POLITECNICO DI MILANO

School of Industrial and Information Engineering

Master of Science in Management Engineering

ENVIRONMENTAL IMPACT OF FUTURE ELECTRICITY GENERATION SCENARIOS IN THE UNITED REPUBLIC OF TANZANIA

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Executive Summary

For any economic system an important question is how to improve its economic growth. One main driver that has a very close relationship with it is the energy and the access the population and industries have to it. Due to this, a sustainable development of the energy sector is relevant for the economic growth of any country. To achieve this, development countries will need to make significant efforts in terms of policy making process to promote investment in renewable energies which at the same time will promote the reduction of the CO2 emissions. Countries of sub – Saharan Africa are between the countries that need to make significant policy efforts to maintain a stable growth of their economies, and more specifically improve the development of their energy sector.

The United Republic of Tanzania is one of those countries and they are currently working on energy policies which will lead to a more reliable and more sustainable electricity sector, in order to improve its industrial activities and the quality of life of its population.

Tanzania's economy has been experiencing a stable growth in the last years, around the 6.7% a year between the years 2000 and 2012. And the poverty indicator, in terms of the share of population living below the basic needs line, has decline from 35% to 33%, between the 2001 and 2007.

Even though energy is relevant for the development of an economy, today there is still a significant number of people with a lack of energy supply, more specifically electricity access (64% of the population). One main factor of this situation is related to the low efficiency in the electricity infrastructure at all the stages of the supply chain (generation, transmission and distribution). To start solving this, the government formulated its first Energy Policy in 1992, which in 2015 was then reviewed to allow a liberalization of the sector and it defined new challenges to overcome it.

These new challenges which are in the long – term, is to achieve an efficient and reliable electricity infrastructure in all stages of the supply chain, efficient end-user systems oriented to a sustainable socio-economic development and by this supporting the national development goals (Tanzania National Bureau of Statistics, 2017).

The demand of primary energy evidences the country's high energy intensity of households, who use biomass mainly for cooking or heating purposes, and this situation reflects the underdevelopment of the industrial and manufacturing sector.

The per capita electricity demand in Tanzania is considerably low, 104.79 kWh per year in 2014, in comparison with the Sub – Saharan Africa's average and is less than half of the low – income countries consumption. However, this situation is changing due to the investment on the productive activities which is starting to increase. According to the Power Sector Master Plan of Tanzania, the target of the government in the load demand is to reach an electrification status around the 75% by 2035 and they expect that the demand from connected users grow according to the growth of the middle – income status (Ministry of Energy and Minerals, 2016).

In terms of electricity generation, the main source used for production is the hydropower, thanks to the natural conditions of the country. However, this technology has lost some share in the generation mix between 2002 and 2006, from 98% to 40% (African Development Bank Group, 2015),

the main reason of this has been the presence of some droughts that the country has faced in that period.

During these draughts, the reservoirs' levels reached very low levels which were not enough to produce electricity. To cope with this situation, TANESCO (the national Transmission System Operator) started to buy the lack of electricity form private thermal generators, an action that generated high costs to the system due to the importation of the fossil fuels needed. After these critical situations for the electricity sector, the government decided to take actions to not relay the electricity generation on one single resource and increase the concern on diversifying the generation mix according to the domestic resources.

The renewable energy offers technology solutions with variable cost-effective options to improve the rate of energy access by a decentralized (off-grid) systems, which is an optimal solution for rural and remote areas. Furthermore, Tanzania for its topographic characteristics is a country with a high potential on renewable resources, like wind, solar, hydropower, geothermal and biomass.

Therefore, this study has the objective to estimate the economic and environmental impact of introducing a more diversified electricity generation mix, with renewable resources in The United Republic of Tanzania. To achieve this and following previous methodologies, an economic modelling approach of Input -Output with hybrid units is purposed and is run under different scenarios with different energy mixes composed by hydropower, solar, wind and biomass for a window of time from 2015 till 2030.

The Input – Output (IO) analysis for energy purposes helps to understand the flows of energy in the economy, according to the total energy required to produce all the outputs to meet the final demand. The method of an IO model has a simple structure of representation of an economy and it provides a convenient way to estimate the relationship between energy use and the economic activities.

To estimate the results, three different scenarios were purposed which are:

1. Business as Usual: This scenario is characterized by a non-modification of the already implemented energy policies of the country to recreate the current energy situation, in other words is a scenario with an energy mix that will keep a similar structure for the upcoming future. The main purpose of this scenario is to define a base case to use it as a benchmark with the other ones.
2. 450 Tanzania: This scenario is defined in the "World Energy Outlook" done by the IEA. The main idea is to establish an energy guideline to achieve the goal of limiting the increase of the global temperature in 2°C by limiting the greenhouse gases emissions to the atmosphere, around 450 parts per million (ppm) of CO_2. The key purpose is to change the energy mix heavily dependent of polluting fuels to renewables, like solar and wind, and by this achieving the agreements settled in Paris in 2015 with the COP21.
3. New Policies: This scenario is a representation of the current situation of the country, on a regulatory point of view and the implementation of new policies that are planned in the future for the energy sector. The aim of this scenario is to forecast the government's view for the development of the energy sector.

With the obtained results of the IO model, is evident to see that in all scenarios the most energy intensive sectors are: electricity and transport. This allows to see that the electricity sector, is not the only sector that will need to have an intervention in order to reduce the environmental impact of the production of the economy.

As is showed in the following graphs, the 450TZ and the NP scenario achieve a renewable energy penetration if 52% and 42% in 2030, due to the application of the new policies and the increase on the investment on these technologies. This higher rate of penetration of renewable sources leads to a change in the primary energy use for the total production of the economy.

The most energy intensive scenario is the business as usual due to the fact that the renewable penetration remains constant, around the 30% for all the time horizon. On the other hand, the other two scenarios have a reduction on their primary energy use, due to an average renewable penetration rate of 43% and a 39% for the 450TZ and the NP correspondingly. As a result of these higher rates, the 450TZ achieved by 2030 a reduction on 10% in relation to the value for the same year of the BAU scenario; in the case of the NP scenario the reduction achieved by 2030 in relation with the BAU was 6%.

The primary energy use for the electricity sector represents around the 30% of the total primary energy use of the country. However, for the increased rate of renewables this share reduces to 27% and 28% for the 450TZ and the NP scenarios correspondingly. In terms of the total reduction in relation to the BAU scenario, for the 450TZ the reduction by 2030 is 5,065 ktoe which is a reduction of the 32%; and for the NP scenario the reduction by 2030 is 2,908 ktoe which is 19% reduction in comparison with the level of the BAU.

This situation changes for the other sectors of the economy, the level of reduction of the two scenarios in relation to the BAU are significantly lower. In the case of the 450TZ the reduction of the use of primary energy is 107 ktoe that is a reduction of 0.3%; and for the NP the reduction is 57 ktoe that is a 0.2% reduction by 2030.

With these results is possible to say that the efforts for reducing the energy intensity of the electricity sector are effective and they promote a reduction of the environmental impact of its activity for meeting their final demand, by having a lower consumption of fossil fuels. However, it would be important to target the other sector of the economy with other type of measures, like energy efficiency, to achieve a more significant reduction on the impact, because they represent the other 70% of the primary energy demand that is meanly concentrated in the transport sector, which is a sector with a high demand of fossil fuels that makes it an energy intensive sector.

One important aspect of the climate change policies for any economy is to separate its climate change impact from its economic growth. For this reason, is relevant to see if the unitary consumption of primary energy is or is not connected the growth of the GDP. After the year 2015 the unitary primary energy consumption starts to decrease, by an average rate of 6% for the 450TZ scenario and 4.5% for the NP one. This reduction of the unitary consumption in comparison with the growth of the GDP are the evidence to show that the policies considered to develop a cleaner electricity sector have a positive impact on separating the economic growth of the country from its energy intensity for polluting fuels. For the BU scenario, the unitary primary energy consumption remains constant with respect to the growth of the GDP, because there is no change on the sources of the electricity product mix.

According to the previous results, the actions taken on each purpose scenario are effective on promoting a more varied and sustainable electricity generation mix. But is the level of reduction according to the investment done in renewable technologies? To have an answer to this question, a ratio between the unitary primary energy consumption and the electricity produce was calculated. According to the results, both scenarios (450TZ and NP) show similar level of effectiveness on the investment between 2013-2020 with a positive result to make the investment. However, after 2020 the investing on renewable shows a very low impact on the reduction of the primary energy consumption. This could mean that after 2020 the investment could be better allocated to another energy intensive activities of other sectors. One of this is the transport sector, that represents the 58% of the primary energy consumption of Tanzania.

On the other hand, the greenhouse gases emissions related to combustion of oil were taken into consideration as well for the analysis. In this case, the variation of the emissions of the total production of the economic system had just a small difference between all the scenarios. In comparison with the BAU, the 450TZ shows a reduction of 2% while the NP shows a reduction of 1%. The reason behind this result is that the emissions for oil combustion are concentrated in the transport sector, with a share of the 68% of the total, while the electricity sector represent around the 7%. Due to this, it was analysed the emission of the electricity sector apart from the rest of the economic systems, in order to see the impact of the renewable penetration on the electricity production.

On the obtained results, that were compared with the economic growth, show that the penetration of the renewable resources helps to decarbonizing the electricity sector and detached it from the growth of the GDP. In the 450TZ scenario the average reduction of the emissions with respect to the BAU scenario, is around 27%. In the NP scenario, the results can be seen as a medium scenario, with an average reduction of 15% in comparison with the BAU.

In summary, introducing renewable energy in the economic system of Tanzania has a positive impact in terms of its environmental impact. Additional to this, there are some other positive impacts of investing on these technologies like the diversification of the electricity generation mix and the improvement on the energy access rate of the country. By the diversification of the electricity generation mix, the country reduces the risk of blackouts for the unpredictability of hydropower generation due to the changing rainfall patterns and recent droughts that the system has faced. The access to modern energy services has a crucial role on improving the manufacturing production, the income generation by household and the education level of an economy, however for a country like Tanzania this mean a very high investment to improve its grid network to arrive on a reliable way to all the population; for this reason investing on renewables allows them to have less costly, fast and off-grid solutions to improve their development and at the same time allowing them to start thinking on other sustainable solutions for other sectors of the economy.

1. Introduction

A key aspect for any economy is its economic growth and how it can be improved. One main driver that has a very close relationship with it is the energy and the access its population and industries have to it. For this strong relationship, energy and more precisely electricity, has become an essential factor for human development and thrive, and has been adopted as one of the goals of the new United Nations Sustainable Development Goals (SDGs), which have established to ensure affordable, reliable, sustainable and modern energy for all by 2030 (International Energy Agency - IEA, 2018).

There have been significant efforts from developing countries to reduce their energy poverty[1] conditions, however by 2016 1.1 billion people are still without access to electricity according to the data of the International Energy Agency – IEA. In the case of the Asian countries, India has reached 89% of the electrification rate while China reached by 2015 its full electrification. On the other hand, the sub-Saharan countries in Africa, despite the significant progress in this region over the last couple of year, the current rate of electrification is 43%. However, it is worth to notice that while some of the countries are on track to reach universal electricity access by 2030, in some other cases, the electrification rate goes at a slower pace than the population growth.

In the case of the sub-Saharan countries, one of the main barriers to access of electricity is the lack of infrastructure to reach rural population, which is something that will require a big investment. One way to overcome this barrier is to go with a decentralized solution which means to invest in off-grid power plants and renewable energy sources technologies (RES). Nevertheless, these solutions faced some constrained to be exploited. The found constrains are: a) institutional and regulatory framework in order to promote the investment, like incentives mechanisms to make a balance between costs and benefits; b) knowledge and capacity, as until now there is limited information about the potential to exploit different renewable resources; and c) economic and financial instruments, as investing on renewables requites a high capital cost and the banks in these regions have just limited experience with the financing of this type of projects (African Development Bank Group, 2015).

Even though these barriers are not easy to overcome for developing economies, the sub-Saharan countries have done some efforts in order to develop their energy sector and to adopt renewable technologies to tackle the energy access problem. Additional to this, renewables can bring benefits to their countries not only on the economic factor, being by now competitive with fossil fuels but giving social and environmental benefits as well.

1.1. Literature Review

The relationship between economic growth, energy consumption and environmental quality has caught the attention of academics and policy makers for a long time, because by understanding this

[1] Energy poverty: lack, scarcity or difficulty in accessing modern energy services by households, in particular it refers to the access of electricity and to modern and clean cooking facilities (Fondazione ENI Enrico Mattei, 2016).

linkage new policies are more consistent with the objectives on achieving a more sustainable economic development. According to the findings of the study of (Keho, 2015) the economic development, industrial output and the population have a positive effect or a straight relationship with the energy consumption in the majority of the sub – Saharan African countries analysed. And since these countries have a trend of increasing its population and its urbanization rate, there is an increase interest to start addressing climate change by starting with the adoption of new policies to improve energy efficiency and accelerate the transition toward renewable energy. This renewable energy transition of African countries, apart from reducing the environmental impact, can bring social benefits by increasing their access to clean forms of energy in a reliable, affordable and rapid way that at the end will help to improve the living standards of the population.

However, the sub – Saharan countries has the lowest human development index in the world, a situation that puts the economic development as a priority in order to achieve the goals on reduction of poverty levels. To follow an ideal path for the economic development, these countries must follow sustainable principles otherwise the outcomes will not be the optimal ones, like an increase on CO2 emissions. To study different development scenarios (Hamilton & Kelly, 2017) purpose five different ones for five large economies of the sub – Saharan Africa, to estimate the environmental impact of the modernization electricity production according to the growth of the GDP, availability of resources, international trade and the development of distributed generation for remote locations. The methodology they used for the analysis is a Multi – Regional Input – Output Model for Africa and the results shown that the five countries by achieving the forecasted GDP and the full access to modern energy service in 2030, will not be able to reduce the CO2 emissions by that year below 2012 levels. This situation is explained by the modernization of the off – grid, that will require an increase in primary energy supply, but the total regional CO2 emissions have a potential reduction from 45% to 35% by meeting a 50%renewable energy supply target in 2030. As a main conclusion to achieve a more sustainable economic development, (Hamilton & Kelly, 2017) suggest that climate change policy has to be address on a multi-sectoral form, due to the high share of agricultural activities in the CO2 emissions.

To have a more precise analysis of the role of the renewable energies in the economy is important to consider and inter – sectoral analysis of the economy. In the study developed by (Nakano, Arabi, & Ayu, 2017), they developed an input – output table for a next generation energy system that included new sectors related to the renewable energies to evaluate the effect of introducing renewable energies in each region of Japan. With this model, they estimated the CO2 reduction related to the decline in the production of conventional electricity production, where the use of residential solar power in metropolitan areas and in rural specific location have a relevant role for the CO2 emission reduction. Additional to these results, one of their main conclusions is that analyses using an inter – regional or inter – sectoral input -output table will be a useful analytical toll for studying the effective use of renewable energy with facilities that are already installed or will be installed in the future.

The life cycle assessment methodology is meanly use when it comes to estimate the environmental impact of the products. To address climate change mitigation is important to start demanding for a change in the technology use to produce final product, which in this case is production of electricity with more renewable energies. (Gibson, et al., 2015) developed a modelling framework of an integrated hybrid life cycle assessment databases and multiregional input – output tables to forecast the change in technology and resources related to solar power production up to the year 2050. They found that the obtained results were relevant, regarding CO_2 emissions per kWh were reduced across different world regions, from 33 to 95 gCO_2 eq./kWh in 2010 to 30 – 87 gCO_2 eq./kWh in 2050. As a conclusion they saw that this model with a life cycle assessment approach is essential to understand the various environmental impacts of mature developing technologies, more specifically for the electricity generation as is an input to every sector of an economy.

