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# Transition Towards Renewable Green Energy Resources

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## ABSTRACT

*The strategy of changing the path away from the conventional usage of fossil fuels to renewable green energy resources like solar, wind, hydropower, geothermal, hydrogen or biomass energy is essential to protect our planet and the life it inhabits. This process will restrict the global rise in temperature to 1.5°C above pre-industrialization levels. This maximum rise in temperature level was targeted in the 2015 global Paris Agreement, hence preventing the catastrophic consequences of global warming. The widespread adoption of renewable sources of energy is pivotal for the achievement of a sustainable and resilient energy future, combating climate change, protecting the environment, promoting economic development, and ensuring equitable access to clean energy for all.*

**Keywords:** Fossil fuels, Renewable Energy resources, Greenhouse gases, Carbon footprints, Net zero.

**Research Question:** Why is there a need for renewable clean energy? What are the harmful consequences of extracting as well as burning fossil fuels for various applications such as generating power, usage in the transportation sector etc.? What is the major cause of global warming? What causes the emission of greenhouse gasses? The white paper discusses the various sources of renewable green energy and its advantages in terms of benefit to the environment as well as humans, long-term savings and increase in employment opportunities in the green energy sector. Furthermore, it shares the regional stake across the world in the transition to renewables and also discusses the success of India in this field. The study concludes with a discussion on carbon footprints, carbon credits and the cost exposure for various nations to achieve net zero emissions.

  

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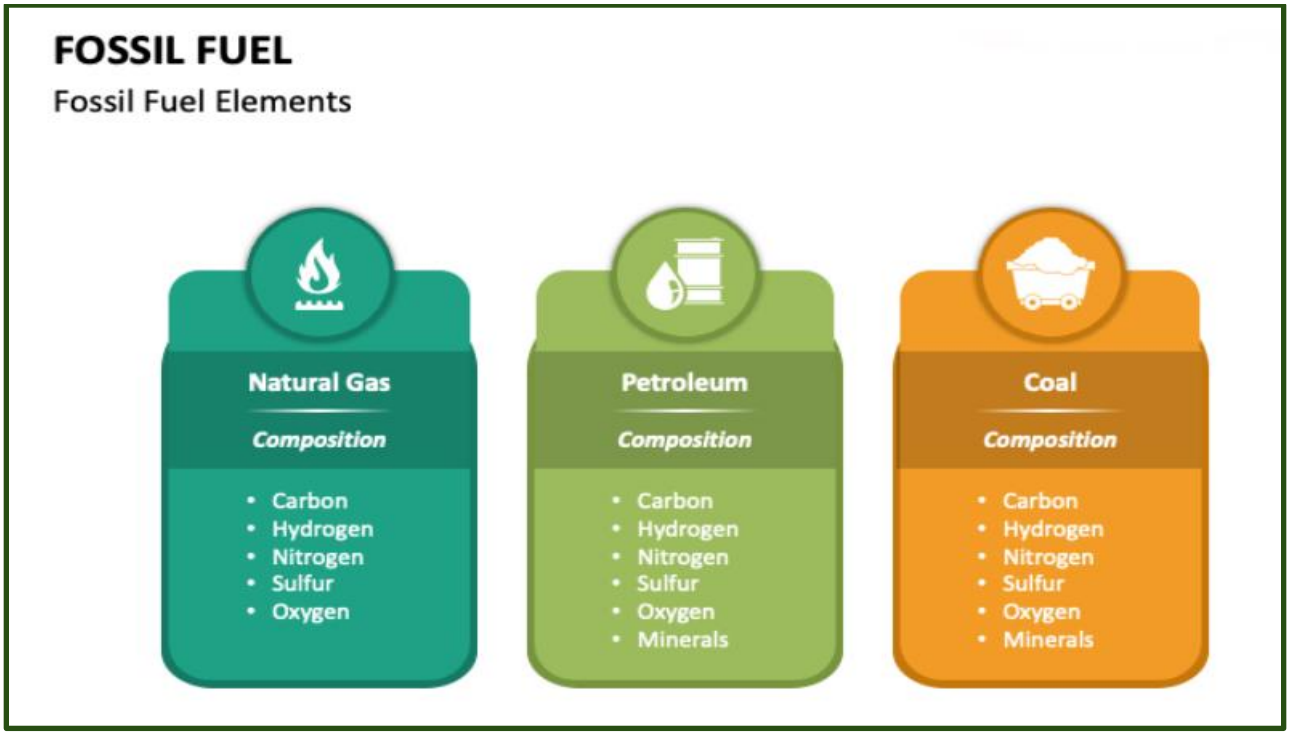
## 1. INTRODUCTION

Fossil fuels constitute oil, petroleum, natural gas, coal and biomass and are typically non-renewable energy resources. Fossil fuels are generated by the decomposition of plants and animals over a number of years. These fuels originate on the earth's crust and constitute carbon and hydrogen, which can be burned to generate power. They have been the dominant sources of energy for much of human history due to their high energy density and ease of use. However, their combustion releases carbon dioxide (CO2) and other greenhouse gases, contributing to climate change and air pollution. Listed in Exhibit 1 are some examples of fossil fuels along with their composition.

**Exhibit 1: Types of fossil fuels and their composition**




Source: Fossil Fuel PowerPoint PPT Slide, SketchBubble

Traditionally, energy resources have been primarily fossil fuels which have been employed for ages. These fuels are consumed in large quantities to generate around 80% of the globe's energy consumption levels, constituting the majority of the global electricity and transportation fuel production (energy). Only 13% of energy is generated employing renewable clean resources. Refer to Exhibit 2 which explains this concept.

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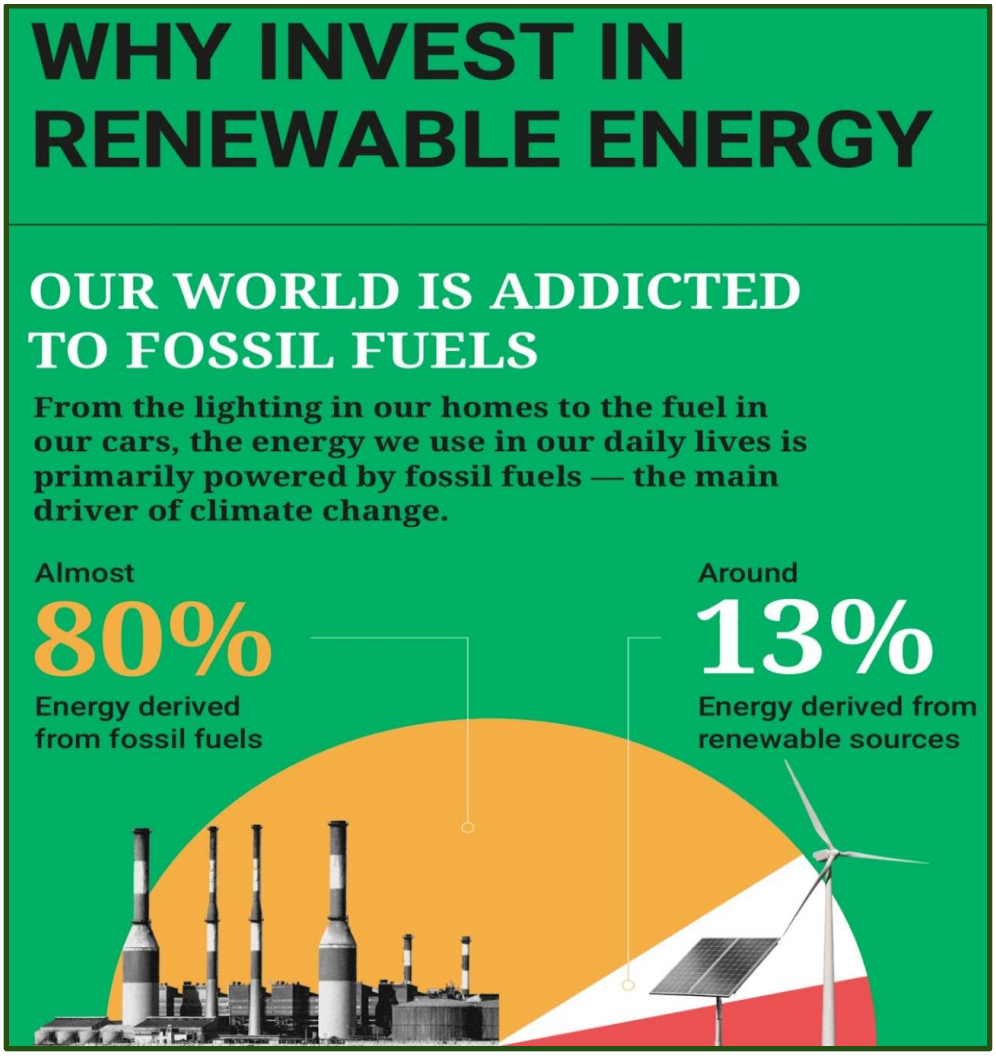
**Exhibit 2: Percentage of energy derived from fossil fuels versus from renewable resources**




Source: "Why invest in renewable energy," United Nations

Fossil fuels have been over-utilized over the last few centuries and now it is becoming relatively impossible to discover and exploit new deposits. Fossil fuels incur lesser initial establishing expenses as compared to cleaner renewable energy resources like solar, wind or ocean energy. However, the international market's dependence on fossil fuels poses several challenges including - deterioration of the environment, adverse impacts on human health, securing only a limited supply of such non-renewable fuels and lack of sustainability. Furthermore, oil and natural gas resources employ higher degrees of technology or investment for production. Refer to Exhibit 3 which discusses the environmental impact by generation and consumption of fossil fuels. Listed in Exhibit 4 are the pros and cons of fossil fuel production and consumption.

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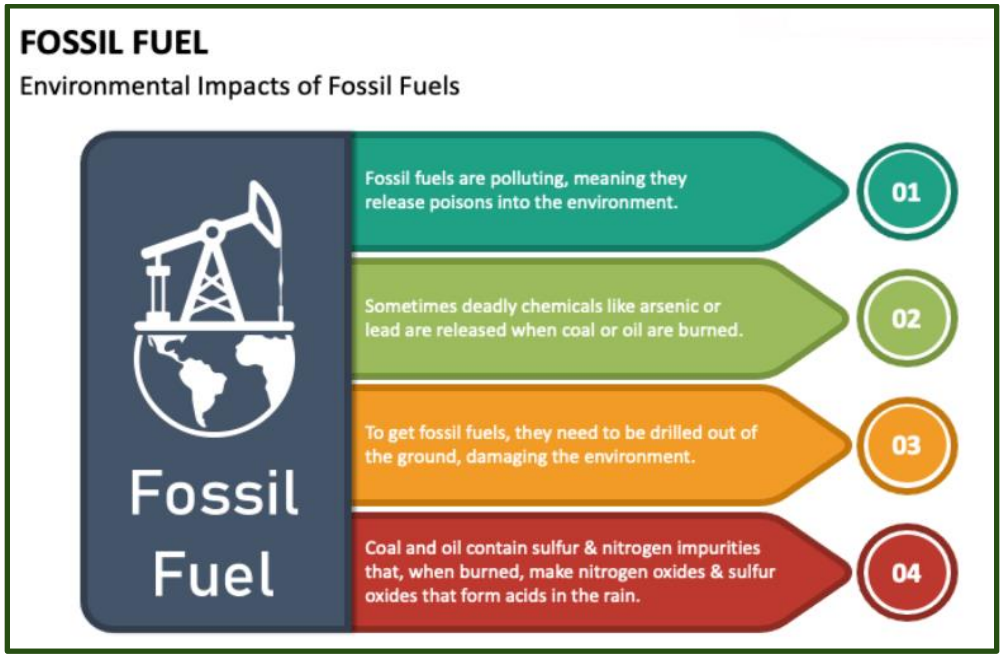
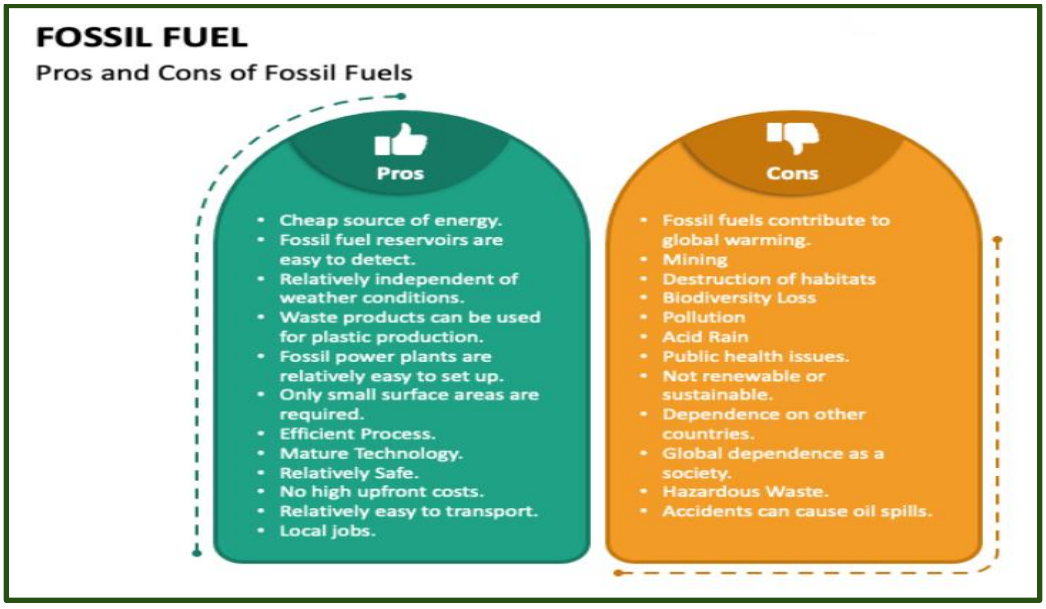
**Exhibit 3: Environmental impacts of fossil fuels**




