Mitigation of CO2 Emissions in Transportation and Industrial Processes using Renewable Energy Technologies- A Review

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Abstract—This study focuses on the mitigation of CO2 emissions in transportation and industrial processes using renewable energy technologies. Carbon dioxide is a colorless, tasteless and odorless gas readily available in the earth’s atmosphere, produced naturally by all aerobic organisms. Increased human activities had created a huge gap between the volume of CO2 emitted into the environment and that absorbed by oceans and vegetation’s. Globally, the transportation sector has contributed more than seven billion, seven hundred and thirty-eight million metric tons of carbon dioxide from fuel combustion since 2015, while industrial processes also generate greenhouse gas emissions during chemical or physical transformation of raw materials from one state to another in their conversion into finished goods. Analysis suggested that the world can achieve 90% of the reduction in CO2 emissions needed to be within the Paris Agreement via an accelerated deployment of renewable energy and energy efficiency, with the remaining 10% met by other low-carbon solutions.

Index Terms—Industrial Processes; CO2 Emissions; Renewable Energy; Transportation

I. INTRODUCTION

Carbon dioxide can be described as a colorless, tasteless and odorless gas readily present in the earth’s atmosphere. It is produced naturally by all aerobic organisms, released into the environment through exhaling and removed from the environment via oceans and vegetation.’ Increased human activities had created a huge gap between the volume of CO2 emitted into the environment and that absorbed by oceans and vegetation’s. Combustion of coal, other fossil fuels, biomass burning, cement, metal and chemical production, deforestation, volcanic emissions and other industrial processes emit billions of tons of CO2 every year [1,2]. Notable engineering achievements in the twentieth century cannot be exhausted without mentioning the design and manufacturing of automobiles, airplanes and as well as spacecraft’s which has revolutionized global transportation of humans and cargos across continents and man’s exploration to Space resulting in economic globalization, tourism boom, increased standard of living and ease of movement either of passengers or freights. This noble achievement in recent times has unwrapped its own limitations and beckons for newer technologies and green solutions to further broaden its collective benefits. Top of these limitations is the dependence on fossil fuel, air pollutions, traffic congestion, safety and contributions to climate changes through release of harmful emissions to the atmosphere. The global transportation sector is of two main modes, freight and passenger; while commercial freight is expanding rapidly as a result of increase in trade and the diversification of product value chains globally, the other comprises of mainly urban travels, characterized by frequent, short-distance trips or long-distance (road, rail and air) travels. Predictions by The International Transport Forum (ITF) supports the claims that both freight and passenger volumes will witness increasing growth up till 2050, with freight transportation projected to move from 110,000 billion to around 330,000 billion tonne-kilometers and passenger transportation demand increasing from 50,000 billion to over 120,000 billion passenger-kilometers. Increase in the number of automobiles is also predicted to be from 1 billion in 2015 to 2.5 billion by 2050. These forecasted expansions bring to mind the vast future emissions from transportation if present status quo is not improved upon. Currently, Freight is estimated to be responsible for 40% of total transportation emissions while 60% of total transportation emissions comes from passenger traffic with nearly half of this generated by urban travels. Around 66% of transportation emissions come from road and rail traffic while air travel accounts for just 16% of passenger transportation emissions, sea traffic makes an almost insignificant contribution. Thus, urban mobility policies will play a substantial role in the fight against global warming [3]. The World Bank suggested that global temperatures will attain 1.5 degree Celsius above pre-industrial eras by 2030 with the Transportation Sector an active contributor to these: the sector contributes to nearly a quarter of global energy-related greenhouse gas emissions, and 18% of all manmade emissions in the global economy, this could rise to 33% of all emissions by 2040 if measures to mitigate these growths are not actualized. Presently, the sector is believed to be the driver responsible for the fastest growth in CO2 emissions, thus minimizing emissions from transport and especially land based mobility is central to solving the climate change equation [4].
Carbon dioxide (CO₂) is the highly leading contributor to global greenhouse gas (GHG) emissions with proven global warming effect on the climate. This is responsible for the increase in temperature experienced on the surface of the earth, warmth is trapped in the atmosphere instead of releasing them to space with the overall increase in temperature responsible for stormier storms, chillier colds, drier deserts, drought and increased flooding [7]. Its mitigation to safe levels for a greener world should be given highest priorities.

