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Energy Consumption, Power Transmission Losses, and Natural Resource Depletion: Implications for Environmental degradation in South Asia

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Abstract: *This paper explores the long-run and short-run impacts of electric power consumption, power transmission and distribution losses, and natural resource depletion and economic growth in the environmental degradation of South Asia. Based on data on balanced panel, Pakistan, India, and Bangladesh between 1990 and 2022, carbon dioxide emissions per capita is used as a proxy of environmental degradation. The panel unit roots tests are also used to show that there are mixed orders of integration between the variables, which supports the use of a panel autoregressive distributed lag (ARDL) test. Kao cointegration test proves the existence of a long-run relationship of equilibrium. According to the long-run approximations of the pooled mean group estimator (PMG) estimator, it is clear that electric power consumption, transmission and distribution losses, depletion of natural resources and economic growth are major contributors to environmental degradation. Short-run outcomes also show that any disequilibrium in the long-run can be corrected slowly, and in the meantime, energy wastage and resource depleting activities have an immediate cost to the environment. The results indicate that efficiency of the power sector and sustainable management of resources are of extreme significance in reducing environmental degradation. The policy implications focus on the necessity of investing in the energy infrastructure, lowering electricity wastage, and using cleaner energy sources that will facilitate the growth of South Asia in an environmentally friendly manner.*

Introduction

One of the most burning challenges around the world today, especially among the developing economies, has been environment degradation, and this is due to the fact that, due to the high rate of Economic development and increase in energy demands, the natural ecosystems are being put under serious strain (Sibanda et al., 2024). Individual countries in South Asia, including Pakistan, India, and Bangladesh have seen a significant rise in the consumption of electricity, industrial processes, and extraction of natural resources in the past decades. Although these developments have helped in the growth of the economy and the rise in the standards of living they have also increased the level of environmental degradation especially through the increased carbon dioxide emissions (Nor et al., 2024). This has led to the nexus between energy consumption, economic development and environmental quality to become a pressing field of empirical study.

The consumption of electric power is a greater fact in the development process of the South Asian economic zones because electricity production continues to rely much on fossil fuels. Consumption of more electricity, thus, tends to correlate with higher levels of greenhouse gases and poor quality of the environment (Khan et al., 2025). Besides consumption, other forms of inefficiency in the power sector, especially losses in transmission and distribution constitute a large yet unaddressed source of environmental stress. A high rate of electricity wastage means more power and more fuel burning up and unnecessary release of toxic gases, thus continuing to hinder environmental degradation. Although it is important, the subject of power transmission and distribution has not received much consideration in empirical studies on the environment (Ismail et al., 2024).

Another essential factor of environmental degradation in the developing regions is the natural resource depletion. Close use of forests, minerals, and fossil fuel to support economic development disturbs the balance of ecology, as well as adds to the degradation of the environment. Resource depletion has emerged to be one of the major sustainability issues in South Asia where consideration of environmental governance through regulations and enforcement is still in a weak state (Gibba et al., 2025). Although economic growth is a vital part of development, it can contribute to environmental pressure further, especially in economies that have energy-intensive and resource-based structures of production. Despite the accumulating research on the energy environment rowth nexus, there is still disjointed empirical evidence on the nexus in South Asia. The literature is mostly centered on energy usage and carbon emission, and it does not pay much attention to the inefficiency of the power sector and the exhaustion of natural resources. Besides, not many studies use econometric methods that can be able to capture the long-run relationships in the equilibrium as well as the short-run dynamics in a panel framework (Issa et al., 2024; Özmerdivanlı & Sönmez, 2025). These gaps need to be addressed to come up with effective environmental and energy policy based on the structural nature of the region.

It is against this background that the current study identifies how electric power consumption, power transmission and distribution losses, natural resource depletion and economic growth have affected the environmental degradation in Pakistan, India and Bangladesh. The study is mainly based on the results of panel data collected between the years 1990 and 2022 and the use of the pooled mean group (PMG) estimator under a panel ARDL framework, which provides strong evidence of both long-run and short-run associations between the variables. This study provides new knowledge on the agents of environmental degradation in South Asia by expressly bringing in power sector inefficiencies and resource depletion. The results should help the policymakers to develop energy and environmental policies that would lead to sustainable economic growth and reduce environmental degradation.