In order to apply a life cycle assessment analysis there is the chance of missing information about the production process of the sectors in the Input – Output tables, this is a limitation of the methodology and can increase the uncertainty of the results. One way to address this limitation is by disaggregating the economic data, a methodology to achieve this was developed in the study of (Linder, Legault, & Guan, 2013). They purpose a methodology to disaggregate the electricity sector of the Chinese 2007 Input – Output table into new sectors, which included all the power generation technologies, transmission and distribution. With the disaggregated sector, they could estimate more detailed embodied emissions of greenhouse gases related to the electricity production.

Another study related the interaction of the energy sector with the economic flows of the other sectors of an economy is the one developed by (Rocco, Rady, & Colombo). This study had the objective to assess the economic and the environmental impact of the governmental perspective of the electricity sector in the Egyptian economy by liking two models, one bottom – up (OSeMOSYS) with a top – down (Input – Output model). The results were positive in terms of reduction on primary energy consumption and greenhouse gases emissions for the following years regarding the electricity sector but considering the other economic sectors the results were the opposite. As a conclusion, there is a need to take into consideration energy efficiency methods on the Egyptian economy.

One additional aspect to take into consideration for an environmental impact analysis is to see the relationship between the CO_2 emissions, renewable and non – renewable energy consumption with the economic growth. This relationship we studied by (Ito, 2017), who analysed the data of 42 countries over a period from 2002-2011. With the obtained results he concluded that the renewable energy consumption contributed to the reduction in CO_2 emissions and have a positive effect on the economic growth in the long term, while the consumption of non – renewable energy has a negative impact on the economic growth. Due to this, he suggests that policy makers in developing countries should make efforts to promote the investment in the renewable energy sector by incentives and taxation to fossil fuels, to promote self-reliance and generating a sustainable economic growth.

1.2. Study Objectives

As previously stated, the development of the energy sector in a sustainable way is relevant for the economic growth of a country. To achieve this, the development countries will need to make significant efforts in terms of policy making process to promote investment in renewable energies which at the same time will promote the reduction of the CO_2 emissions. The countries of sub – Saharan Africa are between the countries that need to make important policy efforts to maintain a stable growth of their economies, and more specifically improve the development of their energy sector.

The United Republic of Tanzania is one of those countries and they are currently working on energy policies which will lead to a more reliable and more sustainable electricity sector, in order to improve its industrial activities and the quality of life of its population. Thus, this study has the objective to estimate the economic and environmental impact of introducing a more diversified electricity generation mix, with renewable resources in The United Republic of Tanzania. To achieve this and followed previous methodologies, an economic modelling approach of Input -Output with hybrid units is purposed and is run under two different scenarios with different energy mixes composed by hydropower, solar, wind and biomass for a window of time from 2015 till 2030.

In order to see the effect of the purposed electricity generation mixes, this study analyses what is the impact on the primary energy intensity of the country, the greenhouse gasses emissions related to oil combustion and the relationship with the investment and the production of the economy.

1.3. Document Structure

The document is structured in the following sections: first, there is description of the current energy situation in Tanzania, more oriented into the electricity sector; second, there is a description of the alternatives and opportunities the country has in order to improve its rate on the energy access to its population; third, there is a description of the methodology followed to fulfil the analysis, the Input – Output model and its characteristics; forth, is a description of the data used and the scenario proposition for the case study; fifth, the results for each scenario and a comparison among them will be shown; lastly, it will be shown the conclusions of the whole study and some possible propositions for future studies.

2. Current Situation of the Energy Sector in Tanzania

The United Republic of Tanzania is located in eastern Africa (Figure 1), which gives to it a tropical climate that can varied according to the topographic characteristics. For this reason, the country has diverse ecosystems and climates. Due to this, there is abundant natural resources, which are vulnerable to climate change and extreme weather events. However, the county has a low emission rate of CO2 at a world-wide level, around 0.2 metric tonnes per capita in 2014[2] which is 4% and is lower than the average rate of the low-income countries (0.3) (International Renewable Energy Agency - IRENA, 2017).

Figure 1. Political map of Africa.

The population of Tanzania is around 44.9 million people, according to the survey of 2012 done by the National Bureau of Statistics[3], where most of the people, three-fourths, is located on rural areas and only 12% have access to electricity.

On the other side, its economy has been experiencing a stable growth in the last years, around the 6.7% a year between the years 2000 and 2012. And the poverty indicator, in terms of the share of

[2] Emissions per capita in 2014: Total world emissions of CO2 in 2014 were 4.97 metric tons per capita (World Bank data). https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?name_desc=true
[3] http://www.nbs.go.tz/

population living below the basic needs line, has decline from 35% to 33%, between the 2001 and 2007.

Is important to mention that the Tanzanian economy is meanly based on the service sector, with the tourism, that represents around half of the GDP. In second place is the Agriculture, that accounts around one quarter of the GDP. To increase the income of these sectors to the country, the role of energy is relevant. For example, in the case of the service sector, access to energy improves the services provided by health centres, schools, water pumping systems and telecommunications; by making them more reliable. On the case of the agricultural sector the government is planning to increase the investment in power generation with renewables to make the sector more productive by reduce the dependency on human activities.

However, the plan of the country in the short and medium – term is to sustain the economic growth with the development of the private sector with a focus of a diversified and semi – industrialized economy. Additionally, the mining sector is significantly underdeveloped and there is a plan for its development, which will lead to an increased in the energy demand and at the same time, that will contribute to the economic growth of the country (African Development Bank Group, 2015).

Even though energy is relevant for the development of an economy, today there is still a significant number of people with a lack of energy supply, more specifically electricity access (64% of the population). Due to this, the government knows they need to make a dramatic transformation to improve their economy, and even more because despite the growing economy the energy sector has not achieved a growth rate at the same level of the Least Developed Countries, with an annual rate around the 6% that is less than half of those other countries.

One main factor of this situation is related to the low efficiency in the electricity infrastructure at all the stages of the supply chain (generation, transmission and distribution). To start solving this, the government formulated its first Energy Policy in 1992, which in 2015 was then reviewed to allow a liberalization of the sector and to define how to cope with new challenges.

These new challenges which are in the long – term, is to achieve an efficient and reliable electricity infrastructure in all stages of the supply chain, efficient end-user systems oriented to a sustainable socio-economic development and by this supporting the national development goals (Tanzania National Bureau of Statistics, 2017).

2.1. Primary Energy Supply

In the last couple of years, the main idea of the government is to change their economy from an agricultural one to a more industrialized one, something that had started to increase the demand of the primary energy sources. In Figure 2, is shown the country's consumption of all primary energy sources and is evident that biomass is the dominant one.

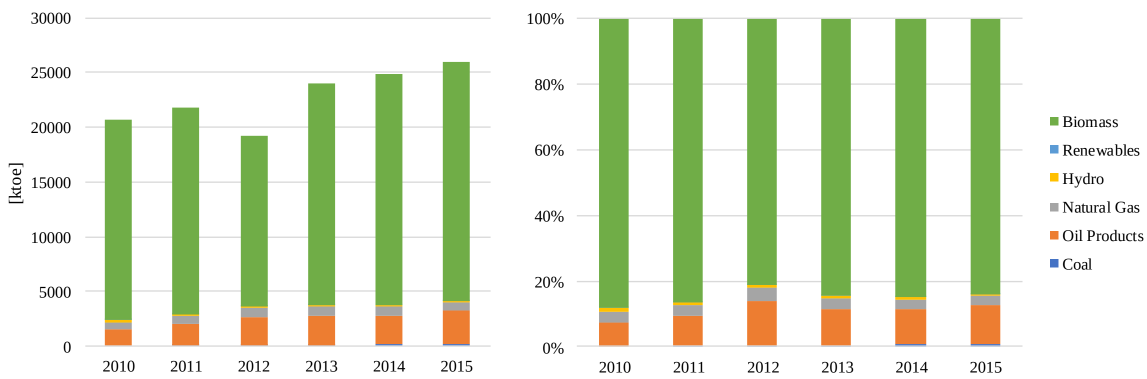

Figure 2. Consumption and shares of total primary energy in Tanzania. Source: IEA.

One key aspect that is worth to mention, is that this structure of the demand of primary energy evidences the country's high energy intensity of households, who use biomass mainly for cooking or heating purposes, and this situation reflects the underdevelopment of the industrial and manufacturing sector. Additionally, this high consumption of the household is also related to the technology and its low efficiency.

On the other hand, the oil products which are meanly used by the transport and electricity generation sector, are primary energy sources that have to be imported and represent a very high cost for the county's economy, which correspond to the 25% of the total imports.

However, an important thing to take into account is that with an appropriate planning, Tanzania has the potential to cover all their primary energy demand and at the same time it has the potential to make the country a middle income one, due to its richness in natural resources (International Renewable Energy Agency - IRENA, 2017).

2.2. Power Sector

At the regulatory and policy level, there are two entities who defines the rules for the power sector. Which are, the Ministry of Energy and Minerals (MEM) and the Energy and Water Utility Regulatory Authority (EWURA). The MEM, is in charge to formulate and review the government policies and the EWURA, is in charge for define and implement the technical and economic regulation.

Before 2015 all the activities of the supply chain were operated by the national utility company, Tanzania Electric Supply Company Limited (TANESCO). But the country has faced lately extensive drought that had lead to blackouts and made evident the need to increase the investment in the electricity sector, in order to increase the installed capacity and its reliability. For this reason, after 2015, there government decided to establish a liberalization of the market. Nowadays, the industry operates on a single buyer model market. The structure for this operating model is composed by the following activities: electricity generation, transmission, distributors and final customers.

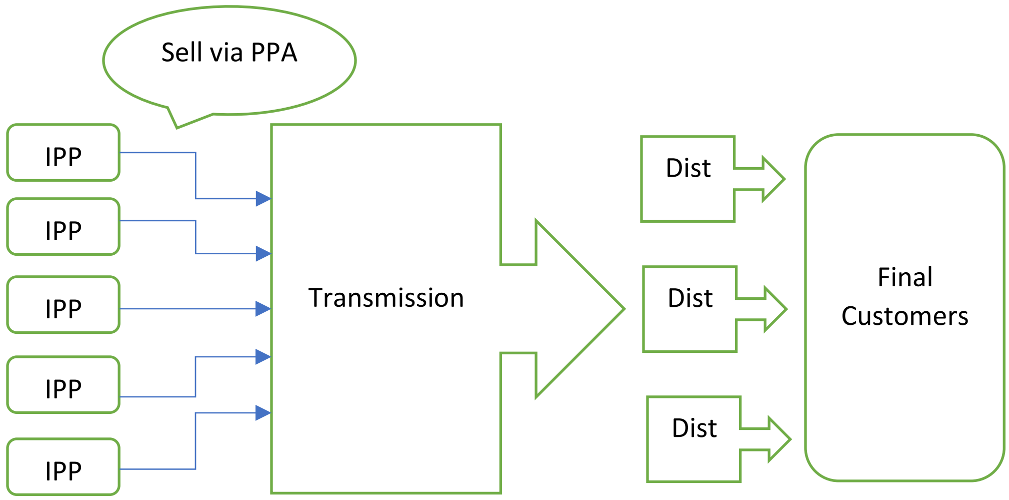

Figure 3. Single buyer model operating structure of the Electricity market.

As shown in Figure 3, there is the competition in the generation activity, that can be called as Independent Power Producers (IPP), who then sell their electricity production to a one single buyer which is TANESCO, via Power Purchase Agreements (PPA), and is in charge to transmit the electricity to local distributors and these agents are in charge to serve the final customers. TANESCO is now only in charge to operate the main grid and the distribution networks, as a monopoly, which covers the large urban centres and for the rural areas it counts with some mini grids (Figure 4).

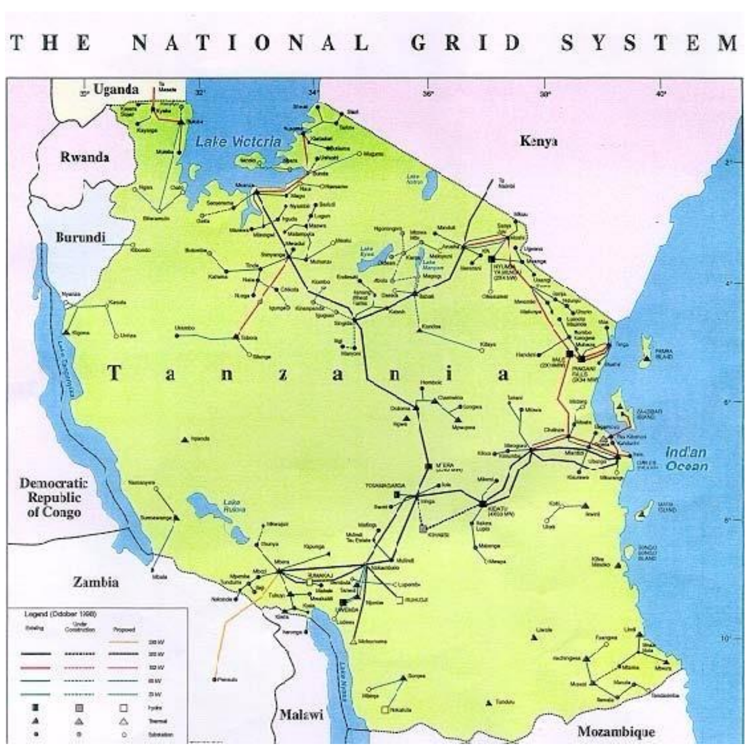

Figure 4. Tanzania's national electricity grid. Source: GENI: Global Energy Network Institute.

Apart from the IPP there are other type of agents, which are, the Emergency Power Producers (EPP) and the Small Power Producers (SPP). These SPPs, normally are located in rural areas and are supported by an entity called, the Rural Energy Agency (REA) which is an autonomous body under the MEM responsibility. The main task of the RAE is to facilitate the process to improve the level of energy access by providing training activities, financial programs and proposition of new energy projects in the community. On the other hand, the EPP are generators that providers of ancillary service and they have a direct contract with TANESCO, in order to maintain the stability and security of the grid by providing frequency control, spinning reserve and operating reserves.

This market system is mainly applied in developing countries where the high growth rate requires new generation capacity and large infrastructure investment. By this structure of the market, the government increase the private investment in this sector and reduce the shortage vulnerability.

Despite this initiative of liberalization of the market, a big share of the generation (98%), transmission and distribution of the electricity is still managed by the public utility, TANESCO, which is still fully owned by the government (Tanzania Invest, 2016) and makes interference between private operators and electricity customers.

The Tanzanian government is working on a reform to gradually change from a single buyer model to a retail competition market, by unbundling TANESCO. To do this, the government of Tanzania has developed a roadmap, that starts in 2014 till 2025 (Ministry of Energy and Minerals of Tanzania, 2014). In this model the generators will be able to compete by selling directly to retailers and final customers, and therefore the customers can choose their own provider of the service.

2.2.1. Description of Electricity Demand

The per capita electricity demand in Tanzania is considerably low, 104.79 kWh per year in 2014, in comparison with the Sub – Saharan Africa’s average and is less than half of the low – income countries consumption. However, this situation is changing due to the investment on the productive activities which is starting to increase.

According to the Power Sector Master Plan of Tanzania, the target of the government in the load demand is to reach an electrification status around the 75% by 2035 and they expect that the demand from connected users grow according to the growth of the middle – income status (Ministry of Energy and Minerals, 2016).

Additionally, TANESCO expects a high demand growth due to investment on mining activity, liquified natural gas plants, factories and water supply schemes. These activities are expected to change the demand peak of 1,000 MW of 2013 to around 4,700 MW in 2015 and 7,400 MW by 2035 (African Development Bank Group, 2015).

2.2.2. Description of the Electricity Generation

By 2013 Tanzania has an installed capacity of 1,564 MW, of which 1,438.24 MW corresponds to capacity connected to the main grid and 125.9 MW corresponds to small power producers, mini grids and imports (African Development Bank Group, 2015).