Industrial processes generate greenhouse gas emissions during chemical or physical transformation of raw materials from one state to another in their conversion into finished goods. These can be visible in Metal Production (aluminum smelting, iron and steel production and metallurgical coke production, zinc, ferroalloys, lead, magnesium and other metals production), Mineral Products (cement production, lime production, limestone and dolomite use in industrial smelting, soda ash use etc.), Chemical and Petrochemical Industry (ammonia production and urea consumption, nitric acid, phosphoric acid, adipic acid, titanium dioxide, organic polymers production, soda ash manufacture, nitrous oxide use, petrochemical production etc.), Non-energy Products from fuel and solvent use (Lubricant use emissions from the combustion of lubricant engine oil in vehicles), Product uses as substitutes for ozone depleting substances (emissions from HFC’s refrigerants in refrigerators and air conditioning equipment’s; fire extinguishers, aerosols, etc.), Other process uses of carbonate (glass manufacturing, flux stone etc.), Semiconductor Production, Silicon carbide Production and Consumption, Sulphur hexafluoride emissions, emissions from food, drink and beverage industry etc [9],[10]. These emissions emerge from the processes listed above. Direct and Indirect emissions from industrial processes are the largest contributor to greenhouse gas emissions in the United States projected to be around 29% in 2016 despite reduction strategies like recycling, energy efficiency, use of cleaner fuels, training and awareness [11]. A mode of reducing these emissions using renewable energy technologies is the burden of this study.

A. Carbon Dioxide Emissions: Present and Future

It is a known fact that industrial revolution has led to an increase in average global temperature predicted to reach 1.5°C above pre-industrial levels within the next two decades, IPCC [12] agreed that climate changes are evident
and with us already. NOAA [13] estimated weather and climate disasters in the United States in 2017 and found it to be 100 billion dollars higher than ever. Etmian et al. [14] and Huntingford and Mercado [15] reported that CO₂ emissions are responsible for most of the climate change that has occurred and will occur while Figueres et al. [16] mentioned that emissions are rising again. Jackson et al. [17] and Le Quéré et al. [18] estimated that global fossil fuel CO₂ emissions was 36.2 gigatones in 2017 (1.6% increase) after three years of negligible emissions growth. Le Quéré [19] projected that emissions in 2018 are expected to grow even faster and could reach record high (between 35.3-38.9 gigatones). Le Quéré [20] inferred from IPCC report in October 2018 that a 2°C above pre-industrial levels will expose more than 1.5 billion people to deadly heat extremes, and hundred millions of individuals to vector-borne diseases as well as increased water scarcity. Figueres et al. [21] reported that rising emissions are of grave concern and all effort must be put in place to keep global warming below or around 1.5°C rise this can be achieved by replacing coal and other fossil fuels with renewables (described as an economic imperative and an ecological necessity). It is anticipated that by 2050, total CO₂ emission would be around 45giga tonnes if reduction strategies are not implemented while it’s expected to drop down to 13 gigatones if low carbon technologies are utilized with renewable energy providing 44% of these anticipated reductions (14.08giga tonnes) while energy efficiency is projected to provide 10.24giga tonnes (or 32%), other low carbon method 3.2giga tonnes (10%) and electrification with renewables providing 4.48giga tonnes reduction in CO₂ emissions in order to achieve the 2050 target [22].

