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Low Carbon Emissions: Future Green Steel Production in Mauritania

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Abstract

Global change can be achieved by greenhouse gas emissions translated by low carbon transition. Mauritania by its promising solar and wind energy would offer a great contribution to energy transition. The future possible green steel production would change the socio-economic context by its diverse renewable energy consumption behaviors and low carbon emission reduction trajectories. Population growth logistic variation method relationship with energy consumption, with and without energy use coefficient, is considered as a great method for the worse and reference case illustration. The country by its intrinsic solar and wind renewable energy potential and ‘’ carbon sink’’, would change the energy transition scenarios completely and theirs trajectory behaviors definitively.

Keywords: green steel; emissions; anthropogenic greenhouse gas; carbon sink; energy transition scenarios; low carbon transition.

1. Introduction

Transition to clean and fair energy can be achieved by various emission reductions pathways translated by low carbon transitions. Mauritania has a distinguishable solar and wind renewable energy along its coast of Alize climate. This renewable energy is a main determinant as mitigation for the emissions of anthropogenic greenhouse gas, CO2.

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In this study an explanation of the importance of the potential of solar and wind energy of the country, worldwide and locally as a principal component of energy transition. The future possible opportunities of low carbon emissions reduction especially green steel production for the continental, and energy efficiency technology innovations impact on emissions reduction and energy saving, have been clarified. The main sources of greenhouse gas emissions and the determinants affecting negatively and positively the emissions reduction represented by the low carbon transitions, have been classified.

Five known energy transition scenarios have been defined, theirs objectives, considerations, adoptions and constrains of construction have been cited. Finally, a case study treating a possible future green steel production in this country has been defined. The impact of energy use coefficient on the emissions reduction trajectories and energy consumption behaviors, have been demonstrated.

2. Main local renewable energy

Some studies have been covered and made on Mauritania renewable energies. Wind and solar energy has taken the big part. The coastal of the country is characterized by a good wind velocity adequate to high output of energy. Onshore turbines have been already in place for some project on the coast of the continental. Solar panels of PV, photovoltaic are preferable especially in the coast due to the effect of the wind velocity that lowers the temperature of the panels and hence enhances the efficiency of the PV for more power output. A hybrid wind and solar along the costal of this country is an appetite for the big companies of sustainable energy. A 5% of the area at this coast yields about 12 Mt of green hydrogen. Any other low-carbon would be possible for steel industry in the continental. Indirect green seawater hydrogen production is among the present planed targets for the companies. The innovation of smart grids and supercapacitors for this intermittent energy would classify this energy as primary sustainable one .This renewable energy would make grate change for the humanity not only in Mauritania but for the out world. Green steel is one of the base industries of this sustainable energy the country considered it as a future ambition plan. Steel is a critical element for building construction, cars, railways and etc. Hydropower energy in Mauritania from Senegal River is shared with their nabors, Senegal and Mali. Manantali plant is dam in Mali, which is the first that assured electricity generation, then Felou and Gouina that have been recently feed a part of the country in electricity. As known, failure is among the main issues that hydroelectric plants face in the world because of the mechanical problems of their turbines like the case of Manantali. The hydropower potential of Senegal River is estimated to be 1200MW. Tindouf basin is among the East West geothermal trend that comprises Canary Archipelago and continues until Algerian Sahara. It has a wide geothermal gradient range and heat flow that varies respectively from 25 to 45°C/km and 70-100mW/m2 [1]. Carbon storage is used worldwide as among the main way s to reduce the anthropogenic CO_2 gas emission to atmosphere. Various types of carbon capture and storage are known worldwide. From the direct one to the one from the facilities processing until it is stored in the geological structures. Carbon capture use and storage, CCUS and the negative bioenergy with carbon capture and storage, BECCS are the main examples. Studies have been made on the gas hydrates indications offshore the country. Usually this gas is found on the slop riser and any depression would emit the green house gas methane to atmosphere which represents another risk geohazard for the environment.. The idea is to inject carbon dioxide in the formation to capture methane and store the carbon dioxide, CO_2 for the stability of the formation containing methane. This type of storage of green house gas mitigates the risk of emission of another green house gas and ads value for lower carbon use worldwide. The anthropogenic CO2 gas can be used with biomass for biofuel production. Per example Plasma technology reactive species and energetic electron could decompose this inert gas rich carbon especially for low carbon biomass feedstock to produce biofuels for energy purpose [2, 3]. Renewable energy, hydrogen, CCUS, BECCS technologies and nuclear are components to energy transition despite the phasing out of nuclear adopted in some scenarios. Carbon storage technologies innovations need huge fund for big scale projects and may have leak risk to environment. Gas hydrate storage type of CO2 and biomass use with CO2 needs thoroughly study. Both carbon storage and gas hydrates storage type play respectively important role in emission reduction and geohazard risk mitigation.

