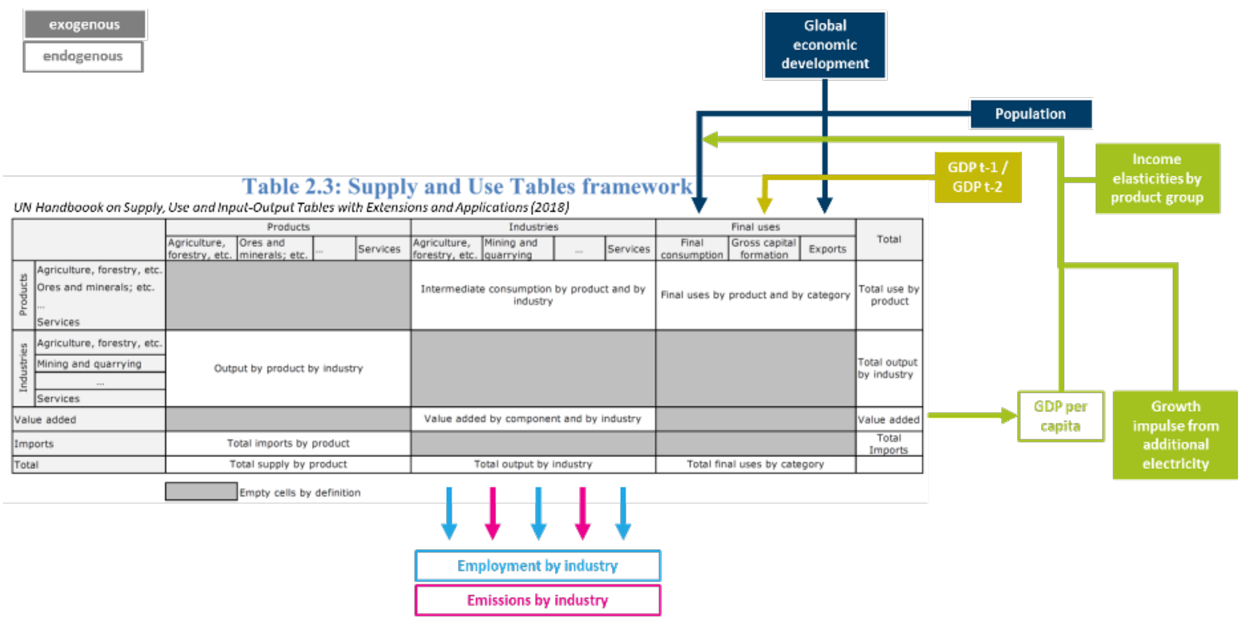
# 3. Green Jobs Assessment Model methodology and data

The GJAM for Zimbabwe is an input-output model with an economic core and based on the 2012 SUT. Economic development is driven by a combination of exogenous and endogenous macro-economic parameters. The philosophy of the model is to represent economic development as simply and transparently as possible, while enabling the employment outcomes of structural economic changes that occur due to climate change mitigation and adaptation policies to be identified, as envisioned by, for example, the country's NDCs.

As presented in Figure 1, the GJAM combines a macro-economic model that is solved iteratively, moving forward one year at a time with a demand-driven input-output model with industry detail. Exogenous drivers are exports and population. Exports grow with the global GDP growth rate from the OECD's Longview [4], adjusted for short-term developments by recent International Monetary Fund (IMF) estimates. Population development is assumed to follow the UN Department of Economic and Social Affairs' (UNDESA) medium fertility scenario [5]. Household consumption expenditures per capita are modelled using income, own-price and cross-price elasticities from the US Department of Agriculture's international food comparison programme [6,7]. Value added (used as a proxy for income for the household demand model) is calculated endogenously using the industry-by-commodity, commodity-demand driven supply and use table (SUT) model and changes from one iteration to the next. This in turn determines household consumption expenditures. The change in household consumption expenditures from one iteration to the next is the convergence criterium: once the change is smaller than 0.5 percent, the model moves on to the next year. Investment demand (gross fixed capital formation) is assumed to grow with last year's value-added growth rate. This was chosen to ensure model stability (investments are exogenous in the solution of a given year), while allowing for path dependency for the individual scenarios (investments grow faster with higher economic growth and, in turn, have a positive influence on economic growth).

For the baseline scenario, the economic structure is represented by the industries' market share coefficients. They include import shares from the supply table and the technical coefficients from the use table and are assumed constant. The emissions coefficients (greenhouse gas (GHG) emissions per use of fossil energy carriers) and labour coefficients (number of workers per unit of value added) are also assumed constant over time. Differences in industry-specific growth rates (value added, emissions and employment) occur due to changing shares of product groups in household demand.

**Figure 1: Schematic presentation of a supply-and-use table embedded in a simple macro-economic model**




Source: Own representation using Table 2.3 from the UN Handbook on SUTs [8]

Data used for GJAM Zimbabwe are described in detail in the Technical Appendix. Figure 2 and Figure 3 show estimates of GHG emissions and employment by supply and use table industry. The different shades of grey in Figure 2 indicate the different GHGs. Note that emissions from agriculture, fossil electricity and households are much higher than those from all other industries; therefore, they are presented in the left panel. The high level of emissions from household biomass burning should be noted. The colours in Figure 3 indicate gender (green for women, blue for men) and skill level (light for unskilled, dark for skilled). In terms of GHG emissions, the industries with the largest number of employees are presented separately in the left panel. Overall, this shows the labour force to be dominated by the "unskilled male" group, although skilled males constitute the largest group in manufacturing and large numbers of skilled women work in food and textile manufacturing. This latter group also have a significant presence in education, public administration, and health and social care services. The structure of the economy, employment and emissions in 2018 is based empirically on national data; the national accounts, the labour force survey, and emissions inventory are all harmonized for the single year 2018 (thus referred to as estimates). They are the starting points for all scenario simulations of the GJAM. The data for Figure 2 and Figure 3 can be found in Table 21 and Table 16, respectively.

**Figure 2: 2018 GHG emissions by industry (estimates): large industries on the left, all others on the right**

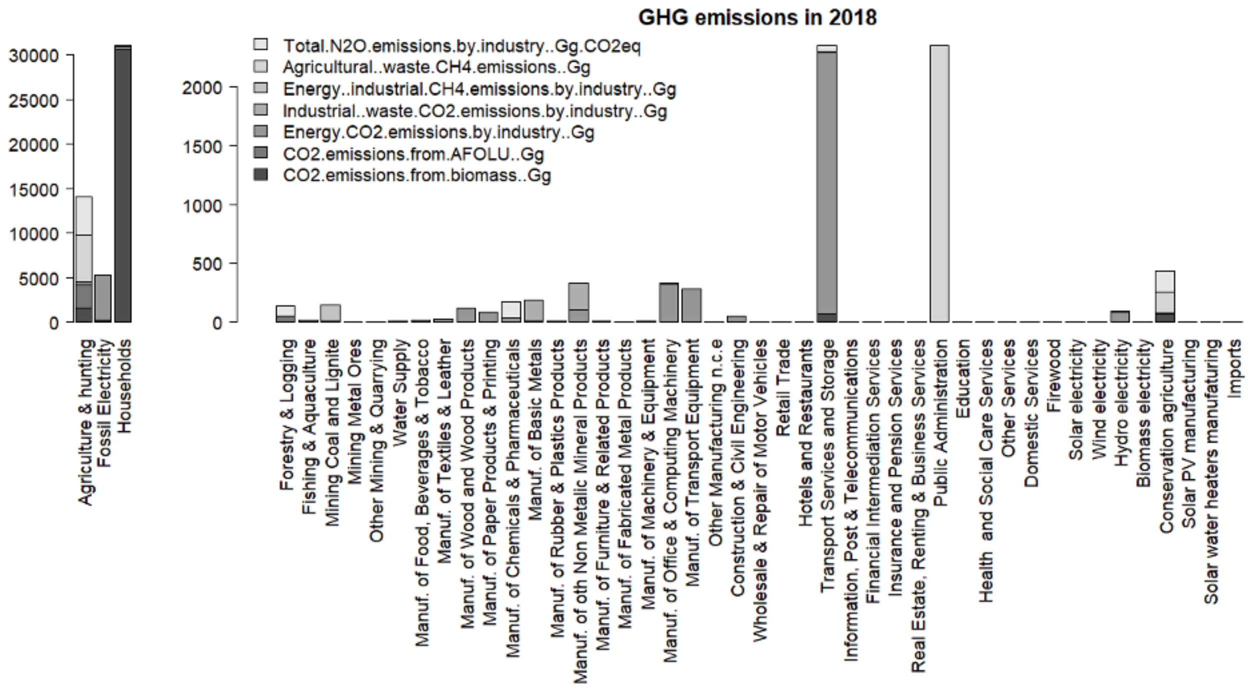
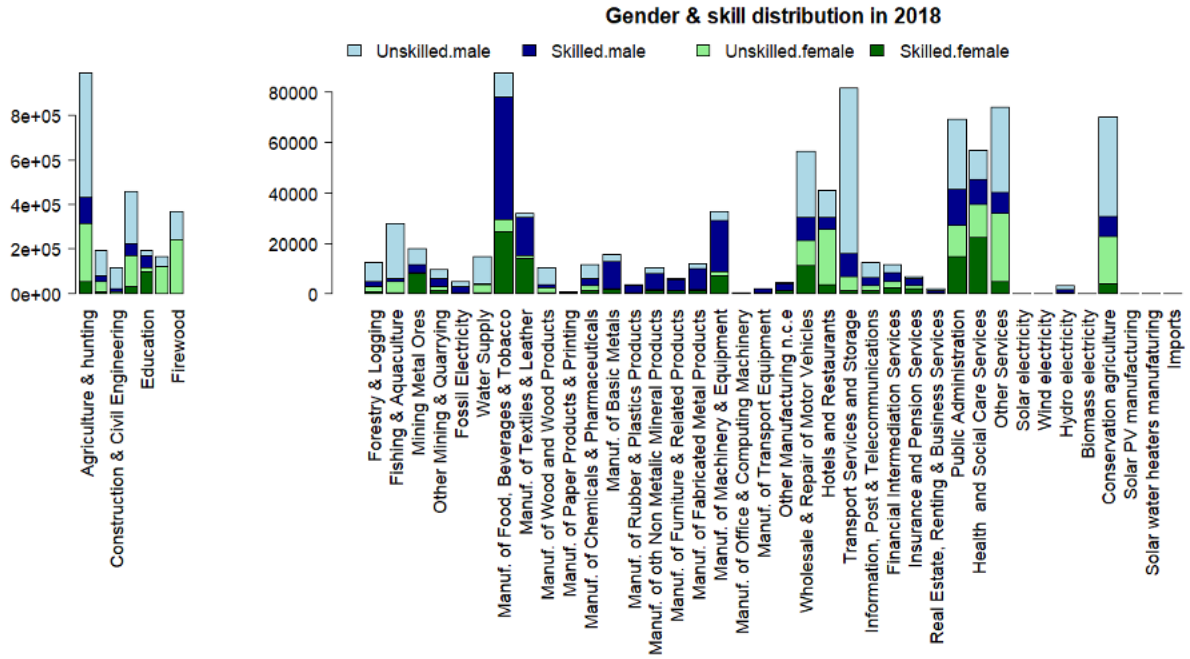


**Figure 3: 2018 employment (self-employed and employees) by industry (estimates), industry groupings into subfigures by order of magnitude**




**NOTE**

**GJAMs are not economic forecasting models. Rather, these models are a tool that provides the possible effects of "what-if" scenarios on emissions and labour demand by industries, assuming that the remaining structure of the economy does not change. The results should be assessed relative to the baseline scenario. They indicate the direction and possible size of the effects, but should not be taken as definitive. For example, actual labour market outcomes also depend on other factors, as well as on dynamic labour market adjustments, that are not considered here. Nonetheless, these models provide an indication of how to design measures and policy goals to maximize the positive implications of climate policies and minimize the negative ones. The merit of input-output and supply and use-based models is that they can also assess indirect effects, on the entire economy, of measures that will change production technology, consumer behaviour or investments, among others. Note that investments are modelled as additional economic activity, not as crowding out other investments.**

**"The term 'scenario' is often used in decision-making to represent an imagined future." A scenario aims at being self-consistent and plausible, but is not a prediction of the future [9].**

## 3.1 Modelling the climate policy scenarios

Energy, IPPU and agriculture policy scenarios are developed as described above for each NDC sector. Some policies, although considered under the energy sector, operate at the intersection of agriculture, forestry, industry and transport policies. Policies are based on the LEDS. The following four main inputs to the model are determined for each policy scenario.

1. What is the **greenhouse gas emission reduction target**? How will it be achieved? (Or, what is the adaptation action?)

2. Which type of **investments** in which industries/products are necessary? How much is needed per industry/product? Over which time periods? Is the necessary technology produced domestically or must it be imported? (Note that investments are modelled as additional economic activity, not as crowding out other investments.)

3. How does the **industrial structure** change in response to the policy? How do both the structure of production (e.g., fewer energy inputs, but more labour inputs) and the structure of demand change (e.g., what happens if more electricity is available?)?

4. How does **demand by households and government** change in response to the policy?

Government officials and stakeholders were consulted and data and information in response to these scenario design questions were discussed during a one-week online workshop in spring 2020 and based on the LEDS. Literature and specific expert knowledge from the Zimbabwe Economic Policy Analysis and Research Unit (ZEPARU) supplemented that activity.

The *outcome* indicators assessed relate to the policies' economic, employment and emission impacts. Table 2 presents them by industry and year. The data on rural and urban employment is incomplete; that is, the totals do not add up to economy-wide totals. Therefore, this report does not present results. No data were available for other labour indicators, such as employment by age group and industry. However, those and other indicators (for example, labour by household income group), can be incorporated into the model if data is available for the base year (2018).

**Table 2: Outcome indicators assessed for each policy scenario**

| EMPLOYMENT INDICATORS (in number of persons) | GHG EMISSION INDICATORS (in Gigagrams $CO_2$ equivalents) | ECONOMIC INDICATORS (US$ million) |
|---|---|---|
| Total employment | $CO_2$ emissions from biomass | Value Added total (vaNtot) |
| Female employment | $CO_2$ emissions from AFOLU | Employee compensation |
| Male employment | Energy $CO_2$ emissions | Gross operating surplus |
| Skilled | Industrial waste $CO_2$ emissions | Mixed incomes (farm and non-farm value added) |
| Unskilled | Energy industrial $CH_4$ emissions | |
| Skilled female | Agricultural waste $CH_4$ emissions | Net taxes on production |
| Unskilled female | $N_2O$ emissions | Household consumption expenditures (by product) |
| Skilled male | | |
| Unskilled male | | Gross fixed capital formation / investments (by product) |
| Rural employment female* | | |
| Rural employment male* | | |
| Urban employment female* | | |
| Urban employment male* | | |

* incomplete data

## 3.2 Baseline Scenario

The results of the policy scenarios should be assessed in comparison to the baseline scenario. It uses a rather conservative economic growth rate and does not model any structural change. Figure 4 displays key macroeconomic indicators.

The top panel of the figure shows both historic and modelled baseline macroeconomic variables: GDP, household consumption expenditures, government expenditures and gross fixed capital formation. The lower left panel shows the relative development of population, GDP from the production side (= value added), GHG emissions and number of workers (employment). The lower right panel shows respective annual growth rates.

Based on the pandemic-induced global recession in 2020, the model is calibrated to have a negative growth rate in 2020, recovering slowly in 2021. No structural changes due to COVID-19 are currently modelled due to a lack of data.

Figure 5 shows the increase in employment. The left panel shows the relative increase between 2018 and 2025 (dark)/2030 (light) by industry. The right panel shows the absolute increase by gender and skill level. The difference in growth by industry is determined by changing the household demand for goods and services. As income per capita increases, households spend a higher share of their income on recreational activities, for example, than food. These differences in economic growth across industries produce a different composition of the labour force. If the demand for services rises, and there is a relatively large share of unskilled females working in services, this group will see the largest increase in jobs. As the right panel in Figure 5 shows, unskilled men are expected to show the largest labour force increase in absolute terms. That is because they currently constitute the largest share of the labour force in most industries (see the light blue bars in Figure 3).

**Figure 4: Macroeconomic trends in the baseline scenario**

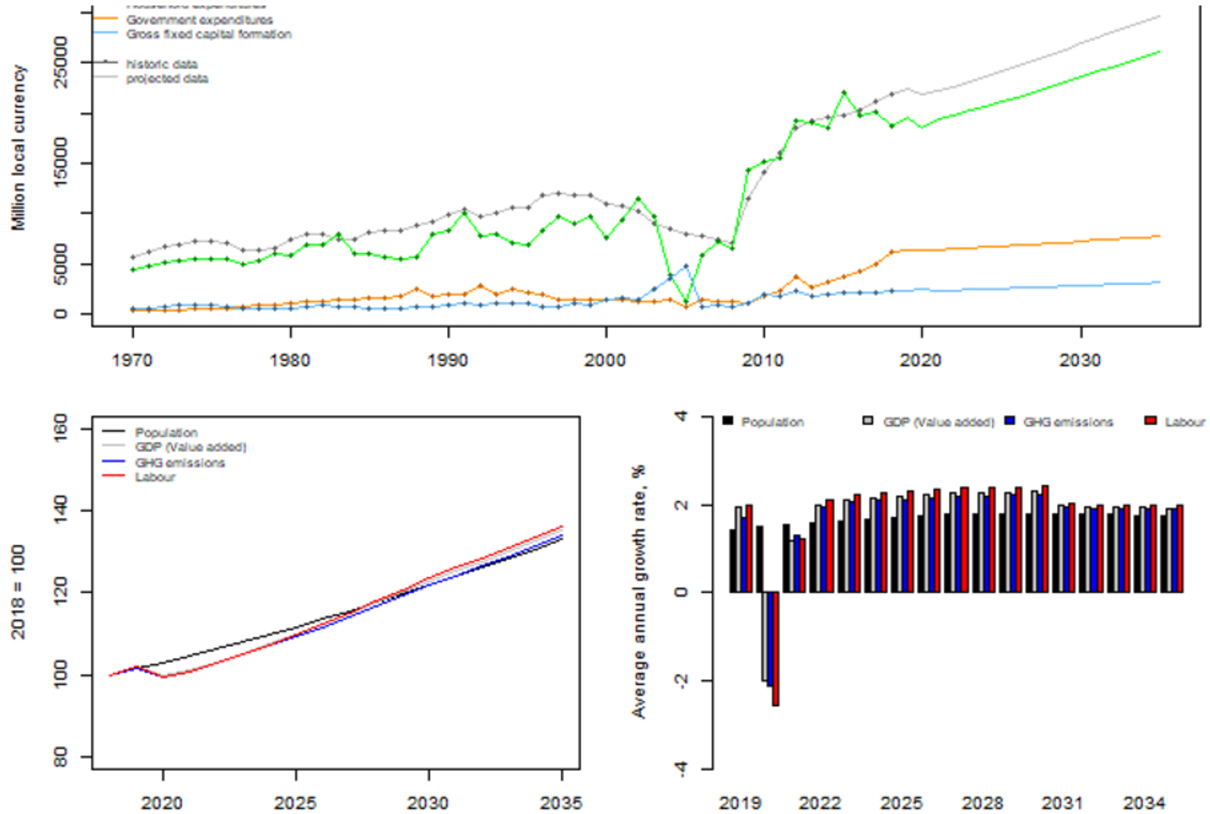
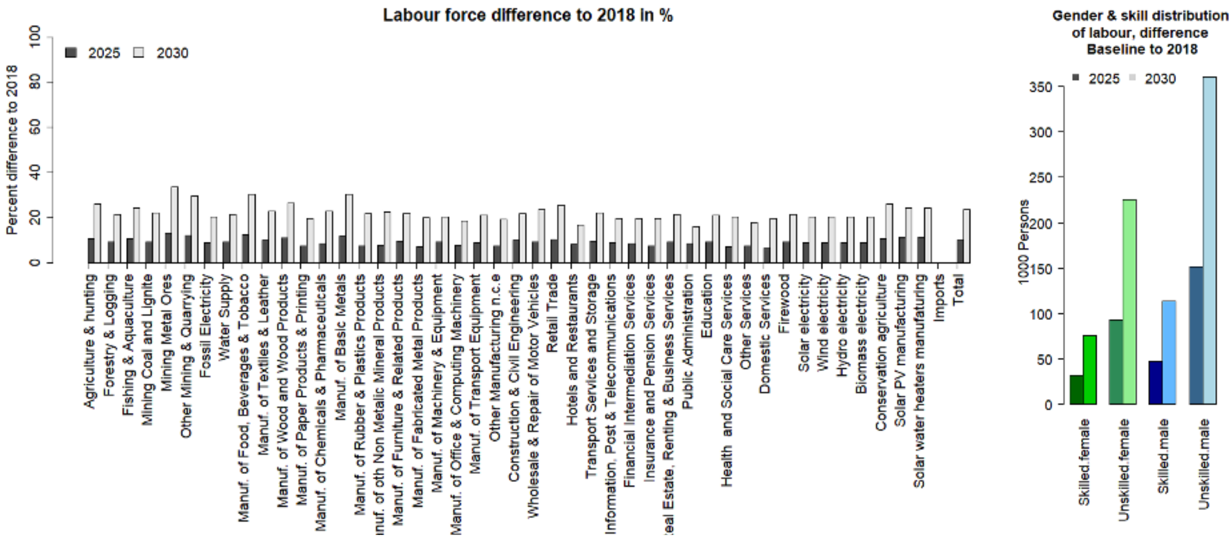


**Figure 5: Employment differences in baseline, 2030 compared to 2018, by industry**




---

**NOTE: GENERAL FOR ALL SCENARIOS**

We implement changes only up to 2030, although the figures show the years up to 2035. In some cases, there is a drop after 2030. This is because investments have larger short-term than long-term effects. The long-term effects reflect the structural changes in the economy.

---

# 4. Policy analysis of scenario results and policy implications

## 4.1 Overview

The 12 climate policies chosen, as described in detail above, are analysed in terms of their immediate short- to medium-term effects (primary), as well as of their long-term and subsequent effects (secondary).

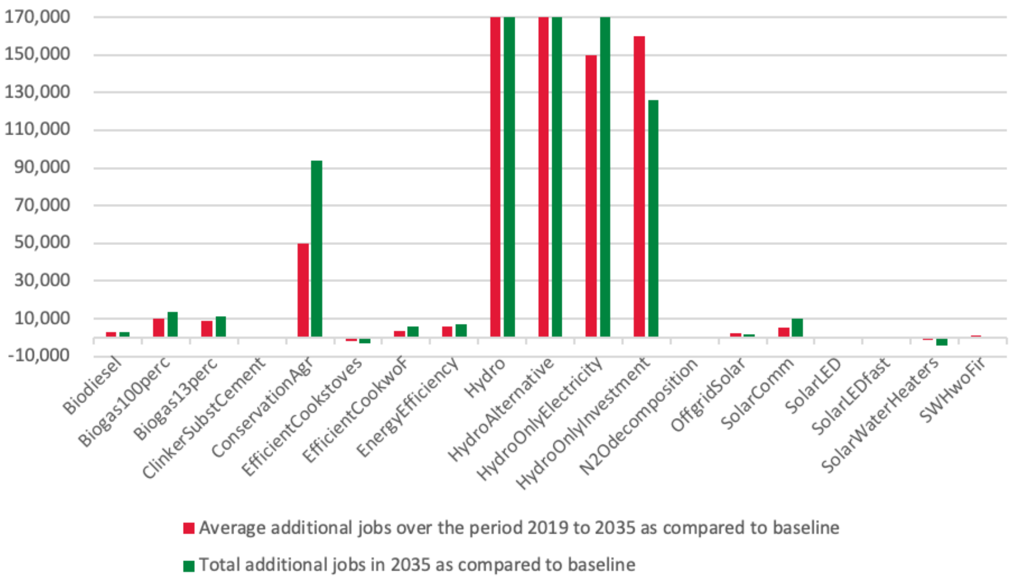
Construction of the mega-multi-billion-dollar Batoka dam, with by far the largest initial investment ($5.4 billion) of all policy scenarios, generates the largest initial investment effects. All three key indicators - GDP, jobs and emissions – increase most under this scenario. By comparison, the biogas policy, with an investment of $100 million, produces only small employment and income gains.

However, the secondary (medium- to long-term) effects up to 2035 should be analysed, when dam construction has been completed and activities shift to operation, maintenance and productive use of electricity. The analysis shows that, in 2035, when construction work is complete, the job creation and income effects will be only half of the total (primary and secondary) effects. Thus, the investment creates a short-term stimulus, primarily for the construction industry and GDP. However, the initial effect vanishes in the long term. In the case of the biogas policy, the secondary effect is more stable in terms of employment creation, as a significant number of workers are still needed to operate and maintain the biogas plants as compared to the capital-intensive Batoka dam.

