HiLL PUBLISHING

Journal of Electrical Power & Energy Systems, 2024, 8(2), 76-93
https://www.hillpublisher.com/journals/jepes/
ISSN Online: 2576-053X
ISSN Print: 2576-0521

The Big Challenge: Reducing Global Emissions and Increasing Global GDP

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How to cite this paper: Silverio Penin y Santos, Elias Felipe de Carvalho, Carlos Alexandre de Souza Penin. (2024) The Big Challenge: Reducing Global Emissions and Increasing Global GDP. *Journal of Electrical Power & Energy Systems*, 8(2), 76-93.
DOI: 10.26855/jepes.2024.12.005

Received: February 25, 2025
Accepted: March 22, 2025
Published: April 21, 2025

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Abstract

This analysis aims to establish a relationship between the population's growth, the GDP growth, the energy consumption growth, and GHG emissions growth from 1950 to 2024 and, with data from this period, predict the global situation in 2050. In present days, the great trend is based on two premises: a) Anthropogenic activity causes excessive emissions of greenhouse gases, increasing the concentration of CO_2 from 250 ppm at the beginning of the first industrial revolution to 425 ppm today. The exaggerated levels of carbon dioxide, methane, and others could not be sustained by the planet. Thus, social pressures led by environmentalists pose obstacles to using fossil fuels for electricity generation, heating, industrial production, transport (people and goods), use of forests for agricultural and livestock. b) However, human pressure for better living conditions opposes the barriers that try to prevent the increase in the use of energy from fossil fuels as a driver of wealth generation. The proposed and consensual path is the rapid replacement of fossil energies by renewable energies. This responsibility falls mainly on wind and solar energy. Biofuels are limited by the need to use the land for food, hydroelectricity is already almost fully used, and nuclear power generates very radioactive wastes. Wind and solar energy have a generation of 30% and 20%-25% of its installed power, while nuclear has 90%, coal 75%- 80%, gas and oil 65%-70%, and hydro 45%-6o%. The difficulty of storing them (Solar and Eolic) in their primary state, the instability of generation, and the quality of the energy generated are strong obstacles for the use of these energies. These difficult renewable energies are needed to quickly meet aspirations for comfort and well-being, increasing the pressure on fossil energies in short-term actions in poor countries. This article explores the need to satisfy the desires of high percentages of populations who have the right to improve their living conditions and who, therefore, will exert pressure to continue using fossil energy sources, but the zero-carbon target must continue. How to succeed in this objective is the great challenge.

Keywords

Energy; Fossil Fuels; Solar; Wind; GHG; Emissions; Steps; APS; NZE; CDR; CCUS

1. Introduction

If the global warming limit of 1.5 ºC prevails as established at the COP-2015 in Paris, perhaps already exceeded (or even 2 ºC), as the limit of the point of no return to avoid environmental catastrophe, the question arises: why did we get here? Reports of catastrophes have been made before. The last one was from the Club of Rome [1], which predicted resource depletion in 2015.

The Meadows Report 1972 [1] underestimated the radical change promoted by Information Technology called the Third Industrial Revolution. It also does not address the capacity of many countries to implement new production policies that resulted in a surprising increase in their production. In 2004, the review of the Meadows Report [1] for the Club of Rome presented several simulations. Once again, the authors imagine resource limitations. Again, a limitation of Malthusianism: the exhaustion of supply sources in general and energy in particular, making the planet incapable of satisfying the population's basic needs, but this limitation did not occur!

The big problem: energy matrices until now are basically based on coal, oil, and gas. In 2024, the share of fossil fuels was 81.5% in global energy consumption.

Analysis of the increase in greenhouse gas emissions shows the consequence of this expansion. In 2024, GHG emissions reached 41GtCO2 and 10-11 GT of other GHGs such as methane (CH_4), oxide nitrous (N_2O), hexafluoride (HFC), and sulfur hexafluoride (SF_6), totaling 51-53 GT of all GHGs [2]. Emissions are more significant in China and rich countries. But many other countries will certainly need to increase their energy to develop.

2. Challenges: Walking along two lines

2.1 Maintain the goal of eliminating extreme poverty on the planet and reduce dramatically inhabitants with income between US$ 2.17 and US$ 6.85 per day [3-5, 5-28]

Below are self-explanatory figures:
Figure 1: Reduction of extreme poverty from 1820 (1 bi or 95%) to 2024(700 mi or 8.5%).
Figure 2: The GWP growth after 1960.
Figure 3: Poverty in two levels. With data from 1990 to 2020, extrapolation to 2050, indicates ≈6% below U$2.17/day and 34% below U$ 6.85/day in 2050 [28].

Figures 2 and 3 show the GDP growth isn't enough to eliminate the extreme poverty with the present inequality. Although the planet's wealth is enough to eliminate absolute poverty, the persistence of 6-8% constitutes a sad and unacceptable situation; and 34% living between U$2.2 and U$ 6.65 is not a mark to be proud of. Corruption and backwardness in certain countries or pockets in others are impediments to the final eradication of extreme poverty.

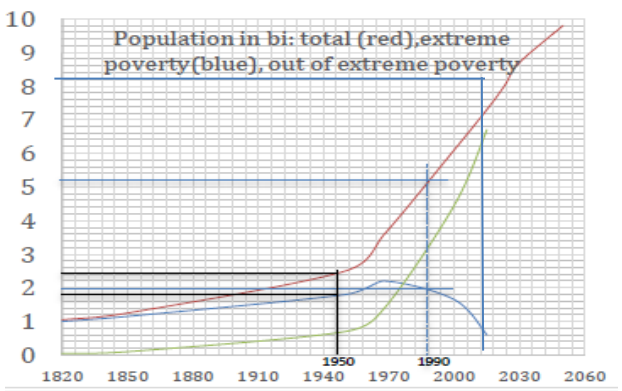

Figure 1. World population and extreme poverty (our world in data with data from World Bank).

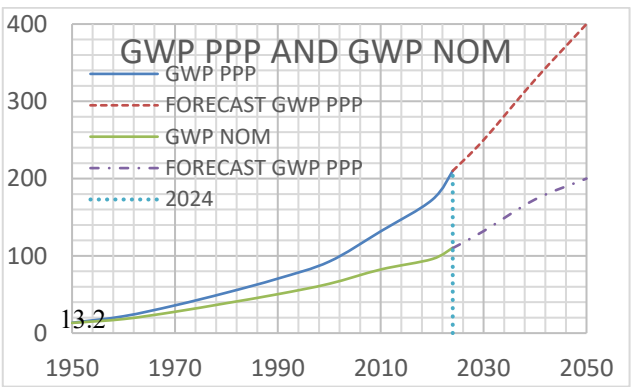

Figure 2. U$ corrected to 2024. GWP PPP and GWP Nom expansion from 1950 (U$13.2TRI). The both curves are exponential up to 2024 and after linear.

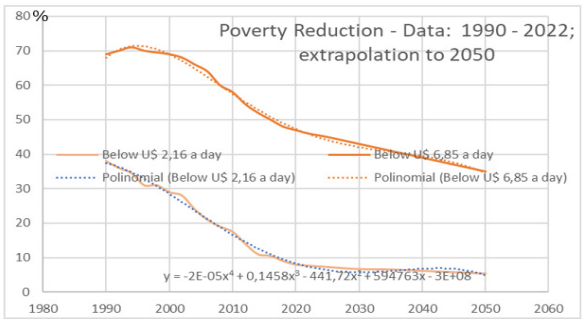

Figure 3. Extrapolation (achieved with 4th polynomial) from 1990 -2020 to 2050.

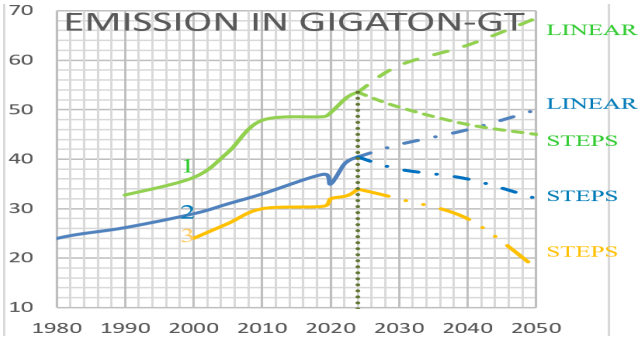

Figure 4. Curve 2: CO2+LULUCF. Curve3: CO2+ LULUCF+ N2O etc. Forecast in two scenarios: growth linear and steps. DNV not considered.

