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Nuclear Energy as a Path towards Achieving Sustainable Development Goals in Pakistan

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Abstract

The research aims to explore the role of nuclear energy in achieving the SDGs in Pakistan and to trace the country's progress toward these goals so far, with particular focus on the energy sector, health and agriculture. The study highlights the intersection of sustainable development and global nuclear governance, which, when at cross purposes, constrain international cooperation and hinder progress toward the professed goals. Nations around the world have recognized the instrumental role of nuclear technology for achieving sustainable development goals, including poverty reduction, enhancing human health, meeting the growing demand for clean and affordable energy, etc. In line with the United Nations Sustainable Development Goals (SDGs) adopted in 2015, Pakistan's peaceful uses of nuclear technology are contributing significantly to promoting sustainable socio-economic development in the country. Pakistan has focused on power generation to bolster the country's power sector, support sustainable, climate-resilient agricultural practices, and improve health care. The study uses a qualitative research design based on thematic analysis of secondary data. The findings of this research show that Pakistan has made significant progress in peaceful uses of nuclear energy to reduce dependence on imported fuels, promote sustainable agriculture, ensure food security, and improve the quality of health care through cancer hospitals and research institutes established across the country by the Pakistan Atomic Energy Commission (PAEC). Besides these relevant domains, peaceful applications of nuclear technology also contribute indirectly towards other SDGs such as industrial innovation, sustainable communities, quality education, and international cooperation.

Key Words: Nuclear Energy, Sustainable Development Goals, Pakistan, PAEC, Peaceful Uses

Introduction

The UN member nations, in 2015, adopted an extensive development agenda known as the Sustainable Development Goals 2030 (SDGs) for the next fifteen years, which aims to protect the planet, reduce extreme poverty, improve human health care, and increase access to affordable, reliable, and clean energy (UNDP, 2013). The SDGs focus on three broad dimensions of sustainable development: Economic Development, social inclusion, and a sustainable environment (IAEA, 2016).

Sustainable development has become a pressing challenge for the international community (Aslam & Muzaffar, 2025; Christoforidis *et al*., 2021). A substantial portion (70%) of CO_2 emissions is attributed to fossil fuel burning and traditional means of energy production, which contribute to environmental degradation and harm resources for sustainable socio-economic development (Rehman *et al*., 2022). In such circumstances, the UN has emphasized the crucial role of science, technology, and innovation in achieving all goals and associated targets within the global development agenda (UNIDO, 2022). Nuclear energy plays a crucial role in the Energy-Water-Food nexus. Nuclear energy plays an indispensable role in sustainable socio-economic development; it is key to achieving other SDGs through International cooperation, and has a wide range of applications, such as in health and agriculture (IAEA, 2023a).

In this regard, nuclear energy is crucial in achieving SDGs through cost-effective, reliable, clean, and low-carbon energy production (Aslam & Muzaffar, 2025a; Buongiorno *et al*., 2018). Since all SDGs are interlinked, progress on any one of them, i.e., Clean and Affordable Energy, is directly related to progress on the others. The SDG-7, which aims to provide access to affordable, reliable, and clean energy, is vital to achieving progress across other SDGs. Additionally, nuclear technology has

peaceful applications in sustainable agricultural production, food security, and poverty reduction, improved health care, quality education, industrial innovation, and other areas of socio-economic development. This research focuses on the role of nuclear energy in achieving SDGs in Pakistan, and the progress made so far, to highlight the growing significance of nuclear technology and its peaceful applications in sustainable socio-economic development.

Given the challenges Pakistan faces, it is important to highlight the role of nuclear energy fields, including power generation, improving health care, sustainable agriculture, industrial innovation, quality education, and climate action through international partnerships. The applications of nuclear technology particularly help the country to boost the power sector by providing cost-competitive electricity to the national grid, ensuring the sustainability of the agriculture sector by increasing crop production, controlling diseases, improving water quality, and reducing environmental effects. Similarly, in the health sector, applications of nuclear technology improve disease diagnosis, prevention, and timely and effective treatment to reduce mortality rates.

For the sake of this study, relevant SDGs are grouped into four broader themes, concerning Pakistan, where nuclear energy plays a significant role: SDG 7 on Affordable and Clean Energy is addressed under the theme Nuclear Energy and Power Production, while the Fourth on Climate Action and Partnership for the Goals, which have interconnected roles and overarching challenges concerning the intersection of SDGs and Non-proliferation Regime. SDGs 1 and 2 on No Poverty and Zero Hunger are placed together under the theme Nuclear Energy and its Applications in Agriculture. The SDG 3 on Good Health and Well-being is addressed under Nuclear Energy, and its Applications in the Health Sector. However, before moving to each theme as a separate section, it is important to draw the analytical linkage between two International frameworks: UN SDGs that call for partnership and universal access to nuclear technology to address challenges that humanity faces, versus an inherently discriminatory non-proliferation regime that restricts cooperation even in peaceful uses of nuclear technology. The intersection of these two frames of analysis also helps in understanding challenges that developing countries like Pakistan face in the application of peaceful uses of nuclear technology in achieving the SDGs.