Policies intended to increase electricity generation from commercial and off-grid solar (around $400 million and $250 million, respectively) are larger than for biogas ($100 million), although they may be small compared to the Batoka dam. Commercial solar policy is expected to create some 10,000 jobs in 2035 in addition to the baseline. The biodiesel, SWH and off-grid solar policies creates fewer than 5,000 additional jobs, primarily because the initial investments are very small.

Figure 6 summarizes the total employment effect (primary and secondary) for each policy scenario. It is capped at 170,000 additional jobs, which are created by considering only the Batoka dam investment phase. Because the investment is enormous relative to the size of Zimbabwe's economy, the total number of jobs created per year, on average, up to 2035 are estimated at around 300,000. The LED streetlight and NO2 policies have very small to no effects on employment. This is because of the very small initial investment (primary effect) and because there is no difference in terms of operation compared to the baseline.

**Figure 6: Additional jobs created by selected climate policies (NDCs) in 2035**



Comparing the total effects of the commercial solar and the biogas policies shows, surprisingly, that the effects are similar (around 10,000 additional jobs in 2035), although investments in biogas total only one-quarter of investments in commercial solar.

This finding is important because it shows that while the total size of the investment matters, the *type* of investment is crucial. The structural economic change that the investment produces will determine the resulting number of jobs, amount of GDP and volume of emissions – whether larger or smaller.

This reveals a third dimension of the policy effects (in addition to the primary and secondary effects) that should be analysed: the total number of jobs created or lost in 2035 per dollar invested. This is important because the type of investment has different primary and secondary effects. The same holds for the effects on GDP and emissions per unit of investment.

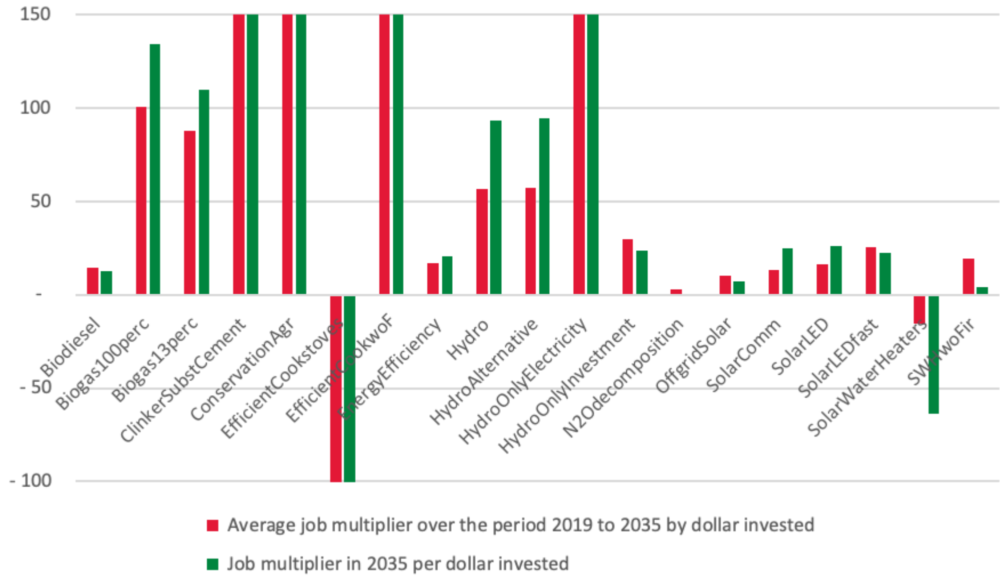
In the case of biogas, $1 million invested stimulates the creation of around 130 jobs economy-wide in 2035. This compares to only 25 jobs for commercial solar and some 100 jobs for the Batoka hydro dam. This is because operating and maintaining biogas plants is more labour intensive than running the hydro dam or operating commercial solar plants. The supply chain effects extend further and are more closely linked to the national economy through the collection, transport and management of local manure and agricultural residues. Operating commercial solar and building the hydro dam also involve significant imports, which have little employment effects (leakage out of the economy).

The biogas scenario described above assumes 100 percent capacity utilization once the plants are completed. However, studies have shown that the current utilization rate is only around 13 percent, which would generate much lower employment multipliers (closer to 100 jobs, which is still comparably high and explained by the fact that the plants still need to be built, even if they are not used later). The comparison between the 100 percent and 13 percent capacity utilization scenarios illustrates a point that is relevant to all other scenarios: just transition policies should accompany climate policies.

The reason is that planning only for capital investments could lead to a situation in which the skilled technicians and companies needed to operate, maintain and manage the biogas plants (or any other capital investment modelled here) are lacking. The subsequent section will discuss the importance of accompanying just transition policies further. Indeed, they are of equal importance to the climate and investment policies. Without them, the secondary effect – the productive use, operation and maintenance of the capital assets created - will not occur.

Figure 7 shows the total employment effect per million dollars invested for each policy scenario in 2035. Two of the energy policies stand out in terms of policy analysis - energy efficient cookstoves and hydroelectricity only.

**Figure 7: Total economy-wide job multiplier per dollar invested of selected climate policies (NDCs), 2035**



A $1 million investment in the production of energy efficient cookstoves creates more than 850 jobs. This is based on the assumption that time spent collecting firewood is not considered employment and that the time is used for other household activities, without income loss. If firewood collection is assumed to be employment, the effect changes to negative and jobs are lost. Some 450 full-time equivalent jobs (net) will be lost in firewood collection. The same applies to investment in SWH. If it is assumed that this reduces firewood collection and, consequently, employment in this activity, then the investment has negative long-term effects on jobs.

This points, again, to the importance of accompanying any climate policy that seeks to reduce firewood use and increase the use of alternatives (such as SWH) with social and labour market policies. These latter policies must ensure that potential income losses in the firewood industry are addressed. Pairing just transition policies with energy and AFOLU sector policies would ensure that potential negative social impacts are buffered and would increase the likelihood that climate policies are adopted, implemented and have an effect. This is because households that derive their main income from firewood collection will need to find alternative income. If no other work opportunities exist, they may continue to collect firewood even if it is banned, thus rendering the climate policy ineffective.

The hydroelectricity-only scenario focuses only on the cost of operating the dam and excludes total investment costs. This is intended to highlight the structural long-term effect (secondary). Operation and maintenance costs are estimated at $66 million over the period 2019-2030 and are marginal compared to the initial $5.4 billion investment. This scenario shows that additional electricity is delivered at marginal cost and is effectively provided for free from the water flow. This investment has massive employment creation potential, if, and only if, it is used productively. A $1 million investment in operations and maintenance and the forward linkages created by using the electricity generated productively may create more than 5,000 jobs.

However, if there are no entrepreneurs, companies or skilled workers to use the electricity productively and it is simply consumed by households for their leisure needs or is exported, the effect will be much smaller. Thus, just transition policies in the area of enterprise and entrepreneurship development are called for to ensure productive use.

Regarding the non-energy climate policies, the IPPU and agricultural conservation scenarios offer significant potential. Agriculture is Zimbabwe's largest sector and employer, providing work for some 40 percent of the labour force. Any policy that is adopted and implemented will have large-scale labour market implications. A policy that involves shifting to climate-smart and conservation farming systems has several significant labour market effects. Conservation farming requires increased use and production of organic fertilizer, creating jobs in supplying industries, reducing the use of chemical fertilizer, reducing imports and chemical industry-related jobs, and creating some 10 percent additional direct agriculture-related jobs in soil preparation, management, harvesting and post-harvest activities.

The policy's net effect on total agricultural employment is estimated at close to 100,000 additional full-time equivalent jobs in 2035. And, because the investment requirements are very small - and relate more to training and up-skilling of farmers than capital - the job multiplier is the highest of all the scenarios. A $1 million investment in conservation and climate-smart agriculture is estimated to create some 30,000 jobs in 2035.

The IPPU policy has little effect on total jobs created, as both the policy and the investments are very modest. However, the job multiplier per million dollars invested is very high, with around 300 total jobs created in 2035 because the cost to the cement industry of substituting clinker with fly ash is marginal. At the same time, a significant number of jobs are created in fly ash collection and transport. The next section discusses the just transition policies in more detail.

## 4.2 Accompanying just transition polices

If climate policies are to be effective, they must be accompanied by just transition policies. The objective to integrate and accompany climate policies with just transition policies is four-fold.

First, the failure to address social consequences may result in the non-implementation and failure of the climate policies. Reasons may include social protest (for example, mass protests against fossil fuel subsidy reform), non-compliance (ban on charcoal production, which is ignored because of lack of alternatives) and/ or economic and social hardship, which prevents any shift away from economically- harmful activities (such as firewood production).

Second, the type of climate policy has significant and very different effects on social and labour market outcomes. Integrating just transition policies in the design stage can maximize social inclusion, pro-poor growth and job creation. As the above analysis shows, climate policies that call for investing in conservation agriculture, for example, have very high job creation potential per million dollars invested, compared to high capital-intensive investments, such as in hydro or commercial solar plants. The low-skilled and rural poor would benefit most from a well-considered agricultural conservation policy, while wealthy urban residents would gain more from large-scale electricity generation plants. This reveals another important policy consideration: the effect of the climate policy on inequality, income distribution, urban versus rural development and potential long-term effects on industrial, agro-processing and aggregate GDP growth. Government and policymakers need to consider these effects to make informed decisions in terms of their long-term development strategy.

The above analysis and consideration of just transition policies can make a difference even within energy sector policies and ensure that social and labour market outcomes are maximized. In the case of the biogas electricity generation policy, for example, ensuring that plants will be serviced, managed and maintained will generate much larger employment creation effects. In fact, this would lead to the highest employment creation multiplier per dollar invested compared to the other green electricity policies. Integrating those findings into climate policies and implementation plans will maximize positive social and labour outcomes when dealing with constrained resources.

Third, well-intended climate policies and capital investments in the low-carbon economy require that managers, workers, enterprises and entrepreneurs have the skills to finance, manage, construct, operate and maintain the capital asset, as well as make productive use of it in the long term. A lack of skilled managers and workers may hinder climate projects and investments.

And fourth, accompanying fiscal, macro, sectoral and industry policies could support structural economic change and enhance economic growth and social development. A main instrument is a fiscally-neutral policy reform with a double dividend: tax carbon while lowering labour costs. This could shift economic growth to low-carbon activities and industries and, simultaneously, reduce the cost of employment, thereby enhancing overall national employment creation. A well-designed local content, foreign direct investment and sustainable procurement policy, in combination with policies that support green infant industry, such as tax breaks, special economic zones or research and development support, would strengthen employment creation and long-term structural change.

In summary, the four objectives of just transition policymaking require a sequenced and balanced inter-ministerial approach. At the initial stage, the priority should be given to defining the type of climate policies and investments to focus on, fast track and frontload. The national development strategy should guide this assessment and prioritization.

Once priority sectors and policies are chosen and aligned with the government's overall development strategy, accompanying fiscal, macro, sector and industry policies are needed to support the direction of economic development policy. Enterprise development, an enabling business environment and entrepreneurship training and support are of utmost importance to achieve and implement the climate policies.

Similarly, social protection measures need to be designed in parallel to address and signal the population concerned that the government will buffer potential negative impacts of the prioritized policies. Social policies include, but are not limited to, extending social protection floors, insurance, public employment programmes, unemployment guarantees, or conditional cash transfer programmes.

Last, a skills development strategy should be developed for each of the priority sectors. A systems approach, rather than an *ad hoc* one, is recommended. This requires integrating the required skills and professions into the country's education and training system at large. It involves creating a mechanism by which government, employers and workers discuss and decide on the skills requirements, the process of developing and regularly updating the curricula, training teachers and trainers, integrating the curricula in schools, TVET institutions and universities and rolling out the skills strategy. Apprenticeship systems and on-the-job learning systems may complement the skills strategy.

# 5. Detailed short- and long-term results by type of climate policy

## 5.1 Hydropower (Energy)

According to the LEDS document, Zimbabwe plans to build two large-scale hydro power plants - the Batoka Gorge and the Devil's Gorge. The Batoka project involves a 181-metre-high dam on the Zambezi River, close to Victoria Falls. As the plant will be located on the Zimbabwe-Zambia border, it will be developed and operated by the Zambezi River Authority, established in 1987 and owned jointly by the two governments [10]. Two power plants will be built, one on each side of the border, and each with planned installed capacity of 1200 MW.

When commissioned, the Batoka plant is projected to constitute a significant share of Zimbabwe's installed capacity and annual production capacity (an additional 5,000 GWh per year). It is also expected to protect the Zimbabwean population from frequent blackouts. Given the country's population growth, electricity production would have to increase by 150-200 GWh annually over the coming decades. If additional electricity were generated, it is assumed that it would boost the economy. To that end, we used historical data to estimate the correlation between additional electricity per capita and GDP per capita and found that each additional kWh electricity per capita increases GDP per capita by $1.47.

The $5.4 billion investment needed to build the construction Batoka plant [11] is substantial, amounting to about 25 percent of total investments in 2018. When implementing this scenario in the GJAM, these investments are spread over 10 years and six product groups from the SUT (see Table 3).

As additional investments are modelled - that is, investments additional to the ongoing investment activities in the baseline scenario - the economy is strengthened compared to the baseline. This increases both employment and GHG emissions. These impacts should thus be compared to a scenario that involves the same high level of investment activity, but that does not generate the structural change related to electricity generation. The scenario that meets that description is “HydroAlternative” in Figure 8.

Comparing "Hydro" and "HydroAlternative" shows that GHG emissions (blue line) are much lower in the Hydro scenario, while there is no significant difference in either value added or employment. Thus, hydropower offers the potential to decarbonize the electricity sector without negative effects on labour and value creation. In addition, the fact that total emissions will rise under either scenario shows clearly - and convincingly - that additional economic activity will always create emissions if it adds to, rather than replaces, more polluting existing activity.

Developing countries, particularly those with very low levels of GDP per capita, such as Zimbabwe, need to grow their economies (as compared to replacing existing productive capital). Rising emissions will follow, specifically in sectors such as construction, where initial and additional investments are made. However, today's decisions regarding the type of economic assets to invest in will have significant medium- to long-term effects on the emissions growth path in the future, as the comparison of the Hydro and HydroAlternative scenarios shows.

To better understand the impact of additional electricity available compared to additional investments, these have been implemented individually in the model. The "HydroOnlyElectricity" panel in Figure 8 shows the effects of additional electricity capacity on the economy. This scenario includes no investments and no structural change in electricity; that is, no changes in the electricity mix (so the emissions are overestimated). The result is that once the additional electricity becomes available in the second half of the 2020s, it provides a permanent boost to the economy. The "HydroOnlyInvestment" panel shows the investments' impacts. They are larger during the years in which the investments are made, but also have a positive long-term effect on the economy.

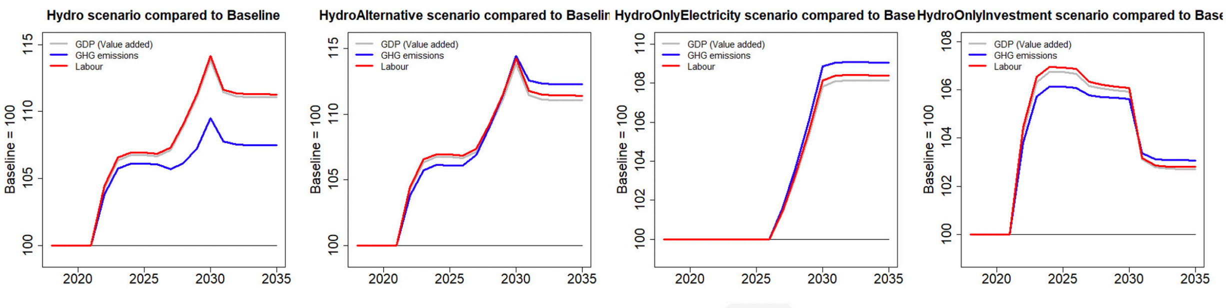
In summary, investments produce large short-term economic effects (the first panel in Figure 8, which presents the main scenario). Emissions and economic activity thus increase and persist over the long term (second panel). The 2030 peak is due to the last year of investments, which return to zero after 2030. **The long-term GHG emissions path is lower compared to an economic activity scenario with the current electricity mix.**

Figure 9 and Figure 10 show changes in employment and emissions by industry relative to the baseline scenario. Figure 9 shows relative changes in employment by industry (left panel), and the **resulting economy-wide changes for employment by gender and skill level in absolute terms (right panel). The investment effects dominate for 2025, while those for 2030 show the long-term structural change.** For all industries except construction, the long-term effects are larger than the short-term ones. As the entire economy is growing overall, no specific gender and skill effects can be identified.

### Table 3: Investment assumptions for hydropower scenario

| PRODUCT GROUP FROM SUT | IMPORT SHARE | INVESTMENT SHARE |
|---|---|---|
| Plaster, lime, cement, concrete, building stone | | 2% |
| General-purpose machinery, engines and parts & electrical | 95% | 5% |
| Construction | | 39% |
| Construction services | 100% | 39% |
| Freight transport services | | 2% |
| Financial intermediation and related services | | 13% |

### Figure 8: Hydro power scenarios compared to baseline: total employment/emissions/value added




### Figure 9: Hydro power scenario compared to baseline: employment by industry/skills and gender

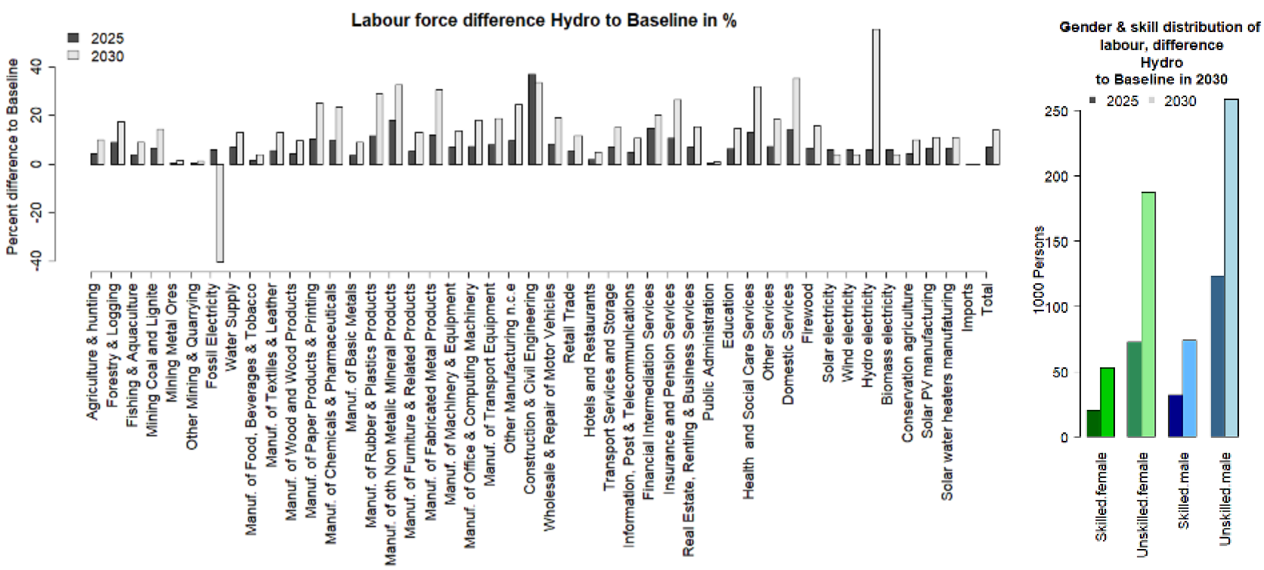
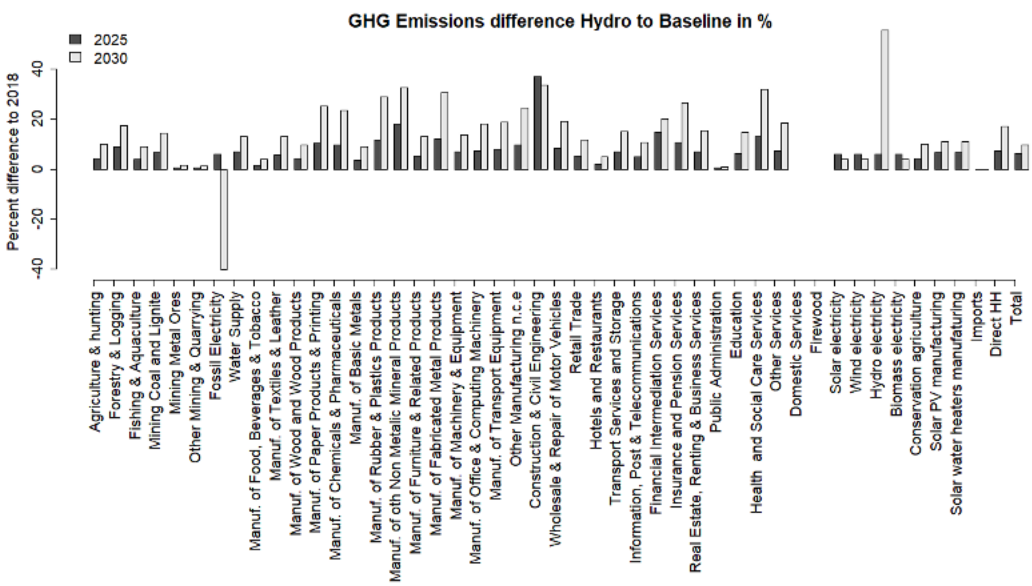


**Figure 10: Hydro power scenario compared to Baseline: GHG emissions by industry**




## 5.2 Biogas (Energy)

The increased installation and uptake of biogas plants has two goals: to replace coal-fired power plants by municipal biogas power plants and to increase decentralized energy access at farms. Data on expected electricity generation are available only for the Mbare biogas plant. However, the LEDS provides the expected investment costs for all the biogas plants. Based on this data, we estimated the generation possibilities of the other plants by assuming constant electricity expected per dollar invested in biogas across all the plants. This provides the following estimates of the electricity level expected for each biogas investment:

- Mbare Biogas: 100kva (= 0.1e-3GWh) from 2024
- Bulawayo Biogas: 1270kva from 2025
- Harare-Firle Biogas: 5077kva from 2026
- On farm biogas: 31904kva increasing from 2024-2026

The modelling uses the total and does not distinguish between the three plants and on-farm biogas. A rapid situational analysis of the biogas history indicates that biogas digesters are not necessarily sustainable after initial investment and construction, especially in rural areas. For example, between 1980 and 2012, only 14 biogas digesters were operating. During that time, 68 were non-functional, three had collapsed and 26 had been abandoned. The probability of sustaining these facilities is thus around 13 percent. We therefore estimate electricity from on-farm biogas to be about 4148kva (13 percent of the total expected). We model total investments of $99.71 million and assume a spread across SUT products and time as displayed in Table 4.

**Table 4: Investment assumptions for biogas electricity scenario in $ million per year and product/ service groups**

| SUT PRODUCT GROUP | IMPORT SHARE | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|
| Plaster, lime, cement, concrete, building stone | 2.8% | 0.045 | 0.602 | 17.112 | 10.279 | 6.700 |
| General-purpose machinery, engines and parts & electrical | 45.0% | 0.058 | 0.775 | 22.026 | 13.231 | 8.623 |
| Construction (building the plants) | | 0.012 | 0.166 | 4.720 | 2.836 | 1.848 |
| Freight transport services | 23.3% | 0.008 | 0.111 | 3.144 | 1.889 | 1.231 |
| Financial intermediation and related services | | 0.006 | 0.074 | 2.115 | 1.271 | 0.828 |

The investments are modelled to start one year prior to utilization. Therefore, GHG emissions begin falling with a one-year time lag, as Figure 11 shows. Full utilization of on-farm biogas has no significant effect on total employment or labour, but reduces total economy-wide GHG emissions by about 0.5 percent in the long run. (This can be seen by comparing the right and left panels in Figure 11. Note that the vertical axes are slightly different sizes). **This shows a small short-term investment effect overall, which translates into a very small economy-wide structural change effect in the second half of the 2020s: about 0.3 percent higher employment and 1 percent lower GHG emissions than under the baseline scenario.**

Figure 12 shows that the positive economic short-term impacts occur primarily in two manufacturing industries: "Other Non-Metallic Mineral Products" and "Electrical Equipment, Machinery & Equipment." Employment increases are largest in absolute terms during the investment phase, with the largest boost among skilled males, relative to the long term. The difference between short- and long-term impacts for unskilled females is small. Both employment and GHG emissions (Figure 13) from fossil electricity production decline by more than 10 percent relative to the baseline. Given that biogas electricity production effectively does not exist today, the relative increase as shown in Figure 12 and Figure 13 is huge.

