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A Comparative Analysis on China's Energy Issues and CO_2 Emissions in Global Perspectives

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Abstract China's CO_2 emissions increased annually at 6.04% growth rate from 1448.47 Million Metric Tons (MMT) to 8715.30 MMT in contrast to global 1.87% from 18433.15 MMT in 1980 to 32578.64 MTT in 2011. This comparative analysis was based on secondary data from 1980-2012 to understand the past energy issues and CO_2 emissions trends along with its future scenarios. It has revealed that China's total primary energy production will be 15-times more with significant 2985 Metric Tons of Coal Equivalent (Mtce) deficiency in 2025 in contrast to global 26745.20 Mtce of production and 26412.54 Mtce of consumption respectively. Moreover, it also showed that China's CO_2 emissions will climb to 30888.29 MT at 2-times growth rate where global emissions would be 50020.14 MTT with 2.5 times in 2025. This analysis will be helpful in energy sector for planning, allocation, efficient utilization, emission reduction to achieve present and future green friendly environment.

Keywords: *energy scenarios, world & China, production, consumption, CO_2 emission, renewable energy*

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1. Introduction

Energy is considered as an essential key factor for sustainable development because of its inter-linkage to all industrial, economical, agricultural and or industrial processes as a prosperity and security for a nation. Consequently, global primary energy production increased from 10343.98 Mtce to 18318.99 Mtce since 1980 to 2010 respectively and expected to rise over by one-third in 2035 [1]. Until 2030, it will grow by 1.6% per year with the 8.3 billion populations i.e., 1.3 billion new users. Consequently, there are additional 36% of global consumption will increase that might be the cause for 26% carbon dioxide (CO_2) emissions in which 48% will be accounts for Asia Pacific regions [2]. Besides, total energy consumption grew 2.5% with net economic growth in 2011 where 71% was accounted for China [3]. At present, World's 90% of primary energy comes from fossil fuels like oil, coal and natural gas and the ratio would be 80% in near future i.e., world will to be highly dependent on the fossil fuels in 2035 [4]. This increasing energy production and consumption trends from burning fossil [5,6,7] accelerating the CO_2 emissions and playing the crucial role as the most influential factor of anthropogenic climate change [8].

As energy is the main actor for economic development, the global consumption intensity has increased over the last few decades. This symbol of development also illustrates the 'economic progress' through industrialization, urbanization, modernization and changes in life style those are responsible for increasing global CO2 emissions and environmental footprint. CO_2 emission is mainly dependent on burning of fossil fuels where the amount of emission is connected to Total Primary Energy System (TPES) and consumption [9]. The nexus among economic development, energy consumption, population growth and CO2 emissions have been demonstrated [10,11]. From this standpoint, understanding of this enegy-economic-CO_2 emissions nexus is important for clean economy and sustainable development [11].

This study seeks for global and China's energy and CO_2 emissions issues with comparing to each other. The main objective of this comparative analysis is to understand the importance of China's green initiatives for achieving green economic developmental goal by global community. It is expected that this study will play an important role for sustainable development, energy consumption modeling and prediction estimation and design for developmental activities, making policy for sensible utilization and potential outage of financial resources for China as well global community.

2. Literature Review

China's energy structure is mix. Due to being rich in coal but poor in oil and gas, coal dominates its mixed

energy consumption that was accounted for 68% of TPES in 2010 [12]. It produced more than half of the total World's coal in 2011 [13] and used in coal-fired plant to generate 81.8% of total electric energy. Its coal demand will increase from 1734 Mtce of 2006 to 2712 Mtce in 2015, and to 3487 tce in 2030 respectively [14]. Coal combustion is a major source of air pollutants for 90% of CO_2, 70% of total smoke and soot dust [15] and 95% of sulfur dioxide (SO_2) emissions [16]. CO_2 is responsible for 58.8% among the six GHGs [17]. As 80% of Total Primary Energy (TPE) will be provided from fossil fuel, CO_2 emissions will increase 1.4-fold from 30.4 Gt in 2010 to 43.4 Gt in 2035.

