



**RESEARCH ARTICLE**

**Development of Nuclear Energy in Pakistan: Prospects and Challenges**

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Article Info	Abstract
<p><b>Keywords:</b> Energy Crisis, Nuclear Energy, Pakistan, Sustainable Development Goals, Climate Change</p>	<p><i>Rapidly increasing population and economic growth are significant factors in Pakistan's precipitous expansion in energy demands. Most of the nation's power generation infrastructure comprises conventional energy sources, including coal, biomass, gas, and oil. These sources are detrimental to the environment and lack sustainability. Nuclear power is a clean energy source providing a sustainable alternative to thermal power sources. Moreover, Pakistan is facing a significant economic challenge in the form of independent power plants (IPPs). These IPPs are costly energy sources and are not sustainable for long-term projects. Additionally, they are a major contributor to environmental degradation, a big issue because of the current climate situation in Pakistan. The research question addressed in this paper is: How is the development of nuclear energy beneficial for Pakistan in mitigating climate change and addressing economic distress? The study identifies the provision of environmentally favorable clean energy sources with zero carbon emissions and cost-effectiveness in production and operation as prospective benefits of energy production in Pakistan. The problems linked with nuclear energy progress include a lack of international cooperation, inadequate financial resources to sustain the expansion of nuclear energy initiatives, long construction timelines, and the requirement for collaboration with other countries. Furthermore, the study analyzed the policy implications and constraints associated with nuclear energy production in Pakistan.</i></p>

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## Introduction

Energy development practitioners and policymakers have debated the demand for using nuclear energy since the middle of the last century, mainly for electricity generation.<sup>1</sup> There has been a growing interest in developing sustainable energy generation in recent times, and nuclear power is a viable and sustainable solution for fulfilling the increasing energy requirements of countries worldwide.<sup>2</sup> As developing nations strive to achieve economic growth, improve living standards, and address energy security concerns, the prospects of developing nuclear energy have become a topic of significant importance.<sup>3</sup> Developing countries face challenges that include a lack of technology, a lack of financial investment, long timelines, dependence on fossil fuels, and short-term plans.<sup>4</sup> Nuclear energy production offers a chance to counter these issues by supplying constant, carbon-free electricity, thus fulfilling the demand and supply gap. However, in the decision to pursue nuclear energy, any state has to take several factors into consideration, including a country's technological readiness to adopt nuclear energy production, economic feasibility, safety and security

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<sup>1</sup> Rizwana Abbasi, "Nuclear Energy Security: Emerging Trends and Pakistan," *Policy Perspectives* 13, no. 2 (2016): 167–92, <https://doi.org/10.13169/polipers.13.2.0167>.

<sup>2</sup> International Energy Association, "Renewable electricity growth is accelerating faster than ever worldwide, supporting the emergence of the new global energy economy - News," Official website, IEA, December 2021, <https://www.iea.org/news/renewable-electricity-growth-is-accelerating-faster-than-ever-worldwide-supporting-the-emergence-of-the-new-global-energy-economy>.

<sup>3</sup> John P. Banks and Kevin Massy, "Nuclear Power in Developing Countries? Let's Talk about It," Brookings, December 2012, <https://www.brookings.edu/articles/nuclear-power-in-developing-countries-lets-talk-about-it/>.

<sup>4</sup> Oluleke O. Babayomi, Davo A. Dahoro, and Zhenbin Zhang, "Affordable Clean Energy Transition in Developing Countries: Pathways and Technologies," *iScience* 25, no. 5 (May 20, 2022): 104178, <https://doi.org/10.1016/j.isci.2022.104178>.

concerns, and public acceptance, which play an important part in deciding whether to pursue nuclear energy or not.

Pakistan, a developing country, has been facing an energy crisis for a long time due to different reasons like increasing energy demand, increasing electricity costs, and a shortfall in energy production. Also, recent short-term policies have put the country at the helm of a new energy crisis, where supply has far exceeded demand. Because of the agreement with IPPs, the cost of electricity has skyrocketed, resulting in a new issue for the country.<sup>5</sup> As a result, Islamabad must pursue long-term policies to tackle these issues and form a sustainable solution to the energy and climate crises. It should prioritize energy production through carbon-free means, such as wind, solar, and hydro energy, instead of non-renewable sources, including oil, gas, and coal.<sup>6</sup>

The prospects of expanding nuclear energy in Pakistan are numerous. One advantage for Pakistan is the existing nuclear energy setup, which is over fifty years old. When implemented, this has the potential to decrease reliance on expensive energy infrastructure such as rental power plants.<sup>7</sup> Another prospect of adopting nuclear energy is energy production source diversification. Nuclear power can diversify Pakistan's energy production sources, which are currently dependent on traditional sources like coal and gas.<sup>8</sup> Nuclear energy also has the benefit of producing cheap electricity

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<sup>5</sup>NEPRA, "NEPRA Power Policies," Official website, 2023, <https://nepra.org.pk/Power%20Policies.php>.

