



Availability of Renewable Energy Sources in Mauritania: Potential, Current Status and Mitigation Potential

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

For decades, Mauritania's economy has been fueled by thermal power. As a developing economy, Mauritania's electricity demand has long been relatively low, though it has increased recently due to economic growth, urbanization, and industrial activities. The rapid growth in demand is making the country more dependent on oil and gas-based generation power plants, which a resultant drain on the national economy. However, Mauritania has abundant renewable energy potential. The deployment of renewable energy can be an alternative solution to reduce the dependence on fossil resources. In this paper, we have reviewed the situation of the power generation sector, the potential of renewable energy, the integration of renewable energy in Mauritania's energy mix and the mitigation potential. The installed capacity in 2018 is 415.5 MW. The percentage of thermal power plants is 59.8% and 40.2% of the integrated capacity is provided by renewable energy. In 2018, the total electric power generation was 1958.5 GWh, the contribution of renewable energy was 979.75 GWh. The IPCC 2006 methodology was used to estimate GHG emissions. The results showed that the integration of renewable energy into the country's energy mix reduced emissions by approximately 212.58 Gg CO₂eq.

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ABBREVIATIONS

<i>MW</i>	: <i>Megawatts</i>
<i>MWh</i>	: <i>Megawatts - hours</i>
<i>IPCC</i>	: <i>Intergovernmental panel on climate change</i>
<i>IRENA</i>	: <i>International renewable energy agency</i>
<i>GHG</i>	: <i>Green House gases</i>

1. INTRODUCTION

Mauritania is located in West Africa and its geographical coordinates are: 21° 0' 28.404" N 10° 56' 27.006" W. It is limited on west by Atlantic Ocean, on south by Senegal, on east and south-east by Mali, on north by Algeria and on north-west by Morocco. It covers an area 1,030,700km² in which 75% is desert area. The country has a 754 linear kilometres coastline.

The country's energy balance has dropped from 80% of traditional fuels of forest origin in 2000 to less than 50% in 2013 [1]. To reach this level, the Mauritanian government has taken a measure that consists of subsidizing fossil fuels by 10%. Demand for fossil fuels has been growing rapidly at an average annual rate of 15%. Today, Mauritania will reduce its level of dependence on fossil resources by exploiting its renewable resources. In contrast to fossil fuel reserves, renewable energies, accepted as a key source for the future, are not only better distributed around the world, but are also harmless to the environment. Moreover, the capital investment needs of these resources are relatively modest if approached in a modular way. These elements make renewable energies a controversial issue both within the scientific community and in political decision-making circles. Mauritania is among the countries with the greatest potential for renewable energy in the world. These renewable energy potentials [2,3,4,5], if efficiently exploited, will ensure energy independence and protection against negative environmental impacts. This work aims to explore the availability and potential of renewable energy sources in Mauritania, as well as to assess government policies and the environmental aspects of renewable energy projects in the country [6]. It also shows the continued growth in renewable energies implementation and the key process to achieve full replacement of mixed electricity generation in the country. Several incentives have therefore

been developed for electricity generation from renewable energy sources through the enactment of laws. According to the multi-criteria analysis developed in the report of the study on technologies needs assessment [7,8,9], the solar PV looks like to be more appropriated in Mauritania. To achieve the recently set renewable energy targets, the government invested in financial projects in solar energy. In this work, we study the renewable energy potential, the large-scale use of renewable energy and the mitigation potential of the electricity sector in Mauritania. This paper is structured as follows:

We first deal the status of electrical energy situation in Mauritania. Then we investigated the potential of renewable energies. The SoDas data were used to make these maps. Finally, we presented the situation of energy production and evaluated the mitigation potential based on the IPCC 2006 methodology [10] of the energy sector.