The installed capacity mix is described in the Figure 5:

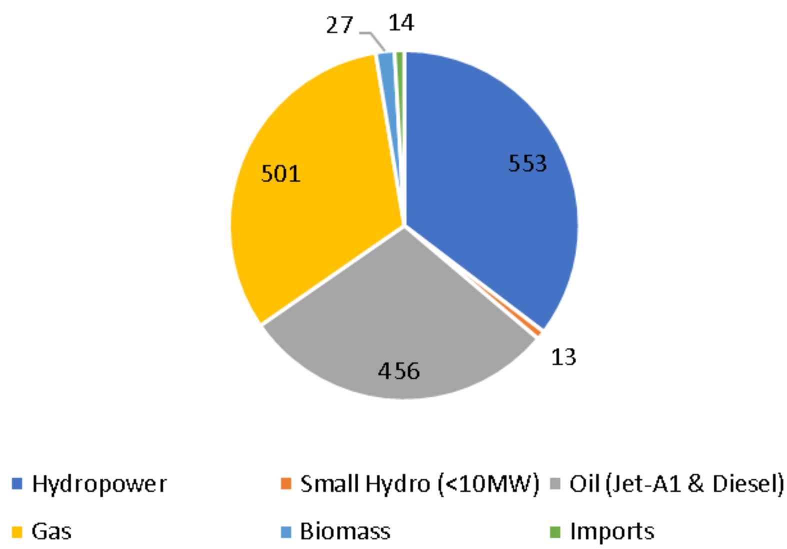

Figure 5. Tanzania's installed capacity mix in MW. Source: (African Development Bank Group, 2015)

As seen in the figure, the installed capacity is meanly thermoelectric (Gas and Oil), that corresponds to a 61% of the total capacity, and in second place is the hydroelectric technology, with a 36%.

Additional to this, most of the supply of electricity is provided by TANESCO, while the independent power producers are in the second place, who have to sell all their production to TANESCO. In Table 1 there is a detailed description of the installed capacity by providers and technology.

Source	TANESCO	IPP	EPP	SPP	Total	Percentage
Hydropower	553	-	-	-	553	35%
Small Hydro (<10MW)	9	-	-	4	13	1%
Oil (Jet-A1 & Diesel)	88	163	205	-	456	29%
Gas	252	249	-	-	501	32%
Biomass	-	-	-	27	27	2%
Imports	14	-	-	-	14	1%
Total	916	412	205	31	1,564	100%
Percentage	59%	26%	13%	2%	100%	

Table 1. Detail description of installed capacity mix of Tanzania in MW. Source: (African Development Bank Group, 2015). Note: IPP = Independent Power Producer, EPP = Emergency Power Producer, SPP = Small Power Producer.

In terms of electricity generation, the main source used for production is the hydropower, thanks to the natural conditions of the country. However, this technology has lost some share in the generation mix between 2002 and 2006, from 98% to 40% (African Development Bank Group, 2015), the main reason of this has been the presence of some droughts that the country has faced in that period.

During these draughts, the reservoirs' levels reached very low levels which were not enough to produce electricity. To cope with this situation, TANESCO started to buy the lack of electricity form private thermal generators, an action that generated high costs to the system due to the importation of the fossil fuels needed. According to the calculations done by the World Bank, this increase in thermal generation generated a cost around the 67 million USD between 2004 and 2005

(Vigone & Miserocchi, 2017). Additional to this situation and two years later, another very critical situation generated more additional costs to the system, 1.7 million USD per day per day, due to a rationing.

After these critical situations for the electricity sector, the government decided to take actions to not relay the electricity generation on one single resource and increase the concern on diversifying the generation mix according to the domestic resources.

3. Alternatives for Energy Access

Almost half of the population in Tanzania are living under poverty conditions and around the 35% of this population has no access to the basic needs, of which energy is one of them. This lack of modern energy services limits the efficiency of production and the opportunities for them to have better social facilities, and do not allow to overcome the poverty condition which can be seen as a vicious cycle, due to the cost of connection fees and investment for a better infrastructure (Energypedia, 2018). In other words, energy access is a barrier for the socio – economic development of a nation.

3.1. Potential and Technology solutions

The renewable energy offers technology solutions with variable cost-effective options to improve the rate of energy access by a decentralized (off-grid) systems, which is an optimal solution for rural and remote areas.

Tanzania for its topographic characteristics is a country with a high potential on renewable resources, like wind, solar, hydropower, geothermal and biomass. In this section it will be described the potentials on each of these resources.

3.1.1. Large and Small Hydropower

The total potential of hydropower capacity is around 4,700 MW, but until 2014 the country has just built 561 MW (International Renewable Energy Agency - IRENA, 2017). The reason behind this slow development to exploit this resource is the geographical location of the new projects, which are far away from the demand centres. However, this resource could play a significant role as a backup for other technologies, like other renewables, due to the water abundance that the country has or as well provide the electricity in peak hours during periods of rainy seasons.

The government has knowledge of this situation and for this reason, on the Electricity Supply Roadmap (Ministry of Energy and Minerals of Tanzania, 2014) they have developed for 2025, the target is to build 1,529 MW of installed capacity that will be developed with large hydropower project.

On the case for small hydropower plants, there is a potential of 480 MW and until 2014 there is only 15 MW of already installed capacity connected to the grid. There are other off-grid plants installed but are owned by private entities (Vigone & Miserocchi, 2017)

3.1.2. Geothermal

As said in (African Development Bank Group, 2015), Tanzania has a significant potential in the geothermal energy due to its location in the East African Rift System, however this potential has not yet been fully quantified. Some studies to identify the potential areas have been assessed since 1949 and until today, 50 potential sites have been identified which are located between three regions, these are:

- In the North: Kilimanjaro, Arusha and Mara region.
- In the South: Rukwa and Mbeya region
- In the East: The Rifiji Basin and Luhoi Spring site

In order to study and develop this technology, the government has formed an entity dedicated to it that is called, Tanzania Geothermal Development Company since 2013.

Figure 6. Region's location of geothermal potential projects. Source: IRENA (International Renewable Energy Agency - IRENA, 2017)

3.1.3. Wind

There are some regions in Tanzania with wind speeds between 6-8 m/s, more precisely in the Rift Valley and along the coastal areas, that gives a good potential to develop project with the wind generation technologies, however the exact potential of the country is still not well known (Vigone & Miserocchi, 2017) and there is the need for further investigations on this resource. There is one study under development by the World Bank, with the World Bank Energy Sector Management Assistance Program (ESMAP), that with satellite analysis showed high wind potential over more than 10% of the country (International Renewable Energy Agency - IRENA, 2017) but the results still have to be validated.

Currently there is an ongoing project of 100 MW, that is the first to be built in the Singida region that is located in the centre of the country.

3.1.4. Solar

The centre of the country is the area with the most significant potential for this technology, that is called The High Plateau. The annual solar resource exceeds 5 kWh/m^2 per day, around the Lake Victoria basin and along the coast; on the more elevated areas, like Moshi, Arusha, Iringa and going to the south the insolation is more reduce, around the 4 kWh/m^2 per day during the cloudy season (International Renewable Energy Agency - IRENA, 2017). These characteristics show that Tanzania has a high potential for solar energy and is a suitable solution to access to modern energy systems in rural areas, due to the fact that it can work as a standalone plant.

According to a study conducted by the Division of Energy Systems Analysis at the Royal Technology of Sweden (KTH) for IRENA, Tanzania has a potential of 314.82 TWh for Concentrated Solar Power generation (CSP) and 388.04 TWh for PV Technology (Vigone & Miserocchi, 2017).

Currently, solar home systems and small-scale systems of PV technology represents the 75% of the installed capacity, the other 25% are PV systems for hotels, schools, health centres and government facilities. There still no PV systems connected to the grid but is a technology that is being analysed to be used as a substitute for thermal plants in mini-grids systems and there is the discussion of large scale projects to be studied (International Renewable Energy Agency - IRENA, 2017).

3.1.5. Biomass

This resource is the most used one of the renewable primary energy sources, in majority by households, public facilities and small – medium enterprise for cooking and heating purposes. But there is a significant problem behind the use of this resource, that is the emissions of CO2 and the depletion of more than 300 hectares of natural forest per day, for the annual consumption of charcoal.

Nevertheless, the biomass sources can be divided into: woody biomass and agro-forestry waste. In terms of agro – forestry, the country has a potential of 315 GWh/year which represents the 10% of the county's power generation. Nowadays, there are two companies that have an installed capacity of 4.5 MW (International Renewable Energy Agency - IRENA, 2017) and supply this energy to TANESCO.

3.2. Energy Policy

The government of Tanzania defined the official Energy Policy of the country in 1992, which has had some review processes to have a better orientation to meet the changed that during the years the country has faced in all sectors and to meet the goals of the country. The last revision was made in 2003, which had to purpose to promote a market mechanism with the main idea to create a more efficient energy sector; by developing more efficiently the local energy sources, improving the reliability and security of the energy, reducing deforestation and developing more human resources (Energypedia, 2018).

The documents that contain all the policy framework of the sector are briefly described as follows:

- **The National Energy Policy (NEP)**

Defines the regulatory framework in order to create the conditions to achieve a reliable, safe, efficient, environmental and cost – effective modern energy service for the country. To do this, it defines the strategies for the development of the sector with future projects of installed capacity, expansion of the transmission and distribution network and the developing of new alternatives for new energy sources, among other more. Additional from the strategies, it established the exploitation of primary energy sources like coal and gas, to reduce the dependency of the country on imported petroleum and start relying more on the local sources (Vigone & Miserocchi, 2017).

- **The Five-Year Development Plan 2017 – 2022 (5YDP)**: is the most recent document concerning new policy guidelines. The new purposed policies have the following main objective: a social and economic transformation with a lower international support and by increasing the private investment.
- Additional to this, another objective is to transform the country to be more industrialize, by improving the productivity with innovation and fostering economic integration. All this in hand with the electricity sector by promoting its development with more renewable sources.
- **The Electricity Supply Industry Strategy and Roadmap 2014 – 2025**: description of the financial, economic, technical and legal activities related to the sector, that are intended to be implemented in the short, medium and long term.

These documents by providing a legal and strategic framework for the sector, have the objective to improve the level of energy and electricity access with the incorporation of programmes in both, grid and off – grid technology solutions. All this to contribute to the growth of the national economy and improving the level of life of its population with a sustainable and environmental way. Additionally, looking for an energy independence from imports by relaying on local energy sources and diversifying the power energy mix.

Other main reason behind this is that through a more developed energy sector the country can achieve a more industrialized economy and increase the average income of the country, in other words a better socio – economic development.

4. Methodology Description for the Analysis

The Input – Output (IO) analysis for energy purposes helps to understand the flows of energy in the economy, according to the total energy required to produce all the outputs to meet the final demand. The method of an IO model has a simple structure of representation of an economy and it provides a convenient way to estimate the relationship between energy use and the economic activities.

In the following section there is a brief description of the methodology behind the IO model for energy analysis, which was implemented for this study.

4.1. The Input – Output Analysis

The Input – Output analysis is an analytical framework developed by the professor Wassily Leontief and the essence of this analysis is to do an interindustry analysis to see the interdependence of the industries of an economy (Ronald Miller, 2009).

The Leontief framework makes a relationship between the total outputs (x_i), of goods produced by the sector i to the sum of intermediate or interindustry consumption, (z), in the economy and an external final demand, (f). The main assumption of the model is that the flow from sector i to another sector j, which is the buyer, has a linear relationship to its total output.

$$x_i = \sum_{j=1}^{N} z_{ij} + f_i, \qquad for\ i = 1, \dots, N+1 \tag{1}$$

Where N is the total number of sectors of the economy and the equation (1) represents the production function of sector i to all other sectors for a period of one year. But to estimate the relationship of the input with its output, a ratio should be calculated and is called the technical coefficients a_{ij}, which is represented by the equation (2):

$$a_{ij} = \frac{z_{ij}}{x_j} \tag{2}$$

Replacing the equation (2) into the equation (1), is possible to be rewritten as:

$$x_i = j = \sum_{j=1}^{N} a_{ij} x_{ij} + f_j, \qquad for\ i = 1, \dots, N+1 \tag{3}$$

To represent a complete economy, this flows between all total sectors, N, can be better explain with a matrix form:

$$\mathbf{X} = \mathbf{AX} + \mathbf{f} \tag{4}$$

Or written on a better form:

$$\mathbf{f} = \mathbf{X} - \mathbf{AX} \rightarrow \mathbf{f} = \mathbf{X}(\mathbf{I} - \mathbf{A}) \quad (5)$$

The main idea is to know that according to a certain level of final demand, f, how much should be the total output of each sector to meet it? This means that f is known, and we would like to know x. To solve this the equation (5) can be written as:

$$\mathbf{X} = \mathbf{f}(\boldsymbol{I} - \boldsymbol{A})^{-1} \quad (6)$$

$$\text{where } (\boldsymbol{I} - \boldsymbol{A})^{-1} = \boldsymbol{L} \; (\boldsymbol{Total\ requirement\ matrix\ or\ Leontief\ inverse\ matrix})$$

4.2. The Hybrid Energy Input – Output Model

The IO model is originally developed with monetary units, but in order to perform an energy analysis is necessary to introduce physical units. The reason why is to estimate how much physical units are embodied by one unit of the total output.

Among the interindustry matrix, z, is included the energy industry represented by the equation (7):

$$\mathrm{g} = \mathrm{Ei} + \mathrm{h} \quad (7)$$

Where g is the total output of the energy sector, E represents the energy flows from the energy sector to all other sectors and h, is the energy produced to meet the final demand. The monetary values of this vector are then substituted by the physical units, like GWh, establishing the creation of the hybrid model system (Guevara & Domingos, 2016).

Since one of the objectives of this study is to estimate the impact of changing the installed capacity of the electricity generation mix it is necessary to disaggregate the energy sector, as it will be explained in the next section. Therefore, a first step to do and in order to have a better manipulation of the data, the energy row is placed at the bottom of the inter – industry matrix, like is showed in Figure 7.

Non-Energy Sectors	Energy sector	Final Demand Non-Energy	Total Output Non-Energy
Energy Sector	Energy sector	Final Demand Energy	Total Output Energy

Z: Interindustry Matrix **f: Final Demand** **x: Total Output**

Figure 7. Hybrid Input – Output model structure.

4.3. Disaggregation of the Energy Sector

One of the purposes of performing an energy analysis on an Input – Output model is to estimate the environmental impact due to the economic activity of the country. However, in this analysis is important to consider the level of aggregation of the sectors, because with the aggregation is possible to not see with more clarity the process with the highest environmental impact and by this there could be some missing information.

For this reason and to understand the environmental impact of the electricity sector is important to consider all resources used to generate one unit of electricity, because not all of them emit the same amount of greenhouse gases. For example, is understandable to think that the CO2 emissions from a kWh of a coal fired power station is much higher than the one produced by a natural gas power station (Linder, Legault, & Guan, 2013).

Therefore, in this section of the document it will be explained the process that it was carried out to disaggregate the electricity sector for the case of Tanzania following the methodology purposed by (Linder, Legault, & Guan, 2013).

The first step to start with the disaggregation process is to define the data required, which is:

- The Input – Output table of Tanzania
- Electricity generation mix, taken by the data base of the International Energy Agency – IEA and from the results of (Vigone & Miserocchi, 2017)
- National budget for each sector, taken from the data base the Ministry of Finance and Planning of Tanzania (Ministry of Finance and Planning of The United Republica of Tanzania , 2013-2015)
- Levelized cost of electricity, taken by the IEA publications (International Energy Agency, 2010)

Now with the needed data defined, is important to define the level of disaggregation. The electricity sector in the IO table is together with the water and natural gas one, so the goal is to disaggregate this sector into 8 new sectors which are: Water, Gas, Transmission & Distribution and 5 more electricity generation sources (oil, gas, biomass, hydro and solar). To make it clearer, each disaggregation level is described in the Figure 8.