The paper offers a comprehensive overview and analysis of the broader role of nuclear energy in the country. It relies on graphical analysis with brief interpretation and analysis of primary and secondary data available to highlight the progress made by the country so far and find gaps to be addressed for future progress.

Analytical Framework

Nuclear Energy is relevant to Pakistan's development goals and is directly linked to the UN SDGs through its contribution to clean energy production, healthcare, water management, and sustainable agricultural practices. It provides reliable, secure, and low-carbon power production, supports climate action, and enables industrial innovation through peaceful use of nuclear technology. The peaceful applications of nuclear energy offer greater potential for environmental sustainability, social inclusion, and economic development, and carry minimal risk of misuse (IAEA, 2023b).

Nuclear energy is directly linked with SDG 7 on Clean and Affordable energy, and contributes directly or indirectly to a range of Pakistan's sustainable development goals (Shoukat, 2015). It is crucial in generating a clean, low-carbon, affordable, and reliable source of energy, and contributes towards SDG 13 on Climate Action. It works at the intersection of the Energy-water-food nexus, and contributes towards SDGs 1 and 2 of No Poverty and Zero-hunger. Similarly, nuclear technology plays a significant role in the agricultural sector. It plays a key role in ensuring food security through applications of nuclear energy in sustainable and climate-resilient agricultural practices and sustainable economic development. In the health sector, applications of nuclear technology have proven to be crucial in ensuring Good Health and Well-being (SDG 3), in terms of diagnosis and treatment, saving millions of lives. These peaceful uses of nuclear technology, as a core enabling factor, are crucial in sustainable development and achieving net-zero emissions through universal access, equity, and cooperation for achieving SDGs (Aslam & Muzaffar, 2025b; Omojola *et al*, 2024). However, the SGDs

7 (Clean Energy) and 13 (Climate Action), though highly interconnected and interdependent, are heavily reliant on SDG 17 on Partnership for the Goals.

Since nuclear governance has a direct and enabling link to sustainable development (WNA, 2026), it offers a unique convergence of opportunity, necessity, as well as challenges for cooperation, which arise from nuclear governance due to discriminatory non-proliferation norms versus an inclusive framework for achieving SDGs. The framework for achieving SDGs through peaceful uses and sustainable applications of nuclear technology intersects with the inherently discriminatory and exclusive non-proliferation regime, especially on the transfer of technology and low-carbon energy production, which undermines cooperation and hinders progress on SDGs, particularly for countries most affected by climate change despite their minuscule emissions in the developing world.

The key disparity arises from two international frameworks: equitable energy transitions and discriminatory non-proliferation norms, which work at cross purposes and hinder international cooperation (Khan, et. al., 2019; Sheikh, 2025). There is a direct link between sustainable development and fair nuclear governance to overcome the paradox of an enabler of decarbonization and a source of geopolitical contention (Qudrat-Ullah, 2025). Consequently, universal access, equity, and cooperation on SDG versus the discriminatory and exclusive norms governing the non-proliferation emerge as the greatest hurdle for developing nations like Pakistan to achieve SDGs through peaceful applications of nuclear technology.

Therefore, there is a greater need for a framework of international cooperation and collaboration, as per SDG 17 on Partnership for the Goals, between the developed world to contribute to addressing climate change and help the developing world that remains vulnerable to climate change despite its minimal share of emissions. This may comprise, but is not limited to, three important pillars: Trust building among the stakeholders, equitable technology transfer, and capacity building in developing nations (Qudrat-Ullah, 2025). In short, there is a greater need for "normalization" and "universalization" of the norms governing non-proliferation, especially the inherently discriminatory nature of the NPT and the exclusiveness of nuclear commerce regulated under the NSG, trust-building measures for sustainable energy transitions, and highlighting the role of nuclear energy in decarbonization and global energy security (Qudrat-Ullah, 2025).