Notes:
1) Figure 2 GWP PPP Gross World Product Power Parity Purchase. GWP Nom it is the Gross product in U$.
data from:
https://ourworldindata.org/grapher/global-gdp-over-the-long-run?tab=table&time=1940.2023&country=
2) Figure 4: GT CO_2 +LULUCF Forecast to 2050 with the Emissions data from 1950(11GT)-2023 [5].
Without LULUCF emissions in 2023 was 37.5 GT as according with [6] and [7].
GT CO2e (CO2 equivalent Without Land Use, Land Use, Change and Forestry-LULUCF).
http://edgar.jrc.europe.eu/report
FORECAST STEPS: Temperature by 2100=2.4º
3) Total output of the world economy: These historical estimates of GWP are adjusted for inflation. "Our worldindata" combines three sources to create this time series: the Maddison Database (before 1820), the Maddison Project Database (1820–1989), and the World Bank (1990 onward).
4) The International Comparison Program (ICP), which facilitates price comparisons across countries and generates Purchasing Power Parity (PPP) data, was launched in 1968 by the United Nations and the University of Pennsylvania.

2.2 Exert high pressure to decarbonize the planet to avoid a loss of control

The figure 4 shows emissions forecast for 2050 according to a linear extrapolation with emissions data from 1950-2023 [6].

The forecasts for 2050 are designed by authors with data imagining no change in previous conditions. However, emissions may behave differently depending on the energy matrix of countries with greater expansion and their ability to adapt to the transition to clean energy: US, Japan and EU maintain GHG emissions very high but constant declining from 1990; energy growth bigger than emissions. China mainly, but other Asia East countries also, increase emissions, many times, more than GWP.

Very dangerous!!!! This scenario is very worrying and must be reversed.

Recent data show that the trend should continue at least in the short term. Long term forecasts are presented here but certainly before 2030 must be revised.

Several innovations are expected to change humanity's level of consumption, for example: a) need for more energy due to Cryptocurrency Mining and in AI training, b) reduction of consumption by efficiency, with led lamps replacing several types of traditional lamps, including incandescent, fluorescent (compact and tubular), halogen and even metal vapor and sodium, c) heat pumps[1] substituting traditional heaters, d) optimization of efficiency and storage obtained with lithium batteries[2] e) using excess of solar and wind energy to produce hydrogen[3], f)

[1] Yes, heat pumps are generally more efficient than conventional heating systems like furnaces and boilers. Heat pumps work by transferring heat, rather than generating it, making them significantly more energy-efficient. They can be 3-5 times more energy efficient than gas boilers.

[2] Lithium-ion batteries use lithium salts, graphite, and lithium cobalt oxide (LCO), lithium manganese oxide (LMO), lithium nickel manganese cobalt oxide (NMC), lithium iron phosphate (LFP). Lithium salts facilitate the movement of lithium ions between the anode and cathode during charge and discharge.

[3] Hydrogen production is hampered by the negative yield of the electrolysis process (1.5 to 1.8 kW for each kW of hydrogen energy), which implies oversizing of the wind and solar energy produced, storage costs and transportation costs.

advancement in nuclear fusion research to get the ‘’grail’’ of energy sources**.** All these technological advances are driven by IA.

CO_2 Emissions increased by 410 million tones, or 1.1%, in 2023 – compared with a rise of 490 million tones the year before – taking them to a record level of 37.4 billion tones [7].

In the next item, several scenarios designed by the IEA will be presented, indicating the respective increase in temperature that needs to be avoided.

3. Forecast for 2050

The goals for 2050 must be bold:

- An increase in wealth to 9.5-9.7 billion inhabitants, but mainly to eliminate 8,5% (or 700 mi) from extreme poverty.
- Reduce the population living on less than $6.85 a day. A linear extrapolation from 2024 to 2050, would result in a reduction of 35% of the global population living on less than $6.85 a day, to 15% in 2050. This number needs to be reduced not only by increasing global GDP, but also by reducing inequality.
- Move the planet quickly to net zero, as soon as possible.
- This audacious net zero objectives conflict with the intense desire of poor countries to achieve levels of wealth compatible with the fair needs of their populations whose well-being references are those of rich countries. This means pressure to increase energy availability and as a consequence, emissions will increase in many countries, mainly in coal-dominated matrices. Increasing energy and making the transition in parallel has proven to be conflicting: a lack of resources to meet both needs. Countries choose to expand the supply of traditional energy, even though it is coal. Therefore, it is urgent to develop campaigns to implement CDR (Carbon Dioxide Removal) and CCUS (Carbon Capture, Utilization and Storage).

3.1 Technological advances

Technological advances led to the fourth industrial revolution, to IoT, to Machine Learning, to the Second Machine Age, that is, machines endowed with cognitive skills with promises of giant leaps in productivity. AI will make it possible to create new materials, accelerate food production, optimize logistics, reduce losses of food, goods, and energy, and improve energy efficiency. Increase productivity!

“Generative AI is poised to unleash the next wave of productivity” [8].

McKinsey teaches: AI add 1.3 -1.5 U$ tri in the next ten years says Bank of America.

Many analyses forecaster: Produce more with less. But there is a danger: the population without instruction? Countries with low education will only use AI tools with a lot of delay and low efficiency.

Thus, differences in wealth could be accentuated in countries with weak educational progress.

The PISA assessment exams and the WEF education-related pillars allow us to identify these countries. Brazil, land of authors, presents 68% of 15 years students in level 1 or below in Math. Can countries, with this performance, continue with increasing productivity levels or will it be restricted to 1/3 or less of the population with the consequent increase in inequality?

Governments, through their education ministries, should work hard to reduce differences.

3.2 Emissions: scenario in 2050

The figure 5 shows the forecast of CO2 emissions to 2050 according to Linear Extrapolation Predictions. These are scary predictions could cause an increase in the planet's average temperature of 4° (a range from 3º to 6º).

So far, in the items above, an analysis was carried out based strictly on concrete and quantified facts. They may not reflect meeting the needs that meet emissions limits and are certainly more in line with meeting the wishes of the population. The scenarios presented by IEA -International Energy Agency, are ideal disregarding the strong pressures from populations that help shape government programs. Medium or long-term promises made in COPs or other forums, considered by the IEA, are little fulfilled.

3.2.1 Considerations regarding ''Scenarios'' according to IEA Outlook 2023 [9]

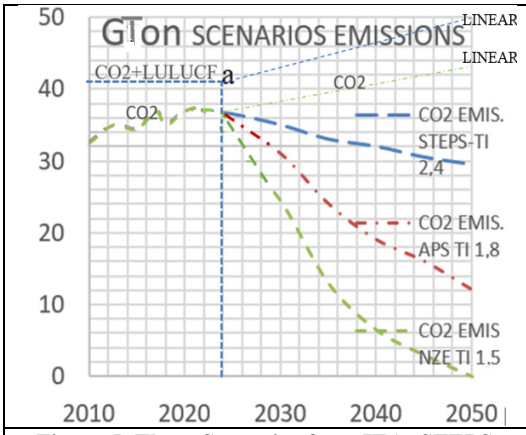

Figure 5. Three Scenarios from IEA: STEPS, APS, NZE. Only CO2 emissions.
Dot **a** presents Emissions 2024 of 41 Gt CO2+LULUCF. Dot Line green is just of CO2.

