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Industrial and Clean Energy Hydrogen : An Overview

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ABSTRACT

Global warming has several adverse impacts on climate and if not contained, may result in rising of sea level to a dangerous point when millions will be required to be displaced and rehabilitated. It is also responsible for climatic changes. Green house gases are the reason behind global warming. Carcon dioxide is main green house gas which is added due to continuing use of fossil fuels. To obtain carbon neutrality and Decarbonization, need of the hour is clean and carbon free source of energy. Hydrogen has emerged as a clean fuel as it does not contain carbon. But hydrogen does not occur in pure form in nature and eventually it has to be manufactured. Conventionally, it is manufactured from fossil fuels such as natural gas or coal and process is called steam reforming. This also requires source of energy. Use of fossil fuel results in green house gas. Hydrogen can also be produced by electrolysis of water and source of energy can be renewable energy like solar or wind energy. This obviates adding of greenhouse gas and is a clean process. There are several ways of producing hydrogen depending on raw input and source of energy, which quantify to what extent the produced hydrogen is green. Hydrogen offer variety of applications across many segments of industry. It is worthwhile to evaluate all manufacturing processes and applications of Hydrogen and its potential contribution in Decarbonization.

Keywords: *Hydrogen Energy; Steam Reforming; Green Hydrogen Generation by Electolysis; Hydrogen Based Fuel Cells; Carbon Capture and Storage; CCUS; Climate Change; UNFCCC; Paris Agreement; Global Warming; Sustainability; Carbon Reduction.*

1.0 Introduction

Climate change which was merely a subject of scientific Inquisitiveness in first few decades of 20th century but was declared a matter of global concern and international emergency in year 2019. Environment and sustainability were the initial matter of global political concern. In year 1972 at Stockholm, an UN organised environmental summit took place concluding into setting up of UNEP (United Nations environmental programme) for protection of natural environment and sustainability. Stern warnings by scientific community about the risks posed by green house gases found attention in many countries later and first world climate conference (WCC-1) was held at Geneva, Switzerland in year 1979. Subsequently, Intergovernmental panel on climate change (IPCC) was established in year 1988 to assess the impact and risks of climate change, which has finished it's several assessments on climate. IPCC was conferred with Nobel Peace Prize in year 2007 for its role. The first assessment report of IPCC was placed public in year 1990 and it concluded that human activities are substantially increasing green house gases in atmosphere. This alarmed a need of international treaty. UN General Assembly with several negotiations designed a UN framework Convention on climate change (UNFCCC) which was adopted in may 1992. It was opened for signature in Rio earth summit 1992. Till date there are nearly 197 signatory countries on this convention. The main objective of the convention which is the first convention on climate change, is to stabilse continually increasing proportion of green house gases in atmosphere in order to control the human interference on climate balance. It also mitigates sustainability risks and minimises cost of adaptation of climate change. Signatory countries to the convention also called parties agreed for annual conference which shall act

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as review of the convention and monitor the implementation. This conference is named conference of parties (COP) and is decision making and implementing body of UNFCCC. First COP held in 1995 resulted into Kyoto Protocol adopted in 1997. This protocol had binding targets on industrialized countries to reduce green house gases emissions even when other countries continued to increase emissions. Next major agreement was reached in COP 21 at Paris in year 2015 and is called Paris Agreement. This was a general agreement between industrialized as well as less developed countries too. Paris Agreement has set a goal to limit the global warming by 1.5°C over the pre industrialized level. All countries are required to produce a Nationally determined contribution and plans accordingly to tackle climate change.[1] Carbon Di Oxide (CO_2) is the largest contributing green house gas besides methane and nitrous oxide. Thus reduction in CO_2 emissions which are from a variety of sectors such an power, agriculture, transportation, industry and buildings is a challenge. In order to meet required temperature increase limit as per Paris Agreement to 1.5 °C , about 50 to 100 billion tonnes of CO_2 in atmosphere has to be removed by year 2050 but emissions still keep increasing year after year.

