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The job impacts of climate and blue economy policies in Madagascar

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The views expressed in this publication are those of the authors and do not necessarily represent those of the ILO and its constituents, the UN Member States, the Government of Madagascar, or the experts involved.

Cover photo

ILO

Presentation of the institutions that contributed to this study

The International Labor Organization (ILO) is a specialized agency of the United Nations based in Geneva, Switzerland. Created in 1919, the ILO brings together governments, employers, and workers from 187 member states to promote social justice and human rights at work. The organization is a pioneer in integrating the social dimension of sustainability through the concept of Just Transition, which aims to reconcile climate action, decent job creation, and economic inclusion.

SINTEF, or tiftelsen for industriell og teknisk forskning, which means “Foundation for Scientific and Industrial Research,” is an independent, non-profit research institute based in Trondheim, Norway. SINTEF is one of the largest applied research institutes in Europe, recognized for its interdisciplinary work linking science, engineering, and technological innovation. It develops concrete solutions to meet the major challenges of sustainability and competitiveness. The institute works to promote a just transition through research into clean technologies, energy efficiency, sustainable resource management, and the creation of green jobs in industrial sectors.

CRED 2 – Centre for Studies and Research in Energy Economics and Sustainable Development (Madagascar) is a research and expertise center dedicated to the economic and strategic analysis of energy and environmental policies. It develops interdisciplinary work on energy transition, resource efficiency, and green growth. Through research, training, and consulting, the center supports public and private decision-makers in the implementation of sustainable and inclusive development strategies, contributing to a just energy transition in Madagascar.

List of abbreviations

Abbreviations	Signification
AEC	African Economic Commission (United Nations)
ASH	Autorité Sanitaire Halieutique
CES	Constant Elasticity of Substitution
CGE	Computable General Equilibrium
CH_4	Methane
CO_2	Carbon dioxide
CRED2	Centre for Studies and Research in Energy Economics and Sustainable Development
DGEP	Direction Générale de l'Économie et du Plan
DSGE	Dynamic Stochastic General Equilibrium
E3Analytics	Entreprise spécialisée dans l'analyse énergétique
EDGAR	Emissions Database for Global Atmospheric Research
EEZ	Exclusive Economic Zone (Zone économique exclusive)
EPM	Enquête Permanente auprès des Ménages
FAO	Food and Agriculture Organization
FTE	Full-Time Equivalent (Équivalent temps plein)
GAIN	Green Jobs Assessment Institutions Network
GDP	Gross Domestic Product (Produit Intérieur Brut)
GFCF	Gross Fixed Capital Formation (Formation brute de capital fixe)
GHG	Greenhouse Gas (Gaz à effet de serre)
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GJAM	Green Jobs Assessment Model (ancien nom du JTAM)
ILO	International Labour Organization
IMF	International Monetary Fund
INFORUM	Interindustry Forecasting Project at the University of Maryland
INSTAT	Institut National de la Statistique de Madagascar
IPCC	Intergovernmental Panel on Climate Change
ISIC	International Standard Industrial Classification
JTAM	Just Transition Assessment Model
LCU	Local Currency Unit (Unité de devise locale)
LULUCF	Land Use, Land-Use Change and Forestry
MA2P	Modèle d'Analyse et de Projection de la Politique économique
MCMM	Modèle de Cadrage Macroéconomique de Madagascar
MEIO	Macro-Econometric Input-Output
MGA	Ariary malgache (devise de Madagascar)
MIDAS	Mixed-Data Sampling
MISA	Modèle d'Impact Sectoriel et d'Analyse
MPEB	Ministère de la Pêche et de l'Économie Bleue
N_2O	Protoxyde d'azote
NA	Not Applicable
NPISH	Non-Profit Institutions Serving Households
OECD	Organisation for Economic Co-operation and Development
PPP	Purchasing Power Parity (Parité de pouvoir d'achat)
RGPH	Recensement Général de la Population et de l'Habitat
SINTEF	Stiftung für industrielle und technische Forschung (Foundation for Scientific and Industrial Research)
SNDAM	Stratégie Nationale de Développement de l'Aquaculture et des Pêches à Madagascar
SNEB	Stratégie Nationale de l'Économie Bleue
SUT	Supply and Use Tables (Tableaux des ressources et des emplois)
UN	United Nations
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNSTATS	United Nations Statistics Division
USD	US Dollar
WWF	World Wide Fund for Nature

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1. Executive Summary

To break Madagascar's endless cycle of poverty this report sets out to assess a new approach to social and economic development. Since independence in 1960, joblessness, low growth, devasting deforestation and increasing climate impacts reversed development and resulted in Madagascar being among the poorest countries in the world. Over 90% of its population are living on less than USD 2 a day and, despite moderate growth episode in the past decades, real GDP per capita steadily declined from 840 US dollars at independence to less than 450 US dollars in 2020.

It is in this context that this analysis looks at a new growth strategy. This new strategy is based on the development and value addition of Madagascar's' natural resources, which constitute its competitive advantage.

The report finds that such strategies, notably those focusing on the fisheries, aquaculture and renewable energy sector – combined with climate adaptation, ecosystem restauration (forest, coral reef, mangroves) and social policies - have the potential to break the poverty cycle, end low-growth, reduce the impact of climate change, create jobs and put Madagascar on a new development path.

The current economy is already and almost exclusively built on Madagascar's rich natural resources, notably agriculture, fishing, forestry, timber and minerals. They provide the basis, not only for the economy, its production and export, but also for the society, its wellbeing and employment at large. In fact, the natural resources sector, dominated by agriculture, fishing and forestry account for over 80% of total employment, compared with some 10% in industry and services. The fishing and aquaculture sector alone contribute to livelihoods for 1.5 million people living along the coast. However, even though nature and its resources provide the asset base for the economy and the population, they are heavily overexploited. Over 90 per cent of primary energy, notably for daily cooking and food intake, is derived from wood fuel. This is leading to massive deforestation, soil erosion and desertification, and thereby, in turn, causing agricultural productivity to further decline and forcing people into an endless cycle of poverty. In fishing, due to overexploitation, ineffective management and insufficient value addition, communities are marginalized and highly vulnerable forcing people to survive on day-to-day fishing and subsistence farming. A vicious cycle of overexploitation, natural destruction, ever-declining productivity and negative impact on GDP and jobs is unfolding.

Event more importantly, overexploitation is destroying Madagascar's wealth and future growth opportunities. Value addition in Fishing and Aquaculture, Tourism, Pharmacy, Biogenetics, Carbon Markets and other natural resources and biodiversity related industries are increasingly at risk of collapse. The endemic nature of the country's living species makes it still a nature sanctuary containing an exceptional wealth and biological diversity of 12,000 plant species and 1,000 vertebrate species with an endemicity rate of over 80%. Building on those natural assets - rather than depleting and destroying them but adding value to them - has the potential to pull Madagascar out of current vicious cycle of the declining natural asset base and increased poverty and climate impacts. If used strategically, natural resources and biodiversity could become a major growth engine for a new development path of a Blue and Green Economy.

However, further social challenges loom large and must be addressed simultaneously. The rapidly growing workforce of today's 19 million to some 23 million people over the next 5 years are putting enormous pressure on the over exploitation of the natural resources. If overexploitation is continued and not addressed, future growth opportunities, notably for youth, are cancelled. While poverty, unemployment and underemployment is widespread already today, Malagasy women are most deprived and less likely than men to participate in the labour market in the future. With 70% of young people not going beyond primary school and around 14% of young people not even attending school most work in precarious and informal. Most are surviving on day jobs or subsistence activities.

In a 'What if' scenario, this study assesses the economic and employment growth opportunities of a new growth strategy build on Blue and Green economic policies, such as the National Fisheries and Aquaculture Strategy (SNDAM) and the National Blue Economy Strategy (SNEB). Such policies aim at reigning in further destruction of the environment by investing into value addition in fishing and aquaculture, renewable energy, sustainable forestry, climate adaptation and the stewardship of the natural asset base.

Pursuing these policies could add some 350,000 new and productive jobs by 2030, contribute to economic growth while ending further natural destruction and addressing climate change impacts. Such a strategy implies significant sectoral changes, transitioning jobs from overexploitation of forests for charcoal and wood fuel towards improved charcoal production, alternative renewable energy, value addition in aquaculture and fishing and forest and mangrove restauration. For example, a scenario to restore mangroves along the coastline results in 16 per cent higher value added and an 18 percent increase in employment in the first years of implementation compared to baseline. This effect of higher level of economic activity is maintained in the long run because of the direct investment effects which trigger positive long term and indirect effects in the value chain of the additional economic returns to aquaculture, fishing, as well as increased skills development and education. In addition, the new jobs increase aggregate household income which in turn is spend on the rest of the economy and induce further economic growth. To ensure the transition is creating new jobs and is just for all, investments into vocational and technical training, re-skilling and up-skilling of women and men, youth as well as social protection for those to transition away from charcoal production to sustainable sectors is required.

2. Background

Madagascar's population is young, with 72.6% under the age of 30 out of a total population of 25,674,196, according to the 2018 general population and housing census, and according to the Madagascar Demographic and Health Survey – EDSMD (INSTAT 2021), 43% of the population is under the age of 15, while only 4% will be over the age of 65 in 2021. This young population is a considerable asset, as it is a source of increased productivity in the country, with an urbanization rate of 19.3% (INSTAT 2020).

In Madagascar, recurrent political crises often hamper development efforts, despite the series of reforms initiated in the country since the late 1980s under the impetus of structural adjustment programs aimed at liberalizing the economy, in particular the privatization of public enterprises. Gross Domestic Product (GDP) growth had already reached 5.3% in 1970, but fell to -1.3% after the political events of 1972. The same scenario was repeated later, as the growth rate rose from 3.1% in 1990 to -6.3% in 1991, following the socio-political riots of that year. In 2002, this rate dropped to -12.7%, while in 2001 it had reached 5.9%, and in 2008 it dropped to -4%, despite having already reached 6.7% due to the political riots (World Bank 2022).

On the other hand, real GDP per capita, which also measures the overall productivity of each worker in the country, has steadily declined from 840 US dollars in 1970 to less than 450 US dollars in 2020. Furthermore, the level of GDP per capita enables us to estimate the level of purchasing power in a country, and therefore the population's ability to satisfy basic needs, particularly food. In 2020, the COVID-19 health crisis led to a -7.1% collapse in the country's gross domestic product.

Although the agricultural sector has always accounted for the majority of jobs in Madagascar, at 64.1%[1] in 2019, value added in the primary sector represents only 24.7% of GDP, highlighting the sector's relatively small share. In fact, over 40 million hectares of arable land are poorly utilized, with arable land accounting for less than 6% and irrigation[2] for only 2% of cultivated land. Furthermore, technological advances are being utilized less and less frequently. In fact, the number of METs (machines, equipment, tractors) used per 100 km2 of arable land fell considerably between 1970 and 2000, from 12 to 3 units during the period, mainly due to a lack of interest and motivation for young people to work in the agricultural sector. The situation has not changed much to date.

Moreover, the level of industrialization in the country remains minimal. In fact, according to economists and many development experts, industrialization is an unavoidable phase in the development process, as it is in currently industrialized market economies and emerging countries. However, analysis of the structure of added value created in Madagascar shows the predominance of the service sector, with over 50% of GDP between 1970 and 2009, and the weak dynamism of industry, whose contribution to GDP has not exceeded 25% (World Bank 2022).

Moreover, for Madagascar, the Blue Economy represents an opportunity that needs to be structured in order to bring its economic, environmental and social benefits to fruition. A number of achievements and projects to develop the country's aquatic potential have made it, in some cases, a world-class example (such as organic algaculture and shrimp farming). What's more, the endemic nature of the country's living species makes it a nature sanctuary containing an exceptional biological diversity of 12,000 plant species and 1,000 vertebrate species (mammals, reptiles, amphibians, birds), with an endemicity rate of over 80%[3].

Consequently, ensuring a just transition to the blue economy and creating green jobs is essential for sustainable development and to meet the challenges of environmental protection, combating climate change, economic development and social inclusion in African island countries. A just transition and the creation of green jobs must therefore be guided by sound knowledge as a basis for informed policies and social consensus.

To this end, the implementation of a Just Transition Assessment Models (GJAMs) at national level, which enable countries to quantify the social, economic and job creation impacts, and to analyze and plan the social and employment outcomes of climate, green and blue economy policies, is proving inescapable to better inform the financing plan development process, direct investments towards interventions that have a multiplier effect in terms of job creation, and develop just transition measures to accompany the blue and green economy.

1. Source: (World Bank 2022) based on ILO modeling.
2. Irrigation remains very insignificant, despite Madagascar's extensive natural hydrographic network, including a large number of rivers and lakes (Alaotra, Itasy, etc.).
3. Data taken from the United Nations CEA Report 'Economie bleue à Madagascar, état des lieux et orientations stratégiques' (United Nations CEA Report 2018).

3. Current state of the Economy, Employment and Emissions

3.1 Economic performance

Madagascar's development continues to be hampered by low growth potential and exposure to frequent, deep-seated, and persistent crises. Growth averaged just 3.5% from 2013 to 2019, barely outpacing population growth (+2.8% on average per year). With a GDP per capita of USD 478 for 2019 and 90% of its population living on less than USD 2 a day, Madagascar ranks among the world's poorest countries (World Bank 2024b).

The COVID-19 pandemic triggered one of the deepest recessions in Madagascar's history. The economic growth rate of 4.4% in 2019 has dropped to -5% in 2020, three times deeper than in the rest of Africa. The poverty rate has reached an all-time high of 80.7% in 2022 (World Bank 2024b). Since 2015, the service sector has been the biggest contributor to economic growth, followed by the secondary sector. The fishing and aquaculture sector accounts for 6.6% of national GDP and 6.6% of exports.

The fishing sector plays a key role in the economy with an annual production of 750 million dollars (INSTAT 2019b). The aquaculture sector's contribution to GDP was 0.52% in 2001 and 0.69% in 2002. Its contribution to public revenue was 0.24% in 2001 and 0.59% in 2002 (FAO 2024). In 2017, aquaculture and fishing exports amounted to 517 billion Ariary, rising to 648 billion Ariary by 2023. Aquaculture production, both continental and marine, has increased significantly since 2005, but its development potential is still considerable (i.e., an annual increase of 3%).

Madagascar's aquaculture potential can be considered significant, given the country's natural potential in both continental and coastal environments. As an indication, with current production of around 30,000 t/year, Madagascar represents around 1% of Africa's production (2.196 million t) and 0.03% of the world's production (82.1 million t) of aquaculture (FAO 2024; World Bank 2024b). Assuming current per capita consumption levels are maintained, production should increase by around 10,000 tonnes by 2020, taking into account population growth (World Bank 2016).

3.2 Employment by industry

Madagascar's labour market shows that young people are in difficulty: of the 4 million unemployed recorded in 2017 in Madagascar, the majority, i.e. 70%, are young people[4], and 62% of the unemployed are first-time applicants, 80% of whom are young people (ONEF 2017). This is explained in particular by the low level of schooling among the workforce, as almost 70% of young people do not go beyond primary school and around 14% of young people do not even attend school, reflecting the predominance of the training-employment mismatch phenomenon. In 2015, despite an increasing number of graduates, 62.5% of young workers did not have the qualifications required for the positions they held. In fact, young people under 26 account for 28% of the workforce in Informal Production Units. In 2015, almost all employed young people worked in the informal sector, accounting for 97.2%, and 83.8% of young people were in vulnerable employment, i.e. self-employed or involved in unpaid family activities. More than 50% of young wage-earners have casual or daily jobs, indicating a lack of social protection and revealing the precariousness of jobs, particularly in rural Madagascar (ONEF, Research Bulletin, April 2017).

In 2010, the total workforce in Madagascar was 10,675,098, compared with 14,122,746 in 2019, representing an average annual growth rate of around 3%. In 2019, employment in agriculture accounted for 74% of total employment, compared with 10% and 16% respectively for industry and services. Malagasy women are less likely than men to participate in the labor market (71.3% vs. 82.4% respectively) and have limited access to better quality jobs, with fewer women in paid employment (24% of working women vs. 35% of working men), and more family workers (14% vs. 5% of male workers) and subsistence farmers (32% vs. 23% respectively) (World Bank 2023).

Fishing and aquaculture also provide a livelihood for nearly 1.5 million people living along the coast, a vulnerable and marginalized community, the majority of whom have no other source of income, not even a plot of land to cultivate.

3.3 GHG emissions by industry

Africa is responsible for just 3.8% of the world's total greenhouse gas emissions. However, global warming, which has accelerated in recent years, now affects the entire globe. The island of Madagascar has not been spared, and the harmful consequences are numerous. Yet the country, which is not highly industrialized, produces only 0.08% of the world's greenhouse gas emissions. These are mainly emitted by the transport, industry, and energy sectors. In terms of mass, carbon dioxide (CO_2) is the main greenhouse gas emitted by Madagascar.

The energy sector is the main source of greenhouse gases in Madagascar. The "energy and transport" sector accounts for 97% of national emissions (3.47 mega tonnes of CO_2 equivalent). The main contributor is the use of fossil fuels for transport vehicles and thermal power stations. In fact, Madagascar's energy consumption is dominated by biomass and, in particular, wood energy, which accounts for 92% of primary energy consumption. Petroleum products rank second in terms of consumption (7%). The use of new and renewable energies remains minimal (Ministry of Energy 2012)

Waste and industrial processes account for 2%. The industrial sector is dominated by the manufacturing industry, whose companies are concentrated around three branches of activity: the food industry, the wood industry and the textile industry. In Madagascar, this sub-sector's greenhouse

4. Individuals aged between 15 and 29 (according to the processing carried out by the information producers consulted).

gas-emitting activities include cement production, lime production, industrial uses of dolomite other than for cement production, asphalt for road surfacing, the pulp and paper industry, alcoholic beverage production and food production.

Forestry and land-use changes account for the remaining 1%. (i.e. 12,202,000). Changes in forest heritage and other woody biomass stocks, conversion of forests to grassland, abandonment of exploited land and CO_2 emissions and/or sequestration by the soil are the main aspects of changes in land use.

Methane is the main greenhouse gas emitted by agriculture (6,983,000). Sources include livestock, rice cultivation, prescribed burning of savannahs and cultivated soils.

4. Policy scenario modelling

4.1 Just transition assessment modelling

JTAMMadagascar is a macro-econometric input-output (MEIO) model, based on data from Institut National de la Statistique INSTAT in Madagascar. The main data sources are the System of National Accounts, supply-and-use tables (INSTAT 2019a), and the general population and housing census (INSTAT 2020). JTAMMadagascar is following the same philosophy and modelling approach as taken for MEIONorway (Aponte et al. 2021; Wiebe et al. 2022) and the models in several other Green Jobs Assessment Reports[5], e.g. Nigeria, Zimbabwe, Turkey, Burkina Faso, or Ghana[6].

The model is structured as follows:

- Section A.1 gives a short background on the modelling philosophy,
- Section A.2 gives an overview on existing economic models in Madagascar,
- Section A.3 a description of how to use this type of models for policy analysis and
- Section A.4 a detailed description of the data used.

The Just Transition Assessment Models (JTAMs) quantify the impacts of policies on:

The economy. Gross value added corresponds to the GDP by industry, giving insights on the effects of climate policies to national GDP growth, and on the growth or decrease of each industry's economic activity

Greenhouse gas emissions. Besides direct changes due to, for example, decrease of coal electricity, it also considers the net changes in emissions including increased emissions from infrastructure investments, and from increased or decreased economic activities in other industries.

