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BLACKOUTS AND ENERGY POVERTY AND MENTAL HEALTH IN PAKISTAN: SOLAR ENERGY AS A RENEWABLE ENERGY SOLUTION

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Abstract

Pakistan has experienced persistent electricity load-shedding and rising energy costs over the past decade, exposing households to chronic energy insecurity. While the economic and infrastructural consequences of the electricity crisis are well documented, its mental health implications remain insufficiently synthesized. This review examines the relationship between electricity outages, energy insecurity, and psychological wellbeing, and evaluates rooftop solar photovoltaic (PV) systems as a potential mitigation strategy within the Pakistani context. Drawing on interdisciplinary evidence from public health, energy policy, environmental psychology, and disaster research, the review identifies consistent pathways linking energy instability to mental distress through sleep disruption, financial strain, uncertainty, reduced productivity, and household conflict. Evidence from global studies on power outages and energy poverty indicates associations with heightened stress, anxiety, and reduced subjective wellbeing. Pakistan's rapid expansion of rooftop solar offers a decentralized response to unreliable grid supply and may buffer households against outage-related stressors by enhancing energy autonomy and routine stability. However, unequal access to solar technologies, regulatory volatility, and affordability constraints risk widening psychosocial disparities between energy-secure and energy-insecure populations. The review highlights the need for empirical research directly assessing mental health outcomes associated with load-shedding and solar adoption in Pakistan. It concludes that energy reliability should be recognized as a structural determinant of mental health and that equitable renewable energy policies may function as public mental health interventions in resource-constrained settings.

1. INTRODUCTION

The electricity sector in Pakistan has experienced supply and demand imbalances for more than a decade, resulting in persistent load-shedding and prolonged daily outages across urban and rural regions (Amjad, 2026). Periods of 6 to 14 hours without electricity have been routinely reported, particularly during peak summer demand and fiscal stress in the power sector (Abdullah, Aqeeq, Memon, & Abdullah, 2025). According to the World Bank report, these electricity crises are due to various structural drivers include aging transmission infrastructure, circular debt, fuel import dependency, and governance inefficiencies (Ahmad, Usman, Hussain, Jahanger, & Abrar, 2022).

The macroeconomic and industrial implications of electricity shortages in Pakistan have been extensively documented, including reduced industrial productivity, rising unemployment, and constrained economic growth (Usman, Raza, & Shahbaz, 2024). However, the mental health, psychological and psychosocial consequences of persistent energy insecurity in Pakistan remain comparatively underexamined. This literature gap is significant because access to reliable electricity is not merely a technical utility, it is also a social determinant of health (Rivera-Rodríguez et al., 2025). This issue is significant in the context of Pakistan since there is a growing need for a solution to the country's mental health issues (Anwar Khan & Madihie, 2026).

In low and middle-income countries such as Pakistan, unreliable and interrupted electricity is increasingly recognized as a chronic stressor that is capable of amplifying socioeconomic vulnerability (Anwar Khan et al., 2025). Moreover, in Pakistan, electricity outages intersect with additional contextual stressors, including rapid urbanization, income inequality, climate-related heatwaves, and limited mental health service coverage (Usman et al., 2024). Heat exposure alone has been associated with increased irritability, aggression, and psychiatric morbidity. Especially, in settings where air conditioning and cooling systems become inaccessible during load-shedding, physiological discomfort may intensify psychological strain. (Taliercio, 2024).

Against this above given backdrop, decentralized renewable energy, particularly rooftop solar photovoltaic systems have emerged as a potential adaptive and protective strategy. Pakistan has witnessed rapid growth in distributed solar installations, driven by declining technology costs and net-metering policies (Abbas et al., 2025). Beyond economic savings and carbon mitigation, solar photovoltaic systems may confer psychosocial benefits by restoring perceived control, ensuring thermal comfort, stabilizing educational and occupational routines, and reducing stress associated with uncertainty (Sadykhanov, 2025). Therefore, energy autonomy may function as a resilience-enhancing resource, buffering the mental health effects of grid instability. However, despite its globally recognized usefulness, empirical research on the benefits of solar photovoltaic systems in terms of psychosocial co-benefits is less studied especially in underdeveloped countries.

The present review synthesizes interdisciplinary evidence on the relationship between electricity outages, energy insecurity, and mental health outcomes, with particular emphasis on stress, depression, anxiety, sleep disturbance, and wellbeing indicators. Furthermore, it critically evaluates whether decentralized solar photovoltaic systems can mitigate psychosocial impacts associated with chronic load-shedding in Pakistan. Therefore, this review aims to (i) conceptualize electricity instability as a mental health determinant, (ii) identify mechanisms linking outages to psychological outcomes, and (iii) assess renewable energy adoption in terms of solar photovoltaic systems as a potential mental health adaptation strategy in climate-vulnerable setting of Pakistan.