2. ELECTRICAL ENERGY SITUATION IN MAURITANIA

Mauritania's total installed capacity in 2020 was 415.5 MW, 11.55 % of this generation was hydro, 59.8 % thermal, 20.36 % solar PV and 8.27 % wind (Fig. 1). Table 1 shows the different power plants installed at the end of 2020. However, a 100 MW wind power plant is under construction at Boulenuar. This plant will significantly increase the share of renewable energy in the country's energy mix. The electricity generation in Table 1 are owned by the state-owned the Electricity Company of Mauritania. It responsible for the distribution.

3. THE POTENTIAL OF RENEWABLE ENERGY IN MAURITANIA

3.1 Solar Potential

3.1.1 Global radiation

Mauritania has a high level of solar radiation, which makes it an ideal place for the production of solar energy. Fig. 2 shows that overall solar irradiation varies between 5.49 and 6.12 kWh/m² a day and is well distributed throughout the country. The available solar energy can be used continuously and optimally.

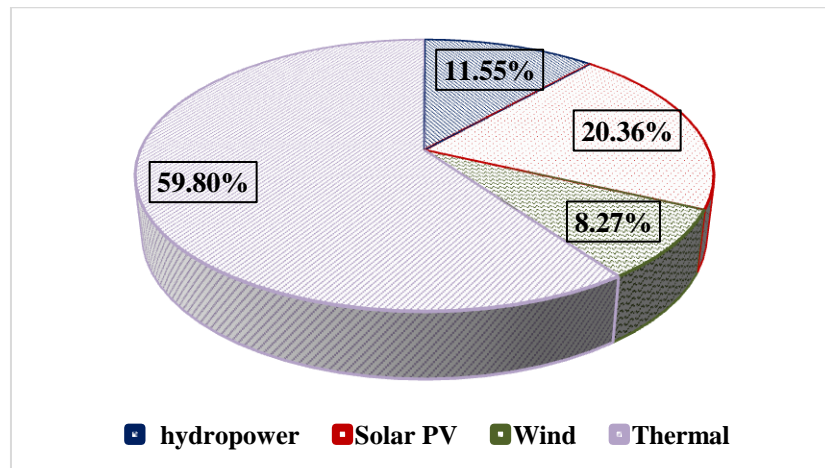


Fig. 1. Mauritania's electricity generation mix in 2018

Table 1. Mauritania's portfolio of installed generation capacity as at 2018

Generation plant	Fuel type	Capacity in MW Installed Available
Thermal power plants		248.5
Nouakchott	Fuel oil	180
Wharf	Fuel oil	36
Arafat	Fuel oil	10.5
Regions (off grid)	Diesel	22
Hydro power plants		48
Manantali	Water	30
Felou	Water	18
Solar PV power plants		84.6
Toujounine	Solar	50
Regions (off grid)	Solar	16.6
Sheikh Zayed	Solar	15
SNIM	Solar	3
Wind power plants		34.4
Nouakchott	Wind	30
SNIM	Wind	4.4

3.1.2 Direct normal irradiation

In Mauritania, the weather stations do not have pyrhemometers. Currently, satellite data are generally used to select favourable areas. The analysis of Fig. 3 shows that the DNI varies from 3.3 to 6.14 kWh/m²/day depending on the study areas. The most favourable areas are in the northern part of the country and they record a DNI ranging from 4.88 to 6.14 kWh/m²/day.

3.1.3 Applications of solar photovoltaic systems

Grid connection:

Two grid-connected photovoltaic solar power plants are installed in Nouakchott. The first is the

one in Cheikh Zayed with a capacity of 15 MW and the second one has a capacity of 50 MW. Cheikh Zayed's solar plant is located more than 20 km from the city of Nouakchott, just north on the road to Nouadhibou. The energy produced is injected into the Nouakchott power grid at a 33/15 kV North distribution station located near the facility. The installation covers an area of 300,000 m² and consists of a 15 MWp photovoltaic field, divided into 29,826 modules of 502.7 Wp each of amorphous technology, inclined at an angle of 10° and facing south. There are also 16 inverters of 760 kW each and a small one of 500 kW. And the one in Toujounine located at 18°4'24.532" North, and 15°52'47.101" West in Nouakchott. It is composed of a solar field of 156,240 320Wp modules of poly crystalline technology, tilted by

12° and facing south. There are also 534 SJB inverters, each with a nominal power of 680 kW (low-voltage circuit breaker disconnecter), 76 and 19 POT (inverter transformer substation).

