ENERGY ECONOMICS ENERDAY ENERGY TECHNOLOGY

Contribution ID: **15** Type: **not specified**

# Strategizing for Carbon Neutrality: Policy-Driven Insights Using LEAP for Pakistan's Energy Sector Transformation

*Friday, April 4, 2025 11:15 AM (25 minutes)*

Pakistan's energy sector, heavily reliant on fossil fuels, facing rising emissions, energy insecurity, and affordability challenges. This study employs the Low Emissions Analysis Platform (LEAP) to model Pakistan's energy landscape, analysing energy demand, generation capacity, emissions, and costs under three scenarios: Reference (business-as-usual), With Existing Measures (WEM), and With Additional Measures (WAM). Using 2022 as the base year and projections until 2040, the results show a significant increase in electricity demand from 184 TWh to 820 TWh under the Reference scenario. The WEM scenario reduces greenhouse gas emissions by 16.3% through energy efficiency measures, while the WAM scenario achieves net-zero emissions with 80% renewable integration by 2040. Although initial costs in the WAM scenario rise to 73.6 billion USD, long-term benefits include improved energy security and equity. This study highlights the need for robust policy interventions, renewable investments, and technological advancements to achieve Pakistan's sustainable energy goals. The escalating challenges of climate change, marked by rising greenhouse gas emissions and global temperature increases, underscore the urgent need for actionable energy strategies. Pakistan, heavily reliant on fossil fuels, faces severe energy security risks, economic burdens, and environmental degradation. With its energy demand expected to quadruple by 2040, the country's current energy infrastructure is insufficient to sustain such growth. This study aims to address these pressing issues by exploring feasible pathways for achieving a low-carbon energy future, leveraging policy-driven interventions and advanced energy modeling techniques.

The Low Emissions Analysis Platform (LEAP) was selected for its robust capacity to model energy demand and supply dynamics, emissions, and economic implications across multiple scenarios. LEAP is highly adaptable, integrating energy system components and allowing for tailored scenario-based analysis. The methodology followed a structured approach, beginning with the development of a comprehensive national GHG inventory in accordance with the 2006 IPCC Guidelines. This inventory captured emissions across all energy generation activities, forming the foundation for modeling future projections.

Energy demand and supply modeling used LEAP's modules to project baseline data for 2022 and forecast scenarios to 2040. Scenarios included:

- The Reference scenario, which extrapolates current trends and policies.
- The WEM scenario, incorporating energy-efficient technologies and incremental policy measures.
- The WAM scenario, emphasizing renewable energy integration and targeting net-zero emissions.

Key data inputs included demographic growth, GDP, sectoral energy consumption, and technology-specific emission factors. The model's outputs provided projections for energy demand, generation capacity, GHG emissions, and associated costs. A comparative analysis assessed the environmental, economic, and security impacts of each scenario.

The results illustrate the transformative potential of policy-driven interventions:

Under the Reference scenario, GHG emissions are projected to rise from 78.7 million tons in 2022 to 345.3 million tons by 2040, primarily due to reliance on fossil fuel-based energy generation. The WEM scenario achieves a 16.29% reduction in emissions by 2040 through the deployment of energy-efficient technologies, while the WAM scenario realizes net-zero emissions by 2040. This is achieved by increasing renewable energy'

s share to 80% of the total energy mix, with significant contributions from solar (60.3 GW), wind (131 GW), and biomass (7.4 GW).

Electricity demand is projected to grow from 184 TWh in 2022 to 820 TWh by 2040 under the Reference scenario. Both the WEM and WAM scenarios mitigate this growth, with demand peaking at 692 TWh by incorporating energy efficiency measures. The diversification of the energy mix under WAM not only enhances energy security by reducing dependence on fossil fuels but also ensures resilience against supply disruptions.

Economic analysis reveals that the Reference scenario's projected electricity production cost of 66.3 billion USD is reduced to 55 billion USD in year 2040 under the WEM scenario, reflecting the cost-effectiveness of efficiency measures. The WAM scenario, though requiring higher upfront investments (73.6 billion USD), delivers long-term affordability through renewable integration, improving energy equity and reducing energy poverty. The higher initial capital costs are offset by lower operational expenses and greater energy access.

This study provides a comprehensive framework for evaluating the implications of different energy transition pathways in Pakistan. The findings emphasize the importance of integrating energy efficiency and renewable energy technologies. While the WEM scenario presents a cost-effective and achievable pathway, the WAM scenario offers the most sustainable long-term solution, with significant benefits for emissions reduction, energy equity, and energy security.

The results highlight the critical need for coordinated energy planning, policy coherence, and investment in renewables. These recommendations serve as a blueprint for aligning national energy policies with global climate goals, enabling Pakistan to transition to a sustainable and resilient energy future.

**Primary author:** VALASAI, Gordhan Das (Quaid-e-Awam University of Engineering, Science and Technology, Nawabshah)

**Co-authors:** Mr ALI, Danish (Department of Mechanical Engineering, Quaid -e- Awam University of Engineering, Science and Technology, Nawabshah, Pakistan); BHANGER, Mahreen (Department of Management and Engineering (DTG), University of Padua, Viale Margherita 87 - 36100 Vicenza, Italy); BROHI, Muhammad Alam (Ostbayerische Technische Hochschule (OTH) Amberg-Weiden, Kaiser-Wilhelm-Ring 23 92224 Amberg, Germany); Dr LANDINI, Stefano (School of Engineering, Mathematics and Physics, University of East Anglia, Norwich Research Park, Norwich, NR4 7TJ, United Kingdom)

**Presenter:** VALASAI, Gordhan Das (Quaid-e-Awam University of Engineering, Science and Technology, Nawabshah)

**Session Classification:** Foreign market insights