<sup>6</sup> Nadir Ali, "Nuclear Energy in Pakistan: Harnessing the Power, Confronting the Complexities," Modern Diplomacy (blog), April 19, 2023, <https://modern.diplomacy.eu/2023/04/19/nuclear-energy-in-pakistan-harnessing-the-power-confronting-the-complexities/>.

<sup>7</sup> Sher Ali Kakar, "Nuclear Energy and Pakistan's Economic Challenges," *South Asian Voices*, February 23, 2023, <https://southasianvoices.org/nuclear-energy-and-pakistans-economic-challenges/>.

<sup>8</sup> Summaiya Malik, "Facing a Climate Crisis, Nuclear Energy Can Be a Viable Option for Pakistan," *South Asian Voices*, July 14, 2022, <https://southasianvoices.org/facing-a-climate-crisis-nuclear-energy-can-be-a-viable-option-for-pakistan/>.

over time. Although the initial investment is high, but the operational expenses of running these nuclear reactors are far less compared to fossil fuel-based power plants.<sup>9</sup> This makes the energy ideal for use over the period at a reduced cost compared to the traditional sources that the country is currently using.

However, certain challenges are also associated with the adoption of nuclear energy. One of the challenges is the safety risks associated with Nuclear Power Plants (NPPs).<sup>10</sup> Ensuring the safety and security of nuclear reactors and management of residue waste disposal is of utmost importance, where adequate safety standards and regulatory structures must be practiced to mitigate the risk concerning the environmental impact of the waste caused by nuclear dumping. Pakistan has a robust nuclear safety and security regime, which has been acknowledged worldwide. In the words of DG IAEA, Rafael Grossi, "Pakistan has a world-class and impeccable nuclear safety record."<sup>11</sup> Pakistan also has an independent nuclear power regulator known as the Pakistan Nuclear Regulatory Authority (PNRA). Other concerns include the high initial cost of setting up NPPs and the time required for building a new plant.

This research explored the prospects, challenges, and potential benefits of nuclear energy production in Pakistan. The research question addressed in this paper is: How is the development of nuclear energy beneficial for Pakistan to help mitigate climate change and address economic distress? Pakistan's growing population and increasing energy demand make nuclear energy an

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<sup>9</sup> World Nuclear Association, "Nuclear Power Economics | Nuclear Energy Costs," Official website, August 2022, <https://world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power.aspx>.

<sup>10</sup> Daniel Poneman, *Nuclear Power in the Developing World* (Taylor & Francis, 2023).

<sup>11</sup> "IAEA Chief Lauds Pakistan's 'impeccable' Nuclear Safety Record," *The Express Tribune*, February 16, 2023, <https://tribune.com.pk/story/2401545/world-class-iaea-chief-lauds-pakistans-impeccable-nuclear-safety-record>.

attractive option for ensuring energy security along with other clean energy production sources.

The research methodology utilized for this paper is qualitative, with data collected from secondary sources. The qualitative research allowed for an in-depth exploration of the literature on Pakistan's challenges and advantages of nuclear energy development. The research study helped in exploring the need to further a nuclear energy program in Pakistan while addressing the challenges associated with the program. The study also highlights some of the prospects of nuclear energy production, including upgrading existing setups, building or procuring new plants, and applying technology to the existing system to reduce power and line losses.

### **Pakistan's Nuclear Energy Profile**

Pakistan's nuclear program commenced in the early years when nascent and the state was cognizant of the importance of science and technology for its development. Pakistan's nuclear energy journey originated with the establishment of the Pakistan Atomic Energy Commission (PAEC) in 1956, under the leadership of Dr. Ishtar Hussain Usmani. In 1962, under the US initiative of the "Atoms for Peace" program, Pakistan received its first nuclear reactor, the five-megawatt "Pakistan Atomic Research Reactor" (PARR-1).<sup>12</sup> Throughout the 1960s and 1970s, Pakistan faced a growing energy deficit due to rapid industrialization and urbanization. The energy crisis became even more pronounced during the global oil market shocks of the 1970s, compelling Pakistan to seek alternative and indigenous sources of producing energy to fulfill its electricity demand. In 1962, there was an agreement between the governments of Pakistan and Canada to purchase heavy water reactors. The commissioning of the Karachi Nuclear Power Plant (KANUPP-1)

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<sup>12</sup> Feroz Khan, *Eating Grass: The Making of the Pakistani Bomb*, 1st edition (Stanford, California: Stanford University Press, 2012).

in 1972 marked a significant milestone as Pakistan became one of the early adopters of nuclear energy in the developing world. Pakistan has installed seven nuclear power plants, six of which are currently operational, KANUPP-1 decommissioned, and one new plant in the pipeline.