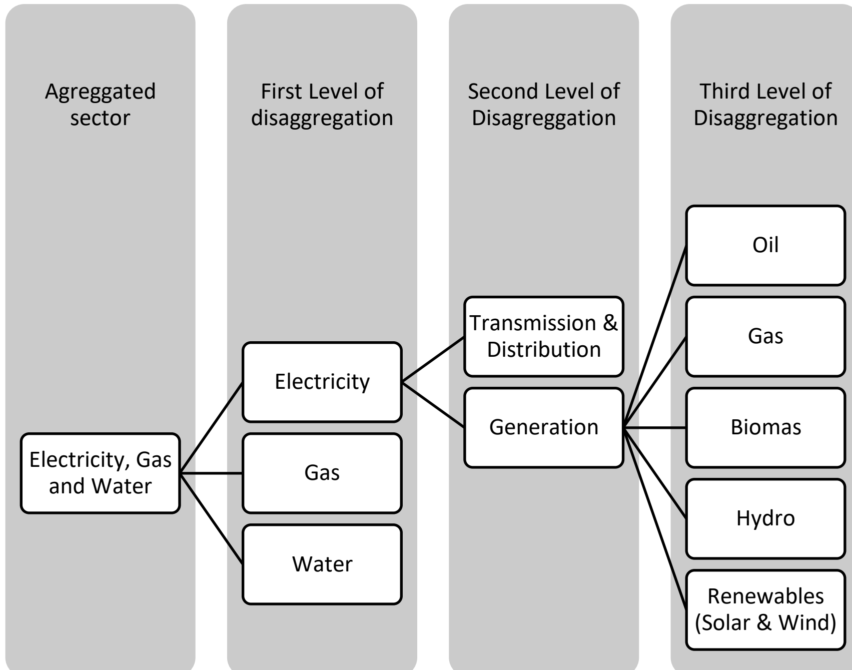

Figure 8.Levels of disaggregation of the Energy sector of the IO table of Tanzania.

At the beginning the IO table has an arrange of 26 sectors, then after the disaggregation process it becomes a matrix of 33 sectors which is shown in the Appendix 2.

4.3.1. First level of Disaggregation

The first level of disaggregation consists on splitting the energy sector into the electricity, gas and water sector. To do this, is necessary to adjust the inter – industry matrix according to the output proportion (production) of each of these sectors to the other common sectors and the other way around, according to the input (which is the monetary supply) from the other common sectors to the water, gas and electricity.

However, is not easy to find data related to the money supplied from common sectors to the electricity, gas or water sector and vice versa. Due to this, it was assumed that in order to estimate these monetary shares related to each sector it could be estimated according to the assigned budget given by the government to each of these sectors. This is a similar assumption taken in (Linder, Legault, & Guan, 2013).

The national budget taken into consideration for this data, was taken from the Citizens Budget of 2013 (Ministry of Finance and Planning of The United Republica of Tanzania , 2013-2015). The amount of money allocated for each sector is described in the section 5.

4.3.2. Second Level of Disaggregation

In the second level of disaggregation, the electricity sector will be divided into productions and transportation, which is generation of electricity and transmission & distribution. The methodology to get this result is the same one used in the previous level, according to the shares of the allocated budget by the government to each of these activities. This information can be found in the section 5.

4.3.3. Third Level of Disaggregation

In this level it will be disaggregated the electricity generation activity into the different sources for electricity generation, which are: oil, gas, biomass, hydro and renewables.

At this level the input from the common sectors and the output to the common sectors were taken into account separately, as it will be described in the following sections.

- Input from common sector to new disaggregated sectors:

  The methodology to estimate a proper proportion for the input to each of the new sectors according to the sources, is by understanding a way to define how the new sectors of the electricity sector purchase from each of the common sectors.

  According to the methodology purposed by Linder in (Linder, Legault, & Guan, 2013), the share for each new sector is estimated according to the weighted sum of the annual operation and maintenance (O&M) cost of the power plants. The reason why to use this cost, is doing the analogy of the allocation of the money received due to the operations of the plants, in other words an analogy on how the money is spent by each new sector.

  However, for the case of the Tanzania electricity sector and to do a similar approach as in (Linder, Legault, & Guan, 2013) instead of using the O&M it was used the levelized cost of electricity (LCOE) for each of the sources of generation, to estimate the revenues received for the operation of the power plants. The LCOE of each of the sources was taken from the "Projected cost of Generating Electricity" (International Energy Agency - IEA, 2010).

  With the levelized costs defined by the IEA for each source of generation, the total revenue of production for 2013 was estimated by source with their corresponding shares. These shares where the ones used to disaggregate the input from each common sector to the new sectors of this level of disaggregation.

- Output to common sectors from new disaggregated sectors:

  In this part of the disaggregation, there is an additional thing to consider apart from the shares of the output to each common sector, the introduction of physical units. Therefore, in this level of disaggregation it will be estimated the total amount of electricity in GWh is demanded by each common sector. The following steps will describe the process that it was taken to estimate the output of the new sectors.

1. The first step is to estimate the share of each common sector according to the total production of electricity in the IO table.

$$\%_{IO\ Table\ i} = \frac{Common\ Sector\ demand_i}{\sum_{i=1}^{n} Production\ of\ Electricity\ sector_i} \quad (8)$$

2. The second step is to estimate the share of each source used to produce electricity according to the total production of electricity with the data of the IEA, which are physical units (GWh) for 2013.

3. The last step is to substitute the money values with the physical values, on relation to the shares estimated in the two previous steps. As a result, the new IO table will be a hybrid unit table, due to the combination of monetary values and the physical ones, gotten from the IEA database. The process to calculate each value was the following:

$$Output\ value_{ixj} = \%_{IOtable\ i}\ x\ \%_{IEA\ -\ source\ j}\ x\ IEA\ Data\ (total\ production\ GWh) \quad (9)$$

- Construction of the intra sector matrix

  This matrix is constituted by the demand of the electricity sector to itself and in physical units. To get each of the values for each new sector of the disaggregation, it is necessary to multiply by the shares of the row(output) and columns (inputs).

$$Intra\ matrix\ Value_{ixj} = \%_{IOtable\ i}\ x\ \%_{IEA\ -\ source\ j}\ x\ \%_{LCOEi\ X}\ IEA\ Data\ (total\ production\ GWh) \quad (10)$$

After applying all the steps, the result is a hybrid IO table of 33x33, which is possible to find in the Appendix 2.

4.4. Shock Analysis

With the IO model is possible to estimate the effects of changes on the structure of the operation of the economic system. These changes can occur for two reasons: a) a change in the technology used in the production of the total output of the sector or b) a change in the consumption behaviour of the final demand.

Due to the structure of the IO model, the analysed changes can only be for the short run to use a long run estimation of the effect of the changes, is better use other types of models, like forecasting ones. The reason why, is due to according to the technical coefficient matrix which will be out of date as the changes progress over the years of analysis.

There are three types of shock analysis that can be applied to the model, these are:

- Shock 1: Change in final demand level or final demand trade patterns
- Shock 2: Change in production technology or endogenous trade patterns.
- Shock 3: Mixed case: change in final demand and production technology.

For this study, the shock applied is the shock 1 and the results obtained for this type of shock is showed as followed:

$$\Delta \mathrm{x} = x_1 - x_0 = L_0 \Delta ftot \tag{11}$$

Due that the only change is in the final demand, the technical coefficient, the Leontief and value-added coefficients remain constant because the technology, in terms of efficiency remain the same. However, the change in the final demand leads to a change and a new total production of the economic system for each additional year.

5. Case Study: The United Republic of Tanzania

This section of the document describes the data used to create the Input – Output model for the case study and the impacts implemented in the model in order to perform the energy analysis.

5.1. Model Settings Data

5.1.1. Input – Output Table Data

To build an Input – Output model there are available three major wold multi – regional databases, which are: World Input – Output Database (WIOD), EORA MRIO database and EXIOBASE. For this case study the database selected among these three was the EORA one, because it provides the data at an individual country level.

By downloading the Tanzania's information, one gets the yearly economic transactions of the country from 1970 till 2013, in two type of prices which are basic and purchasers prices. For this study, the interest is to make an analysis of the basic prices, which is the amount received by the producer from the purchaser, and to use the most recent data, we will work on the data of 2013.

The data is already structured as an input - output table, the representation of this table is shown in the Figure 9.

	Buying Sectors	**F**	**Destination**
Selling Sectors	Domestic Transactions (Z matrix)	Domestic Final demand of domestic goods	Exports
V	Primary Inputs (Value Added)		
Origin Country	Imports of Intermediate demand	Imported goods of Domestic FD	
R	Non - monetari inputs (exogenous transactions)	Emissions associated to domestic FD	

Figure 9. Data structure of the EORA database.

5.1.2. Hybrid Input – Output Table Data

To create the hybrid table for the energy analysis it was needed the physical units related to the energy source used to produce electricity. The official data base to get this information is in the data from the International Energy Agency – IEA, it provides all the information related to the energy sector related to balances, indicators, coal, oil, natural gas, renewables and electricity of all the countries.

The data used for this analysis is related to the electricity production of 2013 and it showed in the following table.

Primary Energy Source	GWh
Oil	1,276
Gas	2,912
Biofuels	21
Hydro	1,717
Solar	15
Total	**5,941**
Electricity Imports	59
Electricity Exports	0
Industry own use	15
Losses/statistical difference	1149
Final use	**4836**
Intermediate use (Industry)	1223
Final use (Residential, Comercial, Agricu	3613

Table 2. IEA data for Electricity production of Tanzania in 2013. Source: IEA.

5.1.3. Data for the Disaggregation of the Energy Sector

For the disaggregation process of the energy sector it was needed the investment done on each of the subsectors on each disaggregation level. The data used on this process was the allocated budget on 2013 by the government to the different sectors, as seen in the following tables.

Sector	Billions of Tanzania Shillings	Share [%]
Electricity	1055.8	56%
Gas	83	4%
Water	747.6	40%
Total	**1886.4**	**100%**

Table 3. Tanzania's Budget allocation of 2013 for the electricity, gas and water sectors. Source: (Ministry of Fincance, 2012)

As seen in the previous data, the budget in allocated for the gas sector is quite low due to the low development of infrastructure which is caused by a lack of interest in planning a major exploitation of this source (Vigone & Miserocchi, 2017).

Activity	Billions of Tanzania Shillings	Share [%]
Transmission & Distribution	399.8	38%
Generation/ Production	645.1	62%
Total	**1044.9**	**100%**

Table 4. Tanzania's Budget allocation of 2013 for transmission, distribution and production of electricity. Source: (Ministry of Fincance, 2012)

The previous data was used for the first and second level of disaggregation, but for the third level which concerns the different sources to produce electricity it was necessary to look for addition data, like the levelized cost of electricity (LCOE) and the shares of each source in the generation mix.

With the LCOE, it was calculated the revenues of the electricity sector according to the production of each source of energy in 2013. To do this, the data of the IEA of Table 2 was use and after this the shares of this revenues were calculated. The shares of each source to produce electricity and the revenues of the electricity sector, according to the LCOE are showed in the Table 5 and Table 6.

Primary Energy Source	Shares [%]
Oil	21.5%
Gas	49.0%
Biofuels	0.4%
Hydro	28.9%
Solar	0.3%

Table 5. Shares of each primary energy source for electricity production. Source: IEA

	Discounted rate		Total Revenue of prod.		Share of cost	
	5%	10%	5%	10%	5%	10%
Oil	393.24	396.62	501,774	506,087	64.4%	60.0%
Gas	83.85	94.84	244,171	276,174	31.3%	32.7%
Biomass	77.73	102.6	1,632	2,155	0.2%	0.3%
Hydro	17.41	33.13	29,893	56,884	3.8%	6.7%
Solar	122.86	186.54	1,843	2,798	0.2%	0.3%

Table 6. Levelized cost of electricity, in constant USD of 2010. Source: (International Energy Agency - IEA, 2010)

5.2. Scenario Proposition for Analysing the Environmental Impact of a more Renewable Energy Matrix

To analyse the impact of changing the electricity generation mix with more renewable energy technologies in Tanzania's economy, three different scenarios were defined according to (Vigone & Miserocchi, 2017). These are: 1) Business as Usual, 2) 450 Tanzania and 3) New Policies; which will be described in the following section.

5.2.1. Business as Usual Scenario

This scenario is characterized by a non-modification of the already implemented energy policies of the country to recreate the current energy situation, in other words is a scenario with an energy mix that will keep a similar structure for the upcoming future. The main purpose of this scenario is to define a base case to use it as a benchmark with the other ones.

The energy mix defined for this scenario is according to the results of (Vigone & Miserocchi, 2017), which shares are showed in the Table 7 for the period 2015 - 2030.

Source	2013	2015	2020	2025	2030
Oil	62.2%	21.9%	25.9%	26.7%	26.8%
Gas	32.0%	43.9%	42.7%	42.2%	42.2%
Biomass	0.2%	0.3%	0.3%	0.3%	0.3%
Hydro	5.3%	33.5%	31.0%	30.7%	30.7%
Renewables	0.3%	0.3%	0.1%	0.1%	0.1%

Table 7. Energy mix for the BAU scenario. Source: (Vigone & Miserocchi, 2017)

5.2.2. 450TZ Scenario

This scenario is defined in the "World Energy Outlook" done by the IEA. The main idea is to establish an energy guideline to achieve the goal of limiting the increase of the global temperature in 2°C by limiting the greenhouse gases emissions to the atmosphere, around 450 parts per million (ppm) of CO2. The key purpose is to change the energy mix heavily dependent of fossil fuels to renewables, like solar and wind, and by this achieving the agreements settled in Paris in 2015 with the COP21.

For this reason, it is expected in this scenario to have a higher penetration of renewables in its energy mix due to significant capital costs reduction of the renewable technology in the world market. These characteristic, makes this scenario a market driven one and with regulatory measures to help the faster penetration of these technologies. The Table 8 describes the shares that were taken into account in the IO table for this scenario analysis.

Source	2013	2015	2020	2025	2030
Oil	62.2%	21.9%	4.0%	5.4%	5.6%
Gas	32.0%	43.9%	40.1%	26.7%	18.1%
Biomass	0.2%	0.3%	1.7%	1.2%	0.8%
Hydro	5.3%	33.5%	54.0%	63.5%	61.0%
Renewables	0.3%	0.3%	0.2%	3.3%	14.5%

Table 8. Energy mix for the 450Tz scenario. Source: (Vigone & Miserocchi, 2017)

5.2.3. New Policies Scenario

This scenario is a representation of the current situation of the country, from a regulatory point of view and the implementation of new policies that are planned in the future for the energy sector. The aim of this scenario is to forecast the government's view for the development of the energy sector.

For this reason and to build this scenario, it was taken into considerations the current strategies developed by the government of Tanzania, more specifically from the Ministry of Energy and Minerals (MEM), for the next couple of years. Their intention is to expand the power generation capacity in order to boost the industrial development to accelerate the economy; and the projects to achieve this goal are described in a report called Power System Master Plan – PSMP. In this report, there is the description of all the project till 2040 with different time frames, like short medium and long – term.

According to these projects and the results obtained by (Vigone & Miserocchi, 2017), the shares of the different sources to generate electricity for this scenario, are described in the Table 9.

Source	2013	2015	2020	2025	2030
Oil	62.2%	21.9%	8.5%	10.3%	9.9%
Gas	32.0%	43.9%	44.6%	30.3%	44.6%
Biomass	0.2%	0.3%	3.4%	2.4%	1.7%
Hydro	5.3%	33.5%	26.2%	34.0%	23.4%
Renewables	0.3%	0.3%	17.3%	22.9%	20.5%

Table 9. Energy mix for the New Policies scenario. Source: (Vigone & Miserocchi, 2017)

5.3. General Input Data

To perform the energy analysis with future electricity generation scenarios is important to feed the model with the forecast of the final demand. This section describes the data needed to calculate the future final demand for the Input – Output model, with two main variables: electricity demand and GDP.