---

**GENERAL OBSERVATION FOR ALL SCENARIOS: LARGE PROPORTIONAL INCREASE IN A SMALL INDUSTRY**

This effect will also become visible in other scenarios where an industry that is very small or non-existent today (e.g., solar power or SWH) is expected to grow substantially. In addition, **overall employment in electricity production does not necessarily decline simply because employment in fossil electricity production does. While direct employment intensities of renewable power do not differ significantly from those of fossil electricity production, the effects of the long-term structural change in the economy are important to note.**

---

**Figure 11: Biogas power scenarios compared to Baseline: total employment/emissions/value added)**

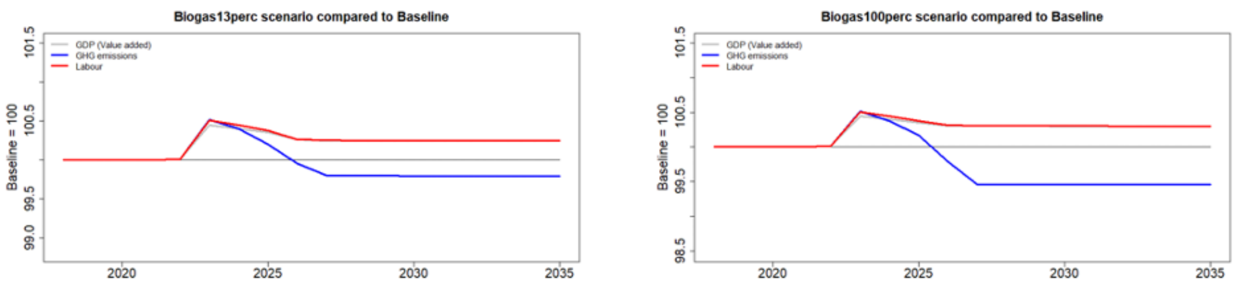


**Figure 12: Biogas power scenario compared to Baseline: employment by industry/skills and gender**

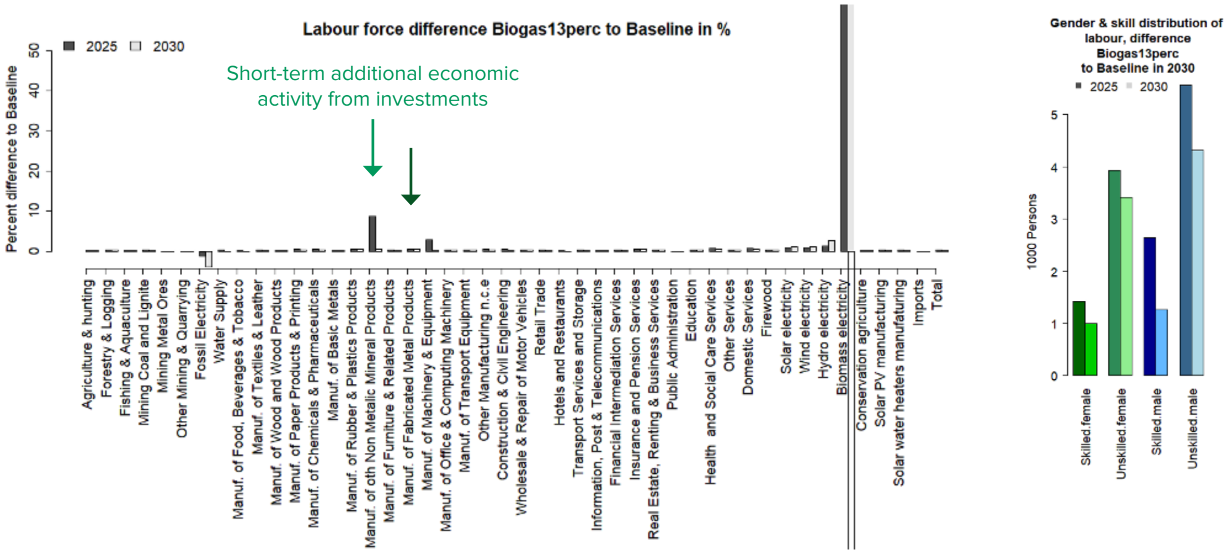
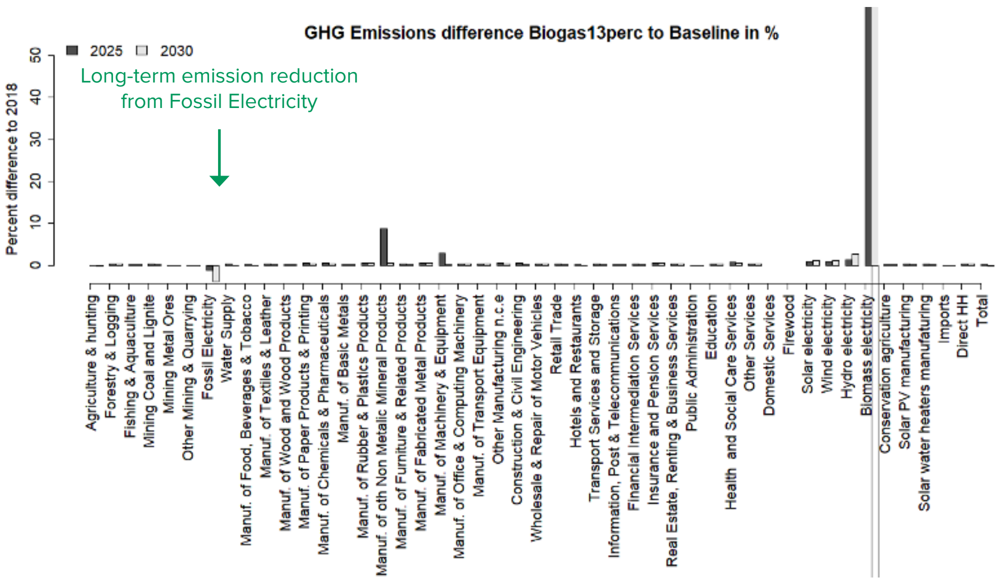



**Figure 13: Biogas power scenario compared to Baseline: GHG emissions by industry**




## 5.3 Commercial solar (Energy)

Solar electricity represents the lowest share of total electricity production, at about 5 percent. Of that, 1.33 percent of total electricity is connected to the grid, while most - 3.7 percent - is off-grid. The total share of solar (both off-grid and on-grid) is expected to increase to **27 percent by 2030**. The LEDS describes three major projects for commercial solar electricity production: commercial building rooftops; independent power producers (IPPs); and the Zimbabwe Power Company's solar plants. Current investment plans add up to slightly more than $400 million. Investments start slowly, but continue to increase over time (see Table 5). In total, this will translate to approximately an additional 1200-1300 GWh of electricity production annually by 2030. Photovoltaic (PV) panels are assumed to be imported.

**Table 5: Investment assumptions for commercial solar electricity scenario by product/service group and year ($ million)**

| SUT PRODUCT GROUP | IMPORT SHARE | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plaster, lime, cement, concrete, building stone | | 0.5 | 0.5 | 5.0 | 5.7 | 6.5 | 7.4 | 8.5 | 9.6 | 11.0 | 12.5 | 14.2 |
| PV panels | 100% | 1.3 | 1.5 | 13.8 | 15.7 | 17.9 | 20.4 | 23.2 | 26.5 | 30.2 | 34.4 | 39.2 |
| Construction | | 0.5 | 0.5 | 5.0 | 5.7 | 6.5 | 7.4 | 8.5 | 9.6 | 11.0 | 12.5 | 14.2 |
| Freight transport services | | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 |
| Financial intermediation and related services | | 0.1 | 0.1 | 1.1 | 1.3 | 1.5 | 1.7 | 1.9 | 2.2 | 2.5 | 2.8 | 3.2 |
| Additional electricity (GWh) | | 7 | 8 | 76 | 87 | 99 | 112 | 128 | 146 | 166 | 189 | 216 |

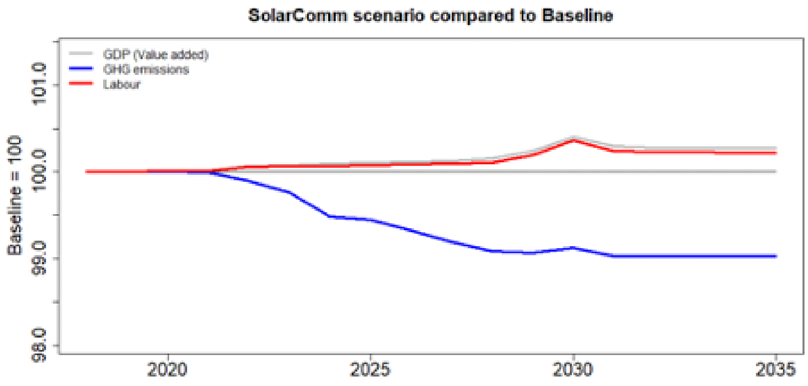
As under the other scenarios, the short-term investment effects are larger for the entire economy than the long-run structural change effects. Starting in the late 2020s, capacity additions become large enough to increase electricity production per capita, providing an additional economic boost. Emissions decrease significantly as installed capacity increases.

At the industry level, the investment demand for "Construction of Buildings & Civil Engineering Work" and related materials from "Manufacturing of Other Non-Metallic Mineral Products" drives positive employment outcomes, both in 2025 and 2030. All industries show small positive employment effects, indicating that an increase in solar power electricity ensures balanced growth across the entire economy. The off-grid solar power scenario, described in the next section, further confirms this.

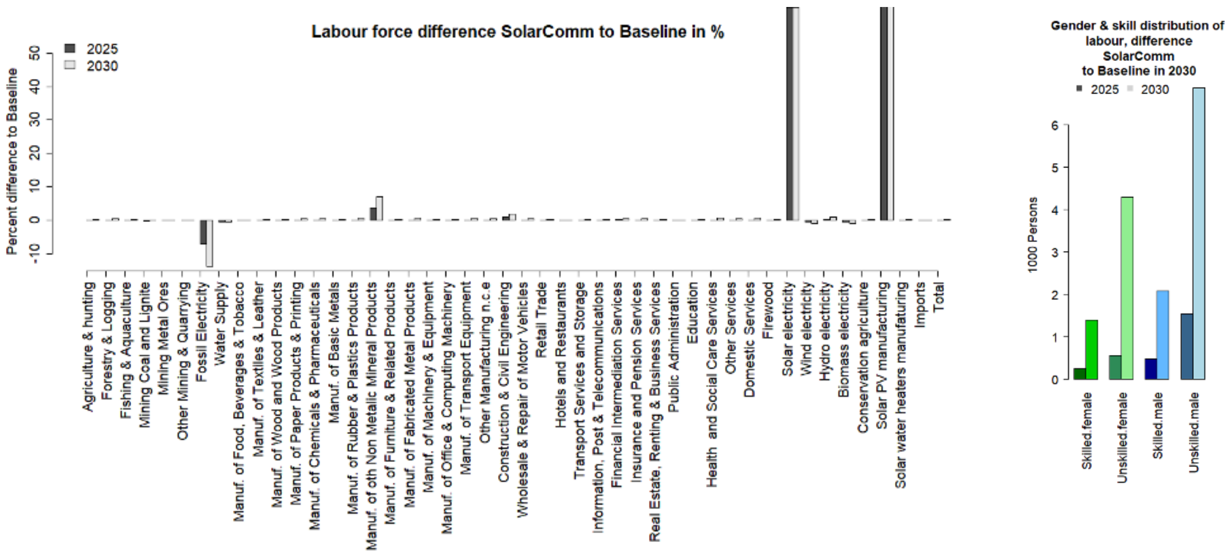
**GENERAL OBSERVATION FOR ALL SCENARIOS: FOSSIL ELECTRICITY OWN USE**

**Positive/negative effects from energy sector investments on other renewable electricity industries are artificial and should be disregarded. This inaccuracy occurs as a result of the modelling of electricity shares. The fossil electricity industry uses a substantial amount of electricity itself. Thus, when the share of fossil electricity decreases, so does the sector's electricity demand, including total electricity demand. This, in turn, reduces electricity demand from renewable sources. For both "solar commercial" and "off-grid solar" scenarios, we have tried to level out this effect on the other renewable industries, but it is not precisely zero. For solar LED streetlights, we did not level it out manually. The decrease in electricity demand in general is amplified by decreasing electricity demand from the fossil electricity industry for its own use. The negative effects observed on renewable electricity industries should be regarded as zero, while the fossil electricity industry will absorb the entire negative effect.**

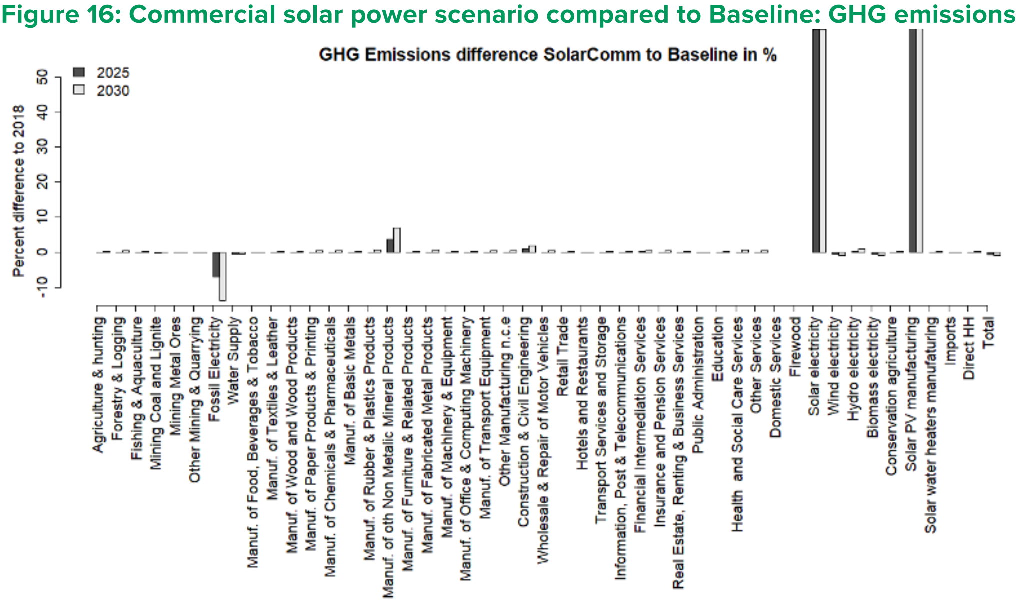
## Figure 14: Commercial solar power scenarios compared to Baseline; total employment/ emissions/ value added




## Figure 15: Commercial solar power scenario compared to Baseline: employment by industry/ skills and gender




## Figure 16: Commercial solar power scenario compared to Baseline: GHG emissions by industry



## 5.4 Off-grid solar (Energy)

The difference between commercial solar and off-grid solar is that the former is part of the grid electricity mix, or replaces grid electricity locally, while off-grid solar involves small solar PV systems used for lighting or to charge phones or other small appliances. This analysis assumes that the electricity is used directly by households, replacing other energy sources (petroleum oil, gas and bitumen). Off-grid solar currently dominates, with a 3.7 percent share, but is expected to increase more slowly than commercial solar, reaching approximately 25 percent off-grid/75 percent grid in 2030 [[12]]. Table 6 summarizes both investments ($250 million) and additional electricity production (total increase of 760 GWh) plans.

In the model and its product groups, off-grid solar is considered power services provided by industry communication network providers. Households may spend less money on fuel lighting or running a generator, but pay communication network providers for off-grid electricity services to charge lamps or phones.

Compared to commercial solar, this scenario assumes that households benefit directly from increased and inexpensive electricity access. Solar power replaces traditional energy sources (diesel generators or firewood), thus significantly reducing local emissions and contributing to better health effects (not modelled here). Solar power also makes it possible to study in the evenings and frees up resources (money and time). Savings are thus assumed to be spent on education, communication and general goods. This, in turn, has positive indirect and induced effects on the entire economy.

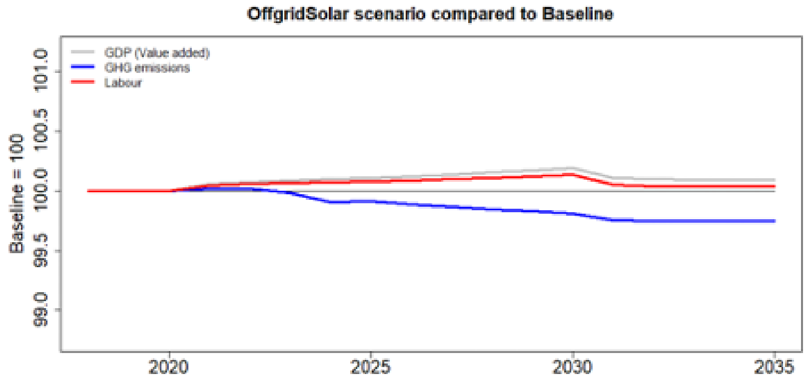
**Table 6: Investment assumptions for off-grid solar electricity scenario by product/service group and year ($ million)**

| SUT PRODUCT GROUP | IMPORT SHARE | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Plaster, lime, cement, concrete, building stone | | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.5 | 0.6 | 0.6 | 0.7 | 0.8 |
| PV panels | 100% | 7.2 | 8.2 | 9.3 | 10.6 | 12.1 | 13.7 | 15.7 | 17.8 | 20.3 | 23.2 |
| Construction | | 3.3 | 3.7 | 4.2 | 4.8 | 5.5 | 6.2 | 7.1 | 8.1 | 9.2 | 10.5 |
| Freight transport services | | 2.0 | 2.2 | 2.5 | 2.9 | 3.3 | 3.7 | 4.3 | 4.9 | 5.5 | 6.3 |
| Telecommunications, broadcasting and information supply services | | 0.4 | 0.4 | 0.5 | 0.6 | 0.7 | 0.7 | 0.9 | 1.0 | 1.1 | 1.3 |
| Additional electricity (GWh) | | 39 | 45 | 51 | 58 | 66 | 76 | 86 | 98 | 112 | 128 |

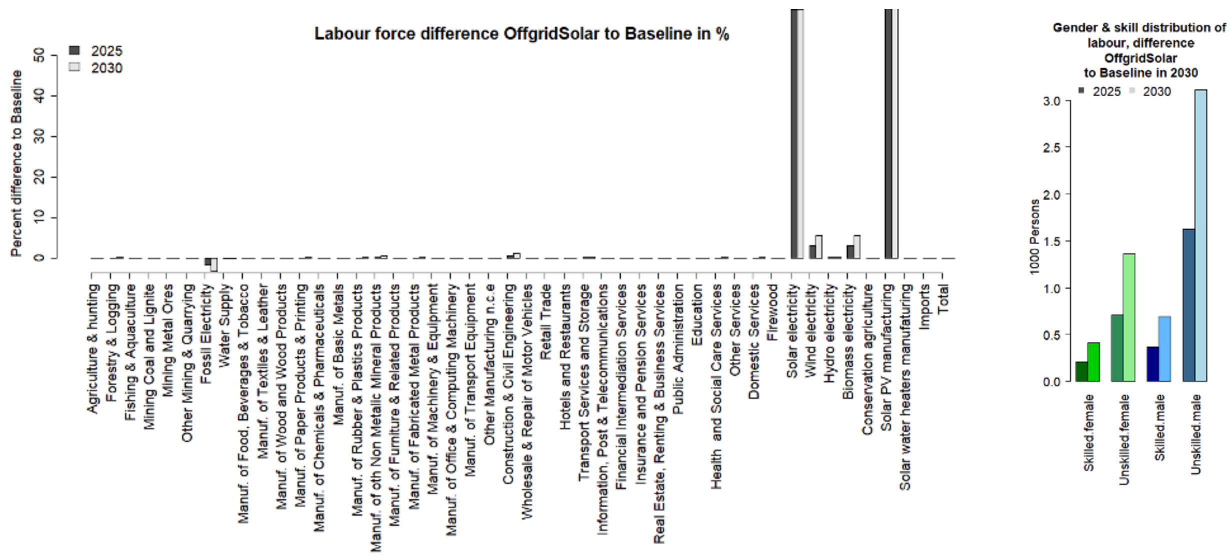
The short-term investment effects increase value added and employment, while GHG emissions increase only in the first year due to enhanced economic activity (Figure 17). For industry, the positive effects on employment are due primarily to investment demand for "Construction of Buildings & Civil Engineering Works" and related materials ("Manuf. of Other Non-Metallic Mineral Products"). The need for "Transport Services and Storage" also increases during the investment phase.

The long-term structural effects are decreasing GHG emissions (due to lower emissions from fossil fuel electricity production), while they are only slightly positive for employment (Figure 17). However, the number of workers needed to operate and maintain the off-grid solar systems is probably underestimated, as current labour coefficients are based on EU/US averages for solar power in general.

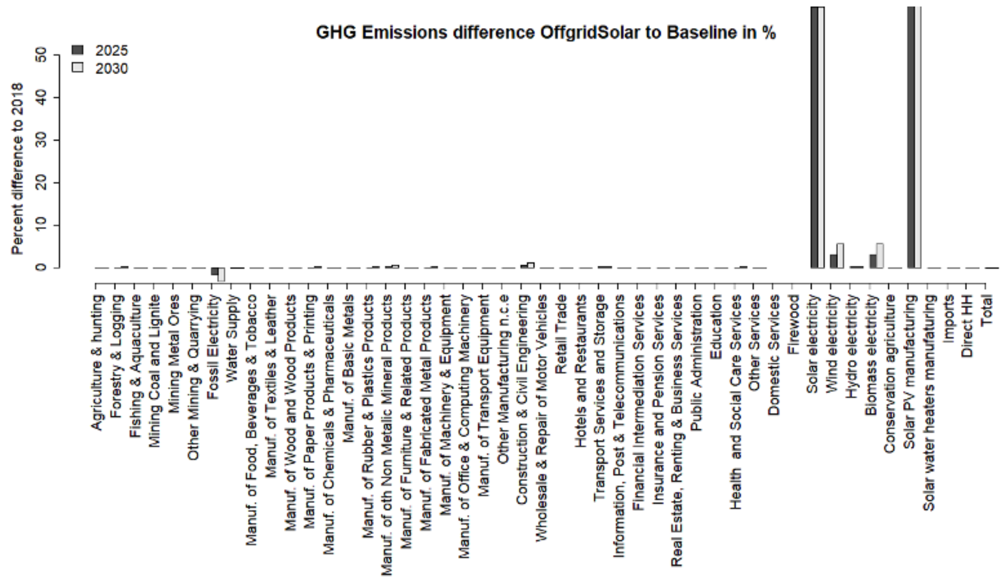
## Figure 17: Off-grid solar power scenarios compared to Baseline: total employment/emissions/ value added




## Figure 18: Off-grid solar power scenario compared to Baseline: employment by industry/skills and gender




## Figure 19: Off-grid solar power scenario compared to Baseline: GHG emissions by industry



## 5.5 Solar LED street lighting (Energy)

Solar LED street lighting will increase the reliability and availability of street lighting, allowing for longer opening hours, especially for informal businesses. Pilot projects include Samora Machel Avenue and Airport Road in Harare. From an energy perspective, off-grid LED lights are more efficient, thus requiring less energy, and do not depend on available grid electricity. Their operating costs are low because there is no need to pay for electricity from the grid. Traditional street lights are typically between 150 and 500 watts per lamp, which can be reduced to 20-50 watts per lamp for LEDs (on average, a reduction from 350W to 35W).

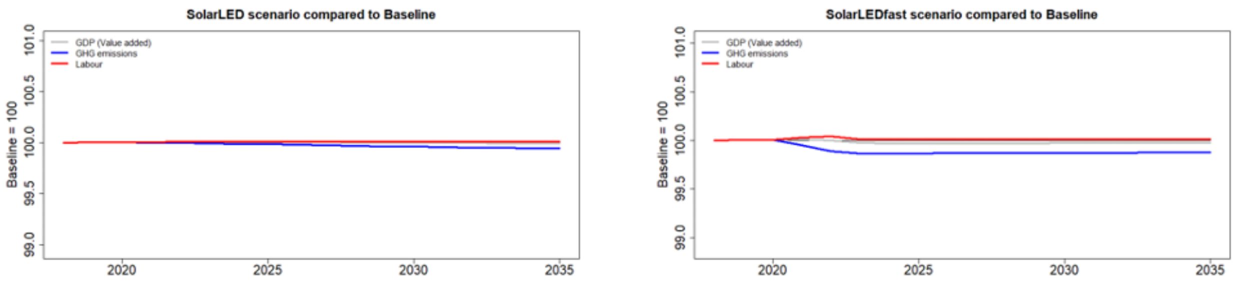
A $26 million investment in LED street lighting and an assumed cost of $500 per lamp can finance 41,520 new street lights. Assuming that lights are used for 12 hours per day for 10 years, between $40 million and $50 **million in electricity costs can be saved**, or about $4-5 million per year. At the same time, the existing infrastructure must be upgraded, including the actual solar LEDs (costs covered by the investment plans) and to rehabilitate and restore the lamp posts and all installations around them. Therefore, we model both investment costs and a shift in government spending, from electricity to construction activities and "General-purpose machinery, engines and parts & Electrical."