### **Share of Nuclear Power in Pakistan's Energy Production**

From July to March 2022-23, Pakistan's energy production capacity has been 94,121 GWh. This period's share of nuclear energy production has been 19,739 GWh or 21%. In December 2022, the share of power supplied by the Nuclear Power Plants (NPPs) was 27% of the total electricity supplied to the national grid, more than any other sector. The share of energy production through nuclear power has risen at a very rapid pace. On the other hand, in FY-22, the power production through thermal plants was 74,862 GWh or 60.9% of the total consumption. The share of thermal power in electricity generation capacity in FY-23 has come down to 43,526 GWh or 46.2%.<sup>13</sup> The rise of electricity production through nuclear energy from 8,101 GWh to 19,739 GWh within four years reflects Pakistan's move from thermal energy sources to nuclear energy (see Table 1). Also, the reduction in energy generation through thermal power sources shows Pakistan's commitment to achieving its goals and objectives for cleaner and affordable energy sources.

In July 2023, Pakistan undertook the ground-breaking ceremony of an eighth NPP – CHASNUPP-5. It will add 1200 MWe to the national grid.<sup>14</sup> The Government of Pakistan has set a target

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<sup>13</sup> “Ministry of Finance Government of Pakistan,” accessed July 7, 2023, [https://www.finance.gov.pk/survey\\_2023.html](https://www.finance.gov.pk/survey_2023.html); “Ministry of Finance Government of Pakistan |,” accessed July 10, 2023, [https://www.finance.gov.pk/survey\\_2022.html](https://www.finance.gov.pk/survey_2022.html).

<sup>14</sup> “PM Breaks Ground on 1200-Megawatt Chashma-5 Nuclear Power Plant,” accessed July 17, 2023, <https://www.thenews.com.pk/latest/1090447-pm-breaks-ground-on-1200-megawatt-chashma-5-nuclear-power-plant>.

of installing 40,000 MWe of nuclear power by 2050.<sup>15</sup> To achieve these objectives, sites are being acquired, and the PAEC is intensifying efforts.<sup>16</sup> Nuclear energy helps Pakistan reduce GHG emissions and provides a substitute for imported energy sources. Almost 40% of Pakistan's primary energy supply is imported oil, gas, and coal.<sup>17</sup> This can help Pakistan by providing cheaper electricity and saving revenue that can be utilized for clean energy projects.

**Table 1:** Share of Nuclear Energy in Electricity Generation of Pakistan<sup>18</sup>

<b>Share of Nuclear Energy in Fiscal Year</b>	<b>Share of Nuclear Energy in Power Generation (GWH)</b>	<b>Percentage of Nuclear Energy in Power Generation</b>
FY-2020	8,101	7.62%
FY-2021	8,218	7.22%
FY-2022	15,182	12.4%
FY-2023	19,739	21.0%

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<sup>15</sup> Sana Jamal, "Pakistan Plans 40,000MW Nuclear Energy by 2050 to Meet Electricity Demands," February 26, 2022, <https://gulfnews.com/world/asia/pakistan/pakistan-plans-40000mw-nuclear-energy-by-2050-to-meet-electricity-demands-1.86031513>.

<sup>16</sup> "[Ministry of Finance Government of Pakistan,]" 2.

<sup>17</sup> <https://tribune.com.pk/author/190>, "Pakistan a Major Fossil Fuel Importer," *The Express Tribune*, January 6, 2023, <https://tribune.com.pk/story/2394481/pakistan-a-major-fossil-fuel-importer>.

<sup>18</sup> "[Ministry of Finance Government of Pakistan];" "Ministry of Finance | Government of Pakistan."

**Table 2:** List of Nuclear Power Plants of Pakistan<sup>19</sup>

<b>Nuclear Power Plant</b>	<b>Gross Capacity (MWe)</b>	<b>Construction Start</b>	<b>First Grid Connection</b>
Chashma Nuclear Power Plant-1	300	1993	2000
Chashma Nuclear Power Plant-2	300	2005	2011
Chashma Nuclear Power Plant-3	330	2011	2016
Chashma Nuclear Power Plant-4	340	2011	2017
Karachi Nuclear Power Plant-1	125	1966	1972 (Decommissioned: 2021)
Karachi Nuclear Power Plant-2	1,100	2015	2021
Karachi Nuclear Power Plant-3	1,100	2016	2022
Chashma Nuclear Power Plant 5	1,200	2023	-

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<sup>19</sup> “Nuclear Power in Pakistan - World Nuclear Association,” accessed October 16, 2024, <https://world-nuclear.org/information-library/country-profiles/countries-o-s/pakistan>.