Source: Fossil Fuel PowerPoint PPT Slide, SketchBubble

**Exhibit 4: Pros and cons of fossil fuel production and consumption**




Source: Fossil Fuel PowerPoint PPT Slide, SketchBubble

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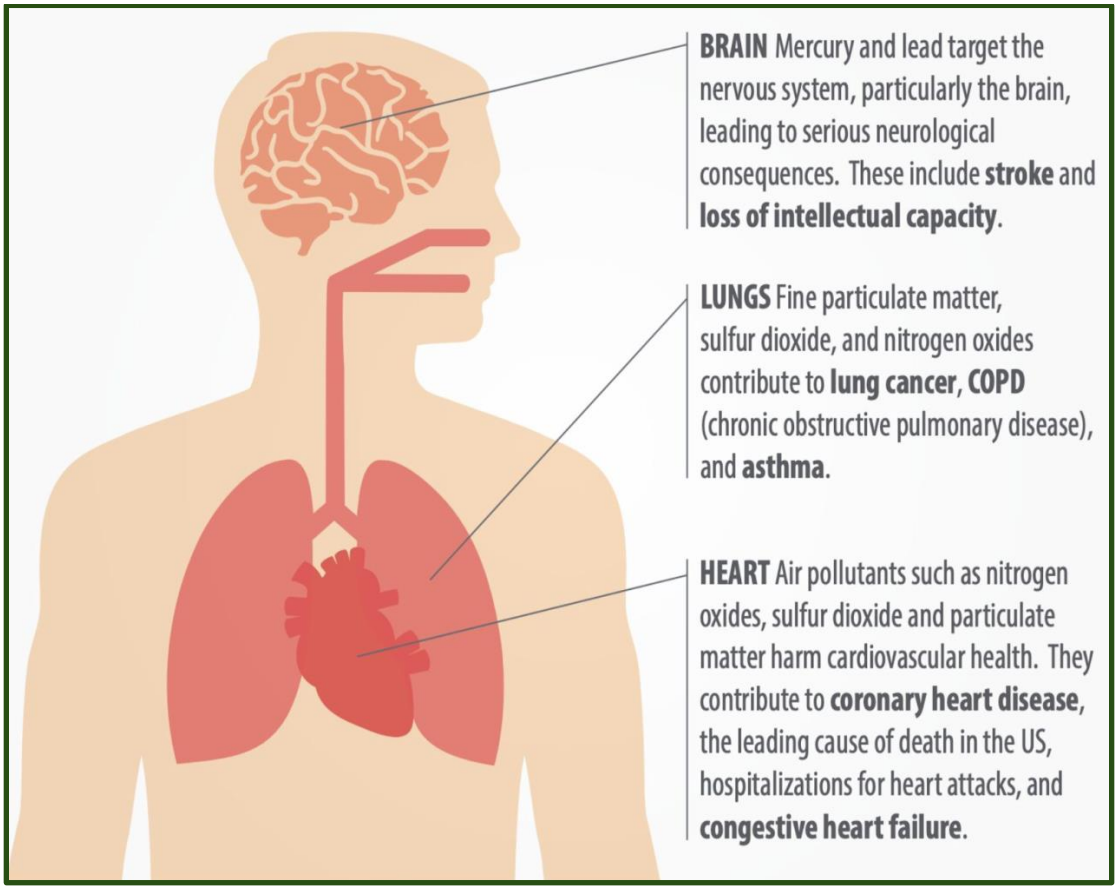
Furthermore, environmental problems associated with the production and consumption of fossil fuel energy resources are namely - air and water pollution, global warming, human health deterioration, wildlife and habitat loss and toxic waste dumping. Coal mining pollutes water, as modifications in groundwater flow developed by mining operations frequently cause unpolluted waters to contact with mineral materials which are leached from the earth and generate an acid mine drainage. Solid waste is moreover a by-product of some forms of coal mining that employs the disposal of huge quantities of earth as well as coal. Oil spills to generate energy lead to water pollution. Moreover, fossil fuel pollutants create an adverse impact on human health which is discussed in Exhibit 5.

**Exhibit 5: Harmful consequences on human health related to fossil fuel pollutants**




Source: "Health Fossil Fuels," Energy Innovation Policy and Technology

Also, the burning of fossil fuels is the immediate contributor to the ejections of greenhouse gasses. According to the United Nations statistics, more than 75% of global greenhouse gas emissions (carbon dioxide, methane, nitrous oxide and fluorinated gasses) and 90% of all carbon

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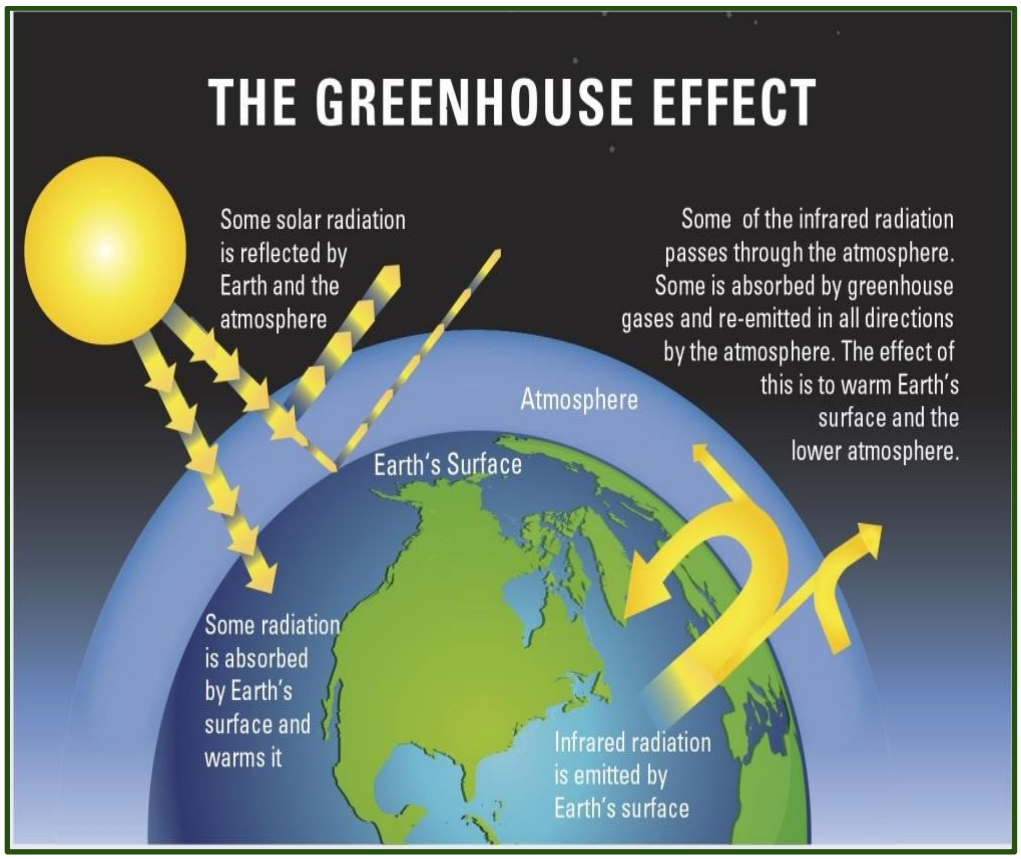
dioxide emissions that envelop our planet and trap the sun's heat are produced due to energy generation. Burning of fossil fuels, namely coal, oil and gas, to generate electricity and heat are the largest contributors to global warming. Refer to Exhibit 6 which explains how the emissions of greenhouse gasses envelop the earth, trap the solar radiation into the earth's atmosphere and not allow it to reflect back, hence causing global warming.

**Exhibit 6: The impact of greenhouse gas emissions**




Source: "Climate change: evidence and causes," The Royal Society

To constrain the dangerous effects of global warming and to preserve life on the planet, the global temperature rise is mandated to be limited to 1.5°C above pre-industrial levels. Currently, the earth's temperature is already about 1.1°C hotter than what it was in the late 1800s and greenhouse gas emissions persist to soar.

Exhibit 7 highlights that the energy sector globally is the largest emitter of greenhouse gasses globally. Exhibit 8 depicts the percentage breakup of the emission of greenhouse gasses emitted by the burning of coal, oil and gas to generate energy; coal being the largest emitter.

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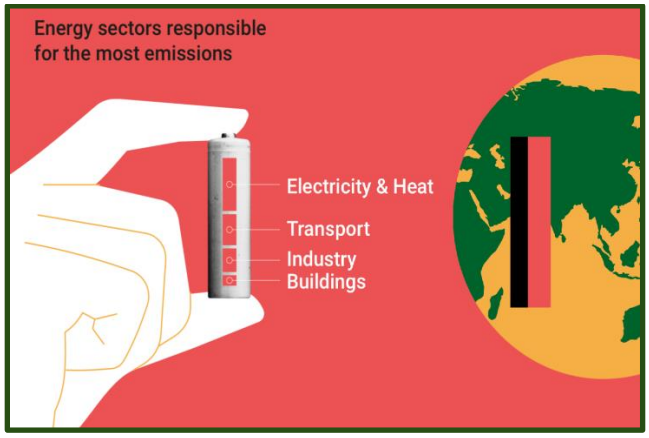
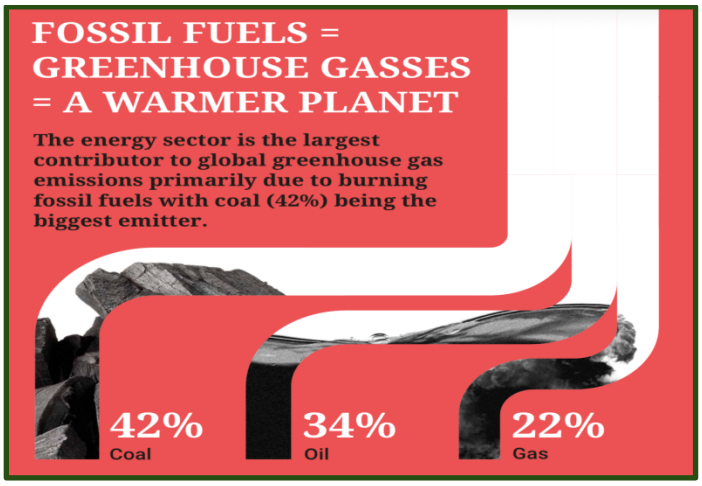
**Exhibit 7: The energy sector globally is the largest emitter of greenhouse gasses globally**




Source: "Why invest in renewable energy," United Nations

**Exhibit 8: Percentage breakup of the emission of greenhouse gasses emitted by the burning of coal, oil and gas to generate energy**




Source: "Why invest in renewable energy," United Nations

The Paris Agreement, a lawfully binding international treaty on global warming embraced by 196 parties at the United Nations Climate Change Conference, in 2015, targeted to retain global warming to not greater than 1.5°C, which implied that emissions would be mandated to be decreased by 45% by 2030 and reach net zero by 2050.

Net zero implies curtailing greenhouse gas emissions to negligible values as feasible, for example, with any lagging emissions re-absorbed from the atmosphere, by oceans and woodlands. Exhibit 9 discusses this concept via an illustration.