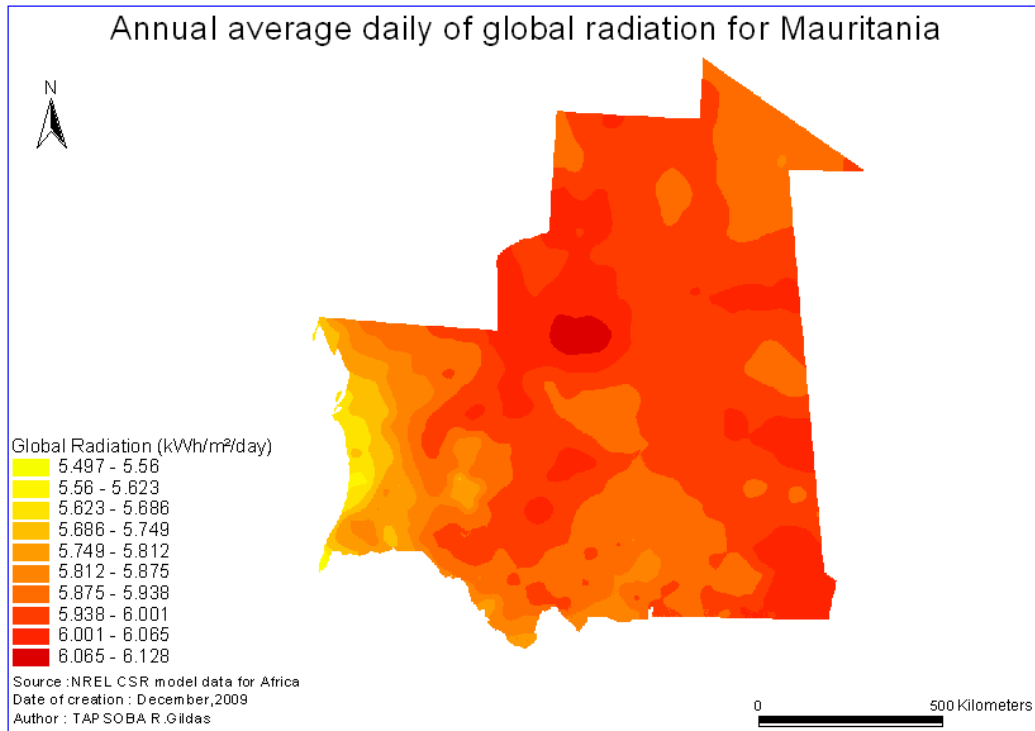


Fig. 1. Annual average daily of global radiation for Mauritania

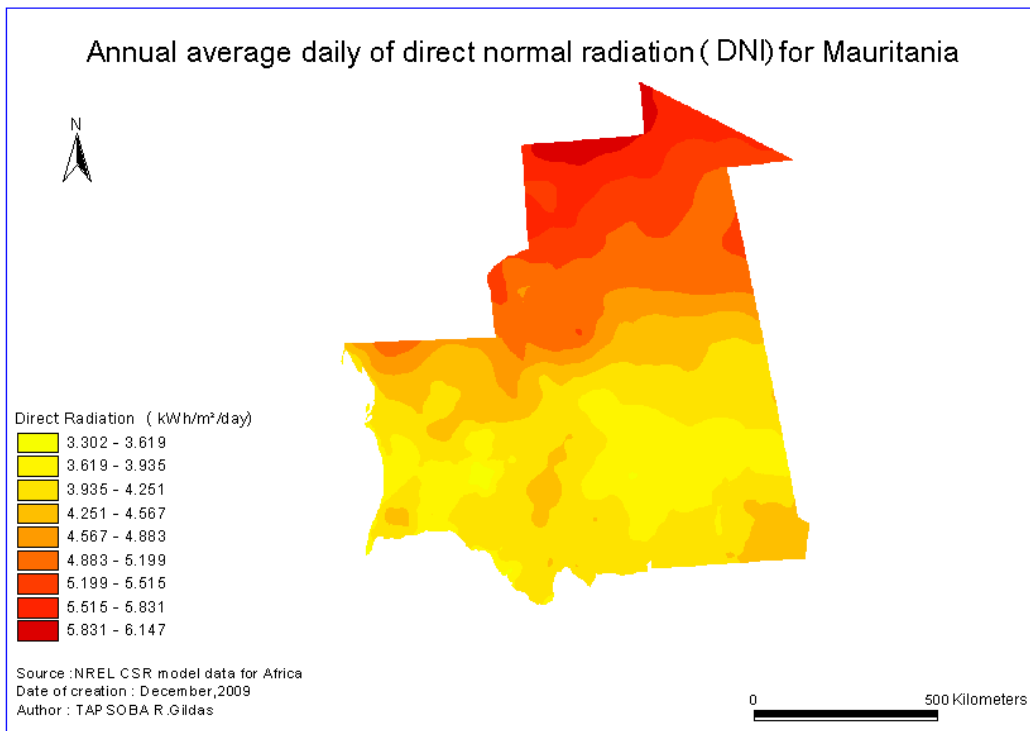


Fig. 2. Annual average daily of direct normal radiation for Mauritania

Applications on isolated systems:

Solar PV in regional capitals, a project for the electrification of regional capitals through small hybrid (PV/Diesel) power plants has been set up by the Mauritanian government. The share of solar energy in the project is 16.6 MWp.

Rural electrification:

A vast and sparsely populated country with 8100 localities of which only 840 have more than 500 inhabitants. Out of 294 localities with more than 1000 inhabitants, 95 are electrified as follows:

- 28 out of 28 localities with more than 10,000 inhabitants
- 17 out of 22 localities of more than 5,000 inhabitants (-5)
- 23 out of 50 localities of more than 2,500 inhabitants (-27)
- 27 out of 194 localities with more than 1,000 inhabitants (-167)

More than 55,000 individual solar kits have been installed throughout Mauritania by the Rural Electrification Agency and other institutions have installed several photovoltaic projects in Mauritania. However, it should be noted that at the individual level, there are several solar kits installed in many countryside in Mauritania.

Water pumping: The PRS (Regional Solar Program) has been financed by the European Union. The Commission has to ensure the supply of drinking water to the entire rural population and improve its living conditions. This is why solar photovoltaic pumping is one of the most widely used systems in rural areas of Africa, particularly in Mauritania.

Multifunctional Solar Platform (MFSP) in Mauritania: The Multifunctional Solar Platform project [11] started in 2008 and is part of the UN support to the implementation of the Poverty Reduction Strategy, which contributes to the achievement of the Millennium Development Goals (MDGs) related to gender equality, poverty, promotion of women, and reduction of energy poverty in rural areas. As in other countries in the sub-region, the United Nations Development Program (UNDP) and the Mauritanian Government have proposed the MFSP as a solution to the problem of fuel poverty in the rural sector. This MFSP technology involves harnessing photovoltaic solar energy to power seed mills, small welding

stations, refrigerators and chargers for telephones. Today, more than 50 multifunctional platforms have been installed in Mauritania and several rural villages have benefited from this service.

Concentrating solar power plant: There is no concentrating solar power plant installed in Mauritania.

3.2 Wind Potential

Mauritania is one of the West African countries with the highest wind energy potential, with an estimated capacity of 7644 kW/m². The wind potential is dominated by three types of winds: sea wind, harmattan and southern monsoon. Wind speed varies from 3 m/s in island regions to more than 9 m/s in the northwest near the Sahara [12,13].