B. Solution: Carbon Dioxide Emissions Removal

Miranda et al. [23] summarised six technologies that could be used to remove carbon dioxide in the atmosphere, these are afforestation, bioenergy with carbon capture and storage (energy generated from burning biomass, capturing and geologically storing the resulting CO₂), biochar (burning biomass under low-oxygen conditions to produce charcoal used to increase soil carbon content), direct air capture (direct capture of CO₂ from ambient air using chemical processes with long-term storage in underground reservoirs etc.), enhanced weathering and ocean fertilisation (fertilizing certain parts of the ocean with nutrients to increase algae growth and CO₂ uptake while allowing carbon sinks to the ocean bed in dead algae thus removed from the earth’s atmosphere). International Renewable Energy Agency [24] divided the carbon dioxide emitting sectors into two main parts, electricity generation & industrial processes and transportation, buildings & district heating with 65% and 35% respectively their contributions to global energy-related CO₂ emissions, its analysis suggested that the world can achieve 90% of the reduction in CO₂ emissions needed to be within the Paris Agreement via an accelerated deployment of renewable energy and energy efficiency, with the remaining met by other low-carbon solutions. IRENA [25] observed that renewable energy is a critical tool for combating climate change and stressed further that most countries under the Paris Agreement included renewable energy as their measure to address climate change in other to achieve their nationally determined contributions (NDCs). Ofoegbu et al. [71] developed an application software to determine air quality index and pollutant information in an environment thereby guiding mitigation strategies to be used as well as informed choices about where to live in for people with cardiovascular diseases. Kamia et al. [26] emphasized that for these NDCs to be implemented there should be at least 1.3 terrawatts added to global renewable installed capacity. IRENA [27] emphasized cost reduction opportunities in renewable energy sources since the end of 2009 and it’s suitability for CO₂ emissions removal. It results affirmed that Photovoltaic module prices has decelerated by 80%, wind turbines prices by almost 40%, biomass, hydropower, geothermal, onshore and offshore wind technologies are now able to provide electricity at utility scale for industrial processes and other functions at competitive prices compared to fossil fuel-fired electricity generation. These costs are expected to further decrease substantially before 2030. The United Nations [28] has itemized six key areas to discuss with countries, regions and cities in its 2019 summit, these are energy transition, climate finance and carbon pricing, industry transition, nature based solutions, cities and local action, and resilience. If it’s theme “A Race We Can Win, A Race We Must Win” is to be achieved which is reducing carbon emission potentials globally to safe levels in accordance to the Paris agreement. Strefer et al. [29] recent study concluded that strengthened action in the near future could largely decrease carbon dioxide removal requirements for the remainder of the century. IPCC [30] special report indicated that carbon dioxide removal requirements to achieve a reduction of 0.2°C or higher during this century might not be feasible.