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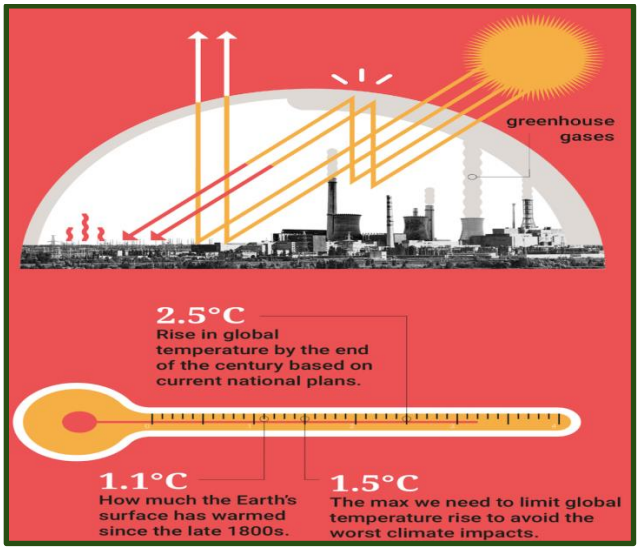
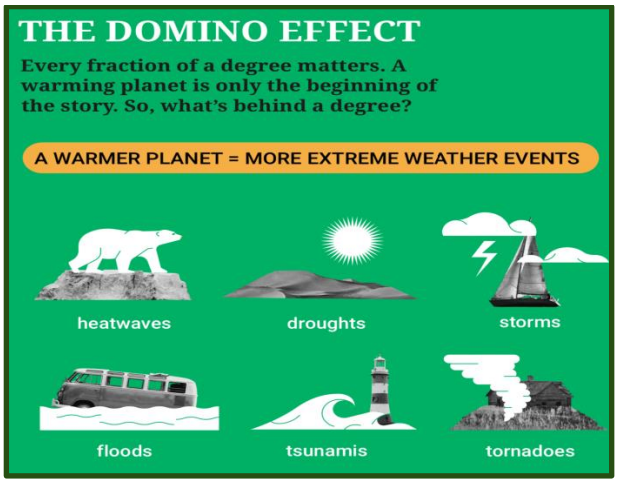
**Exhibit 9: Greenhouse gasses and their impact on global warming**




Source: "Why invest in renewable energy," United Nations

Exhibit 10 highlights the impacts of global warming on the environment in the form of heatwaves, droughts, tornadoes, floods, tsunamis and storms. Furthermore, Exhibit 11 portrays the impacts of global warming on mammals losing their habitat due to the rise in temperature at different levels. Exhibit 12 depicts the consequences of global warming on human health and weather-related locational displacement of mankind.

**Exhibit 10: Impacts of global warming on the environment**




Source: "Why invest in renewable energy," United Nations

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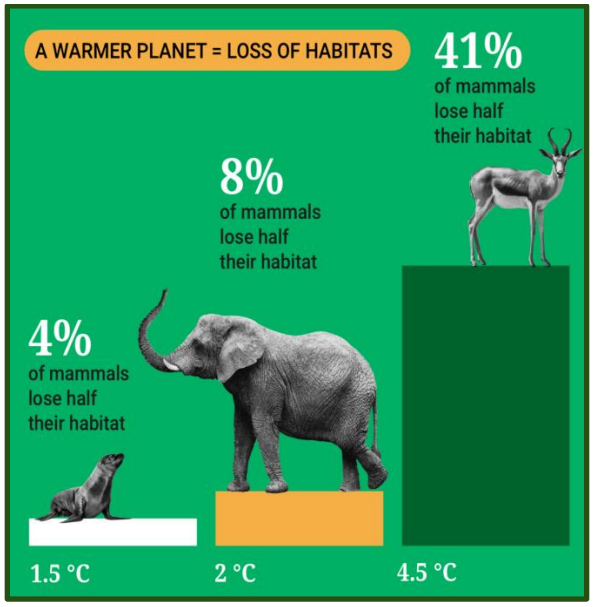
**Exhibit 11: Impacts of global warming on mammals losing their habitat**




Source: "Why invest in renewable energy," United Nations

**Exhibit 12: Consequences of global warming on human health and weather-related locational displacement of mankind**


Source: "Why invest in renewable energy," United Nations

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Hence, to protect our planet and the well-being of all living creatures it is crucial to shift to renewable clean energy resources. Sustainable energy is a clean form of energy generated from resources that are theoretically inexhaustible and do not require to be renewed or restored. For example, sustainable clean energy comprises wind and solar energy, hydropower, geothermal energy (employing the available thermal energy from the interior of the earth) and ocean energy (developed from technologies that utilize the kinetic energy of seawater, waves, tides or water currents to generate electricity or heat). Sustainable clean energy does not cause unfavorable effects on the environment in terms of pollution nor does it lead to global warming, but it further functions as a solution to fulfill global energy requirements. These energy sources are naturally available without any expenditure, nonetheless, there is an expense attributed to building ways to capture sustainable energy.

## 2. Sources Of Renewable Green Energy

The generation of renewable green energy by manipulating natural resources yields negligible detrimental consequences on the environment and on human health, as compared to the burning of fossil fuels to generate energy. Hence, transitioning from deriving energy from fossil fuels, which presently accounts for the lion's share of emissions, to renewable energy is extremely critical in solving the global warming problem. Listed in this section are various types of renewable green energy sources.

### 2.1 Solar Energy

Solar energy is a renewable energy that is vastly obtainable as compared to other alternative energy resources. The rate at which solar energy is intercepted by the earth is about 10,000 times more than the rate at which humans consume energy; therefore it is available in abundance to fulfill human energy requirements. The scientific procedure transforms sunlight into electrical energy either through photovoltaic panels or through mirrors that consolidate solar radiation. Solar energy is utilized for heating, cooling, lighting and electricity and serves as a fuel for innumerable applications.

Solar energy can even be harnessed on cloudy days. Solar panels have a lifespan of approximately 30 years and are available in an assortment of shades depending on the manufacturing material. Even though not all countries have equally invested in solar energy, a considerable contribution to the energy mix involving direct solar energy is currently prevalent worldwide. The expenditure of building solar panels has declined drastically over the last decade, hence, making them not only common but often the most affordable form of electricity. Exhibit 13 illustrates briefly how solar energy is yielded and highlights its utility pattern.

  

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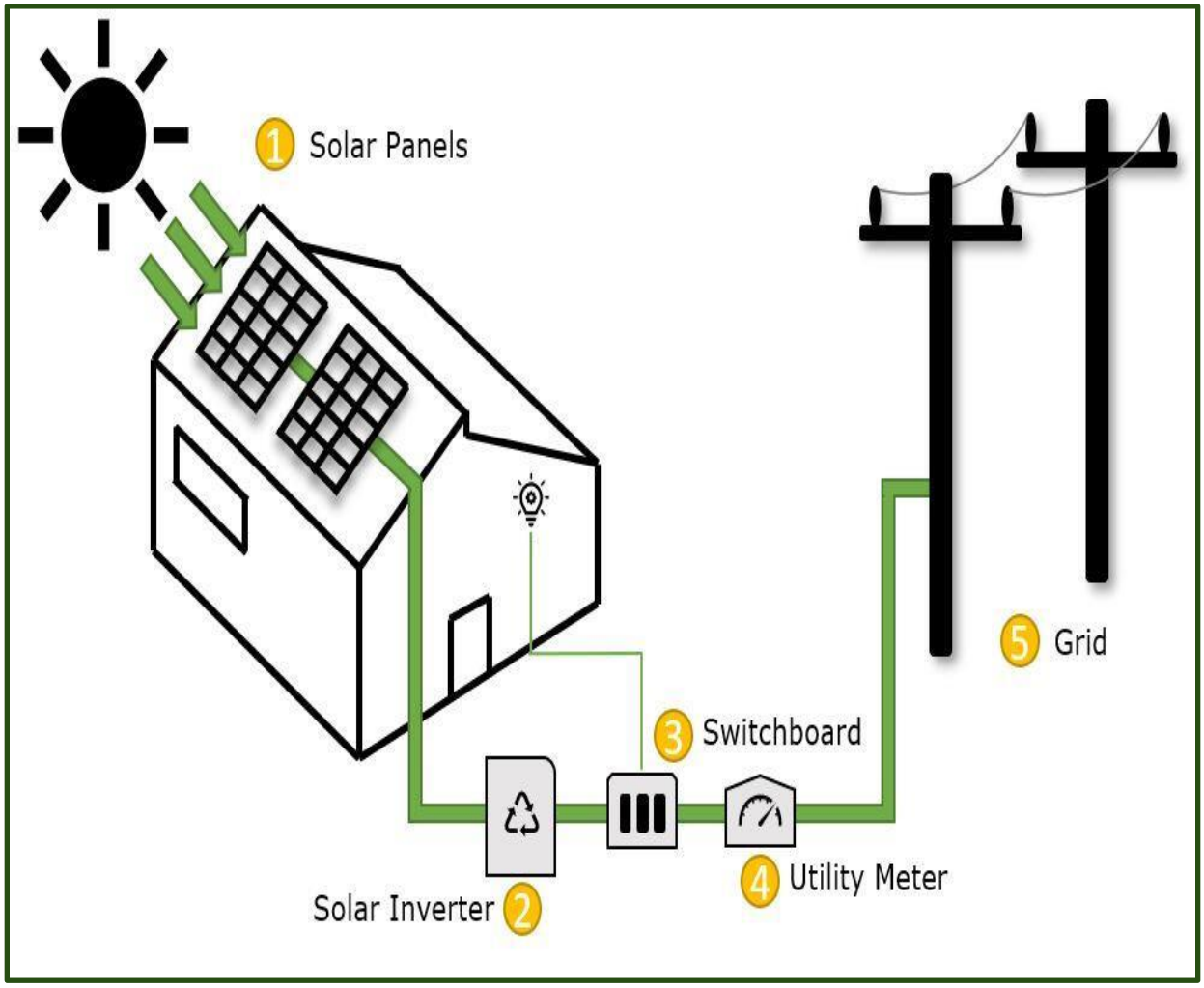
**Exhibit 13: Generating solar energy**




Source: "Solar Explained - How Does Solar Energy Work?" Solar Choice

## 2.2 Wind Energy

Wind energy is yielded by harnessing the kinetic energy of moving air by using massive wind turbines located on land that is onshore or in sea or rivers that are offshore. Wind energy technologies have evolved further utilizing taller turbines and larger rotor diameters to improve electricity generation. Many regions worldwide receive strong wind speeds, but the ideal settings for yielding wind power are remote areas. Offshore wind energy promises incredible opportunities. There is sufficient potential in this field as the world's technological potential for wind energy is greater than global electricity production as well as consumption needs. Exhibit 14 explains how wind energy is generated through wind turbines.

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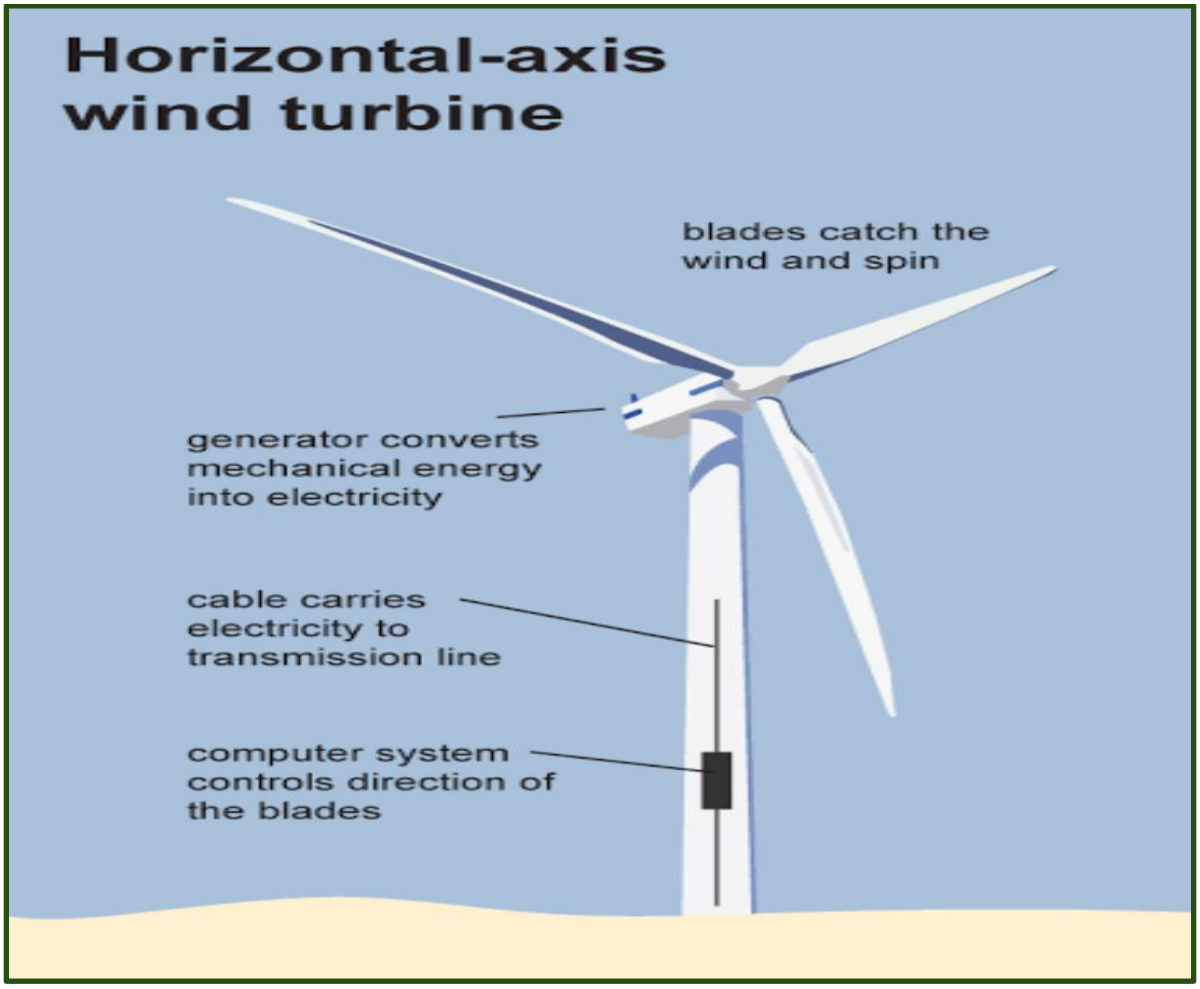
**Exhibit 14: Generating wind power**




Source: "Types of wind - U.S. Energy Information Administration," EIA

### 2.3 Geothermal Energy

Geothermal energy extracts the available heat energy from geothermal reservoirs in the Earth's interior operating through the system of wells. Reservoirs that are naturally sufficiently hot in temperature and penetrable are called hydrothermal reservoirs, whereas reservoirs that are sufficiently less hot and are reinforced with hydraulic stimulation are called enhanced geothermal systems. The scientific procedure for producing electricity employing hydrothermal reservoirs has been operating for over a hundred years and is a reliable technique. Once at the surface, fluids of several temperatures can be used to yield electricity. Exhibit 15 explains how geothermal energy is generated.