5.3.1. Electricity Demand

In order to be consistent with (Vigone & Miserocchi, 2017), the forecast of the electricity demand used was the official one published by the Ministry of Energy and Minerals, that is considerate as the high scenario demand forecast.

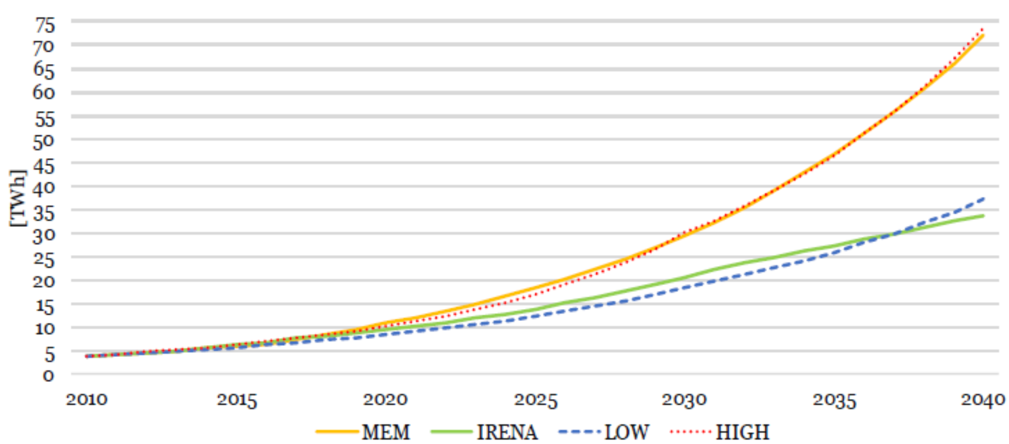

Figure 10. Low and high electricity demand forecast. Source: Vigone and Miserocchi (Vigone & Miserocchi, 2017).

This forecast is used to estimate the final demand produced by each source of electricity generation.

5.3.2. GDP

To forecast the GDP of the country and according to the literature, it is assumed that in developing countries, the economic productivity is directly related to the use or demand of the electricity demand. For this reason, a linear regression was applied to the relation between both, electricity production and GDP, for a period of time from 2000 until 2015. The obtain results are in Figure 11 and the numerical values are shown in Appendix 3.

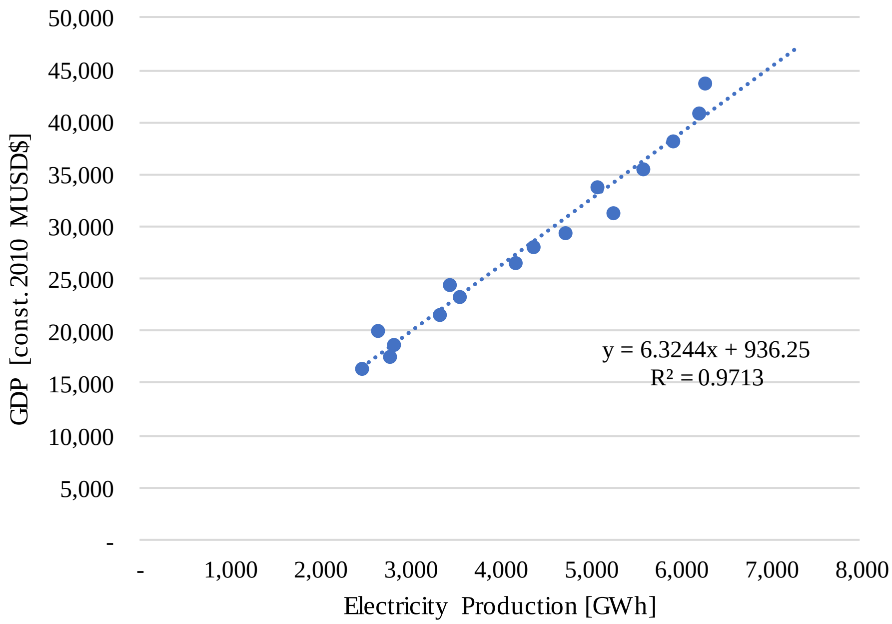

Figure 11. Relationship between electricity demand and GDP.

Is worth to mention that the aggregated GDP, is then disaggregated among the national final demand for each sector by taking into account the corresponding shares of each of them.

6. Results Analysis of the Case Study

This section of the document describes the obtained results according to the conditions of the different purposed scenario. First, it will take place an analysis on each scenario; second, it will be a discussed an analysis based on a comparison between the scenarios; and last, it will be discussed a general comment or summary of the most important results founded in the analysis.

6.1. Scenario Analysis

6.1.1. Business as usual – BAU

As mention before, in this scenario is assumed that no new policies are introduced during the whole-time frame of the analysis, this means that the current energy mix will remain with the same shares over the upcoming years.

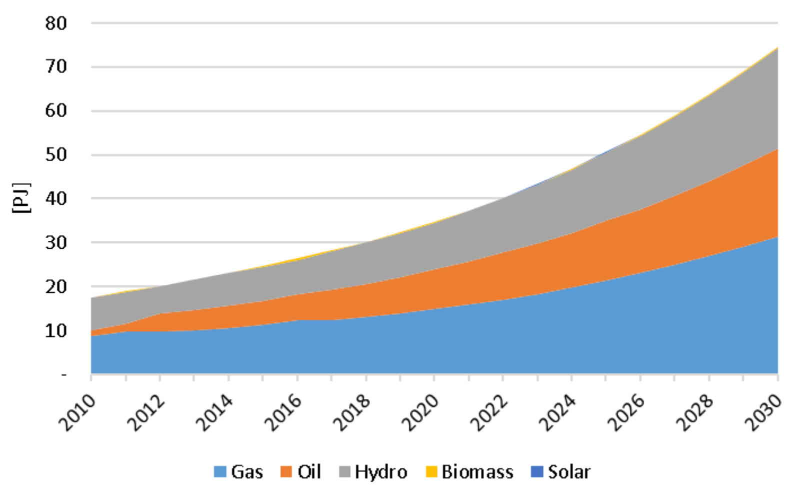

Figure 12. Electricity generation mix in the business as usual scenario. Source: (Vigone & Miserocchi, 2017)

As seen in Figure 12, for this case the electricity is meanly produces by natural gas with an average share of 43%, followed by hydro with around 31% and oil with 26%; as shown in Table 7.

According to this generation mix and after applying the Leontief model to the Input-Output table of Tanzania, the total production of the economy and its environmental impact was estimated, and the obtained results are shown in the Figure 13.

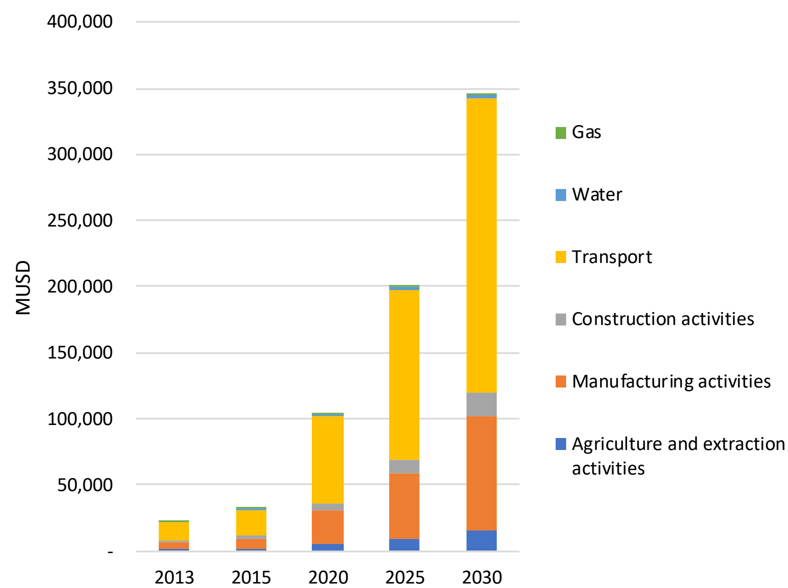

Figure 13. Total production of the economy in the Business as Usual scenario.

The total production of the economy is mainly governed by the transport sector and the manufacturing activities, with a 61% share and a 29% share correspondingly. In 2015, the total production was estimated around 30,000 Million dollars and by 2030, the estimated production is around 400,000 Million dollars.

The shares of the electricity produced in this scenario is expected to have a high thermal capacity, due to the low penetration of renewables. Additional to this, all the other sectors and including the electricity one are expected to demand a high level of primary energy sources, the results are shown in Table 10.

In terms of primary energy, the most energy intensive sectors are: electricity and transport; with shares around the 30% and 57% on average correspondingly, between 2015 until 2030.

	2013	**2015**	**2020**	**2025**	**2030**
Agriculture and extraction acti	20	29	94	181	314
Manufacturing activities	327	466	1,525	2,958	5,114
Transport	1,999	2,852	9,317	18,071	31,250
Gas	39	55	180	350	604
Electricity	1,073	1,863	4,693	8,997	15,700
Final Demand	117	138	270	449	719
Total	**3,575**	**5,403**	**16,079**	**31,007**	**53,701**

Table 10. Total primary energy use of the Business as Usual scenarios [ktoe]

These results show that every 5 years, there is an increase of around 16,000 ktoe on the demanded primary energy sources for the whole economic system. For the case of the electricity sector, the demand of primary energy sources increases by an average of 4,600 ktoe on average every 5 years.

6.1.2. 450 Tanzania: World policies to decreased cost of renewables

In this scenario the penetration rate of the renewables energy technologies in the energy mix for electricity production is expected to by higher, situation that is favoured due to the reduction of capital cost of the global market and the country is expected to follow the market trend.

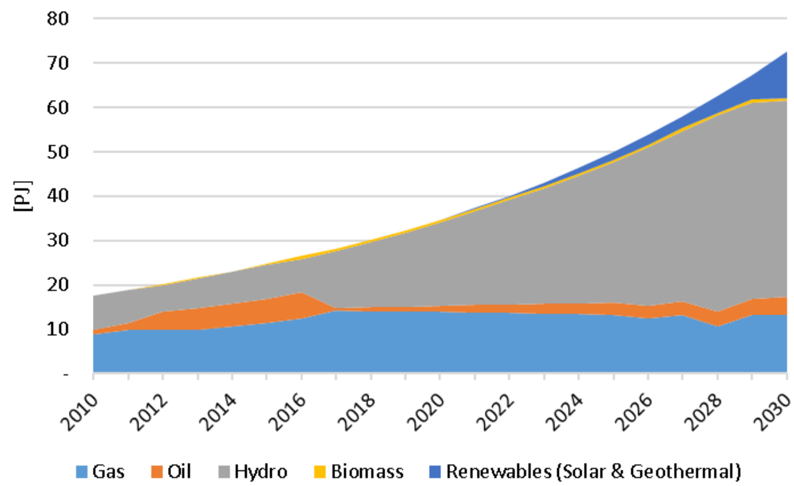

Figure 14. Electricity generation mix in the 450TZ scenario. Source: (Vigone & Miserocchi, 2017)

In this scenario, hydro has the main share in generation, as seen in Table 14, followed by natural gas; with shares around the 53% and 30% correspondingly between 2013 until 2030 (Table 8). One relevant thing to mention, is that in this scenario is expected to have the introduction of carbon taxes policies in order to help financing activities on renewable technologies, as mention in (Vigone & Miserocchi, 2017). Therefore, in the obtained results for this scenario renewable energies reached a share of around 15% by 2030.

According to this electricity production mix and after applying the Leontief model to the Input-Output table of Tanzania, the total production of the economy and its total primary energy use was estimated, and the obtained results are shown in the Figure 15.

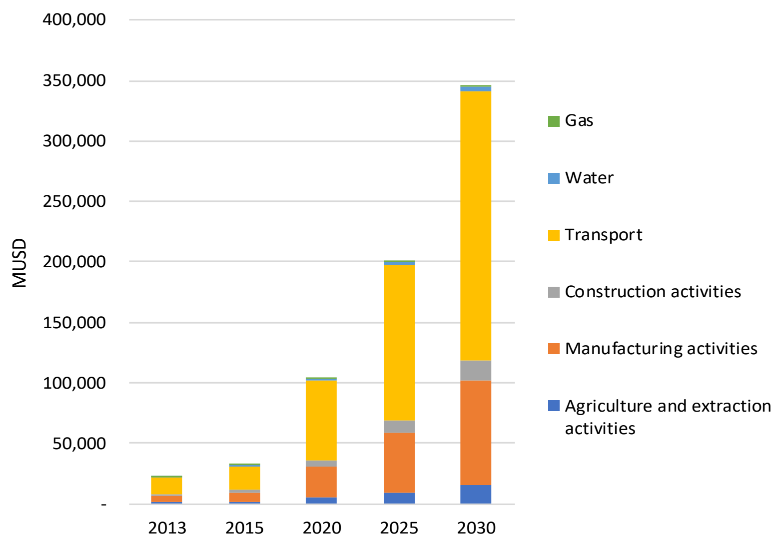

Figure 15. Total production of the economy in the 450TZ scenario.

The total production of the economy is mainly governed by the transport sector and the manufacturing activities, with a 61% share and a 29% share correspondingly. In 2015, the total production was estimated around the 37,000 Million dollars and by 2030, the estimated production is around 400,000 Million dollars.

For the operation of the economy the electricity generation in this scenario is expected to have a higher electricity production with renewable resources. This means that, the primary energy used for all sectors and the electricity to deliver their total output production, presents a change in comparison with the BAU scenario.

The most energy intensive sectors are: electricity and transport, with shares around the 27% and 59% correspondingly. The total primary energy use is shown in the following table.

	2013	2015	2020	2025	2030
Agriculture and extraction acti	20	29	94	181	314
Manufacturing activities	327	466	1,524	2,954	5,108
Transport	1,999	2,852	9,298	18,019	31,152
Gas	39	55	180	349	603
Electricity	1,073	1,863	3,981	6,760	10,635
Final Demand	117	138	270	449	719
Total	**3,575**	**5,403**	**15,346**	**28,712**	**48,529**

Table 11. Total primary energy use of the 450TZ scenario. [ktoe]

These results show that every 5 years, there is an increase of around 14,400 ktoe on the demand of primary energy sources for the whole economic system. For the case of the electricity sector, the demand of primary energy sources increases 3,000 ktoe on average every 5 years.

6.1.3. New Policies

This scenario is an in-between situation between the business as usual and the 405TZ. Due to the implementation of new policies and government's plan, it is expected to have a growth in the use of renewable sources for the electricity generation, but not as high as the 405TZ scenario which is a more optimistic scenario.

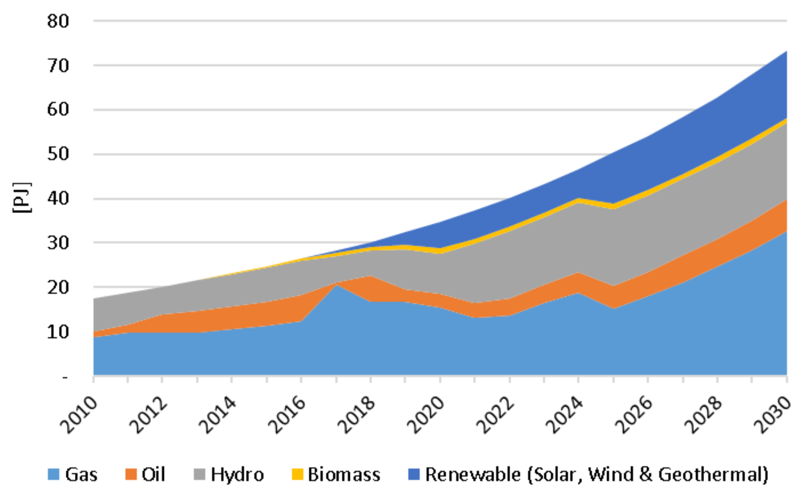

Figure 16. Electricity generation mix in the New Policies scenario. Source: (Vigone & Miserocchi, 2017)

As described in Table 9, there is a growth in the renewable energy generation. The main used source is natural gas, followed by hydro and renewables, like solar, wind and geothermal; with a share around the 41%, 29% and 15% correspondingly.