**Table 7: Investment assumptions for "fast" solar LED scenario by product/service group and year ($ million)**

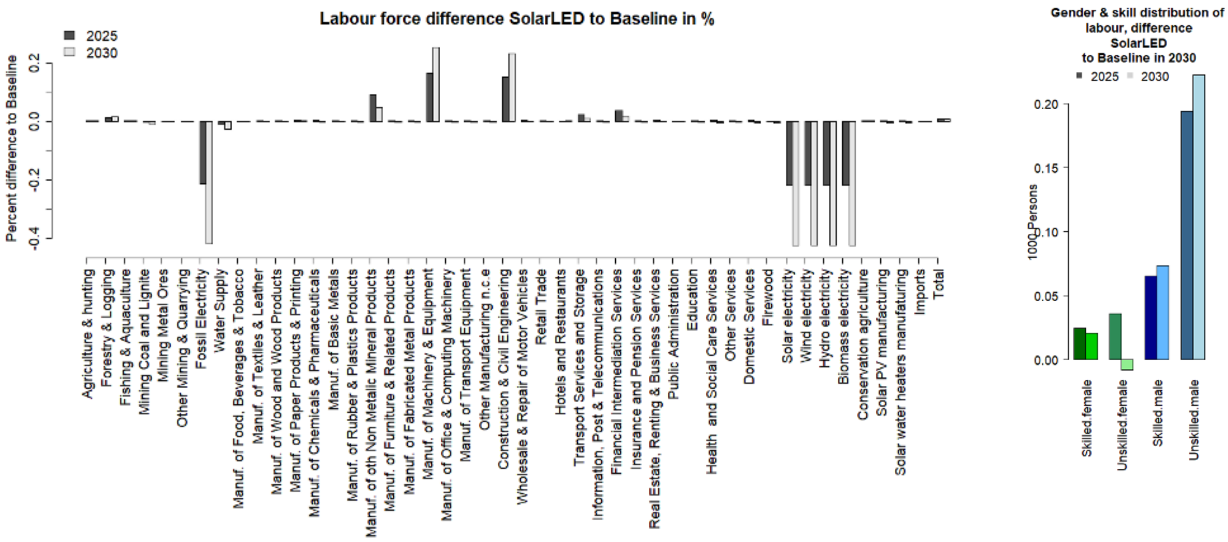
| SUT PRODUCT GROUP | IMPORT SHARE | 2019 | 2020 | 2021 | 2022 | TOTAL | SHARE OF TOTAL |
|---|---|---|---|---|---|---|---|
| Plaster, lime, cement, concrete, building stone | | 0.09 | 0.09 | 0.66 | 0.66 | 1.5 | 8% |
| General-purpose machinery, engines and parts & electrical | 8% | 0.37 | 0.37 | 2.63 | 2.63 | 5.99 | 33% |
| Construction | | 0.09 | 0.09 | 0.66 | 0.66 | 1.5 | 8% |
| Construction services | | 0.09 | 0.09 | 0.66 | 0.66 | 1.5 | 8% |
| Freight transport services | | 0.27 | 0.27 | 1.97 | 1.97 | 4.5 | 25% |
| Financial intermediation and related services | | 0.18 | 0.18 | 1.32 | 1.32 | 3 | 17% |

We ran two scenarios, a "fast implementation" scenario, with all investments completed within the first few years (until and including 2022), and one where investments are spread across 15 years. Figure 20 shows how the two investment pathways evolve. A higher initial investment ("fast" scenario, right panel) has a larger, sustained effect on emissions. However, effects on value added and employment are non-existent overall. Although the right panel in Figure 21 shows some absolute changes, they are very small and do not support any conclusions regarding the direction of the effect. **The slightly more positive effect for male employment is due to investments in construction and machinery and equipment, industries in which men hold the majority of jobs.** We did not model the effect of the possible extension of business hours for street markets. This would likely increase the number of jobs held by women.

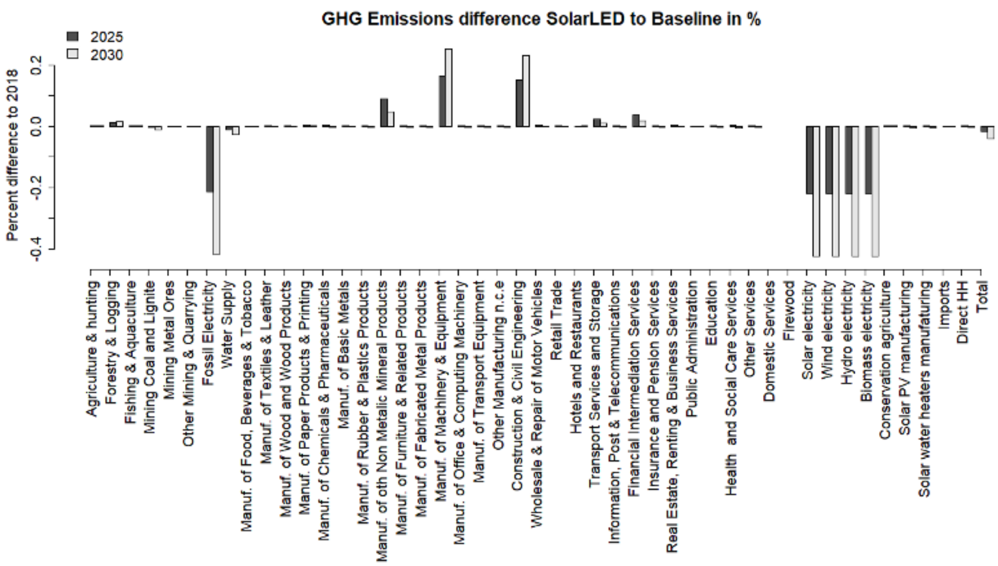
## Figure 20: Solar LED street lighting scenario compared to Baseline: total employment/ emissions/ value added)




## Figure 21: Solar LED street lighting scenario compared to Baseline: employment by industry/ skills and gender




## Figure 22: Off-solar LED street lighting scenario compared to Baseline: GHG emissions by industry



## 5.6 Solar water heaters (Energy)

The primary objective of SWH is to replace grid electricity consumption in accordance with the LEDS. A large share of the hot water used by households, especially in rural areas, is heated using open fireplaces and by burning firewood. This releases substantial GHG emissions and has other harmful effects, such as local pollution, risk of deforestation and burn injuries. Zimbabwe's National Renewable Policy sets a target to install 250,000 solar water heaters by 2030, requiring investment of $90.08 million. This includes equipment for both domestic and commercial use, with the latter installed in public buildings such as hospitals and schools. The government has announced that it intends to ban electric geysers in new domestic and commercial buildings and require all new buildings to use solar geysers.

Most SWH components are imported from China and India. Solar energy equipment is imported duty free but is subject to a 15 percent value added tax. However, most is assembled and installed domestically. It is assumed that financial intermediation and related services (including customs clearance, VAT, insurance and bank charges) make up 25 percent of total cost; freight and transport make up 5 percent; and assembly of the water heaters produced by Zimbabwe's new SWH industry amounts to 70 percent of the total cost. [Note: the table includes two columns that refer to shares: 'import share' (by product), that is, the percentage of the product that is imported (if there is no number, the average of that product is also assumed in the scenario); and 'share of total' investments, that is, the share that each product receives of total investments.]

With 250,000 water heaters, about 6 percent of Zimbabwean households will benefit from the programme. We assume that, on average, each SWH will reduce household energy demand for electricity and gas, petroleum oils, gases and bitumen, coal and lignite (peat), and firewood by 18 percent [[13]]. Households and government will spend their savings primarily on other essential communication, water or retail services (details are available in the detailed scenario input sheets), thereby increasing activity in the water sector (as Figure 23 shows). Economic ripple effects are minimal under this scenario.

**Table 8: Investment assumptions for solar water heaters scenario by product/service group and year ($ million)**

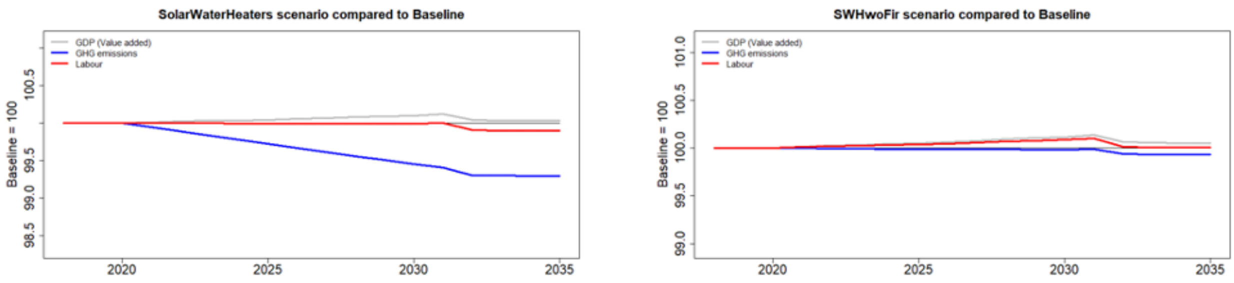
| | IMPORT SHARE | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | TOTAL | SHARE OF TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Solar water heaters | 11 % | 1.3 | 1.9 | 2.5 | 3.2 | 3.8 | 5.0 | 6.3 | 7.6 | 8.8 | 10.1 | 12.6 | 63.1 | 70 % |
| Freight transport services | 23 % | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.4 | 0.5 | 0.5 | 0.6 | 0.7 | 0.9 | 4.5 | 5 % |
| Financial inter-mediation and related services | | 0.5 | 0.7 | 0.9 | 1.1 | 1.4 | 1.8 | 2.3 | 2.7 | 3.2 | 3.6 | 4.5 | 22.5 | 25 % |

Given that both investment costs and structural changes are very small, the effects on value added, jobs and emissions are almost negligible (Figure 23). However, comparing the scenario with and without the reduction in firewood used provides some interesting insights: both employment and emissions effects are basically zero when firewood use is not reduced (right panel in Figure 23). However, when that use is reduced, GHG emissions are reduced by a significant amount (0.5 percent of the country's total emissions), but total employment numbers also fall. However, this is not true for skilled jobs, which are in greater demand under both scenarios; that is, only the unpaid firewood collectors will "lose" their job. In terms of quality of work and income, these jobs do primarily limit people's ability to pursue more productive, higher quality activities. Thus, it might be desirable to replace firewood use with SWH so that people can pursue more productive employment. This will also be discussed under the efficient cookstoves scenario.

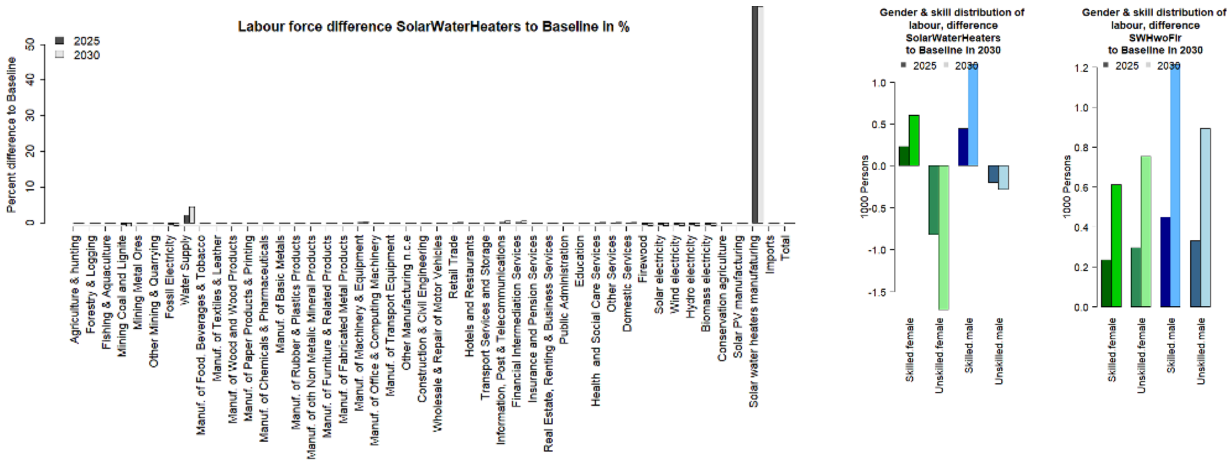
**NOTE**

**SWH investments are modelled only until 2030. SWH investments will likely continue after that time, thus ensuring a long-term increase in economic activity if the equipment is assembled, installed and produced domestically.**

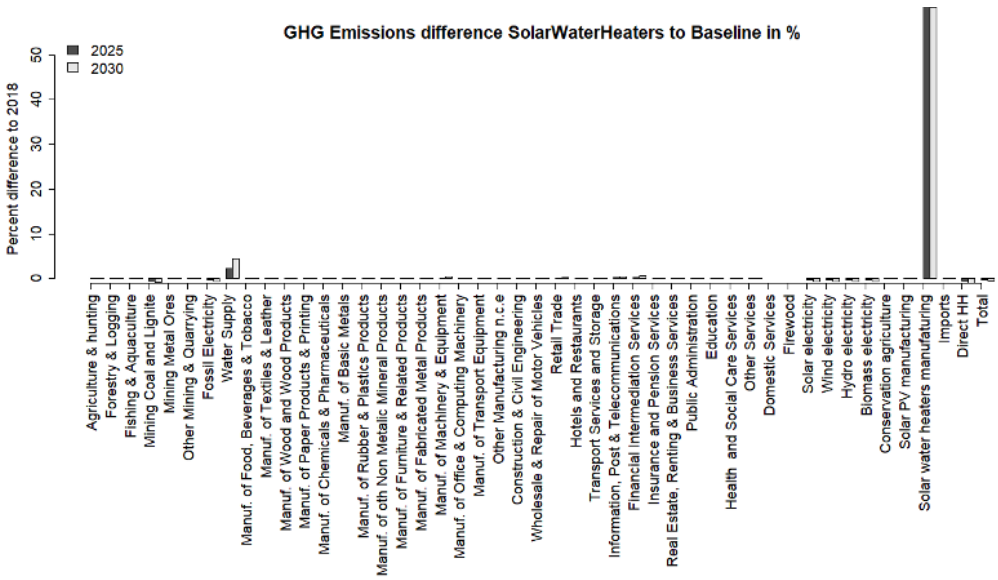
### Figure 23: Solar water heaters scenario compared to Baseline: total employment/emissions/value added




### Figure 24: Solar water heater scenario compared to Baseline: employment by industry/skills and gender




### Figure 25: Solar water heater scenario compared to Baseline: GHG emissions by industry



## 5.7 Energy efficiency (Energy)

The energy efficiency plans target a 30 percent reduction in the use of fossil energy carriers (coal and lignite, coke oven products, and petroleum oils, gases and bitumen) as well as electricity and gas in the following manufacturing industries:

- Manufacture of Food, Beverages & Tobacco
- Manuf. of Textiles, Wearing Apparel & Footwear & leather
- Manuf. of Wood and Wood Products
- Manuf. of Paper & Paper Products & Printing
- Manuf. of Chemical, Pharmaceutical & Chemical Products
- Manuf. of Basic Metals
- Manuf. of Rubber & Plastics Products
- Manuf. of Other Non Metalic Mineral Products
- Manuf. of Furniture & Related Products
- Manuf. of Fabricated Metal Products, Office
- Manuf. of Electrical Equipment, Machinery & Equipment
- Manuf. of Office & Computing Machinery
- Manuf. of Motor Vehicles & Other Transport Equipment & Communication
- Other Manufacturing n.c.e
- Construction of Buildings & Civil Engineering Works

Total investments required to achieve this target are assumed to be $341 million (the sum of the total column in Table 9), with the largest share (36 percent) allocated to more energy efficient technologies (SUT product group, General purpose machinery). However, 88 percent of these technologies are expected to be imported, not produced domestically. Construction and construction minerals (plaster, lime, cement, concrete, building stone) each account for about 9 percent of investment costs. Freight transport services are assumed to be about 27 percent and financial intermediation and related services, about 18 percent. Investments are spread evenly over 10 years (2021-2030).

**Table 9: Investment assumptions for energy efficiency scenario by product/service group and year ($ million)**

| SUT PRODUCT GROUP | IMPORT SHARE | TOTAL | SHARE OF TOTAL |
|---|---|---|---|
| Plaster, lime, cement, concrete, building stone | | 31 | 9% |
| General purpose machinery, engines and parts and electrical | 88% | 124 | 36% |
| Construction | | 31 | 9% |
| Freight transport services | | 93 | 27% |
| Financial intermediation and related services | | 62 | 18% |

Energy efficiency improvements lag investments by one year. Small short-term investment effects on economic activity (value added and employment) occur in the years 2021-2030. A positive structural change effect also occurs and persists after 2030 (Figure 26). While energy-related emissions are reduced significantly in the manufacturing industries (Figure 28), total GHG emissions are reduced by only about 1 percent (Figure 26).

Energy efficiency improvements lead to lower prices. Price effects are captured by the household demand model. They translate into greater demand for manufactured products, which leads to overall higher manufacturing activity, as the increase in positive labour effects across industries shows (Figure 27). The need **for high-skilled labour, both female and male, is relatively higher.**

**Figure 26: Energy efficiency scenario compared to Baseline: total employment/emissions/value added**

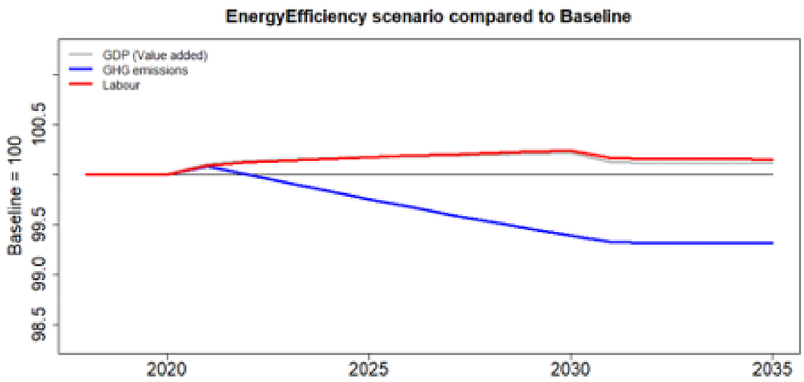



**Figure 27: Energy efficiency scenario compared to Baseline: employment by industry/skills and gender**

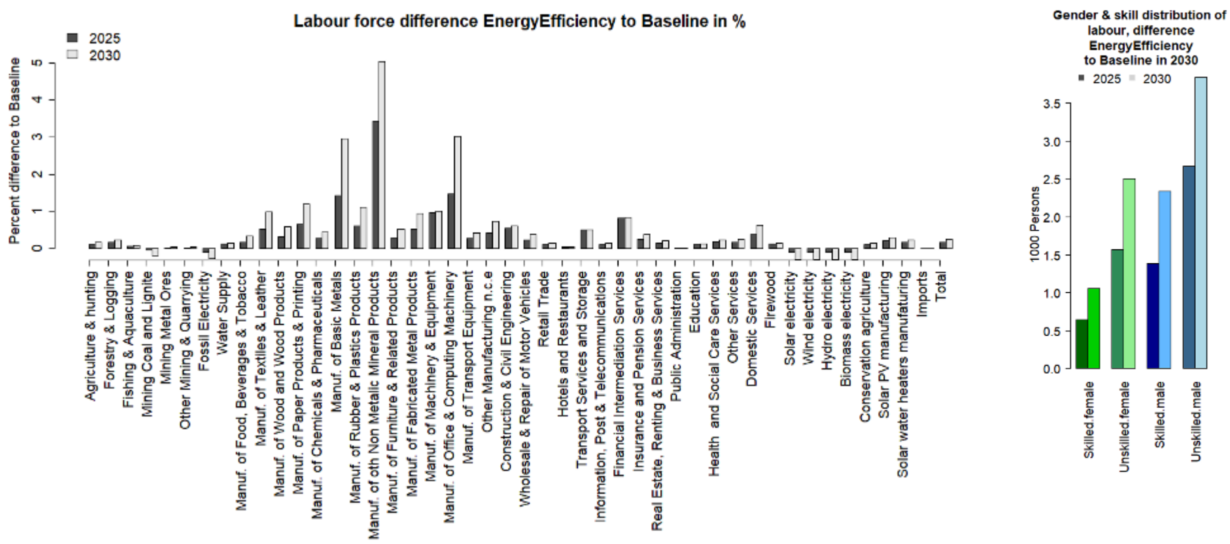
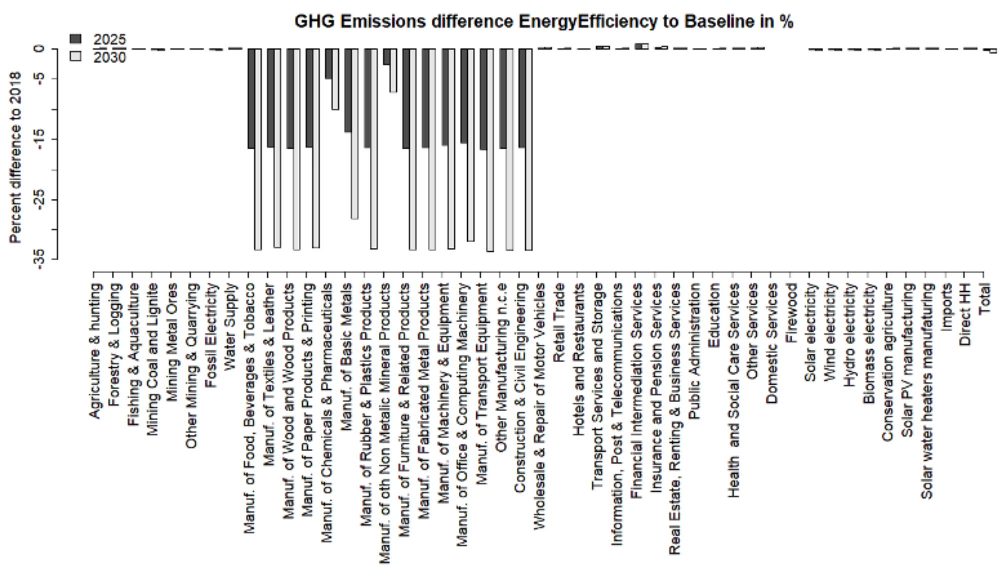



**Figure 28: Energy efficiency power scenario compared to Baseline: GHG emissions by industry**



## 5.8 Biodiesel (Energy, Transport)

A $6 million jatropha processing plant was built in Mount Hampden, Harare in 2007, with annual biodiesel production capacity of 100 million litres. Given that LEDS has estimated accumulated investment needs to be about $300 million, the current capacity may be viewed as negligible. **The goal is to reach 2 percent biodiesel in diesel by 2030. While diesel is imported, plans call for producing the biodiesel domestically; thus, slightly more than two-thirds of total investments are allocated to build biodiesel plants.** We assume investment cost shares to be 90 percent for general purpose machinery, engines and parts & Electrical, 2 percent for construction services, 3 percent for freight transport services, and 5 percent for financial intermediation and related services (see last column of Table 10). The remaining budget is assumed to be spent on agricultural land and feedstock. Biodiesel is produced by the chemical industry and blended into diesel. We model the changes in the structure of the chemical industry as increased use of productive sugar cane, seeds for vegetables and oilseeds, and agriculture support services. Industries and households reduce 2 percent of petroleum oils, gases and bitumen by other chemical products; man-made fibres reflect the 2 percent blending of biodiesel.