Results and Discussion

Pakistan`s Peaceful Applications of Nuclear Technology

Despite constraints in global partnership and access to technology, Pakistan has, over the past seven decades, significantly utilized nuclear technology to achieve socio-economic growth. As a founding member of the International Atomic Energy Agency (IAEA), Pakistan has played a significant role in promoting the agency`s core mission. Since the formation of Pakistan Atomic Energy Commission (PAEC) in 1956, Pakistan has gradually developed its indigenous nuclear science and technology capacity, which has allowed the country to use nuclear techniques in various fields such as energy, agriculture, medicine, industry, water management, etc.

The applications of nuclear technology have overarching and interlinked contributions towards multiple SDGs. The following table shows the relevant areas of sustainable development in Pakistan where nuclear technology directly contributes towards these goals, while the subsequent sections further the discussion on these areas separately.

Table 1
Scope of Applications of Nuclear Technology in Pakistan and Contribution towards related SDGs.

Sr. No	Area	Applications	Contribution towards Relevant SDG(s)
1	Energy	Clean, affordable, reliable, climate-friendly electricity generation	Linked to all the SDGs, particularly contributes towards SDGs 7 (Clean Energy), 13 (Climate Action), and 17(Partnership for the Goals)

2	Agriculture	Mutation breeding, pest control, and food preservation	Contributes to SDGs 2 (Zero Hunger), 3 (Good Health and Well-being), 12 (Responsible Consumption and Production), 13 (Climate Action), 15 (Life on Land), and SDG 17 (Partnership for the Goals)
3	Industry	Radiography, gauging, and sterilization of medical supplies	Contributes to SDGs 7(Clean and Affordable Energy), 9(Industry, Innovation, and Infrastructure), 12 (Responsible Consumption and Production), and 8 (Decent Work and Economic Growth)
4	Security	Radiation scanning and detection	SDGs 16 (Peace, Justice, and strong Institutions), 11 (Sustainable Cities and Communities), 6(Clean Water and Sanitation), 8 (Decent Work and Economic Growth)
5	Water Management	Studying the origin and movement of water	SDGs 6 (Clean Water and Sanitation) and 13 Climate Action)
6	Health Sector	Diagnostics & therapy	SDGs 3 (Good Health and Well-being), 2 (Zero Hunger), and 6 (Clean Water and Sanitation)

Source: *Author's own compilation*

Nuclear Energy and SDG-7 (Clean and Affordable Energy)

Nuclear energy intersects at the Energy-water-food nexus and is directly linked with all the SDGs through the intersection of sustainable environment, inclusive societies, and economic development (IAEA, 2016). It primarily helps reduce energy-related emissions to prevent adverse health effects and serious impacts on the ecosystem, land, and water. Globally, the present energy portfolio is almost 80% reliant on fossil fuel burning, which is mainly responsible for pollution in the world (Holechek *et al*, 2022). Nuclear energy is an efficient and reliable source of energy because of its minimal carbon emissions as compared to other sources.

Pakistan faces a chronic energy crisis due to fossil fuel imports and reliance on thermal energy, which is a key source of GHG emissions and climate change. Nuclear energy offers the best possible alternative for low-carbon, clean, reliable, and affordable energy for socio-economic development. Similarly, Pakistan faces acute climate vulnerability, which impacts its agriculture and other interrelated domains of social and economic development at the Energy-Water-Food nexus. Whereby, the way Nuclear Energy has benefits across the range of intermeshed areas, it also meets the set of challenges of sustainable development across the economic, social, and environmental domains (El-Emam *et al*, 2024).

Nuclear energy offers the best and least expensive alternative due to its low ecological and carbon footprint to balance environmental and economic objectives, as both aspects of society have a direct correlation with energy. It provides an alternative energy solution to address energy security and climate change by reducing the phenomenal impact of population increase, economic growth, energy consumption, and environmental degradation, and replaces the traditional sources of energy production. It offers High energy return on energy investment, helps in the diversification of energy sources to shift towards a clean source of energy required to address the challenges emanating from climate change. Nuclear energy, being low-cost and environmentally friendly, is the best alternative to imported fossil fuel for Pakistan. Therefore, prioritizing nuclear energy helps diversify energy supply, reduces dependence on imported fossil fuels, and increases energy security (Hanif, et al., 2024; ehman, 2025).

Globally, the share of nuclear energy in the energy mix is around 10%, and it is the second-largest source of low-emission electricity after Hydropower (IEA, 2023). Pakistan's share of nuclear energy in its energy mix has increased significantly, growing from a minor contribution to 17 % of total energy produced in 2024. Currently, under PAEC, Pakistan operates six nuclear power plants for low-carbon, cost-effective energy generation. The existing six nuclear power plants, with a capacity of 3,530 MW, supplied 17,174 million units, contributing around 19.1% of the total energy produced during March-July FY2025 (Kiani, 2025). With the collaboration of China National Nuclear Corporation (CNNC), Pakistan is also building the 1200-MW Hualong One reactor in Chashma (C-5) (Kakar, 2023).