According to this generation mix and after applying the Leontief model to the Input-Output table of Tanzania, the total production of the economy and its primary energy use was estimated, and the obtained results are shown in the following graphs.

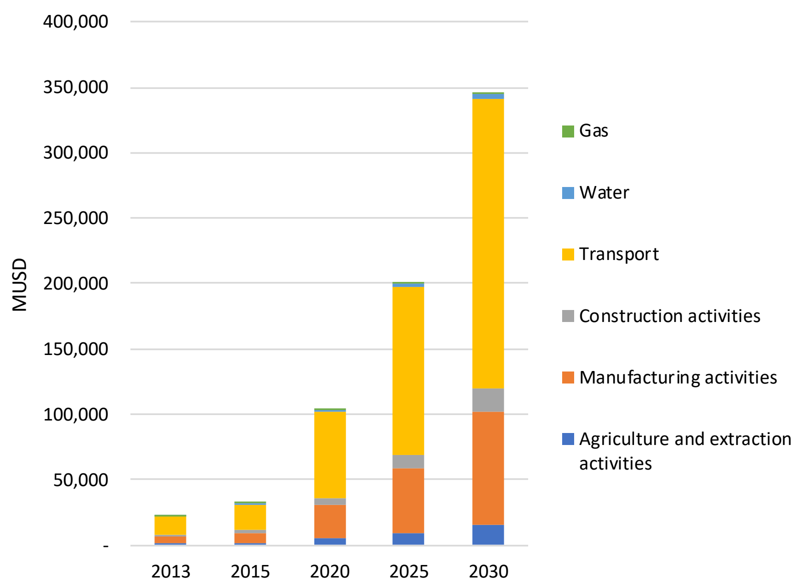

Figure 17. Total production of the economy in the New Policies scenario.

The total production of the economy is mainly governed by the transport sector and the manufacturing activities, with a 61% share and a 29% share correspondingly. In 2015, the total production was estimated around the 37,000 Million dollars and by 2030, the estimated production is around 400,000 Million dollars.

For the operation of the economy the electricity generation denuded in this scenario is expected to have a higher share of renewable resources than in the BAU scenario. This means that, the energy intensity of this scenario is considered to change in comparison with the base scenario, BAU. This is shown in the Table 12.

The most energy intensive sectors are: electricity and transport with shares around the 28% and 58% correspondingly. The total primary energy use is shown in the following table.

	2013	**2015**	**2020**	**2025**	**2030**
Agriculture and extraction acti	20	29	94	181	314
Manufacturing activities	327	466	1,524	2,956	5,111
Transport	1,999	2,852	9,306	18,043	31,197
Gas	39	55	180	349	604
Electricity	1,073	1,863	4,183	7,291	12,792
Final Demand	117	138	270	449	719
Total	**3,575**	**5,403**	**15,557**	**29,269**	**50,736**

Table 12. Total primary energy use in the New Policies scenario. [ktoe].

These results show that every 5 years, there is an increase of around 15,100 ktoe on the demanded of primary energy sources for the whole economic system. For the case of the electricity sector, the demand of primary energy sources increases 3,650 ktoe on average every 5 years.

6.2. Comparison Among Scenarios

In this section it will be discussed the results for the energy analysis of all scenarios in comparison with the business as usual one, that is the base case scenario.

6.2.1. Primary Energy Use

The environmental impact of the operation of the national economy by changing the electricity generation mix can be analysed by making a comparison between the behaviour of the energy use of the all the sectors and the penetration of the renewable technologies.

Therefore, analysing the obtained results of the IO model is possible to see that in all scenarios the most energy intensive sectors are: electricity and transport. This indicates that the electricity sector, is not the only sector that will need to have an intervention in order to reduce the environmental impact of the production of the economy.

As is showed in Figure 18, the 450TZ and the NP scenario achieve a renewable energy penetration if 52% and 42% in 2030, due to the application of the new policies and the increase on the investment on these technologies. This higher rate on the penetration of renewable energies leads to a change in the primary energy use for the total production of the economy, which is shown in Table 13.

	2013	2015	2020	2025	2030
BAU	3,575	5,403	16,079	31,007	53,701
450TZ	3,575	5,403	15,346	28,712	48,529
NP	3,575	5,403	15,557	29,269	50,736

Table 13. Total primary energy used for the total production of the economy for each scenario. [ktoe]

For 2013 and 2015, the values of the total primary energy used remain equal because one year is the base year and the other one had the generation mix of the IEA database. But regarding the values for the following years, the results show the effect of the different energy mix of each scenario.

Comparing the results shown in the Figure 18, the most energy intensive scenario is the business as usual due to the fact that the penetration rate of renewable energies remains constant, around the 30% for all the time horizon. On the other hand, the other two scenarios have a reduction on their primary energy use, due to a penetration rate of renewable energies of around the 43% and a 39% for the 450TZ and the NP correspondingly. As a result of these higher rates, the 450TZ achieved by 2030 a reduction on 10% in relation to the value for the same year of the BAU scenario; in the case of the NP scenario the reduction achieved by 2030 in relation with the BAU is 6%.

Now analysing the obtained results separately, on one hand the electricity sector and on the other hand the resto of the economy, some interesting facts come out.

	2013	2015	2020	2025	2030
BAU	2,502	3,540	11,386	22,009	38,001
450TZ	2,502	3,540	11,365	21,952	37,894
NP	2,502	3,540	11,374	21,978	37,944

Table 14. Total primary energy use of the economy without the electricity sector for all scenarios. [ktoe]

	2013	2015	2020	2025	2030
BAU	1,073	1,863	4,693	8,997	15,700
450TZ	1,073	1,863	3,981	6,760	10,635
NP	1,073	1,863	4,183	7,291	12,792

Table 15. Total primary energy use of the electricity sector for all scenarios. [ktoe]

The primary energy use for the electricity sector represents around the 30% of the total primary energy use of the country. However, for the increased rate of renewables this share reduces to 27% and 28% for the 450TZ and the NP scenarios correspondingly. In terms of the total reduction in relation to the BAU scenario, for the 450TZ the reduction by 2030 is 5,065 ktoe which is a reduction of the 32%; and for the NP scenario the reduction by 2030 is 2,908 ktoe which is 19% reduction in comparison with the level of the BAU.

This situation changes when the other sectors of the economy are analysed, the level of reduction of the two scenarios in relation to the BAU are significantly lower. In the case of the 450TZ the reduction of the use of primary energy is 107 ktoe that is a reduction of 0.3%; and for the NP the reduction is 57 ktoe that is a 0.2% reduction by 2030.

Looking at these results, is possible to say that the efforts for reducing the energy intensity of the electricity sector are effective and they promote a reduction of the environmental impact of its activity for meeting their final demand, by having a lower consumption of fossil fuels. However, it would be important to target the other sector of the economy with other type of measures, like energy efficiency, to achieve a more significant reduction on the impact, because they represent the other 70% of the primary energy demand that is meanly concentrated in the transport sector, which is a sector with a high demand of fossil fuels that makes it an energy intensive sector.

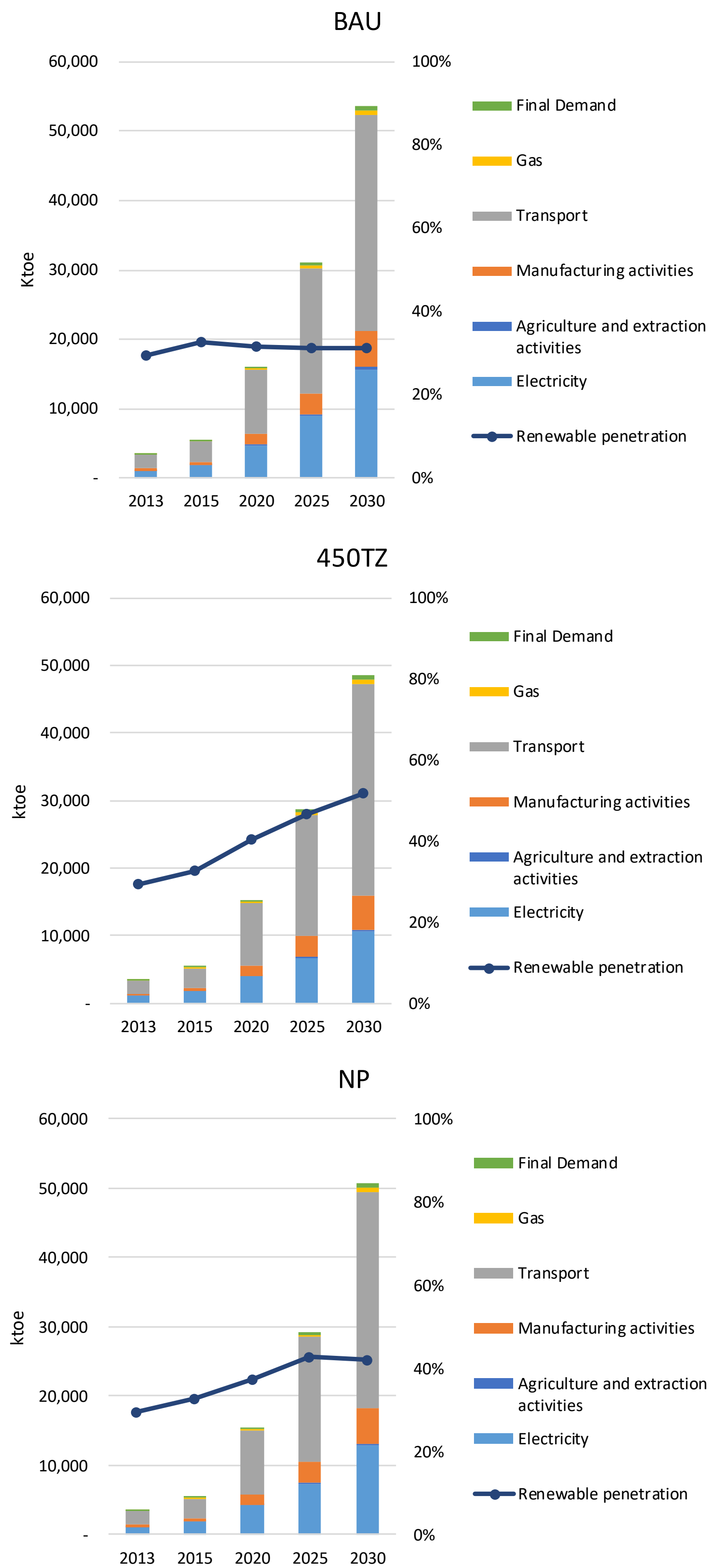

Figure 18. Total primary energy use and renewable energy penetration for all scenarios.

One important aspect of the climate change policies for any economy is to separate its climate change impact from its economic growth. For this reason, is relevant to see if the unitary consumption of primary energy is or is not connected the growth of the GDP.

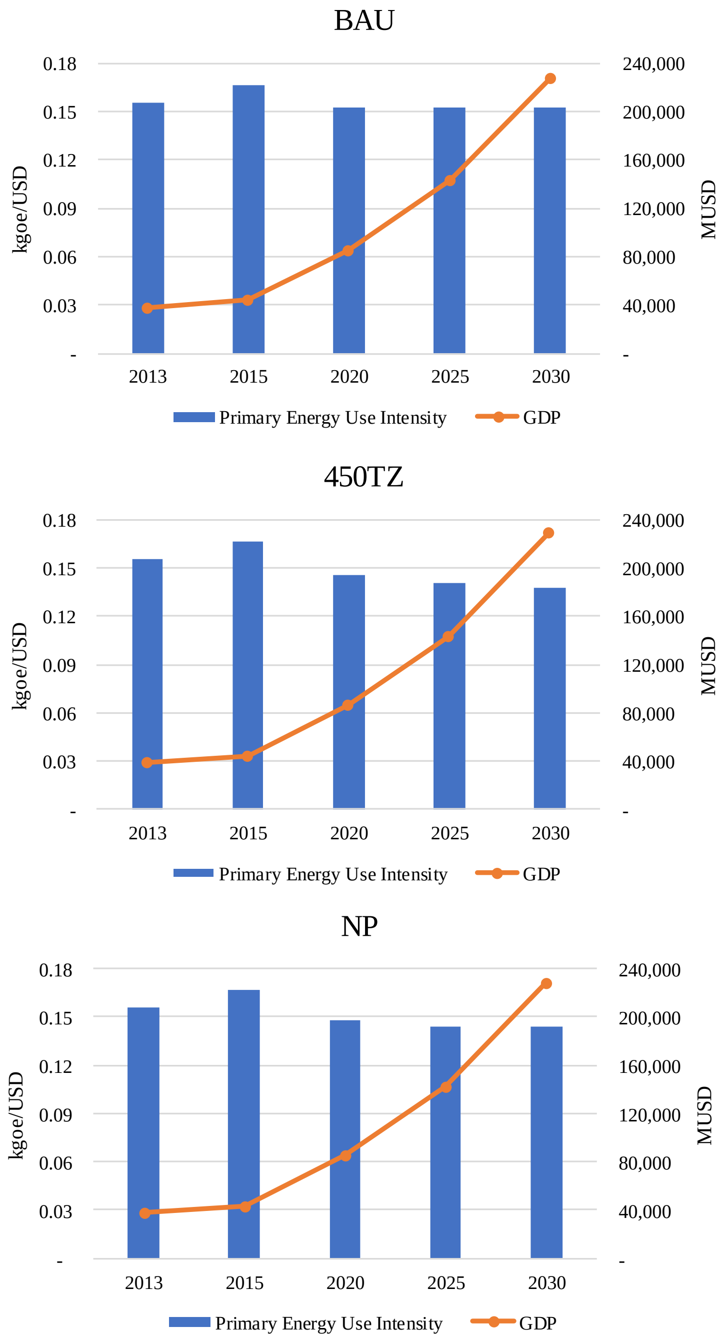

Figure 19. Unitary primary energy use and the GDP for all the scenarios.

According to the results showed in Figure 19, after the year 2015 the unitary primary energy consumption starts to decrease, by an average rate of 6% for the 450TZ scenario and 4.5% for the NP one. This reduction of the unitary consumption in comparison with the growth of the GDP are the evidence to show that the policies considered to develop a cleaner electricity sector have a positive impact on separating the economic growth of the country from its energy intensity for fossil fuels. For the BU scenario, the unitary primary energy consumption remains constant with respect to the growth of the GDP, because there is no change on the sources of the electricity product mix.

After all this having said, there is one main topic to take into consideration which is if the investment done to change the electricity production mix is consistent to the level of reduction achieved on each scenario.

To have a better understanding of the impact of the penetration of renewables in the electricity mix, is important to analyse if the reduction of the primary energy use corresponds to the level of investment that is being done in the sector to become cleaner, an analysis that was made in the paper of Rocco, Rady and Colombo (Rocco, Rady, & Colombo). To estimate the effectiveness of the penetration of the renewable installed capacity between time i and i+1, the following equation was used:

$$\varepsilon_{Reni \to i+1} \left| \frac{e_{PEi+1} - e_{PEi}}{G_{Reni+1} - G_{Reni}} \right| \quad [(toe/MUSD)/GW]$$

Where e_{PEi}[toe/MUSD] is the unitary primary energy use and G_{Reni}[GW]. The following graph shows the obtain results.