China's overall energy consumption in 2011 was equivalent to 3.48 billion tons of coal and expected to be 5 billion tons of coal by 2020. The rapid growth of energy consumption has also come up with considerable pressure on China's energy supply. In 2020, compared with 2009, the energy intensity was forecasted to decrease by 32.15%, 48.0%, and 42.9% in three different scenarios [18]. In advanced technology scenario, global CO_2 emissions will increase to 32.3 Gt in 2020 but peak out by 2030 due to newly efficient innovation of energy and environmental technologies. Emissions in 2035 will be 29.7 Gt, 13.7 Gt or 31% less than in the reference scenario. And by this time, the global energy intensity will be 31% lower significantly with an average 2.2% declining rate due to the energy efficient movement by China and its' sustainable development strategies.

World's CO_2 emissions from energy consumption increased annually 1.87% from 18433.15 MMT in 1980s to 32578.64 MMT in 2011 with per capita 4.14 MMT to 4.7 MMT with a growth rate of 0.41%. Besides, China's emission increased at 6.04 % growth rate from 1.47 MT to 4.69 MT with a per capita 5.01%. In 2010, 5.3% coal, 12.9% crude oil, 18.2% natural gas and 13.1% electricity consumption were increased than 2009 [19] and had surpassed the production by 11.6% in 2010 in contrast to 1.7% of 1995 [20]. In 2010, it surpassed the USA in terms of both consumptions (20.3%) and CO_2 emissions (25%) with 8.2 tons per capita, compared with 7.1 of global average. Its per capita emission growth rate has increased at 9.3% from early industrialization period 1951 to 2002 and predicted to be continued at 5.4% from 2010 to until 2020 [1,6,21].

China is the World's largest consumer of energy and accounts for 21% of global energy use. Its energy consumption increased from 602.8 Mtce in 1980 to 3.25 billion tce in 2010, with an annual growth rate of 5.8% [14]. It has already been documented as the World's largest consumer with contributing 71% within 2.5% of World's primary energy consumption grew for net economic growth [3,22,23]. China is rich in coal resources resulting consumption pattern is dominated by coal used as 70% for electricity generation while only 20% from hydropower [24]. Its energy structure is composed with thermal, hydro, nuclear, wind, solar and remaining geothermal, biomass and ocean power comprising 72.2%, 21.7%, 1.2%, 4.3%, 0.2% and 0.4% installed capacity of 1060GW [25] and 82.2%, 14%, 1.8%, 1.5%, 0.02% and 0.4% of 4740 TWh generation capacity respectively [26] in which renewable energy contributed 15.9% share in 2011 [27,28].

It is the largest and rapid developing emerging economy which is in the middle stage of urbanization, industrialization and modernization in the World [29]. Its rapid urbanization has been observed with economic growth since 1990s [30,31]. Consequently, urban areas containing 40% of the total population through contributing 75% to the national economy, contributes to make up 84% of commercial energy usage and 40% of TPES and CO_2 emissions of China [32]. This rate was 40% in 2005 for 531 million i.e., 17% of total World's total urban dwellers and predicted to be 880 million (60%) in 2030 [33]. This sorts of growth over the last three decades brought it to a important economic power of the World with largest exporter, second largest importer and national economy but at a cost of significant amount of energy consumption [34].

China's energy-economy nexus analysis [10] based on panel data from 1995-2011 found an interconnected bi-directional positive causal relationships to each other and per capita CO_2 emissions will increase between 2012 to 2020 as well whilst their reduction strategies will also be high. Alongside, technological development and industrial structure are the most important affecting CO_2 emissions factors [35]. China's CO_2 emission has classified into three distinctive periodic stages including low emissions (1961-1968); average growth (1969-1997) and high emission stage (2002-2009). During the first stage average growth of CO_2 emission was almost zero which was increased 17.86% during the second stage. But the emission was exponentially increased from 3,694,242 kt in 2002 to 7,687,113 kt in 2009 with economic growth since 2002 after slowing down the Asian financial crisis (1998-2001) [9]. Ref [36] classified China's industrial sectors into three major categories and their study revealed that primary industry will emit more CO_2 compared to secondary (includes mining, electricity, construction, water and gas) and tertiary industry (includes trade and wholesale, residential use, transport sector, post and telecommunication, storage etc). They inferred that expansion of primary industry including forestry, agro & aquaculture and fisheries will accelerate the CO_2 emissions due to increase in new irrigation channels, building constructions and more fuel consumption [37] as well managing total rural electric consumption under national electric corporation since 2007 [38].