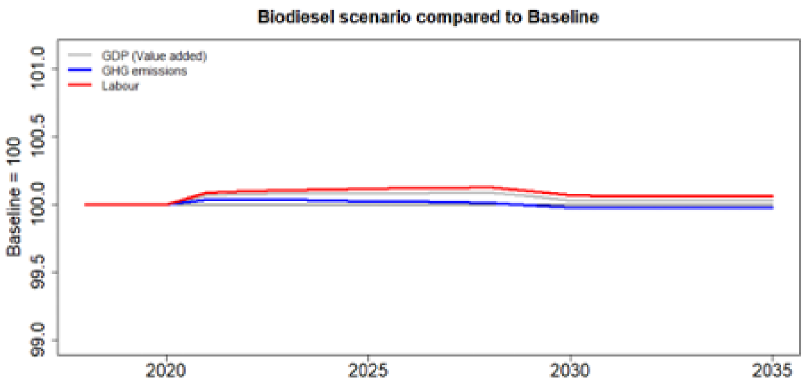
**Table 10: Investment assumptions for biodiesel scenario by product/service group and year ($ million)**

| SUT PRODUCT GROUP | IMPORT SHARE | TOTAL (in $ million) | SHARE OF TOTAL |
|---|---|---|---|
| General purpose machinery, engines and parts and electrical | 63% | 192.85 | 90% |
| Construction services | | 4.45 | 2% |
| Freight transport services | 23% | 5.48 | 3% |
| Financial intermediation and related services | | 10.97 | 5% |

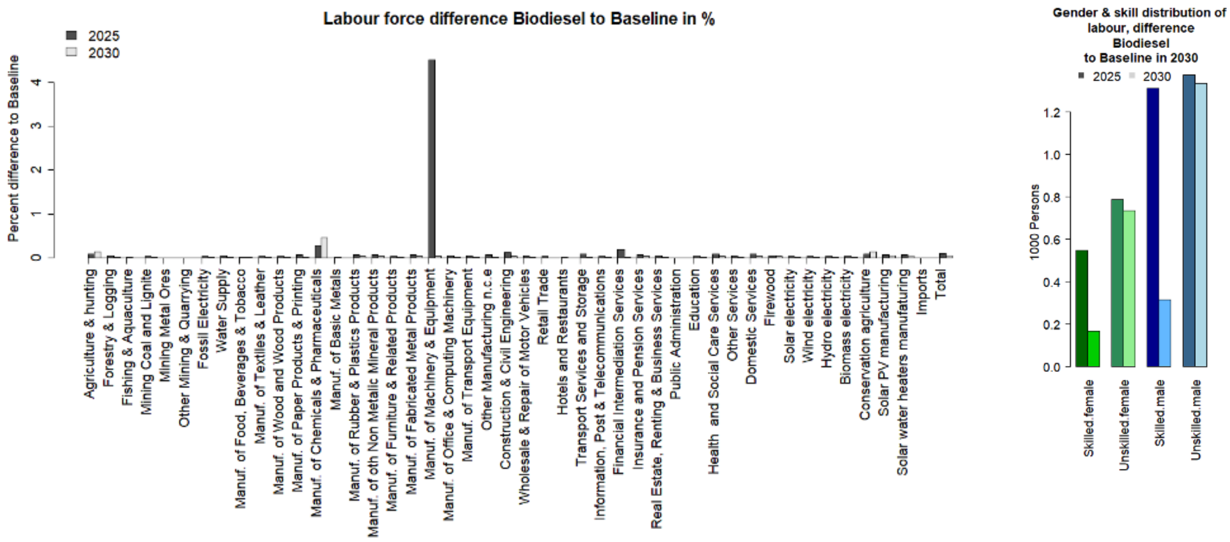
Figure 29 shows that total effects on emissions and economic activity are negligible. In fact, emissions may increase in the short run due to the increased economic activity associated with building the plant, while emissions are not decreased significantly in the long run. Employment and emissions in the **chemical industry will be minimally higher (both less than 1 percent) as imported petroleum products are replaced by domestically produced biofuels. The largest employment effects are in the machinery and equipment industry during construction.**

Biomass for energy uses land, which may create a conflict for growing biomass for food. The model does not capture this effect.

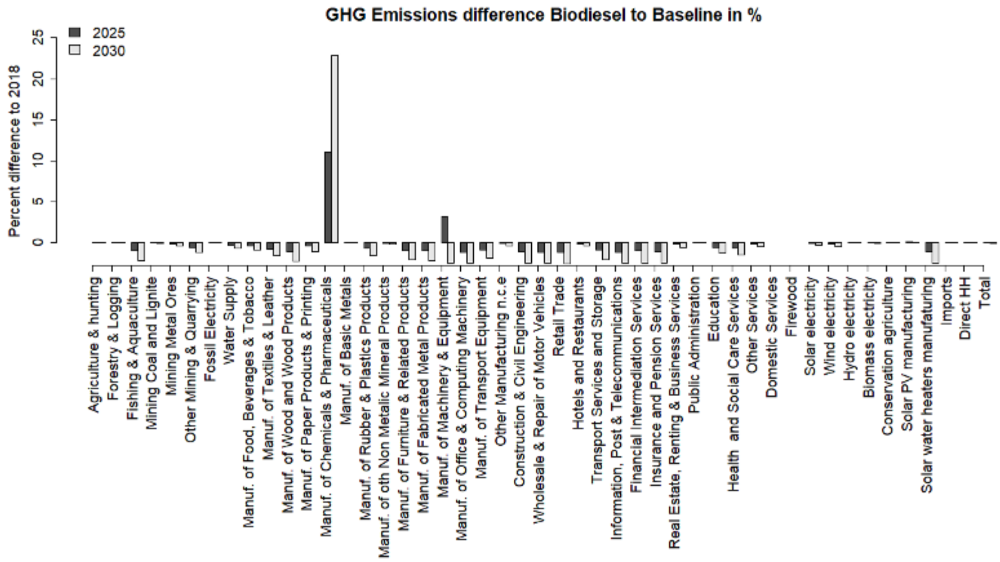
## Figure 29: Biodiesel scenario compared to Baseline: total employment/emissions/ value added)




## Figure 30: Biodiesel scenario compared to Baseline: employment by industry/skills and gender




## Figure 31: Biodiesel scenario compared to Baseline: GHG emissions by industry



## 5.9 Clinker substitution and $N_2O$ decomposition (IPPU)

IPPU emissions are a small share of total GHG emissions: 0.54 $MtCO_2e$ in 2015 compared to a total 11.9 $MtCO_2e$ emissions from energy use [2]. Forty percent of these emissions are related to cement production, 26 percent to nitric acid production and 31 percent to ferrochromium production. We model two options for reducing IPPU emissions, clinker substitution in cement production and technological upgrading. The latter involves installing a secondary catalyst technology at the nitric acid production facility, which is estimated to reduce $N_2O$ emissions by around 80 percent.

### 5.9.1 Clinker substitution

The LEDS suggests two materials for clinker substitution: blast furnace slack and fly ash. Given that the blast oven furnaces for steel production are currently not working, we do not model clinker substitution by blast furnace slack. The scenario analysis is performed for fly ash, which is a by-product of coal mining. This by-product is currently unused, and there is no price for fly ash as a product. We model this as generally increased demand for coal mining products by Manuf. of non-metallic mineral products, where we replace inputs from the own industry (which includes clinker production), by one-third of inputs from coal mining and two-thirds of inputs from freight transport. This switch is assumed to be small and slow. For each year starting in 2022, we reduce clinker inputs into Manuf. of non-metallic mineral products by 3 percent.

As in other scenarios, where the changes modelled are tiny compared to the entire economy, we also observe very small changes here: slightly positive for employment and slightly negative for GHG emissions (Figure 32). Although emissions from coal mining increase (due to increased activity following the demand for the by-product of that industry), that increase is less than 0.1 percent. Estimated 2018 emissions from coal mining are 0.26 percent of Zimbabwe's total emissions. **The overall increase in this industry is thus more than offset by the decrease from cement production (Figure 34). Job losses in Manufacture of Other Non-Metallic Mineral Products are offset by additional jobs in freight transport, although those are lower skilled than jobs in manufacturing of other non-metallic mineral products (Figure 33).**

### 5.9.2 $N_2O$ decomposition

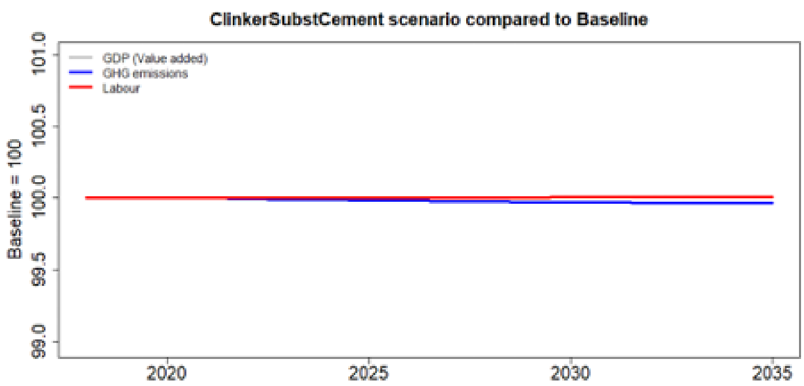
Installation of secondary catalyst technology at the facility would reduce $N_2O$ emissions from the chemical industry. The technology can abate about 80 percent of emissions and the LEDS estimates related investment costs of about $2.84 million. Table 11 shows the distribution of the investments across time and supply and use table product groups. It is assumed that all abatement technology will be fully imported, while installation is performed domestically.

Because the technology will be imported, positive investment effects on economic activity and labour are very small (Figure 35). They also occur only during the installation period, as no change in the production structure is necessary when the technology is in use. However, they do ripple throughout the entire economy, as Figure 36 shows, with an equivalent effect on employment opportunities by gender and skill level relative to their shares in the current labour force. Figure 37 shows the large decreases in emissions by the chemical industry: an 80 percent reduction in $N_2O$ emissions helps to reduce total GHG emissions by 50 percent.

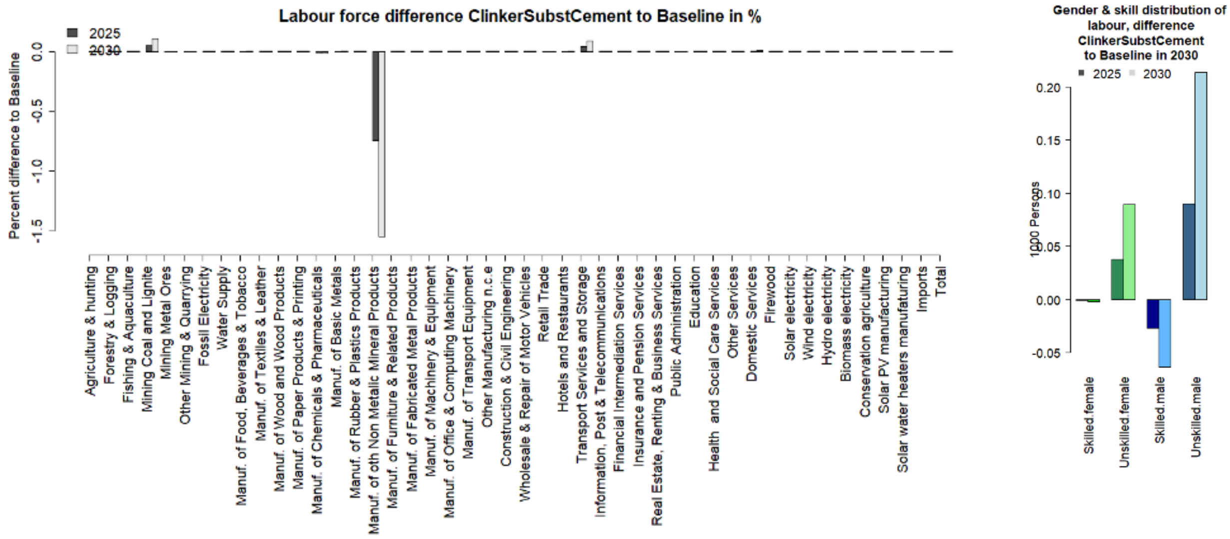
**Table 11: Investment assumptions for $N_2O$ decomposition scenario per product/service group ($ million)**

| SUT PRODUCT GROUP | IMPORT SHARE | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|
| General purpose machinery, engines and parts and electrical | 100% | 0 | 0.9 | 0 | 0 | 0.9 |
| Construction services | | 0 | 0.12 | 0 | 0 | 0.12 |
| Freight transport services | | 0 | 0.3 | 0 | 0 | 0.3 |
| Business services, professional, technical, re-search | | 0.1 | 0 | 0 | 0 | 0.1 |

## Figure 32: Clinker substitution scenario compared to Baseline; total employment/emissions value added




## Figure 33: Clinker substitution scenario compared to Baseline: employment by industry/skills and gender




## Figure 34: Clinker substitution scenario compared to Baseline: GHG emissions by industry

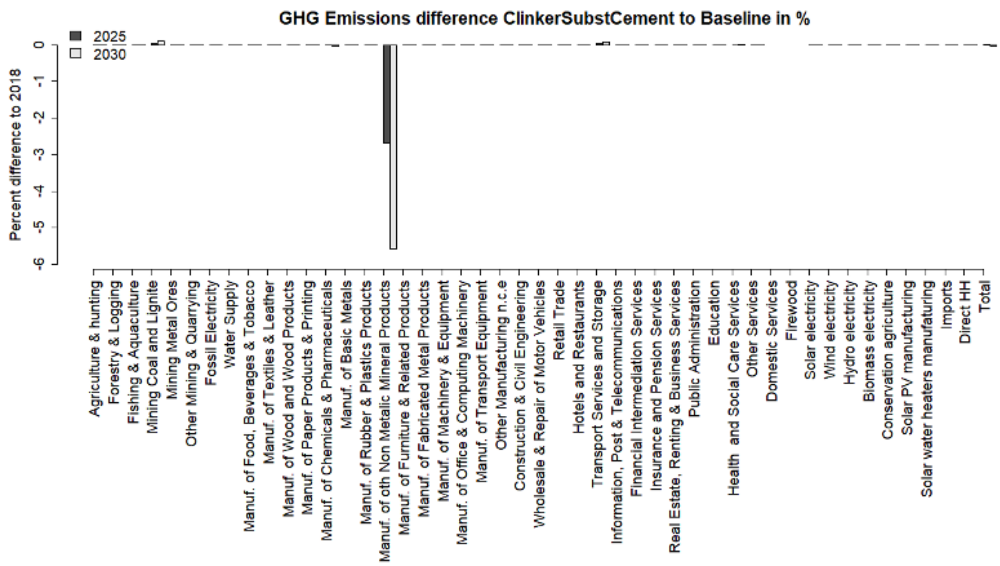


**Figure 35: $N_2O$ decomposition scenario compared to Baseline: total employment/emissions/value added**

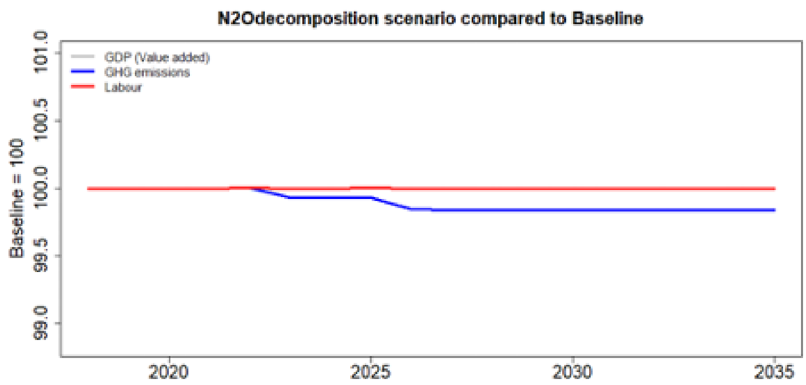



**Figure 36: $N_2O$ decomposition scenario compared to Baseline: employment by industry/skills and gender**

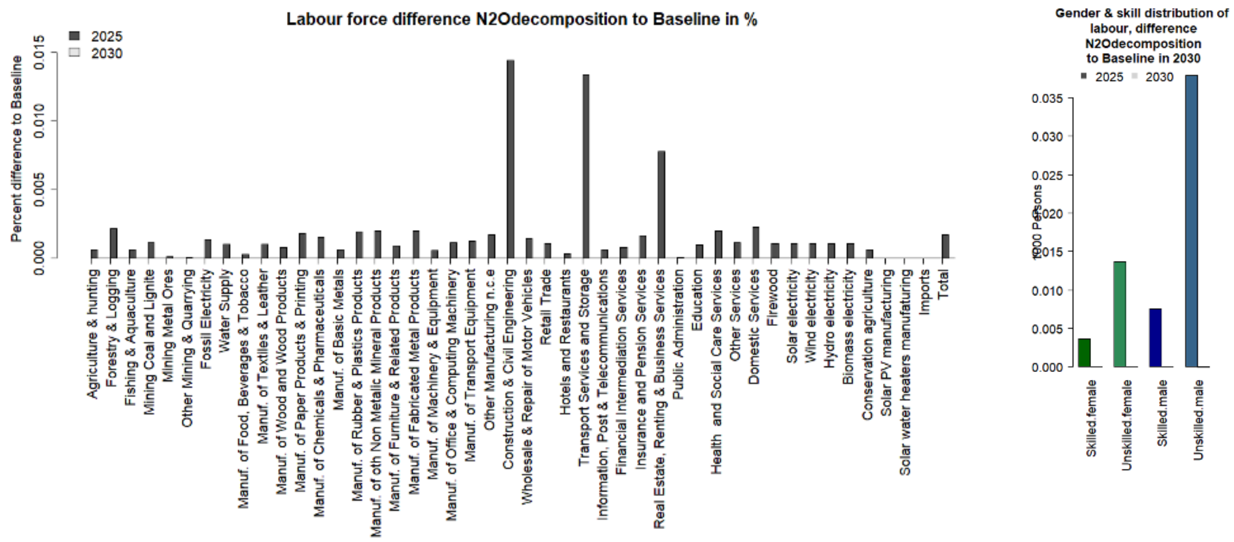
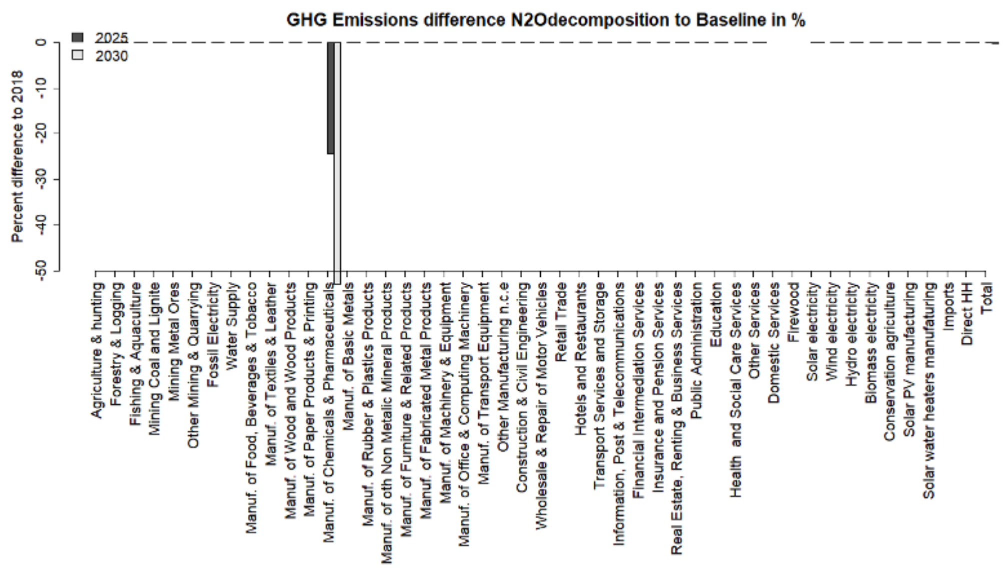



**Figure 37: $N_2O$ decomposition scenario compared to Baseline: GHG emissions by industry**



## 5.10 Conservation agriculture (AFOLU)

Conservation agriculture is one approach to climate-smart agriculture. It produces minimal soil disturbance, involves rotating crops and leaves crop residues in the soil after the harvest. The total area under conservation agriculture in Zimbabwe today totals approximately 5 percent of total agricultural area. According to the LEDS, conservation agriculture management will grow by 5 percentage points annually, reaching around 60 percent of total agricultural production by 2030. Around 70 percent of Zimbabwe's agricultural area is eligible for this practice. Investments are estimated to reach $3.1 million by 2030. Funds are used for construction materials, construction services, machinery, transport, financial intermediation, research and development, and education and training services. The latter are important if the workforce is to acquire the skills needed.

**Table 12: Investment assumptions for the conservation agriculture scenario: by product/service group and year ($ million)**

| SUT PRODUCT GROUP | IMPORT SHARE | TOTAL (in $ million) | SHARE OF TOTAL |
|---|---|---|---|
| Plaster, lime, cement, concrete, building stone | | 0.23 | 7% |
| General purpose machinery, engines and parts and electrical | 4% | 1.84 | 59% |
| Construction | 24% | 0.34 | 11% |
| Freight transport services | 36% | 0.23 | 7% |
| Financial intermediation and related services | | 0.20 | 6% |
| Business services, professional, technical, research | | 0.16 | 5% |
| Other professional, business and technical services | | 0.08 | 3% |
| Education services tertiary | | 0.08 | 3% |

Emission reductions are achieved by changing the use of inputs (less machinery, fuels and chemicals), reducing emissions from livestock production, and stopping prescribed burning (of crop residues or to clear land for agriculture). While additional aspects related to chemical processes in conservation agriculture, such as minimal soil disturbance, are significant contributors to reducing GHG emissions, the GJAM model does not capture them.

Conservation agriculture is also more employment intensive. In the long run, increased labour inputs for conservation practices are provided primarily by household labour, especially women, and do not necessarily result in increased paid farm labour [31]. In the short-run, high-skilled workers also benefit, although primarily during the investment phase (Figure 39). The left panel of Figure 39 indicates a large loss of employment in conventional agriculture, but conservation agriculture absorbs all of those jobs (where the relative increase is huge, given the small size of the industry today). While most industries experience slight additional growth, leading to additional employment, employment in chemicals (due to lower fertilizer demand), firewood and food processing declines only minimally.

While conservation agriculture absorbs the entire production and worker capacity, it produces lower emissions, thereby reducing total emissions significantly (Figure 40). Indeed, GHG emissions increase less than does population under this approach (right panel in Figure 38), making conservation agriculture one of the few options to reduce emissions despite a growing population.

**Figure 38: Conservation agriculture scenario compared to Baseline and relative to 2018: total employment/emissions/value added**

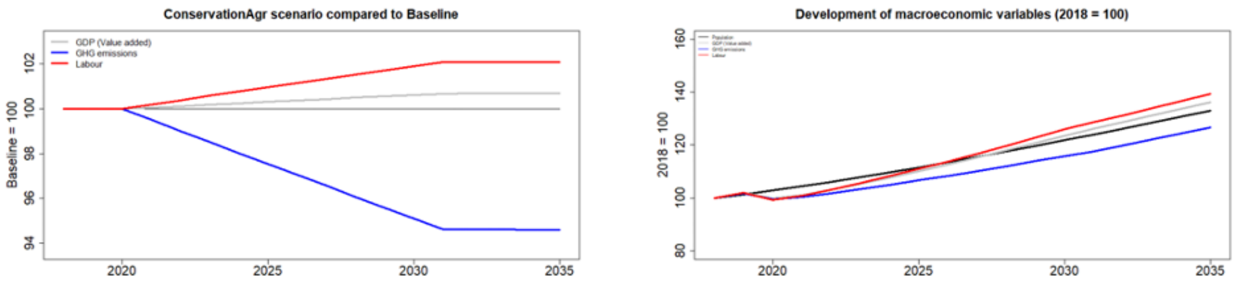



**Figure 39: Conservation agriculture scenario compared to Baseline: employment by industry/skills and gender**

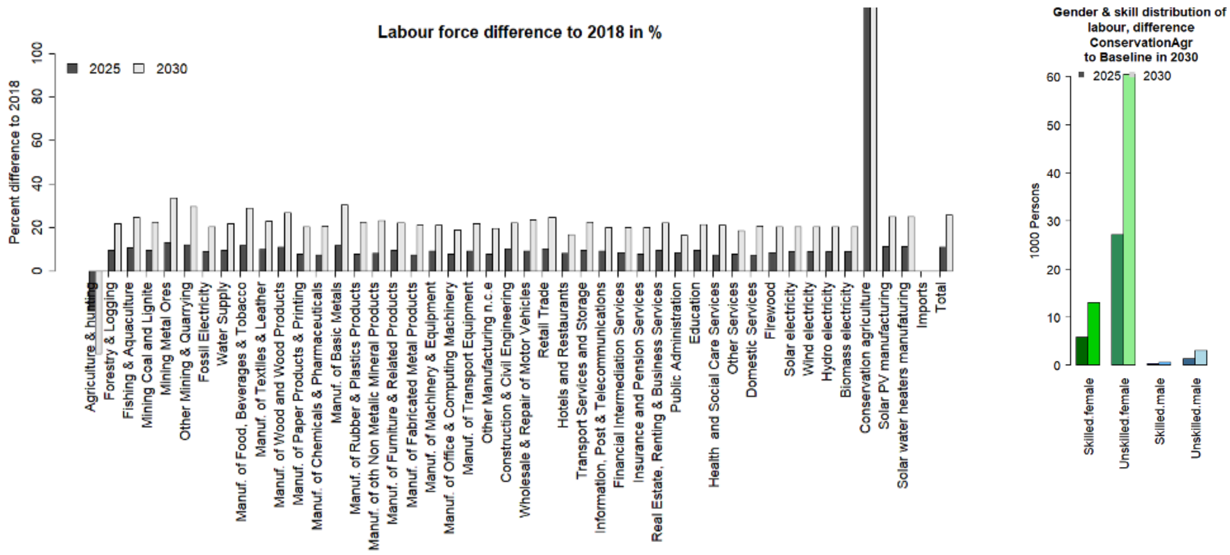
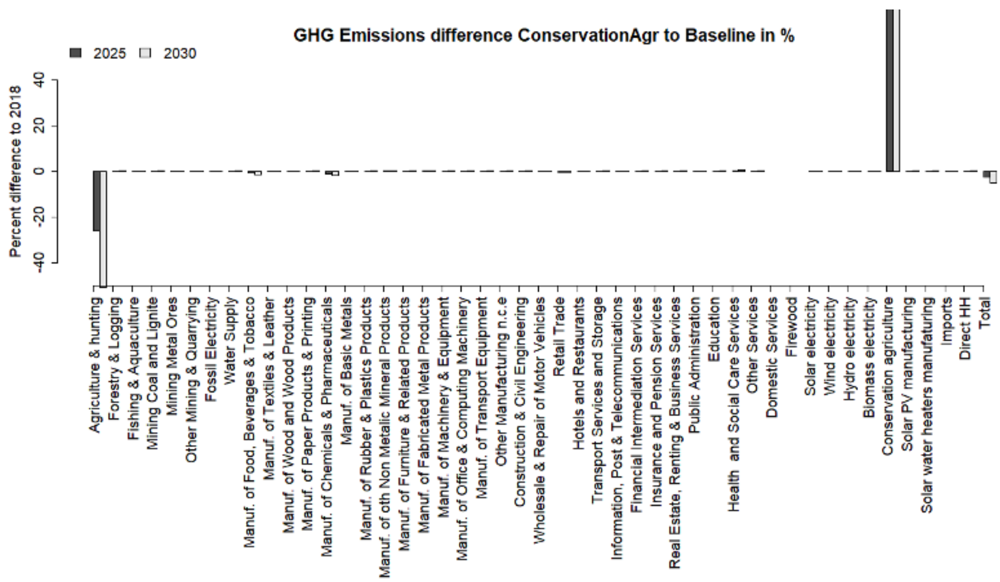



**Figure 40: Conservation agriculture scenario compared to Baseline: GHG emissions by industry**



## 5.11 Efficient cookstoves (AFOLU)

Emissions from the use of firewood and other fuels in inefficient cookstoves are a large share of total GHG emissions in Zimbabwe. Firewood is used primarily in households as a cheap source of energy for cooking and heating. However, the LEDS does not refer explicitly to policies that reduce household use of firewood. One policy could be to expand the use of more efficient cookstoves.