## Atomic Power Generating Authority

The task of generating energy from nuclear power is vested in the PAEC, which is solely responsible for producing power from nuclear plants in Pakistan. The PAEC operates and maintains these sites under the authority of the PNRA, which oversees the autonomous and independent regulatory organization. The PNRA has issued licenses to the PAEC for constructing nuclear reactors in the country. Under these licenses, the PAEC has established reactors in different locations in Pakistan. All of Pakistan's nuclear power plants are under IAEA safeguards.<sup>20</sup>

Apart from the PAEC, Pakistan's national security council introduced a new body, the National Command Authority (NCA). The newly formed body was given a mandate to make decision-making regarding nuclear strategy, doctrine, and the employment of nuclear technology for non-violent purposes. This authority, along with the PAEC, ensures that the policies and operations of power generation, purchasing, and operations are handled considering international standards and contribute towards fulfilling the energy requirements of Pakistan. The benefits of peaceful uses of nuclear energy are not limited to electricity but are also visible in other fields including agriculture, medicines, infrastructure development, and climate change.<sup>21</sup>

One of the major challenges to the expansion of Pakistan's peaceful nuclear program is its exclusion from the global nuclear order. Pakistan's exclusion from export control cartels, including the Nuclear Supplier Group (NSG), is a significant impediment to its

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<sup>20</sup> "Signing of a Safeguards Agreement with Pakistan," Text (IAEA, May 3, 2017), <https://www.iaea.org/newscenter/news/signing-of-a-safeguardsagreement-with-pakistan>.

<sup>21</sup> Syeda Saba Batool, "Pakistan: A Civilian Nuclear Program to Fight Natural Disasters?" *South Asia@LSE* (blog), November 25, 2024, <https://blogs.lse.ac.uk/southasia/2024/11/25/pakistan-a-civilian-nuclear-program-to-fight-naturaldisasters/>.

struggle for harnessing nuclear energy for peaceful purposes. China currently supplies all the six NPPs of Pakistan because no other nuclear power state can have agreement with Pakistan because of the technological restrictions faced by it. Even the Pakistan-China civil nuclear agreement was signed before Beijing became a member of the NSG, and this agreement is under the grandfather clause.<sup>22</sup> The grandfather clause stipulates that the prohibition on supplying nuclear technology pertains solely to future nuclear cooperation and does not encompass supply commitments that were in place when the country joined the NSG.<sup>23</sup>

### **Pakistan Atomic Energy Commission (PAEC)**

The PAEC operates Pakistan's civilian nuclear facilities. Two other departments within the PAEC oversee nuclear power production: Nuclear Power Generation (NUPG), which oversees the operational units, and Nuclear Power Projects (NUPP), which is charged with the design and production of planned units in the country. The licenses to generate power from these plants and include them in the national grid have been issued by NEPRA.

### **Pakistan Nuclear Regulatory Authority (PNRA)**

The PNRA is a regulatory institution established by the government of Pakistan under the PNRA Ordinance 2001. The authority oversees nuclear and radiation safety operations and ensures that the operations align with international standards as per the IAEA guidelines. The domains that fall under the jurisdiction of the PNRA include nuclear safety, radiation protection, emergency preparedness, transportation and waste safety, physical protection,

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<sup>22</sup> Asma Khalid, "China-Pakistan Nuclear Energy Cooperation: History and Key Debates," *South Asian Voices*, February 12, 2020, <https://southasianvoices.org/china-pakistan-nuclear-energy-cooperation/>.

<sup>23</sup> Fred McGoldrick, "The Road Ahead for Export Controls: Challenges for the Nuclear Suppliers Group," *Arms Control Today*, accessed December 6, 2024, <https://www.armscontrol.org/act/2011-01/road-ahead-export-controlschallenges-nuclear-suppliers-group>.

national environmental monitoring program, dosimetry, training and development, research facilitation, and providing technical support to the nuclear operations in Pakistan. The functions of PNRA include establishing the regulatory framework on nuclear activities in the country, authorization and licensing, review and assessment of nuclear activities, inspection and enforcement, communication with stakeholders, and international cooperation. The organization functions autonomously and is tasked with supervising the operations of other agencies, including the PAEC, to ensure adherence to national regulations and international standards.