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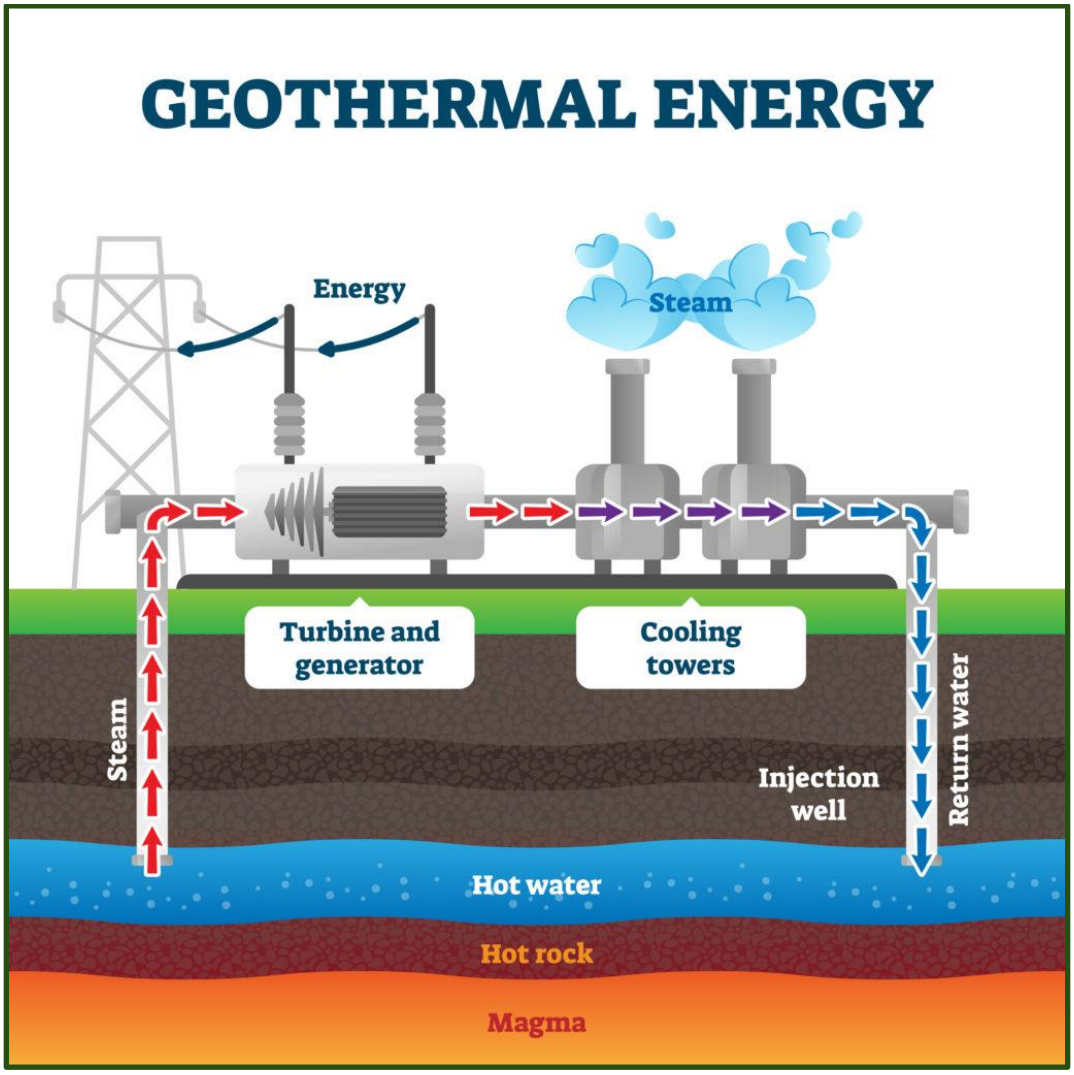
**Exhibit 15: Generating geothermal energy**




Source: "Geothermal Energy," Xeero.io

## 2.4 Bioenergy

Bioenergy is developed from organic materials called biomass - wood, charcoal, dung and other manures for heat and power generation and from agricultural products for liquid biofuels. A bulk of the biomass is used by the needy societies dwelling in rural areas in developing countries for cooking, lighting and heating. Modern biomass systems encompass special crops such as corn and sugarcane, a variety of trees, and agricultural and forestry organic waste. Nonetheless, energy yielded by burning traditional biomass leads to greenhouse gas emissions, but at lesser

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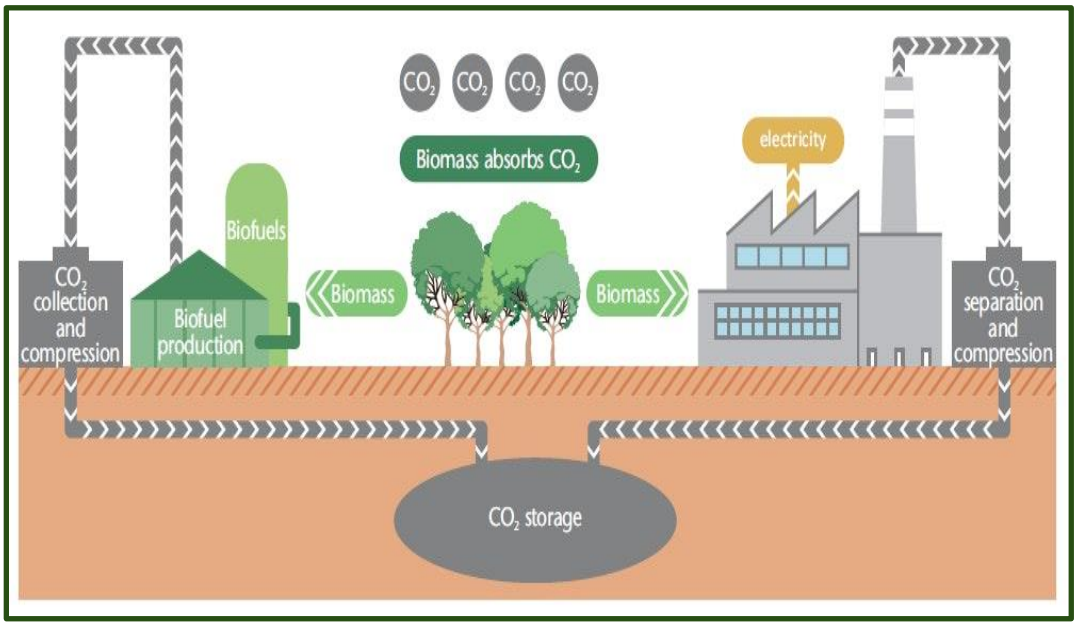
levels as compared to burning fossil fuels. However, bioenergy should only be used in limited applications, given the probable unfavorable environmental consequences related to the big-scale increase in bioenergy plantations and increasing deforestation and land-use modifications. Exhibit 16 depicts how bioenergy is generated.

**Exhibit 16: Generating bioenergy**




Source: IEA Technology

However, some renewable clean energy can be stated as theoretically exhaustive, which means it utilizes resources from our planet which can naturally be replenished. For example, bioenergy is derived from biological masses and agricultural products like sugarcane, wheat and corn and from harvest waste like straw crops, domestic organic waste and biomatter. Since these crops' yields can be repeatedly farmed to produce additional energy, it falls in the category of renewable clean energy. Biofuels are utilized to power automobiles; nonetheless, they do not operate as efficiently as gasoline. They can be blended with gasoline to efficiently and effectively power automobiles and machinery, and do not expel the emissions correlated with fossil fuels.

### 2.5 Ocean Energy

Ocean energy uses scientific technology to utilize the kinetic energy of seawater, waves or currents to yield electricity or heat. The theoretical capacity for ocean energy is greater than the current mankind energy requirements. This form of renewable energy system is nonetheless at an

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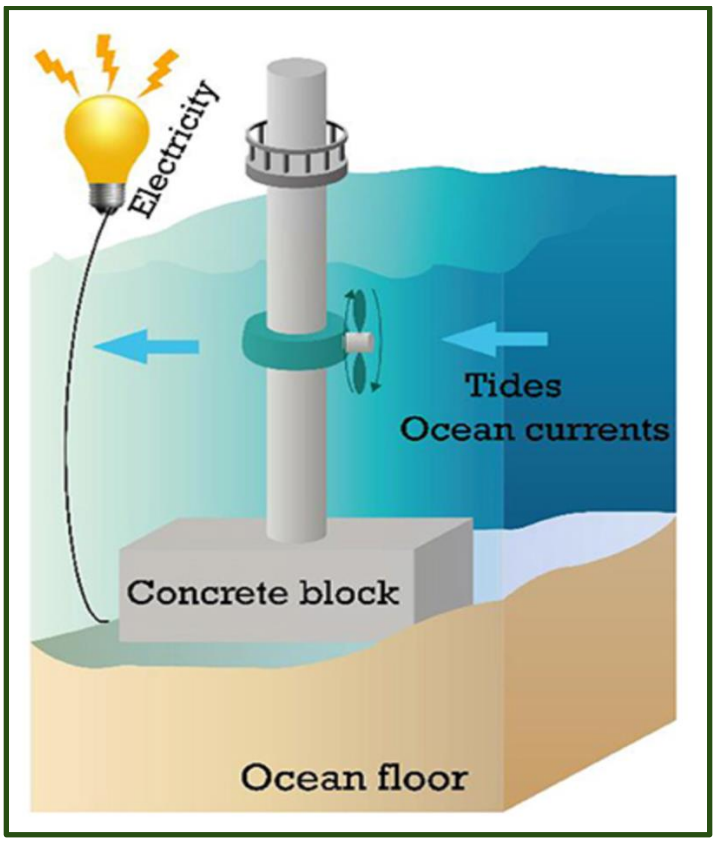
initial stage of development, with an assortment of prototype wave and tidal current tools being evaluated currently.

Generating electricity using ocean currents and tides: The blades of the turbine are swerved by the ocean current action and the energy is captured by an electricity-generating apparatus which is attached to the blades of the turbine. Exhibit 17 explains how ocean energy is generated using turbine technology.

**Exhibit 17: Generating ocean energy using ocean currents and tides utilizing turbine technology**




Source: "How Can We Use Ocean Energy to Generate Electricity?" Frontiers for Young Minds

Generating electricity using wave movement: The floating buoy is attached to a towering column named a spar, which is connected to the seabed containing electricity-generating equipment. Electricity is yielded as the waves ripple and bounce the buoy upwards and downwards the spar, which pushes a piston that propels a generator and electricity, is transmitted to the seashore via an underwater wire. Exhibit 18 illustrates how ocean energy is generated using buoy technology.