3.2.1 Application of wind technology

There are two types of wind energy applications: large wind farm applications and isolated applications (less than 50 kW). For large-scale applications, there is the 4 MW wind farm in Nouadhibou which has been in operation since March 2012 and a 30 MW wind farm in the suburbs of Nouakchott which is commissioned in 2015. Isolated applications of wind energy include water pumping and irrigation, water desalination and various electrical applications. On the other hand, 18 villages with about 50-60 households have been equipped with a 1 kW wind turbine to charge the batteries. Subsequently, 14 health centers were also equipped with 14 cooling systems for medicines and vaccines [14]. Finally, more than 100 mechanical wind pumps, known as the Alize projects, have also been installed in the Trarza region.

3.3 Hydroelectric Potential

Hydropower potential is practically non-existent in Mauritania and is seasonal. The high dam of Fom Gleita with 500,000,000 m³ is mainly used for irrigation. In addition, Mauritania and Senegal are separated by the Senegal River whose source is in the Gulf of Guinea in the Fouta Djallon massif, and flows 1800 km before flowing into the Atlantic Ocean at Saint-Louis of Sénégal; formed by three tributaries: The Bafing (760km), the Bakoye (560km) and the Falémé (650km). We can affirm that its hydropower potential is

part of the sub-regional potential of the Senegal River Valley organization (OMVS).

3.3.1 Hydropower applications

The Manantali hydro power plant dam is a regional project for the Senegal River valley organization (OMVS) commissioned in. It is located on Malian territory, with an installed capacity of 200 MW. Under the agreement reached between the member countries, production is distributed as follows: 52% of the energy produced is supplied to Mali, 33% to Senegal, and 15% to Mauritania. The power plant consists of five vertical shaft Kaplan type turbines of 41 MW each and five generators and transformers of 47 MVA. The energy produced by the Manantali power plant after losses about 10%, is between 501 and 800 GWh/year [14]. This power plant offers Mauritania a significant hydroelectric potential. The power line of the transmission grid extends over three countries and is more than 1500 km long (more than 1300 km at 225 kV, 23 km at 150 kV, and 186 km at 90 kV). Felou hydro power plant commissioned in 2013 with an installed capacity of 60 MW. These two hydro power plants cover between 10 and 15 % of Mauritania's energy needs.

Mauritania is beginning to reap the benefits to develop regional energy integration. The development of energy markets on a regional basis promises substantial benefits. Interconnections create export opportunities for those countries.

4. ENERGY PRODUCTION FROM RENEWABLE SOURCES IN MAURITANIA

Most renewable energy facilities are equipped with meters to measure production and some for GHG emissions. The evolution of production (GWh) by source is shown in Fig. 4.

Hydropower: Fig. 4 shows the status of hydro power generation. This production represents Mauritania's share of the hydro power plants of the Senegal River Valley organization. It is expressed in GWh, with an increase from 111.743 to 236.225 GWh between 2009 and 2016 and a decrease in production between 2017 and 2018. This is explained by the fact that Mauritania has sold part of its share to Mali and Senegal. The production of hydropower exported

to Senegal and Mali from 2009 to 2018 reached approximately 100 GWh in 2018.

Photovoltaic solar: Fig. 4 shows the development of energy production by photovoltaic (PV) solar source in Mauritania. In recent years, the production of energy by solar PV has grown rapidly. This is due to the government's strategic orientations in the power generation sector, which has allowed the installation of two grid-connected solar power plants and hybrid (PV/Diesel) power plants in some of the country's cities.

Wind Power Generation: We have also seen in Fig. 4 the growth in power generation from wind power. Like solar PV, wind power generation has grown from 2,949 to 117,365 GWh, due to the commissioning of a grid-connected wind power plant in Nouakchott in 2015. Currently a 100 MW grid-connected wind power plant is being built in Boulouvar, a coastal town in the north of the country.