### **Prospects of Nuclear Energy Development**

The organization functions autonomously and is tasked with supervising the operations of other agencies, including the PAEC, to ensure adherence to national regulations and international standards. A cohesive electricity generation plan for sustainable energy production that can tackle Pakistan's current electricity generation crisis needs to be formulated.<sup>24</sup> One of the ways to address this issue is to develop sustainable energy sources through nuclear energy production systems.

### **Benefits of Nuclear Energy Development**

Nuclear energy production has numerous advantages over conventional energy production sources. One of the advantages of nuclear energy lies in its minimal environmental impact and sustainability. Unlike carbon-based fuels, nuclear power generation releases a small amount of greenhouse gases into the surroundings, thus making nuclear energy a critical ally of humanity in its fight against the ongoing challenge of climate change.

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<sup>24</sup> Nayyar Hussain Mirjat et al., "A Review of Energy and Power Planning and Policies of Pakistan," *Renewable and Sustainable Energy Reviews* 79 (November 1, 2017): 110–27, <https://doi.org/10.1016/j.rser.2017.05.040>.

## Low Carbon Emission

Nuclear plants emit low-carbon energy and can replace fossil fuels, presenting them as an environmentally friendly option that can help mitigate climate change and global greenhouse emissions.<sup>25</sup> The absence of aerosols and greenhouse emissions from nuclear energy makes it ideal to be used in energy production, along with the advantage of cheap production of nuclear energy compared to fossil fuels.<sup>26</sup> The impact of low carbon emissions and clean production can help attain the United Nations Sustainable Development Goals (SDGs) and the Paris Agreement goals.<sup>27</sup> By investing in nuclear power, Pakistan can considerably lessen its carbon footprint, contributing to international efforts to tackle climate change and mitigate environmental hazards the country is currently facing. Low carbon emissions can also help the country tackle issues like pollution, smog, and other environmental damage produced by traditional sources of energy.

## Energy Security Needs

Globally, efforts are being made to fulfill energy security needs as a priority for any country, including Pakistan. Nuclear power provides a stable and reliable source of electricity. Given the nature of non-renewable energy sources, nuclear energy could be a key player in safeguarding a consistent power supply, reducing the country's dependence on volatile global energy markets.<sup>28</sup> This, in turn,

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<sup>25</sup> Atif Jahanger et al., "Articulating CO2 Emissions Limiting Roles of Nuclear Energy and ICT under the EKC Hypothesis: An Application of Non-Parametric MMQR Approach," *Geoscience Frontiers* 14, no. 5 (September 1, 2023): 101589, <https://doi.org/10.1016/j.gsf.2023.101589>.

<sup>26</sup> S. Z. Jurakulov, "Nuclear Energy," *Educational Research in Universal Sciences* 2, no. 11 (October 13, 2023): 514–18.

<sup>27</sup> David L. McCollum et al., "Energy Investment Needs for Fulfilling the Paris Agreement and Achieving the Sustainable Development Goals," *Nature Energy* 3, no. 7 (July 2018): 589–99, <https://doi.org/10.1038/s41560-018-0179-z>.

<sup>28</sup> Manuela Tvaronavičienė et al., "Chapter 1 - Global Energy Consumption Peculiarities and Energy Sources: Role of Renewables," in *Energy Transformation Towards Sustainability*, ed. Manuela Tvaronavičienė and Beata

enhances energy security and supports industrial growth. Developing countries like Pakistan need energy security for their economic and energy security growth, and nuclear energy provides one of the best alternatives.

### **Economic Growth**

Developing the nuclear energy sector creates employment opportunities and stimulates economic growth. Nuclear power plants and the associated industries, such as uranium mining and nuclear technology research, can contribute to job creation and the overall expansion of the economy. Moreover, the economic cost of generating electricity through nuclear energy is far less than that of fossil fuels. This would help lower the electricity bills for the general public and industries to help stimulate economic growth. The use of fuels like oil and gas can boost economic activities but add to carbon emissions. Comparatively, using nuclear energy increases production and has zero impact on the environment.<sup>29</sup>

### **Diversification of Energy Mix**

Relying on a mix of energy sources, including nuclear power, helps diversify the energy portfolio, which enhances resilience against supply disruptions and price fluctuations in oil and gas markets.<sup>30</sup> A diversified energy mix can provide a buffer against uncertainties, contributing to a more stable economic environment. With a rising population and increasing industrialization, Pakistan faces a

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Ślusarczyk (Elsevier, 2020), 1–49, <https://doi.org/10.1016/B978-0-12-817688-7.00001-X>.