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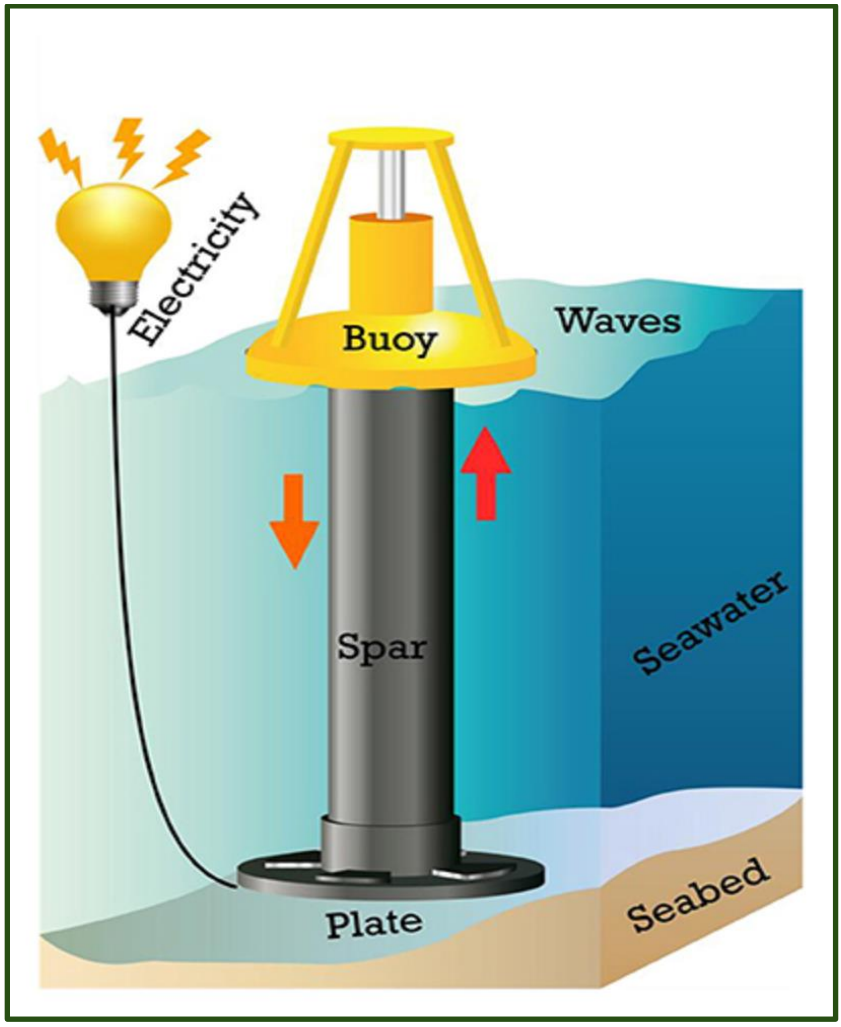
**Exhibit 18: Generating ocean energy using wave movement utilizing a buoy**




Source: "How Can We Use Ocean Energy to Generate Electricity?" Frontiers for Young Minds

## 2.6 Hydropower

Hydropower presently is the most extensively used source of renewable green energy for generating electricity. This procedure harnesses the energy of water moving from higher to lower elevations either from reservoirs or rivers. Reservoir hydropower manufacturers depend on water stored in reservoirs, while run-of-river hydropower plants harness energy from the flowing river. This relies on adequate rainfall and can be adversely impacted by droughts. Nevertheless, the infrastructure required to build hydropower can also impact ecosystems unfavorably. Hence, small-scale hydro is a better environmentally-friendly alternative and is appropriate for communities dwelling in isolated regions. Exhibit 19 depicts how hydropower is generated.

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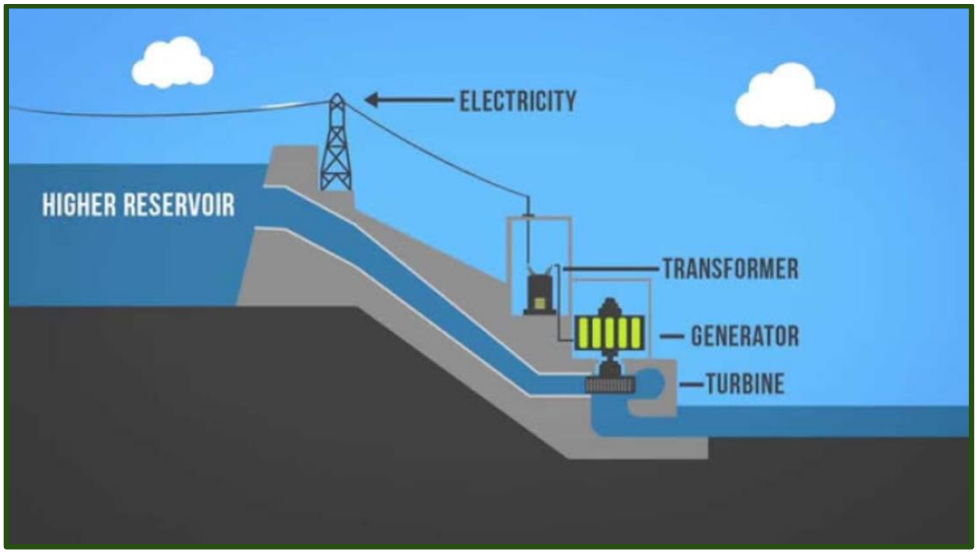
**Exhibit 19: Generating hydropower**




Source: "Hydropower 101," YouTube

## 2.7 Hydrogen Fuel Cell - The Future Sustainable Energy For Mobility

The unfavorable effects of emissions from petrol and diesel have resulted in the evolution towards environmentally friendly fuels such as hydrogen fuel cells. These can be utilized as a future energy carrier that has the likelihood to transmit tremendous energy and can rebuild our fossil-fuel-dependent economy into a hydrogen economy, hence providing an emissions-free transportation fuel.

Hydrogen is a vastly abundant element on our planet. Elemental hydrogen is a diatomic molecule with a single H-H bond and generally does not occur freely in nature and is obtained from alternative energy sources namely - vapor reformation of natural gas, gasification of coal and electrolysis of water. This clean-burning fuel when blended with oxygen in a fuel cell generates heat and electricity with just water vapor as a by-product. Nevertheless, due to hydrogen's distinctive low density, the storage and transport of hydrogen are subjects which require solutions and deep study.

A hydrogen fuel cell can be defined as an electrochemical mechanism that utilizes a spontaneous redox reaction to generate electricity by enabling chemical gasses and oxidants as reactants. The anodes and electrolytes in the fuel cell break down the cation and the anion in the reactant to generate electricity. Fuel cells use reactants, which are not detrimental to the surroundings and generate water as a derivative of the exothermic chemical reaction. Refer to Exhibit 20 which explains this concept.

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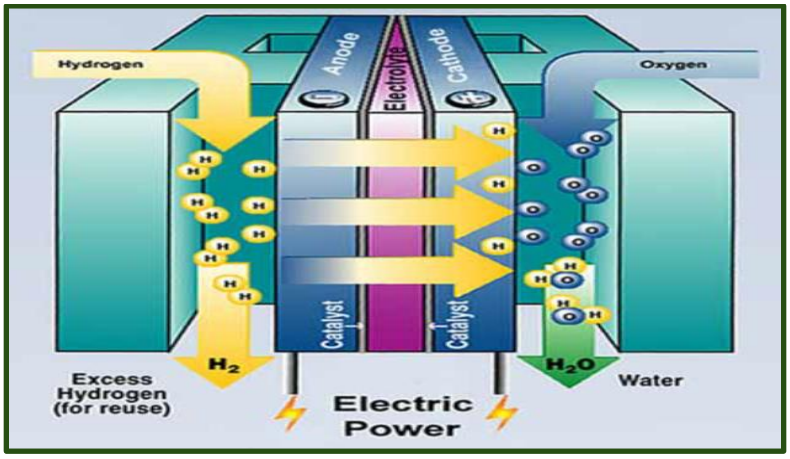
**Exhibit 20: Hydrogen fuel cell functioning process**




Source: Hydrogen Fuel Cell, High School, the University of Illinois Urbana Champaign (UIUC)

Hydrogen proves to be a chemical energy carrier that has the potential to generate electricity upto 39.39kWh/kg, which is greater than the energy density of a majority of batteries. Hydrogen fuel cell vehicles have greater than a 300-mile driving range and can be refueled in less than 10 minutes at a hydrogen refueling station.

Nonetheless, there is a substantial generating expense for hydrogen, since it is a manmade fuel, amounting to nearly three times additional than petroleum refining and requires tremendous research to develop an efficient and sustainable means to generate hydrogen and applications for hydrogen in vehicle engines. Vehicle plants of Honda, Toyota, and Hyundai have begun to develop hydrogen fuel cells in the initial stages. It is foreseen that hydrogen has a tremendous ability for usage as a future fuel and by 2030. Exhibit 21 describes the advantages and disadvantages of hydrogen fuel cells.

**Exhibit 21: The pros and cons of hydrogen as a transportation fuel**

| Advantages | Disadvantages |
|---|---|
| High energy yield (122 kJ/g) | Low density (large storage areas) |
| Most abundant element | Not found free in nature |
| Produced from many primary energy sources | Low ignition energy (similar to gasoline) |
| Wide flammability range (hydrogen engines operated on lean mixtures) | Currently expensive |
| High diffusivity | |
| Water vapor is major oxidation product | |
| Most versatile fuel | |

Source: “Hydrogen: Fuel Of The Future,” Rachel Chamousis, California State University, Stanislaus

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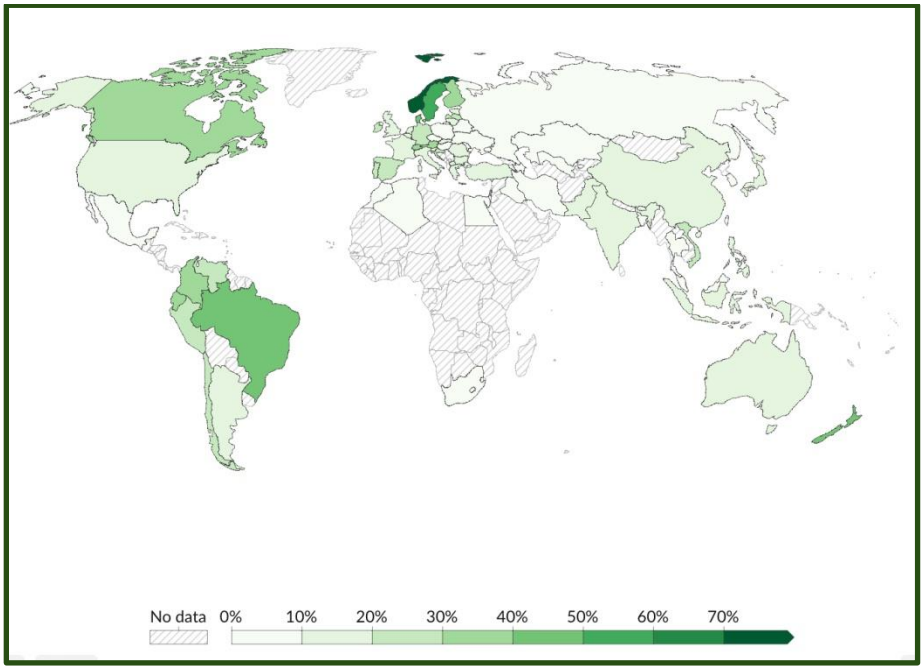
A solar-hydrogen-powered system can provide a totally emissions-free strategy for generating hydrogen. Also, hydrogen can be used in power plants, in place of fossil fuels, to heat water and steer turbines in an eco-friendly manner. Some scientists envision a future hydrogen economy, where hydrogen is generated from a mixture of energy sources, stocked for later utilization and piped to where it is required to transform it into heat and electricity.

### 3. Global Shift Towards Renewable Energy Resources

Renewable green energy plays a critical function in decarbonizing our traditional energy techniques. This section provides a brief overview of this global transition for various renewable green energy resources. Exhibit 30 depicts the worldwide share of primary energy consumption from renewable sources in 2022. These include hydropower, solar, wind, geothermal, bioenergy (modern biofuels), wave and tidal renewable energy resources. Norway, Sweden and Brazil are leading the world in energy consumption from renewables in 2022.

**Exhibit 30: Global assessment of primary energy consumption from renewable sources in 2022**




Source: Energy Institute - Statistical Review of World Energy (2023)

Furthermore, hydroelectric power is one of our oldest and most extensive sources of low-carbon energy and accounts for around 50% of global renewable production. Nonetheless, the scale of hydroelectric power yield trends differs significantly worldwide. China, followed by the U.S.A.,

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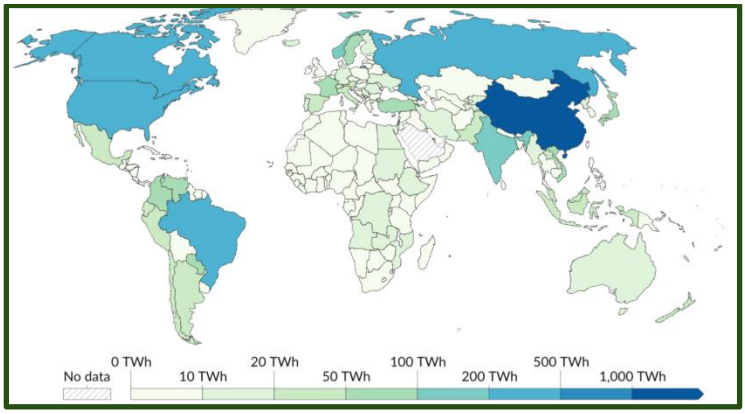
Canada, Brazil and the former U.S.S.R. are leading the world in hydropower generation. Refer to Exhibit 31 for further details.

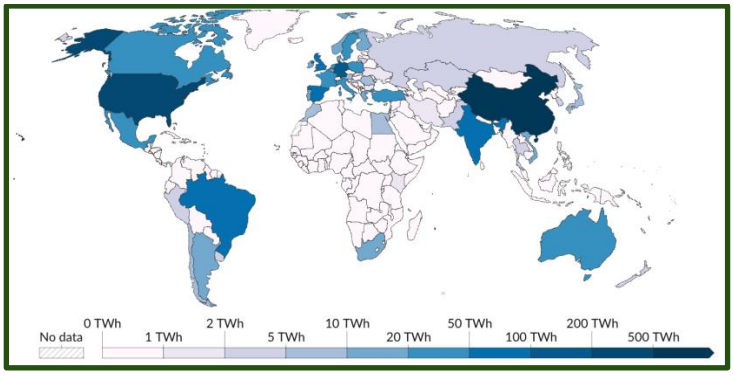
**Exhibit 31: Global annual hydropower generation measured in terawatt-hours (TWh) in 2023**




Source: Energy Institute - Statistical Review of World Energy (2023)

Additionally, Exhibit 32 depicts the amount of wind energy yielded in 2023, comprising onshore and offshore wind farms, measured in terawatt-hours (TWh) in different nations. Wind energy generation as compared to hydropower is somewhat a current renewable energy source but is evolving fast in many nations worldwide. China followed by the U.S. leads the world in electricity generation from winds in 2023. Exhibit 33 depicts the cumulative installed wind energy capacity including both onshore and offshore wind sources, measured in gigawatts (GW) for a certain group of nations, where Germany is the constant leader from the year 2000 to 2022.