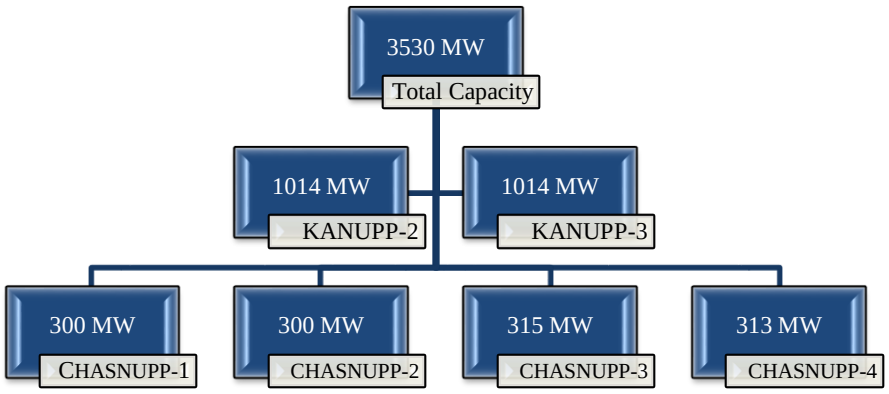


Figure:1 Pakistan`s Installed Capacity of Nuclear Energy Source: Pakistan Economic Survey 2024-25

There is a slight shift in the percentage share of different sources of electricity generation over the decades. Thermal still has a significant contribution to electricity generation in the country despite the decline of its percentage from 62% during Jul-April FY2021 to 51 % during Jul-April FY2022. From July 2020 to March 2021, NPPs generated 2,530 megawatts of energy. From July 2021 to March 2022, the capacity of NNP was increased by 39% to 3,530 megawatts, producing 12.5% of total energy production in Pakistan (Economic Survey of Pakistan, 2024-25). The contribution of nuclear power to the national grid rose to 17% in 2024, from 16.2% in 2023(FAO, 2018). During July-March FY 2025, nuclear energy contributed 19% to the electricity generated during this period (IAEA, n.d)

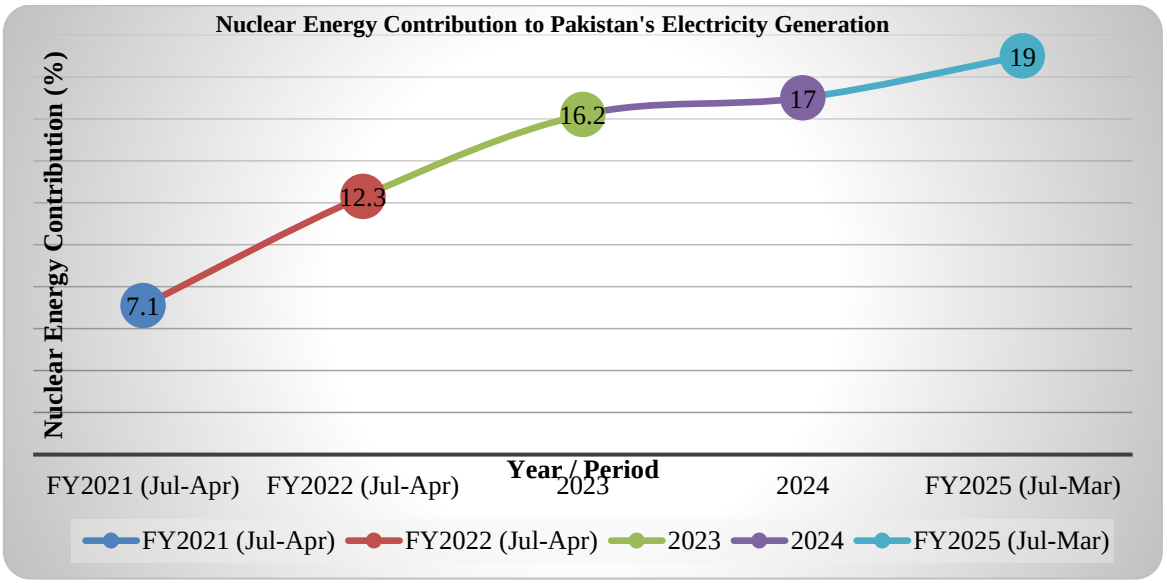


Figure 2 Nuclear Energy Contribution to Pakistan's Electricity Generation

Nuclear power is playing a key role in addressing the energy supply by diminishing energy import reliance, which may enable diversion of financial resources to climate action. Given its efficient role in the power sector, Pakistan has planned to increase the contribution of nuclear energy from 3350 MWe to 8,800 MWe by 2030, and to increase it to 40,000 MWe by 2050, as per the Energy Security Plan 2005. However, the country faces significant challenges to foreign direct investment and international cooperation in the expansion of its power production capacity due to technology denial and discriminatory non-proliferation regimes.