STEPS (Stated Policies Scenario) *was conceived to presents what is the main trend of the energetic for the future accord to several countries' politics landscape. Evaluates the evolution of energy systems with current policies and private sector demands. The Scenario doesn't work with a specific outcome but just present politics and main trends.*
The Announced Pledges Scenario (APS) *assumes that governments will meet, in full and on time, the climate commitments they have made, including their Nationally Determined Contributions and longer-term net zero emissions targets*
The Net Zero Emissions by 2050 (NZE) Scenario *depicts a narrow but achievable pathway for the global energy sector to reach net zero energy-related CO_2 emissions by 2050 by deploying a wide portfolio of clean energy technologies and without offsets from land-use measures.*
Notes: a) The three main scenarios WE-2024. CO_2 EMIS. means a projection of curve generated with data from 2010 to 2024(figures 5).
*b) The forecast curves 2024-2050 shows GT CO2 emissions: Steps, APS NZE and LINEAR. Point ''**a**'' shows 41GTCO2+LULUCF, and the LINEAR FORECAST*
c) LULUCF means: Land Use, Land Use and Change and Forestry

Comments: not foreseen by IEA

a) The scenario presented by the IEA assumes that emissions reach their maximum level in 2024 at a value of 37,5 Giga tons with only CO2. Other sources present CO2+LULUCF as dot a from figure 5 that shows 41 GT emissions.
b) The Coal Power installed in 2024 was 44 GW and retired 25 GW 19GW net. China added 30,5 GW. The installed electrical power is 3.3 Terawatts. Solar power reach 866 Gigawatts.
c) Oil producers report plan for major investments in production until 2045

3.3 The progress was based on fossils in period analyzed [10-12]

Quickly change fossils by renewables! This is the thesis defended by politicians, institutions, bureaucracies, political decision-makers and NGOs connected with preservationist and environmentalist policies who, many times, use these long-term commitments made, without evaluating whether they can be fulfilled, to maintain their authority and benefits. The penultimate COP took place in the Arab Emirates-Dubai and broke participation records. Transport costs added impressive amounts of CO_2 to the atmosphere. Government representatives should be an example by reducing emissions in their activities. Their behaviors however do not seem to be "do as I say, not as I do". Why not online COPs? In the physical location where the COP will take place, each country must be limited to 2 participants for countries with up to 10 million inhabitants, countries with up to 100 million would have 20 and up to 1,5 billion, 200 participants. All the others participants: on line in their countries.

The EIA Scenarios cover the environmental side and highlight it. Developing and poorest countries need intense and cheap energy to achieve better living conditions or to escape the poverty trap.

In reality, scenarios are generic recipes offered by various institutions for countries. Several scenarios present what the planet should do to achieve zero emissions in 2050.

This is intended to ensure that the rise in temperature does not exceed 1.5º/2.0º, as concluded that this would be the limit for not exceeding the "no return point" from which the heating process would feed itself without the possibility of returning.

It is necessary to ensure that the planet's temperature does not exceed 2.0 elevation. But it is necessary to understand the need for energy to increase in the countries to leverage the expansion of wealth and provide better living conditions for its inhabitants.

The fact is that the world's population increased practically 8 times from 1.05 billion to 8 billion: between 1820 and 1965 it increased from 1.05 to 2.5 billion, but from 1965 to 2022 it increased to 8 billion inhabitants. The jump in population of 5.5 billion in 57 years and the reduction in extreme poverty, required a very high increase in the wealth of the world, a jump of wealth from U$ 30 trillion (GWP PPP) or U$22tri (GWP Nom) in 1965 to U$ 180-

200 tri (GWP PPP) or U$110 trillion (GWP Nom) in 2024 (U$ 2024).

In the same period, from 1965 to 2024, extreme poverty fell from 2 billion to 700 million inhabitants in 2024.

4. A quick overview of energy sources. New consumers

Although used since the domination of fire, the concept of energy was consolidated with the beginning of the 1st industrial revolution (steam revolution) at the end of the 18th century. Coal came to join the traditional bio mass, then the only fossil energy source, to provide energy for the various transport types[4] and heating process, to which was added the motorized transport of populations and goods, as well as, the very rapid expansion of industrialization mainly in textiles and steelmaking. At the end of the 19th century, the implementation of second revolution (electrical plants), oil, gas and hydropower joined coal, which continued to be hegemonic. In the 60s of the 20th century, biofuels such as hydrated alcohol or sugar cane bagasse, tree bark, corn straw and nuclear fission energy increased the extent of energy consumption. Around 1980, wind and solar energy timidly began their participation in the energy matrix (wave energy and geothermal energy still do not score). The complications caused by the quality of energy, which requires additional filtering systems, and the lack of inertia that can cause instability in electrical systems, and mainly the reduced levels of use, around 20%-25% of solar and between 25% to 30% of wind, cause huge storage difficulties add significant costs.

New technologies, boosted by AI, raise hopes that these new energies, clean and potentially available, with no limits in sight, can be hegemonic in the future. However, betting on this great challenge being overcome by 2050 does not seem feasible. But the goal of Net Zero may be postponed, but it must continue to be pursued. **So, it seems that the best solution is to accelerate the CDR - Carbon Dioxide Removal and the CCUS - Carbon Capture, Use and Storage.**

Before analyzing CDR and CCUS, a fast highlight about changes in course.

4.1 New consumers and change of old one

How much will the energy supply need to increase to support crypto currency mining and artificial intelligence? It is reported that cryptocurrencies and AI will represent between 1.2% and 1.5% of global electrical demand in 2023. Even if exaggerated, the value raises concerns about the scale of its energy impact; on the other hand, replacing incandescent and other light bulbs with LEDs, as well as, replacing electric heaters and gas boilers with heat pumps, will reduce energy consumption [13].

4.1.1 Energy for mining crypto currency

Energy Consumption: People, institutions and governments are investing in cryptocurrencies on a scale of more than US$ 2 trillion at a value similar to Brazil's GDP; this means a very real deal.

But encryption consumes a lot of energy. How much? Bitcoin, the largest cryptocurrency in the world currently consumes 150 to 200 Twh corresponding to an average income of a country with 50 million.

The production of this energy emits around 65-75 Mton CO_2 annually.

Energy for crypto is significant for global emissions and climate change.

4.1.2 Energy for training IA

The approach to this topic is more appropriate to qualify the energy quantum to power the huge and growing number of data centers than to quantify energy use.

Existing estimates are unreliable as the numbers are partial and contingent, offering only a generic idea of the total energy use of AI.

Machine learning is incredibly variable, as settings can change your energy consumption between far extremes. There has also been no willingness on the part of players to support any disciplinary bill that would oblige them to share relevant information. Thus, quantifying methodologies on energy use and the carbon impact of AI are in the construction phase.

4.1.3 Heat pumps: Improving energy efficiency

A heat pump uses technology similar to that found in a refrigerator or an air conditioner. It extracts heat from a source, such as the surrounding air, geothermal energy stored in the ground, or nearby sources of water or waste

[4] Before steam revolution was with horses or rowing ships or sailing ships.

heat from a factory. It then amplifies and transfers the heat to where it is needed. Because most of the heat is transferred rather than generated, heat pumps are far more efficient than conventional heating technologies such as boilers or electric heaters and can be cheaper to run. The output of energy in the form of heat is normally several times greater than that required to power the heat pump, normally in the form of electricity. For example, the coefficient of performance (COP) for a typical household heat pump is around four, i.e. the energy output is four times greater than the electrical energy used to run it. This makes current models 3-5 times more energy efficient than gas boilers. Heat pumps can be combined with other heating systems, commonly gas, in hybrid configurations.

Half of the energy consumed on the planet is to produce heat. Considering that 85% of energy is produced by fossil fuel, this means that between 36%-40% of GHG emissions are the responsibility of heat production. To heat spaces and water the buildings require 46%. In countries with a temperate climate, the share of heat generation for buildings can reach 60 to 75% of all energy demand.

The decarbonization of energy for heating becomes a priority to meet goals aimed at NETZERO.

5. Population, GDP, energy, emissions [14]

Wealth Growth is the path chosen by governments, measured by GDP expansion! Is there a possibility of providing the energy demanded by the world to provide the wealth to rescue such significant amounts from extreme poverty without the participation of fossils?