<sup>29</sup> Qiang Wang et al., “Exploring the Role of Nuclear Energy in the Energy Transition: A Comparative Perspective of the Effects of Coal, Oil, Natural Gas, Renewable Energy, and Nuclear Power on Economic Growth and Carbon Emissions,” *Environmental Research* 221 (March 15, 2023): 115290, <https://doi.org/10.1016/j.envres.2023.115290>.

<sup>30</sup> Charilaos Mertzanis, “Energy Policy Diversity and Green Bond Issuance around the World,” *Energy Economics* 128 (December 1, 2023): 107116, <https://doi.org/10.1016/j.eneco.2023.107116>.

growing energy demand. Nuclear power can play a crucial role in meeting this demand because it can generate large amounts of electricity. It can serve as a base load power source, supplementing recurrent renewable energy sources and ensuring a steady power supply. It is recommended that government agencies and organizations invest more in green and sustainable energy resources through green finance schemes<sup>31</sup> that not only diversify the energy resources but also provide a reliable energy production unit.

### **Low Dependence on Fossil Fuels**

Like most states, Islamabad depends profoundly on hydrocarbon products to meet its energy demands. This has raised many issues in the country including production of expensive energy, lack of sustainable energy resources, and environmental damage.<sup>32</sup> Transitioning to nuclear energy reduces dependence on these finite resources, mitigates environmental impacts, and helps manage the economic challenges associated with fossil fuel dependence. Pakistan needs to ensure that it develops nuclear energy production to reduce its dependence on fossil fuels. This will help the country tackle issues like climate change and environmental damage, which have hit the country very hard.

### **Achievement of SDGs**

Nuclear energy can also play a vital role in Pakistan's achievement of SDGs. There are a total of 17 SDGs interlinked in a manner that progress in any of them would lead to progress in all the others. Nuclear energy can play a very positive role in achieving SDG 7 and

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<sup>31</sup> Muhammad Imran et al., "Does Nuclear Energy Reduce Carbon Emissions despite Using Fuels and Chemicals? Transition to Clean Energy and Finance for Green Solutions," *Geoscience Frontiers*, April 11, 2023, 101608, <https://doi.org/10.1016/j.gsf.2023.101608>.

<sup>32</sup> Aifeng Liu et al., "Reducing Carbon Emissions with Geoscience Solutions: A Look at the Contributions of Nuclear Energy, Technology, and Green Finance," *Geoscience Frontiers*, August 22, 2023, 101698, <https://doi.org/10.1016/j.gsf.2023.101698>.

SDG 13. SDG 7 links to affordable and clean energy, whereas SDG 13 links to Climate Action. Nuclear energy, being a clean energy source, would directly lead to progress in both these SDGs that would indirectly help achieve all the other goals.

### **Potential Challenges**

Integrating nuclear power into Pakistan's energy portfolio has not been without challenges. The risks of security and safety linked with nuclear technology necessitate meticulous planning, stringent regulatory frameworks, and international cooperation. Pakistan has already developed a stringent nuclear safety and security regime at par with the best practices in the world. Pakistan's nuclear plants are under the IAEA safeguards and in the words of the IAEA's DG, Rafael Grossi, "Pakistan's nuclear safety and security record is impeccable."<sup>33</sup> As Pakistan struggles to meet its growing energy demands and enhance its energy security, nuclear energy has emerged as a key component of its energy strategy.

Nuclear power has become increasingly popular and adopted worldwide because of increasing concerns about the impact of climate change.<sup>34</sup> Despite the concerns, in reality, the damage caused by energy production resources accounts for 8.7 million deaths per year from fossil fuel sources, and from nuclear sources, there have been only 46 deaths in the Chornobyl nuclear accident in 1986, and no other casualty has been reported so far.<sup>35</sup> The challenges

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<sup>33</sup> news. Desk, "IAEA Chief Lauds Pakistan's 'impeccable' Nuclear Safety Record," *The Express Tribune*, February 16, 2023, <https://tribune.com.pk/story/2401545/world-class-iaea-chief-lauds-pakistans-impeccable-nuclear-safety-record>.

<sup>34</sup> Rafael Mariano Grossi, *Nuclear Law: The Global Debate* (Vienna: International Atomic Energy Association, 2022), <https://doi.org/10.1007/978-94-6265-495-2>.

<sup>35</sup> World Nuclear Association, "What Are the Effects of Nuclear Accidents? - World Nuclear Association," Official website, World nuclear association, n.d., <https://world-nuclear.org/nuclear-essentials/what-are-the-effects-of-nuclear-accidents.aspx>.

associated with nuclear power generation include high upfront building costs and the prolonged time frame required for plant development.