2. Electricity and Power Crisis in Pakistan

Electricity crisis in Pakistan is not an episodic anomaly rather than a structural condition embedded within the national power system (Nazar & Abbas, 2025). For many decades, the electricity supply and demand imbalances, transmission losses, circular debt accumulation, and fuel import dependency have chronically contributed to unending power crisis in Pakistan (Anwar & Saeed, 2023). The electricity crisis has hardly hit the rural areas of Pakistan where there are 12 to 16 hours daily load shedding and scheduled outages in peak summer season. In similar way the urban areas are also affected but not to that much extent (Mehmood, 2025).

In addition to routine rotational outages, Pakistan has experienced large-scale grid collapses. Notably, the January 2023 nationwide blackout disrupted electricity supply across nearly the entire country, with restoration taking between 12 and 72 hours in different provinces (Hussain, 2023). Such system-wide failures underscore the systemic vulnerability of the national grid and illustrate the precarious nature

of energy security. These incidents highlight the urgent need for infrastructure upgrades and improvements in Pakistan's energy sector to prevent future widespread power outages. Additionally, addressing issues such as transmission losses and outdated equipment will be crucial in ensuring a more reliable and resilient electricity grid for the country.

The unending electricity crisis in Pakistan has broader effects on social life and health of people. During prolonged outages, municipal water distribution systems may fail, refrigeration for medicines and vaccines becomes unstable, and healthcare facilities must rely on costly backup systems. The fragility of essential services during power disruptions illustrates how electricity insecurity translates into broader public health vulnerability (Faiz, Fatima, & Ullah, 2025). Similarly, educational institutions and students face particular strain. Load-shedding during examination periods interrupts study routines, limits digital access, and increases cognitive fatigue, especially in contexts where extreme heat coincides with outages (Ullah, Bhaumik, Salman, Ahmad, & Awan, 2025). Finally, at the household level, inconsistent electricity supply disrupts daily rhythms, sleep patterns, and thermal comfort (Parveen, Salman, & Jamil, 2025).

3. Power Crisis and Outage as Psychosocial Stressor

Empirical studies quantifying the mental health effects of electricity outages in Pakistan are limited, yet existing interdisciplinary evidence suggests that power interruptions serve as significant psychosocial stressors. Research on disaster-related blackouts, energy poverty, and infrastructure instability consistently demonstrates associations with psychological distress, anxiety symptoms, sleep disturbance, and reduced subjective wellbeing (Vivian, 2025). These associations appear particularly robust when outages are frequent, prolonged, and unpredictable, conditions characteristic of chronic load-shedding rather than isolated emergency events.

Systematic reviews examining large-scale power outages have identified increases in stress-related symptoms, mood disturbances, and behavioral strain, especially in communities where outages disrupt social cohesion, communication networks, and access to essential services (Manongi et al., 2024). Energy insecurity literature further conceptualizes unreliable electricity as a chronic social determinant of health. Inadequate energy access has been linked to depressive symptoms, emotional strain, and diminished life satisfaction across multiple settings (Ahmed Khan, 2024).

In Pakistan, power crisis and load-shedding intersects with climate vulnerability, urban density, and socioeconomic precarity. Extreme heat events, intensified by climate change, exacerbate irritability, aggression, and sleep disruption when cooling systems become inaccessible (Naqvi, 2022). Students preparing for examinations, healthcare workers reliant on functioning equipment, and low-income households lacking backup systems may experience cumulative stress exposure. Conceptually, therefore, chronic load-shedding can be framed not merely as infrastructural inconvenience but as a sustained environmental stressor with plausible mental health consequences.

In conclusion, th psychosocial pathways linking electricity outages to mental health outcomes are multifactorial and as given below:

i. Electricity outages frequently coincide with nighttime hours and sleep (de Klerk, Mentoor, Correia, & Rampf, 2026).
ii. Routine electricity disruptions can cause issues such as inability to cook, study, or maintain household tasks may elevate tension within families (Nduhuura, Garschagen, & Zerga, 2021).
iii. Electricity crisis can be financial burden, especially for economically vulnerable families, these expenditures may constitute a significant financial burden (Khosa et al., 2022).
iv. Electricity instability disrupts work routines, digital connectivity, and academic preparation (Trentmann, 2020).

4. Renewable Energy Solutions of Solar Photovoltaic Systems in Pakistan

In response to chronic load-shedding, rising grid tariffs, and recurrent nationwide blackouts, Pakistan has experienced a rapid expansion in solar photovoltaic deployment (Mehran, Khan, & Farhan, 2025). Several structural factors underpin this growth. First, declining global solar photovoltaic deployment module prices have reduced upfront system costs (Santa Catarina & Chaves, 2025). Second, rising electricity tariffs and fuel adjustment charges have increased household incentives for grid defection or partial energy autonomy (Jose & Patra, 2025). Third, net-metering regulations introduced under distributed generation framework in Pakistan have enabled households to offset consumption and sell surplus electricity back to the grid (Kiani, 2026).

Importantly, the motivation for rooftop solar adoption in Pakistan extends beyond environmental sustainability. While climate mitigation and decarbonization remain policy goals, household decision-making is primarily shaped by reliability concerns and cost predictability. Solar photovoltaic deployment systems are increasingly perceived as protective infrastructure, an adaptive response to grid fragility. In this context, decentralized solar functions as both an energy transition strategy and a resilience mechanism within a structurally unstable power system.

