

Industrialization, CO₂ Emissions, and the Role of Renewable Energy in Building a Sustainable Future

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Introduction

The rapid advancement of human society has been underpinned by the extensive exploitation of natural resources. Minerals, fossil fuels, forests, and water have been extracted and consumed at an unprecedented scale to meet the demands of industrialization and economic development. While these resources have enabled technological progress, they have also brought about severe environmental consequences—most notably, the steep rise in carbon dioxide (CO₂) emissions. Today, climate change stands as one of the greatest threats facing humanity, driven largely by the combustion of fossil fuels and deforestation. To combat this, the transition to renewable energy has emerged not just as an alternative, but as a necessity.

Exploitation of Resources and the CO₂ Surge

The global economy, especially since the Industrial Revolution, has relied heavily on non-renewable resources like coal, oil, and natural gas. These energy sources have powered industries, transportation, and households—but at a cost. The burning of fossil fuels releases significant quantities of CO₂ into the atmosphere, a greenhouse gas directly linked to global warming.

Industrialization has also accelerated deforestation, both for timber and to clear land for agriculture and urban expansion. Forests act as natural carbon sinks, absorbing atmospheric CO₂. Their destruction, therefore, not only eliminates this vital service but also releases the carbon stored in biomass and soil. The cumulative effect of these activities has resulted in a sharp increase in atmospheric CO₂ levels.

The rise in CO₂ levels has led to global warming, with the Earth's average surface temperature increasing by over 1°C since pre-industrial times. This warming has triggered a cascade of environmental changes: melting polar ice caps, rising sea levels, more frequent and intense

heatwaves, droughts, floods, and wildfires. These changes not only threaten biodiversity but also jeopardize food security, water availability, and human health.

Developing countries, which often lack the infrastructure and resources to adapt to these changes, are disproportionately affected. In this context, the conversation around climate justice has gained prominence, emphasizing the need for global cooperation and equitable solutions.

CO₂ Emissions: Then and Now

In the 1990s, global awareness about climate change began to increase. The Kyoto Protocol, adopted in 1997, was one of the first major international agreements aimed at reducing greenhouse gas emissions. During that period, global CO₂ emissions stood at approximately 22 billion metric tons per year. However, in the decades that followed, emissions continued to rise, reaching over 36 billion metric tons annually by the early 2020s. This represents a more than 60% increase in just three decades.

This sharp rise in emissions can be attributed to the continued industrial growth of developing economies, increased global energy demands, urbanization, and the widespread use of personal vehicles and electronic appliances. While some countries have made progress in stabilizing or reducing their emissions, the overall global trend remains concerning.

Moreover, the carbon intensity of many economies has not decreased sufficiently. Although advances in technology have improved energy efficiency, the sheer scale of economic activity and consumption patterns has offset much of the progress. The atmospheric concentration of CO₂ has now crossed 420 parts per million (ppm), compared to around 355 ppm in 1990, indicating a significant rise with potentially irreversible consequences.

Pathways to Reduce CO₂ Emissions

To effectively reduce CO₂ emissions, a multifaceted approach is needed, with renewable energy at the core. Key strategies include:

- **Accelerating Renewable Energy Deployment:** Governments must prioritize the development of renewable energy infrastructure through incentives, regulatory support, and investments in grid modernization.
- **Energy Efficiency and Conservation:** Reducing energy demand through efficient appliances, better building designs, and smart energy management complements the benefits of renewables.
- **Protecting and Restoring Ecosystems:** Forest conservation and reforestation initiatives can enhance carbon sequestration. Integrating nature-based solutions with renewable energy adoption amplifies climate resilience.
- **Carbon Pricing and Emission Trading:** Economic tools such as carbon taxes and cap-and-trade systems create financial incentives for reducing emissions and investing in clean energy technologies.
- **Public Engagement and Education:** Citizens must be informed and empowered to make sustainable lifestyle choices—such as using public transport, conserving electricity, and supporting green businesses.

The Crucial Role of Renewable Energy

Among the various strategies to mitigate CO₂ emissions, renewable energy stands out as the most promising and sustainable solution. Unlike fossil fuels, renewable energy sources such as solar, wind, hydro, geothermal, and biomass generate power with little to no greenhouse gas emissions. Their deployment can decouple economic growth from carbon emissions, paving the way for a low-carbon economy.