Hydrogen is used as main input for manufacture of Methanol and Ammonia. Methanol is required reactant in production of wide variety of polymers and ammonia is used for manufacturing fertilizer, pesticudes, dyes and other chemicals as well as is used as refrigerant and water purifier. Hydrogen is also used as reducing agent in steel production processes such as Blast Furnace (BF) production process and Direct reduction iron (DRI) process. Large part of Hydrogen as industrial input, is mainly used in fertilizer manufacturing and refineries. Fertilizer plants use hydrogen to produce ammonia and refineries use hydrogen as sulphar removing agent from the finished products containing sulphur such as Gasoline, Diesel, Kerosene and Natural gas through process called Hydro-desulphurisation (HDS).

It is natural that these plants have captive Hydrogen manufacturing plant. The current global demand of hydrogen is 70 million metric tons per year, in energy terms its around 330 million toe (tonnes of oil equivalent). Most of which is being produced from fossil fuels (76% from natural gas and around 23% from coal, remaining from electrolysis of water) which consumes 6% of the global natural gas and 2% of the global coal.[2] Global hydrogen production results in CO_2 emissions of around 830Mt/year. CCUS not in place, most of the CO_2 emission is not captured, only about 10% of CO_2 emission is being captured and used mostly in fertilizer industry. The emission scenario will change when the hydrogen production will increase from non fossil fuel based feedstock resources and with greater consumption of renewable energy. This will lead a process shift towards green hydrogen production.

The production methods employed are basically dependent on the feedstock resources available locally. Depending on which input feedstock is selected, the different choices of routes for hydrogen production can be evaluated such as reforming, gasification, pyrolysis, fermentation and electrolysis or photolysis. However, the most widely used method for hydrogen production globally limits to steam methane reforming, methanol reforming, partial oxidation of hydrocarbons, thermochemical processes, thermal reforming, coal gasification and electrolysis of pure water.

The most extensively used Hydrogen manufacturing process is steam reforming process of hydrocarbons(Methene) and heat requirement is obtained by burning of fossil fuels. Fossil fuels inevitably increase the global warming gas carbon dioxide in atmosphere and also many other pollutant gases. In order to minimise and contain emission of carbon dioxide, the foremost greenhouse gas, while manufacturing Industrial Hydrogen, first emphasis should be on using:

1. Low carbon fuel as source of raw input and energy. Natural gas is preferred option compared to other options such as coal.
2. Carbon capturing and storing (CCS) may be applied to capture carbon dioxide and store it in a sink such as an empty oil well or any other suitable storage. The hydrogen manufacturerd with this technology is popularly called Blue Hydrogen. CCS imposes some additional cost but imperatives of decorbonising is met.
3. Finally Renewable energy source such as Solar or wind, may be used for energy requirements in manufacturing of the hydrogen. Instead of Steam Reforming, The Hydrogen may also be produced by Electrolysis of water, which requires more energy. But the Hydrogen produced by Electrolysis of water using Renewable energy is

fully decorbonized and is popularly known as Green Hydrogen. The cost of Green hydrogen may be high enough for industrial hydrogen manufacturers to adopt the process as of now. Unlike conventional steam reforming process which is continuous, Electrolysis can be readily switched off and on and this facilitates accommodation of hybrid energy system which can use various sources of energy including renewable energies. Availability of the required renewable energy within the fertilizer plants and refineries or in a nearby area may be a concern for many of them. But the first two options can be easily adopted by most of them with immediate effect and to a certain level, electrolysis process can be adopted with hybrid energy system instead purely depending on fossil fuels or renewable energy.

4. There should be greater emphasis on industrial and societal reuse of carbon dioxide. Several research has been conducted in this direction. Carbon dioxide can be reduced to carbon monoxide, which can then be converted to many chemicals. Carbon can also be converted and stored as liquid fuels using renewable energy, thus enabling use of fuel such as gasoline without increasing green house gases.

2.0 Hydrogen as Clean Energy Source

When fossil fuels are burnt the final products inevitably consist of water and green house gases- oxides of carbon. There may be oxides of nitrogen and other obnoxious gases such as sulphar dioxide depending on impurities in fuel and unburnt hydrocarbons too.

Thus burning of fossil fuel always results in addition of carbon dioxide in atmosphere. This requires that use of fossil fuels be minimised or reduced to nil in order to achieve higher degree of Decarboniization of the atmosphere.

Hydrogen has higher heat content than fossil fuels and is free of carbon. When hydrogen is used as fuel, the final product will not contain oxides of carbon. This is very positive aspect in decorbonising and reaching the goal of carbon neutrality.