Employment. The model gives insights of the potential increase or decrease of the demand for workers in different industries. By including information on the structure of workers in each industry – per gender, skill level, and formality status – it can measure how the demand for skills will change in the economy, and how it can affect workers in disadvantaged groups.

The results of the green scenarios are always assessed relative to a reference (baseline) scenario: This serves as a baseline to which the development in the green scenario can be compared. Here, we assume for the baseline that the economy grows (as specified in more detail in Section A.5), but that the general structure of the economy does not change: industries are continuing to produce with the same production technology and the import shares of products remains stable.

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

In other words, the JTAM-Madagascar simulator serves as a laboratory for testing 'what if' scenarios rather than predicting the future. It compares a baseline scenario, based on current trends, with a 'green' scenario incorporating new climate policies. By measuring the gap between the two, the model assesses the impact on three pillars: the economy (growth by sector), the environment (overall infrastructure-related emissions) and society (employment and skills needs by profile). This tool thus reveals the knock-on effects of the transition to ensure that it benefits the entire population, guaranteeing that no one is left behind in the ecological transition.

5. The Green Job Assessment Model (GJAM), now renamed the Just Transition Assessment Model (JTAM), reflects a major conceptual shift. This change in name marks the shift from an approach focused solely on assessing green jobs to a more holistic perspective, integrating them into a just transition dynamic. This encompasses the social, economic and environmental dimensions of climate change policies in a cross-cutting manner.

6. The reports are available for download at http://www.ilo.org/gain.

How do Just Transition Assessment Models work?

Just transition assessment Models are built to answer one main question: **How do climate and other green policies affect workers?**

Here is how it works:

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

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

Next, these scenarios are implemented in the model:

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

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

The results of the JTAM model, then, comprise all (direct and indirect) impacts of the modelled policies on the economic output of every industry in the national economy, and how these affect workers and greenhouse gas emissions in each industry.

4.2 Increasing Aquaculture production

In line with the strategy for the blue economy in Madagascar (Ministry of Fisheries and the Blue Economy 2023), the country has an ambition of increasing the aquaculture industry. The objective is to accelerate the growth of this industry to compensate for the decline in inland fishing and provide additional income to communities. This plan aims to focus on the following three main points:

- Creating conditions for private aquaculture initiatives.
- Establishing support services for aquaculture development.
- Improving stewardship in the aquaculture sector.

Specifically, the scenario focuses on the necessary investments that make the aquaculture industry more than double in size in the period 2024-2030. Table 1 shows the expected annual investments required to scale up the aquaculture industry in Madagascar and their match to the products on the Madagascar SUT:

Additionally, we assumed that the equipment purchase is 100% imported as this is not produced in Madagascar. These investments from 2024 to 2030 allow the aquaculture sector to increase, leading to a growth in exports that account for an increase of over 150% of the sector between 2024 and 2030. After 2030, exports remain at high level (but lower increase year to year) due to the increased capacity and more consolidated aquaculture sector in the country.

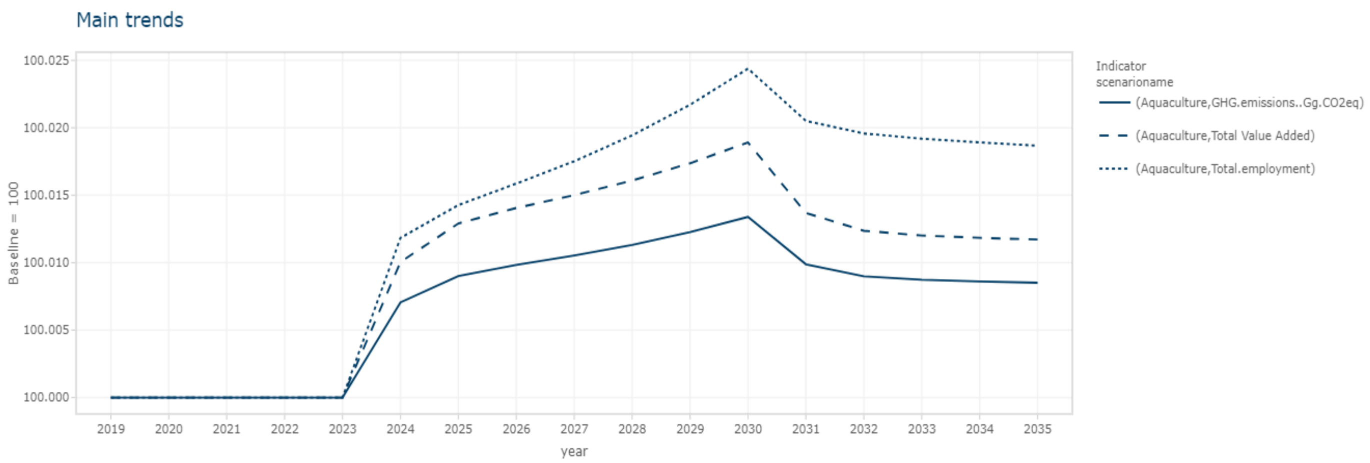
Figure 1 summarizes the changes on annual value added, employment, and GHG emissions between the baseline scenario and the Aquaculture scenario. The outcomes of any scenario should always be compared to the baseline scenario, since the JTAM does not attempt to forecast what happens in the economy, only measures a “what if” situation comparing what are the effects of investments and expansions of the aquaculture sector compared to the business-as-usual scenario. The outcomes illustrated in Figure 1 are due to a combination of impacts of investments in aquaculture, structural changes in the aquaculture industry and in the demand for goods and services from other industries required for aquaculture production.

Table 1 - Annual Investment structure for Aquaculture

Aquaculture	Initial investment cost structure CAPEX (MGA)	Product
Land Acquisition	518,509,653	Real estate services
Infrastructure Development	725,913,514	Construction
Design and Engineering Services	414,807,722	Other business services
Equipment Purchase	114,0721,236	Machine, electrical equipment
Seed Stock	259,254,826	Other fishing
Licensing and Permits	194,441,120	Other business services
Training and Consultation	972,205,598	Education

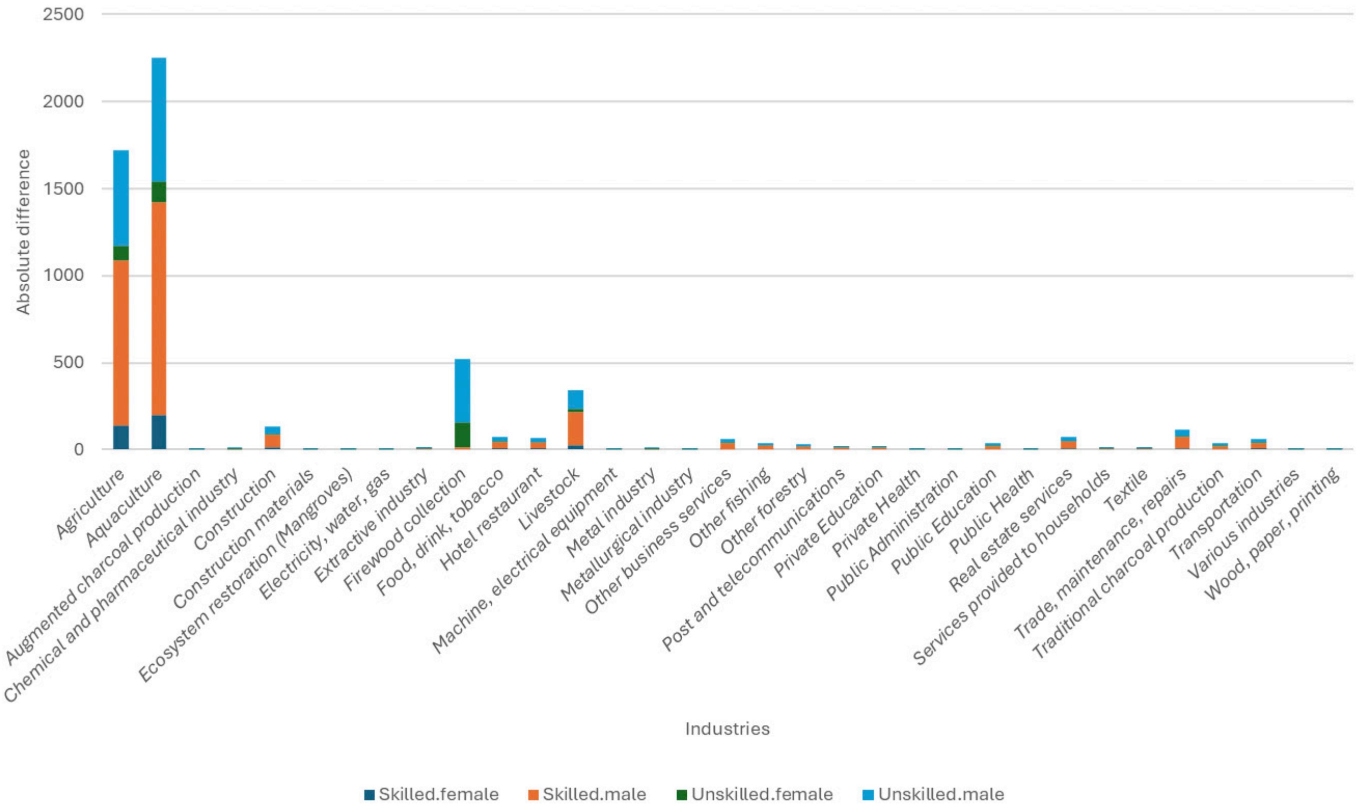
Source: SNDAM National Strategy for the Development of Aquaculture in Madagascar 2021 – Appendix 1 and authors’ calculations

Figure 1 - Main trends comparison between Aquaculture scenario and baseline for Madagascar



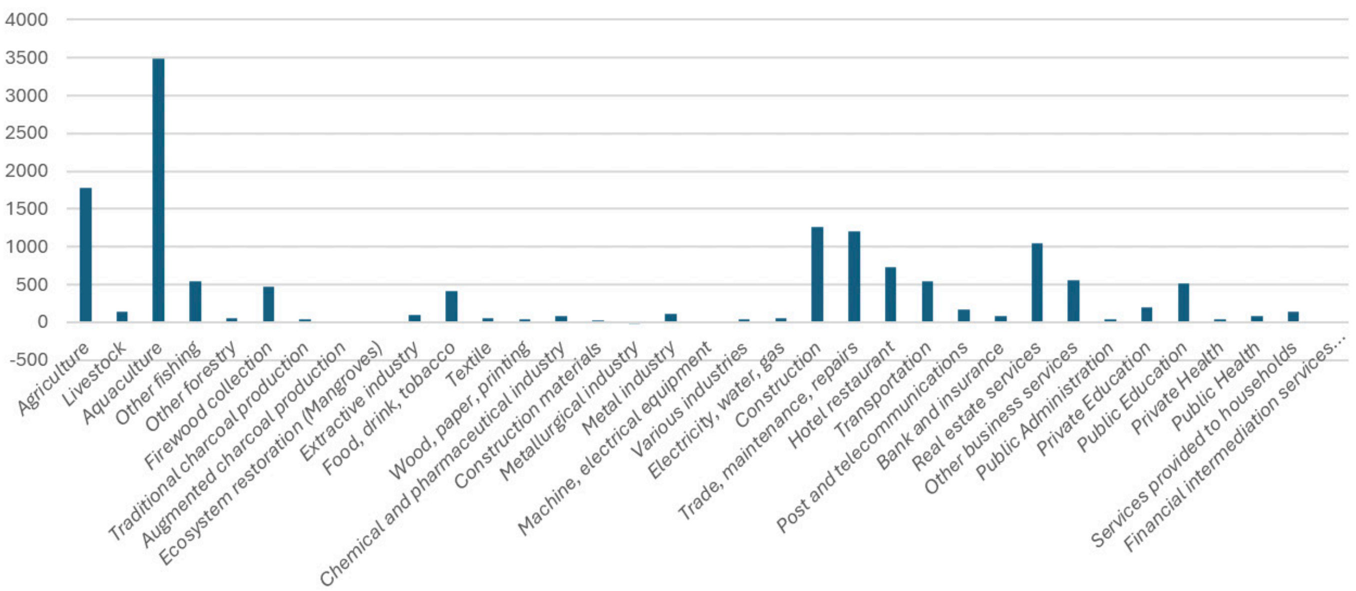
Compared to the baseline, the aquaculture scenario brings around 5500 additional jobs to the economy by 2030 of which 2000 jobs correspond to unskilled males, 2800 to skilled males, 395 unskilled females, and 436 skilled females. Figure 2 shows the employment distribution by industry and category.

▶ **Figure 2 - Job creation by industry and category for Madagascar in 2030 in the Aquaculture scenario**



Regarding Value-added, the aquaculture scenario shows a 0,20% higher total value added of the Malagasy economy when compared to baseline, this implies a value of 17393.97 million MGA in the economic structure of the country distributed as shown in Figure 3. The highest increase is observed in the aquaculture industry, followed by agriculture, construction and trade and maintenance and repair activities.

▶ **Figure 3 - Value added by industry for Madagascar in 2030 in the Aquaculture scenario**



4.3 Mangroves restoration

Madagascar has 2% of the world's mangroves (Martin and Burgess 2024) and 20% of these need restoration and conservation activities. These ecosystems are important for the country as they represent a source of biodiversity, provide natural protection against floods, regulation of water flows, maintenance of soil fertility, and climate regulation as mangroves can sequester high amounts of carbon (The Blue Carbon Initiative 2024). Sectors like fishing, aquaculture, and agriculture will benefit from mangroves because of their natural services. This scenario focuses on the necessary investments needed to restore and conserve mangroves in Madagascar from 2024 to 2030, we assume that 15,000 hectares of mangroves are restored annually (Rabemananjara, Rakotosoa, and Ratovoson 2021). Table 2 provides the expenses required for these activities.

Table 2 - Yearly expenses for Mangrove restoration activities

Mangroves Restoration & Conservation	Expenses (MGA)	Import share
Land Acquisition	40,229,875	
Equipment and materials	7,181,236,974	80%
Seed Stock	39,948,297	
Licensing and Permits	60,573,389	
Consulting and training	1,658,458,731	50%

Values from Table 2 represents around 0.02% of Madagascar GDP in 2019. We assume these expenses every year from 2024 until 2030. Additionally, based on (Su, Friess, and Gasparatos 2021) the additional benefits from mangroves to sectors like aquaculture, fishing and education research are modelled based on the number of hectares recovered by year as follows:

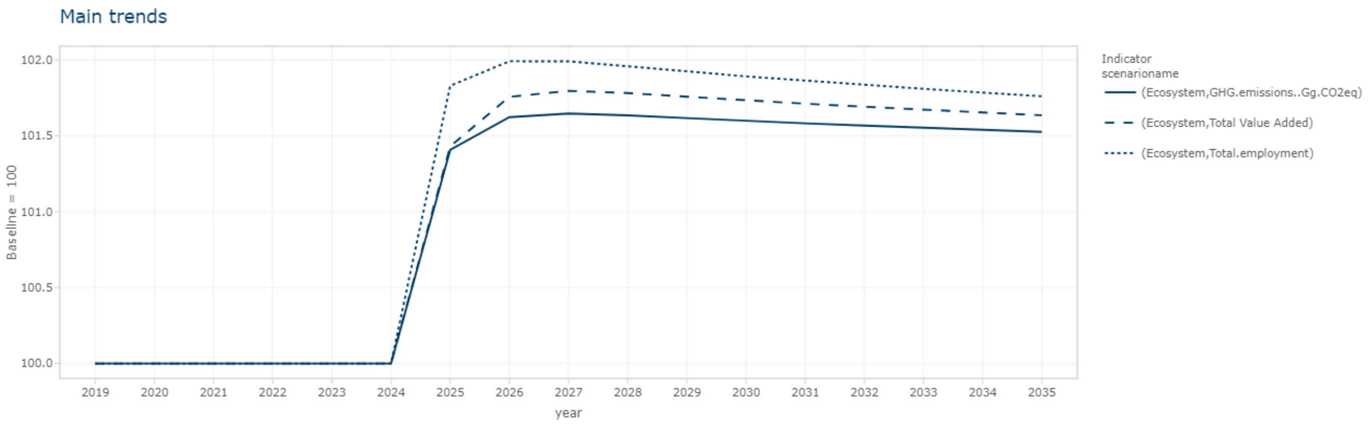
Exchanges rates are taken (World Bank 2024a) and the additional yearly benefits to sectors are showed in Table 3. These additional benefits persist in time even after the restoration activities are concluded because of the higher mangrove conserved area.

Table 3 - Economic benefits to other sectors from Mangroves restoration

Sector	Economic benefits from mangroves (Million MGA)
Aquaculture	143,605.96
Other fishing	143,605.96
Education	105,622.01

Aggregated results from the scenario compared to the baseline are presented in Figure 4. Mangroves restoration activities result in 16% higher value added and a 18% increase in employment compared to baseline, the higher level of economic activity is maintained overtime because of the direct investment effects, the indirect effects of investments through the economic value chain, the additional economic benefits to aquaculture, fishing, and education, and the induced effects of higher consumption of households.

Figure 4 - Main trends comparison between ecosystem restoration scenario and baseline for Madagascar



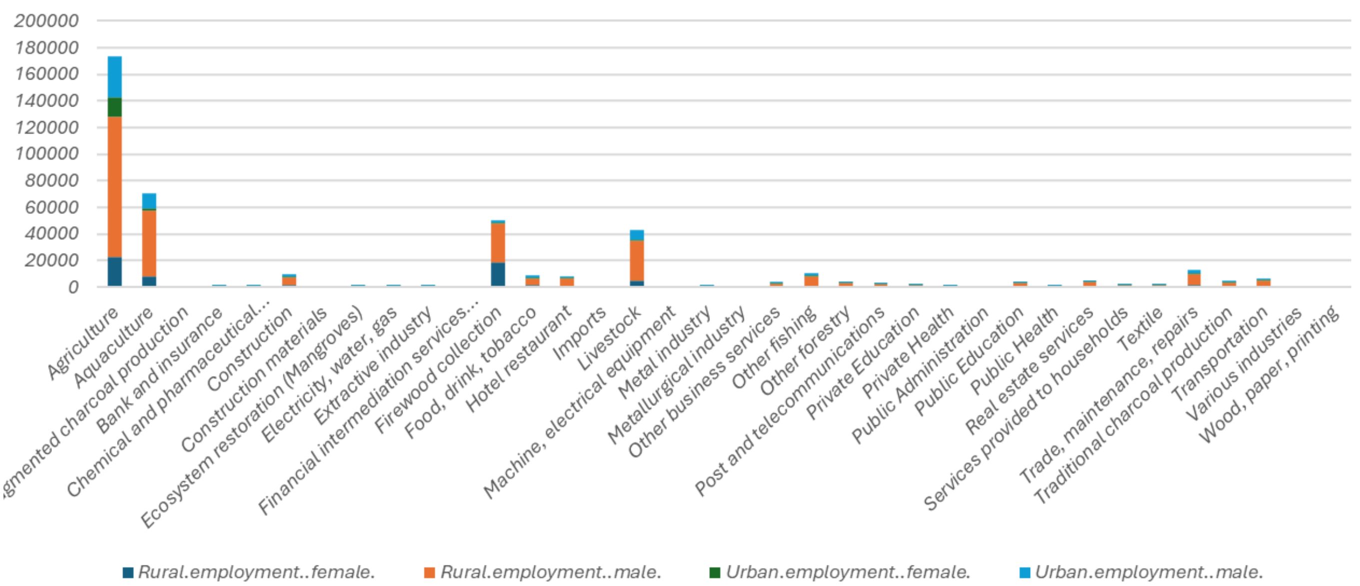
Regarding greenhouse gas emissions, there is a total increase compared to baseline, this is mainly due to the induced effect of the higher of consumption by households. There is a higher demand to emission intensive industries in the economic structure of Madagascar from products like electricity, agriculture, food, and recreation activities. However, these results do not consider the carbon sequestration potential of the Mangroves ecosystem. Estimates of carbon sequestration range from 6 to 8 tons of CO_2 equivalent per hectare (The Blue Carbon Initiative 2024). We estimated the annual carbon sequestration potential of the restored mangrove area, results are shown in Table 4. The potential is estimated linearly and as such it should be taken as the minimum potential as real carbon sequestration dynamics are usually non-linear. The results show that around 1.28% of total GHG emissions for Madagascar can be sequestered by the restored Mangroves area by 2030.