There are three types of discourses: environmentalist and political lines with little commitment to the well-being of the poorest populations. These lines lead the IPCC and the COPs. Their actions are commendable, as they warn of the great dangers of human actions, going beyond the point of no return. Force governments to improve projects in which environmental protection is an important variable.

The other stream is the responsible executives of countries, especially poor ones, who will accelerate growth to generate wealth for their ecosystems.

The third current aligns with the need to generate wealth, but disregarding any care for the environment.

The figure 6 shows the participation of different sources in the production of total energy produced and consumed by the world in 2023.

The sum results in almost 180000 Twh and the respective curve is presented in figure 7 just with data from 1960 to 2022. Projection to 2050 result in almost 210000, improving the efficiency or -236000TW-h.

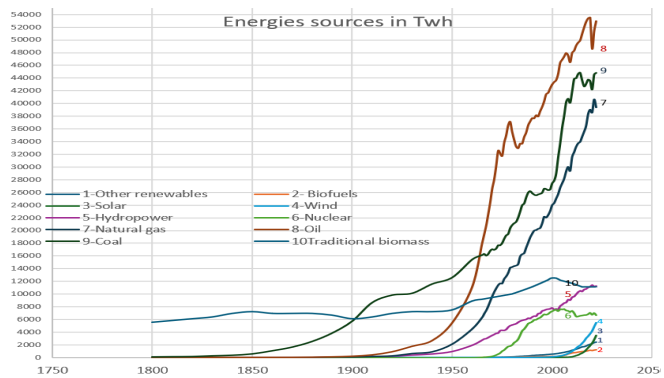

Figure 6. Energies by source in 2022. Sum:175000 TWh.

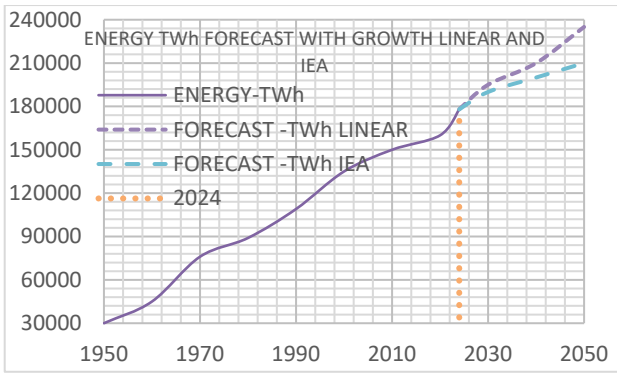

Figure 7. Energy in TWh with forecast for 2050 with data from EIA.

Notes:

Figure 6: Data from EIA. Graphs by authors.

Figure7: Graphs and linear extrapolation by authors with a polynomial equation degree 1. A second projection, data from IEA.

Analysis of the Figure 6 shows the share of fossil fuels and non-GHG emitting fuels: 76.72%. Non-GHG emitting energy sources account for 23.18%. Probable scenarios between 2022 and 2050 will be analyzed below.

Other analyses were carried out with data between 1950 and 2022 to provide greater reliability.

Figure 8 shows the predicted behavior until 2050 of fossil and non-emitting sources. The scenario for 2050 is very optimist. It supposes very slow grown until 2045 and them a decrease to 2050. Figures 8 and 9 are more realist.

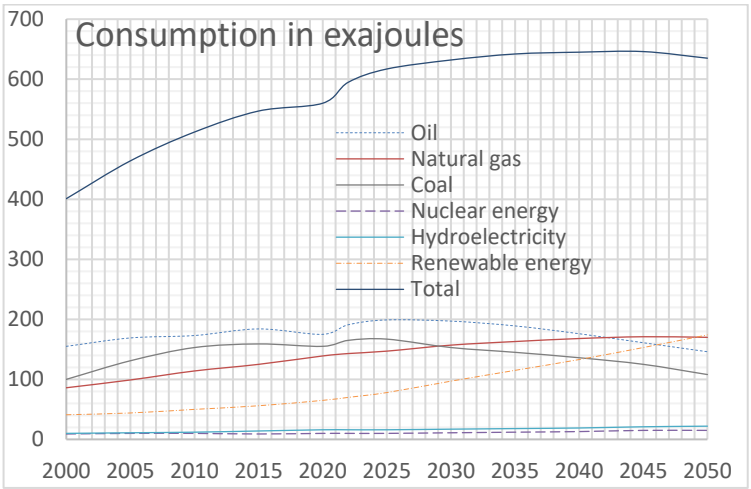

Figure 8. Very optimist scenario: Forecast to 2050 of all sources in Exajoules with data from 2000 to 2022. 01 Exajoule=277.77778TWh. Fossil fuels: 66,3%, Nuclear: 2,7% and Renewables: 31% [14]

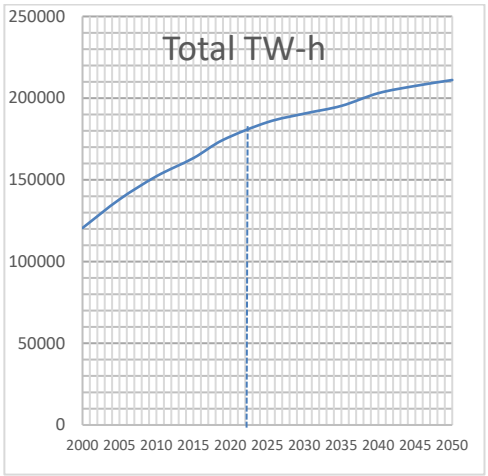

Figure 9. Forecast to 2050 (with data from 2000-2020 in TW-h. It is similar with extrapolation with a polynomial order 2th. Extrapolation in 2050 results in 210000TW-h similar with IEA forecast shows in Figure 7.

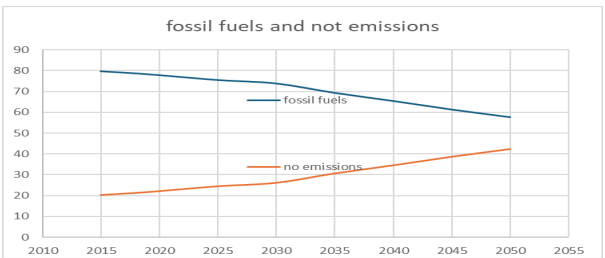

Figure 10. Fossil fuels and non-emitters.

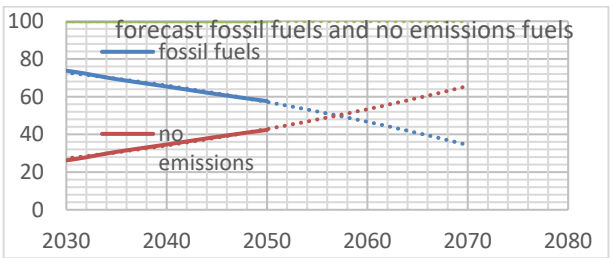

Figure 11. Equal contributions in 2057.

The projections of energy consumption in 2050 in figure 8, 9 and 10 show a value of 210000-236000 TWh.

This forecast for energy is to sustain GWP growth to U$227 tri foresees the use of 58.20% of fossil fuels. Fossils and non-emitters should equalize in 2058 and only in 2074 fossils will be 1/3 and non-emitters 3/3. The projection for 2050 is made by www.statistcs.com according to the address above in Figure 11.

New trends

Development projections skew towards East and South Asia whose wealth expansion began around the 1960 with Tigers 1990s and 1990 with China and others continues to grow faster than Europe, the US and Japan.

The new Asian developing countries: After the Tiger countries, China, India, Indonesia, Vietnam, Philippines, Malaysia, Thailand, Bangladesh, Pakistan stand out for having expanded faster or are in a very rapid expansion phase, which should put pressure on emissions because most of them use coal as their main source of energy.

Great efforts must be made to help these countries use alternatives to the use of coal and, when unavoidable, make full use of the CDR and CCUS mechanisms. The main focus of this research is the well-being of humanity. Therefore, the following figures are highlighted and repeated to identify the ability to generate wealth to serve the growing population.

However, the creation of wealth is directly dependent of energy. Energy has been a direct consequence of the increase in emissions. Figures 1(population), Figure 2(GWP-PPP; GWP NOM), Figure 4(emissions), Figures 7 and 9(Energy in TWh) present an overview of the four main variables that permit to find the better solutions.