Carbon neutrality is obtained, when the carbon added to the atmosphere is nullified by removing the equal amount of carbon molecules from the atmosphere. But Hydrogen does not exist in free form naturally and has to be manufactured. Manufacturing of hydrogen requires input of lots of energy which results in green house gases normally. But if hydrogen is manufactured using renewable energy resources such as solar, wind, geothermal or biomass, it can be used as storage for renewable energy. This stored renewable energy in hydrogen can then be deployed and used as source of energy without increasing green house gases in atmosphere serving as a source of clean energy. Fuel cell electric vehicles are seen as viable clean and green transportation means and advantage of hydrogen is that it can be used as fuel in fuel cells. In fact hydrogen - oxygen based fuel cells are most popular fuel cells in transportation. One of the major constraint in renewable energy resources is it's storage. Hydrogen is one of the options to store renewable energy resources. Hydrogen is inflammable and it needs safety and care in its storage and transportation in order to establish a Hydrogen supply chain from manufacturing point to refueling stations, which is not available at present in the majority of society.

The use of hydrogen prima facie , appears in following areas,

1. Energy
2. Transportation
3. Buildings and household
4. Agriculture

2.1 Energy

Fossil fuels are used as fuel and non fuel (as Raw material) in manufacturing sector among industries in approximate ratio of 65% as fuel source and 35% as raw material. Requirement of manufacturing energy alone, in an industrialized society is estimated to be 75% of total industrial energy and among manufacturing sector, Chemical, petroleum & coal, primary metal, food and paper industry are dominant shareholders. As Fuel, it finds applications in-

a. heating required in industrial processes
b. as boiler fuel for generating process steam or hot water and
c. fuel for generating electricity in boilers, gas turbines, generators etc.

Hydrogen is a clean substitute for fossil fuels in all these applications thereby resulting in considerable reduction in carbon dioxide emissions. Hydrogen used as direct fuel in combustion results in only water and burnt gases does not contain carbon dioxide. However since nitrogen is available in air, possibilities are that it will contain nitrogen oxides (NOx). But NOx production can be controlled by controlling temperature and can also be captured.

For heating up to 400 °C , focussing type solar collectors are most green options, but cost may be a factor. But if temperature requirement is above 400°C then solar collectors may not be feasible option. Hydrogen can be used as fuel in boilers to produce process steam and hot water.

Hydrogen can be used in Thermal power plant steam generators to produce thermal electricity reducing considerably the green house gases as well as other gaseous pollutants and harmful suspended particles. It can be burnt in combustion chambers of gas turbines to generate energy instead of fossil fuels or can be mixed partly.

2.2 Transportation

Transport vehicles can be powered by hydrogen in two ways

1. Using hydrogen as fuel in internal combustion engines or gas turbines instead of carbon based fuels like Gasoline, Diesel etc.
2. Using hydrogen based fuel cells as source of power in Fuel Cell Electric vehicles(FCEV)

Fuel cell can also be used as auxiliary power unit in vehicles. If hydrogen is directly burnt as fuel, exhaust tail end gases will not have carbon dioxide but may still have obnoxious Nitrogen Oxides (NOx). Fuel cell based vehicles are zero emission, since only output is water. Fuel cell have been designed for different and almost all size of transportation means from scooters to small trucks and for trains and aeroplanes.

Hydrogen was fuel used in rockets and auxiliary power unit of spacecrafts are fuel cells. It was also thought to produce hydrogen in moving vehicles using Methanol by conventional reforming process to avoid transportation and refueling of hydrogen. But this requires high level of technical competence and more research is called for to achieve it.

Deployment of fuel cell or direct hydrogen fuel vehicles require a hydrogen supply chain, a network from hydrogen manufacturing point to hydrogen storage to finally hydrogen refueling stations. This involves transportation and storage of a highly inflammable gas, necessitating high degree of safety. In few part of advanced countries, it is already there in place and operational.

2.3 Buildings and households

In buildings and households, hydrogen can be used as fuel for space heating instead of fossil fuel as well as for electricity requirements. In addition in can be partly supplied in natural gas for cooking network of households resulting in less green house gas emissions.

2.4 Agriculture

Agriculture is heavily dependent on fossil fuel for its energy requirements of farming equipment. Farmers have space availability which can be used to generate solar and wind power. Solar and wind power are intermittently available and not stable source.