Table 4 - Carbon sequestration potential of restored Mangroves

Year	Cumulative restored Mangroves area (Hectares)	CO_2 saving potential (Tonnes)	Reduction in total GHG emissions
2024	30,000	240,000	0.323%
2025	45,000	360,000	0.548%
2026	60,000	480,000	0.711%
2027	75,000	600,000	0.866%
2028	90,000	720,000	1.014%
2029	105,000	840,000	1.154%
2030	120,000	960,000	1.287%

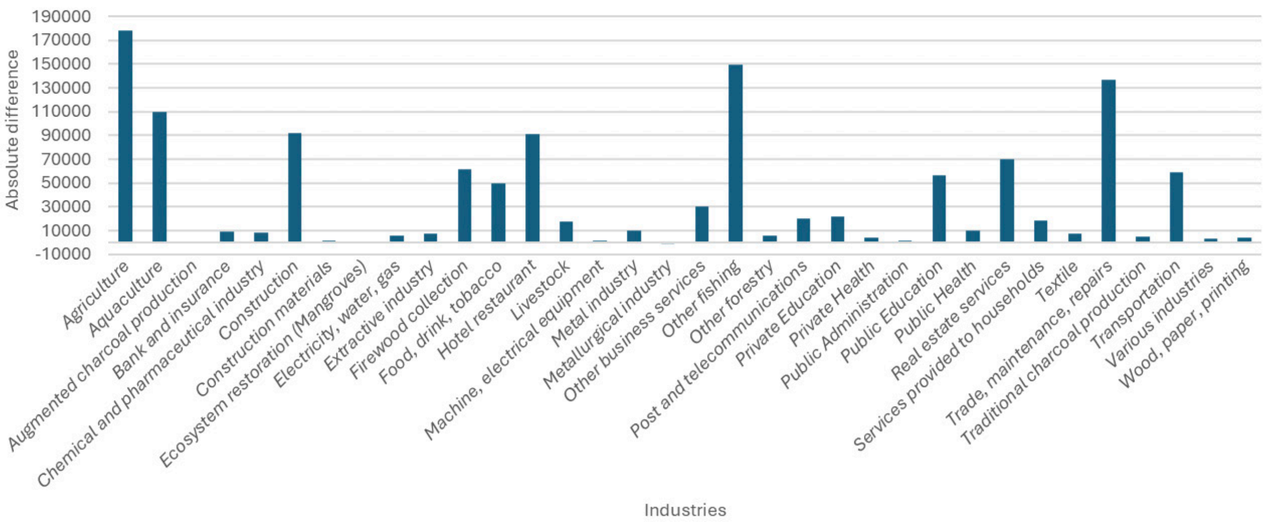
Employment results shows more than 400000 additional jobs by 2030 when compared to baseline, these jobs are created mostly in rural areas where there is an increase of about 270000 for males and about 65000 for females compared to 67000 for males and 26000 for females in urban areas. Most of these jobs are created in agriculture, livestock, and aquaculture as shown in Figure 5.

Figure 5 - Job creation by industry and category for Madagascar in 2030 in the ecosystem scenario



Employment results are better understood if we took a deeper look into the value added created on this scenario. Figure 6 shows that the biggest increase in value-added comes from the agriculture, fishing, and trade, maintenance, repairs sectors. By comparing employment and value-added figures they follow the same pattern but at different scales, this is because of the structure of the economy of Madagascar, where rural primary sectors (Agriculture, fishing, among others) are more labour intensive than urban secondary and tertiary sectors (e.g. Trade, transportation, Hotel).

▶ **Figure 6 - Value added by industry for Madagascar in 2030 in the Aquaculture scenario**



4.4 Improvement of carbonisation techniques and cooking equipment

The charcoal sector is an essential source of income generation for tens of thousands of people, particularly the rural poor. For example, household income in the commune of Soalara Sud (south-west Madagascar) is largely dependent on cattle rearing and charcoal production from the region's dry, thorny forests. Charcoal production in south-west Madagascar is a means of diversifying income sources and meeting financial needs, serving to fill off-season gaps for farmers and representing a fallback option when income-generating activities are no longer viable or sufficiently productive. For a town of 100,000 inhabitants, wood energy users generate income for 20 to 30,000 people, mainly rural dwellers, and for each supply basin, several thousand charcoal makers and woodcutters are involved (Montagne et al, 2010).

Wood energy (firewood and charcoal) is the preferred cooking fuel for 90% of Malagasy households (Montagne et al, 2010). An urban family consumes around 60 to 70kg of charcoal per month, which corresponds to around 2 bags. Nationally, consumption is estimated at 1.75m3/pers/year in urban areas. In the Analamanga region, it would be 100kg/person/year (ministry of energy 2012). Average wood energy consumption is estimated at 2.57 m3/capita, with annual growth of 15% (WAVES Partnership 2016).

Charcoal produced in Madagascar comes from 3 main sources: peasant forest plantations, exploitation of natural formations and industrial plantations. In many parts of Madagascar, the wood raw materials for charcoal production are provided by natural forest formations. Two types of wood harvesting can be distinguished: (i) selective cutting, where charcoal makers collect only those species in the forest that are suitable for carbonization, and (ii) the recovery of wood eliminated during land clearing.

Wood supply from natural forests is mainly observed in Mahajanga, Fort Dauphin, Antsiranana, Toliara and Morondava. Specifically in the case of the recovery of wood eliminated during land clearing, charcoal production is linked to the desire to appropriate agricultural land. This type of pro duction exists in the western regions of Madagascar, from Boeny in the north to Atsimo Andrefana in the south.

Industrial plantations consist of the pine forests included in the Société Fanalamanga concession at Moramanga, in the Alaotra Mangoro region. Industrial plantation forests cover a total area of around 65,000 ha. Carbonization is only a secondary activity, fuelled by the recovery of by-products from silvicultural operations such as pruning or thinning, or by the recovery of logging slash (ministry of energy 2012).

Increasing charcoal consumption by urban and suburban households is the main factor increasing pressure on forest resources. The natural forests that supply major consumption centers are the most threatened in terms of resource depletion, as is the case of centers in the Atsimo Andrefana and Boeny regions. With an average reduction of almost 40,000 ha per year, forest cover fell from 9.4 million ha in the mid-2000s to less than 9 million ha in the mid-2010s. Mangroves contribute around 4.7% of these needs (ministry of Economy and Finance General Secretariat 2022).

Due to environmental degradation and deforestation, the collection point has become distant from the villages. Households currently have to travel an average distance of 3.3 kilometers from their homes to fetch wood from natural forests, riparian forests or nearby vegetation. Some have to travel up to 9 kilometers. Collectors spend an average of 4 hours 30 minutes per trip. However, the median collection time per trip is 3 hours. Collecting has become less frequent. The scarcity of firewood is forcing households to reduce and moderate their use of fuel.

Improvements in carbonisation techniques have made it possible to produce high-quality charcoal that burns more slowly, while reducing wood consumption and emissions. This method requires 30% less fuel (Ministry of Energy and Hydrocarbons) than traditional production methods. It is assumed here that all the wood used comes from sustainably managed renewable sources. Although these techniques are more efficient, labour intensity and job structure (gender and skills) are considered in this model to be identical to those in the traditional sector.

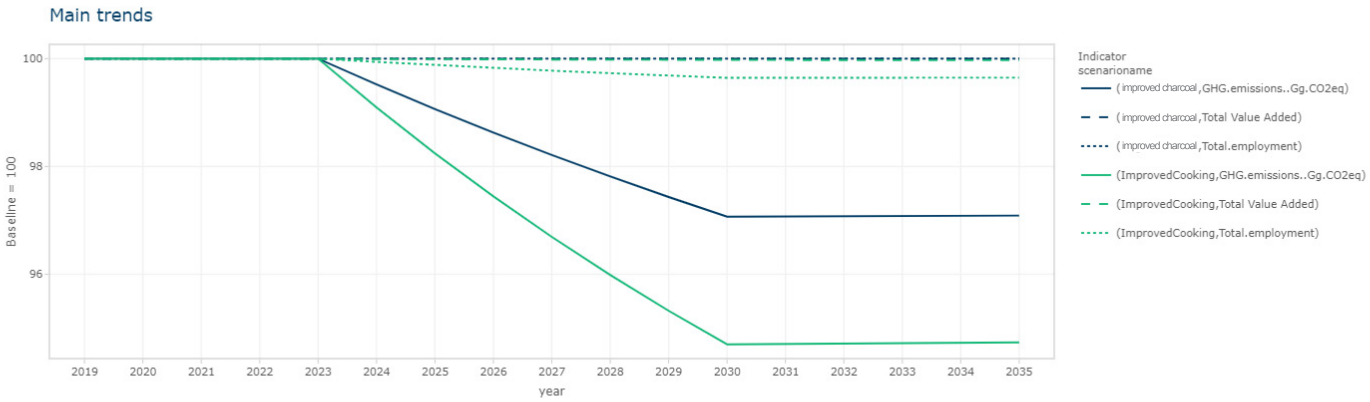
We are analysing two scenarios, an improved charcoal production scenario and a clean cooking scenario, which also uses an improved charcoal production scenario. The target for the augmented charcoal production scenario is defined in the national energy policy as, by 2030, 20% of the charcoal production should be "green", produced efficiently and from legal and sustainable forest resources.

For the second scenario, the clean cooking scenario we estimate that, by 2030, 70% of the urban households would have access to more energy-efficient charcoal cookstoves, called "fatana mitsitsy". These efficient stoves use 50% less charcoal than current stoves (Ferrer 2018) and are produced locally by small-scale producers using materials such as clay, concrete, sheet metal, sand, and/or dung (Sustainable Energy for All, E3Analytics, and Catalyst 2019).

For both scenarios, the clean cooking scenario and the an improved charcoal production scenario, we explicitly do not model any policy change to help people to find new jobs outside the charcoal and firewood sector. This is done on purpose to quantify and show the negative employment and income effect of climate and energy policies banning firewood and charcoal without offering an alternative. We argue that so called 'Just Transition Policies' are required to accompany workers and enterprises in the charcoal and firewood supply chains with financial, social and skills training programs (see policy section).

In terms of emissions, as can be seen in Figure 7, greening of the charcoal value chain and improved cooking equipment have considerable potential for reducing carbon emissions in Madagascar, with savings up to 3% and 5%, respectively. These results are highly driven by the assumptions regarding the diffusion of the new technologies. If the uptake of augmented charcoal production and improved cooking equipment is higher, so will be the GHG savings. The higher decrease in the improved cooking scenario is due to the fact that in addition to using charcoal from the new technology, the new cook stoves also need less charcoal. This in turn has a slightly negative effect on employment possibilities in charcoal production. Lower charcoal demand from efficient cookstoves will impact informal labour in traditional charcoal production, with opportunity for the workers to tend to productive economic activities. The switch from conventional to aan improved charcoal production alone has no effect on employment, as for both technologies, the same number of workers are needed per ton of charcoal produced.

▶ Figure 7 - Main trends comparison between improved charcoal production and improved cooking equipment scenarios and baseline



▶ Figure 8 – Employment impacts by industry for clean cooking scenario compared to baseline, in % difference

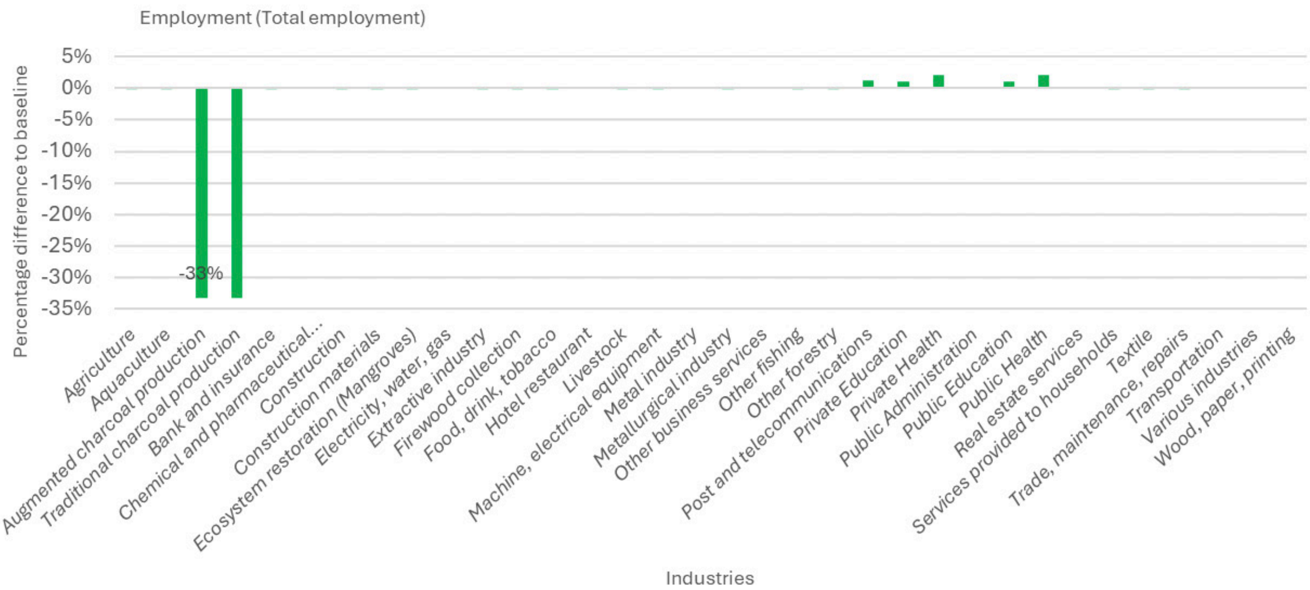


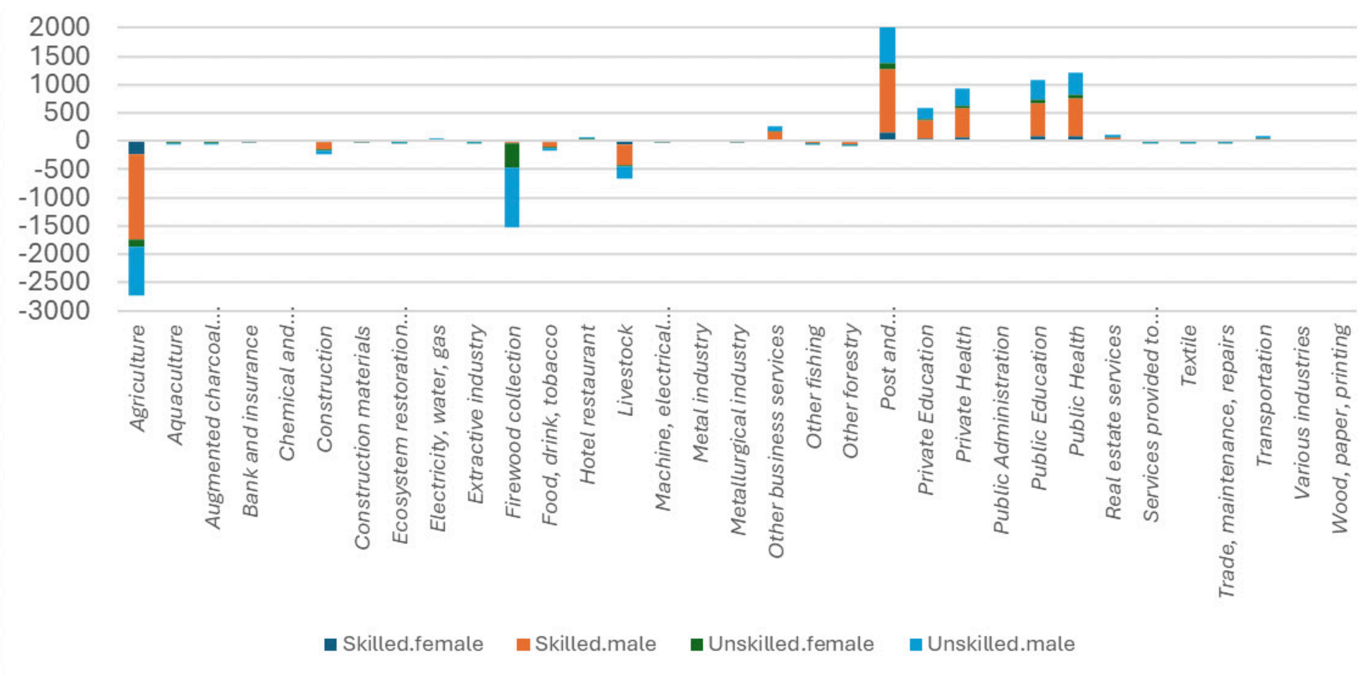
Figure 8 shows the %-differences in employment between improved/clean cooking scenario and the baseline scenario. The largest decrease in employment is, as mentioned above, in the charcoal production industries, equally in both traditional and augmented charcoal production. Industries that require most additional workers relative to their current workforce are education, health, and post and telecommunications. This is not surprising, as people use their additional funds freed up by lower spending on fuel (charcoal) to spend on schools, medicine and communication. There is a loss in employment in agriculture, livestock, firewood collection, food and drinks and construction. This is due to the artificial negative income effect. As in this scenario, fewer people are employed in charcoal production and through the value chain effect also in firewood collection, the total employment effect is negative. This has the largest consequences on food and beverages consumption and upstream agriculture industries. As indicated above, in the scenario there is no Just Transition policy to help people to find new jobs outside the charcoal and firewood sector. Hence, without such policy there is a negative effect. Such policies would accompany workers and enterprises in the charcoal and firewood supply chains with financial, social and skills training programs to find new jobs and entrepreneurship.

At the same time as there is negative income effect from workers and enterprises loosing their jobs and markets, demand for education, health, and telecommunications are boosted due to lower spending on charcoal (which is produced highly efficiently and much cheaper) offsetting negative consequences. The freeing up workers for more productive activities than firewood collection and charcoal production could be modeled with the addition of Just Transition policies, but is not modelled due to the currently lacking national policies. In such an approach, training could lead to assigning these workers to other industries where they can earn an income and with their spending boost economic activity even further.

Looking into more detail, we find that there is an increase in demand for skilled workers (green and yellow in Figure 9) in rural areas (green and yellow in Figure 10) in the service industries (the bars on the right side of the figures).