3. Green steel future project

The heavy industry of steel production needs a lot of energy in form of heat using sources like electrical energy or coal for heat energy. About 8% of anthropogenic green house gas is due to this industry. The chemical reaction of carbon and iron oxide forms steel with dioxide carbon. That is to say steel is the result of carbon reduction of oxygen from the iron oxide. The global economy consumes about 1700 Mt a year. From 1990 to 2017, the world's total steel production increased by 850 Mt, of which 87% came from China that produced almost the half (49, 2%) of world's steel production at 2017 [4]. An expected slowly demand grows toward 2105 Mt in 2050. The industry is facing numerous pressures especially the environmental one. There will not be a sufficient scrap available for less carbon- intensive process to provide all the steel that the global economy will consume. Green steel industry is a clean form of low carbon steel production. The heat energy source and the hydrogen used for processing are purely from renewable source. Green hydrogen today in market is about 1% from global hydrogen production. There is a competition between green hydrogen price and hydrogen from other sources price that will be expected to be around 2$ in 2025. Companies that have committed to low-carbon production represent only 8% of total global steel production. Mauritania is the second producer of iron ore in Africa. In its ambitious plan, the country wants to capture up to 1% of global green steel market by 2050. Its distinguishable coastal with its Alize climate could generate enough green hydrogen by the hybrid wind and solar renewable energy for green steel production. As first major step of decarbonization in heavy industry, in 2022 SNIM, National Industrial and Mining Company signed with ArcelorMittal an MoU for the purpose of green steel production. CWP and Chariot have shown their interest on land by their famous projects of wind and solar renewable energies in west and north of the country.

Energy efficiency technology innovation is among the main factors contributing to fair and reliable energy transition. Plasma technology type is the key industry tool behind semiconductor processing. WBG, wide band gap devices can eliminate 90% of electricity loss when converting current from AC to DC or DC to AC. GaN and SiC are example of this WBG semiconductors materials which have high efficiency compared to Si devices. The smart grid technology is another important example in energy and power generation. Renewable energy micro-grid can be injected in transmission lines as distribution lines in case of power outage. Renewable electricity capacity addition rose to 340 gigawatts (GW) as a result renewable energy now account for 30% of global electricity generation. Non thermal plasma technology with its low temperature and effectiveness of its energetic electrons toward the inert carbon dioxide becomes the new interest for biomass and CO2 conversion to energy. The conversion represents a great reduction of CO2 emission and added value. Energy efficiency in general, the so called first fuel, lowers energy bill and strengthens the energy security. China in its plan for energy efficiency has replaced more than 80% of old motors and focuses on the efficiency of the heavy industry like steel, aluminum and cement fabrication. EU countries regulated rules in 2023 and target 11.7% of energy saving by 2030. The inflation Reduction Act, IRD in USA is expected to boost the energy efficiency and brings energy bills down. Culture of saving in energy has been extended over the world. The incandescent bulb of 100 or 60watt can be replaced by LED light bulb of 9watt.