## **Radioactive Waste**

Radioactive or nuclear waste is defined as the byproduct of a nuclear reactor, research facilities, medical facilities, fuel processing plants, or during decommissioning or disposal of nuclear plants.<sup>36</sup> Types of radioactive waste include high-level waste (Nuclear fuel and waste generated by nuclear reactors), Transuranic waste (man-made from radioactive elements), Uranium and Thorium mill tailing waste (waste generated from extracting uranium or thorium), and Low-level waste (radioactive waste not from the above categories).<sup>37</sup> Issues associated with radioactive waste management exist. For instance, spent fuel and other byproducts of nuclear reactions could remain radioactive for centuries.<sup>38</sup> Proper disposal and management mechanisms of such waste are critical to prevent environmental contamination and public health risks.

Another issue related to radioactive waste material is storage and disposal. The safe storage and disposal of nuclear waste present technical challenges, as there are concerns regarding the prolonged safety and security of waste storage facilities.<sup>39</sup> In Pakistan, the

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<sup>36</sup> US Nuclear Regulatory Commission, "Backgrounder on Radioactive Waste," Official website, NRC Web, 2019, <https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/radwaste.html>.

<sup>37</sup> US EPA, "Radioactive Waste," Overviews and Factsheets, US Environment Protection Agency, November 28, 2018, <https://www.epa.gov/radtown/radioactive-waste>.

<sup>38</sup> Charles W. Forsberg, "Radioactive Wastes," in *Encyclopedia of Physical Science and Technology (Third Edition)*, ed. Robert A. Meyers (New York: Academic Press, 2003), 643–59, <https://doi.org/10.1016/B0-12-227410-5/00642-6>.

<sup>39</sup> M. I. Ojovan and W. E. Lee, "1 - Introduction to Immobilisation," in *An Introduction to Nuclear Waste Immobilisation (Second Edition)*, ed. M. I. Ojovan and W. E. Lee (Oxford: Elsevier, 2014), 1–6, <https://doi.org/10.1016/B978-0-08-099392-8.00001-2>.

PAEC has established two waste disposal facilities: 1) the National Institute for Conservation of Environment (NICE) and 2) the Regional Repository South (RRS). The NICE is located in the country's northern region, and the RRS is in the Southern region.<sup>40</sup> These steps underscore Pakistan's commitment and success in tackling this challenge.

### **Accidents and Meltdowns**

Other risks and challenges associated with nuclear energy production are nuclear reactor or facility accidents and meltdowns. Some of the renowned nuclear accidents include the 1986 Chernobyl disaster and the 2011 Fukushima Daiichi meltdown.<sup>41</sup> These accidents led to the fallout and discharge of radioactive materials, affecting the surroundings and human health. Similarly, in the future, the same tragedy can happen again if the power plant's cooling system begins to stop working or other safety failures, including the reactor's meltdown when its fuel rods become overheated and breach containment, thus releasing radioactive materials.<sup>42</sup>

Although the overall record of the health and safety of nuclear reactors is quite good, there are still concerns regarding nuclear accidents and meltdowns that can pose challenges for installing or upgrading nuclear facilities in any country regarding generating nuclear energy. Efforts to minimize these risks include strict safety regulations, regular safety inspections, improved reactor

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<sup>40</sup> "Radioactive Waste Management Facility," PNRA, accessed October 16, 2024, <https://www.pnra.org/>.

<sup>41</sup> Georg Steinhauser, Alexander Brandl, and Thomas E. Johnson, "Comparison of the Chernobyl and Fukushima Nuclear Accidents: A Review of the Environmental Impacts," *Science of The Total Environment* 470–471 (February 1, 2014): 800–817, <https://doi.org/10.1016/j.scitotenv.2013.10.029>.

<sup>42</sup> K. Obaidurrahman et al., "Chapter 8 - Nuclear Reactor Safety," in *Physics of Nuclear Reactors*, ed. P. Mohanakrishnan, Om Pal Singh, and K. Umasankari (Academic Press, 2021), 449–510, <https://doi.org/10.1016/B978-0-12-822441-0.00015-7>.

designs, and emergency preparedness and response plans, which need to be considered. Pakistan's nuclear facilities follow international safety standards, and their record over the past fifty years is impeccable.

