

EFFECTS OF ENERGY ON POLLUTION: AN OVERVIEW

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ABSTRACT

Nuclear energy has become an essential part of the low-carbon energy mix as countries work to battle climate change and cut carbon emissions. Even though fossil fuels are still the world's most popular energy source, reducing pollution and combating climate change require a shift to greener energy sources like nuclear power and renewable energy. In this paper, an overview of the effects of various energy sources on pollution is given in this review, which also looks at how they affect the quality of the air, water, and soil in addition to climate change.

INTRODUCTION

The correlation between the generation of energy and pollution is among the most urgent problems of our day (Sutton et al., 2013). The environmental effects of different energy sources have come under examination as civilisations work to fulfil rising energy demands. An overview of the effects of various energy sources on pollution is given in this review (Smil, 2017), which also looks at how they affect the quality of the air, water, and soil in addition to how they affect climate change.

FOSSIL FUELS

For millennia, the main sources of energy have been fossil fuels, such as coal, oil, and natural gas (Abas et al., 2015). But when they burn, a lot of pollutants, like carbon dioxide (CO₂), sulphur dioxide (SO₂), nitrogen oxides (NO_x), and particulate matter (PM), are released into the environment. These pollutants are involved in the production of smog, acid rain, air pollution, and respiratory illnesses. Furthermore, the extraction and transportation of fossil fuels may result in habitat damage and water contamination, among other forms of environmental degradation (Govorushko, 2013).

Historical Significance:

Fossil fuel discovery and use signalling a revolutionary period in human history. Since coal was first mined for heating and metallurgy in antiquity, it has powered scientific breakthroughs and urbanisation during the 18th and 19th centuries' Industrial Revolution (Ahuja, 2015). With the invention of the internal combustion engine in the late 19th century, oil—which was originally used for lubricating and lighting—completely changed the transportation industry. Long thought of as a byproduct of oil extraction, natural gas became a flexible energy source for industrial processes, heating, and electricity production in the 20th century (Smil, 2000). When combined, these fossil fuels transformed geopolitical dynamics, economies, and social structures, promoting swift global development and economic expansion (Hafner and Tagliapietra, 2020).

Environmental Implications:

Fossil fuels have a significant negative impact on the environment even though they are essential to human growth. Carbon dioxide (CO₂) and other greenhouse gases are released into the atmosphere

during the combustion of coal, oil, and natural gas, hence intensifying climate change and global warming (Wuebbles and Jain, 2021). Elevated temperatures cause disturbances to meteorological patterns, hasten the melting of polar ice, and jeopardise global ecosystems and biodiversity. In addition, burning fossil fuels releases air pollutants such particulate matter (PM), nitrogen oxides (NO_x), and sulphur dioxide (SO₂), which all contribute to smog formation, respiratory illnesses, and air pollution. There are environmental dangers associated with the mining, transportation, and processing of fossil fuels, such as disturbances to ecosystems, water pollution, and habitat destruction. Natural disasters including oil spills, gas leaks, and coal mining mishaps have wreaked havoc on ecosystems and populations (Iheriohanma, 2016).

Transitioning to Sustainable Alternatives:

There is tremendous push to switch to cleaner, renewable energy sources as the environmental costs of fossil fuels become more and more obvious (Heinberg and Fridley, 2016). With no greenhouse gas emissions or air pollution, renewable energy sources including solar, wind, hydroelectric, and geothermal power provide environmentally friendly substitutes for fossil fuels in the production of electricity (Rahman et al., 2022). Moreover, conservation and energy-efficiency initiatives can lower energy use and lessen their negative effects on the environment. But switching to renewable energy is not without its difficulties. These include infrastructural requirements, storage constraints, and intermittent nature of the energy. To overcome these obstacles and hasten the transition to a sustainable energy future, communities, businesses, and legislators must work together (Parra et al., 2017).

RENEWABLE ENERGY:

Fossil fuels can be replaced by greener energy sources, such as geothermal, hydroelectric, solar, and wind power (Rahman et al., 2022). When in use, these sources don't release any damaging pollutants or greenhouse gases into the atmosphere. However, there may still be environmental effects from the production, setting up, and upkeep of renewable energy infrastructure, including altered land use, displaced species, and material consumption. Moreover, some renewable energy sources have the potential to modify aquatic ecosystems and interfere with natural water flow, such as hydroelectric dams (Ding and Somani, 2010).