**Exhibit 32: Global electricity generation from wind measured in terawatt-hours in 2023**




Source: Energy Institute - Statistical Review of World Energy (2023)

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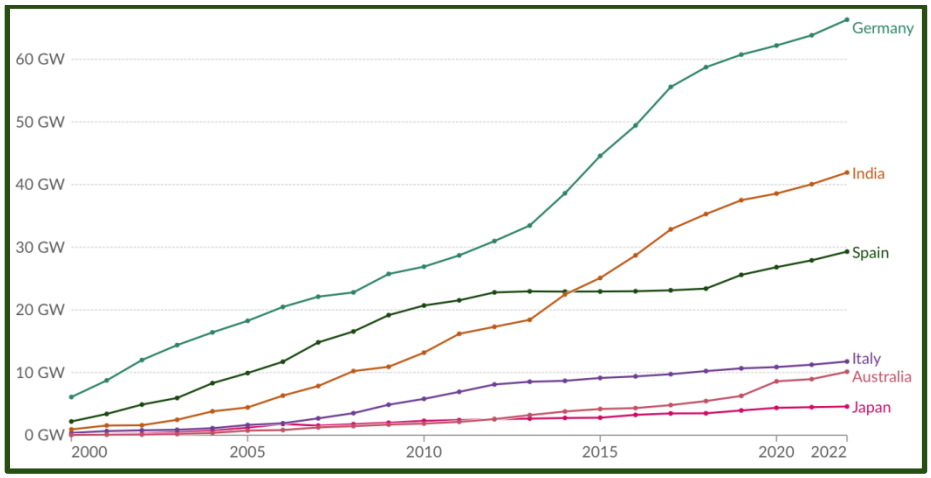
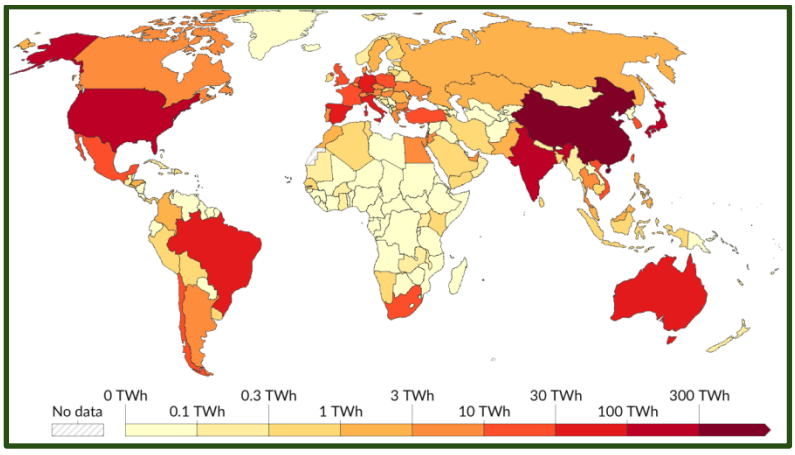
**Exhibit 33: Cumulative installed wind energy capacity including both onshore and offshore wind sources measured in gigawatts (GW) from 2000 to 2022**




Source: Energy Institute - Statistical Review of World Energy (2023)

Solar energy generation also, as compared to hydropower, is a fairly current renewable energy source but is rising fast in multiple nations worldwide. Exhibit 34 depicts the regional solar power generation measured in terawatt-hours (TWh) in 2023 and China followed by India and the U.S. seems to be the leading nations in 2023.

**Exhibit 34: Solar power generation measured in terawatt-hours (TWh) in 2023**




Source: Energy Institute - Statistical Review of World Energy (2023)

Modern biofuels such as bioethanol and biodiesel are fuels generated from crops like corn, sugarcane, hemp, and cassava. They are currently a significant vehicle fuel in multiple nations.

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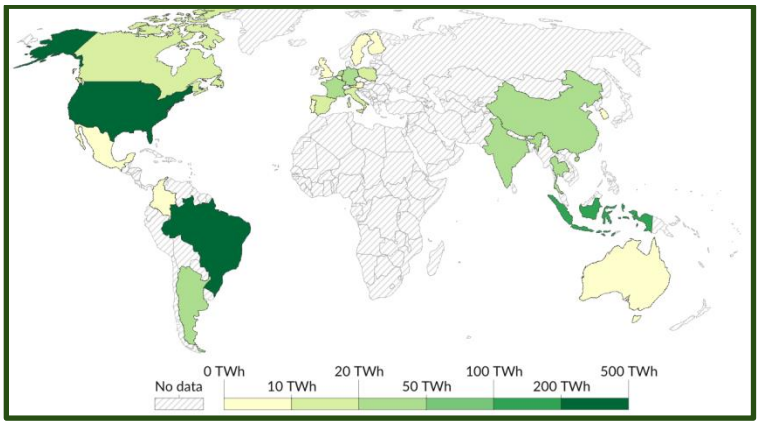
Exhibit 35 portrays the regional modern biofuel energy production in 2022 measured in terawatt-hours (TWh). The U.S. and Brazil are leading the world in this field in 2022.

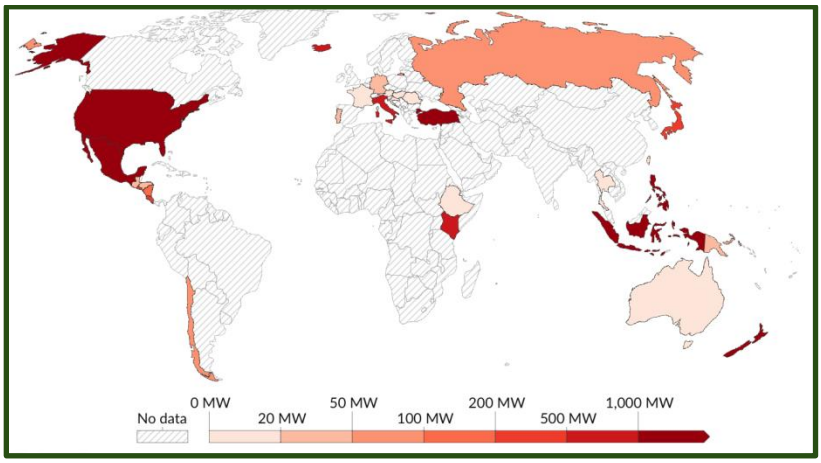
**Exhibit 35: Global biofuel energy production in 2022 measured in terawatt-hours (TWh) comprising both bioethanol and biodiesel**




Source: Energy Institute - Statistical Review of World Energy (2023)

Exhibit 36 demonstrates the regional installed capacity of geothermal energy globally in 2022. The U.S., regions in south-east Asia, New Zealand and Turkey lead the world in this field in 2022.

**Exhibit 36: Cumulative installed capacity of geothermal energy in 2022 measured in megawatts**




Source: International Renewable Energy Agency (2023)

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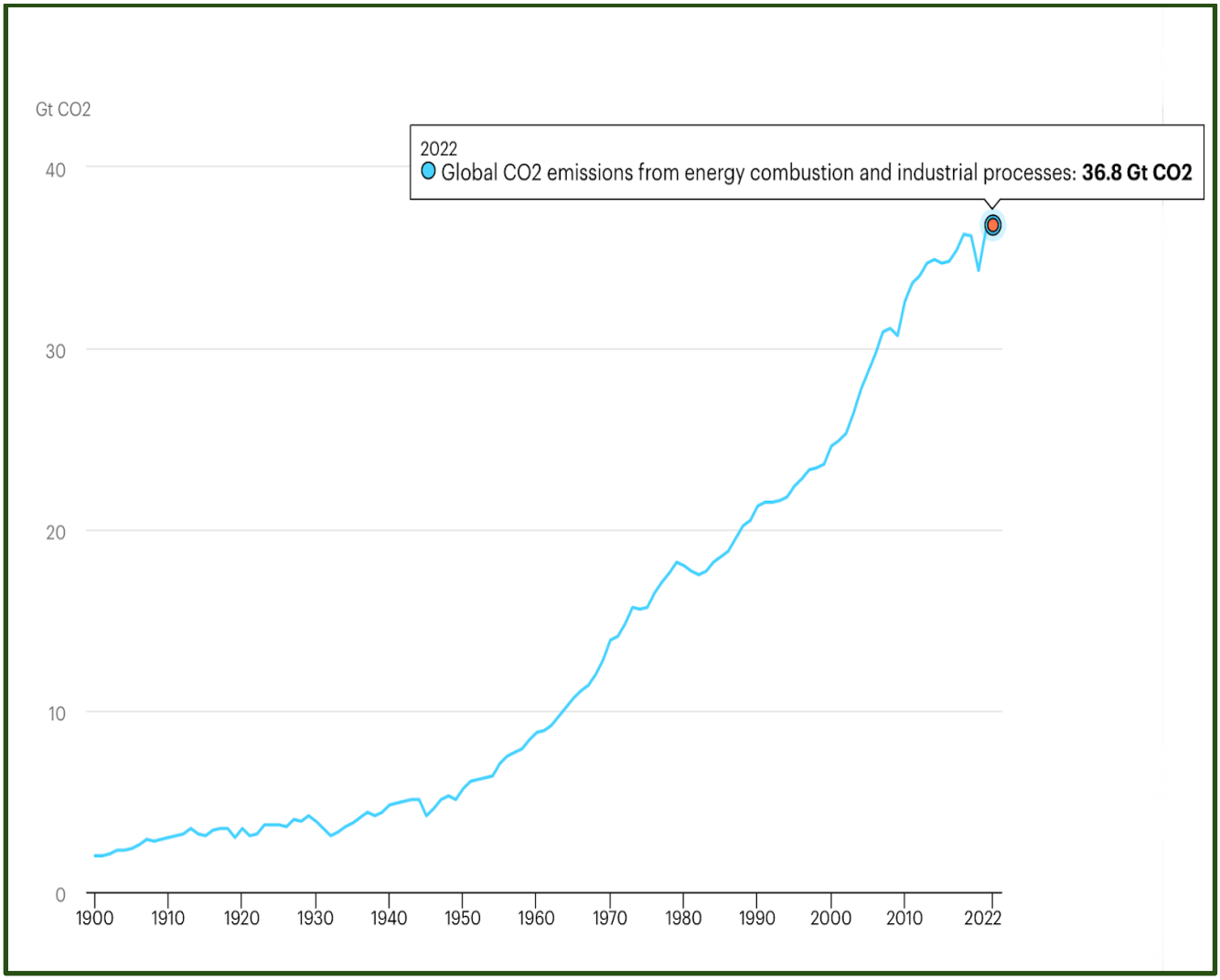
## Conclusion: Striving To Create a Reduction in Carbon Footprints

The rising trend of greenhouse gasses is creating public awareness and leading to the path of adopting renewable green energy resources at a rapid rate. Refer to Exhibit 37 which depicts the constant ascending tendency in worldwide carbon dioxide emissions from energy combustion and industrial processes from 1900 to 2022. Furthermore, Exhibit 38 portrays the increase in global energy-related greenhouse gas emissions from 2000 to 2022.