Sustainable Agriculture Practices (SDGs 1-No Poverty and 2-Zero Hunger)

Since there is a strong correlation between poverty and income levels with access to electricity, especially in low-income countries, nuclear energy plays an important role in achieving SDGs 1 and 2,

and contributes towards related areas. Similarly, nuclear technology applications play an important role in food security, healthy growth, and poverty reduction through sustainable agricultural practices.

Poverty and hunger have become global concerns and key indicators of poverty, malnutrition, and starvation, as some 821 million people struggle with one meal a day, while undernutrition results in taking the lives of around 3.1 million children annually (Hanif, et al., 2024a). This is further exacerbated by the impacts of climate change on sustainable sources of food and nutrition in climate-hit countries in the developing world. International efforts focus on addressing challenges to sustainable agricultural practices by applying nuclear and isotopic techniques to ensure food security and poverty eradication, including green farming, higher food harvests, high-quality fruit and vegetable production, and healthier livestock (FAO, 2010). Recent years have witnessed a considerable decline in the production of cotton as well as the area sown, mainly due to abiotic stress and extreme weather conditions. Climate change has affected the cotton industry, resulting in a significant decline in yields (IAEA, n.d). Climate change is resulting in the decline of crop production. It is predicted that by the year 2040, there will be a rise of 3°C that will result in a great loss of wheat production in Asian countries (Muzamil, 2010), and the loss to Pakistan could be even greater.

Agriculture in Pakistan contributes 20 % of its GDP, and is home to some 44% employment. Despite an agrarian economy, it faces acute poverty, hunger, malnutrition, and stunted growth due to food insecurity. Its agriculture faces challenges such as climate vulnerability, increasing food demand due to overpopulation, high cost of crop production, water scarcity, low yield and productivity, limited land cultivation, and animal and crop diseases. Application of nuclear technology and international cooperation play a crucial role in addressing these challenges through sustainable agricultural practices, increased productivity, pest control, improved breeding and seed modification, environmental protection, and food preservation. (Hanif, et al., 2025, Rana, 2018)

In such a circumstance, peaceful nuclear applications are a more sustainable alternative to advance socio-economic progress. PAEC is utilizing nuclear energy to improve the productivity of the agriculture sector. It has introduced modern methods that are helping in discovering new varieties of crops and preserving food grains and fruits. In addition, it helps in determining the optimum fertilizer uptake for plants under different soil conditions (Jalil, 2025).

Pakistan has established agricultural institutes under the PAEC (See Table 2) to improve the productivity of the agriculture sector by introducing new varieties of crops, technologies to control pests, plant nutrition, and management of water. PAEC is collaborating with the IAEA and the Food and Agriculture Organization of the UN to improve cotton production through long-term technology transfer and capacity-building programs, training, workshops, and providing training to Pakistani scientists in plant breeding techniques on developing cotton varieties resilient to drought and extreme temperatures.

Pakistan Atomic Energy Commission (PAEC) pays considerable attention to the promotion of nuclear and isotopic techniques for high yield, adaptability, and performance stability, tolerance to diseases and abiotic stress, e.g., drought, heat, cold, and salinity (PAEC, Webinar Report, 2025). It also collaborates with the IAEA with particular focus on improving crop yield, pest control, livestock health, and food safety (Fatima, 2025). Some of the techniques used in climate-resilient and sustainable agricultural practices are induced mutation for disease-resistant crops, mutation breeding for desirable plant characteristics, mutability, genetic manipulation, and genetic analysis.