4. Low carbon transition

The low carbon transition corresponds to change in socio-economic systems to assure that the anthropogenic greenhouse emissions is in line with keeping the global worming below 2°C or 1.5°C. That is to say it must be in line with achieving net zero emissions at the global level in the second half of this century. It corresponds to the balance between anthropogenic greenhouse gas emissions and their absorption by carbon sinks for example technology that increases natural carbon sinks like reforestation or the artificial CO2 removal technologies by for example the common called bio-energy with carbon capture and storage, BECCS. The main sources of greenhouse gas emissions come from:

- Energy use from combustion of fossil fuel or biomass, the gases emitted are CO2, methane, CH4 and nitrous oxide, N2O.
- Agriculture, nitrogen fertilization of soil and rice cultivation, the emitted gases are CH4, N2O and CO2
- Some industrial process such as, in cement industry and the use of solvents, the emitted gas are CO2, CH4, N2O and fluorinated gases like HFC and SF6.
- Waste during the incineration, the gases emitted are N2O, CH4 and CO2.
- Land –use, Land-use change and forestry LULUCF), the emission may be negative especially forestry absorbs more greenhouse gas than it emits which is referred to carbon sink. Dioxide carbon emission is the vast majority then N2O and CH4.

Studies have recently shown that emissions from carbon based sediments are of hundred millions tones that it had not be taken into account in the transition scenario.

Different energy transition scenarios have been made by institutions and organizations. All of them have a climate target and vision on the trajectory of the anthropogenic gas of CO2. The international energy agency, IEA adopts the Net Zero emission by 2050. The objective is the emission neutrality by 2050 while meeting other universal access to energy access and coking by 2030. The Announced Pledge Scenario, APS and Stated Policies Scenario, STEPS are their exploratory scenarios. All NZEs are pathways but not all pathways are necessary NZEs. The main climate target is to limit the global warming temperature rise below to 1.5 or 2°C by 2050. Among the socio-economic context of the transition, there are population change and economic growth from the GDP. Greenpeace Advanced Energy Revolution Scenario has a target below 2°C and the emissions are drastically reduced to reach zero in 2050. IRENA, the international Renewable Energy Agency, REmap considerations of the climate target are over the cumulative emission between 2015 and 2050 which is below the carbon budget that gives a 67% probability of limiting global warming rise below to 2°C. BP Rapid Transition scenario adopts the increase of electrification, the energy storage and the use of hydrogen and bioenergy. Low Energy Demand, LED has a carbon budget as constrain of 390 GtCO2 for 2020-2100 in the model used for its construction. Two main analytical approaches are adopted to distinguish between model s of transition scenarios. Model built around global, macro-economic approach known as top-down, they are used to analyze the economic impact of climate policies. Models built around techno-economic approach known as bottom-up, they are based on general or more detailed representations of technology, their OPEX, emission factor and etc. Depending on the type of model, some parameters may be input or output. As an example GDP is generated through the macro-economic model, it is an output or endogenous parameter. Among the innovation in energy sector, addressed by the long-term energy scenarios, LTES, there are innovation in decentralization, digitalization and electrification. Global changes supposed have the same climate goal, which can be achieved by various greenhouse gas emission reduction pathways representing potential low carbon transitions that depend on the following determinants:

- Change in the socio-economic context: demographic, economic, political, technological changes and etc.
- Reduction efforts over time by sector and by country
- The type of mitigation solution deployed and their importance in the reduction of the emission. Four key mitigation solution types from IPCC research can be distinguished:

1. Emission control from agriculture systems and soil
2. Decarbonising the energy mix through:

- The deployment of renewable energy
- Electrification of transport sector, industry and building
- The deployment of nuclear power
- The deployment of carbon capture use and storage(CCUS) technologies
- The decrabonisation of non-electric fuel by per example the use of renewable hydrogen

3. Managing demand for energy and greenhouse gas-intensive materials
4. Using negative emission that absorb the anthropogenic gas, CO2

- The role of different drivers of transition, political, technological and behavioral that can be used to deploy these solutions [5].