**Exhibit 37: Global carbon dioxide emissions from energy combustion and industrial processes from 1900 to 2022**




Source: "CO2 Emissions in 2022 Analysis," IEA

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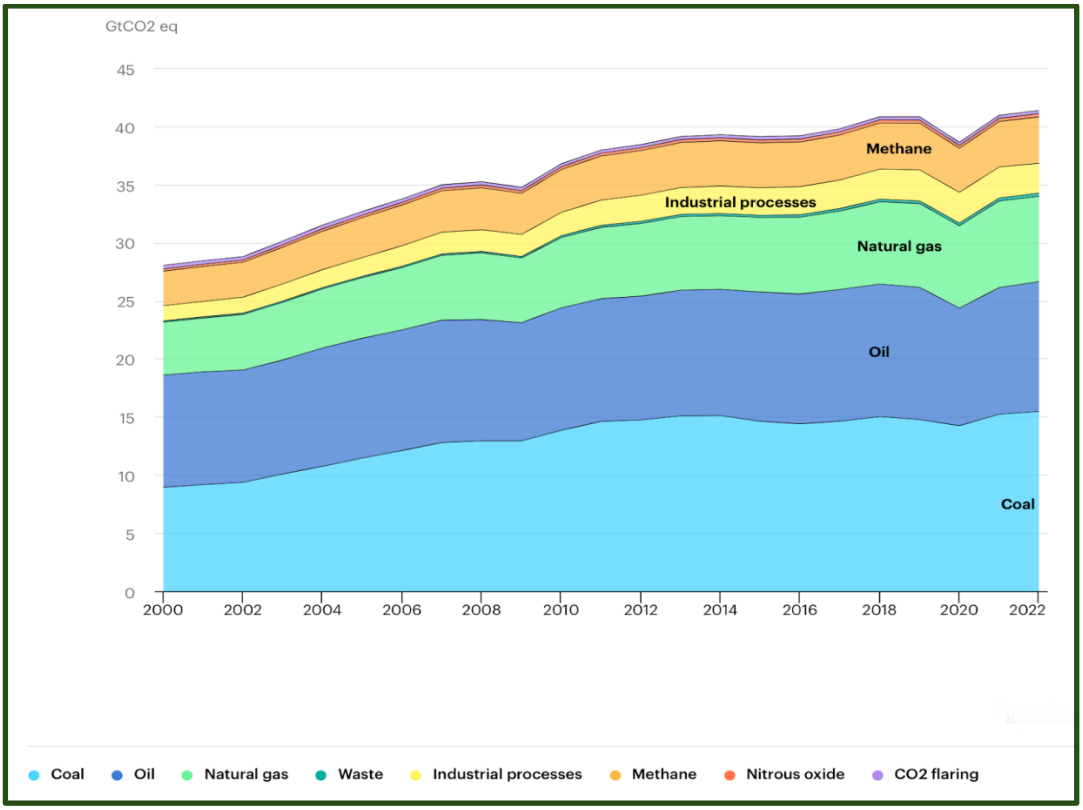
**Exhibit 38: Global energy-related greenhouse gas emissions from 2000 to 2022**




Source: "CO2 Emissions in 2022 Analysis," IEA

Carbon footprint portrays the greenhouse gas emissions which can be attributed towards human activities, causing global warming and other environmental hazards. Greenhouse gasses are emitted by the burning of fossil fuels, transportation activities, land clearance and deforestation, industrial activities and meat-eating trends.

On the other hand, a carbon offset or carbon credit is a reduction or elimination of emissions of carbon dioxide or other greenhouse gasses generated to neutralize the emissions generated elsewhere. Several greenhouse gas deduction programs can be utilized to build offsets and credits, for example, reforestation, utilizing renewable energy such as solar energy, wind farms, biomass energy, hydropower, biogas and destroying methane at landfills. These carbon credit proposals have been specified as paths for nations to meet their nationally determined contribution commitments and accomplish the goals of the Paris Agreement at a lesser cost.

Globally, nations are striving to create public awareness among people, businesses and societies of the carbon footprints created by them and promoting the concept of renewable green energy

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resources. Nations are stimulating actions which will facilitate market tools to drive these sources to purchase carbon offset certification programs to diminish greenhouse gas emissions to satisfy carbon neutral, net-zero or other greenhouse gas reduction goals. Exhibit 39 explains some of these initiatives.

**Exhibit 39: Green energy initiatives**


Source: "Why invest in renewable energy," United Nations

Less developed nations, those who are heavily dependent on fossil fuels are likely to be impacted the most in a net-zero transition cost. Although they are likely to have greater development prospects and are more sensitive to modifications in output, capital stock and employment as their exposed sectors comprise fairly considerable aspects of their economies.

It is anticipated that there is likely to be increased grades of exposure in nations with lesser GDP per capita, like Pakistan, Bangladesh, India, Indonesia, Nigeria and Kenya, as these nations tend to have moderately elevated share of employment, GDP, and capital stock in economic sectors that have emissions-intensive processes and their production processes and supply chains are likely to face greater levels of transition. Furthermore, higher fossil fuel resource manufacturing produces an elevated exposure for nations involved in this process, namely the UAE, Qatar, Russia, and Saudi Arabia. These nations' GDP is directly connected to the fossil fuel extraction

  

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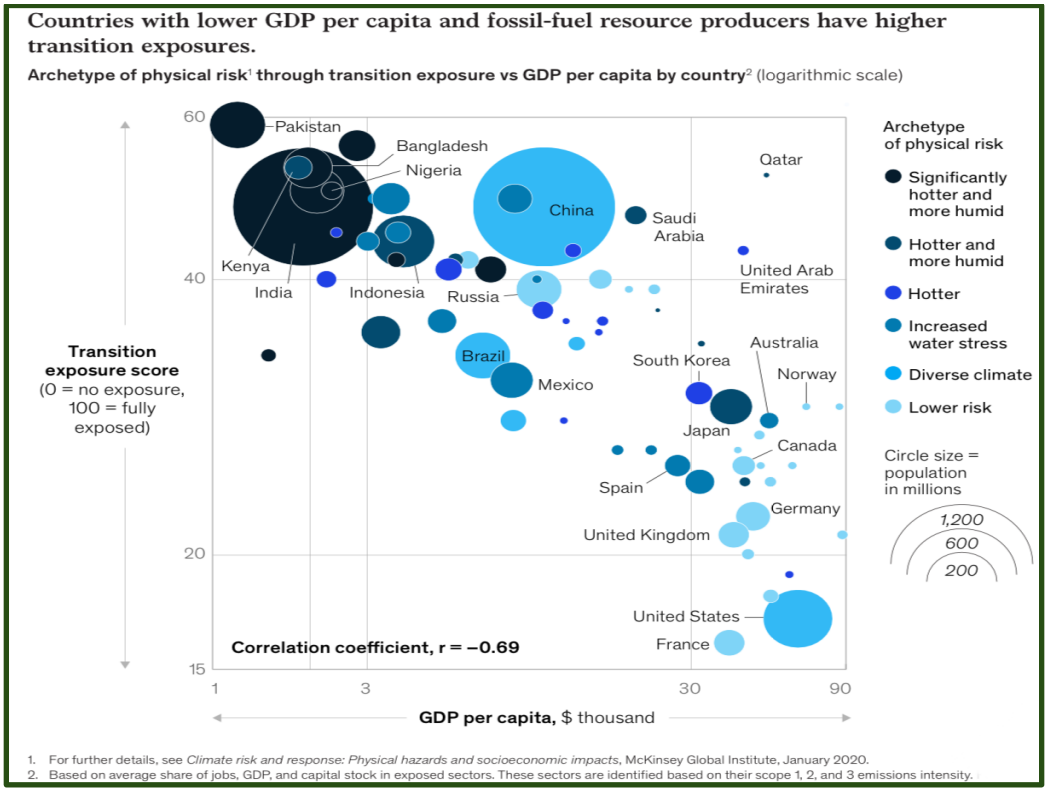
process, so the greater the extraction of fossil fuels the higher their GDP and vice versa. Refer to Exhibit 40 for further graphical inputs related to the subject.

**Exhibit 40: Countries with lower GDP per capita and fossil fuel-producing nations are likely to have greater transition exposure**




Source: Oxford Economics; OECD; ILO; World Input-Output Database; IHS Connect; World Bank; International Energy Agency; US Bureau of Labor Statistics; India NSS-Employment survey; China National Bureau of Statistics; UN; International Renewable Energy Agency (IRENA); MINSTAT; INDSTAT; Global Solar Atlas; Global Wind Atlas; US Geological Survey; WEF; McKinsey Nature Analytics; McKinsey Global Institute analysis

For example, sub-Saharan Africa and India would be required to invest 1.5 more than developed economies as a percentage of their GDP to sustain economic expansion and construct low-carbon infrastructure. The global most developed economies such as the United States, China, Australia, New Zealand, Canada, the European Union, Japan, and the United Kingdom account for nearly 50% of the international spending on physical assets and this can be estimated at nearly 6% of their combined GDP from 2021 to 2050. Exhibit 41 depicts the names of such nations whose economy is based on fossil fuel production as well as developing countries which would require to spend a higher percentage of their GDP as compared to other nations to modify and develop physical assets for energy and land usage procedures.

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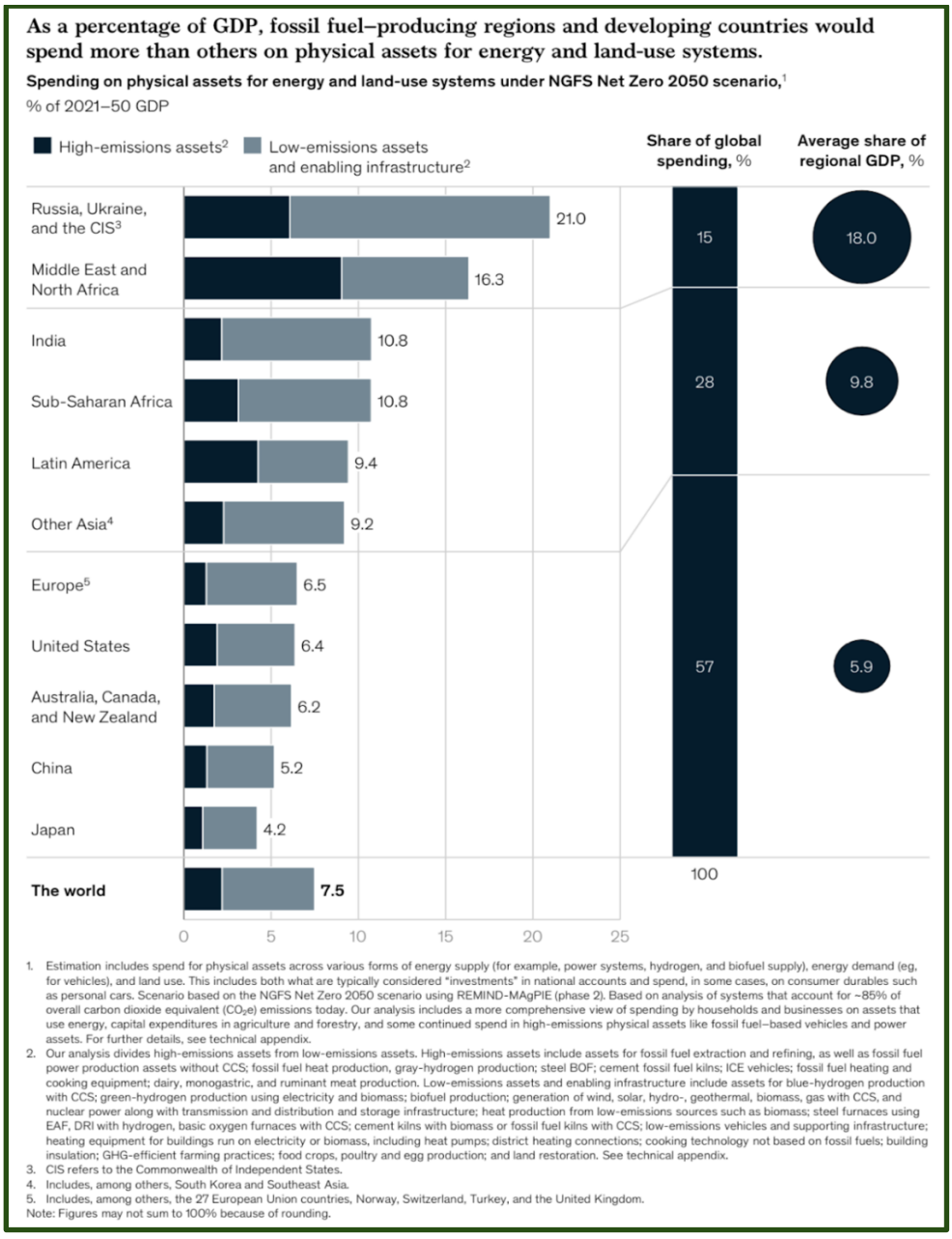
**Exhibit 41: List of nations whose economy is based on fossil fuel production as well as developing countries and their net transition cost**




Source: Network for Greening the Financial System 2021 (Net Zero 2050 scenarios) REMIND-MAgPIE model; Vivid Economics; McKinsey Center for Future Mobility Electrification Model (2020); McKinsey Hydrogen Insights; McKinsey Power Solutions; McKinsey–Mission Possible Partnership collaboration; McKinsey Sustainability Insights; McKinsey Agriculture Practice; McKinsey Nature Analytics; McKinsey Global Institute analysis