### **High Installation and Decommissioning Costs**

The costs associated with the installation and dismantling of nuclear facilities are a major hindrance to establishing new nuclear plants. Although the expense of operating and maintaining a nuclear plant is relatively cheaper than that of any other non-renewable energy source, the establishment and setup costs of these facilities are quite higher than those of traditional sources like energy generation through coal plants.<sup>43</sup> According to estimates, the cost of the eighth nuclear power plant, the CHASHNUPP-5, can be around \$4 billion.<sup>44</sup> In contrast, the Sahiwal coal power project, which has a combined capacity of 1320 MWe, costs around \$1.9 billion.<sup>45</sup>

### **Time-Frame for New Plants**

Another pertinent challenge to developing nuclear plants is the time frame of establishing new plants. On average, building a nuclear plant takes a considerable amount of time. This time frame is more than a fossil fuel plant that can be operational in two years. Because of the rapid increase in energy demands, Pakistan fell back to short-term options and turned to IPPs to increase its energy capacity. Shortfalls in energy and blackouts led to the policies that increased IPPs. However, a slow increase in economic growth because of political instability led to an exponential growth in dollar prices and

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<sup>43</sup> World Nuclear Association, "Nuclear Power Economics | Nuclear Energy Costs."

<sup>44</sup> "Pakistan Formalises Chashma 5 Approval," *World Nuclear News*, accessed December 6, 2024, <https://world-nuclear-news.org/articles/pakistan-formalises-chashma-5-approval>.

<sup>45</sup> "1320MW Sahiwal Coal-Fired Power Plant | China-Pakistan Economic Corridor (CPEC) Secretariat Official Website," accessed December 6, 2024, <https://cpec.gov.pk/project-details/2>.

inflation, resulting in a massive hike in electricity prices. High electricity bills have turned out to be a major issue for the domestic market and also caused serious economic problems for the country. Now that Pakistan has a surplus in energy production capacity, it should turn towards long-term sustainable energy sources that may take some time to construct. However, there have been advantages for the country over the years. Nuclear energy is a perfect substitute for this and, in the present situation, is a necessary pathway for Pakistan to follow. It is high time for policymakers and politicians in Pakistan to look beyond short-term solutions and make long-term sustainable planning.

### **Conclusion**

Considering the ongoing energy crisis, Islamabad must concentrate on renewable sources, including nuclear energy, because of the advantages like zero carbon emission, clean and green energy, and low costs linked to the assembly and operations of these sources. High electricity prices and generation costs cause Pakistan's current energy crisis. An energy mix diversification in the country can also help in tackling energy security concerns and, at the same time, resolve greenhouse gas emissions issues. Pakistan needs to increase the power generation through nuclear energy by extending the existing facilities and developing new facilities along with other green sources like solar, wind, and hydroelectricity to fulfill the electricity deficit in the country. Pakistan should augment renewable energy in its overall energy mix. Pakistan is one of the countries globally with an immaculate record in nuclear safety and zero hazards. Nuclear energy has numerous benefits, including reducing emissions, boosting the country's economic activities, and tackling global warming. There is also a need to develop a funding and financing policy that encourages the construction of new NPPs.

An important step Pakistan should take in this regard is the indigenous development of nuclear power plants. Currently, China

has supplied all of Pakistan's NPPs. By developing indigenous power plants, Pakistan can cut the initial cost of developing power plants. Pakistan has had technical expertise and a workforce operating nuclear power plants for over fifty years. Developing indigenous power plants is the logical next step for adding additional nuclear power to Pakistan's energy mix. Another problem Pakistan faces is discrimination by international non-proliferation and export control regimes. Pakistan has applied for NSG membership but has yet to receive a positive response. On the other hand, India has been given a waiver by the NSG that is evident enough of the discriminatory behavior of the regime. The blockage of Pakistan's access to the international nuclear energy market has been a challenge for expanding and utilizing the benefits of Pakistan's nuclear program. Islamabad has demonstrated that the country is a responsible actor, and it is time for its rightful inclusion in the international non-proliferation regime. Pakistan is a front-line state against climate change, and it should focus on sustainable policies for its own betterment. Technological restriction has been a hindrance to Pakistan's overall goal of reducing its carbon emission plans set out in its National Determined Contributions (NDCs). Pakistan is also a signatory of Paris Peace Agreement and is working had to cut its greenhouse gas emissions. Although, Pakistan's contribution to global green house gas emissions is less than 1%, it is still playing its role in the interest of the humanity. Nuclear energy can help in stimulating economic growth, fostering climate-resilient sustainable infrastructure and overcoming energy crisis. Long-term planning and overcoming initial high-cost can be a challenge but it can be overcome if Pakistan is rightfully provided its space in the global nuclear market. Climate change is not a problem only faced by Pakistan but all the countries in the world and only together through a joint effort can this impending catastrophe be averted. It is high time for the international community to look beyond the narrow lens of geopolitics because only through cooperation, a joint threat of climate change can be mitigated.