Currently, China's per capita power consumption is 3,400 kilowatt hours (kWh) annually compared to western countries' average 8,000 kWh and 15,000 kWh of USA. In order to meet tight energy supply in the future, it has suggested that China should develop more energy sources like shale gas and hydropower. China has set an ambitious goal under the 12^{th} Five Year Plan (FYP) to reduce its carbon intensity 17% by 2015 and 40-45% by 2020 to develop a low-carbon economy and to strengthen its energy security. The introduction and implementation of a carbon emission trading scheme (ETS) is a critical component for China to achieve these ambitious goal.

Energy demand management is incredible important for conservation, planning, monitoring, design, proper allocation, effective and efficient utilization based on available resources. It is an amalgamation process of consideration for future energy requirements, conservation measures, prioritization of resources, strategy for efficiency, emission reduction, planning, design, monitoring,

implementation, and cost-benefit analysis, technical and behavioral solutions by using models of macroeconomic variables for present and future green friendly environment [39]. This paper has demonstrated World and China's energy issues and CO_2 emission to understand present and future situation for developing and achieving a local and global green economy.

3. Methodologies

Projection of energy consumption is inevitably important for promotion of its maximum efficiency, cost minimization, mitigating exergy losses, abatement of CO_2 emission for a sustainable future [8,19]. In this study, regression analysis was used to determine the coefficient which is using as one of the most popular modeling techniques to predict equally spaced and univariate time series data as a linear combination of its own past and past errors [40,41]. This comparative study was mainly based on the secondary data retrieved from IEA [1], EIA [17] ESCAP [13] and NBSC [14].

3.1. Equation

ARMA (p,q) Model (Equation 1) was used for time series analysis from 1980-2011. This trend analysis was done for forecasting of energy production, consumption and CO_2 emissions as well as the future situation of renewable energy resources in global and China's perspectives.

$$x_t = \left[\sum_{i=1}^{p} \varnothing_i x(t-i)\right] + \left[\sum_{j=1}^{q} \theta_j a(t-j)\right] \quad (1)$$

Where, x_t is the forecasted value of the time series at time t (1980-2012), p is the order of the autoregressive (AR) component model, $\varnothing_1, \varnothing_2, \varnothing_3, \ldots\ldots \varnothing_p$ are the AR (p) model coefficients, q is the order of the moving-average (MA) component model, $\theta_1, \theta_2, \theta_3, \ldots\ldots \theta_q$ are the MA (q) model coefficients and a_t is the model's residual at time t. $[a_t \sim i.i.d] a_t \sim N(0, \sigma^2)$.

4. Results and Discussions

4.1. Primary Energy Production and Consumption

Global primary energy production increased annually with a growth rate at 1.88% from 10343.98 Mtce to 18318.99 Mtce in contrast to relatively high consumption rate of 1.99% from 10193.26 to 18379.53 Mtce since 1980 to 2010 respectively [23]. It is expected to be reached 26745.20 Mtce of production and 26412.54 Mtce of consumption with an annual growth of 2.49% and 2.38% in 2025 respectively.

On the other hand, China's primary energy consumption increased 4.9% in 2012 (4156.24 Mtce) in compare to 2011 (3963.57 Mtce) and magnified by approximately 5.5 times to 1992 (767Mtce). It is predicted to reach 4324 Mtce and 5666 Mtce in 2050 and 2100, respectively [42,43]. It also has been experiencing from gradually increasing energy demand since 30 years for moving economy through industrialization. The consumption in recent years was 2354.45 in 2007, 2850 in 2008, 3353.20 in 2009 and 3631.68 (Mtce) in 2010 respectively. It has been rising with a trend at 8.98% since 2000 and to be increased with an average 3.2% of 5.5% GDP growth rate per annum over 2004-2030, 4.5% over 2004-2015 and then falling to 2.2% over 2015-2030 [14,44]. This analysis found that its primary energy consumption has been tremendously increased with 5.65% growth. Consequently, it will lead a significant deficiency of almost 2985 Mtce of production in 2025 although its production could be increased 15 times more in 2025 (shown in Figure 1).