5. MITIGATION POTENTIAL

In this case to fight against climate change, Mauritanian government has set up a strategy for the development of renewable energy. This strategy has made it possible to diversify energy production sources. In this work, we used the IPCC methodology. Direct (CO₂, CH₄, N₂O, HFC) and indirect (NO_x, CO, NMVOC, SO₂) greenhouse gas emissions were estimated based on the 2006 IPCC Guidelines. The estimated gases are converted to CO₂ equivalent. Thus, solar and wind power plants have been added to hydroelectricity in the national energy mix. These efforts have shown an increasing evolution to avoid GHG emissions from 2009 to 2018 (Fig. 5). Hydroelectric production from OMVS has allowed for recording avoided GHG emissions varying from 78.228 to 98.0458124 Gg Eq CO₂. Then, between 2013 and 2015, the Cheikh Zayed solar and wind power plants in Nouakchott were commissioned, which increased the avoided emissions from 141.406575 to 166.412976 Gg Eq CO₂. Between 2016 and 2018, the Toujounine solar power plant and the hybridization (thermal/solar PV) in the capital city have increased the avoided GHG emissions to 212.5821 Gg Eq CO₂. As the GHG emissions of the energy sector is 3307.944 Gg Eq-CO₂ in 2018. the government's efforts in terms of development of renewable energy have reduced the GHG emissions of the energy sector by about 6.43%.