5. Solar Power System as a Mitigation Strategy for Mental Stress

Although the direct mental health effects of rooftop solar adoption have not been systematically studied in Pakistan, theoretical and empirical evidence suggests plausible psychosocial benefits. By reducing exposure to unpredictable load-shedding, solar photovoltaic deployment systems can stabilize daily routines and restore environmental control (Rivera-Rodríguez et al., 2025). The solar power system electricity can be beneficial for mental health in following ways:

i. Reliable electricity ensures nighttime lighting, cooling systems, and functional fans or air conditioning during heatwaves.
ii. Households reliant on diesel generators or fuel-based backup systems incur recurring costs. Solar systems, despite higher upfront investment, reduce dependence on volatile fuel markets and emergency expenditures.
iii. For students and remote workers, uninterrupted power facilitates academic continuity and digital engagement.
iv. For workers and employees, the presence of electricity at workplace due to solar photovoltaic deployment systems can have positive effects on their productivity and mental health.

6. Discussion and Policy Implications

The synthesis presented in this review positions electricity unreliability as more than a technical deficiency; it functions as a chronic environmental stressor embedded within everyday life in Pakistan. Drawing on stress theory, energy insecurity literature, and public health evidence, load-shedding can plausibly contribute to psychosocial strain through interrelated mechanisms: sleep disruption, financial stress, interpersonal tension, occupational and academic instability, and diminished perceived control. Although direct longitudinal studies in Pakistan remain sparse, the theoretical coherence and convergent findings from comparable settings support the interpretation that chronic electricity instability may amplify vulnerability to anxiety, depressive symptoms, irritability, and reduced subjective wellbeing (Hernández, 2016; Thomson et al., 2017; McEwen, 2007).

However, the current evidence bases directly linking solar adoption to mental health outcomes remains limited. Most available data focus on economic savings, carbon mitigation, and grid performance rather than psychosocial wellbeing. Studies in post-disaster contexts suggest that restoration of reliable lighting and communication reduces stress and social isolation (Saulnier et al., 2017), yet analogous research examining chronic infrastructural instability is scarce. This gap highlights a critical research opportunity: rigorous longitudinal and quasi-experimental studies are needed to quantify mental health trajectories before and after

decentralized solar adoption, particularly in climate-vulnerable underdeveloped countries contexts.

The findings of this review carry important implications for energy governance and public health policy in Pakistan:

i. Policymakers, in collaboration with institutions such as the Alternative Energy Development Board and the National Electric Power Regulatory Authority, should design frameworks that prioritize equitable diffusion rather than reinforcing energy privilege.
ii. Expanding evaluation frameworks to include psychosocial indicators would enable a more holistic appraisal of energy interventions
iii. Intersectoral collaboration between energy regulators, public health authorities, and academic institutions is essential to embed mental health metrics into planning processes.
iv. Shared solar systems, microgrids, and community-based storage solutions may provide scalable resilience, particularly in low-income or rural areas where individual rooftop systems are unaffordable.
v. Community microgrids can enhance local reliability while reducing strain on centralized infrastructure. Such models may also foster social cohesion and collective efficacy—factors associated with improved mental health outcomes.
vi. Supportive yet adaptive regulatory frameworks are necessary to balance distributed generation with grid modernization. Investments in storage integration, smart metering, and transmission upgrades can ensure that solar expansion strengthens rather than destabilizes national energy security.
vii. Decentralized renewable energy should be framed not only as a decarbonization strategy but also as a public health adaptation tool. Reliable cooling access during extreme heat may prevent both physiological and psychological stress amplification.

7. Conclusion

Electricity load-shedding in Pakistan should no longer be framed solely as an engineering or macroeconomic problem. The evidence reviewed indicates that chronic electricity unreliability constitutes a persistent psychosocial stressor that disrupts sleep, undermines daily routines, intensifies financial strain, and contributes to psychological distress at the household and community levels. Although direct empirical studies linking load-shedding to diagnosable mental disorders in Pakistan remain limited, the broader literature on power outages and energy insecurity consistently demonstrates associations with stress, anxiety, reduced wellbeing, and social strain. In this context, energy instability operates as a structural determinant of mental health.

Rooftop solar photovoltaic systems present a promising mitigation pathway. By reducing exposure to outages, stabilizing household energy access, and potentially lowering long-term energy costs, solar adoption may enhance perceived control, routine continuity, and resilience. However, the mental health benefits of renewable energy transitions are not automatic. Unequal access to solar technology, financing barriers, and regulatory instability may exacerbate disparities between households able to buffer themselves from grid unreliability and those who remain exposed.

Future research in Pakistan should move beyond descriptive accounts of the energy crisis and adopt interdisciplinary approaches that integrate energy policy, public health, and mental health metrics. Longitudinal studies examining psychological outcomes before and after solar adoption, as well as equity-focused analyses of energy transitions, are especially needed. Policymakers should recognize that energy reliability is intrinsically linked to population wellbeing. A just and inclusive renewable energy strategy has the potential not only to address environmental and economic concerns but also to function as a structural intervention for mental health resilience in Pakistan.

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