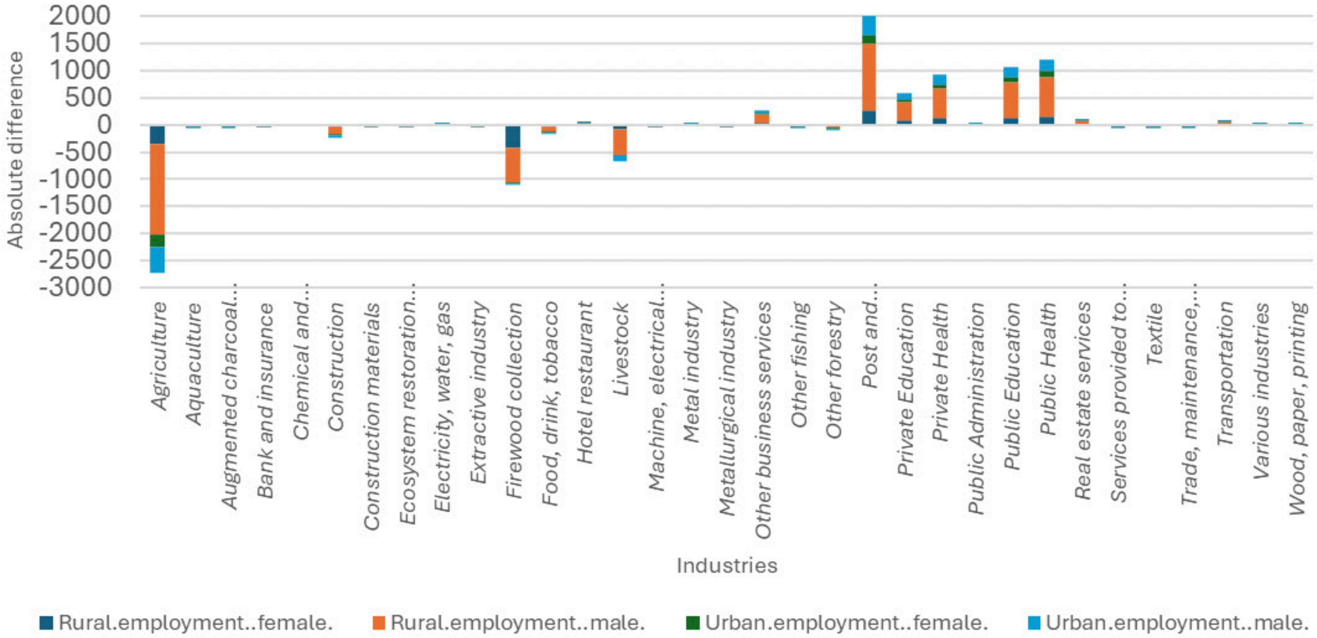
In general, men are more affected by these changes (yellow and blue part of the bars in both Figure 9 and Figure 10), but this is due to the higher share of male employment across all industries. One exception is firewood collection, where the unskilled and rural female labour share are significantly higher than in other industries. Recall, jobs in firewood collection are informal and considered to not be decent jobs[7]. Therefore, the fewer people need to do firewood collection, the better.

▶ Figure 9 - Job creation and losses for selected industries by skill level for clean cooking scenario in 2030



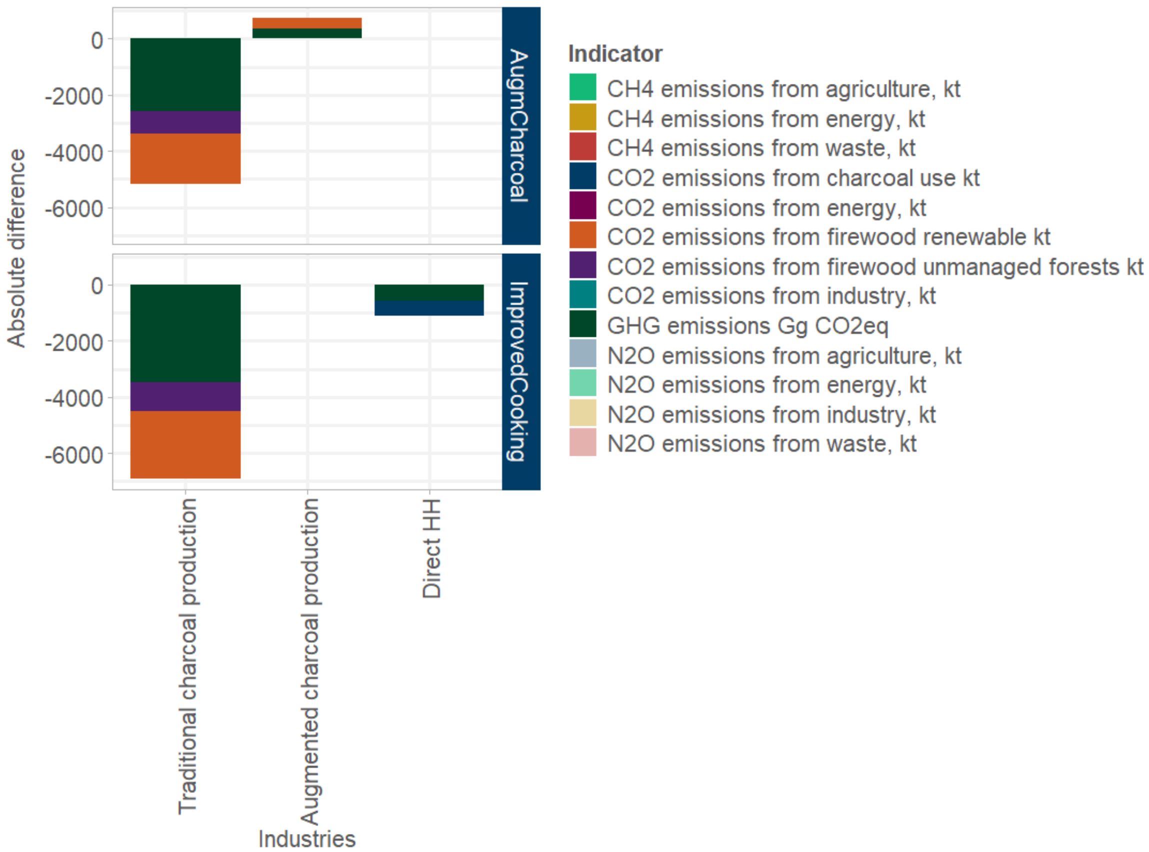
7. « Decent work sums up the aspirations of people in their working lives. It involves opportunities for work that is productive and delivers a fair income, security in the workplace and social protection for all, better prospects for personal development and social integration, freedom for people to express their concerns, organize and participate in the decisions that affect their lives and equality of opportunity and treatment for all women and men.» (ILO 2024)

▶ Figure 10 - Job creation and losses for selected industries by location for clean cooking scenario in 2030



Significant changes in GHG emissions are only for the two industries traditional and augmented charcoal production, as well as direct emissions by households, displayed in Figure 11. In the augmented charcoal production scenario, the increase in emissions in the augmented charcoal industry compared to the baseline is due to this industry not producing anything in the baseline. But it becomes immediately clear that, the increase in emissions by augmented charcoal production is more than offset by the decrease in emissions by traditional charcoal production. Further, all emissions from wood from unmanaged forests disappear. This, again, is not an outcome of the scenario, but by the design of the scenario, i.e. an explicit political choice. In the clean cooking scenario, in addition, direct emissions by households decrease, decreasing health problems related to indoor air pollution (IEA 2024).

▶ Figure 11 - GHG impacts by industry augmented charcoal production and improved cooking equipment scenarios compared to baseline



5. The Job impact of climate and blue economy policies

It should be noted that this study focuses on the aquaculture and mangrove ecosystem sub-sectors of the blue economy. The figures below estimate the impact of investments on productivity, added value, green jobs created and greenhouse gas (GHG) emissions. Furthermore, climate mitigation policies, particularly those relating to the production of improved cooking stoves and improved charcoal, have an impact on reducing greenhouse gas emissions and creating green jobs. They are highly beneficial to the blue economy, as they contribute to the conservation and preservation of mangrove forest ecosystems on coastlines.

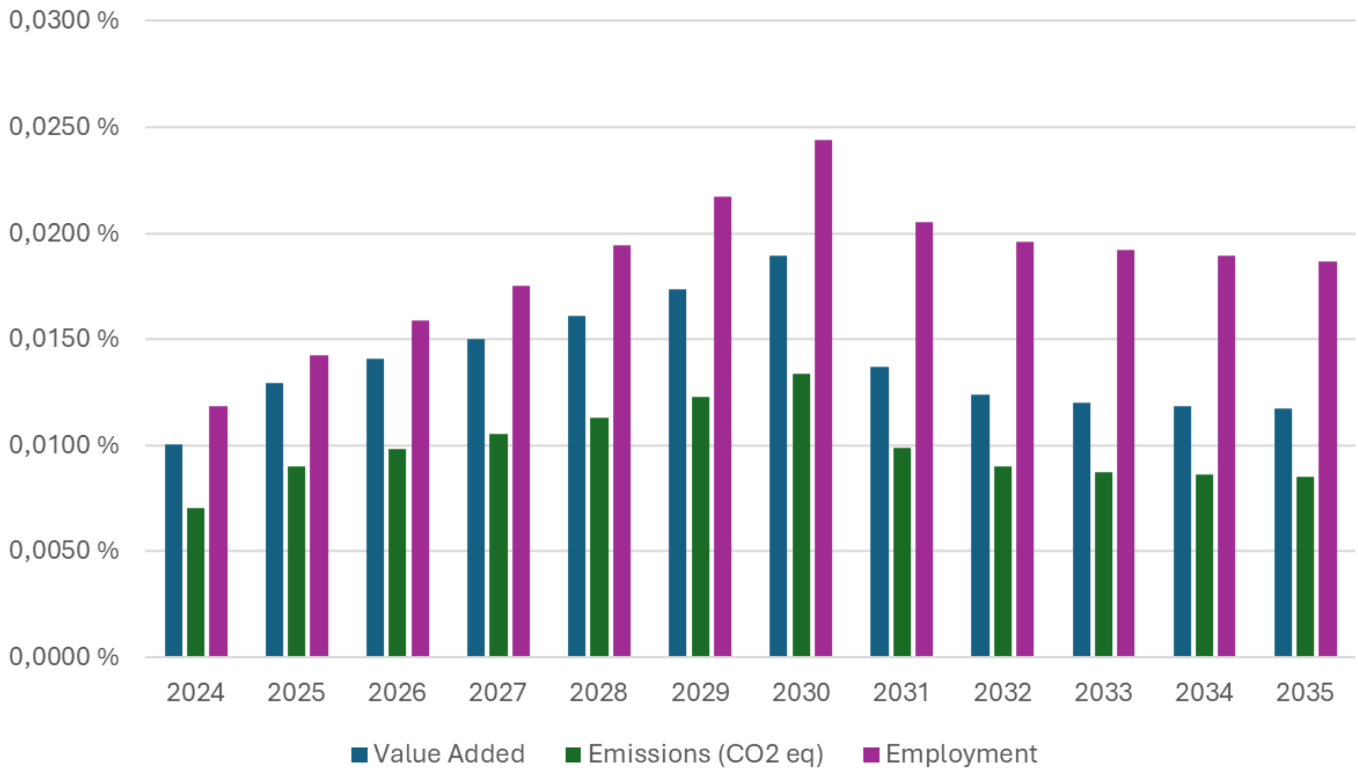
5.1 Impacts of investments in aquaculture

According to JTAM model estimates, with an annual investment of approximately one (01) million US dollars in aquaculture, an increase of 0.0189% in added value in the aquaculture sector will be recorded as an impact in 2030, whereas the current trend in 2024 is 0.01%. This increase will be accompanied by a 0.0244% increase in jobs and a 0.0134% increase in greenhouse gas emissions in 2030.

In general, forecasts for 2024 to 2030 show an upward trend, while a downward trend is identified between 2031 and 2035. It is estimated that there will be a 0.0244% increase in jobs created in 2030, compared to an increase of only 0.0187% in 2024. The same applies to the effects of investments on added value, with growth estimated at 0.0189% in 2030 compared to 0.0117% in 2035. In addition, the effects of investments in the aquaculture sector on CO_2 emissions can also be described as positive from 2030 to 2035, according to JTAM model estimates. These emissions are expected to fall from 0.0134% in 2030 to 0.008% in 2035, after showing an upward trend during the period 2024-2030.

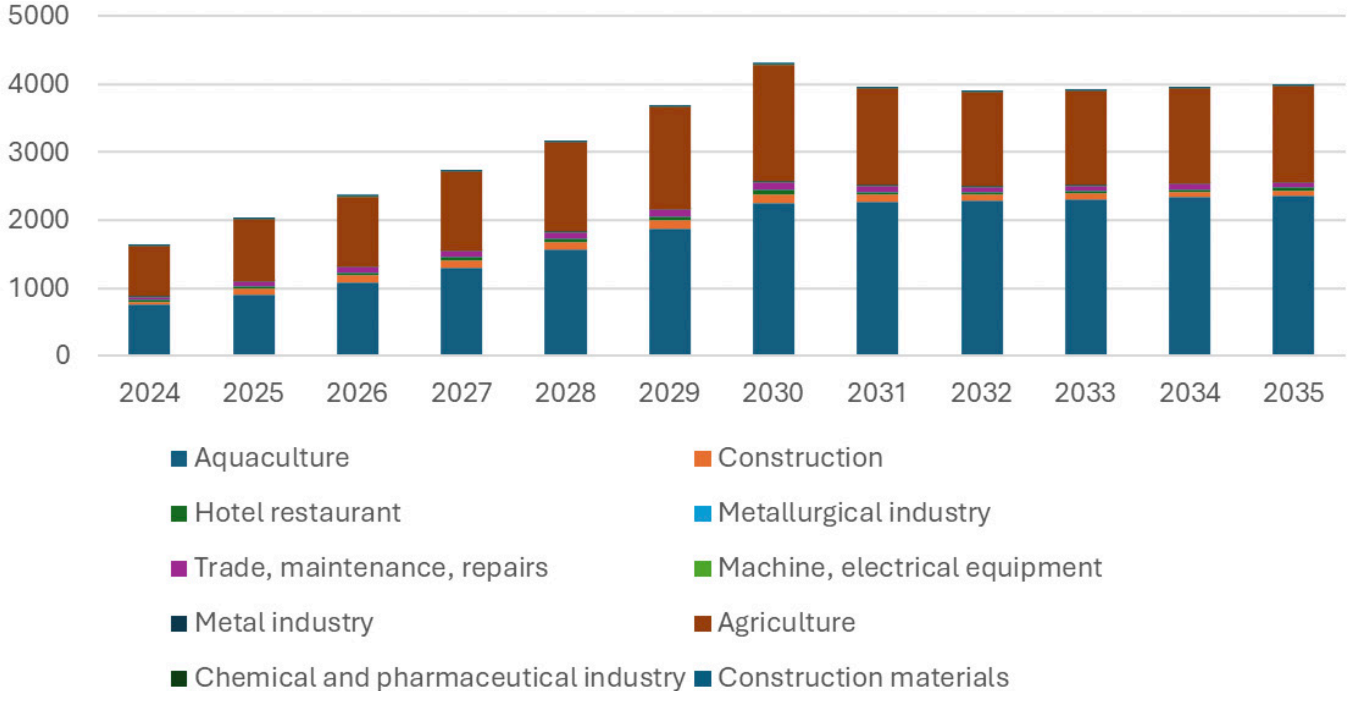
In summary, there is a clear difference in the impact of investments in the aquaculture sector in terms of added value, jobs created and greenhouse gas emissions between the period 2024-2030 and the period 2031-2035.

Figure 12 - Percentage increase in value added, employment and emissions in the aquaculture scenario compared to the baseline scenario



Thanks to investments in aquaculture, 756 jobs were created in this sub-sector in 2024 and another 737 in the agriculture sector, which accounts for the majority of jobs in Madagascar. The impact in terms of jobs created in other industrial and service sectors is relatively minimal. The period 2024-2030 saw an increase in job creation in the aquaculture sector, with 2,249 jobs created in 2030. The trend is similar for the agricultural sector, which will see a total of 1,718 jobs created in 2030 as a result of investments in aquaculture. Furthermore, the aquaculture and agricultural sectors will see stable job creation between 2031 and 2035. They will grow from 2,249 in 2031 to 2,357 in 2035 for aquaculture and decrease slightly from 1,426 in 2031 to 1,415 in 2035 for agriculture.

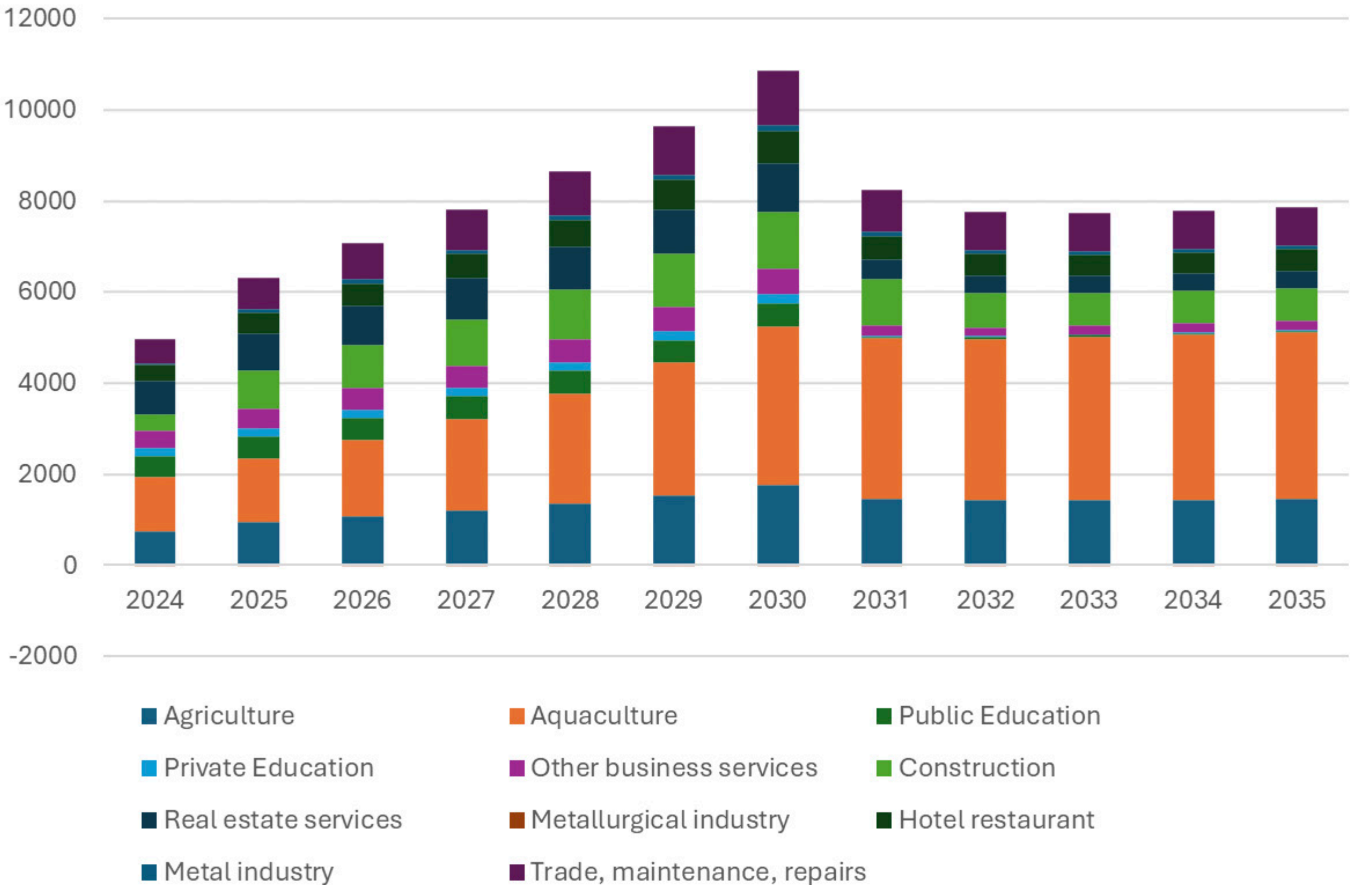
Figure 13 - Employment trends in the main sectors of activity for the Aquaculture scenario compared to the baseline scenario



Source : JTAM modelling- Madagascar, 2024.