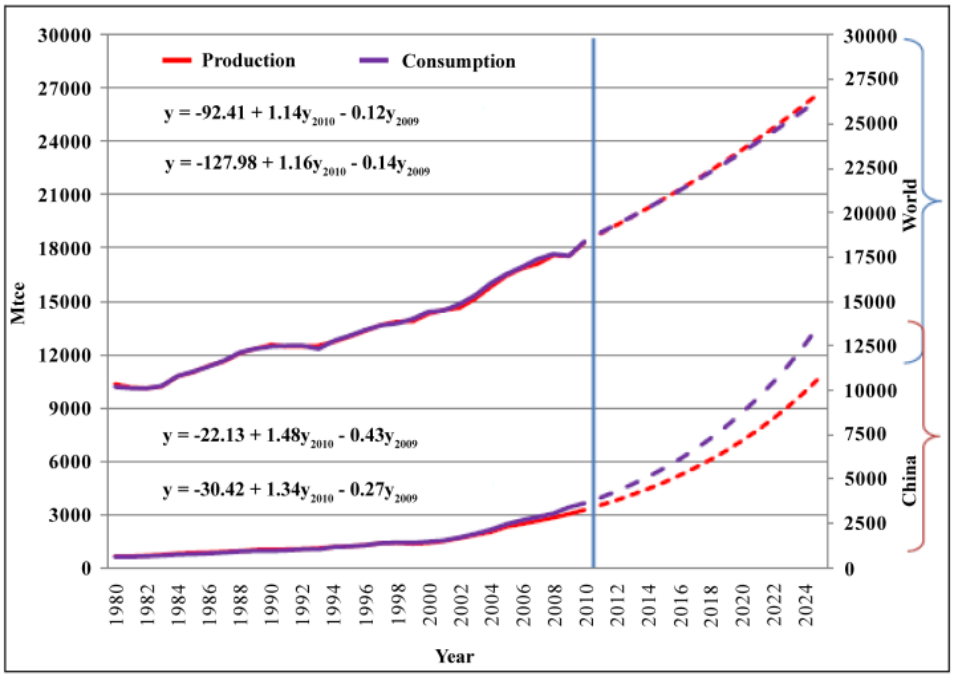

Figure 1. Comparison of primary energy production and consumption

4.2. Sector-wise Energy Consumption

Industrial sector has been dominating as the highest primary energy consumption by World since 1980 to 2010 (Figure 2) although the trend was decreased from 33% to 28%. Besides, commercial and transport sectors were increased a bit of 20% to 21% and 23% to 27% where residential sector was been constant (24%). On the other hand, China's residential sector was responsible for almost half of the TPES (49%) in 1980s along with 38% in industrial, 5% in transport and 8% in commercial sectors. Residential energy consumption was increased by 1.3% from 343.3 Mtce to 507.4 and expected to be 570.6 Mtce in 2025 with an increasing trend of 0.8%. It is also revealed that in 2010, transport sector has come out as the highest consumption sector because of consuming 35% TPE although pattern of residential and industrial sectors was decreased significantly to 27% in contrast to no change in commercial sector (Figure 3).