5. Case study

Mathematical low establishment

Logistic Growth Model is one of the mathematical empirical methods used for the population projection especially for the requirement of energy resources. The global energy demand increases in direct proportion with the world's population $N_w(t)$:

$$E_w(t) = e_w\, N_w(t) \qquad (1)$$

Where e_w (equivalent to 1.8 toe, tones of oil equivalent) is the average per capita stationary energy consumption in the world in the 21st century.

The energy efficiency coefficient or energy use rate that reflects the world's technology level follows also the logistic low:

$$K_{ee} = \frac{K_{ee0}(1+c)}{1+c*\exp[-d(t-T_{ee0}\}]} \qquad (2)$$

The parameters $c, d\ and\ K_{ee0}$ are determined by the initial conditions at T_{ee0}.

Any increase in energy consumption can be expressed by the normalized $\overline{K}_{ee}$ coefficient,

$$\overline{K}_{ee} = \frac{K_{ee}}{K_{ee0}} = \frac{1+c}{1+c*\exp[-d(t-T_{ee0})]} \qquad (3)$$

The real energy consumption is the sum of energy supplied by fossil fuel and renewable energy. The present used of hydrocarbon energy as supply in industry, transportation, production or building gives in idea about the left of renewable energy as energy supply in reality or for a possible energy transition. Based on estimation in the 21st century, the decreasing of coal and the increasing of gas utilization, the anthropogenic CO_2 emission, $C_w(t)$ relationship with hydrocarbon energy, E_{wff} can be written as:

$$C_w(t) = c_c . E_{wff}(t) \qquad (4)$$

Where $c_c = 0.57$. [6]

The energy demand is estimated using equation (1) based on the medium population projection variant. The diverse technologies contributing to energy efficiency have been taken into account in the coefficient of energy use scenarios to estimate the real consumed energy from equation (2).

The renewable energies used in this estimation are hydropower, wind and solar for electricity generation and industry sector from the latter. The equivalent of green hydrogen production and processing from solar and wind energy for green steel production, is used to estimate the contribution of this new industry in the reduction of the anthropogenic gas CO2. With 50-55kWh required to produce 1kg of hydrogen, and 50kg of hydrogen required to produce 1 ton of steel, in the case of Germany (the EU's largest steel producer}, it would require about 100 terawatt-hours (TWh) of renewable energy to fully decarbonise the annual production of 42 megaton's (Mt) of steel. Electricity generations are from solar and wind renewable and hydroelectric power of the country from Manantali, Felou and Gouina plants. The share of Mauritania from Manantali, Felou and Gouina are respectively 15, 30 and 33%. Biomass in this Saharian country is especially in the south where the forests exist in heavy rain places and near the Senegal River. The plausible means of emission reduction of low carbon emission is the production of green hydrogen through wind and solar renewable energy. Two trajectories have been considered to show the pathway of the anthropogenic CO_2 gas emission considering two cases, using the energy use coefficient or neglecting the use of this coefficient that takes into account all types of energy efficiency for developed and developing countries from 1900 to 2100 [7]. Low carbon steel production industry in this country is favorable as ambition plan for the national economy growth and as mitigation for the greenhouse gas emissions of CO2. The 2.1Regreens, 2.1 Mt, average green steel production shows that the greenhouse gas emission from the hydrocarbons consumed by the 5 million people in 2025, peaks at 2Mt of CO_2 in the case of using the energy use coefficient. This 2.1 Mt of green steel production could not satisfy the emission neutrality by 2050 and the renewable share by 2030. . **Figure.1, 2.**