Given the investments made in the aquaculture sector, many industries are seeing positive spin-offs, particularly in terms of added value and knock-on effects on the local economy. These include aquaculture, agriculture, construction, real estate services, trade, maintenance and repair, hotels and restaurants, and both public and private education[8] (see Figure 3 below).

Figure 14 - Changes in value added, main sectors of activity for the Aquaculture scenario compared to the baseline scenario



Source : JTAM modelling- Madagascar, 2024.

8. Especially for the period from 2024 to 2030.

5.2 Impacts of mangrove ecosystem conservation and restoration policies

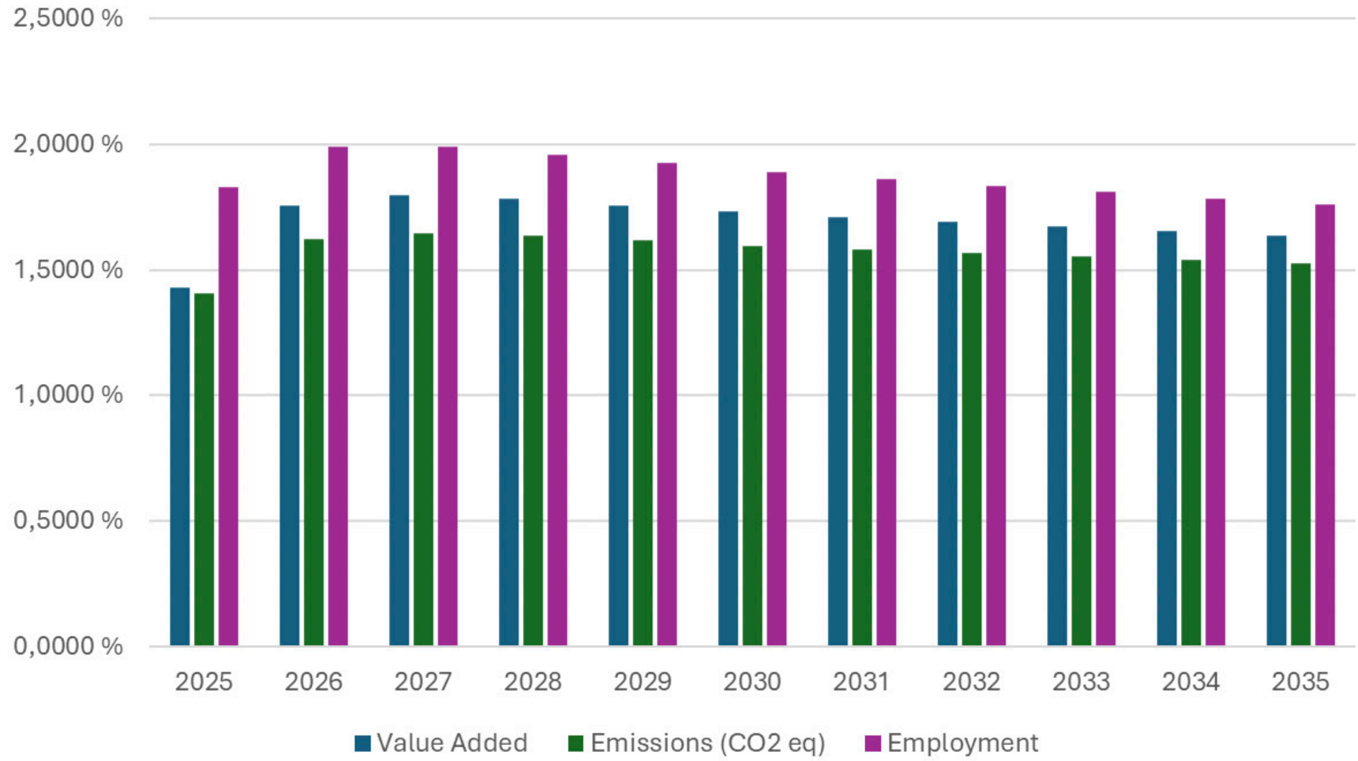
Mangroves can withstand natural hazards such as storm surges and tsunamis, making them valuable protectors of communities and infrastructure against coastal threats (UNESCO, 2023). Madagascar has 2% of the world's mangroves, 20% of Africa's mangroves, and 30% of the mangroves in the western Indian Ocean region. With a total area of 218,750 ha, annual deforestation is estimated at 6,572 hectares [9] of mangroves in Madagascar in 2021. In addition, it is necessary to restore 15,000 ha of mangroves per year, of which 10,000 ha are dedicated to conservation and 5,000 ha to sustainable exploitation. Despite the ban[10] on cutting mangrove forests, illegal exploitation of their ecosystems persists in the country. Restoring one hectare of forest worldwide costs an average of $3,450 (FAO, 2020).The JTAM model also estimates the impact of investments in conservation and restoration on the mangrove ecosystem in terms of jobs, added value and greenhouse gas emissions. The jobs created are considered green, as restoration activities significantly reduce emissions.

Thus, an investment of US$3,450 per hectare in the annual restoration of 15,000 hectares of mangroves would have an impact on job creation. The growth rate of these jobs, estimated at 1.83% in 2025, would remain relatively stable over the following decade, reaching 1.89% in 2030 and then 1.76% in 2035.

The impact of conservation and restoration policies on added value is estimated at 1.43% in 2025, 1.73% in 2030 and 1.63% in 2035.

As for the effects on greenhouse gas emissions, they are relatively minor, at 1.4% in 2025, 1.59% in 2030 and 1.52% in 2035.

▶ **Figure 15 - Percentage increase in value added, employment, and emissions in the ecosystem scenario compared to the baseline scenario**



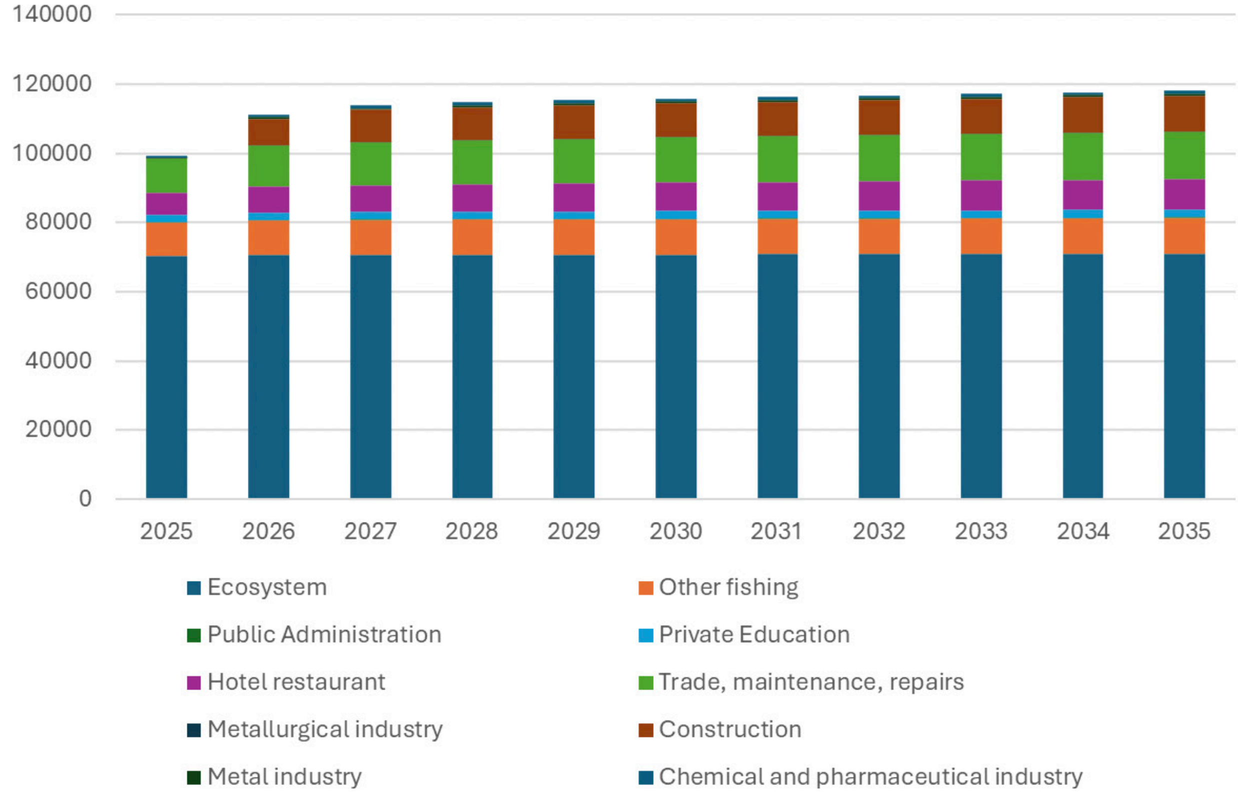
Source : JTAM modelling- Madagascar, 2024.

Similarly, the implementation of mangrove conservation and restoration policies has a significant impact on employment, particularly in sectors related to the mangrove ecosystem, the fishing industry, public administration, trade, and maintenance and repair services. By 2025, these interventions are expected to contribute to the creation of nearly 70,391 jobs in the mangrove sector, 9,754 in fishing activities, 77 in public administration, and 9,812 in trade. By 2030, these figures are expected to increase to 70,954, 10,407, 141, and 13,805 jobs, respectively, reflecting the sustained momentum of economic development associated with coastal ecosystems.

9. Rabemananjara Zo Hasina, Rakotosoa Andrianina, Ratovoson Arimino Aina Navale (2021). Assessment of the socio-economic role of mangroves and their conservation framework in Madagascar. WWF Madagascar, Antananarivo.

10. Act prohibiting the exploitation of mangrove forests enacted in 2014.

Figure 16 - Employment trends in key sectors of activity for the "Ecosystem" scenario compared to the baseline scenario

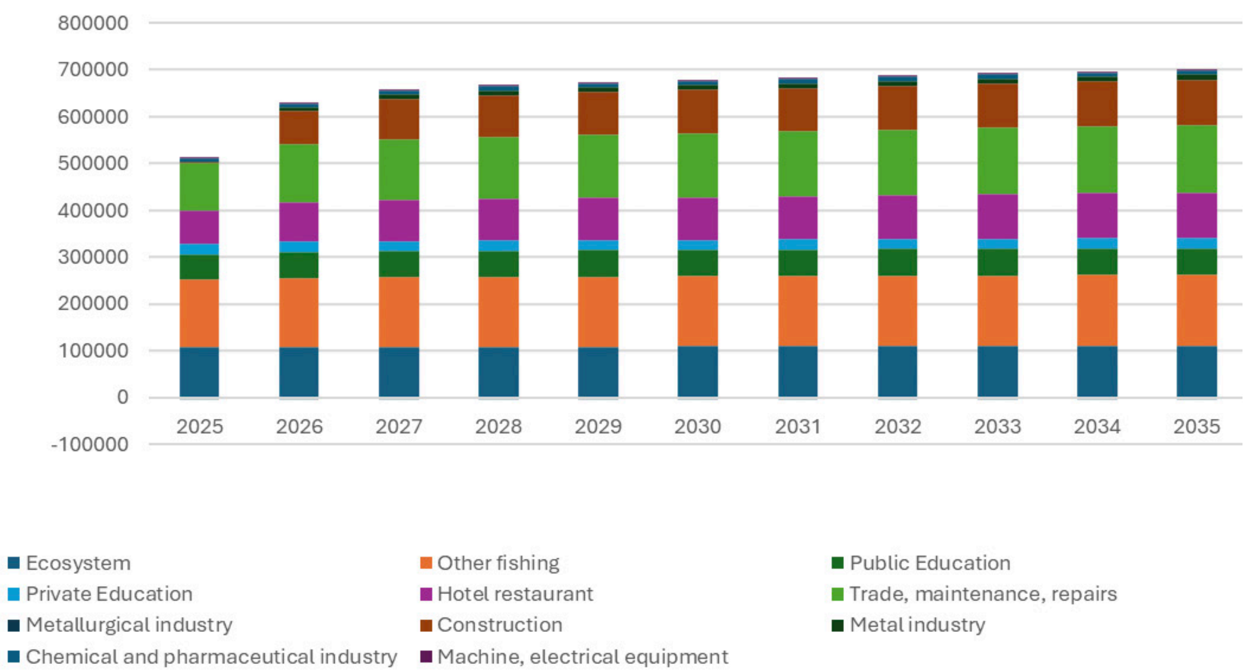


Source : JTAM modelling-Madagascar, 2024.

In the blue economy, mangrove ecosystem restoration and conservation activities are extremely important because they generate knock-on effects in terms of added value both for the sub-sector itself and for a number of productive industries. These include other sub-sectors of fishing, public and private education, hotels and catering, trade, maintenance, repair and construction.

For example, protecting the mangrove ecosystem improves the coastal and marine environment, which is home to a large number of marine species, both animal and plant. Furthermore, mangroves play an essential role in protecting the coastline from strong winds and tides. They also constitute forest ecosystems of great ecological and economic value, promoting photosynthesis, rainwater (they serve as nurseries, refuges and feeding grounds for a multitude of species (fish, crustaceans, birds, reptiles)) regeneration and, when managed sustainably, the use of firewood. Their presence also contributes to the development of eco-tourism and the resilience of coastal communities.

Figure 17 - Changes in value added, main sectors of activity for the ecosystem scenario compared to the baseline



Source : JTAM modelling-Madagascar, 2024.

5.3 Impacts of improved cooking policies

In Madagascar, 99%[11] of the population cooks with wood energy, more than 95% of them using traditional, inefficient stoves. These practices cause disastrous environmental problems (deforestation, soil erosion, greenhouse gas emissions, etc.) and major health problems (respiratory and eye diseases), which are believed to be the direct cause of more than 12,000 deaths per year in the country. Wood remains the main fuel used in households, used by 68.3% of the Malagasy population, followed by coal at 30.7%.

Improved cooking policies aim to promote the adoption of more efficient, cleaner and energy-efficient stoves and cooking practices by households. These strategies are considered green economy policies because they help reduce the destruction of forest cover. They also help consolidate the creation of green jobs, as the manufacture of improved cooking stoves reduces the consumption of charcoal, which accounted for 44.4% of wood energy consumption in 2015[12], or 8 million m3 in 2015, while fuelwood consumption amounted to 10 million m^3 for the same year.

An improved stove performs better (fuel consumption, cooking time, etc.) than a traditional 'three-stone' stove. Existing improved stoves are mainly made from clay (combustion chamber) and sheet metal, reducing heat loss. They thus enable fuel savings of between 15 and 60%. The impacts of their use are

(i)• Economic – by creating economic momentum around their production, marketing at the macroeconomic level and reducing fuel expenditure and collection time at the household level;

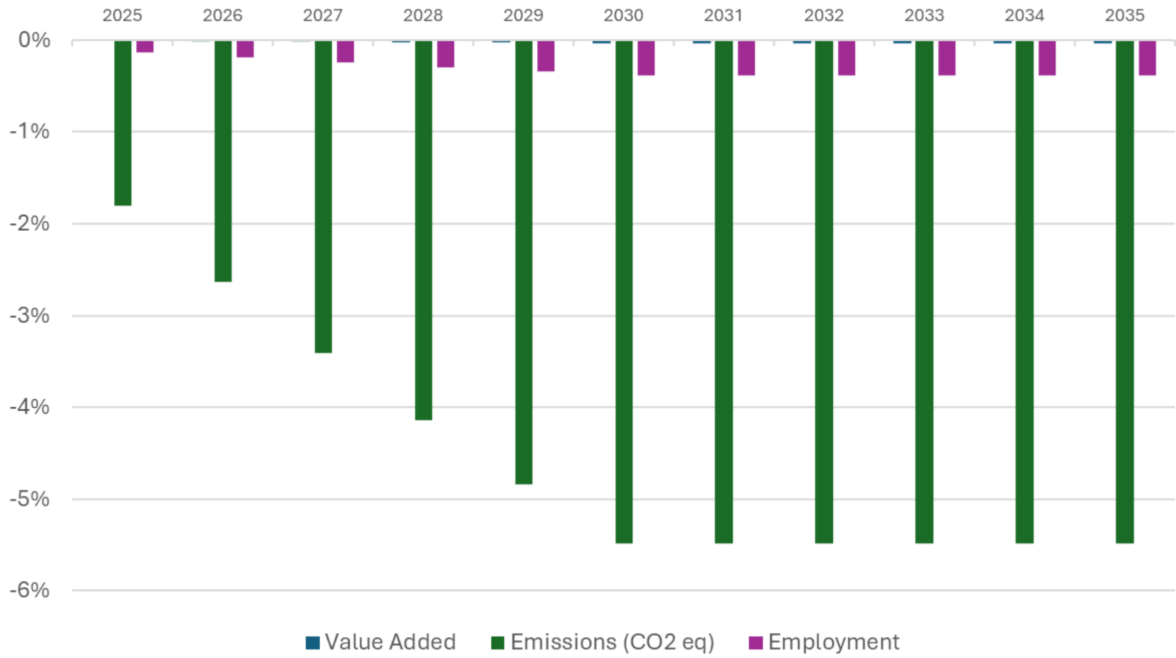
(ii) Environmental – by reducing deforestation and associated GHG emissions;

(iii) Social – by improving cooking conditions and reducing the time spent collecting wood.

Among the energy sources that can power an improved stove for domestic cooking is the biodigester, whose initial investment cost remains relatively high—between €600 and €1,200, depending on the domestic model, which generally ranges from 6 to 15 m^3. In Madagascar, less than 5% of the population uses an improved stove. Biodigesters are fixed and cannot be moved. Using a biodigester requires a certain amount of discipline: filling it almost daily, regular checks and maintenance, and recycling biogas and digestate to avoid harmful effects (GHG emissions, soil pollution). In Madagascar, there are 414 registered biodigesters, of which around 83% are still operational.

The results of the JTAM modeling show that the impact of using improved cooking stoves on greenhouse gas emissions is the most significant, with a 1.8% reduction in emissions expected by 2025. The situation is set to improve further in 2030, with emissions falling by 5.48% and remaining stable until 2035. A similar trend can be seen in terms of the impact on green jobs created, with a 0.1278% increase in jobs projected for 2025, improving over time to reach 0.385% in 2030 and 0.3817% in 2035. The impact on added value exists but remains insignificant.