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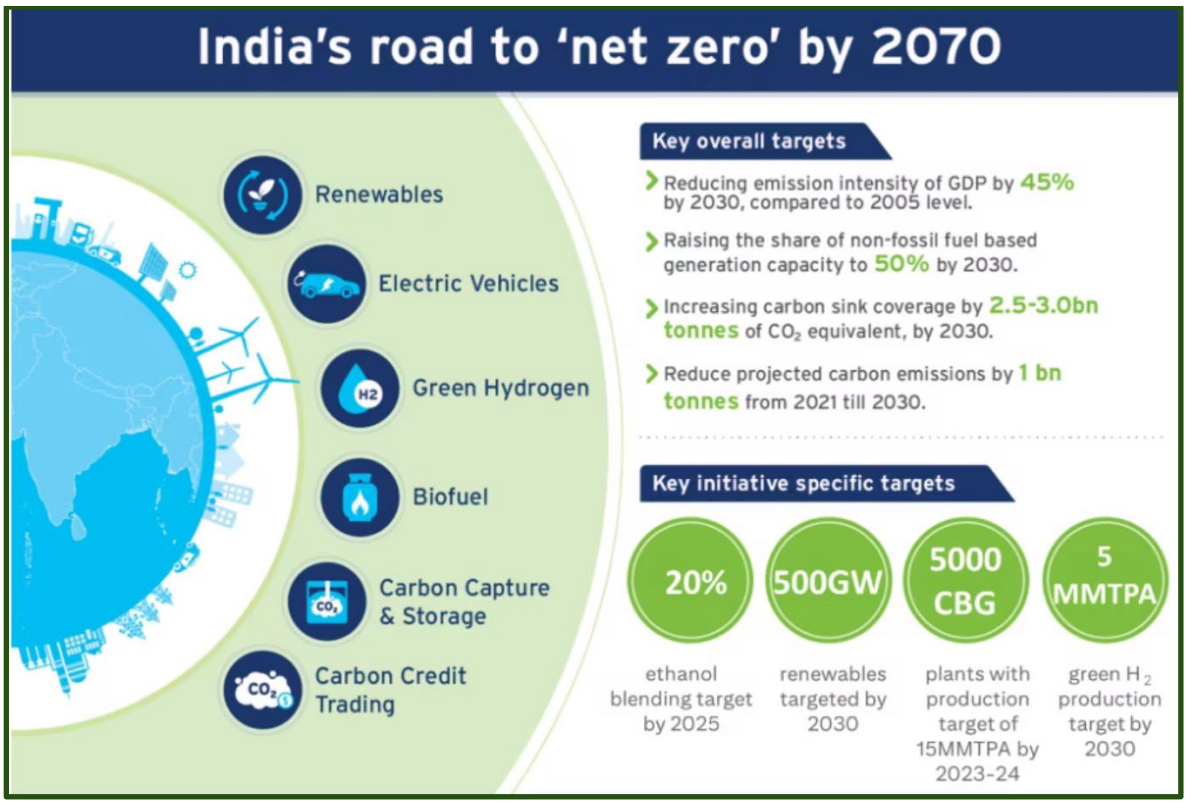
Nonetheless, it is essential to develop renewable green energy resources extensively, noting that attaining net-zero emissions and restricting global warming to 1.5°C would reduce the likelihood of creating the most catastrophic consequences of global temperature rise, restricting the hazard of biotic feedback loops and preserving our environment. Therefore, businesses would need to modify their business prototypes incorporating climate-related aspects into decision-making procedures for planning, finance, and capital allotment.

**Appendix Section: Case Study of India's Progress on Renewable Green Energy**

The Indian government is striving to have net zero emissions by 2070. The nation pledged at the Conference of Parties 26 in Glasgow in 2021 to take action against climate change. Following these developments, India's administration has announced recent laws and policies, and focused regulatory efforts on targeting evolving technologies to enable the world's most populated country to fulfill its environmental-related goals. Exhibit 42 highlights some of these policies and strategies to achieve net zero by 2070.

**Exhibit 42: India's target to achieve net zero by 2070**




Source: India Clean Energy: Progress & Policy, Citigroup

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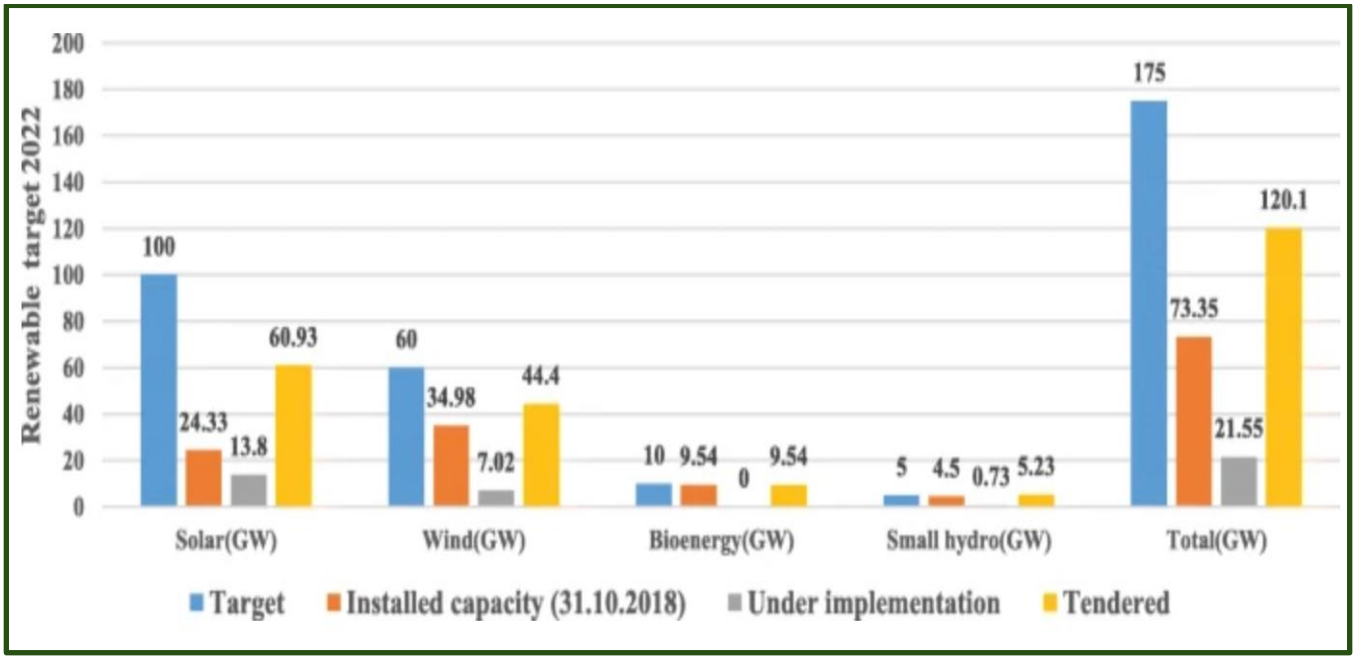
Building public awareness in the nation has evolved multiple corporations and organizations to declare their own net zero objectives, and disclose their agendas and strategies to diminish their carbon footprint by employing current technologies. These green energy techniques are largely concentrated on using renewable energy resources, formulating battery storage devices, developing electric vehicles, evolving carbon capture technology and examining and developing green hydrogen and biofuels. Exhibit 43 highlights the renewable energy development in India in 2022 taking into account solar energy, wind energy, bioenergy and small-scale hydropower. The targeted focus within the year is to expand solar energy followed by wind energy. The highest installed capacity in 2018 was wind energy.

**Exhibit 43: Renewable energy targets 2022**




Source: Renewable energy for sustainable development in India: current status, future prospects, challenges, employment, and investment opportunities, Energy, Sustainability and Society

The renewable energy sector in India has noticed an enormous favorable transformation over the last decade. The Indian government has an enterprising goal of achieving 500 GW of non-fossil fuel-based ability by 2030. Hence, policies have been concentrated on boosting the contribution of renewables to the across-the-board energy mix. Exhibit 44 demonstrates the installed power capacity mix in India from 2010 to 2023. Furthermore, the stake of renewables in installed power generation capacity has risen from 10% in 2010 to 30% in 2023. Exhibit 45 depicts the rise in renewables in the power generation mix in India from 5% in 2014 to 13% in 2023.

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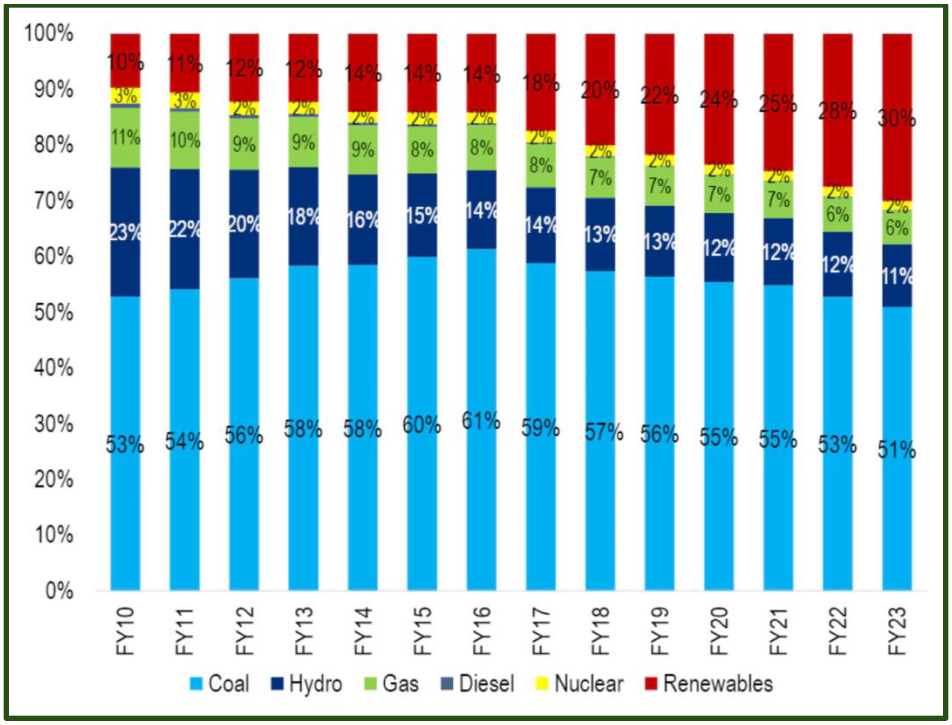
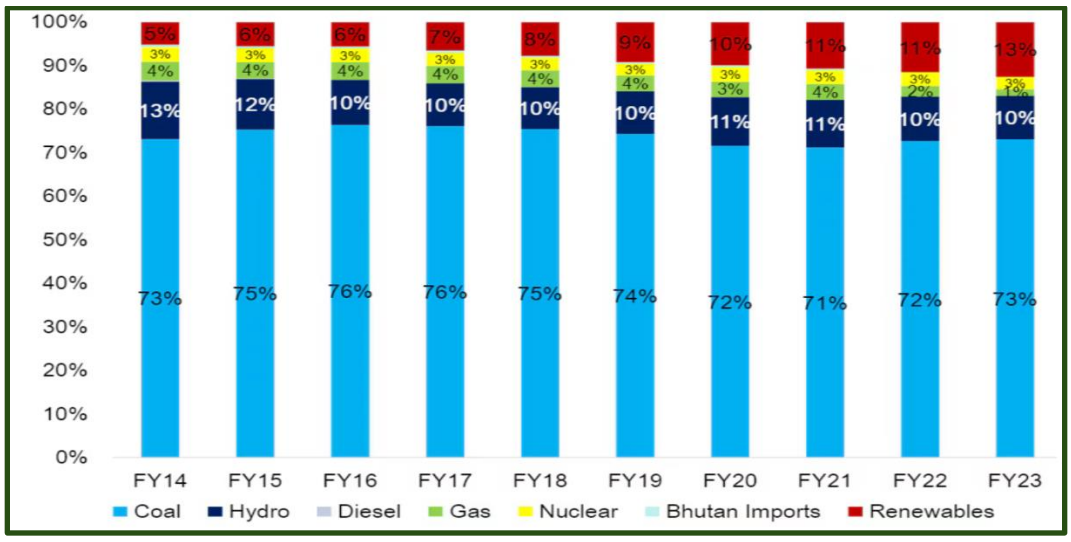
**Exhibit 44: Installed power capacity mix in India from 2010 to 2023**




Source: India Clean Energy: Progress & Policy, Citigroup

**Exhibit 45: Power generation mix in India from 2014 to 2023**




Source: India Clean Energy: Progress & Policy, Citigroup

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The Indian government has propelled the adoption of electric vehicles using multiple policy measures. In the Indian market electric vehicles prove to be cost-competitive in the ride-sharing and 2-wheeler classifications, where increased use along with public incentives, directs to considerable expense conservation. On the other hand, electric buses, even with subsidies, have an increased life-cycle expense. The primary limitations to increased electric vehicle adoption comprise lofty upfront expenses, regulatory issues and import dependence.

In January 2023, the Indian government approved the National Green Hydrogen Mission (NGHM), which targeted to yield at least 5 MMTPA of green hydrogen by 2030. Furthermore, the Indian government, striving to promote the concept of green hydrogen, promised to supply incentives up to Rs50/kg for green production.

The nation has a goal to attain 20% ethanol blending in petrol by 2026, from around 12% currently. Original Equipment Manufacturers are already producing E20 petrol vehicles and several of them have demonstrated their advancement with flex-fuel technology, the ability to operate on 100% ethanol. Nevertheless, compressed biogas adoption has been insufficient due to the scarcity of available technology and increased production expenses.

The national government is creating awareness on the importance of carbon trading. It has authorized a Carbon Credit Trading Scheme extending policies and approaches to create an Indian carbon market. For this purpose, business undertakings and multiple organizations would have to comply with emission regulations pre-set by the Indian Ministry of Power and Bureau of Energy Efficiency. The growth of carbon markets in the nation would stimulate business undertakings and multiple organizations to monetize their investments in green energy technologies to reduce the extremely high expenses of such green projects.

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