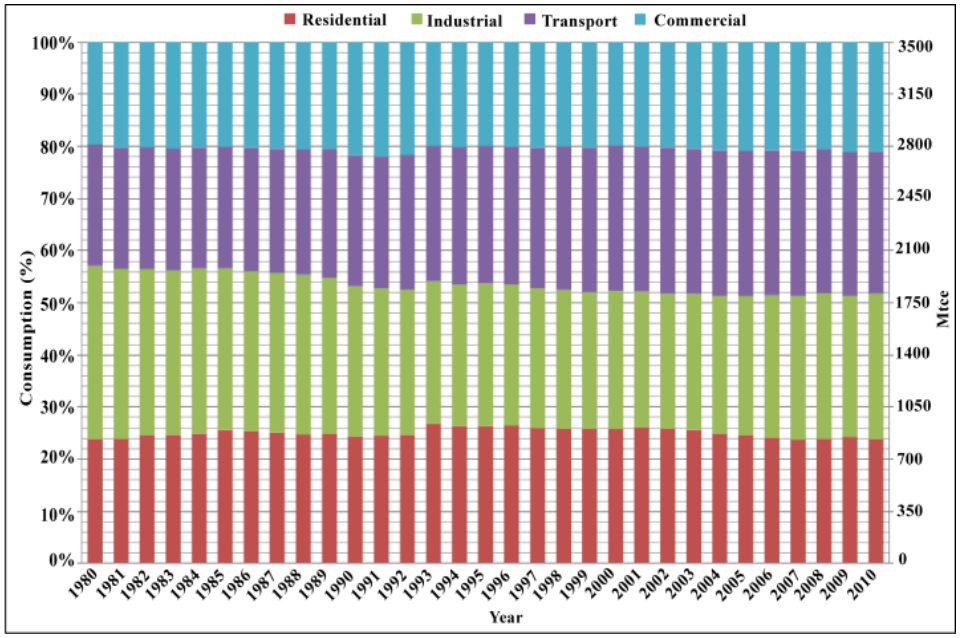

Figure 2. Sector-wise energy consumption by World

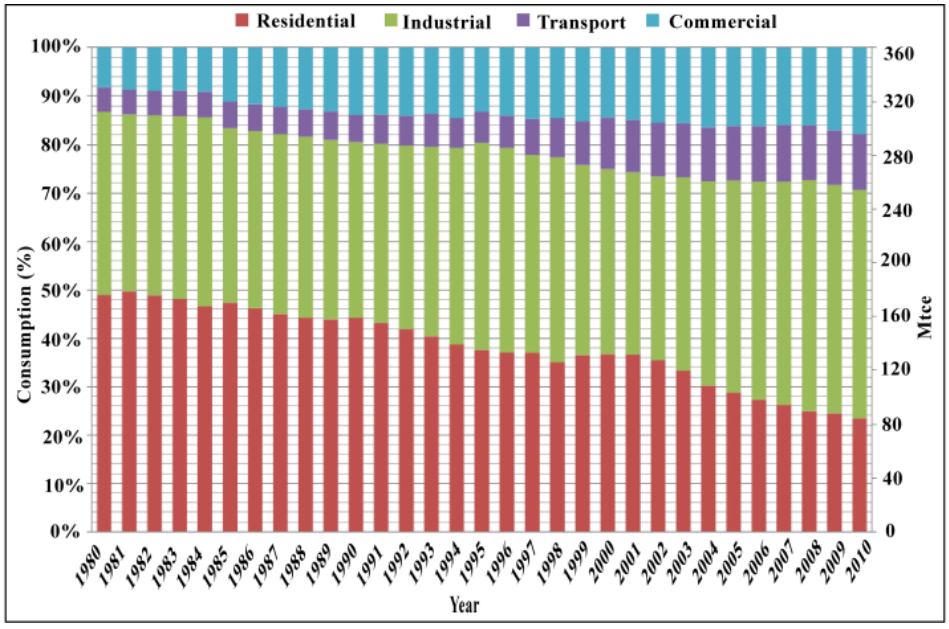

Figure 3. Sector-wise energy consumption by China

4.3. Energy Consumption by Sources

World's sources of energy supply were dominated by petroleum since 1965 from 1516.16 Mtce to 4130.53 Mtce in 2012 with a growth rate at 2.20%. Moreover, gas consumption was increased 3.53% from 593.81 Mtce to 2987. 06 Mtce, coal 3.08% from 1429.04 Mtce to 3730.08 Mtce, nuclear 10.89% from 5 Mtce to 560.39 Mtce and renewable energy use 3.54% from 210.21 Mtce to 1068.56 Mtce respectively (Figure 4). This analysis is demonstrating that coal consumption would be 5855.72 Mtce with an annual growth rate at 3.53% in 2025 i.e., the highest source of energy supply. Besides, energy from petroleum would be 4154.88 Mtce with 0.04%, gas 3896.14 Mtce with 2.06%, renewable 1940.86 Mtce with the highest rate of 4.7% along with 0.16% growth rate being 547.72 Mtce