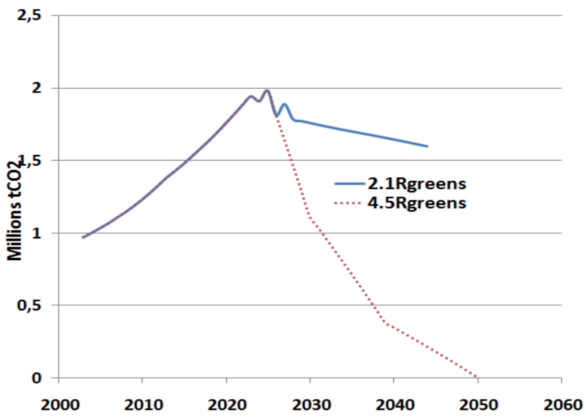

Figure 1: Anthropogenic gas emissions reductions from 2.1 Mt and 4.5 Mt, average green steel productions in the case of using the energy use coefficient.

The 4.5Rgreens trajectory peaks at 2025 and shows anthropogenic gas emission, CO_2 neutrality by 2050. **Figure.1** The renewable energy share is about 60% by 2030 which translate the country ambition by 2030. **Figure.2.** The 4.5 Mt, average green steel production, could be considered as one of the ambitions the country wants to capture from green steel market before 2050. It represents the 1% of green steel production estimating at least 20% of companies for the commitment of low carbon emission. This trajectory, with the country ambition and limitations represents a great emission reduction toward a clean energy by 2050. In the other case that neglects totally the energy use coefficient, 10.3Regreens of average 10.3 Mt of green steel production, satisfies the country ambition by 2030, and the emissions reduction by 2050. **Figure.3, 4**. It really shows a great reduction, even by neglecting an important component in energy transition which is the energy efficiency represented by an energy use coefficient of 0.1 to 0.9 in 2100 century for both developing and developed country.**Table.1.**

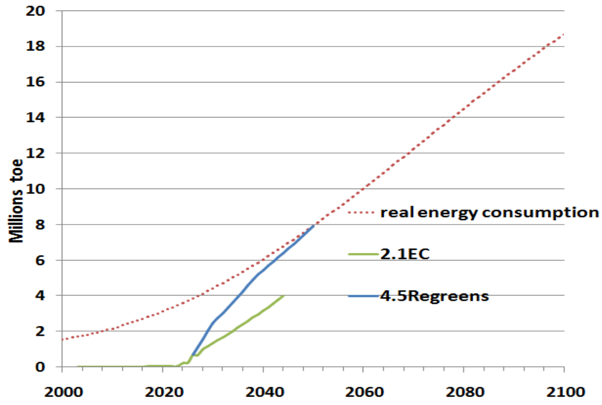

Figure 2: Renewable energy consumptions of 2.1 Mt and 4.5 Mt, average green steel productions and the real energy consumption in the case of using the energy use coefficient.

Results in some studies show that technological innovations is unlikely to reduce energy consumption growth, as some academics and government agencies have recognized. In china for example, energy consumption growth is an inevitable trend along with technological innovation and social development at the present development stage. Lund holds that there are three ways to achieve sustainable development through technological innovation in energy: energy saving on the demand side, efficiency improvements in energy production and replacement of fossil fuel by various sources of renewable energy [8]. Renewable energy consumptions in the two cases in this study with and without the energy use coefficient, follow a logistic growth function minimizing the energy consumption and at the same time satisfying the emission neutrality for medium and long term regime. They are derived from a logistic method that describes population growth. The variation of this logistic method has well matched the census result in the 18 and 19 century in the United States. Following the same them of logistic variation in energy consumption that depends to population growth, would lead to acceptable results. Using zero green hydrogen or low carbon hydrogen for steel production is considered a great step for the national economy growth and low carbon emission reduction. Exporting low carbon hydrogen which includes the zero, the green hydrogen, is a major contribution for the global level emission reduction needed internationally as energy supply and for the clean energy transition to limit global temperature rise below of 2 or 1.5°C above the pre-industrial level.