Figure 18 - Percentage increase in value added, employment, and emissions in the improved cooking scenario compared to the baseline

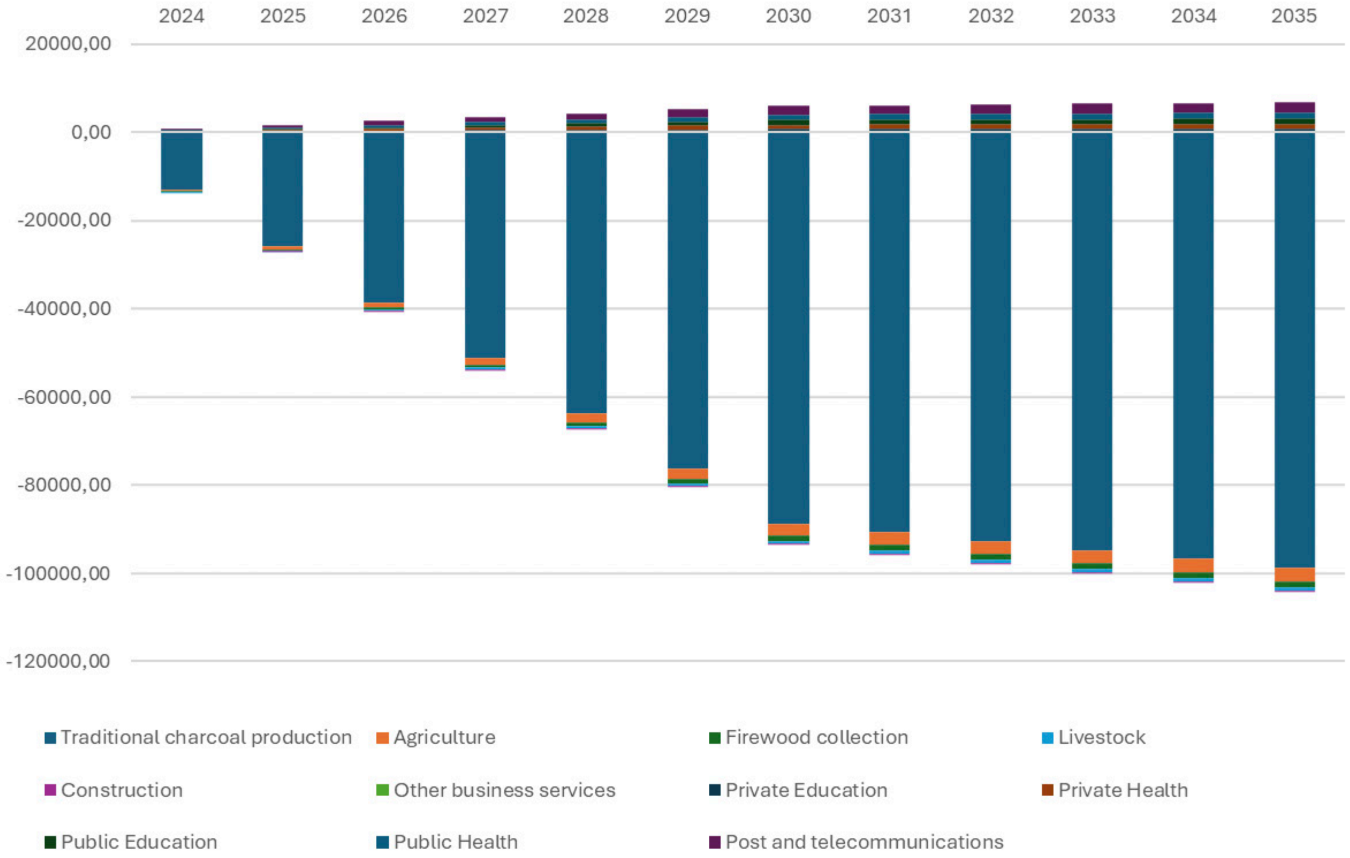


Source : JTAM modelling- Madagascar, 2024.

11. Source : INSTAT/EPM 2021-2022. National Institute of Statistics/ Household Survey.
12. Source: National Strategy on Wood Energy Supply – SNABE 2015 – Ministry of Energy and Hydrocarbons of Madagascar.

Furthermore, in terms of the impacts of climate policy on the production and use of improved cooking stoves, the modeling results show, on the one hand, the destruction of jobs considered non-green in certain sectors (traditional charcoal production, agriculture, wood energy[13] collection, livestock farming, house construction, and other private services) and, on the other hand, the creation of so-called green jobs in other service production activities, namely: public health, postal and telecommunications services, public education, private health care, and private education. 25,745 jobs are expected to be lost in 2025 in traditional charcoal production due to the use of improved stoves, and modeling estimates point to a decline of 88,745 jobs in 2030 and 98,689 in 2035. These figures mean that traditional charcoal production will require less and less labor as traditional charcoal production declines. However, it should be noted that these jobs are informal jobs carried out by rural households, who are the producers of charcoal.

▶ Figure 19 - Changes in employment, main sectors of activity for the improved cooking scenario compared to the baseline scenario



Source : JTAM modelling- Madagascar, 2024.

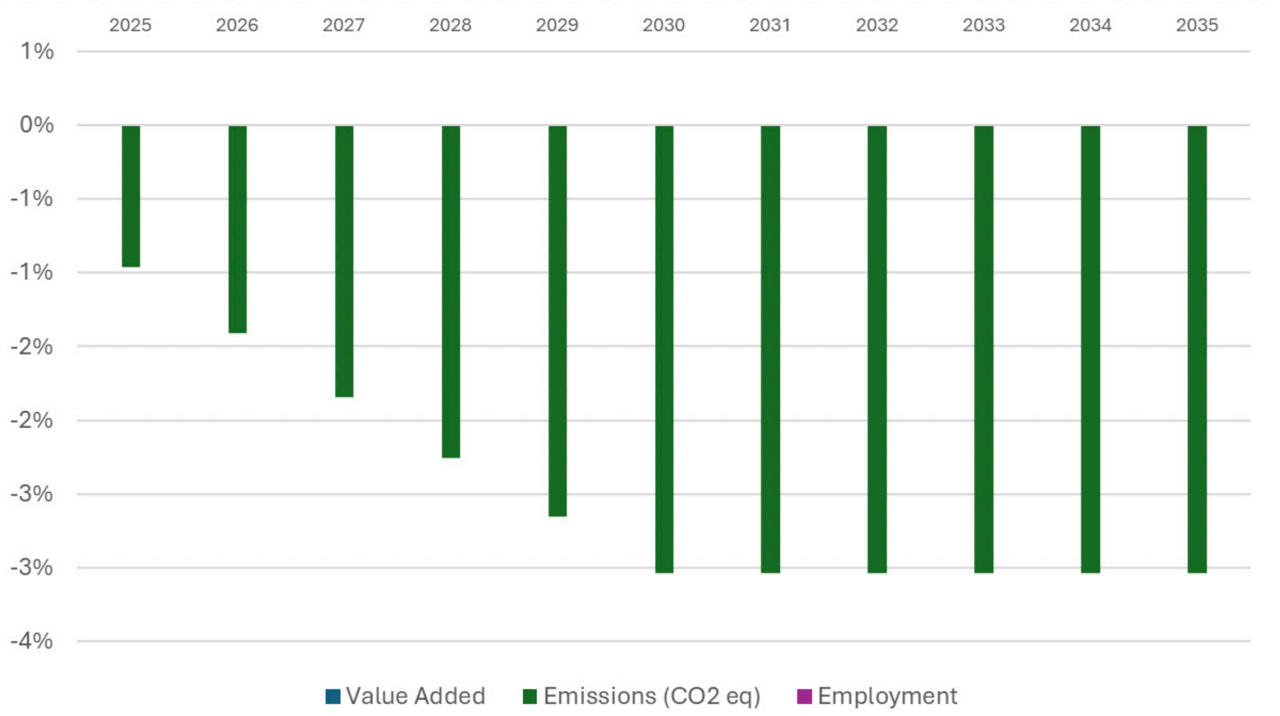
5.4 Impacts of improved charcoal production policies

Charcoal production, which accounts for 30.7% of the fuel used for cooking by Malagasy households (compared to 68.3% for firewood) in 2021, puts enormous pressure on mangrove ecosystems, which are also exploited by coastal communities for energy wood. Consequently, improved charcoal production is proving to be an effective strategy for reducing this pressure, especially in terms of greenhouse gas emissions.

Following efforts to encourage the production of improved charcoal, a 0.96% reduction in emissions would be observed in 2025. It should also be noted that this decline continues in the period 2030-2035, as the reduction in emissions is significant, reaching an average of 3.03%.

13. It is practically only firewood.

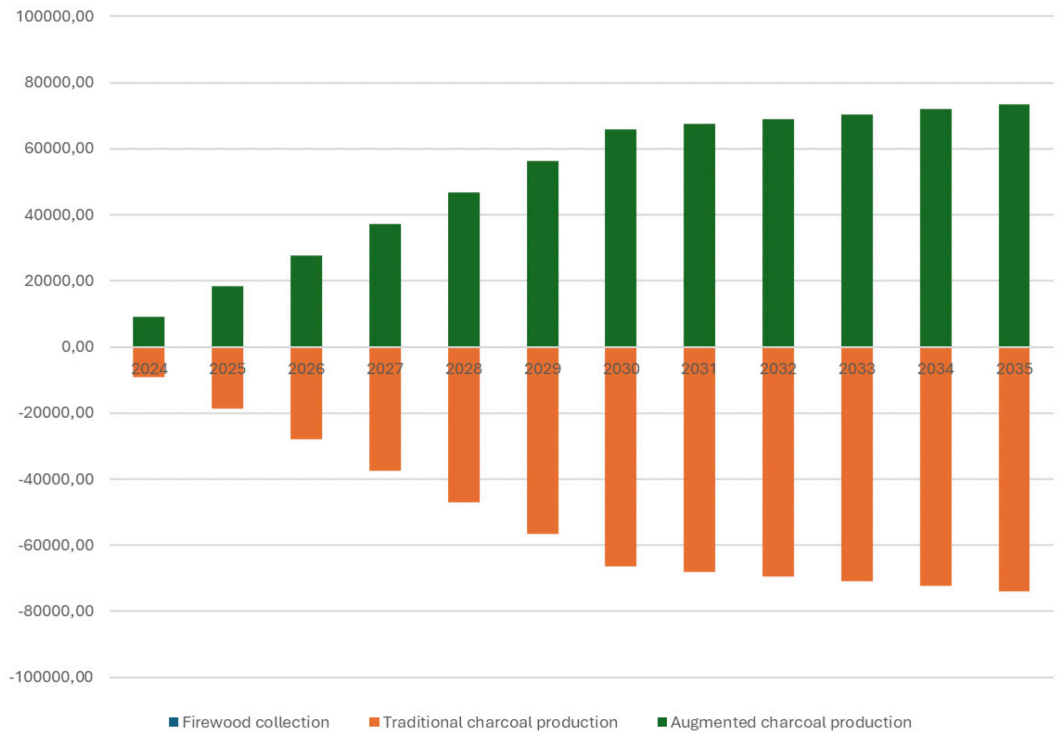
Figure 20 - Percentage decrease in value added, employment, and emissions in the improved charcoal scenario compared to the baseline scenario



Source : JTAM modelling- Madagascar, 2024.

In addition, in terms of the impacts of the climate policy on improved charcoal production, the modeling results show, on the one hand, the loss of jobs considered non-green in certain sectors of activity, namely: traditional charcoal production, agriculture, house construction, fuelwood collection, food production, beverages and tobacco, and other private services. On the other hand, they show the creation of green jobs in other service production activities: public health, postal and telecommunications services, public education, private health care, and private education.

Figure 21 - Employment trends in key sectors for the increased charcoal scenario compared to the baseline scenario



Source : JTAM modelling- Madagascar, 2024.

Estimates show a growing number of green jobs being created in the improved charcoal production sub-sector, ranging from 18,379 in 2025 to 65,941 in 2030 and 73,387 in 2035. At the same time, 18,547 non-green jobs are expected to be lost in 2025, 66,474 in 2030 and 73,920 in 2035 in traditional charcoal production activities in Madagascar.

6. Policy implications and analysis

For Madagascar, the Blue Economy represents an opportunity that needs to be structured in order to bring its economic, environmental and social benefits to fruition. A number of achievements and projects to develop the country's aquatic potential make it, in some cases, a world-class example (such as organic seaweed and shrimp farming). Furthermore, the endemic nature of living species leads the country to present itself as a nature sanctuary containing an exceptional biological diversity of 12,000 plant species and 1,000 vertebrate species (mammals, reptiles, amphibians, birds) with an endemicity rate of over 80 percent (United Nations CEA Report 2018).

Comparing the fisheries potential of the Malagasy Exclusive Economic Zone with a potential of 50,000 tonnes of tuna gives hope for growth in fisheries production. Illegal fishing by national and international operators, and the lack of means to monitor small-scale fisheries production, are in all likelihood at the root of the underestimation of actual catches in the Malagasy EEZ. Fishing zones 30-40 km (and even further) from the coast are, these days, rarely visited by national operators. First and foremost, therefore, we need to adapt and improve the safety of sail-propelled pirogue fishing.

As for aquaculture, Madagascar's natural and geographical environment is conducive to the development of both marine and continental aquaculture. The aquaculture sector plays an important role in meeting crucial social and economic challenges, such as food security, employment, value-added food production and the maintenance of essential services in rural and coastal communities, as well as alleviating poverty as a whole. In addition, the export of safe and wholesome food products sold for consumption in external markets makes this sector a net contributor to the Malagasy economy to the tune of around 120 million USD in revenue collected for 1,768 export health certificates issued by the Autorité Sanitaire Halieutique (ASH) in October 2022. x

In 2018, the fishing and aquaculture sector accounted for 6.6% of national GDP and 6.6% of exports in Madagascar (INSTAT 2019b). The pool of fisheries stock assessors, supported by the Swiofish2 project in collaboration with the Institut Halieutique et des Sciences Marines and the RESOLVE consultancy, plays a crucial role in the sustainable management of marine resources in Madagascar.

The main expectations in terms of economic and social spin-offs from the aquaculture sector in Madagascar, i.e. seaweed, sea cucumber, crab, shrimp, cage fish farming, pond fish farming, rice-fish farming and spirulina, are as follows:

(i) income support for village communities and fishermen in areas with high aquaculture potential,

(ii) job creation,

(iii) contribution to the sustainable management of natural fish stocks,

(iv) contribution to foreign exchange earnings,

(v) contribution to satisfying national demand for seafood (and inland water products),

(vi) contribution to food and nutritional security among the most vulnerable populations,

(vii) contribution to the fight against rural exodus,

(viii) contribution to Madagascar's technological prestige.

The scenarios put forward in the National Blue Economy Strategy are as follows:

- An increase in production for national markets of +15% for the shrimp sector, +25% for the crab sector, +300% for cage fish farming, +100% for pond fish farming, +150% for rice-pisciculture, +100% for Spirulina cultivation.
- An increase in production for export markets of +140% for the Algae sector, +30% for the Shrimp sector, +100% for the Sea Cucumber sector, +40% for the Crab sector.
- A contribution to foreign exchange earnings of +100% for the seaweed sector, +40% for the shrimp sector, +30% for the sea cucumber sector and +40% for the crab sector.

Weak waste management and pollution prevention have led to contamination of rivers, lakes and groundwater, as well as soil. All socio-economic activities produce waste and/or pollutants, much of which is discharged without prior treatment. The intensification of these activities only exacerbates the situation. In addition, climate change is at the heart of global concerns, as it is in Madagascar. Improving the resilience of ecosystems, particularly mangroves, to climate change means protecting them within Marine Protected Areas, restoring them and revitalizing their ecosystem functions...

In Madagascar, mangroves cover an area of 2,260 km2, the largest in the Western Indian Ocean region (Harper et al. 2007). What's more, 98% of Madagascar's mangroves are found in 29 sites on the west coast, with the remaining 2% on the east coast. The mangroves of Mangoky, Tsiribihina, Ranobe (Besalampy), Betsiboka, Mahajamba and Mahavavy (Baie d'Ambaro) are the largest, covering more than 20,000 ha. There are still 20,000ha of degraded mangroves potential for restoration activities within the landscape (Reference: WWF, 2018). Mangroves provide services necessary for human well-being. In Madagascar, the total economic values (TEVs) provided by mangroves are estimated at around 82,627,833 USD per year, with an average per hectare of around 578 USD per hectare per year (WWF Madagascar, 2021).

The volume of wood energy consumed in 2015 in Madagascar was 18 million m3, including 10 million m3 for fuelwood and 8 million m3 for charcoal. This consumption is twice as large compared to the sustainable production potential of Malagasy forests, estimated at 9 million m3 in 2015 (SNABE, 2018). Projections for quantitative objectives on charcoal for cooking by 2030: Furthermore, in urban areas, the annual consumption of charcoal will be 125kg per person compared to 110kg per person in rural areas (Source: GIZ/ECO, 2015).

The trend related to the creation of efficient cooking equipment is more dominated by the use of improved charcoal, that is to say both more economical and more ecological. Unmodern utensils and accessories already exist for firewood users but they are still made for very little activity and also used by very few people, such as pizza ovens, stoves and wood-burning fireplaces. Indeed, “Madagascar is the country in Africa with the least use of clean cooking methods, with less than 1% of households using clean fuels and less than 1% of households using wood or charcoal cooking ovens. improved. The cooking oven market in Madagascar is dominated by small producers, scattered across the country, mainly producing artisanal ovens. Many of these producers make charcoal stoves, while some of them produce wood stoves. Although production is small scale, stove manufacturers are still fairly consistent in the materials they use. These materials include clay, concrete, sheet metal, sand and/or manure. Faced with this apparent continuity, technical innovations in the field of manufacturing and design of cooking ovens are considerable.” (Sustainable Energy for All et al. 2019). Absolutely, it is still possible to improve the use of wood-fired cooking in the country by modelling more efficient equipment such as bread and pizza peels, oven brushes, fire starters and grills. As part of the New Energy Policy (2015), the country has defined several targets related to clean cooking by 2030, including:

- 70% access to improved cooking stoves;
- 50% of the wood must come from legal and sustainable forest resources; And
- 20% of charcoal must be “green”, meaning it must have been produced efficiently and from legal and sustainable forest resources.

Otherwise, construction and services do not actually use charcoal. Any consumption in this area is only for domestic and private use, in particular for final household consumption. Hence, the total consumption of charcoal is simply assimilated to the total quantity of charcoal used by households.

In the energy balance, firewood and charcoal are two distinguished elements and they each have their own quantity and consumption values. Firewood is intended for household final use. It does not include the wood needed for charcoal production. It is mainly consumed by the rural population which largely exceeds the urban population in Madagascar (RGPH3,2018).

Furthermore, the core plans for clean cooking/efficient stoves to be included in our analysis for climate policy are :

The implementation of improved carbonization techniques in the charcoal production process (“augmented charcoal”: a sort of carbonization 2.0 which makes it possible to produce charcoal more efficiently, by burning less wood, thus saving the trees and, with them, their stored carbon. A technique which takes 10 to 15 days, compared to 5 days for traditional methods, but which produces high quality charcoal, more energy dense.

Promotion, awareness and advocacy for the use of energy-efficient cooking equipment, known locally as “fatana mitsitsy” (economic stoves), which have been introduced and are increasingly used by especially urban households to slow down combustion, optimizing energy consumption and thus reducing charcoal consumption (charcoal).

These improved stoves, combined with more efficient production techniques, make it possible to save up to 50% of charcoal consumption.

In 2012, more than 70% of the wood supply intended for charcoal, i.e. 5.3 million m3, was stored in rural farmers’ plantations (peasant plantations) composed of Eucalyptus and pine, and 20% of the wood supply came from natural forests, representing a stock of 1.38 million m3. This change in the source of energy wood, which increasingly comes from peasant plantations, is becoming more and more confirmed given the plans mentioned above.

This trend is correct for two main reasons: (a) the implementation of improved carbonization techniques which make it possible to produce high quality, more dense energy and increased charcoal and therefore reduce wood consumption. (b) The use of energy-efficient cooking equipment, locally known as “fatana mitsitsy”, optimizes energy consumption and thereby reduces charcoal consumption.

The main conclusions are as follows:

- Greening of the charcoal value chain has considerable potential for reducing carbon emissions in Madagascar
- Changing from traditional to augmented charcoal production results in a significant decrease in carbon emissions, without impacting charcoal workers (there is no change in total employment as workers are simply moved from traditional to augmented charcoal production)
- Lower charcoal demand from efficient cookstoves will impact informal labour in traditional charcoal production, with an opportunity for the workers to tend to productive economic activities

The results of our simulation highlight a major challenge for the ‘just transition’ in Madagascar: while the adoption of efficient stoves (fatana mitsitsy) effectively reduces carbon emissions, it simultaneously undermines the incomes of thousands of informal workers in the charcoal industry. To turn this risk into an opportunity, public policies must create bridges between skills across different sectors. For example, the growth dynamics observed in aquaculture and mangrove restoration (valued at USD 578/ha/year) offer a natural outlet for the retraining of loggers and charcoal burners. A national training programme could thus guide this rural workforce towards new jobs in the blue economy or the local manufacture of clean cooking equipment, ensuring that environmental gains do not translate into increased social insecurity.