1. **Decarbonizing the Power Sector:** The power sector remains the largest contributor to global CO₂ emissions due to its dependence on fossil fuel-based electricity generation. Transitioning this sector to renewable energy can drastically lower emissions. Solar photovoltaic systems are now widely used in residential,

commercial, and industrial settings to generate clean electricity. Large wind farms are being developed in coastal and open inland regions to harness wind energy effectively. Hydroelectric power stations are also established along rivers and reservoirs to produce sustainable electricity with minimal emissions. In areas with geothermal activity, geothermal plants provide a stable and continuous power supply. Additionally, hybrid systems that combine solar, wind, and storage technologies are helping ensure a stable and reliable energy grid. As these technologies continue to evolve, the power sector can rapidly shift away from fossil fuels and lead the way toward a low-carbon future.

2. **Supporting Energy Access Without Emissions:** Access to reliable and clean energy remains a challenge in many rural and remote areas. Renewable energy offers decentralised and sustainable solutions to bridge this gap without adding to CO₂ emissions. In off-grid regions, solar home lighting systems provide electricity for basic household needs, improving quality of life. In hilly and forested areas, mini- and micro-hydropower systems offer a consistent power supply for small communities. Solar microgrids are also being installed in remote villages, supporting not only lighting but also powering schools, clinics, and small businesses. For cooking and heating, domestic biogas plants convert organic waste and agricultural residues into clean fuel, reducing the need for firewood and charcoal. Solar-powered irrigation pumps are helping farmers access water more efficiently, improving agricultural productivity without the use of diesel-based systems. These applications highlight how renewable energy can simultaneously address energy poverty and environmental sustainability.
3. **Reducing Dependence on Fossil Fuels:** Heavy reliance on fossil fuel imports exposes economies to global price fluctuations, supply shortages, and geopolitical tensions. Renewable energy, being sourced from local natural resources, strengthens energy independence and resilience. Countries are increasingly investing in solar and wind parks

to harness their own energy potential. Households and businesses are adopting rooftop solar systems to reduce their dependence on centralised power grids and lower electricity bills. Biomass energy, derived from locally available agricultural and organic waste, is also being utilised in power generation and industrial heating. The promotion of decentralised energy systems reduces transmission losses and provides more stable electricity in underserved regions. Furthermore, initiatives to manufacture solar panels, wind turbines, and battery storage systems domestically are creating local jobs and reducing the need for imported energy technologies. These measures collectively reduce carbon emissions while enhancing national energy security and economic stability.

4. **Enabling Clean Transportation:** The transportation sector is a significant and growing source of CO₂ emissions, largely due to the widespread use of petrol and diesel-powered vehicles. Transitioning to electric mobility is an essential part of the clean energy transition, but its true environmental benefit is realised only when the electricity used is generated from renewable sources. Electric vehicles (EVs), when powered by solar or wind energy, can drastically reduce transportation-related emissions. Solar-powered EV charging stations are emerging in urban and highway networks, enabling cleaner and greener

mobility. Public transportation systems such as metro trains and trams are also being integrated with renewable energy sources to further reduce their carbon footprint. In rural areas, the electrification of local transport with solar-charged vehicles is proving to be a sustainable alternative to fossil fuel-based systems. In parallel, the use of biofuels such as ethanol and biodiesel, produced from crops and organic waste, is also gaining traction as a renewable option in the transport sector. These developments demonstrate how renewable energy is reshaping transportation systems to become more sustainable and climate-friendly.

Conclusion

The current trajectory of CO₂ emissions, driven by industrialization and the overuse of natural resources, is unsustainable. The contrast between the 1990s and the present in terms of emissions underscores the urgency of action. While several mitigation strategies exist, the transition to renewable energy remains the most transformative and long-term solution.

Renewable energy not only addresses the root cause of carbon emissions but also fosters energy security, economic resilience, and environmental stewardship. By investing in and adopting clean energy systems, societies can reconcile the goals of development and ecological sustainability. The future hinges on our ability to embrace renewable energy – not just as an option, but as the foundation of global climate action.