C. Transportation Sector, CO₂ Emissions and Renewable Energy

IEA [31] report revealed that one of the main factors limiting global transportation system is its high dependence on conventional fuels, with over 94% of total energy needed for transport provided by oil, 3% by natural gas and other fuels, 2% by biofuels and 1% by electricity. Passenger transport statistics from Eurostat [32] showed that within the EU, passenger cars had 82%, buses (12%) and rails (6%), making passenger cars responsible for 12% of total CO₂ emissions within the EU. A new regulation by [33] for new cars registered in the EU (2015 and beyond) approved an emission of 130grams of CO₂ per kilometer but since 2014 new passenger cars sold has not met this target. In 2013, only about 3.5% of renewable energy was consumed in transport sector globally. To achieve at least 50% chance of limiting average global temperature increase to 2°C, the sales of electric vehicles need to move from less than 1% presently to over 40% of total passenger car sales by 2040, biofuel usage can also be used in 10% of road transport and higher in ships and aircrafts fuel demand by 2040 [34]. Natural gas can also be used to minimize CO₂ emissions from heavy-duty vehicles where potential application of electrification appears to be more limited [35]. Hua et al. [36] described in their study that cars, ships, aviation, freight, urban transport etc can be powered using electricity from on board batteries, electric grid, hydrogen or methane.
to power fuel cells or ICE engines of heavy duty vehicles, ships and aircrafts where electric means are not feasible. Information from [37] in 2015 expressed that biofuel consumption within the transport sector between 2000 and 2012 increased by 600% while natural gas use increased by 1000% but yet these increases are still an insignificant share of total global fuel consumption. Policies to strengthen the potential linkage between electric vehicles and renewable energy have received little attention on a global scale [38]. ASME [39] rolled out policies that could reinvent global transportation, this included (1) Acceleration of the development of electric vehicles as well as advanced electric grid capable of energy storage in other to better partner it with renewable electricity (2) Accelerated development of alternative propulsion technologies including more efficient engines and power trains systems, including engines using renewable fuels (3) Development of an environmentally sustainable transportation fuels including cellulosic ethanol, hydrogen fuel cells, algae-generated bio fuels and other alternative fuels (4) Adopting sustainable lifecycle design changes to minimize energy and environmental footprint. This can be achieved through (i) Developing and deploying advanced battery and/or energy storage-power systems for use in plug-in and electric vehicles (ii) Usage of current and next generation biofuels in a cost effective and environmentally responsible manner (iii) Leveraging on parallel, multiple potential energy carriers such as liquid & gaseous fuels and electricity (iv) Utilization of low carbon fuels and propulsion alternatives across multiple modes of transport and (v) Optimization of conventional propulsion systems while developing advanced propulsion technologies. IEA-RETD [40] believed renewable energy uptake in transport depends on the availability of energy carriers and fuels produced from renewable energy sources, release of vehicles that can use renewable fuels and the development of energy and fuel infrastructures. IATA [41] reported that over one hundred thousand commercial flights have used sustainable aviation fuels in the form of bio-jet fuels. IRENA [42] proposed that alternative propulsion technologies such as solar-powered aircraft, use of cryogenic hydrogen and electric aircraft can offer ways to integrate renewable energy in aviation thou this advances are still at an early stage. Reference [43] reported that ships can use biofuels and other renewable-based fuels (e.g. electricity-based hydrogen or ammonia) for propulsion, or they can directly incorporate wind and solar energy. Lloyds-UMAS [44] assessed that biofuels and ammonia are the best options for green shipping. IRENA [45] believed the integration of renewable energy in the shipping sector does not seem to be advancing. WSDOT [46] responded that though renewable energy hasn’t played a major role in the sector yet, there are examples of electric and hybrid-electric ferries in Denmark, Finland, Norway and Sweden, and biodiesel ferries in the United States. REN21 [47] mentioned that rails can utilize biofuels as alternatives to oil driven trains (which is estimated to be around 57% of global rail fleet) and renewable electricity for rail fleets powered by electricity (36% of global rail fleet). It further mentioned that some countries particularly in Europe have reached 100% utilization of renewable energy in their rail sector. ITF [48] asserted that Liquid biofuels (ethanol and biodiesel) provided up to 4% of global road transport fuel in 2016. IEA [49] report showed that 26% of electricity consumed by electric vehicles were renewable but the use of renewable energy in long-distance road transport especially long haul road freight is very limited thou IEA [50] reported that high energy density biofuels, hydrotreated vegetable oil, bio methane, ED95 ethanol and technically mature freight vehicles are in existence. The king review [60] identified the properties of a good fuel and summarized as follows, it must be easily storable and transportable, stable over a wide range of temperature, causes no damage to the car engine, not expensive to produce and distribute, available from secure sources, ability to provide fast and convenient refueling of the vehicle, not harmful to local air quality and must have low CO₂ emissions from its production, distribution to its usage.