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Annex: Method and data

A.1 Background and modelling philosophy

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

The methodology has also been used for GJAMNigeria (ILO and UNDP, Wiebe, Simas, et al. 2021), GJAMZimbabwe (ILO and UNDP, Wiebe, Andersen, et al. 2021), GJAMTurkey (UNDP and ILO et al. 2022), GJAMBurkinaFaso (ILO, Wiebe, Simas, et al. 2023), and GJAMGhana (ILO, Wiebe, Aponte, et al. 2023).

A.2 Existing economic scenario models in Madagascar

In Madagascar, modelling has hardly aroused the interest of Malagasy technicians (Ramaharo et al. 2023). Few models have been developed within the ministries responsible for economic policy (Projet MADIO, 1994). There are several reasons for this lack of interest:

- lack of equipment (departments not equipped with microcomputers);
- the virtual non-existence of management training in modelling;
- the fact that models are seen as complicated tools requiring mathematical formulas that don't "fit" with reality.

According to (Edi and Laffiteau 2017), modeling work in Africa faces common difficulties, namely:

- the managers in charge of the models do not benefit from regular training and refresher courses;
- some models are abandoned as soon as the managers responsible for running them leave;
- some over-sophisticated models can only be improved by the consultants who designed them, and run the risk of being abandoned for lack of maintenance;
- countries have difficulty finding the financial resources to maintain, update and upgrade their models;
- insufficient or non-existent statistical data on economic indicators make it impossible to produce accurate macroeconomic projections.

From 2019 onwards, the design and operationalization of economic models will be carried out by the Direction des Études et de la Modélisation Économiques (Directorate of Economic Studies and Modeling), attached to the Direction Générale de l'Économie et du Plan (DGEP) of the Ministry of Economy and Finance (MEF, 2019), and the Institut National de la Statistique - INSTAT, which is now attached to the MEF. The "new" models the macroeconomic models developed from 2019, internalized within the DGEP and technically, those adopting the new 2019 national accounts, and the new consumer price index are:

- The MA2P model, which was initially developed within the Ministry of the Economy in order to correct the imperfections of the MAROA model and to integrate the new rebased 2007 national accounts, and above all to meet needs relating to the monitoring and analysis of macroeconomic indicators, macroeconomic estimation and forecasting, and above all the implementation and management of the information systems required for knowledge of the current situation and likely evolution of the national and international economy. MA2P is structured around a clearly identified set of exogenous variables (international environment assumptions, supply branch assumptions, economic policy assumptions) and 5 interrelated modules: Real Sphere (volume and prices), Public Finance and Debt, Balance of Payments, and Monetary Situation (Ponty, 2018).
- The MCMM or Modèle de Cadrage Macroéconomique de Madagascar is intended to be the finalized version of MA2P (UNDP, 2019), which resulted in a branch much closer to the IMF's Financial Programming Model, nevertheless enriched with several behavioral relationships rooted in economic theory and calibrated to the Malagasy economy using econometric methods. The model runs on Excel and is fed by the same macroeconomic data as MA2P, whose structure it has retained. MCMM also introduces various looping scenarios to simulate macroeconomic framing exercises. The economic growth rate can thus be determined endogenously or targeted on the basis of assumptions exogenous to RMSM (Razafindrabe, 2019).

- The MISA model: Given the vulnerability of the Malagasy economy to shocks, and in view of the Covid-19 pandemic, the government requested UNDP support in developing rapid, efficient and quantitatively sound decision-support tools to simulate structural random shocks to the Malagasy economy and make timely fiscal policy decisions to mitigate their negative effects (UNDP, 2020). It was in this context that the MISA or Madagascar Industrie, Services et Alimentation (Industry, Services and Food) model was developed, which is a DSGE (Dynamic Stochastic General Equilibrium) rational expectations dynamic model. The MISA model is a simplified representation of the economy described by four aggregate sectors: the food sector, which includes the Agriculture, Livestock and Fishing, Forestry and Agrifood branches; the industrial sector, which includes all industrial branches except Agrifood; the market services sector, which includes the Education and Health branches; and the public sector, which includes the Administration and the rest of the Education and Health branches (Cahu & Kankanamge, 2021). As a result, the model has been used to predict and assess the impact of Covid-19 shocks on Madagascar's economy, thus assisting policy-makers in drawing up the government's response plan to the pandemic (MEF, 2020). MISA is simulated on MATLAB[14] software combined with Dynare[15] routines.

- The MIDAS (Mixed-Data Sampling) econometric model is a method for analysing and forecasting economic variables using data of different frequencies. Unlike traditional models based on data of the same frequency, the MIDAS model combines high-frequency data with low-frequency data (Ghysels et al., 2004; Andreou et al., 2010). The MIDAS model is used to forecast quarterly GDP. Monthly leading indicators are used as explanatory variables. The indicators adopted display an intuitively justifiable statistical relationship with the target variable, and have the advantage of being available more quickly than the official figures for quarterly GDP and its components (Ramandray, 2022; Andrianady, 2023; Rajaonarison et al., 2023). The model is developed on Eviews.

- The Machine Learning model: Machine Learning can be seen as both an alternative and a complement to traditional econometrics for the analysis of economic data. While econometrics generally relies on theoretical economic models and statistical techniques, machine learning focuses on the ability to learn from data without prior assumptions. Machine learning models have the ability to identify trends and patterns in historical data, enabling more reliable predictions to be made over short periods. Popular machine learning algorithms such as Lasso, Ridge, Elastic net, Principal component regression, Random forest, K-Nearest Neighbor and Support Vector Machines are trained on sixteen leading indicators of the Malagasy economy, including, among others, central government spending, the exchange rate, fuel consumption and credit to the economy (Rasolofomanana & Ramaharo, 2023).

The Just Transition Assessment Model (GJAM) developed here, extends this modelling suite, focussing on the analysis of what-if policy scenarios, rather than being an economic forecasting tool. The labour and emissions extension further enable the analysis of impacts of policies on these two important domains.

A.3 Using supply-and-use tables for policy analysis[16]

Policies have effects throughout the economy. A climate or blue economy policy that directly impacts a specific sector, such as fishing and aquaculture, can trigger extensive ripple effects throughout the broader economic landscape. The shift towards sustainable practices in the aquaculture industry, for instance, will influence not only the demand for seafood products but also various interconnected sectors. The reduced demand for traditional fishing methods due to the expansion of offshore aquaculture operations will inevitably affect the fishing equipment manufacturing industry. As a result, companies producing fishing nets, trawlers, and related machinery may experience decreased demand. This, in turn, will have repercussions for the materials required in manufacturing, such as plastics and steel. Furthermore, the adoption of sustainable aquaculture practices often involves technological advancements, such as underwater monitoring systems and eco-friendly feed production. The increased use of these technologies will drive up the demand for specialized electronic components, software, and agricultural input providers. These direct effects of blue economy policies, such as the expansion of sustainable aquaculture and offshore renewable energy, propagate indirect economic impacts that resonate across diverse industries. Suppliers to the primary industries affected will experience changes in demand, as will the suppliers of their suppliers, creating a ripple effect that cascades through the entire economic system.

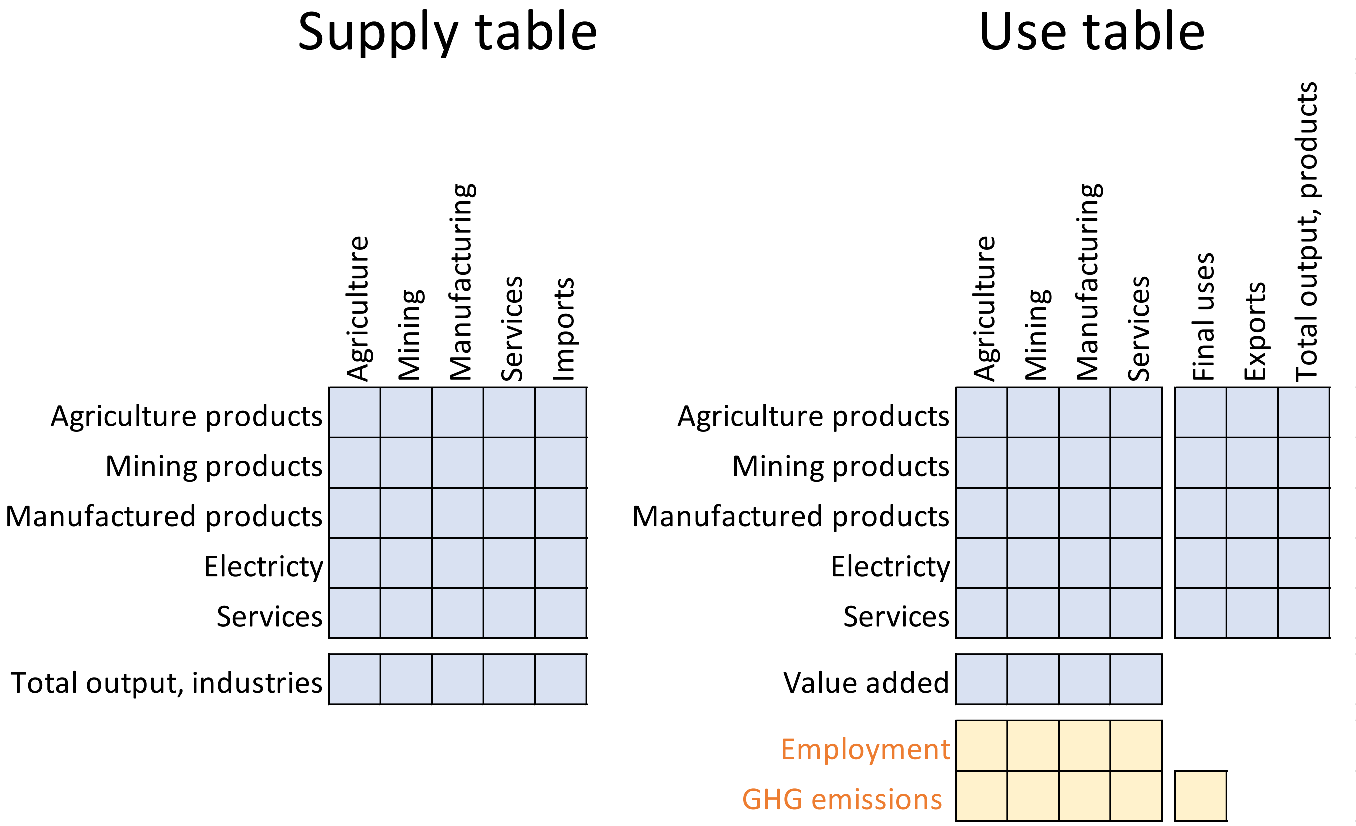
The increase or decrease of economic activity will impact jobs. With any policy, there will be industries which will increase their economic output and therefore increase the demand for workers, but there will also be industries that will have a decrease in their economic output, leading to job losses.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

JTAMsare built to quantify these ripple effects of climate policies and green structural change. JTAMsare macro-economic models based on IOTs or SUTs that integrate economic data with data on jobs and GHG emissions. The starting point are the economic SUTs, compiled by statistical offices. These tables give a picture of the total supply and the total use of goods and services in the economy, quantifying the transactions in products between industries, purchases by final consumers, and to and from international trade. Supply tables describe what industries produce and how much of each product is imported. It also includes the trade and transport margins and taxes less subsidies on products,

14. https://fr.mathworks.com/products/matlab.html
15. https://www.dynare.org
16. This section in based on the GJAM report for Turkey (Moana Simas et al. 2022)

which represent the difference between the production (basic) prices and the final consumer (purchase) prices. Use tables describe all products used by industries in the country, as well as products purchased by final consumers and exported, and gross value added (VA) generated by industries.

▶ Figure 22 - Simplified illustration of a supply table (left) and a use table (right), extended with employment and GHG emissions data per industry.



Models based on SUT can simulate the direct and indirect effects of different policies on the economic output of the different industries. Not only that, but supply-and-use and input-output tables can be linked with social and environmental indicators (called extensions) that describe direct impacts of each industry on workers and on the environment. A simplified supply-and-use table is illustrated in Figure 12.

Note that we do not model inflation. The only price changes that can be modelled are those due to changing technology of production in the scenarios, which are reported in constant prices.

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

For the scenarios it is possible to model

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

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

General limitations and strengths of the modelling approach

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

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

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

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

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

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

- While the option for price changes is given, there is no adjustment of production structure or investments based on price changes. Household demand for different product groups, however, is modelled using own- and cross-price elasticities.

- Investments grow with the previous year’s growth rate, and the structure of the investment remains the same, with one exception: the exogenously given investment for individual scenarios, which comes in addition to the general investments. This entails that the additional investments in the scenarios are not crowding out other investments but come as an additional economic stimulus.

The results show which industries are likely to have an increased demand for labour, and which industries might contract. The actual labour market outcomes also depend on other factors as well as dynamic labour market adjustments such as wage adjustments, labour availability, labour productivity changes etc, that are not considered here.

The current modelling of international trade is very simplified. Import shares by product are based on the supply table from the base year. Exports grow with global GDP projections from the IMF or OECD.

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

- The model depends on very few types of data, which can be combined into one consistent framework with few equations.

- The model is data-driven and reflects country-specific characteristics very well.

- Scenarios are implemented using one Excel sheet and the model runs in only a few seconds, which allows to calculate a large number of scenarios and thereby assessing the validity of different scenario assumptions.

- For every single result, we can find an explanation that is in the data or one of the very few assumptions underlying the model.

A.4 Data for the Just Transition Assessment Model

A.4.1 Overview over data sources for the Just Transition Assessment Model

The main data sources are

- Supply-and-use tables (SUT)
- System of National Accounts (SNA)
- Data on labour force by industry
- Data on greenhouse gas (GHG) emissions by industry

In addition, we need detailed data on

- Charcoal production
- Aquaculture industry
- Ecosystem services and mangrove restoration

In this report, we use the Madagascar **SUT table** for the year 2019, available from The National Institut of Statistics of Madagascar (INSTAT 2019a). These tables describe the economy for 31 products and 29 industries (see Table A1 in appendix for the full industry-product detail). Therefore, the base year is 2019 and the economic development is estimated on 2019 constant prices. See Section A.4.2 for more information on the SUT.

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

For the econometric estimations, we use a historical time series of data from the UN System of National Accounts. Please see Section A.1 for a detailed description of the econometric model. The estimated parameters together with exogenous information on the development of exports/ global economic (Guillemette and Turner 2018) and population (UN 2019) growth, are the main parameters defining the baseline scenario pathway.

The **labour data** for 2019 comes from INSTAT, General population and housing census (INSTAT 2020), processed and harmonized by INSTAT to match the industry classification of the SUT. It is available in a high detail of indicators of labour force composition, describing employment by gender, skill level, and rural/urban location. The total employment indicators used for the GJAM Madagascar model are available in Table 7.

The **GHG emissions** data used**,** excluding emissions from burning of firewood and charcoal, comes from the Emissions Database for Global Atmospheric Research (EDGAR) (Joint Research Centre 2021). The EDGAR database is an international database for air emissions, including the GHG emissions carbon dioxide (CO_2), methane (CH4) and nitrous oxide (N2O), which are used in the GJAM. The emissions in the EDGAR database are reported in kilotonnes of each gas per activity, following the 2006 IPCC guidelines for reporting GHG inventories (IPCC 2006), and for every year between 1970 and 2021. However, the IPCC activity classification does not match the SUT ISIC classification, so a reallocation of the emissions to the SUT industries was performed, see Section A.4.4.

The data for modelling **aquaculture and ecosystem restoration** is mostly coming from the Blue Economy Strategy (Ministere de la Peche et de l'Economie Bleue 2023), with additional data from literature on the structure of these industries. In the SUT, the aquaculture industry is reported in the aggregated product and industry "Lifestock and Fishing". Ecosystem restauration is part of the "Forestry" industry, which we have split into wood energy, charcoal, mangrove ecosystem restoration and other forestry. More information on aquaculture and ecosystem restoration is available in Section A.4.5.

Madagascar has a high share of its population relying on **firewood or charcoal** for cooking and one of the lowest adoptions of improved cookstoves in the world, with only around 0.6% of households using clean fuels and only around 0.3% using improved wood or charcoal stoves (INSTAT 2013). It is estimated that, in 2019, Malagasy households consumed 12.2 million tonnes of firewood and approximately 508,000 tonnes of charcoal, based on our calculations using various data sources (Ferrer 2018; Innovation Energie Développement 2017). A detailed description of the assumptions used to model firewood collection and charcoal production and consumption in GJAM Madagascar is found in the Section A.4.6 below.

A.4.2 The Madagascar supply and use table

The SUT for Madagascar shows the flows of goods and services between industries and final consumers, in MGA, throughout the entire year of 2019. It describes the entire Madagascar production economy in 31 products and 29 industries (Table 5) as well as final users of goods and services and volume and distribution of value added in each industry (Table 6). The supply table describes the total supply of the 31 products in the economy and how those products are distributed by the 29 supplying industries and imports.

▶ Table 5 - List of SUT 31 products and 29 industries

Product Name	Industry Name
Rice (Paddy)	Agriculture
Other agriculture	Livestock, fishing
Livestock_Fishing	Forestry
Forestry	Extractive industry
Extractive	Food, drink, tobacco
Food, drink, tobacco	Textile
textile, leather	Wood, paper, printing
Wood, paper, printing	Chemical and pharmaceutical industry
Oil products	Construction materials
Chemical and pharmaceutical industry	Metallurgical industry
Construction materials	Metal industry
Metallurgical industry	Machine, electrical equipment
Metal industry	Various industries
Machine, electrical equipment	Electricity, water, gas
Various industries	Construction
Electricity, water, gas	Trade, maintenance, repairs
Construction	Hotel restaurant
Maintenance, repairs	Transportation
Trade	Post and telecommunications
Hotel restaurant	Bank and insurance
Passenger transport	Real estate services
Merchandise transport	Other business services
Transport auxiliaries	Public Administration
Post and telecommunications	Private Education
Bank and insurance	Public Education
Real estate services	Private Health
Other business services	Public Health
public Administration	Services provided to households
Education	Financial intermediation services indirectly measured
Health	
Services provided to households	

▶ Table 6 - Final demand and value categories in the Madagascar SUT

Final demand categories	Value added category
Household consumtpion expenditure	Net taxes on production (incl subsidies)
Government consumption expenditure	Compensation of employees
Non-profit organizations serving households (NPISH)	Net operating surplus
Gross fixed capital formation	
Changes in inventories	
Exports	

A.4.3 Labour extensions

Labour extensions refer to the employment statistics from the population and housing survey RGPH (INSTAT 2020), allocated to each industry in the SUT. For each industry, we have the amount of people employed per gender, skill level, and urban/rural status. The labour extensions in GJAM Madagascar comprise of 8 indicators, detailed in Table 7.