for nuclear energy supply. By the same time, the mix energy consumption pattern of China was dominated by coal that increased from 114.42 Mtce to 1873.31 Mtce at 6.32% growth rate and predicted to be remained as the highest supply source at 6.89% growth rate for rising to 4453.95 Mtc. Besides, there is a significant development has revealed in renewable energy generation. It was climbed from 5 Mtce to 226.69 Mtce with an annual growth rate at 8.79% and would be 1153.42 Mtce with an increasing trend at 13.35%. Petroleum and gas supply was also increased from 10.96 Mtce and 0.99 Mtce to 483.67 Mtce and 129.45 Mtce with a rate at 8.78% and 11.5% and projected to be 1017.8 (5.89%) and 852.37 Mtce (15.06%) respectively. Although nuclear energy generation in China started since 1993, increased a relatively slower growth rate at 0.54% for 0.37 Mtce to 24.27 Mtce and expected to be 70.39 Mtce with 9.34% annually (shown in Figure 5).

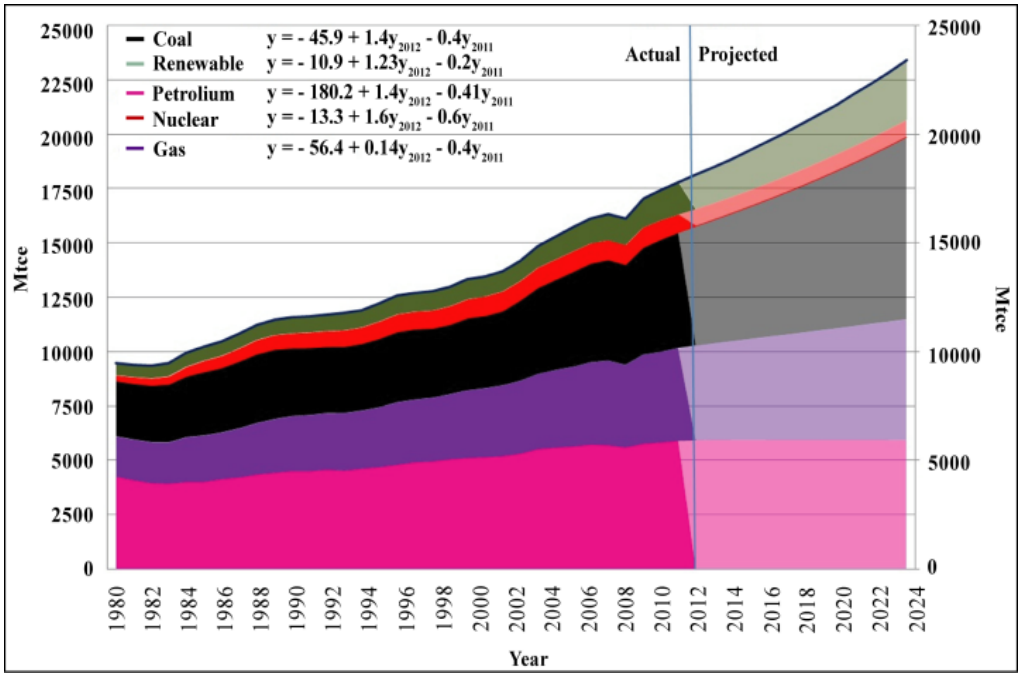

Figure 4. World primary energy consumption by sources

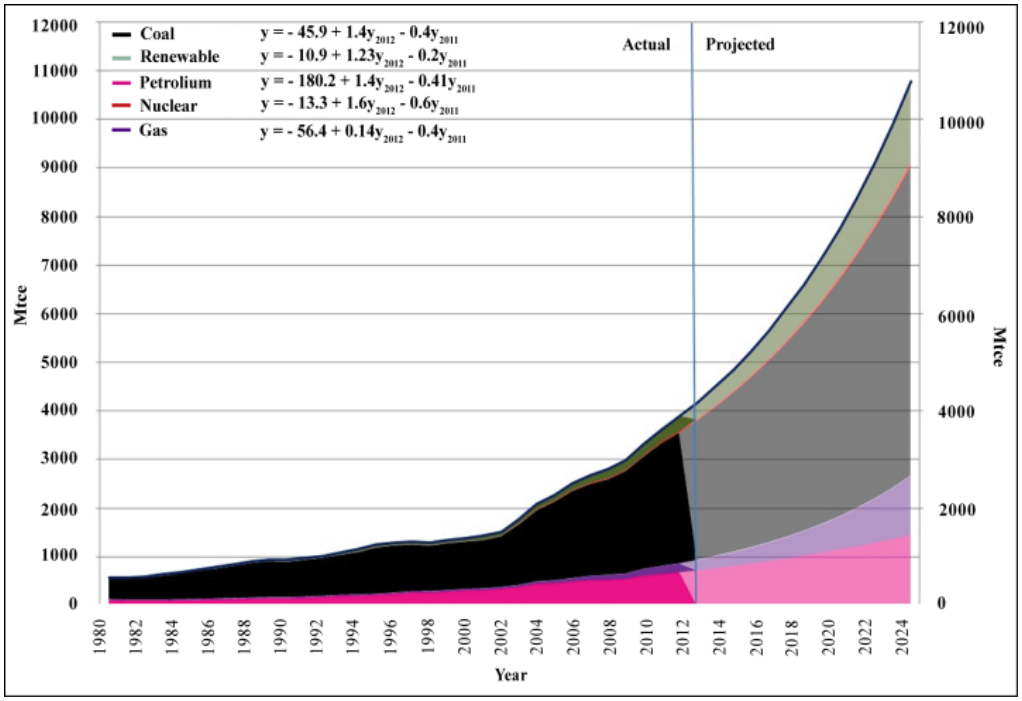

Figure 5. China primary energy consumption by sources

4.4. Total and Per Capita CO_2 Emissions

World's CO_2 emission from energy consumption was increased annually 1.87% from 18433.15 MMT in 1980s to 32578.64 MMT in 2011 with per capita 4.14 Metric Tons (MT) to 4.7 MT with a growth rate at 0.41%. Furthermore, China's total emission was increased at 6.04% along with per capita 5.01% growth rate to rise from 1.47 MT to 4.69 MT. It is also found that World's emission would be 50020.14 MMT in contrast to China's