D. Industrial Processes, Co₂ Emission And Renewable Energy

Reference [39] explained that manufacturing industries emit CO₂ directly via in-plant fossil fuel combustion, the use of carbon materials as feedstock and calcinations of calcium carbonate in cement production while indirectly via electricity consumption for industrial purposes with direct emissions larger than indirect emissions. IEA [62] report showed that out of 128 exajoules of energy demands in the global industrial sector in 2009, 78 exajoules of fuels were used to generate process heat, 9 exajoules was used by blast furnaces and coke ovens for iron and steel production, petrochemical feedstock used for the production of chemicals and polymers was about 16 exajoules while electricity demand was 24 exajoules for various uses such as electrolysis, motor drives, cooling or refrigeration. Almost 61% of industrial sector energy demand is from process heat requests. EIA [54] stated five industries consuming 68% of all energy used in the industrial sector these are chemical industries (29%), iron and steel industries (20%), non-metallic minerals (10%), pulp and paper (6%) and nonferrous metals (3%). These industries also emit very large quantities of CO₂ in relation to their energy use and their production process. EPA [56] categorized industrial emissions into three namely direct (on-site fuel combustion), indirect (electricity purchased for power and off-site steam generation) and process (CO₂ liberated as a reaction by-product) and concluded that process emissions constitute a relatively small percentage of industrial emissions. IRENA [61] reported that the manufacturing industry is a crucial end-user sector and comprises of 33% of the total global energy demand therefore the sector needs to be engaged for a doubling of renewable energy use globally, it also agreed with the fact that the extent to which renewable energy technologies can contribute to deceleration of industrial sector’s fossil fuel demand has so far not attracted enough attention. Gasper [64] highlighted two key areas for exploiting the potentials of renewable energy these were energy-intensive sector with small and medium enterprises (SME), the energy intensive sector contributes to 75% of the total industrial energy demand thus the need to consider renewable energy options not only as an integral part of new build capacity, but also as part of existing capacity, SME’s play an important role in increasing the deployment rate of
renewable energy technologies, by providing local manufacturing opportunities and stimulating cost reductions through learning by doing. ASME [39] posited that for energy efficiency in industrial processes to be achieved industrial process heating requirements need to be optimized. Thekdi [51] observed that for steel production high efficiency heating systems are under development with potential of reducing CO₂ emissions by 17 million tonnes within 10 years. EIA [52] discussed the recovery and reuse of waste heat in cement production and its utilization for electricity generation. Mason [53] discussed on highly efficient and low emission process heaters in petroleum and chemical industries which are able to produced reduced CO₂ emissions. Tamaryn et al. [55] observed that no single technology can be focused on for CO₂ emission reduction from industrial sector but a piecewise approach to mitigating emissions is required, four key actions to reducing industrial sector CO₂ emission laid out are firstly, Maximizing energy efficiency potential by replacing older, inefficient processes with current best available technologies and best practice technologies, secondly, Demonstration and deploying of fuel switching to low carbon energy sources, next is accelerated research into industrial CO₂ capture and integrated industrial CO₂ Capture and Storage (CCS) plants and finally altered product design and waste protocols to facilitate reuse and recycling in order to close the materials loop. IRENA [61] posited that by 2030, estimated global industrial process energy use will have grown by about 20% compared to current levels of 152 exajoules with some proportion of the global industrial energy use in 2030 coming from new capacities (40EJ), which also offers important potential to deploy renewable energy technologies. Analysis by UNIDO [63] suggested that, by 2050, biomass could constitute 22% (9EJ/year) of final energy use in the chemical and petrochemical sectors with alternative fuels constituting up to 30% (5ExaJoules/year) of final energy use in the cement sector. For the industrial sectors as a whole, biomass has the potential to contribute 37 EJ/yr. But this potential depend on a well-functioning market and the development of new standards and pre-processing technologies. Solar thermal energy has the potential to contribute 5.6 EJ/yr to the industry by 2050 with almost half of this projected to be used in the food sector. Heat pumps also have a part to play in low temperature process applications and are estimated to contribute 4.9 EJ/year in 2050. The application will be mostly concentrated in the food sector. Gasper [64] opined that biomass has the largest substitution potential in the manufacturing industry nevertheless immediate and internationally coordinated action is required to alleviate the serious supply constraint of sustainable sourced and low-cost biomass resources and to deploy the most resource efficient biomass use applications. Also, solar thermal heat systems have a large technical and realizable economic potential in small scale plants and less energy-intensive industries like textile and food sectors, but the vicious circle of high initial capital costs and low deployment rates needs to be broken. In Iceland, geothermal heat is typically used for fish drying according to Arason [67], the drying of tomatoes is done with geothermal heat in Greece as reported by EGEC [68][69]. Geothermal heat can be directly applied to industrial processes if the distance between the heat source and the end user is sufficiently close [69]. Ministry of Renewable Energy India [65] analyzed that solar energy technologies can be used for solar water heating systems, steam generating systems and air heating systems based on flat plate or evacuated tube collectors and automatically tracked solar concentrating collectors thereby reducing the consumption of fuel oil mainly during day time. 10,000 liters per day solar water heating system can save around 14,000 litres of fuel oil per year for a period of about 20 years while solar concentrated technology can provide steam up to a temperature of around 300°C which is the direct need of industries. In India, the fixed receiver East-West automatically tracked parabolic concentrators and the tracked heat receiver and dish reflectors are two technologies currently in use.