Global Population: Figure 1- Population grew from 2.4 Bi to 8 Bi or **3.3 times** from 1950 to 2024. The projection to 2050 is 9.7- 10 bi or **4.04- 4.166 times** since 1950.

GWP or Global GDP: Figure 2: GWP PPP grew from 13.4 U$ Tri (1950) to US$ 170-200 Tri (2024) or **12.7-14.9 times** from 1950 to 2024. The projection to 2050 is 370-400 U$ Tri or **28-30.3** times since 1950. GWP Nom grew from 13.2 U$ Tri to US$ 110 Tri or **8.33 times** from 1950 to 2024. The projection to 2050 is 170-200 U$ Tri or **12.9-15.15** times since 1950.

Global Energy: Figure 7: Energy grew from 30,000 to 178,000 Tw-h or **5,93 times** from 1950 to 2024. The projection for 2050 is 236,000 or **7,9 times** since 1950 in linear growth. In IEA projections the estimated value in 2050 will be 210,00TWh ou **7 times**

Global emissions: Figure 4:

a) CO2+LULUCF- GT - LINEAR GROWTH Emissions grew from11.8 to 41 BiTonCO_2 or **3.5 times** from 1950 to 2024. The projection for 2050 is 50 BitonCO_2 approximately 4.3 times since 1950.
b) EMISSIONS CO2+LULUCF+CH4+N20+...GT-STEPS GROWTH. Emissions grew from 16 to 53 BiTonCO_2 or **3.3 times** from 1950 to 2024. The projection for 2050 is 50 BitonCO_2 approximately 4.9 times since 1950.

Table 1. Summary of curves of Figures 1, 2, 4 and 7

FIGURE 1-POPULATION- BI INHABITANTS.	1950 2,4	2024 8	2050 9,7
FIGURE 2-GWP PPP U$ TRI- GWP NOM U$ TRI	13.38 13.2	170-200 110	360-400 170-200
FIGURE 7-ENERGY TWh -LINEAR GROWTH ENERGY TWh – IEA GROTH	30000	178000	236000 210000
FIGURE 4-EMISSIONS CO2+LULUCF- GT - LINEAR GROWTH EMISSIONS CO2+LULUCF+CH4+N20+...GT-STEPS GROWTH	11,8 16	41 53	50 78

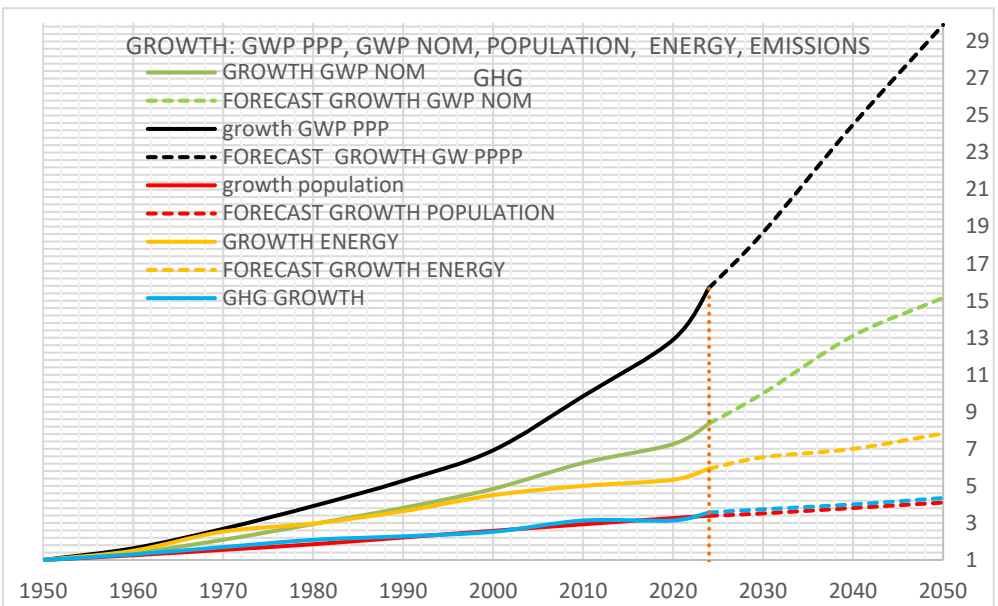

Figure 12. Comparisons of the main variables.

The analysis of Figure 12 shows a spectacular increase in wealth that results in a large expansion of GWP/capita. As inequalities are high, huge communities of extreme poverty persist, representing 7% of the total.

The spectacular reduction of extreme poverty happened because the expansion of wealth, much greater than the increase in population.

The energy needs of 178,000TW-h in 2024 shows needs of 5.93 times the energy of 1950; for 2050, the projected

value of 236,000 (in other graphs with data of other sources, of 210,000) means an expansion of 7.93 times between 1950 and 2050.

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The expansion of emissions from 6 Bi Tons in 1950 to 38 Bi Tons in 2022 or 6.5 times and an expansion to 50 Bi Tons in 2050 shows an expansion of 8.4 times between the extreme limits of the period.

Next, table 1 on the left shows the number of growths, population, GDP, Energy, and Emissions. The right shows "Emissions of Billions of tons of CO_2" by "billions of inhabitants" and "Emissions of Billions of tons of CO_2" by GDP in U$ tri.

Table 2

Summary: Increase in the period from 1950 to 2050

	Population	GWP PPP	GWP NOM	Energy	Emissions	
					Linear	steps
Increase 1950-2024	3.3	14.9	8.33	5.93	3.6	3.6
Increase 1950-2050	4.04	29.8	15.5	7-7.9	4.3	2.8

Highlights the growth in wealth of 14.9 times from 1950 to 2024 and 29.8 times by 2050-GWP-PPP. Of 8,33 times from 1950 to 2024 and 15,5 times by 2050-GWP-Nom.

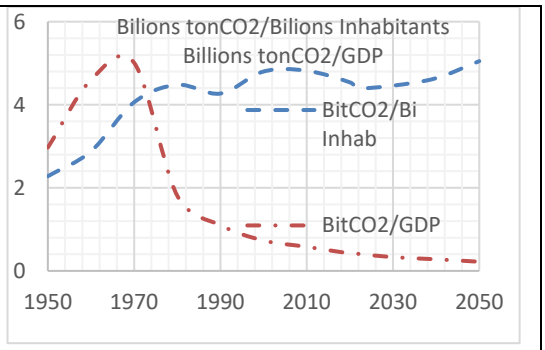

Figure 13. Stabilization of emission by inhabitants and reduction of emissions by GDP.

6. Building the future

6.1 Effective investment of renewable energies: Solar and Eolic

The presentation of projections shows an extremely worrying panorama. Several solutions are in progress with a greater or lesser degree of maturity. The solution equations are very dynamic and customized for each specific reality of each country and must be based mainly on a) application time and b) the necessary resources.

It must be considered that the increase in renewable energy impacts the cost of installing the electrical plants versus obtaining energy due to the dependence on meteorological conditions on solar and wind.

It is necessary consider renewables energies installation costs of power(watts) and the result in production of energy (watts-hour or joules).

Considerations about solar, wind, nuclear and coal energy costs (Table 3).

- The costs of 1 MW **solar electrical plant** in 2023 price are in turn of U$ 1.0-1.5 mi without land costs. One MW need 4.0-6.0 ha. Land costs present an extreme limit. One ha in Africa's north could varies 5 times to Brazil northeast and more than 40 times to USA far lands.
- The costs of 1 MW **wind electrical plant** in 2023 price is in turn of U$ 1.2-2.0 mi without land costs. One MW need 8 ha. Land costs present extreme limits.
- The costs of 1 MW **nuclear electrical plan**t in 2023 price are in turn of U$ 5.0 – 6.0 mi without land costs. This installation requires several precautions to safety. Around 440 nuclear electrical plants operate at present in 32 countries; total installed capacity: 390 GW produces 2.553 Tw-h≈ 10% of total being built in 19 countries mainly China, India, Russia, and the United Arab Emirates (UAE).
- The costs of 1 MW **coal electrical plant** in 2023 price is in turn of U$ 1.2-4.0 mi without land costs. The cheaper

are without GHG filtering, CDR or CCS. Most OECD countries do not allow the installation of new plants due to environmental requirements.

a. "Capacity Factor – CF"

CF is common term used to analyze various types of electrical power plants. CF analyzes the ratio of the actual output of a plant to its maximum possible output if it were to operate at full capacity continuously. The Capacity Factor is a crucial metric in determining the performance and economic viability of different types of power plants. It is widely used across the energy industry to evaluate and compare the operational efficiency of power generation facilities.