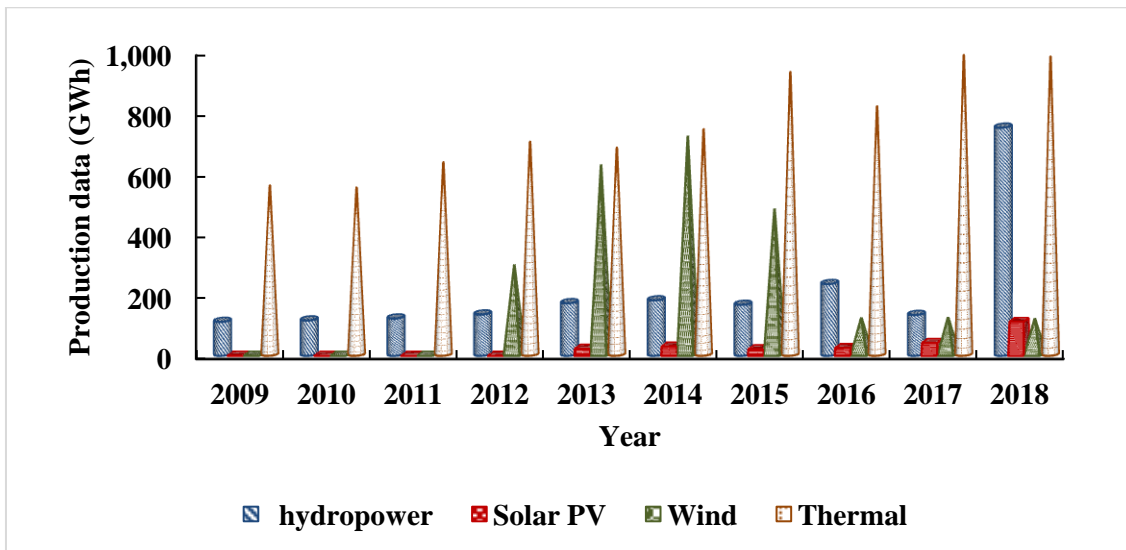


Fig. 3. Mauritania's electricity production mix

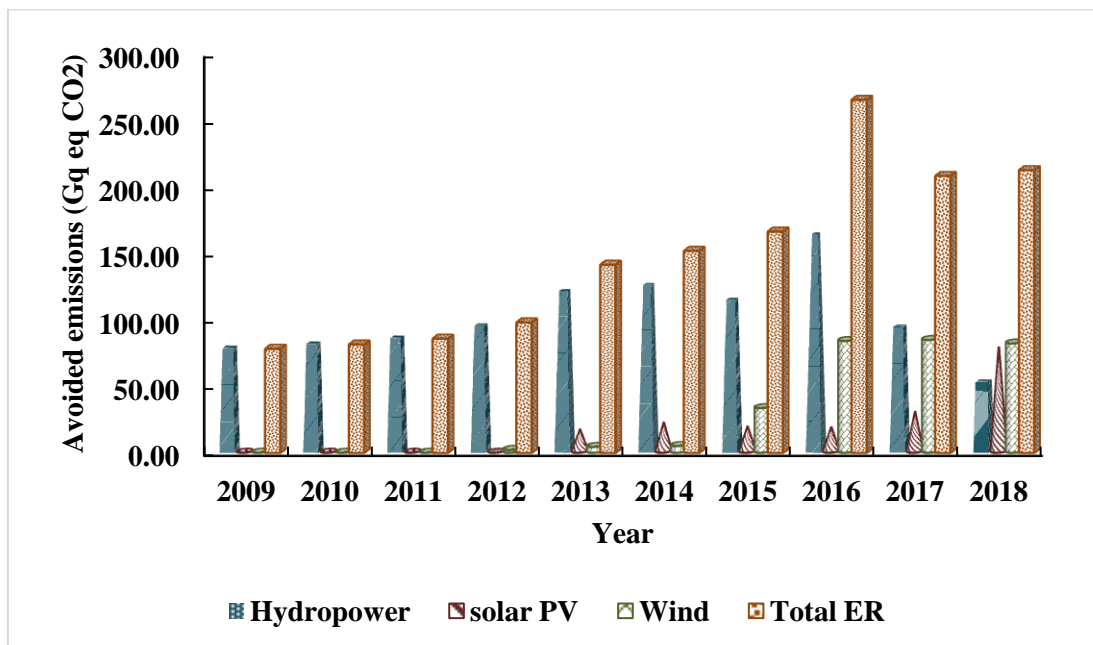


Fig. 5. Potential of mitigation

6. CONCLUSION

This study presented the electrical energy sector in Mauritania. The current energy situation in the country was discussed. Despite the considerable efforts made to develop the energy sector, in particular renewable energy, the objectives in terms of achieving the MDGs are far from being reached. Consequently, the Mauritanian government must increase its efforts to advance these goals. Rural areas remain marginalized, with only 2 to 5 per cent of them having access

to electricity by private individuals. The penetration rate (number of households connected to the grid) is very low in semi-urban areas of the country. Due to the low level of electrification in rural areas, we propose to planners and government experts to use renewable energy sources to expand electrification through autonomous systems; a new design approach is needed, it will be possible to combine renewable energy sources with diesel generators and micro-grids. Similarly, as urbanization accelerates due to both

population growth and economic expansion, energy demand should increase. This will require the extension and intensification of the electricity grid. In addition, the country is highly dependent on the import of fossil resources (oil, gas) and the renewable potential remains little exploited. However, there are renewable energy generations in the large cities (Nouakchott and Nouadhibou due to wind and solar energy) and in the rural sector due to solar photovoltaic kits. After an extensive visit to rural areas and on the basis of studies, a series of recommendations were made, some of them oriented towards technical, social and economic aspects for the improvement of solar platforms [15]. The system, which stands alone, suffers from innate disadvantages such as low factor capacity, excessive battery costs and limited electricity storage capacity, forcing the disposal of the surplus energy generated. The potential solution to these problems is to use the hybridization of several energy sources.

Finally, we have presented the situation of energy mix of Mauritania. It is always dominated by the use of fossil fuels, but the penetration rate of renewable energies is around 41%. The integration of renewable energies in the energy mix of Mauritania has enabled to stock 212.58 Gg Eq CO₂.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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