II. RENEWABLE ENERGY POTENTIALS IN TRANSPORTATION

In 2015, Transportation accounted for 71% of total U.S. petroleum use and 33% of it’s total carbon emissions[57] while 98.4% of cars registered in Germany as at the first month in 2017 were powered by internal combustion engines coupled with increasing road freight transport having low efficiency improvements leading to an increase in greenhouse gas emissions from the transport sector [58]. These scenarios are commonly observed amongst nations thus the need to explore renewable energy potentials.

Achieving reduction in oil dependencies within the transport sector must lead to utilization of cleaner fuels, low-carbon vehicles, smarter transportation network while not compromising on safety, affordability as well as efficiency in other to achieve the sustainable global transportation in view.

Fig.5. Share of Oil in Global Transportation Sector [34]

Fig.6. Current and Future Potentials in Transport [34]
Future Transport is expected to be based on renewable energy sources as listed above as well as other low carbon fuels.

Fig.7. Future Vision for Sustainable Transportation [57]

Autonomous or self-driven greener vehicles, safer road networks, fuel cell vehicles, hybrid vehicles, cleaner fuels (from renewable energy sources), non-motorized alternatives are amidst present and future vision for greener transport which will involve stakeholders like forest managers, oil and gas companies, biofuel producers, pipeline operators, urban planners, commuters, other renewable energy producers, energy infrastructure distributors etc.

Fig.8. Renewable Potentials in comparison to Gasoline [57]

Future vehicles are expected to run mostly on renewable energy sources for a greener world.

Fig.9. Renewable Energy Supply Options for Transport [59]

III. RENEWABLE ENERGY POTENTIALS IN INDUSTRIAL PROCESSES

According to IRENA [61] postulations renewable energy potentials in the industrial sector by 2030 can be grouped into two parts, realizable technical potentials and realizable economic potentials. The realizable technical potential can be described as the share of energy demand that can be technically provided by renewable energy sources without considering resource availability or cost barriers while realizable economic potential considers renewable energy sources based on their costs and regional/national resource availability. 60% of Biomass potential application is within high temperature industrial processes and as feedstock for materials production. Solar thermal has a technical potential of 15 exajoules with new capacity systems, geothermal can provide 1.9 exajoules of renewable energy for industrial processes while heat pumps potential is estimated at 2.3 exajoules. Introduction of CO2 emission fine as well as economic policies are expected to stimulate deployment of renewable energy technologies, also the availability of low-cost renewable energy resources.

<p>| TABLE I: BIO-BASED HEAT PRODUCTION TECHNOLOGIES |</p>
<table>
<thead>
<tr>
<th>Temperature level (in °C)</th>
<th>Regions/Sectors where the technology is already deployed</th>
<th>Sectors with large potentials by 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass fired boilers for steam</td>
<td>Non-metallic minerals, wood and wood products, pulp, paper, food and tobacco sectors in most developing countries</td>
<td>All sectors except Iron and Steel and non-metallic minerals sector</td>
</tr>
<tr>
<td>Biomass fired CHP plants for steam and direct heat</td>
<td></td>
<td></td>
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<tr>
<td>Biogas Fired CHP for Steam</td>
<td>Food, Chemical and Petrochemical sectors in developed regions</td>
<td>Transport equipment, machinery, textile, pulp and paper, mining and quarrying, food and tobacco etc.</td>
</tr>
<tr>
<td>Biogas gasification and direct heat applications</td>
<td>Various Sectors in India</td>
<td>Iron and Steel Sector and Non-metallic mineral sectors</td>
</tr>
<tr>
<td>Charcoal for direct heat</td>
<td>Iron and Steel Sector in Brazil</td>
<td>Iron and Steel Sector</td>
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<p>| TABLE II: SOLAR THERMAL HEAT PRODUCTION TECHNOLOGIES [61] |</p>
<table>
<thead>
<tr>
<th>Temperature level (in °C)</th>
<th>Regions/Sectors where the technology is already deployed</th>
<th>Sectors with large potentials by 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat Plate Collector</td>
<td>Food and Tobacco, textiles, pulp and paper, chemical and petrochemical sectors in various countries</td>
<td>All sectors except Iron and Steel and non-metallic minerals sector</td>
</tr>
<tr>
<td>Evacuated Tubes</td>
<td>Food and Tobacco, textiles, pulp and paper, chemical and petrochemical sectors in various countries</td>
<td>All sectors except Iron and Steel and non-metallic minerals sector</td>
</tr>
<tr>
<td>Concentrating</td>
<td>Food and Tobacco</td>
<td>Transport</td>
</tr>
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</table>
Newer technologies involving parabolic trough concentrators with single axis tracking arrangement and paraboloid dishes with two axis tracking especially for power generation has been successfully demonstrated [65].