Table 3. Estimated[5] cost and Capacity Factor- Estimated costs from 2023/2024

Fuel Source	Cost by 1 MW	Capacity Factor	Replace coal plant
Wind	U$ 1.2-2.0 mi	0.25-0.30	2.7
Solar	U$ 1.0-1.5 mi	0.20-0.25	3.33
Nuclear	U$ 5.0 – 6.0 mi	0.9	0.83
Hydro	U$ 2.0-2.5mi	0.45-0.65	1.49
Coal	U$1.2 – 4.0 mi	0.70-0.80	1

b. Transportation: Electrification of the global fleet of vehicles for moving people and goods

The transport of products and goods accounts for between 30% -32% of the total energy consumed. Fuel oil is predominantly used, mainly gasoline, although biofuel (sugarcane or corn ethanol, soy diesel, and gas will have a 5% share in 2023 and 6% in 2030 as spglobal [15].

Electric Vehicles implies in a radical change in energy and electric matrix. The transportation share is 32%, at present, based on oil, gas and bio fuel. Going from the current matrix incorporating a total or partial 32% of energy for transport is a task that poor or developing countries will take much longer than two and a half decades.

Expansion should be considered:

a) Capacity Factor
b) Energy Storage
c) Increased system inertia

6.2 Storage

6.2.1 Batteries

Solar and wind have a low-capacity factor and do not have the possibility of storage their energy. Batteries are the main way to storage these kind of energy for two uses: a) storage wind and solar energy for the absence of wind and absence of sun. b) storage wind and solar energy for electric vehicles.

Other way to storage solar and wind energy is obtaining green hydrogen, an excellent source of clean energy. This subject will be covered later.

Replacing fossil fuels with solar or wind energy has some disadvantages mainly because:

a) The storage in traditional energies is easier and cheaper.
b) The building of towers mainly for wind power implies in utilization of intense use of materials that consume a lot of energy in manufacturing: cement, steel, aluminum are intense energy consumers similar with hydro power and therefore big GHG emitters. In this research material for fossil power plants wasn´t studied but in general terms they should be considered.

Electric vehicle batteries: Main materials/components

The most important component of electric vehicle technology is the battery. Modern electric vehicles mainly have lithium-ion and lithium polymer batteries due to the relatively higher energy density compared to weight.

The major materials required in lithium-ion batteries are the chemical components: lithium, manganese, cobalt, graphite, steel, and nickel. These components all have different functions in the typical electric vehicle battery that contribute to improved performance.

[5] Costs of land where the plant will be installed not considered.

Lithium- Lithium-ion batteries internally move lithium ions from one layer, the anode, to another, the cathode, to generate power. Lithium-ion batters are more convenient to use in electric vehicles because compared to lead-acid or nickel-metal hydride batteries, they offer higher energy densities, making it possible to reduce battery size while maintaining storage capacity.

Manganese- Safety is the main reason why manganese is used in lithium-ion batteries. Because of its increased energy density properties and reputation for stability, manganese is known to increase capacity and improve driving range. Additionally, manganese reduces the combustibility of electric vehicle batteries, which is problematic with lithium-ion batteries that contain cobalt.

Cobalt- Cobalt helps extend the life of batteries, (guarantee for eight to ten years, and avoid that cathodes do not quickly overheat or catch fire.)

Graphite- Graphite plays a critical role in the anode that stores lithium ions. Most commercially available lithium-ion batteries employ graphite due to its good cycle stability and energy density.

Steel- Steel provides the best balance of strength, mass reduction, performance, cost, and environmental impact. Steel is the preferred material for today's automobiles and will continue to be the preferred material for vehicles in the future.

Nickel- Electric vehicle batteries contain nickel, jet engine turbines employ nickel alloys, and passenger trains and subways use stainless steel that contains nickel. Materials containing nickel provide improved corrosion resistance as well as dependable and effective electrical and spark systems.

China is de biggest world manufacturer. The world largest lithium producers Australia, Chile, China.

6.2.2 Hydrogen

Grey Hydrogen: 95% of global hydrogen production

It is produced from natural gas using a process called steam methane reforming (SMR), which involves,

It is produced reacting methane with high-temperature steam to produce hydrogen and carbon monoxide that is then reacted with more steam to produce additional hydrogen and carbon dioxide. This hydrogen type is cheaper than the others but generates significant carbon emissions, which contribute to climate change. It is estimated that for every kilogram of hydrogen produced using SMR, around 9-12 kilograms of CO_2. It is not considered a sustainable source of energy.

To produce ammonia NH3 an excellent fertilizer, the hydrogen used in the Haber-Bosch process is typically referred to as "grey hydrogen."

Blue Hydrogen: A Cleaner Option

Similar to grey to produce it, but it includes an additional step known as carbon capture and storage (CCS). After capturing the CO_2 emissions, the process implies in storing them in geological formations deep underground.

Emissions of CO_2 are reduced by up to 90%. However, the carbon capture and storage process is complex and costly.

Green Hydrogen: The Cleanest Option

Green hydrogen is produced using renewable energy sources, such as solar or wind power, to power the process of splitting water into hydrogen and oxygen through an electrolysis process. This results in a zero-emissions hydrogen source, making it the cleanest option. The hydrogen produced can then be used to power a range of applications, from transportation to industry.

While green hydrogen is the most sustainable source of hydrogen, the production process is currently more expensive than grey or blue hydrogen. It also requires significant investment in renewable energy infrastructure, such as solar or wind farms, to produce the necessary electricity.

To produce green hydrogen, the energy input required to produce 1 kg of hydrogen which contains approximately 33.33 kWh of energy, it is necessary 50 kWh of energy.

A distance of a medium car needs 1 kg of hydrogen. To produce 1 kg, it is necessary 50 kWh. It is estimated other 20 to 30kg for service to put the hydrogen in car tank[6]. According to car makers a medium car needs 30kWh for a distance of 100 km. Hydrogen however has a bigger density of energy than batteries. So, for heavy loads the

[6] Compressed to 700 bars, hydrogen achieves a density of 42 kg/m^3, and five kilograms of hydrogen (which suffice for propelling a car about 500 km) can be stored in a 125 liter (L) tank.

use of hydrogen is advantageous if compared with batteries. Other application is to generate electric power using Hydrogen Fuel-Cell.

If hydrogen is able to compete with batteries alternatives, its future for storage will not limited to niche applications. Several countries are investing in green hydrogen. So, it is probable an increase in efficiency and reduction of costs and hydrogen could be an excellent solution as future energy.

Note: Other Types of Hydrogen aren't covered in this article.

6.2.3 CDR or CCUS [16]

The more realistically projected panorama for 2050 based on the current behavior of poor countries located mainly in Southeast Asia shows a growing need for energy and therefore the intensive use of coal has not allowed a focus primarily on reversing emissions. The desire for growth to provide well-being for its population determines the path forward for governments. This puts strong pressure on emissions Removal or Capture?

The persistent increase in GHG emissions has occurred since the first Industrial Revolution with the use of coal to generate steam. The incorporation of oil as another source meant another leap in wealth generation and also in emissions. The intense use of airplanes, the use of gas turbines to generate electricity and use of gas to heating completes the use of the three fossil fuels that drove the creation of wealth that reduced extreme poverty from 95% in 1850 to 7% today. The result: increased emissions of CO_2, CH_4, N_2O, CFCs, and H_2O vapor. Responsible for the increase in the planet's temperature, it is necessary to reduce emissions and expand the removal or capture, use and storage processes.