Emissions from burning biomass are included in the GHG inventories as a memo item to avoid double counting those carbon emissions described in the AFOLU sector from emissions and removals (that is, afforestation and deforestation).

**Table 13: Investment assumptions for efficient cookstoves scenario by product/service group and year ($ million)**

| SUT PRODUCT GROUP | TOTAL (in $ million) | SHARE OF TOTAL |
|---|---|---|
| Plaster, lime, cement, concrete, building stone | 1.75 | 25% |
| Fabricated metal products | 1.75 | 25% |
| Construction | 1.75 | 25% |
| Wholesale trade services and repairs | 1.75 | 25% |

Under this scenario, we assume that 50 percent of Zimbabwe's approximately 2 million households could use more efficient cookstoves. We further assume that 1 percent of them are gradually switching to efficient cookstoves. Based on a rough comparison of the many available technologies, we assume that the cookstoves are three times as efficient. This would decrease the use of fuels (firewood and kerosene) by 0.17 percent per year. We therefore assume a total investment of $0.7 million per year (1 percent of 2 million households at $35 per cookstove). Savings from reduced fuel expenditure (petroleum oils, gases and bitumen and firewood) are allocated to other household consumption, divided equally among education, retail trade, telecommunication, hotels and restaurants, and financial services.

This switch in demand stimulates overall economic activity measured in terms of value added (grey line in Figure 41), while employment decreases slightly (red line) and GHG emissions are reduced significantly (blue line). The employment "loss" represents the reduction in time (work hours) spent on firewood collection, notably by women and girls. It also results from the smaller number of people collecting firewood. However, employment in all other economic sectors increases (Figure 42). As mentioned in the SWH scenario, the work of collecting firewood prevents people from pursuing more productive, higher quality activities, provided that they are available. Only when they are available can the lost work opportunities related to firewood collection be absorbed by more productive paid employment in other industries.

Figure 43 shows that overall GHG emission reductions are reduced significantly due to lower direct household emissions from burning fuel and firewood. These reductions more than offset the increased emissions from increased economic activity in all other industries.

**NOTE: FIREWOOD DATA**

**Firewood production and consumption in the model are not estimated as part of the International Standard Industrial Classifications of All Economic Activities (ISIC). Further, the reduction of work hours in the firewood industry (calculated as loss of full-time work equivalent) requires interpretation: households collect most of the firewood used in Zimbabwe, with that work performed by unpaid household workers and women. The estimation process is explained in detail in Section A.2.4.1. Firewood collection also contributes to deforestation and land degradation. Emissions from deforestation cannot be included in the model, as they cannot be linked directly to current or future economic activity. Thus, the emission reduction possibilities are likely underestimated here.**

**Figure 41: Efficient cookstoves scenario compared to Baseline: total employment/emissions/value added**

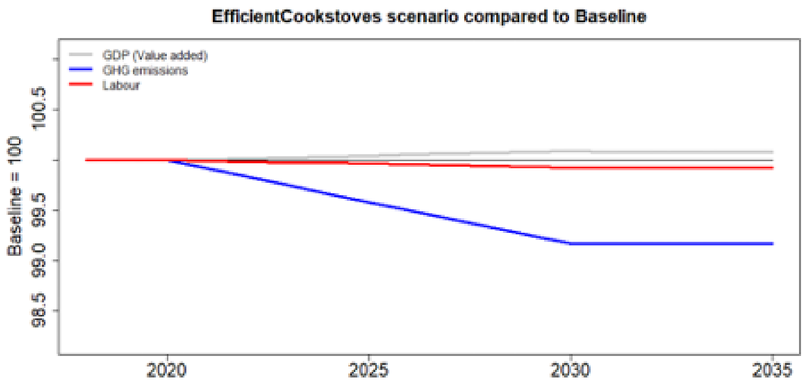



**Figure 42: Efficient cookstoves compared to Baseline: employment by industry/skills and gender**

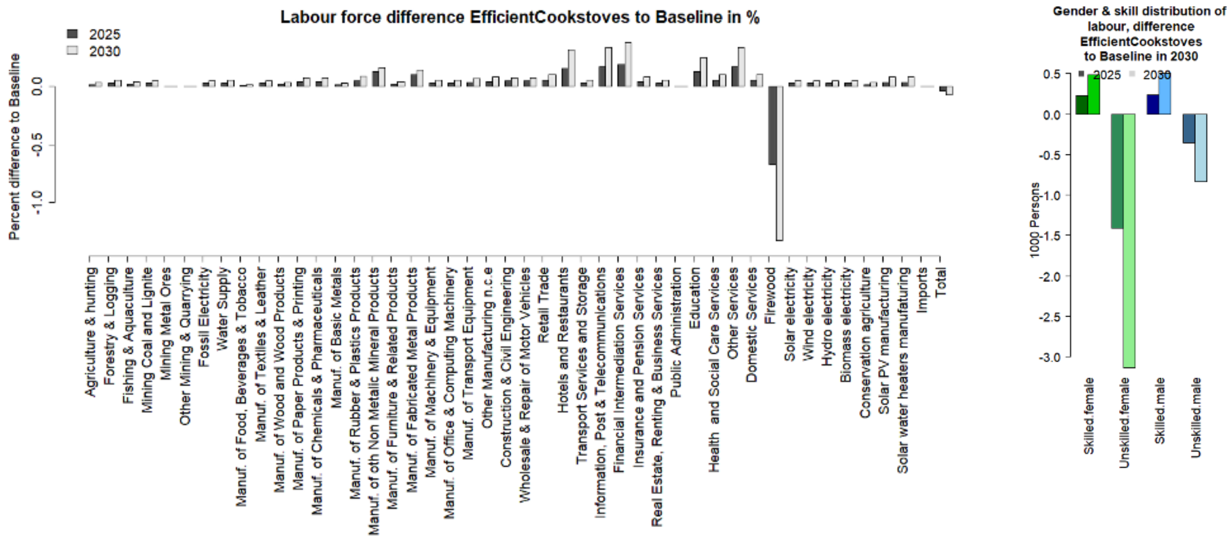
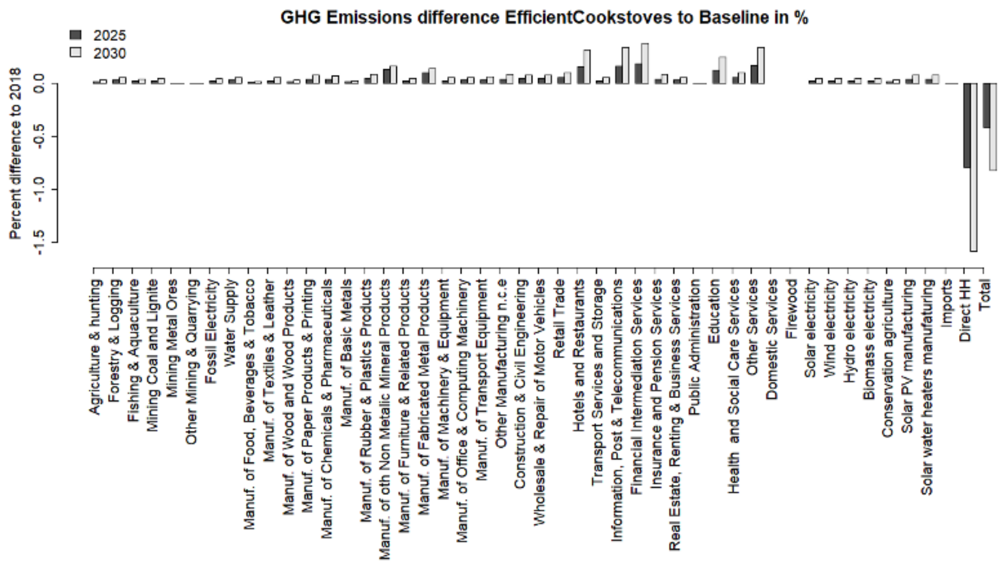



**Figure 43: Efficient cookstoves scenario compared to Baseline: GHG emissions by industry**



# 6. Summary and policy recommendations

The employment effects of the climate policies analysed here are positive overall and for all skills and genders in all but two scenarios. The policies with a net positive effect include the four to increase electricity generation through hydro, solar off-grid and commercial biogas plants. They also include the two energy efficiency policies (increased energy efficiency in manufacturing and LED street lights), the climate-smart agriculture and conservation policy, the biodiesel policy, and the two IPPU-related policies (see Figure 44 for an overview (note different scales for all figures)).

The two policies that have a negative effect on total hours work are those for SWH and efficient cookstoves. The negative effect occurs under the assumption that firewood collection is considered employment, which means that the activity generates an income through market sales. If firewood collection is considered work but does not generate income, this negative effect on total work hours may be interpreted as efficiency gains: less household work means more time available for other productive activities. The work hour losses are for low-skilled workers and due only to a smaller number of hours and people collecting firewood.[1]

In terms of the short-term (primary) effect, the size of the initial increases in the number of jobs depends heavily on the *size* of the related investment activities. The larger the investment, the larger the number of jobs required to build the capital assets and carry out the economic activity. While the long-term (secondary) effect is usually smaller than the short-term effect, it is still in the same order of magnitude for each of the scenarios. Importantly, however, the *type* of investment has a significant and sizable impact on the long-term structural change effect. This is because, once in use, each type of technology has different operating and maintenance, supply chain, import, final demand and price effects. The climate investments modelled here have very different job growth implications, per unit of dollar, in the medium to long run.

Conservation agriculture generates the largest *employment multiplier* by far per unit of investment. It is estimated that $1 million invested in climate-smart production systems could increase output and productivity and create up to 30,000 jobs. This compares to approximately 100 jobs for each $1 million invested in a hydro dam and just 25 in commercial solar. This is because those technologies are capital intensive: their labour requirements are lower in the long term after construction is completed. Biogas stands out in terms of its employment multiplier. If – and only if – 100 percent of the biogas plants built are serviced, maintained and operated productively, it is expected to create approximately 130 jobs per million dollars invested.

Given the much higher investment costs and greater structural change in electricity production and use, the *total increase in jobs* is much larger under the hydro-power scenario than under other scenarios. (Approximately 300,000 jobs are estimated to be created, on average annually, up to 2035). In terms of net job creation potential, the hydropower policy is followed by conservation agriculture (agriculture overall is the country's largest employer) which offers the possibility of creating around 100,000 additional jobs. Here, the long-term structural effects are much more significant than the short-term investment effects. Biogas electricity and commercial solar are estimated to create around 10,000 jobs each, although biogas investments total only one-quarter of those in commercial solar. This underscores the importance of factoring in the multiplier effect. Off-grid solar and energy efficiency measures create approximately an additional 8,000 jobs. The estimates of off-grid solar jobs are conservative as they are based on developed countries' employment figures. Actual job figures may be much higher as maintenance and operation in the African rural context differ significantly from those in urban and industrialized countries.

Hydropower offers the largest emission mitigation potential when compared to a scenario with equally high economic activity, but based on the current electricity mix. Biogas and solar electricity, as well as energy

1 The changes implemented in the scenarios are relatively small (with the exception of the hydropower scenario) and do not comprise a complete list of the climate change mitigation and adaptation actions that the Zimbabwean government plans to take. While we generally follow the LEDS, we have modelled only 15 of the 38 measures listed in Table 8.1, due to a combination of lack of data and possible representations of the policy options in this type of model. This represents about half of total investments in monetary terms (excluding hydropower).

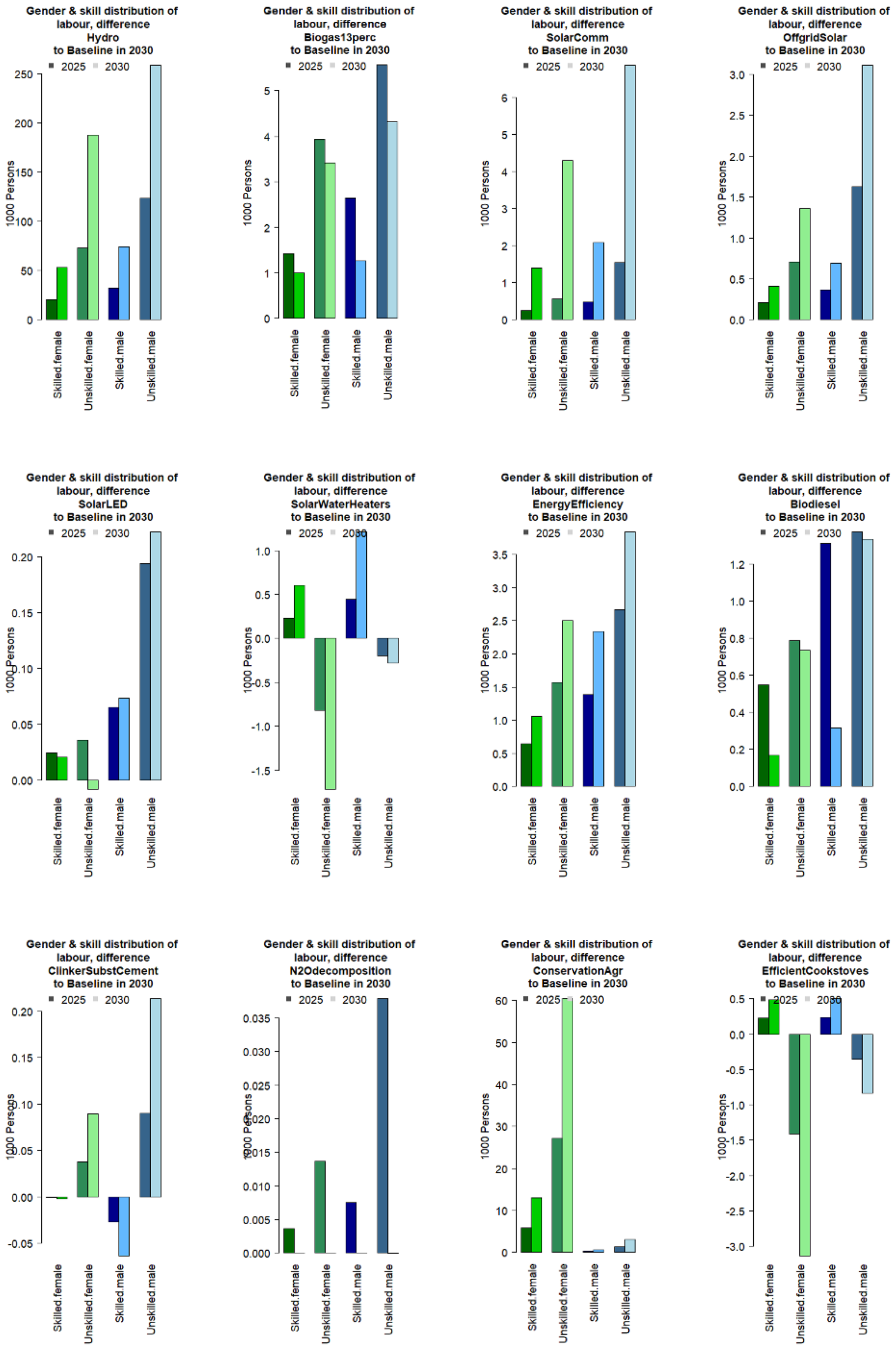
efficiency and efficient cookstove scenarios, could reduce economy-wide GHG emissions by about 1 percent each, relative to the baseline development. These emission reductions estimates may be conservative as all of the scenarios are implemented individually and some of the effects could multiply. This is particularly true when considering the energy efficiency and IPPU mitigation actions, which can counteract rising emissions in industries with rising levels of economic activity.

Overall, GHG mitigation and adaptation actions are having positive impacts on the labour market and GDP growth. Zimbabwe is no exception. This leads to the conclusion that climate policies do not come at the expense of economic development. On the contrary, they boost growth and job creation. Studies of other countries confirm this, such as the ILO report, “World Employment and Social Outlook 2018: Greening with jobs,” which focuses on Europe, OECD countries and large emerging economies, and the 2020 Interamerican Development Bank and ILO report, "Jobs in a net-zero emissions future in Latin America and the Caribbean."

The model and the scenario analysis above do not answer one important question: what kind of policies are required to finance and ensure this boost to GDP and employment creation?

In addition to the need for the financial investments, just transition policies are required to enable government, enterprises, workers and the labour market to respond and implement the climate policies and investments. Without adequate just transition policies, the boost to GDP and employment creation may not materialize. This could result from social protest against the climate initiatives and lack of social protection measures to direct workers from declining activities (firewood collection) to growing industries (biogas). It could also be due to a lack of workers with the skills to install and operate renewable electricity and energy efficient technologies (solar installers, electric hydro engineers and biogas technicians). And, if the enterprises and entrepreneurs do not put the additional electricity to productive use, economic growth will not follow. This calls for strong just transition policies in the fields of social protection, skills development, and enterprise and entrepreneurship.

## Figure 44: Overview employment effects by gender and skill



# 7. References


1. National Development Strategy 1 – 2021-2025: http://www.zimtreasury.gov.zw/index.php?option=com_phocadownload&view=category&id=64&Itemid=789
2. UNFCCC. ADOPTION OF THE PARIS AGREEMENT. *Conf. Parties Twenty-first Sess*. **FCCC/CP/20,** (2015).
3. *Government of Zimbabwe. Zimbabwe Long-term Low Greenhouse Gas Emission Development Strategy (2020-2050).* (2020).
4. International Labor Office (ILO), G. J. A. I. N. (GAIN). *How To Measure and Model Social and Employment Outcomes of Climate and Sustainable Development Policies.* (2017).
5. Guillemette, Y. & Turner, D. The Long View: Scenarios for the World Economy to 2060. *OECD Econ. Policy Pap.* (2018) doi:https://doi.org/10.1787/b4f4e03e-en.
6. United Nations. World population prospects 2019, Online Edition. (2019).
7. Muhammad, A., Seale, J. L., Meade, B. & Regmi, A. *International evidence on food consumption patterns: An update using 2005 international comparison program data. Int. Food Consum. Patterns Glob. Drivers Agric. Prod.* 1–104 (2015) doi:10.2139/ssrn.2114337.
8. Meade, B., Regmi, A., Seale, J. L. & Muhammad, A. New International Evidence on Food Consumption Patterns: A Focus on Cross-Price Effects Based on 2005 International Comparison Program Data. *SSRN Electron. J.* (2014) doi:10.2139/ssrn.2502881.
9. United Nations. *UN Handbook on Supply, Use, and Input-Output Tables with Extensions and Applcations.* (United Nations, Department of Economic and Social Affairs, Statistics Division, 2018).
10. Shepherd, T. G. *et al.* Storylines: an alternative approach to representing uncertainty in physical aspects of climate change. *Clim. Change* **151**, 555–571 (2018).
11. ZAMBEZIRA. http://www.zambezira.org/about-us/background. (2020).
12. Jeans, H. Annex R: Greenhouse Gas (GHG) Assessment. in *Proposed Batoka Gorge Hydro-Electric Scheme (Zambia and Zimbabwe) on the Zambezi River* (Zambezi River Authority (ZRA), 2019).
13. *National Renewable Energy Policy, MINISTRY OF ENERGY AND POWER DEVELOPMENT, Republic of Zimbabwe.* (2019).
14. https://www.energy.gov/energysaver/heat-and-cool/water-heating.
15. Allcott, H., Collard-Wexler, A. & O'Connell, S. D. How do electricity shortages affect industry? Evidence from India. *Am. Econ. Rev.* **106**, 587–624 (2016).
16. Morimoto, R. & Hope, C. The impact of electricity supply on economic growth in Sri Lanka. *Energy Econ.* **26**, 77–85 (2004).
17. Omri, A. An international literature survey on energy-economic growth nexus: Evidence from country-specific studies. *Renewable and Sustainable Energy Reviews* vol. 38 951–959 (2014).
18. Chen, S. T., Kuo, H. I. & Chen, C. C. The relationship between GDP and electricity consumption in 10 Asian countries. *Energy Policy* **35**, 2611–2621 (2007).
19. Campo, J. & Sarmiento, V. The relationship between energy consumption and GDP: Evidence from a panel of 10 Latin American countries. **Lat. Am. J. Econ**. **50**, 233–255 (2013).
20. International Energy Agency (IEA). Total energy supply (TES) by source, Zimbabwe 1990-2018. *Data & Statistics* https://www.iea.org/data-and-statistics?country=ZIMBABWE&fuel=Energy supply&indicator=TPESbySource (2020).

21. ZIMSTAT. *Poverty, Income, Consumption and Expenditure Survey 2017 Report*. www.zimstat.co.zw (2017).

22. ZIMSTAT. Poverty Income Consumption and Expenditure Survey 2017: Scientific Use File. *Online Microdata Catalog - Zimbabwe National Statistics Agency* http://www.nada.zimstat.co.zw/nada/index.php/catalog/79 (2019).

23. ZIMSTAT. Labour Force and Child Labour Survey. *Zimbabwe Natl. Stastical Agency* (2020).

24. Bhattacharya, S. C., Albina, D. O. & Abdul Salam, P. Emission factors of wood and charcoal-fired cookstoves. *Biomass and Bioenergy* **23**, 453–469 (2002).

25. Food and Agricultural Oorganisation (FAO). Annex III - Measuring fuelwood and charcoal. *Wood Fuel Surveys* http://www.fao.org/3/q1085e/q1085e0c.htm (1983).

26. Mujuru, L. & Oeba, V. O. *Forestry sector engagement in climate change action: the role of public and private sectors in Zimbabwe. International Forestry Review* vol. 21 (2019).

27. Government of Zimbabwe. *The 2020 Mid-Term Budget and Economic Review.* (2020).

28. Bauer, J. *The Flight of the Phoenix: Investing in Zimbabwe's Rise from the Ashes During the Global Debt Crisis.* (epubli GmbH, 2013).

29. Manyanhaire, I. O. & Kurangwa, W. *Estimation of the impact of tobacco curing on wood resources in Zimbabwe. International Journal of Development and Sustainability* vol. 3 www.isdsnet.com/ijds (2014).

30. Government of Zimbabwe. *National agriculture policy framework (2018-2030).* (Government of Zimbabwe, Ministry of Lands Agriculture and Rural Resettlement, 2018).

31. FAO. *Identifying opportunities for climate-smart agriculture investments in Africa.* (2012).

32. Montt, G. & Luu, T. Does Conservation Agriculture Change Labour Requirements? Evidence of Sustainable Intensification in Sub-Saharan Africa. J. *Agric. Econ.* **71**, 556–580 (2020).

33. IEA. Electricity generation by source, Zimbabwe 1990-2018. *Data & Statistics* https://www.iea.org/data-and-statistics?country=ZIMBABWE&fuel=Energy supply&indicator=ElecGenByFuel (2020).

34. Wood, R. et al. Global Sustainability Accounting—Developing EXIOBASE for Multi-Regional Footprint Analysis. *Sustainability* **7**, 138–163 (2014).

35. Lehr, U. *et al. Kurz- und langfristige Auswirkungen des Ausbaus der erneuerbaren Energien auf den deutschen Arbeitsmarkt.* (2011).