Hydrogen can be used to store intermittent renewable solar and wind energy for farming energy requirements. Hydrogen powered fuel cell tractors are already made in few countries. Other sectors which also are energy intensive, are mining and construction.

3.0 Challenges, Alternatives and Further Developments

3.1 CCUS/CCS

Total GHG emissions of India was 3,394,870 KTonne CO2e in year 2019 (world Bank).[3] Electricity and heat accounts for largest 37% share of total green house gases emissions. Agriculture (21%), manufacturing / construction (17%), Transportation (9%) and Industrial processes (5%) are the other major contributing sectors. [4]

Global emissions of GHG was 46,287620 KTonne CO_2 equivalent in year 2019. Globally the major sources of green house gas emissions are electricity and heat (32%), Agriculture (12%), Transportation (17%), Manufacturing (13%) ,Fugitive emissions(7%), Industrial process (6%) and building (6%).

Energy production of all kind is responsible for 72% of all emissions. Global green house gas emissions continue to rise even when need of the hour is that it falls rapidly.

Distribution of GHG emissions by various contributing individual gases is estimated to be approximately CO_2 (65%), Methane (16%), Nitrous

Oxide (6%), CO_2 by forestry and other land use (11%) and rest 2% by F- gases. Fossil fuel use is primary source of CO_2. Methane is generated by agricultural activities mainly animal waste and biomass burning. Nitrous oxide (N_2O) emission is primarily from fertilizer usage in agriculture. Fossil fuel combustion also generate nitrous oxide. Fluorinated gases (F-gases) are emitted by industrial processes, refrigeration and use of many consumer products. F-gases is a common noun used for Hydro fluoro carbons (HFCs), Per fluoro carbons (PFCs) and sulfur hexa fluoride.

According to BP annual report, fossil fuels still account for 84% of world's primary energy (oil 33% , coal 27% , natural gas 24%). Share of hydropower is 6% , renewables 5% and nuclear power is 4% in primary energy. Another finding in the report is that, primary energy consumption grew by 1.3% in year 2019 compared to 2.8% growth in year 2018. [5]Though growth of energy consumption of renewables was 41% followed by 36% increase in natural gas consumption, which is a shift in right and desirable direction.

To sum up, dependence of the world on fossil fuels in near future is inevitable. Carbon capture, utilisation & capture (CCUS) and carbon capture and storage(CCS) are tools which allow reduce carbon emissions while fossil fuels still remain in use. CCS is a process of where CO_2 emitted by a plant for example a coal based power plant or a cement plant is captured from flue gases, pressurized and then transported to a geological formation and stored permanently usually at least a mile under the earth surface. This disallows CO_2 to escape into earth's atmosphere (which it would have without capture) and thereby it doesn't become part of GHG emissions responsible for global warming. Sequestration of CO_2 in emptied oil wells has advantage that it can add value in fossil resources when explored after few years when output has been enriched by sequestered carbon. CCUS is process fundamentally different from CCS in that CO_2 captured is utilised in manufacturing of useful organic compounds like methanol, or fuel or plastics or bricks. These products can be used and the captured carbon di oxide is recycled in value chain rather than entering into atmosphere and adding into GHG emissions. Both are carbon emission reduction processes. These techniques makes it possible to use fossil fuels nearly at zero emissions.

Several different technologies that are being used to capture CO_2 at the source facility which results in CO_2 emissions, can be broadly categoriesed into three types namely, 1. post-combustion carbon capture, most popular and primary method used in CO_2 capture from existing power plants, 2. pre combustion carbon capture , most extensively used in CO_2 capture from ndustrial processes, and 3. oxy-fuel combustion systems. In post-combustion carbon capturing, CO_2 gas has to be separated from the multiple gas exhaust of the combustion process. There are several commercially available technologies for pre-combustion CO_2 capture, which are being practiced in industrial facilities. This technology requires gasifying fuel and separating out the CO_2 before fuel is fed to combustion process.. It is less costly compared to other technologies but it can only be pre applied into a new plant being commissioned. It would be many times costly to retrofit an existing plant with pre-combustion CO_2 capture. Still efforts are under research to stall pre-combustion capture in running power plants, so as to reduce the cost of post capturing. In third option that is called oxy-fuel combustion, fuel combustion takes place with nearly pure-oxygen environment, rather than atmospheric air, which results in a more concentrated stream of CO_2 emissions. It is less costlier and easier to capture concentrated CO_2. Carbon capturing results in helpiing global commitments towards climate change, yet using fossil fuels and raw inputs which is an immediate need till fossil fuels are phased out. CO_2 can be captured before production (pre capture) or it can be captured from outlets after production starts (post capture). CCUS technique has ability to be adopted by an existing and operational plant(retrofitted capture) for example CO_2 can be captured from an operational thermal power plant.