Fig.10. Renewables potential in industry by 2050 [63]

Geothermal heat (excluding geothermal source heat pumps) can be used as a source for low temperature process heat applications. Today less than one percent of the total industrial heat use is provided from geothermal sources [66]. Conventional deep geothermal heat-production technology for low-temperature heat applications offers the largest potential in all industry sectors with the exception of the chemical and petrochemical and the iron and steel sectors, where medium- and high-temperature process heat dominates the demand. [61]

| TABLE III: RENEWABLE ENERGY APPLICATION IN TRANSPORT AND INDUSTRIAL PROCESSES [70] |
|---------------------------------|---------------------------------|-----------------|-----------------|
| Renewable Energy Utilization    | Heating and Cooling             | Power           | Transport       |
| Biomass                         | Combined Heat and Power         | Biofuels        |                 |
| Solar Thermal                   | Biomass Gasification            | Hydrogen        |                 |
|                                 | Solar Thermal                   | and co-generation|                 |
|                                 | Geothermal                      | Fuel Cells      | Solar Energy    |
|                                 | Solar Thermal                   |                 |                 |

IV. CONCLUSION

The global renewable energy share can attain and exceed 30% by 2030 with technologies to achieve these already available, quantifiable renewable energy growth must be experienced in the transportation and industrial sector in other to amplify the crusade for a greener world and reduced global warming as well as present and projected environmental challenges. It’s anticipated that technology cost will continue to decline significantly as a result of technological innovations, growing market, regulatory policies and competition. Our world will be a more healthier place to live in if (the over dependency on) fossil fuel based energies are replaced by significant renewable based energies, jobs will be further created and climate change mitigated, this can be achieved via realistic transition pathway, enabling business environment, deployment strategies, integration of existing infrastructures, greener innovations, supportive policies, competitive costs of renewable energies etc.

The mitigation of CO₂ emission from transportation sector and industrial processes has been extensively reviewed in this study; the following conclusions are further drawn:

1. The transportation sector contributes majorly to the high increase in CO₂ emissions into the earth’s atmosphere, thus reduction or elimination of CO₂ emissions from transport and especially land based mobilities is central to solving the global energy crisis from CO₂ emission.

2. The emission of CO₂ from industrial processes can also be reduced or eliminated by the demonstration and deployment of fuel switching to low carbon energy sources such as renewable energy for industrial energy demands.

3. The world can achieve 90% of the reduction in CO₂ emissions needed to be within the Paris Agreement via an accelerated deployment of renewable energy and energy efficiency, with the remaining 10% met by other low-carbon solutions.

4. Deliberate increased global efforts must be made to enforce policies and technologies that would create a greener transportation and efficient industrial processes with vastly reduced or eliminated CO₂ emissions.

5. Efforts should be made towards practical deployment of renewable energy sources for industrial usage with an efficiency comparable or superior to conventional energy sources currently used in industries.

6. Global warming concerns are visible in our present world and forecasted experiences of 1.5°C and 2°C increases above pre-industrial era must propel us towards finding lasting solutions to emissions from transport, industrial sectors as well as household, electricity generation and other sectors.

REFERENCES


DOI: http://dx.doi.org/10.24018/ejers.2019.4.5.1118


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