36. Intergovernmental Panel on Climate Change. *2006 IPCC Guidelines for National Greenhouse Gas Inventories.* (Institute for Global Environmental Strategies, 2006). doi:10.1016/S0167-5060(08)70670-8.

37. Demirhan, H. dLagM: An R package for distributed lag models and ARDL bounds testing. *PLoS One* **15**, e0228812 (2020).

38. Pesaran, M. H., Shin, Y. & Smith, R. J. Bounds testing approaches to the analysis of level relationships. *J. Appl. Econom.* **16**, 289–326 (2001).

39. Wolde-Rufael, Y. Electricity consumption and economic growth: A time series experience for 17 African countries. *Energy Policy* **34**, 1106–1114 (2006).

# Annex: Technical description of the model and data

The model documentation provides details on the its technical aspects. Understanding the data underlying the model is crucial for understanding and interpreting the results. Their quality depends directly on the quality of the underlying data. If the data present major uncertainties, the model cannot correct them and the outcomes will be equally uncertain.

## A.1 General limitations and strengths of the modelling approach*

** Excerpt from general documentation of economic core model (SUT_core).*

Supply-and-use table based macroeconom(etr)ic input-output models / GAIN-type GJAM 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 baseline scenario. They indicate the direction and possible size of the effects, but should not be taken exact 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 2018), which in turn might be estimated based on older supply-and-use tables. For some countries, the most recent available supply-and-use table might be from 2010 or 2012. To extrapolate data based on this until over the next decade will not necessarily give a complete picture, but it is 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 investment 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. That means that 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 of course 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 only a few seconds, so that a large number of scenarios can be calculated for 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.

## A.2 Data requirements and available data

The absolute minimum data requirements for the GJAM are:

- Input-output table (IOT) or supply-and-use table (SUT) for a recent year;
- Time series of system of national accounts (SNA) data, with as much detail by industry as possible;
- Data on employment by industry, e.g., a labour force survey for the same industry classification as the IOT or SUT;
- Data on emissions by industry, e.g., from the GHG inventories, for the same industry classification as the IOT or SUT; and,
- Data on changes in consumption and production structure for the green scenarios.

For GJAM Zimbabwe the following data are used:

- Population 2018 – 2050: UNDESA World population forecast;
- Global economic development: OECD Longview;
- Supply-and-use table 2012: ZIMSTAT (~120 products, ~45 industries), own estimates of green industries;
- System of National Accounts 2018: ZIMSTAT + ZEPARU;
- Household energy consumption expenditures (electricity, fuel, charcoal): estimated from ZIMSTAT household survey;
- Employment (gender and skill) by industry: ZIMSTAT;
- GHG emissions by industry: Fourth National Communication (not yet published), 2017 energy emissions, 2015 industrial emissions, 2018 AFOLU emissions and 2013 waste.

### A.2.1 The supply-and-use table (SUT)

Several steps are involved in updating the original 2012 the supply-and-use table data (in basic and purchaser's prices) to reflect the 2018 data in basic prices with additional green industries and products.

1. Original 2012 SUT: Final SUT 30 September 2018 (1).xlsx  (2012 data, compiled in 2018)
    - conversion of USE from purchasers to basic prices in Excel
2. Update SUT to 2018: 2018_SUT_Zimbabwe_VAbyindustry.xlsx
    - Updated to 2018 using a simple iterative RAS procedure, using UNSNA main aggregates data and ZIMSTAT Gross value-added components by industry for 2018

3. Include employment and GHG extension data
   - sheets added for extension data and concordance matrices for emission extensions and HHdemand model
   - more information on extension data in Section A.2.5

4. Update SUT to consider unaccounted firewood industry (2018_SUT_Zimbabwe_VAbyindustry_Firewood_out.xlsx)
   - introducing the new industry/product
   - using SUT price model to update the entire table for including the cost of firewood

5. Update SUT to include "green" industries (2018_SUT_Zimbabwe_VAbyindustry_SectorSplit.xlsx)
   - See Section A.2.4

## A.2.2 Macro-economic drivers

The model is driven by the macro-economic demand-side variables as shown in Figure 1.

### A.2.2.1 Household demand model

Given that a supply-and-use based model includes household consumption by products, their possible development can be determined using a **demand system**. Household consumption by product prod depends on total income (GDP) and income, own-price and cross-price elasticities el, eop, with grX denoting the % growth in variable X

HHEprod[t] = HHEprod[t-1] + el*grGDP + eop*grOwnPrice + ecp*grOtherPrices

Here, we take income, own-price and cross-price elasticities from the USDA international food comparison programme (doi:10.2139/ssrn.2114337). We adjust elasticities downward for consumption categories "Medical & health" and "Others." The original elasticities greater than 4 led to model instabilities and non-covergence issues. Own-price and cross-price elasticities were taken from the same publication.

**Income elasticities for broad consumption categories, 144 countries, 2005**

| Food, beverages & tobacco | Clothing & footwear | Housing | House furnishing | Medical & health | Transport & communication | Recreation | Education | Other |
|---|---|---|---|---|---|---|---|---|
| 0.831 | 0.969 | 1.082 | 1.058 | **2.086** | 1.281 | 2.05 | 0.936 | **2.096** |

### A.2.2.2 Government expenditures

Government expenditures are assumed to grow proportionally with population. We thus estimated government expenditure as a function of population using a simple OLD model. While population was, indeed significant, the explanatory power of the regression was not very high. The equation implemented in the model is:

GOVR[t] = -1526.89 + 0.00031663 * POPU[t]

The error term in the last year was 3183.4, so we need to correct for that. While this may not be the best way to model this, it is a simple elegant solution that ensures model transparency, as it avoids too many complicated details.

Population development is based on the medium fertility scenario from UNDESA's population prospects. For a different development, simply exchange the data in the Excel input file.

#### A.2.2.3 Gross-fixed capital formation

General gross fixed capital formation/investments are assumed to grow in line with the previous year's growth rate. General investments are thus exogenous to the model in the current year, contributing to stabilizing the model. However, this makes it possible to capture the effect of increased economic activity on investments; that is, investments are higher if last year's GDP growth is higher. This also enforces some path dependency for investments.

The investment structure - the shares of investment spending on different product groups in the SUT in total investments - is assumed to be constant.

Scenario-specific investments are modelled as additional to the general investments. Here, the product structure is flexible; that is, given as a model input. This modelling may overestimate the effect of investments in general, as investments from a scenario may sometimes crowd out general investments.

#### A.2.2.4 Exports

Exports grow with the global long-term GDP growth rate from the OECD Longview from 2022. Estimates for prior years are drawn from the IMF. While 2021 growth is expected to be higher, we adjusted it down to 2 percent. For a different development, simply exchange the data in the Excel input file.

| | 2018 | 2019 | 2020 | 2021 | 2022-2030 | 2030- |
|---|---|---|---|---|---|---|
| Global GDP growth rate | 3.0% | 2.5% | -4.9% | 2.0% | 3.4% | 2.4% |

Export product shares are assumed constant; that is, the type of products that are exported changes. This assumption can be modified for future model versions.

### A.2.3 Modelling the economic boost from additional availability of electricity

A significant share of NDC plans include additions of renewable electricity generation capacity. In most high- and middle-income countries, these are meant to replace existing fossil power plants. In many developing countries, however, the capacity addition constitutes additional electricity supply. In the GJAM model, these capacity additions and their effects are gradually introduced into the economic system.

1. The additional capacity needs to be deployed
   - Investment goods must be purchased: technology components, water or wind turbines, solar PV panels, and the components connecting the electricity generating technology to the (min-)grid;
   - The hydropower plant needs to be built and/or solar and wind power capacity needs to be installed.

While domestic workers would do most of the construction/installation work, thereby generating additional income and demand, most technology components would be imported. Thus, it is important to know the approximate share of the technology component imported and as the construction/installation work and related services, such as project planning.

2. When the new electricity generation is online, it will influence a country's overall economic activity in two key ways.
   - Employment and value creation related to the additional electricity production, i.e., all workers at the hydro-power dam and the workers responsible for repair and maintenance of wind and solar installations. This will generate income and related additional demand by households and for investments.

- If significant electricity supply shortages and frequent outages occurred previously, then additional electricity supply will generate additional production possibilities. Additional employment will be generated for those economic activities that were previously constrained by electricity supply. Again, additional income will influence final demand.

Two questions related to the second aspect remain: First, which economic activities will benefit most from the additional electricity supply? And, second, by how much will economic activity increase?

#### A.2.3.1 Which economic activities will benefit most from the additional electricity supply?

In keeping the demand-driven economic perspective inherent to input-output models, production of goods and services and related economic activity are determined by demand, both final and intermediate. These are determined, in turn, by household behaviour, investment demand and foreign trade. Regarding the latter, political industrial strategies may play a major role, whether by promoting the export of selected goods and services (for example, specific agricultural products, raw materials - or processed versions of both - or tourism) or by aiming at import substitution. Zimbabwe's NDC does not articulate such, except for solar water heater production.

Final demand is dominated by household consumption expenditures, followed by demand for investment goods. The household demand system is based on income and price elasticities from [6,7]. Analysing these in detail shows that with increasing income, consumption of goods and services that are more electricity-intensive increases. More specifically, the "food, beverages and tobacco" and "education" categories are the least elastic. We therefore assume that the additional goods and services that will be consumed when they can be produced are consistent with the inherent changes in consumption patterns of the demand system implemented. For investment goods, one could assume that relatively more will be invested in machinery and equipment that rely on electricity availability. With the exception of "office, accounting and computing machinery" and "radio, television & communication equipment" (Zimbabwe), electrical machinery and equipment and similar products already represent large shares of investment goods. The low share of computers and related equipment is due to the fact that the SUT is based on the year 2012. However, given that no better information is available, we assume that the structure of investment goods remains the same. That is, investment will increase as more electricity is available and will be directed to those goods and services that already receive a higher share.

#### A.2.3.2 By how much will economic activity increase?

For most European countries, as well as OECD countries, economic activity is unlikely to increase due to capacity additions of renewable energy generation technologies. Rather than generating additional economic activity, the market share of renewables will increase accordingly.

In the context of countries with geographic areas or population segments that still lack access to reliable electricity supply, electricity shortages could hamper economic development [14,15]

The approach described below assumes that the extra electricity that will be available from the capacity additions will be absorbed by extra economic activity, rather than replace existing electricity generation.

The evidence for the direction of the relationship between economic growth (in terms of GDP per capita) and energy use, specifically electricity consumption, is mixed across both countries and estimation methods used. Comprehensive literature reviews on the bidirectional relation are given in [16] and [17]. In the demand-driven GJAM model, electricity production does depend on demand. However, we need to account for the possibility of an expansion due to the availability of additional electricity. We therefore estimate the bi-directional relationship between electricity consumption and GDP per capita based on historic data from 1971 to 2018 for Zimbabwe, Nigeria and all of Africa. Data sources are the UNDESA population data; the UNSNA main aggregates database for value added per capita in constant prices (this, rather than GDP per capita, is the variable that GJAM uses); and two different electricity data series (electric power consumption (kWh per capita) from the World Development Indicators (WDI Indicator code: EG.USE.ELEC.KH.PC) for 1971-2014 and electricity production (kWh) from the World Bank's Africa Development Indicators[2] (ADI Indicator code EG.ELC.PROD.KH) for 1971-2010). For Zimbabwe, data on electricity production was available for 2009 – 2019 from the Zimbabwe Electricity Supply Authority. Using the growth rates from the Africa Development Indicators Electricity production (kWh) data, we extrapolated Zimbabwe's electricity production back to 1971. This ensured that we used the country-specific data available for the most recent years. Such data was not available for Nigeria. Electricity consumption data is available for the most recent years from the IEA country profiles. We applied those growth to generate estimates for the years after 2014. The econometric models were estimated including and excluding the years after 2010/2014, respectively. We could not find a significant difference between the coefficients.

We test the system of equations[3] as specified by [18]:

$$GDPpc_t = \alpha_G + \beta_G ECpct + \varepsilon_{Gt} \qquad (A.2.1)$$

$$ECpc_t = \alpha_E + \beta_E GDPpc_t + \varepsilon_{Et} \qquad (A.2.2)$$

where $GDPpc_t$ is real GDP per capita and $ECpc_t$ is electricity consumption per capita in year t. The simple OLS estimation shows a strong relationship between development in GDP and electricity consumption per capita for Zimbabwe, as presented in Table 14.

**Table 14: OLS estimation results for Equations 1 and 2**

| | EQUATION (1) GDPpc ~ ECpc(ADI) | EQUATION (1) GDPpc ~ ECpc(WDI) | EQUATION (2) ECpc(ADI) ~ GDPpc | EQUATION (2) ECpc(WDI) ~ GDPpc |
|---|---|---|---|---|
| **Coef** | 1.32985 | 1.08837 | 0.71185 | 0.89002 |
| **SE** | 0.05055 | 0.03134 | 0.02706 | 0.02563 |
| **t-stat** | 26.30858 | 34.72409 | 26.30858 | 34.72409 |
| **p-val** | 0 | 0 | 0 | 0 |
| **Adj. Rsq** | 0.94529 | 0.96787 | 0.94529 | 0.96787 |

The causal relationship between GDP per capita and electricity production is provided through the household demand system integrated into the supply-and-use framework. However, the effect of the increase in electricity supply on GDP per capita is missing. To incorporate this into GJAM, we use the results from Equation A.2.1 and include them in order to provide additional growth impulses when initializing GDP per capita at the start of each year. That is, rather than initializing value added per capita for the first iteration by last year's value, value added per capita grows by what is expected from the estimated Equation A.2.1 based on the increase in electricity supply per capita available that year due to capacity additions.

### A.2.4 Adding new industries and products to the supply and use tables

The original industry and product classification in the supply and use tables were supplemented by the additional industries and products needed to implement the GJAM. The following industries and products were included:

- "*Firewood*" industry, which supplies the new product "*Firewood*";
- "*Hydropower*", "*Solar Photovoltaics*", "*Wind*", and "*Biomass Electricity*" renewable electricity industries, which supply the existing products, "*Electricity and gas*," "*Electricity and gas and (on own account) secondary products*," and "*Support services electricity and gas*;"

2 https://databank.worldbank.org/source/africa-development-indicators#
3 We also tested for unit roots and possible cointegration using the dLagM package in R 36, which allows for PSS cointegration test 37 that avoids the possible bias that can occur to the pre-tests for unit roots and was suggested to be used in this context by 38. Results are available upon request.

- "*Photovoltaic Panels*" and "*Solar Water Heaters*" new manufacturing industries, producing, respectively, the new products "*Photovoltaic panels*" and "*Solar water heaters*;" and,
- New "*Conservation Agriculture*" industries that supply existing agricultural products.

These were needed due to the amount of energy and GHG emissions in the case of firewood, and are central to implementation of many of the scenarios. Below, we provide details on the assumptions and data on which we based the addition of these new industries and products to the SUT.

#### A.2.4.1 Firewood

Fuelwood accounts for nearly 70 percent of all energy supply in Zimbabwe [19]. The highest use of firewood is as cooking fuel by households, followed by tobacco production. In rural areas, 93.8 percent of households use firewood for cooking and heating. this share drops to 16.7 percent of households in urban areas [20]. The use of firewood as cooking fuel is highly associated with poverty; almost 97 percent of extremely poor households depend on firewood, compared to 82 percent for poor households, and 38 percent for non-poor households [20]. The inclusion of firewood production and consumption is necessary to this model because it represents a large share of the energy economy, particularly for households, and plays a major role in GHG from biomass burning and deforestation. Furthermore, the effects of moving towards clean, affordable energy and clean and efficient cooking and heating sources in households should be assessed. However, there are significant uncertainties associated with estimates of this industry.

The first challenge is allocating a monetary value to a non-monetary activity, as most users of firewood collect their own. In fact, fuelwood is, to a large extent, obtained free of charge, both by industries (e.g., agriculture and tobacco) and households. Current household expenditures on firewood is only 1.3 percent of total household expenditures in rural areas, and 0.3 percent in urban areas [21]. This low spending on firewood is not relative to low use, but to the fact that households gather most of their fuelwood themselves at no monetary cost. According to estimates, 92 percent of firewood consumed by households is gathered, while in urban areas, over 65 percent of firewood used by households is purchased [21]. In addition, the Tobacco Research Board estimates that producers of cured tobacco – the largest use of firewood outside households – purchase only around 8 percent of their fuelwood, gathering the remaining 92 percent themselves at no monetary cost.

The non-monetary nature of this activity is related to the second challenge: the employment created by this industry involves largely, but not exclusively, unpaid household activities. The Labour Force and Child Labour Survey reports that in 2019, 2.9 million people in the working age population were involved in gathering firewood for their own household use in 2019 [22]. This is equivalent to the number of people working in all industries in Zimbabwe in the same year. This activity is reported together with other household activities, such as preparing food (5.2 million), washing clothes (4.9 million), cleaning the house (5 million), shopping (1.4 million), fetching water (3.8 million), and caring for children (3 million). In comparison, around 1 million people are employed in agriculture, and another 922,000 are involved in subsistence agriculture, producing for their own consumption. These activities might be performed either by people whose main activity is caring for the farm or household, or by people who fetch water and firewood before going to their main jobs. However, individuals involved in each of the activities for own use cannot be added as additional employment in the model. Thus, employment in the firewood industry was re-estimated based on generation of value added, as detailed in section A.2.5.1.

**Estimating production and consumption of firewood**

Many statistics are available regarding the total production and consumption of firewood by households. In most cases, they conflicting, ranging from eight to 22 million $m^3$ of firewood used annually. For this model, we chose to use the consumption of firewood consistent with the energy emissions update for the GHG emissions inventory. The following assumptions were used:

- Total $CO_2$ emissions from biomass burning were taken as a starting point to estimate the amount of biomass used in Zimbabwe: 32 554 Gg $CO_2$ from solid biomass combustion in 2017.
- Estimated physical amount (in tons) of firewood using average emission factors from burning of fuel wood in cookstoves [[23]]. Emissions factors for cookstoves were used because households use predominantly firewood for cooking and heating.
- Estimated physical amounts in volume (million $m^3$) were estimated using an average density for tropical fuelwood of 720 kg/$m^3$ [[24]].
- The assumption used to estimate total monetary supply and use was that households or industries would pay an average of $1.00 per bundle for all biomass consumed (1 bundle = around 0.04$m^3$) [[25]].
- All value generated by demand for this firewood would be translated to wages to the firewood producers, thus allocated to value added.
- It was assumed that 62 percent of the 295 million kg of tobacco produced in Zimbabwe [[26]] was cured by wood [[27]] and that an average of 14 kg of wood is required to cure each kg of tobacco[[28]].
- Of the remaining wood, 0.7 percent was allocated to electricity and heat, based on the GHG emissions inventories, and the remaining (84 percent) was allocated to households. This share is smaller than that estimated by the GHG emissions inventories (94 percent) due to the bottom-up estimates for tobacco curing.

#### A.2.4.2 Conservation agriculture

The original agriculture industry (Agric, Animal, Hunting, and related Services) was divided between conservation agriculture and all other agriculture activities. It is estimated that 100,000 hectares are currently occupied by farms that practice conservation agriculture [[29]].

Conservation agriculture can be distinguished from conventional agriculture by its primary characteristics: minimum mechanical soil disturbance (no-tillage or low tillage agriculture); maintenance of ground cover with organic matter; and diversification of crop species grown in rotation. Conservation agriculture is also estimated to create more jobs and increase income for agriculture workers [[2]].

The new conservation agriculture industry structure was based on the original agriculture industry, including a few assumptions:

- Crop rotation and no/low tillage requires less machinery, less mechanization of agriculture production and more human labour [[2,30]]. Conservation agriculture requires less machinery – two-wheel tractors, instead of utility tractors - to prepare the land. These smaller tractors have a 25 percent lower annual cost (25 percent lower inputs from special-purpose machinery, agriculture or forestry machinery) than the utility tractors used in conventional agriculture. Lower adoption of machinery leads also to lower fuel demand, for an estimated 70 percent savings in diesel [[2]].
- Due to higher demand for human labour (especially during harvesting and threshing), labour input, in value added (compensation of employees, gross operating surplus, and mixed income), was assumed to be 18 percent higher based on labour requirements for the full adoption of conservation agriculture practices in maize farming in five sub-Saharan African countries [[31]]. However, the increase in labour inputs is higher for farms adopting full conservation agriculture practices (intercropping, residue retention and minimum tillage). Labour requirements may be lower for farms adopting only one or two of these practices. Furthermore, increased labour inputs are provided primarily by household labour, especially women, which does not necessarily result increase paid farm labour.
- Improvements to soil organic carbon due to conservation tillage require lower amounts of fertilizers, but higher amounts of pesticides. Farms adopting full conservation agriculture practices in five sub-Saharan African countries [[31]] reported using 33 percent less synthetic fertilizers per hectare, but 150 percent more pesticides. Assuming a similar structure of fertilizer and pesticide consumption in Zimbabwe compared to Nigerian crop production in the SUT (fertilizers represent 67 percent of chemical inputs into crop

production and pesticides represent 10 percent), conservation agriculture was estimated to reduce the consumption of chemical inputs by 7 percent, compared to conventional agriculture.

- Changes in livestock diets, health control, genetics and reproduction, and grassland management practices would lead to increased animal productivity and a decrease of 18 percent in direct methane emissions [2,30].

#### A.2.4.3 Renewable electricity

The electricity industries were divided into five categories: *hydropower, solar photovoltaics, wind, biomass electricity* and *Electricity and gas*. The original electricity and gas industry was divided between hydropower and the remaining electricity and gas. The other renewable electricity industries (solar PV, wind and biomass) were added as new (non-existent in 2018) industries. It is important to note here that these new industries correspond to the operation and maintenance of these electricity industries. They do not include the construction of new electricity infrastructure or the production of energy equipment (e.g., photovoltaic panels or wind turbines).

**Hydropower and the division from the original *electricity and gas* industry**

Hydropower electricity corresponded to 54 percent of electricity supply in 2018 [32]. Electricity and gas was divided between *Hydropower* and the remaining *Electricity and Gas* based on the following assumptions:

- According to the Zimbabwe energy balance, there is no substantial use or supply of gas, so 54 percent of the monetary production (total output of the industry) from the original Electricity and Gas industry was allocated to Hydropower, and the remaining 46 percent was allocated to the remaining electricity and gas.

- The input structure of the hydropower industry (intermediate inputs from other industries and value-added inputs, such as labour compensation and gross operating surplus) was based on estimated inputs for the operation and maintenance of the new Batoka hydropower plant [11], adjusted to match the products used by the original Electricity and Gas industry.

- The products used to produce hydropower were subtracted from the original electricity sector, resulting in a new industry structure for the (remaining) Electricity and Gas industry.

- The outputs from the hydropower industry were distributed as the outputs from the three energy products from the original Electricity and Gas industry: *Electricity and gas* (88.4 percent), *Electricity and gas* and (on own account) *secondary products* (0.8 percent) and *Support services for electricity and gas* (10.8 percent).

**Solar photovoltaic, wind, and biomass electricity**

The three new renewable electricity industries were added as new industries that did not exist in 2018. The input structure (intermediate inputs from other industries and value-added inputs, such as labour compensation and gross operating surplus) for these industries were estimated based on input coefficients of different electricity generation industries from the EXIOBASE input-output [33]. As they are new industries, they have not been divided (or allocated) from the electricity and gas industry. Instead, their structure was described in the base-year supply and use tables with virtually no output ($1 dollar).

#### A.2.4.4 Production of photovoltaic panels and solar water heaters

The production of solar photovoltaic panels and SWH were also added as own industries, so scenarios can assume different shares of imports versus local production of equipment. The input structure for the *Production of solar photovoltaic panels* was based on Lehr et al. [34] The input structure of the *Production of solar water heaters* was assumed to be the same as for Manufacture of Electrical Equipment, Machinery & Equipment. Both industries are assumed to have had no production in 2018 and their structure is described in the base-year supply and use tables with virtually no output ($1 dollar). It is important to note here that the import shares of inputs allocated to these industries is as the product import share described in the model. That is, the intermediate inputs that are imported currently (for example, petroleum products and special-purpose machinery) will still be imported if solar photovoltaic panels and SWH are produced in Zimbabwe.

## A.2.5 Labour and environmental extensions

The inclusion of labour and emissions effects requires that labour and emissions are classified in a way that is fully consistent with the economic data in the SUT, in terms of same industry classification and base year. This section details the data needs in these extensions and the steps used to build them for the GJAM Zimbabwe.

### A.2.5.1 Labour extensions

Labour extensions refer to the employment statistics found in labour force surveys (LFS). They include, at least, the total number of people employed by gender and by skill level (skilled or unskilled). Additional indicators can be included to provide additional analysis of which jobs will be affected by structural economic changes. These additional indicators may refer, for example, to job location (rural and urban employment) or employment status (employee, self-employed or unpaid family worker).