Solar Power:

With its endless supply and abundance, solar energy has great

potential as a clean energy source. Solar thermal systems use solar radiation to create heat or electricity, whereas photovoltaic (PV) technology directly turns sunlight into electricity (Khan and Arsalan, 2016). Concentrated solar power (CSP) facilities, solar farms, and rooftop solar panels provide flexible options for producing electricity on a utility-scale and decentralised basis. In addition to lowering dependency on fossil fuels, solar power enables local communities to produce their own clean energy, promoting resilience and energy independence (Newman et al., 2017).

Wind Power:

Using wind turbines to capture wind energy, wind energy has become one of the world's most popular renewable energy sources. Wind farms use the kinetic energy of the wind to create electricity (Tong, 2010). They can be found offshore or onshore. The efficiency and competitiveness of wind power have increased due to advancements in turbine technology, which include larger rotor diameters and taller towers. Together with solar energy and other renewable energy sources, wind energy provides a dependable, affordable option for producing electricity, resulting in a diversified energy portfolio (Ellabban et al., 2014).

Hydroelectric Power:

Water movement provides hydropower, a dependable renewable energy source, for a long time. The gravitational force of water is used by hydroelectric dams and run-of-river facilities to produce electricity. Small-scale hydroelectric projects offer decentralised options for rural electrification and off-grid communities, while large-scale dams offer enormous energy capacity. In spite of environmental worries about emissions from reservoirs and disturbance of habitats, contemporary hydropower technologies aim to reduce ecological footprints and maximise energy efficiency (Yüksel, 2010).

Geothermal Power:

Geothermal energy uses the heat from the earth to heat buildings and generate electricity. Steam or hot water reservoirs located beneath the surface of the earth are used by geothermal power plants to operate turbines and produce energy (Barbier, 2022). In areas without natural geothermal resources, geothermal heat pumps and enhanced geothermal systems (EGS) provide creative ways to capture geothermal energy. In addition to providing a steady supplement to sporadic renewable energy sources like sun and wind, geothermal power also produces consistent baseload electricity (Mock et al., 1997).

NUCLEAR ENERGY:

Although it is a low-carbon electricity source, nuclear power raises special safety and environmental issues. Nuclear power facilities produce radioactive waste, which needs to be managed and disposed of carefully even if they don't release greenhouse gases when they're operating. Nuclear mishaps can have disastrous outcomes, such as the release of radioactive materials into the environment and long-term environmental pollution. Examples of these accidents are the Fukushima and Chernobyl tragedies. Public opinion and the handling of radioactive waste continue to be major obstacles to the use of nuclear energy, even in spite of improvements in safety protocols and reactor technology (Zehner, 2012).

Low-Carbon Energy:

Using nuclear fission to create electricity, nuclear power emits fewer greenhouse gases than fossil fuels. Nuclear energy has become an essential part of the low-carbon energy mix as countries work to battle climate change and cut carbon emissions. Nuclear power facilities operate continuously, producing almost no carbon dioxide while producing dependable baseload electricity. Their ability to produce vast amounts of electricity with no environmental consequences renders them a compelling choice for diminishing dependence on fossil fuels and shifting towards a sustainable energy future (Brook et al., 2014).

Environmental Concerns:

Nuclear power has an influence on the environment even with its low carbon characteristics. Risks to human health and ecosystems arise throughout the nuclear fuel lifecycle, from uranium mining and processing to reactor operation and waste disposal. Reactor mishaps and radioactive spills endanger human safety and

environmental integrity, and uranium mining can damage land and water. Furthermore, there is currently no widely agreed-upon method for the efficient management of nuclear waste, making the long-term storage and disposal of radioactive waste problematic concerns. It is essential to address these environmental issues if nuclear energy is to be sustainable and widely accepted during the energy transition (Rashad and Hammad, 2000).

Safety Challenges:

Because nuclear accidents can have devastating repercussions, safety in the production of nuclear electricity is of utmost importance (Sagan, 1993). Events like the Fukushima Daiichi tragedy in 2011 and the Chernobyl disaster in 1986 highlight the possible risks connected to nuclear power facilities, such as reactor meltdowns, radiation leaks, and long-term environmental contamination. Even though sophisticated safety mechanisms and strict regulatory control are incorporated into modern reactor designs, maintaining the safe operation of nuclear reactors is still a top priority. Strict safety procedures, readiness for emergencies, and ongoing observation are necessary to reduce the likelihood of mishaps and safeguard the environment and public health (Heymann et al., 2007).