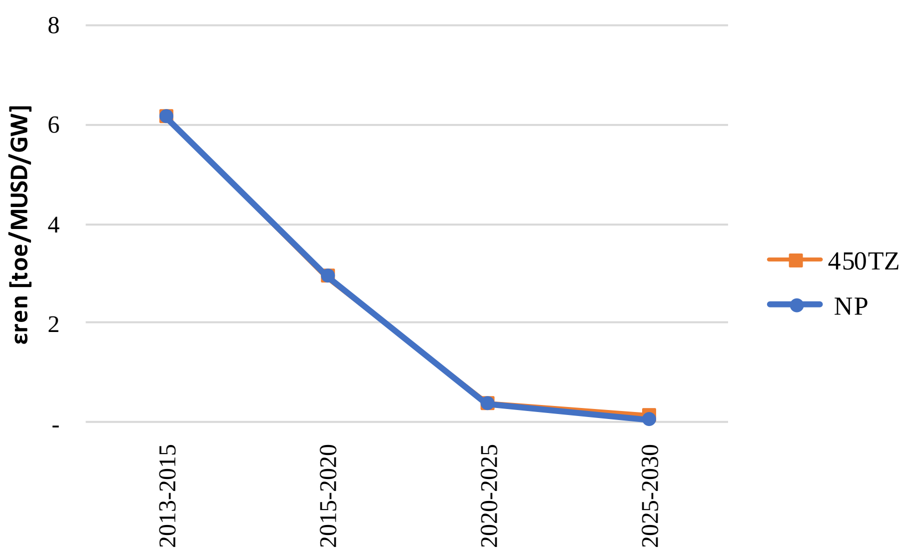

Figure 20. Effectiveness of the renewable electricity generation on the reduction of primary energy use.

This shows that both scenarios have a similar level of effectiveness and between 2013-2020 this effectiveness is on its highest, after 2020 till 2030 investing on renewable electricity production will have fewer or almost not relevant impact on the reduction of the primary energy consumption. This result is the evidence, that after 2020 the investment address to renewables could be address to other activities of the other sectors that have high energy intensity processes. For example, the transport sector that has the highest consumption of primary energy in Tanzania, around the 58%, could have a high potential on energy efficiency solutions in order to reduce its impact on the environment and at the same time, help Tanzania to reach its environmental target goals.

6.2.2. Greenhouse Gases Emissions for Oil Combustion

On the other hand, the greenhouse gases emission for each of the scenarios are described in this section of the document.

In following table shows the total greenhouse gases (GHG) emissions, each scenario has a slight variation with respect to the BAU. For the 450TZ scenario the average in the reduction of the emissions in the time horizon, is around 2%. On the case of the NP scenario, the obtained results are more moderated, as is the most realistic scenario of the three, with an average rate of reduction of 1% on the time horizon. As it was expected, the 450TZ is the one with the highest level of reduction on the emission because is the most optimistic one.

	2013	2015	2020	2025	2030
BAU	9.9	14.3	46.0	89.2	154.4
450TZ	9.9	14.3	45.3	87.3	150.8
NP	9.9	14.3	45.6	88.1	152.5

Table 16. Total GHG emissions of each scenario. [kTonCO2eq]

The reason behind this result, is because the GHG emissions for combustion in Tanzania are meanly related to the activity of the transport sector, that represents around the 68% of the total emissions while the electricity sector is around the 7%.

However, and by analysing the electricity sector and the rest of the economic sector separately the results are completely different and present a significant reduction on the environmental impact. Like in the case of the reduction on the primary energy consumption, the actions in order to make the electricity mix cleaner achieve the final result of decarbonizing the electricity sector and detached it from the economic growth of the country, as can be seen in the following graph that despite the fact that the economy keeps growing, these actions can reduce its environmental impact due to the use renewable resources.

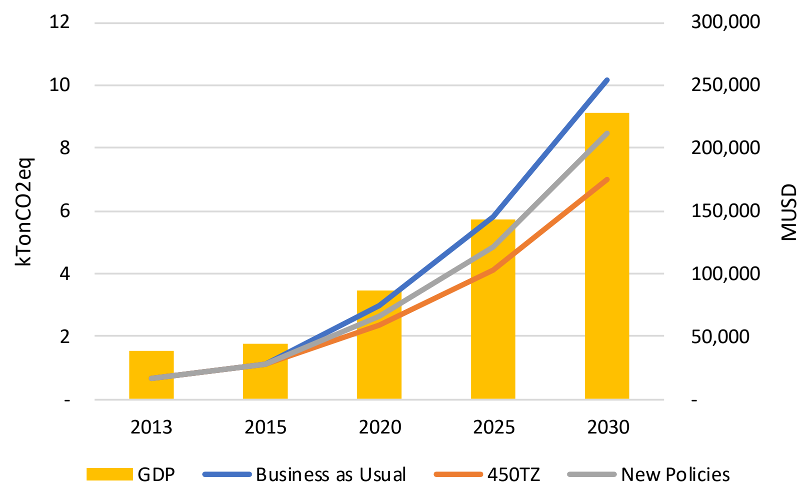

Figure 21. GHG emissions of electricity sector and GDP of electricity sector.

For the 450TZ scenario the average in the reduction of the emissions in the time horizon, with respect to the BAU scenario, is around 27% and by 2030 the reduction on emissions reaches the 31%. On the case of the NP scenario, the obtained results are more moderated, as is the most realistic scenario of the three, with an average rate of reduction of 15% on the time horizon and it reaches the 17% reduction in 2030 in comparison with the BAU.

	2013	2015	2020	2025	2030
BAU	0.6	1.1	3.0	5.8	10.1
450TZ	0.6	1.1	2.3	4.1	7.0
NP	0.6	1.1	2.6	4.9	8.5

Table 17. GHG emissions of electricity sector for each scenario. [kTonCO2eq]

7. Findings and Conclusions

For this study it was used an Input – output (IO) analysis to model the interindustry economic flows of The United Republic of Tanzania, the main objective was to perform an energy analysis in order to estimate the impact of a more renewable mix for electricity production. For this reason, it was needed to construct a hybrid IO model that consists on physical and monetary units.

To perform the analysis three scenarios where purpose: a) business as usual (BAU), b) 450TZ and c) new policies (NP). Each of these scenarios had a different mix for the electricity generation, which were established according to the results of another study done by Vigone and Miseocchi (Vigone & Miserocchi, 2017). The BAU, is the reference scenario with a constant electricity generation mix; the 450TZ is the most optimistic scenario with a high rate of renewable generation and the NP is the most realistic one, with a rate of renewable penetration according to the Tanzania's government policies.

After applying the Leontief model with the according shocks of each scenario, the total production of the economy, the primary energy consumption and the greenhouse gases emissions where estimated for a window of time between 2015 until 2030.

The total production of the economy for all the three scenarios presented similar results, with a production mainly governed by the transport and manufacturing sector that represent the 61% and the 29% shares correspondingly. In 2015, the total production was estimated around the 30,000 Million dollars and by 2030, the estimated total production reached a sum around the 400,000 Million dollars.

On the other hand, the production of electricity is similar as well for all scenarios but there is a difference related to the shares of the energy mix according to the different rates of renewable sources penetration; which comprises biomass, hydropower, solar and wind. These rates of penetration are around the 32% for the BAU, around 43% for the 450TZ and around 39% for the NP scenario between the analysis time horizon. These difference produces an impact on the flows of the economy in terms of the primary energy consumption and as expected in the emission of greenhouse gases related to combustion of oil.

In all the scenarios the most energy intensive sectors are the transport and electricity sector. In the BU scenario, their use of primary energy was around the 57% and the 30% respectively from the total economy and by 2030 they reached a level of 31,250 ktoe and 15,700 ktoe. For the 450TZ scenario, the share of the transport sector is around the 59% and for the electricity is 27% and by 2030 the demanded primary energy is 31,152 ktoe and 10,635 ktoe respectively. In the NP scenario, 58% of the total primary energy is consumed by the transport sector and a 28% is consumed by the electricity sector; in 2030 they reach a level of 31,197 ktoe and 12,792 ktoe respectively.

As expected, the penetration of the renewable sources leads to a reduction of the primary energy consumption in both the 450TZ and the NP scenarios, with respect of the level of consumption of the BAU scenario. Between 2015-2020, the BAU scenario increases by 10,677 ktoe it consumption on primary energy sources, this is higher by 7 % (9,943 ktoe) to the increase level obtained in the 450TZ scenario and 5% (10,154 ktoe) higher to the NP one. Between 2020-2025, the increase level in the BAU is 14,927 ktoe, that is 10% (13,366 ktoe) higher from the 450TZ scenario and an 8% (13,712 ktoe) higher than the NP one. Between 2025-2030, the increase is 22,695 ktoe in the BAU, that is 13% (19,817 ktoe) higher to the level of the 450TZ and a 5% (21,467 ktoe) higher to the NP one.

Taking into consideration just the results of the electricity sector the reduction in the consumption of primary energy sources is more significantly between both 450TZ and NP scenarios with the BAU. Between 2015-2020, the BAU presented and increase in consumption of 2,830 ktoe, that is 25% (2,119 ktoe) and 18% (2,321 ktoe) higher than the 450TZ and the NP scenarios increase rate. Between 2020-2025, the consumption in the BAU scenario increased by 4,304 ktoe, that is 35% (2,778 ktoe) and 28% (3,108 ktoe) higher than the increase level of the 450TZ and the NP scenarios. Between 2025-2030, the increase in consumption in the BAU is 6,703 ktoe, that is 42% (3,875 ktoe) and 18%(5,501 ktoe) higher than increase in the 450TZ and the NP scenarios.

Another important aspect for climate change policies for any economy is to separate its climate change impact from its economic growth. For this reason, it was important to analyse the relation between unitary consumption of primary energy and the grow of the GDP.

The unitary consumption of primary energy in relation to the total output of the economy remains constant in the BAU scenario, while in the 450TZ and the NP reduces by an average rate of 6% and 4.5% respectively. This reduction means that the policies taken into consideration to promote a more sustainable electricity production mix have a positive impact and separate the economic growth of the energy intensity of the economic sectors.

According to the previous results, the actions taken on each purpose scenario are effective on promoting a more varied and sustainable electricity generation mix. But is the level of reduction according to the investment done in renewable technologies? To have an answer to this question, a ratio between the unitary primary energy consumption and the electricity produce was calculated. According to the results, both scenarios (450TZ and NP) show similar level of effectiveness on the investment between 2013-2020 with a positive result to make the investment. However, after 2020 the investing on renewable shows a very low impact on the reduction of the primary energy consumption. This could mean that after 2020 the investment could be better allocated to another energy intensive activities of other sectors. One of this is the transport sector, that represents the 58% of the primary energy consumption of Tanzania.

On the other hand, the greenhouse gases emissions related to combustion of oil were taken into consideration as well for the analysis. In this case, the variation of the emissions of the total production of the economic system had just a small difference between all the scenarios. In comparison with the BAU, the 450TZ shows a reduction of 2% while the NP shows a reduction of 1%. The reason behind this result is that the emissions for oil combustion are concentrated in the transport sector, with a share of the 68% of the total, while the electricity sector represent around the 7%. Due to this, it was analysed the emission of the electricity sector apart from the rest of the economic systems, in order to see the impact of the renewable penetration on the electricity production.

On the obtained results, that were compared with the economic growth, show that the penetration of the renewable resources helps to decarbonizing the electricity sector and detached it from the growth of the GDP. In the 450TZ scenario the average reduction of the emissions with respect to the BAU scenario, is around 27%. In the NP scenario, the results can be seen as a medium scenario, with an average reduction of 15% in comparison with the BAU.

In summary and as described before, introducing renewable energy in the economic system of Tanzania has a positive impact in terms of its environmental impact. Additional to this, there are some other positive impacts of investing on these technologies like the diversification of the electricity generation mix and the improvement on the energy access rate of the country. By the diversification of the electricity generation mix, the country reduces the risk of blackouts for the unpredictability of hydropower generation due to the changing rainfall patterns and recent droughts that the system has faced. The access to modern energy services has a crucial role on improving the manufacturing production, the income generation by household and the education level of an economy, however for a country like Tanzania this mean a very high investment to improve its grid network to arrive on a reliable way to all the population; for this reason investing on renewables allows them to have less costly, fast and off-grid solutions to improve their development and at the same time allowing them to start thinking on other sustainable solutions for other sectors of the economy.

8. Future Recommendations

During the analysis done for this study, it was concluded that in order to achieve a more complete analysis it would be convenient to develop the following studies:

- One additional factor that could be analysed to understand better the investment on renewable energy and the economic impact of their penetration into the electricity generation mix, is the impact of different taxes or incentives, like a carbon tax for the polluting technologies and the Feed – In tariff, for the renewable sources.
- Another further consideration for future studies related to the environmental impact, is to identify the potential actions to reduction energy intensity of other sector of the economy and analyse it together with the results of this study. This could help to give an idea of a proper balance on the investment related to renewables and other solutions, like energy efficiency measures.
- As seen in the results of this study, there is a reduction on the consumption of primary energy resources in all sector of Tanzania. This means that there is an amount of money that the country is saving due to the higher share of renewables, which have lower costs; it would be interesting to make an estimation of the total saving due to this new electricity generation mix, in order to see if this amount of money could be better invest on other projects related to improve the energy profile of the country.

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Appendix 1: EORA IO – Table Tanzania's Economy [MUSD]

MIOT of Tanzania, 2013		Agriculture 1	Fishing 2	Mining and Quarrying 3	Food & Beverages 4	Textiles and Wearing Apparel 5	Wood and Paper 6	Petroleum, Chemical and Non-Metallic Mineral Products 7	Metal Products 8	Electrical and Machinery 9	Transport Equipment 10	Other Manufacturing 11	Recycling 12	Electricity, Gas and Water 13
Agriculture	Z1	49	0	0	111	2	10	1	0	0	0	0	0	0
Fishing	Z2	0	0	0	12	0	0	0	0	0	0	0	0	0
Mining and Quarrying	Z3	1	0	5	1	0	0	25	2	0	0	0	15	45
Food & Beverages	Z4	17	0	0	80	1	0	1	0	0	0	0	0	0
Textiles and Wearing Apparel	Z5	0	0	0	1	25	1	1	0	0	0	2	0	0
Wood and Paper	Z6	4	0	1	59	6	75	12	2	3	1	24	1	1
Petroleum, Chemical and Non-Metallic Mineral Products	Z7	29	3	8	44	47	23	230	10	34	12	24	26	9
Metal Products	Z8	2	0	4	59	4	4	16	115	46	16	29	15	2
Electrical and Machinery	Z9	3	1	13	9	6	11	17	21	229	118	32	0	6
Transport Equipment	Z10	1	1	2	5	0	0	4	1	11	102	12	0	0
Other Manufacturing	Z11	0	0	0	4	3	1	1	0	1	2	4	0	1
Recycling	Z12	0	0	0	0	0	0	0	1	0	0	0	1	1
Electricity, Gas and Water	Z13	8	0	4	20	4	6	28	6	7	1	1	1	10
Construction	Z14	3	0	17	6	3	6	9	5	4	1	2	0	20
Maintenance and Repair	Z15	0	0	0	2	0	0	0	0	0	0	0	0	0
Wholesale Trade	Z16	15	1	2	53	15	20	38	16	42	14	14	0	3
Retail Trade	Z17	1	0	0	2	1	0	2	0	1	0	2	0	0
Hotels and Restraurants	Z18	0	0	0	2	1	1	1	1	1	0	1	0	2
Transport	Z19	15	1	12	38	11	18	26	11	9	4	9	20	19
Post and Telecommunications	Z20	1	0	1	3	2	4	6	3	14	1	2	0	3
Finacial Intermediation and Business Activities	Z21	64	1	37	89	34	44	150	48	160	42	24	0	45
Public Administration	Z22	0	0	0	0	0	0	0	0	0	0	0	0	0
Education, Health and Other Services	Z23	2	0	0	2	1	1	3	1	2	0	1	0	2
Private Households	Z24	0	0	0	0	0	0	0	0	0	0	0	0	0
Others	Z25	1	0	0	4	2	1	1	1	1	0	0	0	1
Re-export & Re-import	Z26	0	0	0	0	0	0	0	0	0	0	0	0	0
Imports	Im	42	8	40	211	58	146	466	179	577	257	72	7	101
Compensation of employees D.1	V1	8	3	4	29	6	14	24	14	36	9	6	0	17
Taxes on production D.29	V2	0	0	0	0	0	0	0	0	0	0	0	0	0
Subsidies on production D.39	V3	-1	-0	-10	-124	-1	-3	-16	-4	-19	-5	-2	-0	-51
Net operating surplus B.2n	V4	360	26	62	114	17	46	129	31	90	28	17	1	188
Net mixed income B.3n	V5	2	0	1	1	0	1	1	1	1	0	0	0	2
Consumption of fixed capital K.1	V6	41	3	9	13	3	7	22	7	20	5	3	0	38
Natural Gas	R1.1	-	-	-	-	-	-	65.921	-	26.990	-	6.544	2.675	606.669
Coal	R1.2	-	-	-	-	-	-	4.371	-	4.920	-	1.199	0.492	17.006
Petroleum	R1.3	0.152	0.013	0.076	0.406	0.136	0.207	70.937	0.237	80.013	0.330	19.442	7.977	14.116
I-GHG-CO2eq emissions (Gg)	R2.1	0	0	0	0	0	0	1	0	1	0	0	0	2
IEA - Total primary energy supply (Mtoe)	R3.1	0.0128	0.124	0	0	0	0	0	0.145	2	0.107	19.9	0	-