▶ Table 7 - Labour Extensions SUT

Population	Gender	Skill	Loca-tion	Share
All Madagascar	Male	skilled	NA	55,18 %
All Madagascar	Male	unskilled	NA	32,03 %
All Madagascar	Female	skilled	NA	8,09 %
All Madagascar	Female	unskilled	NA	4,70 %
All Madagascar	Male	NA	Rural	60,43 %
All Madagascar	Male	NA	Urban	17,82 %
All Madagascar	Female	NA	Rural	13,17 %
All Madagascar	Female	NA	Urban	8,58 %

A.4.4 GHG extensions

GHG emissions extensions refer to the GHG emissions statistics from the EDGAR database, allocated to each industry in the SUT. For each industry, we have the emissions per gas and main activity (energy use, industrial production, agriculture, and waste management). In addition, we have emissions from biomass, which include emissions from production of charcoal, burning of firewood by households, and burning of charcoal by households. The GHG emissions extensions in GJAM Madagascar are made of 15 indicators and their distribution in total emissions in 2019 as detailed in Table 8.

Most of the emissions from the EDGAR database have a direct correspondence with a SUT industry: 41.4% of CO_2 emissions, 99.94% of CH4 emissions, and 95.9% of N2O emissions, which totalise 89.8% of total GHG emissions (excluding biomass), can be allocated to one specific industry in the SUT, and no assumptions were used. For emissions from fossil fuel combustion, when allocation was necessary between one inventory activity (e.g. 1.A.2 Emissions from fuel combustion in manufacturing industries and construction) and two or more industries in the SUT, emissions were allocated based on the share of fossil energy products use by industry from the use table. The available GHG emission indicators and the correspondence between original activity in the GHG inventory and allocation to the 29 SUT industries and to households is available in Table 9.

The emissions from biomass, which comprise charcoal production, burning of firewood by households, and burning of charcoal by households, was estimated based on data on use of firewood and charcoal from household. The accounting for production and consumption of firewood and charcoal in the SUT, and emissions and labour associated are described in detail in the Section A.4.6.

Table 8 - GHG emission indicators and the distribution of emissions in 2019 by activity and by gas

Gas	Activity	Emissions in 2019 (kt)	Share in total emissions, with biomass	Share per gas	Share in total emissions, without biomass	Share per gas, without biomass
CO_2 biomass	Emissions from firewood, renewable	5 567	10.4%	51%		
	Emissions from firewood, unmanaged forests	20 572	38.3%			
	Emissions from charcoal use	1 199	2.2%			
CO_2	Energy emissions	4 386	8.2%	8%	16.6%	17%
	Industrial emissions	155	0.3%		0.6%	
	Agriculture	-	-		-	
	Waste management	-	-		-	
CH4	Energy emissions	20	0.0%	40%	0.1%	81%
	Industrial emissions	-	-		-	
	Agriculture	16 880	31.4%		64.0%	
	Waste management	4 510	8.4%		17.1%	
N2O	Energy emissions	30	0.1%	1%	0.1%	2%
	Industrial emissions	0	0.0%		0.0%	
	Agriculture	214	0.4%		0.8%	
	Waste management	195	0.4%		0.7%	

Table 9 shows the distribution of emissions from activity in the original EDGAR data (JRC 2023) to the SUT industries. This distribution was done, mostly, by a direct correspondence between activity and industry: 41.4% of non-biomass CO_2 emissions, 99.94% of CH4 emissions, and 95.9% of N2O emissions were allocated from the original activity to a single industry. For the remaining, emissions were distributed according to the use of reference products by each of the corresponding SUT industries.

For energy emissions that spam over multiple industries (categories 1.A.2 – Manufacturing industries and construction, 1.A.4 – Residential and other sectors, and 1.A.5 – Non-specified), the reference was the use of fuel products (Oil products) as these categories refer to the emissions from the combustion of fossil fuels by industry, services, and households. All non-energy emissions were possible to be directly allocated to a single SUT industry.

Table 9 - Correspondence table for emissions by the activities in the EDGAR database and SUT industries

EDGAR Activities CO_2		Total emissions			Correspondence to SUT industries
		CH4	N2O		
1.A.1.a	Main Activity Electricity and Heat Production	12.1%	0.00%	0.4%	Electricity, water, gas
1.A.2	Manufacturing Industries and Construction	51.6%	0.03%	2.7%	All manufacturing industries (9 industries) plus Construction
1.A.3.a	Civil Aviation	0.4%	0.00%	0.0%	Transportation
1.A.3.b_ noRES	Road Transportation no resuspension	25.4%	0.04%	4.0%	
1.A.3.c	Railways	0.4%	0.00%	0.6%	
1.A.3.d	Water-borne Navigation	0.1%	0.00%	0.0%	
1.A.4	Residential and other sectors	3.7%	0.01%	1.2%	Agriculture, livestock, fishing, forestry, and other extractive industries, all services except for transport, construction and utilities, and households
1.A.5	Non-Specified	3.2%	0.02%	0.1%	Agriculture, livestock, fishing, forestry, and other extractive industries,
1.B.2	Oil and Natural Gas		0.00%		Extractive industry
2.A.1	Cement production	1.7%			Construction materials
2.A.3	Glass Production	0.02%			
2.A.4	Other Process Uses of Carbonates	0.01%			Chemical and pharmaceutical industry
2.D	Non-Energy Products from Fuels and Solvent Use	1.4%			
2.G	Other Product Manufacture and Use			0.02%	Machine, electrical equipment
3.A.1	Enteric Fermentation		45.0%		Livestock
3.A.2	Manure Management		1.6%	37.0%	
3.C.6	Indirect N2O Emissions from manure management			4.4%	
3.C.7	Rice cultivations		31.9%		Agriculture
4.A	Solid Waste Disposal		4.9%		Electricity, water, gas
4.C	Incineration and Open Burning of Waste		0.03%		
4.D	Wastewater Treatment and Discharge		16.4%	49.6%	

LULUCF emissions

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

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

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

Following the same reasoning, nitrogen emissions from managed soils cannot be allocated to economic activities, as there is not a linear relationship between agricultural output and growth of land use, or of activities that can influence the nitrogen release from managed soils.

A.5 Aquaculture & Ecosystem restoration (Mangroves): Modelling of new industries

Madagascar's Blue Economy Strategy (2023-2027) acknowledges the significant opportunities the Blue Economy offers for economic, environmental, and social advancement (Ministere de la Peche et de l'Economie Bleue 2023). In 2021, this recognition was further institutionalized when the Blue Economy was officially integrated into the government structure, leading to the renaming of the Ministry in charge of Fisheries to the Ministry of Fisheries and the Blue Economy (MPEB). Decree No. 2021-856 established the missions and functions of the MPEB, signalling a strengthened commitment to this sector.

The country's rich biodiversity, with a high rate of endemic species, had previously led to the adoption of a Blue Policy Letter and a National Strategy for the Blue Economy in the mid-2010s. Despite facing challenges such as rapid population growth, climate change, and the impacts of the COVID-19 pandemic on marine resource sustainability, Madagascar's strategy highlights the potential of its maritime areas in sectors like fishing, aquaculture, and tourism, necessitating sustainable practices and international collaboration.

An important component of this strategy is "Axis 2: Promotion and Development of Natural Resources in Relation to the Environment." Within this axis, the strategy focuses on two main interventions: Strengthening Ecosystem Protection and Aquaculture Development. Thus, in our modelling of the scenarios, we have considered two related scenarios: ecosystem restoration and aquaculture expansion.

Ecosystem (Mangrove) Restoration
The strategy of Strengthening Ecosystem Protection focuses on maintaining healthy ecosystems to support sustainable employment, income, and food supply. This involves protecting critical areas like mangroves, wetlands, and watersheds, and conserving marine ecosystems such as coral reefs and seagrass beds. It also includes engaging local communities and NGOs in environmental protection, with a particular emphasis on ecosystem restoration.

The ecosystem restoration in Madagascar has been modelled in the SUT system by increasing investment in the industry. The gross fixed capital formation (GFCF) vector in the model is adjusted for the new industry, Ecosystem Restoration Mangrove, by the amount of investment required.

The forestry industry, given the needs of expertise, are divided into four sub-branches: wood energy, charcoal, mangrove ecosystem restoration and other forestry.

Aquaculture Expansion
The strategy of Aquaculture Development aims to enhance aquaculture, compensating for the decline in inland fishing and creating new income opportunities. This strategy involves facilitating conditions favourable for private aquaculture initiatives, establishing support services for aquaculture development, and promoting improved stewardship within the sector. The focus is on expanding infrastructure and supporting private ventures in areas suited for aquaculture.

Modelling of Aquaculture expansion in the SUT system includes investments into Aquaculture, changes in the market share of other fishing and aquaculture industries, and the expansion of aquaculture export increases.

In the initial Supply and Use Tables, the Fishing branch includes aquaculture. Consequently, we had to distinguish and highlight aquaculture and other fisheries by collecting the most detailed data possible on the Aquaculture sub-branch. For Madagascar, we divided aquaculture into two sub-sectors: marine aquaculture (shrimps, seaweed, sea cucumbers, crab) and inland aquaculture (pond fish farming, cage fish farming and rice-fish farming). In the end, we have two branches representing fishing: Aquaculture and other fisheries.

A.6 Augmented charcoal production and clean cooking: Modelling of new industries

Madagascar has a high share of its population relying on firewood or charcoal for cooking and one of the lowest adoptions of improved cookstoves in the world, with only around 0.6% of households using clean fuels and only around 0.3% using improved wood or charcoal stoves (Sustainable Energy for All et al. 2019).

In GJAM Madagascar we model consumption of firewood and charcoal by households, emissions from burning biomass in cooking stoves, and the emissions associated with the production of charcoal. We use average price for consumers for bundles of wood and charcoal to estimate the total revenue from the production of firewood and charcoal. It is estimated that, in 2019, Malagasy households consumed 12.2 million tonnes of firewood and approximately 508,000 tonnes of charcoal (source : nos estimations, la nouvelle politique énergétique (2015), RGPH3,2018; Ades Madagascar, 2018; Sustainable Energy FOR ALL, 2019). Estimated prices for firewood consumption are 3.5 USD per bundle of wood, and 7 USD per bundle of charcoal. Average exchange rates for 2019 were of 3,618.32 MGA/USD. As it is an informal economic activity, all the revenue from sold firewood and charcoal are reported as income (Net operating surplus) and correspond to the same amount as total product output.

In addition to modelling the economic flows of firewood (that is, firewood purchased by households), we also model the "virtual flows" of self-collected firewood. The total value added and employment associated with self-collection firewood for subsistence do not represent actual monetary flows and labour, but it reflects invisible labour and lost income. This is time that the population spends on an activity that takes time from education, activities that generate income, or other social and leisure activities in the household and community. Most urban households use charcoal, while most rural households rely on firewood for cooking. It is estimated that around 95% of all firewood used by households is self-collected (Ministere de l'Energie 2012). It is estimated that rural households spend 4 hours per day for wood collection, and we estimate that urban households spend 1 hour per day. Labour associated with self-collected firewood is estimated based on hours per year spent collecting firewood and converted to full-time employment equivalents assuming 2200 hours of work per year, as it is the legal hourly limit for agricultural labourers (Source: ILO)96% of the FTE workers are located in rural areas. It is assumed that 40% of the total FTE collecting firewood are women, and 60% are men, based on the share of the population per gender collecting firewood in Madagascar (UNSTATS 2010). It is also assumed that firewood collection is an unskilled work. The FTE labour associated with collection of firewood for subsistence reflects invisible labour and lost income. This is time that the population spends on an activity that takes time from education, activities that generate income, or other social and leisure activities in the household and community.

Labour associated to purchased firewood and charcoal production is assumed to be included in forestry labour in the LFS and split from the original forestry labour in the SUT, assuming same intensity of employment per value added. The distribution of workers per gender, rural-urban status, and skill level also follows the same as for the SUT forestry industry.

Charcoal is produced by rural households, and it is estimated that approximately 70% of charcoal is produced from peasant plantations, mostly composed of exotic forestry species. Thus, it is assumed that 70% of the wood for charcoal production (and therefore, emissions) comes from managed forests and is assumed to be renewable. The remaining is assumed to come from natural forests, leading to forest degradation and/or deforestation. It is also assumed that sold firewood comes from managed forests, while self-collected firewood comes from natural forests.

Charcoal production requires approximately 10 kg of wood for each kg of charcoal. It is assumed that emissions to produce charcoal are of approximately 1.4 kg CO_2 per kg charcoal produced, which corresponds to the average emission factor of different earth mound kilns in Kenya (Pennise et al. 2001). Of these, 70% is assumed to be emissions from renewable biomass, and 30% from unmanaged forests. Emissions from fuel wood coming from unmanaged natural forests is considered as non-renewable, as the withdrawal of wood contributes to forest degradation and/or deforestation, as withdrawal exceeds renewal capacity (SNABE 2018).

The emissions for burning firewood and charcoal in cooking stoves is assumed to be of 1.59 kg CO_2/kg firewood and 2.36 kg CO_2/kg charcoal (Bhattacharya, Albina, and Abdul Salam 2002).

A.7 Baseline development[17]

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

In the reference scenario, we calibrate the model to follow the macro-economic trends from the UN System of National Accounts for the years up to 2021 for the demand side variables changes in inventories, exports, government consumption and gross fixed capital formation, as displayed in Table 10.

Table 10 - Values for exogenous variables 2020-2021 from the OECD Economic Outlook (OECD Statistics 2021)

Selected variables: ready-made growth rates (in Percentage, 2019)	2020	2021
Change in inventories, contributions to changes in real GDP	-9.05 %	-1.49 %
Exports of goods and services, volume (national accounts basis)	-20.05 %	4.24 %
Government final consumption expenditure, volume	24.35 %	15.48 %
Gross fixed capital formation, total, volume	-9.99 %	3.03 %
Gross domestic product, volume, growth	-4.42 %	9.08 %

After 2021, Government consumption grows (exogenous to the model) as a function of population, Gross fixed capital formation (exogenous to the model for the current year) grows with the previous year's GDP growth rate, Exports (exogenous to the model) grow with the global GDP growth rate, Changes in inventories (exogenous to the model) decrease by 1% annually. For both time periods (up to and after 2021), the product shares for these variables in the total are constant, there is no structural change.

Household consumption is endogenous to the model, as is GDP (the sum over all industries' value added). The household consumption model utilises income elasticities from USDA international food comparison programme (Meade et al. 2014; Muhammad et al. 2015) for nine consumption categories, see Table 11. The change in household income for the consumption model is approximated by the change in GDP.

17. Based on the description of the baseline scenario used for GJAM Turkey, adapted to the model for Madagascar.

Table 11 - Income elasticities for broad consumption categories for Madagascar from the USDA international food comparison programme (Meade et al. 2014; Muhammad et al. 2015)

Food, beverages & tobacco	Clothing & footwear	Housing	House furnishing	Medical & health	Transport & communication	Recreation	Education	Other
0.805	0.968	1.077	1.056	1.913	1.23	4.012	0.932	1.942

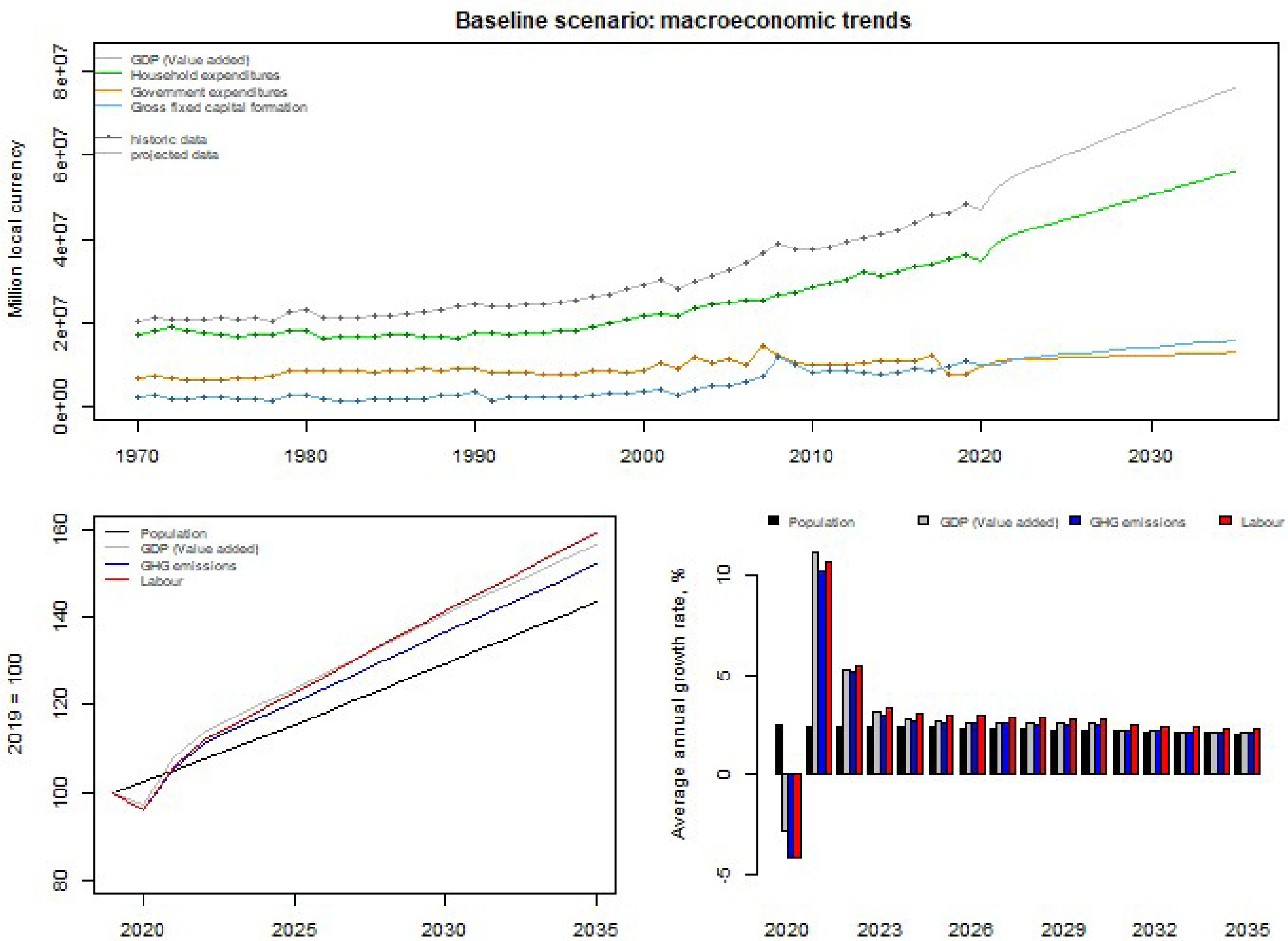
The economic structure (described by the market share matrix D, calculated from the 2019 supply table) and the technology coefficient matrix B (calculated from the 2019 use table) are kept constant for the years 2020-2030. This entails that the economy is assumed to have a static Leontief production function without technological change or any economies of scale or price effects. Import shares per product are constant. As there is no technological change or changes in the structure of primary inputs (value added components), prices are constant.

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

Since the technology coefficient matrix B is constant, the share of value added in total industry output is also constant. Value added per industry is then determined endogenously, by multiplying the value added in output shares with output per industry. Total GDP equals the sum over all industries' value added and is then used to determine the development of household consumption expenditures. Since both total value added/GDP and household consumption expenditures are endogenous to the model, they are not completely equal to the forecast, with a slightly lower growth rate in 2021 (8.0% compared to 9.0%) and a higher growth rate in 2022 (5.6% instead 3.3%) than in the OECD Economic Outlook (see lower right panel in Figure 13 for the model projections and the last row in Table 10 for the OECD Economic Outlook projections). These differences are for a large part driven by the changes for the export growth rate assumption to ensure model stability.

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

Figure 23 - Macroeconomic trends as per JTAM Madgascar for the Baseline scenario



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