The gaseous constituents of the atmosphere, biogenic and anthropogenic, absorb solar radiation and re-emit radiation at specific wavelengths within the terrestrial radiation spectrum, emitted by the Earth's surface, the atmosphere itself and clouds. These wavelengths are Infrared. This property causes the greenhouse effect, whereby heat is retained in the Earth's atmosphere. Water vapor, CO_2, N_2O, CH_4, and O3 are the main GHGs found naturally in the Earth's atmospheric layer, also known as the Atmospheric Boundary Layer (ABL). A number of human-produced GHGs are also found in ABL. Halocarbons and other substances that carry chlorine and bromine, controlled by the Montreal Protocol, are examples of anthropogenic ones. The Kyoto Protocol is applied to GHGs: CO_2, N_2O and CH_4, sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

The main residual, or trace gas, related to GHG, is CO_2. This gas is so significant that its concentration is used as a reference to calculate the carbon dioxide equivalent (CO_{2eq}). This index describes the impact of a given GHG (CO_2, CO, CH_4, N_2O, etc.) converting its mass into the equivalent mass of CO_2 that would have the same global warming effect.

The mass of a GHG is converted to the mass of CO_{2eq} based on the potential of the GHG molecule to affect global warming, or its global warming potential (GWP). The GWP takes into account the effect of the thermal increase of GHGs and the lifetime of the gas in the atmosphere, and depends on the time horizon, which is most commonly 20 years (GWP20) or 100 years (GWP100). These values are different because GWP varies over time and CO_2 GWP is always unity, regardless of the time horizon.

The Kyoto Protocol in 1997 and the Paris Agreement in 2016 seek to commit industrialized countries and economies in transition to limit and reduce greenhouse gas emissions in accordance with agreed individual targets. (UNFCCC) and combat climate change by aiming for a sustainable future with low carbon emissions. (UNFCCC)

6.2.4 Carbon Dioxide Removal (CDR)

CDR are activities that promote the removal of CO_2 from the atmosphere and store it permanently in geological, terrestrial or oceanic reservoirs, or transform it into industrial products. CDR includes enhancement of biological or geochemical sinks and direct air capture and storage (DAC), but excludes natural CO_2 absorption not directly caused by human intervention. The CDR approach refers to methods, which may not be complete CDR systems, that can achieve carbon dioxide removal. For example, DAC, in the absence of permanent storage, is a CDR approach, but is not in itself a CDR system. A system with the capacity to generate net negative emissions, but which will not necessarily do so under all conditions. A comprehensive life cycle analysis (LCA) and other analyzes are required to conclusively demonstrate that a "potential" CDR system is, in fact, a CDR system. For example, in the absence of an LCA, a CDR system that barely achieves net negative emissions could look the same as one that achieves much larger net climate benefits per ton of CO_2 removed from the atmosphere.

Large-scale CDR promotes carbon dioxide removal on the order of or close to gigatons of CO_2 removed per year

($GtCO_2$). It refers to one billion metric tons (metric tons) of CO_2, which is equivalent to 1012 kg. 1 $GtCO_2$ is equivalent to 0.273 gigatons of carbon (GtC). This unit of measurement is most often used when discussing the scale of CDR needed to prevent the worst impacts of climate change and to keep warming below 1.5°C (i.e., gigaton-scale CDR).

For the CDR, it is very important to carry out a detailed study of the sinks and sources of greenhouse gases. Any process, activity, or mechanism that removes a greenhouse gas, a greenhouse gas precursor, or an aerosol from the atmosphere. Together with the processes, activities or mechanisms that create a greenhouse gas, a precursor to a greenhouse gas or an aerosol. In this sense, positive emissions will arise, when a specific source, created or enhanced by human activity, adds greenhouse gases to the atmosphere, or negative emissions, when a sink, created or enhanced by human activity, removes greenhouse gases from the atmosphere. Net negative emissions are achieved when more greenhouse gases are removed from the atmosphere than are emitted into it. Net zero emissions is achieved when the total emissions entering the atmosphere are balanced by the total removal of emissions from the atmosphere. It is sometimes used interchangeably with the term carbon neutral. Life cycle analysis (LCA) is the balance of positive and negative emissions associated with a given process, which includes all flows of CO_2 and other greenhouse gases, along with relevant environmental or social impacts. This analysis also includes greenhouse gas emissions that result from the materials used to construct a given process (commonly referred to as embodied emissions), as well as the energy resources used to satisfy the process's energy requirements. These embodied emissions result from the production or use of any good, or the provision of any service. For example, embodied emissions from steel used in a reactor will include emissions associated with the acquisition of raw materials, processing, manufacturing, transportation and the energy used in steel production.

When studying CDR, it is important to observe emissions that are difficult to avoid, that is, those that are physically and extremely difficult to eliminate within a certain period of time (for example, due to dependence on a specific infrastructure with a long timeframe for carbon-free substitution, either because avoiding it would require technology that relies on a scarce resource) or that would be unacceptable to avoid from a social justice perspective (for example, if mitigation would deprive people of the means to satisfy their basic needs, such as food security).

Avoided emissions are those that can be permanently stored during production, that is, what would be a CO_2 emission, to avoid an increase in atmospheric CO_2. This is different from CDR because the source of CO_2 is a potential emission and not the atmosphere. The climate benefit of such an intervention depends on the counterfactual scenario – what would have happened without our action? – which can only be estimated, not observed. If a project claims to avoid emissions that wouldn't happen anyway, and other emissions may continue in exchange, then an avoided emissions project could do more damage to the climate than doing nothing.

A human intervention to reduce or avoid greenhouse gas emissions is defined as emissions mitigation. Some publications have used the broad term “mitigation” to refer exclusively to emissions mitigation, while others use mitigation (or “climate change mitigation”) to include emissions mitigation, CDR, and any other strategies to combat climate change.

Another important point to note is storage. Reservoirs refer to the place where a greenhouse gas is stored. Examples include geological formations, alkaline-containing minerals, forest biomass and soils. Stock is a carbon reservoir that exchanges carbon with the atmosphere on relatively short timescales (e.g., less than 100 years), including the terrestrial biosphere (CLA) and shallow oceans. In comparison, other reservoirs, such as geological formations and deep oceans, exchange carbon on much longer time scales (e.g. 1,000 years). It is also important to highlight Storage (or Hijacking). Two terms that can be used interchangeably to describe the addition of CO_2 removed from the atmosphere to a reservoir, which serves as its final destination. For example, some CDR strategies store carbon in biological systems such as forests or soil ecosystems, while others inject CO_2 underground or chemically transform CO_2 into stable mineral forms. In Brazil, research known as (Free-Air CO_2 Enrichment) is being implemented in the Amazon forest. This experiment is called Amazon FACE. It aims to verify whether there is permanence (or durability) that measures the duration for which CO_2 can be stored in a stable and safe way.

Storage duration can vary significantly depending on the type of reservoir. For example, concentrated CO_2 stored in deep underground geological formations is effectively permanent (thousands of years), while forest carbon reserves can release carbon back into the atmosphere due to forest fires or tree harvesting. The current stage of the AmazonFACE project is verifying the resilience of the Amazon forest. It is important to check, in this case, the (physical) leak, where the initially stored CO_2 (or other GHG) left its storage state and returned to the atmosphere.

Examples include the combustion of a fuel produced from CO_2, the burning of biomass, and the migration of CO_2 from underground storage. An important measurement for greenhouse gases is their flow through the atmosphere. It measures the rate of movement of trace greenhouse gases between reservoirs (e.g. CO_2 capture through the chemical reactions of photosynthesis), resulting in the storage of carbon in a plant's biomass. The carbon cycle is given by the residence time and flow of carbon, in various chemical states, between the ocean, the land, the terrestrial biosphere, the atmosphere and the Earth's geological formations.