Table: 2
Pakistan's Established Agricultural Research Institutes and Their Contribution

Sr. No	Institute	City/Year	Research areas	Contribution SDG(s)
1	Nuclear Institute of Agriculture (NIA)	Tando Jam (1962)	Crop Mutation breeding, pest control, soil fertility, and Horticulture.	**SDG-2** (Zero Hunger, (**SDG-13** (Climate Action), and **SDG-15** Life on Land
2	Nuclear Institute for Agricultural and Biology (NIAB)	Faisalabad (1972)	Crop improvement, plant pathology, entomology, and livestock research	**SDG-2** (Zero Hunger), **SDG-3** (Health and Wellbeing), **SDG-12** (Responsible consumption and production)

3	Nuclear Institute for Food and Agriculture (NIFA)	Peshawar (1982)	Food Irradiation, Stress-tolerant crops, isotope hydrology, and animal health.	**SDG- 2** (Zero-Hunger), **SDG-3** (Health and Well-being), and **SDG-6** (Clean Water and Sanitation)
4	National Institute for Biology and Genetic Engineering (NIBGE)	Faisalabad (1994)	Genetic Engineering, industrial biotech, environmental biotech, and medical biotech.	**SDG-9** (Industry, innovation, and infrastructure), **SDG-3** (Health and Well-being), and **SDG-12** (Responsible Consumption and Production)

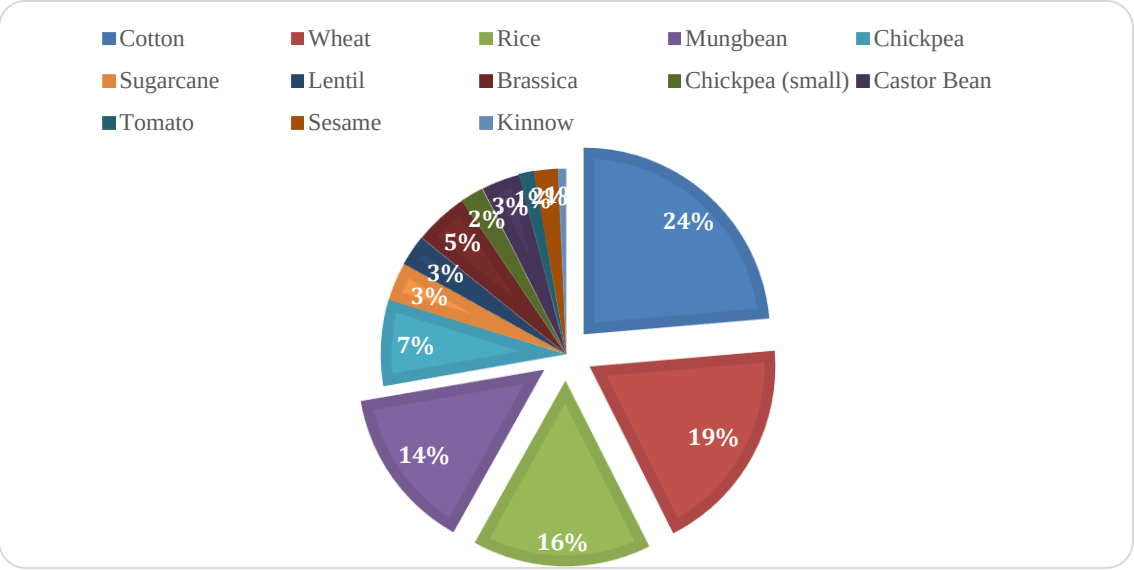


Figure 3 Major Crops varieties

The PAEC has developed some 150 crop varieties as of 2025, out of which 76 are currently used in the forms as contribution towards sustainable and climate-resilient agriculture practices (Economic Survey of Pakistan, Ibid).

The abovementioned table suggests that applications of nuclear technology in agriculture research have a cumulative contribution towards SDG-2 on Zero Hunger and Health and Well-being, which directly support the progress on SDG-1 No Poverty. These institutes play a significant role in ensuring food security, health, climate resilience, and innovation in agriculture, and serve as engines driving Pakistan's progress towards multiple SDGs.

Nuclear Technology and SDG 3 (Good Health and Well-being)

Health is a key indicator of a sustainable economy, and a healthy society correlates with economic growth, vice versa. Therefore, the health sector plays a crucial role in achieving SDG 3 on Good Health and Well-being for sustainable socio-economic development in the country. SDG-3 ensures good health and well-being, and seeks improved health care, universal health coverage, and access to safe, affordable, and effective medicines and vaccines (Economic Survey of Pakistan, Ibid). Nuclear Energy plays a significant role in healthcare, including diagnoses, treatment, and disease prevention, through medical Imaging techniques, cancer therapy, sterilization of medical equipment, and nutrition monitoring.

Cancer and cardiovascular disease cause the deaths of millions of people across the world. Nuclear techniques in the field of medicine have brought a remarkable advancement in the treatment of cancer, which was once not curable. Cancer is now treated more efficiently and diagnosed at an early stage through nuclear techniques such as radiation and radionuclides. Studies have shown that nuclear applications in health give productive results, especially in treating cancer, which is one of the leading causes at the global level. Greene & Wilkinson (2015) argue that the nuclear technique is an effective instrument for cancer disease. Nuclear medicine helps diagnose a disease. Also, it plays a key role in

treatment and prognosis. It is specifically effective for early-stage diagnosis of breast cancer. Another study by Richard (2017) reveals that nuclear technology is used as an effective instrument for diagnosis and therapy. He argues that nuclear technology has been a functional imaging tool over the decades.