Table 15 presents the indicators included in GJAM Zimbabwe. All indicators are quantified by number of people. Each indicator corresponds to a row, describing the people employed in each of the 36 industries in the SUT. Data for employment originates from the 2019 LFCLS [22]. Scaling from the original base year (2019) to the SUT base year (2018) took into account the growth of value added per industry between 2008 and 2009, income growth, and employment elasticities for each industry. Historical data was used to estimate sector employment elasticities.[4] For industries where there was no sector-specific elasticity, the closest sector or the overall economy elasticities were used. Growth of employment between 2008 and 2009 by gender, skill level, and location (urban/rural) was assumed to be the same as for total employment for each sector. Table 15 shows the indicators available in the labour extensions in the GJAM Zimbabwe.

**Table 15. Indicators for labour extensions in GJAM Zimbabwe, by persons**

| |
|---|
| Total employment |
| Female employment |
| Male employment |
| Skilled employment |
| Unskilled employment |
| Skilled female |
| Unskilled female |
| Skilled male |
| Unskilled male |
| Rural employment female |
| Rural employment male |
| Urban employment female |
| Urban employment male |

4 Employment elasticities from historical data were provided by ZEPARU and ZIMSTAT, as follows: 0.309 for the distribution sector; 0.721 for construction; 0.521 for manufacturing and 0.448 for mining.

### Labour extensions for the new industries

The labour data was divided further into the new industries based on the assumptions below.

**Firewood industry:** The number of workers estimated in the firewood industry was calculated assuming that the average wages of firewood collectors would be the same as agricultural workers' wages. Thus, the number of workers in the firewood industry does not match the number of workers who collect firewood as reported in the LFCLS, as section A.2.4.1 explains. Workers in the *firewood industry* are additional in the economy and are not included in any of the SUT industries in the LFCLS, as this activity is reported as subsistence (i.e., production of goods and services for own use). The gender distribution of workers in the *firewood industry* would follow those as reported in the LFCLS and the skill and rural/urban distribution would be similar to those in agriculture.

**Conservation Agriculture:** Employment extensions were assumed to follow the same number of people employed per labour compensation (employee compensation, gross operating surplus and mixed income) as in the *Agric, Animal, Hunting, and related Services* industry. The same structure of employment (gender, area, skill level) was also assumed.

**Renewable energy industries:** For solar photovoltaics, wind, biomass electricity and hydropower, employment extensions were assumed to follow the same number of people employed per labour compensation in the *Electricity and Gas* original industry. Employment in Hydropower was subtracted from the original *Electricity and Gas* industry. The structure of employment (gender, area and skill level) was assumed to be the same across all electricity industries.

**Production of solar photovoltaics panels and solar water heaters:** Employment extensions were assumed to follow the same number of people employed per labour compensation in the Manufacture of Electrical Equipment, Machinery & Equipment industry. The same structure of employment (gender, area and skill level) was also assumed.

### Table 16: Employment by industry, 2018 estimates

| | Total employment | Skilled female | Unskilled female | Skilled male | Unskilled male |
|---|---|---|---|---|---|
| **Agric, Animal, Hunting, and related Services** | 996,868 | 5,3490 | 261,159 | 115,977 | 566,241 |
| **Agric Forestry & Logging** | 12,177 | 559 | 2,323 | 1,803 | 7,493 |
| **Agric, Fishing & Aquaculture** | 27,809 | 296 | 4,329 | 1,486 | 21,698 |
| **Mining Coal and Lignite** | 193,452 | 7,958 | 44,922 | 26,995 | 113,577 |
| **Mining Metal Ores** | 17,693 | 7,936 | 509 | 3,005 | 6,243 |
| **Other Mining & Quarrying & Support Services** | 9,444 | 1,268 | 1,475 | 3,098 | 3,603 |
| **Fossil Electricity, Gas** | 4,916 | 49 | 324 | 2,287 | 2,256 |
| **Water Supply** | 14,655 | 285 | 3,179 | 638 | 10,553 |
| **Manufacture of Food, Beverages & Tobacco** | 87,592 | 24,742 | 4,722 | 48,813 | 9,315 |
| **Manuf of Textiles, Wearing Apparel & Footwear & leather** | 31,767 | 13,959 | 1,252 | 15,194 | 1,362 |
| **Manuf. of Wood and Wood Products** | 10,235 | 263 | 2,152 | 1,111 | 6,708 |
| **Manuf. of Paper & Paper Products & Printing** | 793 | 184 | 49 | 442 | 117 |
| **Manuf. of Chemical, Pharmaceutical & Chemical Products** | 11,613 | 1,094 | 2,009 | 3,001 | 5,509 |
| **Manuf. of Basic Metals** | 15,293 | 1,513 | 347 | 10,927 | 2,507 |
| **Manuf. of Rubber & Plastics Products** | 3,460 | 360 | 22 | 2,898 | 179 |
| **Manuf. of Other Non-Metallic Mineral Products** | 10,297 | 1,237 | 457 | 6,284 | 2,320 |
| **Manuf. of Furniture & Related Products** | 5,935 | 1,104 | 54 | 4,557 | 221 |
| **Manuf. of Fabricated Metal Products, Office** | 12,012 | 1,200 | 272 | 8,595 | 1,945 |
| **Manuf. of Electrical Equipment, Machinery & Equipment** | 32,550 | 7,310 | 1,248 | 20,493 | 3,499 |

| | Total employment | Skilled female | Unskilled female | Skilled male | Unskilled male |
|---|---|---|---|---|---|
| **Manuf. of Office & Computing Machinery** | 170 | 78 | 13 | 68 | 12 |
| **Manuf. of Motor Vehicles & Other Transport Equipment & Communica-tion** | 2,009 | 365 | 62 | 1,351 | 231 |
| **Other Manufacturing n.c.e** | 4,244 | 1,064 | 135 | 2,703 | 343 |
| **Construction of Buildings & Civil Engineering Works** | 114,582 | 1,447 | 8,842 | 11,987 | 92,307 |
| **Wholesale & Repair of Motor Vehicles** | 56,390 | 11,068 | 9,824 | 9,231 | 26,267 |
| **Retail Trade** | 457,600 | 31,054 | 141,466 | 51,315 | 233,766 |
| **Hotels and Restaurants** | 41,171 | 3,533 | 21,780 | 5,080 | 10,779 |
| **Transport Services and Storage** | 81,501 | 1,136 | 5,645 | 8,931 | 65,790 |
| **Information, Post and Telecommunications** | 12,175 | 1,243 | 1,954 | 3,054 | 5,924 |
| **Financial Intermediation Services** | 11,552 | 2,425 | 2,183 | 3,544 | 3,399 |
| **Insurance and Pension Services** | 6,671 | 1,950 | 1,248 | 2,753 | 720 |
| **Real Estate Renting & Business Services** | 1,856 | 283 | 248 | 706 | 619 |
| **Public Administration** | 69,172 | 14,741 | 12,499 | 14,172 | 27,761 |
| **Education** | 194,426 | 98,040 | 20,345 | 54,303 | 21,739 |
| **Health and Social Care Services** | 56,791 | 22,302 | 13,039 | 9,950 | 1,1500 |
| **Other Services** | 73,983 | 4,905 | 27,090 | 8,271 | 33,717 |
| **Domestic Services** | 167,531 | 1,590 | 118,915 | 95 | 46,931 |
| **Firewood** | 368,116 | 0 | 243,243 | 0 | 124,873 |
| **Solar electricity** | 0 | 0 | 0 | 0 | 0 |
| **Wind electricity** | 0 | 0 | 0 | 0 | 0 |
| **Hydro electricity** | 3,031 | 30 | 200 | 1,410 | 1,391 |
| **Biomass electricity** | 0 | 0 | 0 | 0 | 0 |
| **Conservation agriculture** | 63,789 | 4,183 | 20425 | 6,661 | 32,520 |
| **Solar PV manufacturing** | 0 | 0 | 0 | 0 | 0 |
| **Solar water heaters manufacturing** | 0 | 0 | 0 | 0 | 0 |

### A.2.5.2 Greenhouse gas emissions extensions

The GHG emission extensions are based on emissions reporting following the IPCC guidelines. This reporting follows four main activities: energy; *IPPU; AFOLU*; and *waste management*. In addition, *$CO_2$ emissions from biomass burning* are also reported and included in GJAM Zimbabwe.

The three main emissions are separated out in GJAM Zimbabwe ($CO_2$, $CH_4$ and $N_2O$, other gases were not included) and categorized into activities that can be performed separately based on the different scenarios. The emissions categories are shown in Table 17 and explained in detail below.

**Table 17: GHG emissions indicators in Gg $CO_2$-eq and correspondence to emission inventory categories**

| | $CO_2$ | | | | | $CH_4$ | | | | $N_2O$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy | IPPU | AFOLU | Waste | Biomass | Energy | IPPU | AFOLU | Waste | Energy | IPPU | AFOLU | Waste |
| $CO_2$ emissions from combustion of solid biomass fuels | | | | | • | | | | | | | | |
| $CO_2$ emissions from prescribed burning | | | • | | | | | | | | | | |
| $CO_2$ emissions from fuel combustion (fossil fuels) | • | | | | | | | | | | | | |
| $CO_2$ emissions from industrial processes and waste treatment | | • | | • | | | | | | | | | |
| $CH_4$ emissions from fuel combustion (fossil fuels) and industrial processes | | | | | | • | • | | | | | | |
| $CH_4$ emissions from agriculture activities and waste treatment | | | | | | | | • | • | | | | |
| $N_2O$ emissions from all activities | | | | | | | | | | • | • | • | • |

## Emissions from energy

Following the 2006 IPCC guidelines [35], emissions from energy are reported for the three gases and divided based on main energy activities and fuel use. The categories in the original data are:

- **Emissions from fuel combustion activities:** includes all emissions from fuel combustion and is divided into:
  - **Energy industries:** emissions that are directly allocated to the **energy transformation sector** for production of electricity and fuels and does not include burning these energy products. In the IPCC guidelines, those emissions are listed for three main activities: *Main activity electricity and heat production; Petroleum refining; and Manufacture of solid fuels and other energy industries.*
  - **Manufacturing industries and construction:** emissions generated through the **use of energy products** in industries and construction activities. The industries include: iron and steel; non-ferrous metals; chemicals; pulp, paper and print; food processing, beverages and tobacco; non-metallic minerals; transport equipment; machinery; mining (excluding fuels) and quarrying; wood and wood products; construction; textile and leather; and other non-specified industries.
  - **Transport:** emissions from the use of fuels by civil aviation, road transportation, railways and water-borne navigation. This may include other transport, such as transport by pipelines.
  - **Other sectors:** direct emissions from fuel combustion in agriculture (fuels used in agriculture machinery), commercial and institutional sectors, and residential emissions. Residential emissions include emissions from burning fuel for heating and cooking, but not for passenger cars.
  - **Non-specified:** stationary and mobile emissions from non-specified industries.
- **Fugitive emissions from fuels:** emissions allocated to **mining of fossil fuels**. This includes fugitive emissions from solid fuels (coal mining and handling), extraction of oil and natural gas (including venting and flaring of oil and natural gas), and other emissions from energy production (such as fugitive emissions from charcoal production, biochar production, coke production, gasification transformation processes such as coal to liquids).

Energy emission data were obtained from the preliminary work to update the Zimbabwe Fourth National Communication to the UNFCCC and correspond to 2017. Given the lack of further information enabling us to scale those emissions from 2017 to 2018, we distributed 2017 emissions into 2018 economic structure. Table 18 details how emissions were allocated to the SUT industries. The main categories of emissions are in grey and the details under each category are in white. The sum of the detailed categories in white corresponds to the main categories. The table shows that 90 percent of energy emissions corresponded to an industry, while 10 percent were allocated among different industries based on the consumption of energy products in the economic SUT.

**Table 18: Allocation of energy emissions from original activity reported in the national inventory to the industry classification in GJAM Zimbabwe**

| ACTIVITY IN THE INVENTORY | SHARE OF ENERGY EMISSIONS | ALLOCATION TO SUT INDUSTRIES |
|---|---|---|
| **Energy Industries** | **54.0%** | |
| Electricity and Heat | 52.7% | Electricity and gas |
| Other Energy Industries | 1.3% | Electricity and gas |
| **Manufacturing** | **8.7%** | |
| Iron and steel | 0.1% | Manuf. of Basic Metals |
| Non-ferrous metals | 0.0% | Manuf. of Basic Metals |
| Chemicals | 0.1% | Manuf. of Chemical, Pharmaceutical & Chemical Products |
| Non -metallic minerals | 0.5% | Manuf. of Other Non-Metallic Mineral Products |
| Transport equipment | 2.9% | Manuf. of Motor Vehicles & Other Transport Equipment & Communication |
| Machinery | 2.4% | Allocated between Manuf. of Electrical Equipment, Machinery & Equipment and Manuf. of Office & Computing Machinery, based on the use of energy products in the SUT |
| Mining (excluding fuels) and quarrying | 0.0% | Allocated between Mining Metal Ores and Other Mining & Quarrying & Support Services, based on the use of energy products in the SUT |
| Food and tobacco | 0.1% | Manufacture of Food, Beverages & Tobacco |
| Pulp, paper and print | 0.6% | Manuf. of Paper & Paper Products & Printing |
| Wood and wood products | 0.9% | Manuf. of Wood and Wood Products |
| Construction | 0.6% | Construction of Buildings & Civil Engineering Works |
| Textile and Leather | 0.1% | Manuf of Textiles, Wearing Apparel & Footwear & leather |
| Non-specified | 0.3% | Allocated to all other manufacturing and mining industries, based on the use of energy products in the SUT |
| **Transport** | **23.6%** | |
| Domestic Aviation | 0.1% | Transport Services and Storage |
| Road transport | 22.0% | Transport Services and Storage |
| Rail transport | 1.6% | Transport Services and Storage |
| **Other Sectors** | **8.9%** | |
| Commercial and public services | 0.1% | Allocated to all service industries, except transport, based on the use of energy products in the SUT |
| Residential | 4.7% | Allocated directly to households |
| Agriculture/Forestry/ Fishing | 4.1% | Allocated between Agric, Animal, Hunting, and related Ser-vices, Forestry and Logging, and Fishing and Aquaculture, based on the use of energy products in the SUT |
| **Non-specified** | **3.4%** | **Allocated to all manufacturing industries, based on the use of energy products in the SUT** |
| **Fugitive emissions** | **1.4%** | |
| Solid fuels | 1.4% | Mining Coal and Lignite |

### Emissions from industrial processes and product use

Following the 2006 IPCC guidelines [35], IPPU emissions are reported for the three gases and divided by main industrial processes. This covers non-energy industrial emissions; for example, those from chemical and physical reactions in industrial processes. Under the IPCC guidelines, inventories for IPPU emissions cover the mineral industry, chemical industry, metal industry, non-energy products from fuels and solvent uses, electronics industry, product uses as substitutes for ozone depleting substances, and other product manufacture use.

The IPPU emissions used in the GJAM Zimbabwe correspond to the IPPU emissions described in the LEDS and cover GHG emissions in 2015 for the production of cement, nitric acid, and ferrochromium in 2015. The remaining IPPU emissions (3 percent) were allocated according to the IPPU emissions obtained for 2013, which distribute the remaining emissions to lime production, glass production, use of soda ash and lead production.

### Emissions from agriculture, forestry and other land use (AFOLU)

AFOLU emissions cover emissions and removal processes, including emissions from livestock (enteric fermentation and manure management), land use (emissions from managed soils, rice cultivation, liming, urea application), prescribed burning of forest land and crops residues, and deforestation.

Zimbabwe's AFOLU emissions are drawn from the LEDS and correspond to 2018 emissions. They cover emissions from enteric fermentation, prescribed burning, manure management, deforestation and other AFOLU emissions. We distributed the "other" emissions (28 percent) based on the remaining activities described in data for AFOLU emissions from 2010. Those were drawn from an assessment for the AFOLU emissions update, which distributes the remaining emissions to rice cultivation and direct and indirect nitrogen emissions from managed soils. In this model, we allocate emissions that can be allocated to economic activities. Thus, emissions from deforestation are not included in this assessment, as deforestation is a one-time event to access land and changes in deforestation emissions cannot be estimated using an economic model.

Emissions from prescribed burning and managed soils were allocated to agriculture and forestry, based on value added in these two industries.

### Emissions from Waste

We used the most recently updated value for emissions from waste management as part of preliminary work to update the national inventory. These correspond to 2012 emissions from municipal solid waste collected.

### Emissions from burning of solid biomass

The emissions from biomass burning estimated for 2017 were the starting point for accounting firewood consumption in the Zimbabwe economy. However, total emissions (and physical and monetary amounts) were redistributed as described in section A.2.4.1. Emissions from solid biomass are assumed to all come from firewood, which is mostly from unmanaged production. We assume all emissions from firewood are an addition to emissions from other sources, as firewood collection from unmanaged forests would contribute to deforestation and depletion of carbon sinks in Zimbabwe. We do not add emissions from modern biofuels (e.g., biodiesel and ethanol) as biomass emissions as they would likely come from managed biomass sources, with a net zero effect on carbon emissions. Table 19 shows the distribution of $CO_2$ emissions from the emissions inventory (in red) and the new distribution in the GJAM Zimbabwe after the re-estimation of firewood use for tobacco curing.

### Table 19: Distribution of $CO_2$ emissions from biomass burning in the updated energy emissions for 2017 and re-distribution in the GJAM Zimbabwe

| $CO_2$ EMISSIONS FROM BIOMASS BURNING | DISTRIBUTION INVENTORY / GJAM | NOTE: NOT INCLUDED IN ENERGY EMISSIONS INVENTORY, FOLLOWING THE IPCC GUIDELINES. |
|---|---|---|
| Electricity and Heat (solid biofuels) | 0.7% / 0.7% | Allocated to Electricity and gas. |
| Road transport (ethanol) | 0.2% / 0 | Not included |
| Residential (solid biofuels) | 93.9% / 83.9% | Allocated to households; share re-estimated based on new dis-tributions for firewood consumption; see section A.2.4.1. |
| Agriculture (solid biofuels) | 5.2% / 15.4% | Allocated to Agric, Animal, Hunting, and related Services; share re-estimated based on new distributions for firewood consump-tion; see section A.2.4.1. |

### Emissions extensions for new industries

To estimate emissions extensions for new industries, we assume that they are proportional to the use of products responsible for direct emissions. Those are detailed in Table 20. For example, hydropower electricity uses 2.9 percent of fossil fuels of the original electricity industry. Therefore, 2.9 percent of $CO_2$ emissions from fuel combustion (fossil fuels) is allocated from the electricity industry to hydropower and the remaining is allocated to fossil electricity.

### Table 20: Products used to estimate GHG emissions from new industries

| EMISSION INDICATOR | PRODUCTS USED AS REFERENCE FOR SCALING EMISSIONS |
|---|---|
| $CO_2$ emissions from combustion of solid biomass fuels | Firewood |
| $CO_2$ emissions from prescribed burning | Crops and livestock products; forestry products |
| $CO_2$ emissions from fuel combustion (fossil fuels) | Coal and lignite (peat); electricity and gas; coke oven products; pe-troleum oils, gases and bitumen |
| $CO_2$ emissions from industrial processes and waste treatment | Mining and quarrying; basic chemicals; plaster, lime, cement, con-crete, building stone; public administration |
| $CH_4$ emissions from fuel combustion (fossil fuels) and industrial processes | Coal and lignite (peat); mining and quarrying; electricity and gas; coke oven products; petroleum oils, gases and bitumen |
| $CH_4$ emissions from agriculture activities and waste treatment | Crops and livestock products; forestry products; public administra-tion |
| $N_2O$ emissions from all activities | Crops and livestock products; forestry products; coal and lignite (peat); electricity and gas; coke oven products; petroleum oils, gases and bitumen; public administration |

### Table 21: GHG emissions by industry: estimates for 2018

| | $CO_2$ emissions from biomass Gg | $CO_2$ emissions from AFOLU Gg | Energy $CO_2$ emissions by industry Gg | Industrial waste $CO_2$ emissions by industry Gg | Energy industrial $CH_4$ emissions by industry Gg | Agricultural waste $CH_4$ emissions Gg | Total $N_2O$ emissions by industry Gg $CO_2$eq |
|---|---|---|---|---|---|---|---|
| **Agric, Animal, Hunting, and related Services** | 1,607 | 2,633 | 308 | 0 | 11 | 5,182 | 4,334 |
| **Agric Forestry & Logging** | 0 | 53 | 1 | 0 | 0 | 0 | 88 |
| **Agric, Fishing & Aquaculture** | 0 | 0 | 18 | 0 | 1 | 0 | 3 |
| **Mining Coal and Lignite** | 0 | 0 | 12 | 0 | 135 | 0 | 4 |
| **Mining Metal Ores** | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| **Other Mining & Quarrying & Support Services** | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| **Fossil Electricity, Gas** | 218 | 0 | 5,078 | 0 | 1 | 0 | 19 |
| **Water Supply** | 0 | 0 | 6 | 0 | 1 | 0 | 2 |

| | $CO_2$ emissions from biomass Gg | $CO_2$ emissions from AFOLU Gg | Energy $CO_2$ emissions by industry Gg | Industrial waste $CO_2$ emissions by industry Gg | Energy industrial $CH_4$ emissions by industry Gg | Agricultural waste $CH_4$ emissions Gg | Total $N_2O$ emissions by industry Gg $CO_2eq$ |
|---|---|---|---|---|---|---|---|
| **Manufacture of Food, Beverages & Tobacco** | 0 | 0 | 22 | 0 | 0 | 0 | 0 |
| **Manuf of Textiles, Wearing Apparel & Footwear & leather** | 0 | 0 | 30 | 0 | 0 | 0 | 0 |
| **Manuf. of Wood and Wood Products** | 0 | 0 | 118 | 0 | 0 | 0 | 1 |
| **Manuf. of Paper & Paper Products & Printing** | 0 | 0 | 90 | 0 | 0 | 0 | 1 |
| **Manuf. of Chemical, Pharmaceutical & Chemical Pro-ducts** | 0 | 0 | 32 | 0 | 0 | 0 | 141 |
| **Manuf. of Basic Metals** | 0 | 0 | 13 | 173 | 0 | 0 | 0 |
| **Manuf. of Rubber & Plastics Products** | 0 | 0 | 13 | 0 | 0 | 0 | 1 |
| **Manuf. of Other Non-Metallic Mineral Products** | 0 | 0 | 107 | 226 | 0 | 0 | 1 |
| **Manuf. of Furniture & Related Products** | 0 | 0 | 13 | 0 | 0 | 0 | 1 |
| **Manuf. of Fabricated Metal Products, Office** | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| **Manuf. of Electrical Equipment, Machinery & Equip-ment** | 0 | 0 | 14 | 0 | 0 | 0 | 0 |
| **Manuf. of Office & Computing Machinery** | 0 | 0 | 328 | 0 | 1 | 0 | 3 |
| **Manuf. of Motor Vehicles & Other Transport Equip-ment & Communication** | 0 | 0 | 284 | 0 | 1 | 0 | 1 |
| **Other Manufacturing n.c.e** | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| **Construction of Buildings & Civil Engineering Works** | 0 | 0 | 57 | 0 | 0 | 0 | 0 |
| **Wholesale & Repair of Motor Vehicles** | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| **Retail Trade** | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| **Hotels and Restaurants** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Transport Services and Storage** | 75 | 0 | 2,217 | 0 | 2 | 0 | 54 |
| **Information, Post and Telecommunications** | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| **Financial Intermediation Services** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Insurance and Pension Services** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Real Estate Renting & Business Services** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Public Administration** | 0 | 0 | 1 | 0 | 0 | 2,352 | 0 |
| **Education** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Health and Social Care Services** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Other Services** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Domestic Services** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | $CO_2$ emissions from biomass Gg | $CO_2$ emissions from AFOLU Gg | Energy $CO_2$ emissions by industry Gg | Industrial waste $CO_2$ emissions by industry Gg | Energy industrial $CH_4$ emissions by industry Gg | Agricultural waste $CH_4$ emissions Gg | Total $N_2O$ emissions by industry Gg $CO_2$eq |
|---|---|---|---|---|---|---|---|
| **Firewood** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Solar electricity** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Wind electricity** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Hydro electricity** | 0 | 0 | 86 | 0 | 1 | 0 | 9 |
| **Biomass electricity** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Conservation agriculture** | 75 | 0 | 6 | 0 | 0 | 198 | 197 |
| **Solar PV manufacturing** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Solar water heaters manufacturing** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Households** | 30,654 | 0 | 260 | 0 | 193 | 0 | 1 |

**UNDP NDC Support Programme**

United Nations Development Programme (UNDP)
304 E 45th Street, New York, NY 10017
www.ndcs.undp.org
@UNDPClimate

IN CONTRIBUTION TO THE
NDC PARTNERSHIP

Supported by:
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
based on a decision of the German Bundestag

Federal Ministry for Economic Cooperation and Development

aecid
Spanish Agency for International Developement Cooperation

UNDP