CCUS/CCS are mandatory tools to achieve net zero emissions across wide range of industries such as cement, iron and steel, thermal power plant, plastics, polymers and other chemical plants. But CCUS/CCS are energy intensive and significant cost is also associated with it. Cost of capturing CO_2 is dependent on purity and concentration of the CO_2 in the end mixture. Cost of capturing low concentration CO2 is higher as in power and cement plant, whereas cost of capturing high concentration CO_2 from sectors like gas fields and chemical plants is lower. Sso the carbon capture cost varries from sector to sector. This has to be passed on to consumers or government or partly to both. The products arriving from CCUS enablee plants can be sold at premium prices and secondly government may think of subsidy and tax incentives in proportion to per ton of CO2 equivalent captured to such plants in order to recover the additional cost of capturing as well as promotion of the global cause of climate preservation. At present, USA has largest number of CCUS/CCS sites and it has a policy of passing tax credit of $ 35-50 per tonnes of reduction in CO_2 equivalent of GHG emissions. For certain sectors like gas processing and chemical plants the technology is matured and for certain other sectors like thermal power plants the technology is less matured. Cost reduction and effective capture is required in those sectors. Captured CO_2 can be used as input for food and beverage industry or can be reduced to methanol which is a fuel as well as input to variety of chemicals. CCUS based methanol can replace fossil feed stock naptha and natural gas used for manufacturing organic chemicals like ethylene, propylene, benzene and xylene etc. CCUS is energy intensive and source of energy should be renewable energy.

3.2 Hydrogen

It can be easily concluded from the above note that our full focus should be, to produce Hydrogen as green as possible and use it in most efficient way to achieve maximum level of Decarbonization. At one end hydrogen is being used to store renewable energy, technology has beeen developed to reduce carbon dioxide to either carbon mono-oxide or carbonic liquid fuels using renewable energy making it possible to recycle carbon. Ammonia can be alternative to hydrogen in setting up transport, storage and Refueling stations chain in some countries as its network is already available along distributed fertilizer plants. Ammonia though hazardous, is less inflammable compared to hydrogen and has higher calorific Value also.

A new research area is production of hydrogen by a biological process called Biophotolysis. Biophotolysis uses sunlight as source of energy. This process can be divided into two stages. In first stage Algae is cultivated in water using photosynthesis. Later stage is Bacterial decomposition of Algae to finally produce Hydrogen. Important observation in this research is, if Algae is deprived of sulphur, normal photosynthesis does not take course and instead of oxygen, hydrogen is produced in light due to activation of an enzyme. If the process is successfully upgraded to a greater efficiency, energy requirements of hydrogen production will be obtained merely from sunlight.

There is growing consensus on necessasity of immediate action for averting the most obnoxious and destructive impacts of global warming and climatic changes that emanate from GHG emissions, which necessitates rapid reduction initially and ultimately elimination of all global man made greenhouse gas (GHG) emissions. This is the reason behind advocacy of sustainable hydrogen as a fundamental catalyst to a rejuvenated, decarbonised energy society. As it has been mentioned in earlier paragraphs, Hydro gen is already used as chemical feedstock, for example for production of ammonia used in fertilisers or in production of hydrocarbons used for plastics. In the future, hydrogen can be used as an energy carrier and energy storage medium. It has vast and practical applications across a range of hard to abate sectors that need to be decarbonised, such as energy, transport, industry, power generation and heat for buildings. In particular, hydrogen can progress the decarbonisation of hard-to-abate sectors, such as energy intensive industries using high temperatures where use of electricity is only partially possible, or the technology does not yet exist. Hence a rapid shift to a "hydrogen ecosystem" is desirable consistent with the aims for global carbon Neutrality by 2050. A decisive, deliberate, rapid and extensive expansion of renewable energy and low-carbon hydrogen production is a must in near future until anything better than hydrogen is conceived. The challenge to expand sustainable hydrogen production quickly enough means that policy makers should consider all options of hydrogen production. These include low-carbon sources, such as using fossil fuels preferably in combination with carbon capture, use and storage (CCUS) or nuclear power in combination with renewable energy. Because within time frame of year 2050, hydrogen production from electrolysers using only renewable energy supply, will not be sufficient enough, especially when considering the needs of energy intensive industries. Revolution to green hydrogen is not without challenges of research objectives such as cost reduction and improved efficiency of electrolysers. An electrolyser is a device which converts pure water and electricity into pressurised hydrogen, oxygen and low temperature heat. Two types of Electrolyser are prevelant namely, Alkalyne electrolyser and Polymer membrane electrolyser and are available for production of hydrogen. Third, Solid oxide electrolyser is at advance level of research while others are at initial research stage. Alkaline and polymer membrane electrolysers deliver pressurized hydrogen without a compressor and 99.99% pure, dry and carbon-free hydrogen.