Over 50 million nuclear medicine procedures are performed around the world annually with an increasing demand of radioisotopes. (World Nuclear Association, 2026) Under PAEC, over 1.0 million procedures are carried out in AECHs, and about 40,000 new cancer patients are treated annually (Pakistan Atomic Energy Commission, 2026), following the IAEA's motto, "Cancer Care for All".

Pakistan is using nuclear techniques to improve the quality of the health sector and provide people access to cancer treatment. PAEC has established 19 cancer hospitals across the country that are providing diagnostic and treatment facilities (Pakistan's NDCs, 2022-23). Apart from cancer, these hospitals provide treatment to patients suffering from thyroid, liver, kidney, hypertension, and brain tumors. Since the cancer treatment is very costly and the general public finds it difficult to afford, PAEC provides facilities either free or at affordable rates (Ishaq and Khan, 2024). Additionally, these hospitals are contributing to the national cancer awareness and prevention program by spreading awareness about cancer among the general public. For this purpose, PAEC hospitals, in collaboration with medical institutions and NGOs, organize seminars, workshops, and conferences. (PAEC)

Table 3
Nuclear Health Infrastructure in Pakistan (as of 2025-26)

Sr. No	Facility Type	Numbers	Key Services	Contribution-SDG(s)
1	Nuclear Medicine Centers	51	PET/CT, SPECT diagnostic Imaging	**SDG-3 target 3.4** reduce premature mortality from NCDs, and **SDG-10 and target 10.2** (promote social inclusion through diagnostics in public hospitals)
2	Oncology Centers	49	Radiotherapy, Chemotherapy, Cancer surgery	**SDG-3 target 3.8** (Achieve universal health coverage), and **SDG-10 target 10.3** (ensure equal opportunity and reduce inequalities)
3	Atomic Energy Cancer Hospitals (AECHs)	19	Specialized Cancer Treatment and Radiotherapy	**SDG-1 target 1.4** (equal access to essential services) and **SDG-3 target 3.c** (increase health workforce)
4	Research and Training Centres	Multiple	Radiotherapy, isotope Production, and medical research	**SDG-4 target 4.3** (equal access to affordable technical education), and **SDG-9 target 9.5** (enhance scientific research and innovation)

Overall, the health facilities across the country collectively strengthen SDG 3 (Health and Well-being), advance SDG 4(Quality Education), support SDG 9 (Innovation and infrastructure), and promote SDG 10 (Reduced Inequality) and SDG 1(No Poverty). All in all, these facilities reduce disease burden, expand healthcare equity, and build national expertise, which position Pakistan health sector as a driver of sustainable development.

Pakistan is making efforts to achieve SDG-3 (good health and well-being) and reduce the burden of diseases faced by the country. Cancer has become a more prevalent disease in Pakistan. Breast cancer is growing more common in Pakistan, which has the region's highest rate. Besides, head and neck cancer, lung cancer, urinary tract cancer, and liver cancer are registered cases in Pakistan. By offering patients cutting-edge diagnostic and therapeutic services, either for free or at heavily discounted fees, AECHs considerably contribute to the achievement of SDG-3 (Good health and well-being). Furthermore, these institutions seek to raise awareness of cancer and the value of early detection and treatment. Pakistan is broadening the use of nuclear technology in the medical field. Pakistan has also set up a cyber-knife facility in NORI, Islamabad, to treat cancer patients through this method. NORI has been officially designated as an "Anchor Centre" by the IAEA. (Khan, 2023) Therefore, Nuclear Energy plays a transformative role in healthcare in Pakistan, especially in cancer care and diagnostics, making it an emerging leader in the region in nuclear medicine.

Nuclear Energy: Climate Action (SDG 13) and Partnership for the Goals (SDG 17)

As the above discussion suggests, clean energy offers the best possible alternative to replace fossil fuel imports, reduce GHG emissions, and ensure sustainable economic development. Nuclear

energy plays a significant role in Pakistan's Nationally Determined Contribution (NDCs) and Climate Action (SDG 13) by providing low-carbon energy production; however, its expansion is tightly linked to the Partnership for the Goals (SDG 17) and constrained by non-proliferation concerns that limit access to nuclear technology and green financing.