30888.29 MMT with 2.5 times and 2-times more growth rate in 2025 (shown in Figure 6).

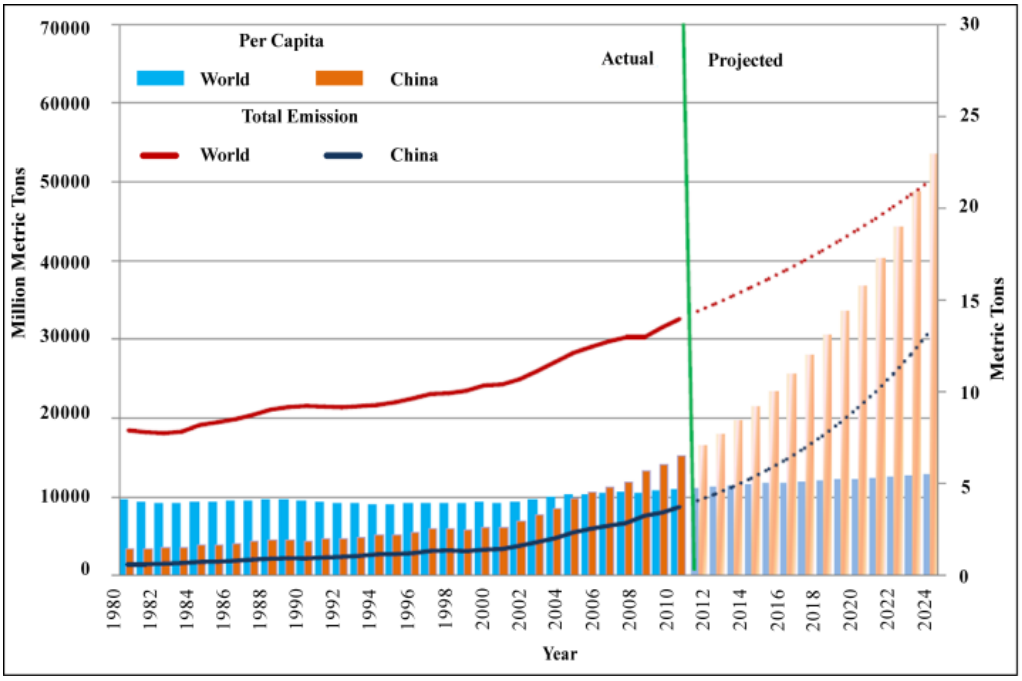

Figure 6. Total and per capita CO_2 Emission

4.5. Renewable Energy

The World is gradually moving to green. Currently, hydroelectric power generation is the most prominent green energy source practicing globally. It has been dominating as the maximum amount of clean energy sources. Its install capacity increased at 2.45% growth rate from 1699.67 Million Megawatts (MWs) in 1980s to 3673.12 Million MWs in 2012. It is found to be climbed at 4958.54 Million MWs with 2.33% increasing rate in 2025. Among the other sources, wind energy was the fastest renewable technology in the green energy World. It has contributed to generate 0.28 Million MWs in 2012 from 10 MWs of 1980 at 44.75% growth rate and projected to be 2.21 Million MWs in 2025 with exceeding 17.1% raising rate. The World has also experienced with rapid growth of photovoltaic (PV) energy from 7 MWs to 0.10 Million MWs through 44% positive trend and could be 50.52 Million MWs with 17.1% growth rate in 2025. By this time, although geothermal energy was significantly increased annually at 11% from 3885 MWs to 11445.8 MWs but the trend would be very slow as 2.33% annually that might be 15147.31 MWs. On the other hand, Hydropower is the largest renewable energy source of China. In 1980, China's install capacity was 58.22 Million MWs and increased with an average trend at 9.05% per year to reach 860.85 Million MWs and initiatives to enhance the generation by 10.33% for 3074.9 MWs in 2025. Although PV energy utilization by China started in 1958 in 12 m^2 bathroom [45] but noteworthy use was observed in 1997 from 1 MW to 8300 MWs in 2012. It has been increasing as the highest growth rate at 89.81% along with the expected 215% of install capacity for 24905.6 Million MWs in 2025. Moreover, wind energy also was famous during this time period as it was increased at 61.31% from 38 MWs to 75372 MWs and has a potential capacity of 0.24 Million MWs in 2025. Alongside, geothermal energy generation has a negative 1% of decreasing trend from 31 MWs to 23.83 MWs and the cumulative installment could be decreased annually at 0.11% to come down 23.5 MWs.

5. Conclusions