A major disadvantage of alkaline electrolyser is it uses liquid and corrosive alkali solution. Polymer membrane Electrolyser (PEM) overcomes this by using ionically conductive solid polymer membrane instead of the corrosive liquid electrolyte used in alkaline electrolysers. Solid oxide electrolyser are designed with solid ceramic material as the electrolyte.

Solis oxide electrolyser (SOE) operate at a much higher temperature (above 500C) than alkaline and PEM electrolyzers (up to 80C) and have the potential to offer much higher efficiency due to thermodynamic advantage when compared to PEM and alkaline electrolyser. The large scale storage and distribution over long distances of hydrogen will be next future technical challenge.

The existing natural gas infrastructure will play a significant role to ramp-up the hydrogen market in developed countries. Repurposing towards hydrogen of existing natural gas distribution infrastructure might emerge as a practical and economic distribution options to accelerate hydrogen fuel economy. Ports and marine carriers dedicated to hydrogen transportation are already being developed and international supply chain of hydrogen is being visualised. Since the feasibility of sufficient future hydrogen storage is uncertain, investments will be required to convert hydrogen into a form that is easier to store and use, such as ammonia, methanol and synfuels.

These will also help to promote the adoption of a hydrogen economy because they can be internationally traded and can be easily used in many industrial processes. Whenever fossil based fuels and sources (coal, peat, crude oil, natural gas, naptha) are burnt the final products inevitably consist of water and green house gases like CO, CO_2 or N_2O. There may be other oxides of nitrogen and other health hazzard gases such as sulphar di oxide etc. depending on impurities in fuel used and unburnt hydrocarbons too. Thus burning of fossil fuel always results in addition of carbon dioxide in atmosphere making carbon neutrality a mirage. Attaining carbon neutrality requires that use of fossil fuels be minimised in combination with ccus or reduced to nil. The two biggest investments required in this direction will be retrofitting ccus in hard to abate sectors and accelerating hydrogen supply, distribution and adoption to achieve carbon neutrality by 2050 besides already matured energy efficiency and recycling & waste management processes. Electricity & Heat and manufacturing sectors are two top sectors responsible for global GHG emissions. Energy efficiency in organisations reduce electricity and heat consumption and thereby reduced ghg emissions. Likewise revycling and effective waste management reduce raw material manufacturing and thus reduced ghg emissions. Afforestation and plantation, besides preservation of natural forest are another way to create carbon sink which can offset a part of CO_2 emissions.

At one end transition of energy sources from fossil fuel to renewables should accelerate and on the other simultaneously electrolysers should be deployed instead of waiting for 100% energy transition or cost of electrolysers to come down drastically. It is author's personal opinion that primary energy mix of the most of the countries will stabilise around 40% of fossil fuels and 60% of renewable energy in next 4 to 6 decades.

In developed nations however, the primary energy mix may be leveraged by another 10 to 15% in favour of renewable energy. Transition from fossil and conventional fuel sources to renewable energy resources has social and economic impacts too. Enough job opportunities has to be created for the people who would loose employment or earning opportunities due to phasing down of fossil resources.

But this may not hinder the transition as onset of renewable resources will create plethora of opportunities in coming years. The ray of hope is almost all countries are paying attention to global warming and climate change under Paris Agreement 2015, and most of all have nationally determined plans to be zero net economy by 2050 to 2070, though resources and strategy adopted may be different from country to country. [6]

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