6.2.5 Carbon Capture, Utilization, and Storage CCUS

CCUS is a process that involves capturing carbon dioxide (CO_2) emissions from sources like power plants or industrial facilities, transporting it to a storage site, and storing it underground to prevent it from entering the atmosphere and contributing to global warming. CCUS plays a crucial role in reducing GGS emissions and combating climate change. Below are presented some key points about CCUS:

(1) **Carbon Capture**: The first step in CCUS is capturing CO_2 emissions from sources such as power plants, cement plants, or refineries. There are different technologies for capturing CO_2, including post-combustion capture, pre-combustion capture, and oxy-fuel combustion.
(2) **Transportation**: After capture, the CO_2 is compressed into a dense fluid for transportation via pipelines or trucks to a suitable storage site.
(3) **Storage**: Once at the storage site, the CO_2 is injected deep underground into geological formations like depleted oil and gas reservoirs or saline aquifers, where it can be stored securely for long periods of time.
(4) **Costs**: The costs associated with CCUS projects can vary depending on factors like the scale of the project, the location, the technology used, and regulatory requirements. Currently, one of the main challenges of CCUS is the high cost of implementation. However, as technology advances and more projects are developed, costs are expected to decrease.
(5) **Quantities**: The amount of CO_2 that can be captured and stored through CCUS is significant. Globally, CCUS has the potential to capture billions of tons of CO_2 emissions each year, helping to mitigate climate change by reducing overall greenhouse gas emissions.

As CCUS technologies continue to advance and more projects are deployed, the costs are expected to decrease, making CCUS a more economically viable option for reducing carbon emissions and combating climate change. Additionally, governments and industries are increasingly recognizing the importance of CCUS in meeting emissions reduction targets and transitioning to a more sustainable energy future.

Where do we need to go?

CCUS deployment has been behind expectations in the past but momentum has grown substantially in recent years, with over 500 projects in various stages of development across the CCUS value chain. Nevertheless, even at such level, CCUS deployment would remain well below what is required in the Net Zero Scenario.

7. Impact of Solar and Wind on energy power quality [17-18]

At present energies from synchronous or asynchronous generators are issuers of small quantities of harmonics less than 5% of the fundamental, value sufficient to guarantee energy quality.

- **In the 1960s**, SCRs expanded exponentially the manufacture of AC/DC converters with output voltages controlled by switching the SCRs. **In the 1980s**, IGBTs expanded the manufacture of inverters. These non-linear loads created harmonics called temporal. Harmonics cause heating in machines, transformers, and conductors as well as cause system instabilities. Mitigations are carried out with filters or Synchronous Generators- SG, whose design focus is aimed at reducing transient and sub-transient reactance. To face these new challenges due to the new technologies which increase Harmonics, Flickers, Notches, Telephonic Interference Factor -TIF, Fast Transients, was necessary to provide standards to limit not only harmonics but also the other electromagnetic emissions which provoke bad functioning of the power electric system (PES):

The "519-Recommended Practices and Requirements for Harmonic Control in Electric Power Systems establishes the threshold criteria of voltage harmonics and current, whose limits are a function of input impedances, also called Short Circuit impedances. **The IEEE 519-2014** guidelines do not cover aspects related to the user equipment. Voltage and current harmonics are part of the Specifications without any mention of equipment. Inter harmonics are focused in “Interharmonic in Power Systems-IEEE Interharmonic Task Force, Cigré 36.05/CIRED 2 CC02 Voltage Quality Group.

7.1 The IEC/ENELEC 61000 Serie-parts from 1 to 9

standardize approaches to basic Electromagnetic Compatibility (EMC) publications. They define electrical and electromagnetic functions and environments, EM, emissions, term definition techniques, electromagnetic guidelines, measurement standards, limits, testing, installation guidelines, and mitigations. IEC 61000 3-2 for devices with currents up to 16 A, IEC 61000 3-12 for devices from 16 to 75 A, and IEC 61000 3-4 for devices with currents greater than 75 A.

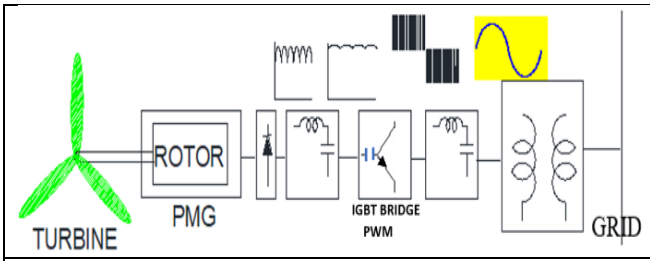

Figure 14. A S G with PMG with gear or not. Source – A study of Generators. Selection for large Wind Turbines Generator.

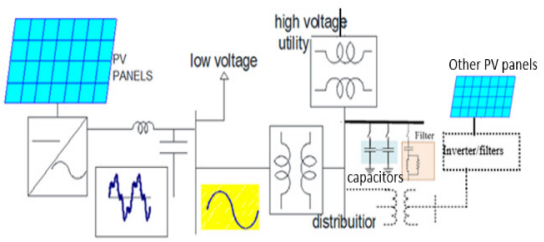

Figure 15. PV solar source with capacitors meeting IEEE 1547 and 519.

- **Since the 2000s,** the growth of wind and solar energy has been exponential: **Solar PV**: the electrical energy from the solar source in the photovoltaic process is in DC [19].

The inversion to the grid frequency is carried out by inverters based on IGBTs, in switching processes that model the wave in a process called PWM.

The wind generation is in AC in all types of generators: Induction or Synchronous Generator (Field Excited or PMG). The most used are: a) Turbine powering an Induction Generator Double Excited. b) Turbine powering, using gear (or not), a SG Permanent Magnet (PMG), above in Figure 14.

Often, AC generator voltage output is rectified and then inverted and elevated to connect with the grid.

The inverters used in Solar or Wind generation generate harmonics. Expensive Filters are needed to attend the THD normalized limits, as well as the TIF, Notches and others, above in Figure 15.

At the end of the nineties has been started a quick growth of distributed resources and, so, it was necessary to provide a uniform standard for interconnection with EPSs with requirements to the performance, operation, testing, safety, and maintenance of the interconnection. An IEEE project started in 1999 results in IEEE 1547-2003.

IEEE 1547-2018 incorporated the knowledge developed in new installations and operations.

In Europe, the European Network of Transmission System operators for electricity-ENTSO-E establishes the criteria to connect and operate the new sources.

IEEE 1547 complements IEEE 519 and IEC 61000 and highlights power quality mainly in four items below:

- Limitation of dc injection.
- Limitation of voltage fluctuations induced by the DER.
- Limitation of current distortion.
- Limitation of overvoltage contribution.

Sometimes, it is necessary to install capacitors in the system to control the voltage of distribution circuits.

In addition to the harmonics caused by inverters that are configured in major sources of harmonics, there is also a certain amount of background harmonics in the distribution circuit coming from customer load and utility equipment and could have also someone from resonance with capacitors.

Finally, we need to consider the lack of kinetic energy from wind and especially solar energy. Therefore, it is necessary to provide a Spinning Reserve system, consisting of synchronous generators operating at low load to avoid swing.

Table 4. Abbreviation meaning

IEEE-Institute of Electrical and Electronic Engineering	SCR-silicon Controlled Rectifier
IEC-International Electrotechnical Commission	IGBT- Insulated gate Bipolar Transistor

8. Final considerations

The path to net zero through the rapid replacement of fossils in the so-called energy conversion, conflicts with the need for expansion in poor and developing countries, eager for cheap energy. Therefore, the complement of CDR and CCUS must be at the heart of the matter with a level at least equal to the replacement of fossils in the matrix.

At present, the share of Solar and Wind Energy in the grid rarely surpasses 25% to 30%. Traditional Grid, fed by Synchronous Generators which anchor the Power Electric System- PES could absorb harmonics, unbalances and give kinetic energy to system. Nevertheless, a malfunction could appear when PV solar and wind electric power, together, surpasses traditional power energy. Therefore, the challenges that will arise to maintain the quality of energy with compliance with the afore mentioned IEEE 519, 1547-2018, IEC 61000, among others, will increase with Wind and PV Solar Power energy increase. The world faces a “Great Challenge”.

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