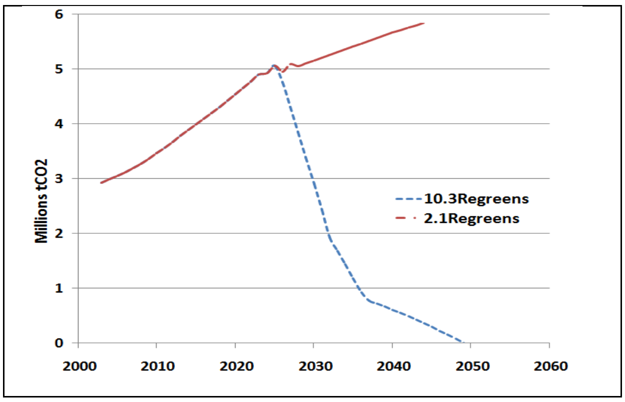

Figure 3: Anthropogenic gas emissions reductions of 10.3 Mt and 2.1 Mt, average green steel productions in the

case of neglecting the energy use coefficient.

Managing energy demand for consumption is difficult task to be handled. For example China as a developing country is still in the stage of rapid urbanization, motorization and industrialization and will still consume more energy in the future development process. Hence, it faces a problem of energy consumption [9]. In Russia Federation, the Green Balance house in low –rise building construction reduce energy consumption by 60% compared to standard type of building construction. This is due to the innovation in energy efficiency technology in this domain of energy use that impacts directly the socio-economic context and people lifestyle [10].

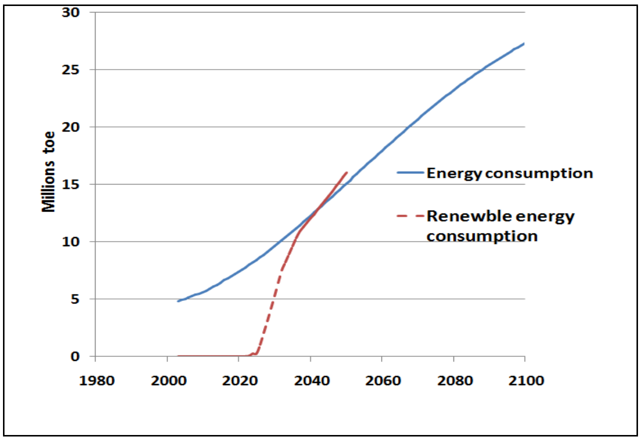

Figure 4: Renewable energy consumptions for 10.3 Mt, average green steel production and energy consumption in the case of neglecting the energy use coefficient.

A robust model could show all sensitivities for energy use in this new technology of green steel production industry. This new technology industry is among the determinants that will change the socio-economic system for this part of the world, and thus a great transition is expected to satisfy the emission neutrality in the second half of this century. Carbon budget is the maximum cumulative emission that must not be exceeded to maintain certain temperature of global warming. In the IPCC 1.5°C special report, the remaining carbon budget from January 2018 is estimated at 1170 GtCO2 to keep global warming below 2°C and 420 GtCO2 for 1.5°C. The daily estimated of 12Mt of green hydrogen of the 5% of the area from the country corresponds to a yearly reduction of green house gas emission of about 10 GtCO2. In the five scenarios of energy transition mentioned in this study, the anthropogenic gas emission peaks at 32.5-35GtCO2 in 2020. This Mauritania ‘’ carbon sink’’ contribution could affect the climate target adopted by the energy transition scenarios and boost the emission neutrality before per example the half of this century as adopted by some of scenarios. Scenarios, if updated based on this possible green hydrogen production from Mauritania in the future; would change completely and theirs trajectories behave differently.

Table 1: The two cases of energy use coefficient utilization

	Case 1 (Using the coefficient)	**Case 2 (Without the coefficient)**
2.1 Mt	Less emission reduction, does not satisfy RE by 2030	less emission reduction, does not satisfy RE by 2030
4.5 Mt	Emission neutrality by 2050, RE satisfaction by 2030.	
10.3		Emission neutrality by 2050, RE ambition satisfaction by 2030.

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