BIOENERGY:

Bioenergy has gained popularity as a sustainable energy source that has the potential to lower greenhouse gas emissions because it is sourced from organic materials like biomass and biofuels (Guo et al., 2015). However, the manufacturing and burning of biofuels may release particulate matter and volatile organic compounds (VOCs) into the atmosphere. Concerns regarding sustainability and biodiversity loss are also raised by the development of feedstocks for biofuel, such as corn and sugarcane, which can result in land-use changes, deforestation, and competition with food crops (Liu et al., 2014).

Biomass Utilization:

The principal fuel for the production of bioenergy is biomass, which is made up of organic resources such as forestry waste, agricultural wastes, and specially cultivated energy crops. Biochemical, biochemical, and physical processes can transform biomass into a variety of energy sources, such as heat, electricity, and biofuels. Compared to fossil fuels, biomass power plants produce less greenhouse gas emissions while producing electricity and heat through combustion or gasification. Additionally, biofuels made from biomass, like ethanol and biodiesel, provide renewable substitutes for traditional transportation fuels and aid in the fight against climate change and energy security (Demirbaş, 2001).

Waste-to-Energy:

Anaerobic digestion and landfill gas recovery are two other processes that turn organic waste streams into useful energy sources. This process is known as bioenergy. Food scraps and sewage sludge are processed via anaerobic digestion to create biogas, a renewable fuel high in methane. Biomethane can be produced from biogas and injected into natural gas pipelines or used as fuel for automobiles. Biogas can also be used for heating and electricity generating. Similar to this, methane emissions from the breakdown of organic matter in landfills are captured by landfill gas recovery systems, which then use the methane to produce heat or power. This lowers greenhouse gas emissions and lessens environmental pollution (Bharathiraja et al., 2018).

Carbon Neutrality and Sustainability:

The ability of bioenergy to attain carbon neutrality when derived from biomass feedstocks that are sustainably maintained is one of its main benefits (Srivastava et al., 2021). Bioenergy maintains a closed carbon cycle by recycling carbon from recently grown biomass, in contrast to fossil fuels, which release carbon stored over millions of years (Anastassiadis, 2016). Reforestation, agroforestry, and crop rotation are examples of sustainable bioenergy production techniques that can improve soil health, carbon sequestration, and biodiversity preservation while bolstering ecosystem resilience and mitigating the effects of climate change. To avoid unfavourable outcomes like deforestation, land degradation, and competition with food crops, it is necessary to carefully analyse land usage, resource availability, and environmental repercussions in order to ensure the sustainability of bioenergy (Miyake et al., 2012).

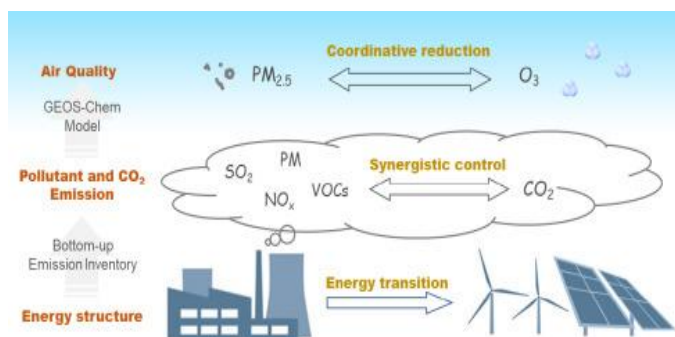


Figure: Coordinated effects of energy transition on air pollution mitigation and CO₂ emission (Yuan et al., 2022)

CONCLUSION:

Depending on the type of energy source and its lifecycle affects, energy has a variety of effects on pollution. Even though fossil fuels are still the world's most popular energy source, reducing pollution and combating climate change require a shift to greener energy sources like nuclear power and renewable energy. To guarantee sustainable development, however, the environmental effects of renewable energy technology must be properly controlled. In addition, boosting conservation initiatives and increasing energy efficiency are essential tactics for cutting pollution and minimising the environmental impact of energy production and use.

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