MIOT of Tanzania, 2013		Construction 14	Maintenance and Repair 15	Wholesale Trade 16	Retail Trade 17	Hotels and Restraurants 18	Transport 19	Post and Telecommunications 20	Finacial Intermediation and Business Activities 21	Public Administration 22	Education, Health and Other Services 23	Private Households 24	Others 25	Re-export & Re-import 26	Final Demand f	Total Production x
Agriculture	Z1	2	0	0	1	8	0	0	4	1	2	0	0	0	501	692
Fishing	Z2	0	0	0	0	1	0	0	0	0	0	0	0	0	44	58
Mining and Quarrying	Z3	3	0	0	0	0	2	0	1	2	1	0	0	0	141	247
Food & Beverages	Z4	0	0	1	5	58	0	0	5	6	20	0	0	0	672	866
Textiles and Wearing Apparel	Z5	1	0	1	1	1	0	0	1	1	4	0	0	0	219	260
Wood and Paper	Z6	18	1	11	13	11	3	13	46	22	32	1	1	0	83	445
Petroleum, Chemical and Non-Metallic Mineral Products	Z7	97	1	9	13	16	57	8	34	51	119	2	3	0	299	1,207
Metal Products	Z8	53	0	4	6	8	6	2	15	7	6	0	1	0	54	474
Electrical and Machinery	Z9	65	2	13	29	8	11	13	43	62	45	2	1	0	513	1,273
Transport Equipment	Z10	12	1	2	38	1	15	1	13	44	2	1	0	0	336	609
Other Manufacturing	Z11	7	0	3	3	3	1	1	10	2	10	0	0	0	224	282
Recycling	Z12	0	0	0	0	0	0	0	0	0	0	0	0	0	93	98
Electricity, Gas and Water	Z13	5	0	6	11	31	9	5	30	21	50	0	0	0	213	478
Construction	Z14	4	1	6	16	12	13	10	89	59	39	1	1	0	789	1,117
Maintenance and Repair	Z15	0	0	0	0	1	0	0	1	0	1	0	0	0	43	52
Wholesale Trade	Z16	40	1	20	16	33	10	5	33	23	50	1	1	0	515	980
Retail Trade	Z17	14	0	1	3	10	5	1	10	1	7	0	0	0	878	942
Hotels and Restraurants	Z18	1	0	2	2	5	2	4	29	8	16	0	0	0	656	734
Transport	Z19	27	2	39	36	16	62	11	39	23	43	1	2	0	401	894
Post and Telecommunications	Z20	15	2	38	35	20	31	85	83	54	60	2	3	0	352	819
Finacial Intermediation and Business Activities	Z21	167	9	182	209	121	162	148	1,120	236	445	10	16	0	2,570	6,132
Public Administration	Z22	0	0	0	0	1	0	0	3	4	2	1	5	0	1,335	1,354
Education, Health and Other Services	Z23	3	0	4	6	12	4	13	54	30	105	1	1	0	1,979	2,227
Private Households	Z24	0	0	0	0	0	0	0	0	0	0	0	0	0	41	41
Others	Z25	1	0	4	1	2	1	1	6	1	3	0	0	0	44	76
Re-export & Re-import	Z26	0	0	0	0	0	0	0	0	0	0	0	0	0	13	13
Imports	Im	195	10	175	59	90	190	93	347	281	249	8	11	7		
Compensation of employees D.1	V1	141	5	122	118	66	68	67	426	149	309	3	2	0		
Taxes on production D.29	V2	0	0	2	2	1	0	0	3	0	1	0	0	0		
Subsidies on production D.39	V3	-6	-1	-19	-14	-4	-6	-5	-114	-3	-45	-0	-0	-0		
Net operating surplus B.2n	V4	195	12	298	262	142	137	277	3,170	187	518	3	24	0		
Net mixed income B.3n	V5	5	0	6	6	3	3	4	32	9	13	0	0	0		
Consumption of fixed capital K.1	V6	43	2	35	40	24	26	53	475	63	92	0	4	0		
Natural Gas	R1.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Coal	R1.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Petroleum	R1.3	0.432	0.021	0.301	0.308	0.277	1,067.641	0.239	1.161	0.542	0.760	0.022	22.022	-	186.061	
I-GHG-CO2eq emissions (Gg)	R2.1	0	0	0	0	0	7	0	0	0	0	0	0	-	1	
IEA - Total primary energy supply (Mtoe)	R3.1	0	0	0	0.61	0.122	0.0171	0.166	0	0	0	0	0	0.194	0.5509	

Appendix 2: Disaggregated Hybrid IO Table of Tanzania [MUSD and GWh]

Hybrid MIOT of Tanzania, 2013		Agriculture	Fishing	Mining and Quarrying	Food & Beverages	Textiles and Wearing Apparel	Wood and Paper	Petroleum, Chemical and Non-Metallic Mineral Products	Metal Products	Electrical and Machinery	Transport Equipment	Other Manufacturing	Recycling	Construction	Maintenance and Repair	Wholesale Trade	Retail Trade	Hotels and Restraurants	Transport	Post and Telecommunications	Finacial Intermediation and Business Activities	Public Administration	Education, Health and Other Services	Private Households	Others	Re-export & Re-import	Water	Gas	Electricity: T&D	Electricity: Generation Oil	Electricity: Generation Gas	Electricity: Generation Biomass	Electricity: Generation Hydro	Electricity: Generation Solar	Final Demand	Total Production
		1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21	22	23	24	25	26	13.1	13.2	13.3A	13.3B1	13.3B2	13.3B3	13.3B4	13.3B5	f	x
Agriculture	Z1	49	0	0	111	2	10	1	0	0	0	0	0	2	0	0	1	8	0	0	4	1	2	0	0	0	0	-	-	-	-	-	-	-	501	692
Fishing	Z2	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	44	58
Mining and Quarrying	Z3	1	0	5	1	0	0	25	2	0	0	0	15	3	0	0	0	0	2	0	1	2	1	0	0	0	18	2	10	10	5	0	1	0	141	247
Food & Beverages	Z4	17	0	0	80	1	0	1	0	0	0	0	0	0	0	1	5	58	0	0	5	6	20	0	0	0	0	0	-	-	-	-	-	-	672	866
Textiles and Wearing Apparel	Z5	0	0	0	1	25	1	1	0	0	0	2	0	1	0	1	1	1	0	0	1	1	4	0	0	0	0	0	-	-	-	-	-	-	219	260
Wood and Paper	Z6	4	0	1	59	6	75	12	2	3	1	24	1	18	1	11	13	11	3	13	46	22	32	1	1	0	1	0	0	0	0	0	0	0	83	445
Petroleum, Chemical and Non-Metallic Mineral Products	Z7	29	3	8	44	47	23	230	10	34	12	24	26	97	1	9	13	16	57	8	34	51	119	2	3	0	3	0	2	2	1	0	0	0	299	1,207
Metal Products	Z8	2	0	4	59	4	4	16	115	46	16	29	15	53	0	4	6	8	6	2	15	7	6	0	1	0	1	0	0	0	0	0	0	0	54	474
Electrical and Machinery	Z9	3	1	13	9	6	11	17	21	229	118	32	0	65	2	13	29	8	11	13	43	62	45	2	1	0	2	0	1	1	1	0	0	0	513	1,273
Transport Equipment	Z10	1	1	2	5	0	0	4	1	11	102	12	0	12	1	2	38	1	15	1	13	44	2	1	0	0	0	0	0	0	0	0	0	0	336	609
Other Manufacturing	Z11	0	0	0	4	3	1	1	0	1	2	4	0	7	0	3	3	3	1	1	10	2	10	0	0	0	0	1	-	-	-	-	-	-	224	282
Recycling	Z12	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	-	-	-	-	-	-	93	98
Construction	Z14	3	0	17	6	3	6	9	5	4	1	2	0	4	1	6	16	12	13	10	89	59	39	1	1	0	8	1	4	4	2	0	0	0	789	1,117
Maintenance and Repair	Z15	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	43	52
Wholesale Trade	Z16	15	1	2	53	15	20	38	16	42	14	14	0	40	1	20	16	33	10	5	33	23	50	1	1	0	0	3	-	-	-	-	-	-	515	980
Retail Trade	Z17	1	0	0	2	1	0	2	0	1	0	2	0	14	0	1	3	10	5	1	10	1	7	0	0	0	0	0	-	-	-	-	-	-	878	942
Hotels and Restraurants	Z18	0	0	0	2	1	1	1	1	1	0	1	0	1	0	2	2	5	2	4	29	8	16	0	0	0	0	1	-	-	-	-	-	-	656	734
Transport	Z19	15	1	12	38	11	18	26	11	9	4	9	20	27	2	39	36	16	62	11	39	23	43	1	2	0	7	1	4	4	2	0	0	0	401	894
Post and Telecommunications	Z20	1	0	1	3	2	4	6	3	14	1	2	0	15	2	38	35	20	31	85	83	54	60	2	3	0	1	0	1	1	0	0	0	0	352	819
Finacial Intermediation and Business Activities	Z21	64	1	37	89	34	44	150	48	160	42	24	0	167	9	182	209	121	162	148	1,120	236	445	10	16	0	18	2	10	10	5	0	1	0	2,570	6,132
Public Administration	Z22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	4	2	1	5	0	0	0	0	0	0	0	0	0	1,335	1,354
Education, Health and Other Services	Z23	2	0	0	2	1	1	3	1	2	0	1	0	3	0	4	6	12	4	13	54	30	105	1	1	0	1	0	0	0	0	0	0	0	1,979	2,227
Private Households	Z24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	41	41
Others	Z25	1	0	0	4	2	1	1	1	1	0	0	0	1	0	4	1	2	1	1	6	1	3	0	0	0	0	1	-	-	-	-	-	-	44	76
Re-export & Re-import	Z26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	13
Water	Z13.1	3	0	2	8	2	3	11	2	3	0	1	0	2	0	2	4	12	4	2	12	8	20	0	0	0	2	0	1	1	0	0	0	0	84	189
Gas	Z13.2	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0	9	21
Electrocity: T&D	Z13.3A	2	0	1	4	1	1	6	1	1	0	0	0	1	0	1	2	7	2	1	6	5	11	0	0	0	1	0	0	0	0	0	0	0	46	102
Electricity: Generation Oil	Z13.3B1	14	0	8	37	8	12	52	11	13	1	2	2	9	1	11	20	58	17	9	55	40	93	0	1	0	8	1	4	6	3	0	1	0	776	1,276
Electricity: Generation Gas	Z13.3B2	33	0	18	85	19	27	119	25	30	3	6	5	20	2	26	47	133	38	21	126	91	213	1	1	0	18	2	10	14	7	0	1	0	1,771	2,912
Electricity: Generation Biomass	Z13.3B3	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0	13	21
Electricity: Generation Hydro	Z13.3B4	19	0	11	50	11	16	70	15	17	2	3	3	12	1	15	27	78	22	12	74	54	126	0	1	0	10	1	6	8	4	0	1	0	1,044	1,717
Electricity: Generation Solar	Z13.3B5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	9	15
Imports	Im	42	8	40	211	58	146	466	179	577	257	72	7	195	10	175	59	90	190	93	347	281	249	8	11	7	40	4	22	22	11	0	2	0		
Compensation of employees D.1	V1	8	3	4	29	6	14	24	14	36	9	6	0	141	5	122	118	66	68	67	426	149	309	3	2	0	7	1	4	4	2	0	0	0	-	8,657
Taxes on production D.29	V2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1	0	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	-	
Subsidies on production D.39	V3	-1	-0	-10	-124	-1	-3	-16	-4	-19	-5	-2	-0	-6	-1	-19	-14	-4	-6	-5	-114	-3	-45	-0	-0	-0	-20	-2	-11	-11	-6	-0	-1	-0	-	36,802
Net operating surplus B.2n	V4	360	26	62	114	17	46	129	31	90	28	17	1	195	12	298	262	142	137	277	3,170	187	518	3	24	0	74	8	40	40	21	0	3	0	-	
Net mixed income B.3n	V5	2	0	1	1	0	1	1	1	1	0	0	0	5	0	6	6	3	3	4	32	9	13	0	0	0	1	0	0	0	0	0	0	0	-	
Consumption of fixed capital K.1	V6	41	3	9	13	3	7	22	7	20	5	3	0	43	2	35	40	24	26	53	475	63	92	0	4	0	15	2	8	8	4	0	1	0	-	
Total Value added	VT	412	33	65	33	25	65	160	48	129	38	24	1	378	18	443	415	231	229	396	3,992	406	887	7	29	0	77	9	42	42	21	0	4	0		
		733	52	249	1,014	290	492	1,433	521	1,330	616	290	99	1,148	52	1,017	1,010	960	890	851	6,257	1,523	2,617	39	76	7	217	31	117	126	65	0	11	1	16,550	40,682
Natural Gas	R1.1	-	-	-	-	-	-	65.92	-	26.99	-	6.54	2.68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	39	-	-	675.00	-	-	-	-	
Coal	R1.2	-	-	-	-	-	-	14.62	-	15.17	-	11.35	10.74	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Petroleum	R1.3	20.00	-	0.08	0.41	0.14	0.21	64.44	0.24	80.01	0.33	19.44	7.98	-	-	-	-	-	1,999.00	-	-	-	-	-	-	-	-	-	-	398.00	-	-	-	-	117.00	
I-GHG-CO2eq emissions (Gg)	R2.1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	-	1	0	0	0	0	0	0	0	1	
IEA - Total primary energy supply (Mtoe)	R3.1	0.013	0.124	-	-	-	-	-	0.145	2.000	0.107	19.900	-	-	-	-	0.610	0.122	0.017	0.166	-	-	-	-	-	0.194	-	-	-	-	-	-	-	-	0.551	

Appendix 3. Electricity Demand and GDP

Year	Electricity Production	Δ Electricity Prod.	GDP	ΔGDP
	GWh	GWh	(const. 2010 MUS$)	(const. 2010 MUS$)
2000	2,472		16,511	
2001	2,785	313	17,502	990
2002	2,826	41	18,755	1,254
2003	2,659	- 167	20,047	1,292
2004	3,338	679	21,616	1,569
2005	3,555	217	23,383	1,767
2006	3,448	- 107	24,473	1,090
2007	4,184	736	26,544	2,071
2008	4,389	205	28,022	1,478
2009	4,741	352	29,530	1,508
2010	5,274	533	31,408	1,878
2011	5,093	- 181	33,891	2,483
2012	5,589	496	35,633	1,742
2013	5,941	352	38,221	2,588
2014	6,219	278	40,883	2,662
2015	6,295	354	43,728	5,507