The impacts energy consumption from fossil fuel burning on climatic conditions has already been realized by global communities. The target oriented comprehensive initiatives are increasing through the share of green energy utilization in TPES. Although rapid population and urbanization growth are tremendously rising global energy demand and concerning for CO_2 emissions but magnifying input of clean energy is forming prospect for green economic development. In 2010, supplied renewable energy was 16.7% in world's total consumption along with investing highest $257 billion. Besides, there are almost 67 countries globally set renewable energy targets to cut down green house gas emission in different timeframe [46]. Consequently, renewable energy use in industrial, commercial, transport and residential sectors for electricity, cooling, heating etc are considered significantly and getting acceptance notably.

China's national policies are aimed to develop a green economy by reducing their 16% CO_2 emissions intensity by introducing 11.4% renewable shares in TPES by 2015. This study is reflecting the World and China's primary energy consumption and production along with the required demand in 2025. The detailed analysis on sector-wise consumption, sources of energy along with the depth illustration of CO_2 emissions, are reflecting a significant overview to realize and assume the China's present and future energy and emission scenarios in context to World perspectives. This research found the importance of practicing for "energy efficiency" and "clean energy" for abating CO_2 emissions and green economic development.

Energy efficiency can be achieved from efficient and sensible use of existing supplied energy, household appliances, dematerialization of appliances etc where share of clean energy could be increased by enhancing power generation from wind, solar, geothermal and hydrological sources. Although the share of renewable sources in total energy systems has been increasing in essence, but large scale government policy initiatives are needed to cope with the energy crisis, CO_2 emissions and global climate change. In this vein, this study also observed necessity of some other issues besides 'mandatory target' for achieving this goal. The local authorities and international agencies could emphasize on more specific guild lines and legislations, budget, audit and enforcement, highlighting benefits for every socio-economic and environmental compartments as well as drawing adverse impacts to encourage, capacity building of mass people for renewable resources. Furthermore, training, subsidies, financial assistance and logistic supports are also important to green energy.

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