Even though nuclear energy is crucial in climate mitigation, it is highly dependent on the Partnership for the Goals, which restricts the expansion of Pakistan's current power production capacity due to technology denial regimes. Currently, Pakistan is on the way to achieving its Energy Goals of 4,800 MW by 2030 with KANNUP 3 and Chashma 5 under construction; however, to meet its energy target of 2050 and support climate action, it would need to almost double the existing power production capacity to meet 8,800 MW by 2050.

Nuclear energy is vital in achieving climate goals in Pakistan, but its success is highly dependent on trust-building and partnerships, while overcoming barriers posed by the discriminatory non-proliferation norms. The following table briefly analyzes the intersection of two areas of international cooperation that heavily rely on each other but are often at cross purposes due to challenges and limitations of international cooperation the field of nuclear energy, to help mitigate the effects of climate change, especially in developing countries.

Table 4
Role of Nuclear Technology in Climate Action and Challenges of Partnership for the Goals

Sr. No	Nuclear Technology	SDG 13 (Climate Action)	SDG 17 (Partnership for the Goals)	Challenges
1	Contribution	Low-carbon and cost-effective Electricity production	Bilateral cooperation with China on NPPs for power production.	Technology denial regimes
2	Benefits	Energy Security and Reduced Emissions	Capacity building and recognition through cooperation with the IAEA	Difficulties with Green Financing
3	limitations	Progress depends on the expansion of existing power production capacity	Limited Global Partnership	Discriminatory treatment due to non-NPT status

Conclusion

Nuclear energy plays a transformative role in achieving SDGs as a contribution towards broader sustainable socioeconomic development in Pakistan. Pakistan has, despite discriminatory and biased global nuclear governance, harnessed nuclear energy to advance its development goals beyond the bomb, within its own limited resources and indigenous expertise. Development of nuclear energy helps Pakistan directly contribute towards six of the SDGs (1, 2, 3, 7, 13, and 17) and indirectly contributes towards five more of the SDGs (4,5 8, 9, 16), their related targets, and improvement on their indicators.

This research suggests that nuclear energy plays a pivotal role in the country`s progress under the framework of the SDGs by promoting carbon-free energy production, sustainable economic growth, quality healthcare, and climate-resilient agricultural practices. Since all seventeen SDGs are interlinked, nuclear energy helps Pakistan achieve SDGs, meet relevant targets, and work towards a sustainable future. The range of facilities and institutes developed by PAEC offers a glimpse into the development of nuclear energy in crucial sectors such as Energy, Health, and Agriculture, which indirectly contribute towards climate mitigation and adaptation.

Institutions are contributing to human resource development by providing quality education through PAEC`s high-ranked educational institutes. Particularly, the Centers of Excellence (CEs) and Research and Development (R&D) may help in promoting a culture of sustainable growth and development, so that the learning experience for the field of peaceful applications of nuclear technology can be applied in the remaining areas such as Reduced Inequalities (SDG 10), Clean Water and Sanitation (SDG 6), Sustainable Cities and Communities (SDG 11), Responsible Consumption and Production (SDG 12), Life Below Water (SGD 14), Life on Land (SDG 15), etc.

The research suggests that nuclear power is a viable option for Pakistan for bolstering progress on SDGs and ensuring energy security in the long term by offering a stable, consistent, and low-carbon supply of power. Pakistan, whose energy needs are ever rising, nuclear energy provides a steady

electricity supply and, at the same time, limits the environmental effects. Furthermore, expanding the capacity of nuclear energy will reduce the country`s dependence on imported fossil fuels, which places strong pressure on the economy. Increased reliance on foreign fuel pressures foreign exchange reserves and national currency to an extent that the energy sector is susceptible to international market price fluctuations and disruptions to supply. (Sun at al., 2023) This, as a result, manifests as load shedding, higher electricity prices, and slower industrialization, ultimately affecting economic stability and growth. Hence, indigenously generated nuclear energy helps enhance a more reliable and sustainable energy future by diversifying the energy mix and reinforcing the domestic generation base.

Nevertheless, there are also serious external barriers to the development of nuclear energy capacity, especially the lack of international cooperation and discrimination of export control regimes. Pakistan, despite a remarkable record of nuclear safety and security, has been denied access to international support. The discriminative and selected role of these regimes poses challenges in expanding the role of nuclear technology for SDGs, despite its role being recognized globally. These restrictions not only impair the potential of developing states to increase clean and reliable energy sources but also destabilize the increased global production of clean energy to support the SDGs. Lastly, there is a greater need for international collaboration for inclusive, universal, and sustainable development through applications of nuclear technology.

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