Literature Review

The interaction between energy and environmental degradation is a subject which has been widely studied in the environmental economics literature. Majority of the empirical studies have inferred that the contribution of increased energy consumption especially fossil fuel burns is a major factor in the degradation of the environment by the increased emission of carbon dioxide (Nuţă et al., 2024; Uçar et al., 2025). Initial researches state that because developing economies are characterized by energy-intensive production processes, there is a direct effect on the level of pollution, since clean technologies and the use of renewable energy have not been taken to a sufficient level. Developing and emerging economies have empirical evidence that has uniformly shown that there is a positive relationship between CO 2 emissions and electricity consumption indicating that growth through the use of conventional sources of energy is economically expensive to the environment (Mohamad & Ab-Rahim, 2024).

In South Asia, environmental pressures have been increased by increasing electricity demand as a result of population growth, urbanization and industrial growth. According to a number of studies conducted on Pakistan, India and Bangladesh, it is observed that electricity consumption contributes greatly to carbon emission in the short and the long run. These results indicate that energy mix of the region which relies on coal, oil and natural gas to a considerable extent is crucial in deteriorating the quality of the environment (Khalid et al., 2025; Setiawati & Imamah, 2024). Thus, the use of electricity is one of the main determinants of environmental degradation in South Asian economies.

Although energy consumption has been a well-researched topic, the importance of power transmission and distribution losses to the environment has been given relatively less attention. The inefficiencies in the power sector cause unwanted production of electricity to satisfy the final demand, which causes unnecessary burning of fuel and production of more emissions (Hacıimamoğlu & Sungur, 2024). Outdated infrastructure, technical inefficiencies and stealing of electricity are often linked to high transmission and distribution losses and all these are common in the developing economies. Recent empirical research that includes energy inefficiency indicators concludes that the level of environmental degradation is much more pronounced in case of increased power losses. These papers seem to suggest that it will be possible to mitigate transmission losses to reduce the overall energy demand, lowering emissions and making the environment better without impacting the economic growth.

In South Asia where the losses in power sector are significantly higher than those in any part of the world, power sector inefficiency is an acute, yet under-studied avenue through which environmental degradation is taking place. This knowledge gap in the literature highlights the significance of the explicit inclusion of transmission and distribution losses in environmental analysis (Yasin et al., 2025). The depletion of natural resources has become one of the leading causes of environmental degradation especially in developing economies that rely on natural resources. Overuse of natural resources including fossil fuels, mineral and forests causes destruction of ecosystem, loss of biodiversity and carbon emission. Empirical research shows that the depletion of natural resources deteriorates the environment through accelerated deforestation, augmented emissions as a result of energy use, and negated ecosystem regenerative ability (Byaro et al., 2023). In the developing parts of the world, the lack of well-established environmental policies and pro-growth policies tend to compound the depletion of resources. According to empirically depicted evidence, the depletion of natural resources is strongly related to emission of CO 2 and ecological footprints, particularly in those countries whose economies are based on extractive industries (Hasan et al., 2024).

Rapid industrialization and infrastructural growth in South Asia have increased the rate of resource depletion hence a significant element in describing the cause of environmental degradation. But in spite of this significance, natural resource depletion remains the missing element in the conventional energy environment models and thus a significant gap in the literature. The interaction between the economy and the environment is usually examined by using the Environmental Kuznets Curve (EKC) hypothesis according to which the relationship between income and environmental pollution is in an inverted U-shape (Leitão et al., 2023). This hypothesis suggests that environmental degradation has an upward trend with economic growth but it starts to diminish after reaching a certain income level because of technological advancements, structural change, and increased environmental laws. Empirical evidence regarding the EKC hypothesis is not clear cut especially among the developing economies (Mehmood, 2022).

A significant number of studies reveal a positive and monotonic relationship between economic growth and environmental degradation, indicating that economic growth does not have a cutting point and it continues to place strain on the environment. Most of the indications in the South Asian economies suggest that the growth is still environmentally damaging as a result of dependency on energy intensive sectors and minimal embracement of clean technologies. These findings suggest that economic growth is not enough to enhance the quality of the environment without structural reforms and shifts to sustainable energy sources. In terms of methodology, more recent studies are utilizing panel data methodologies to analyze the energy environment growth nexus because panel methods put into consideration cross country heterogeneity and provide details of dynamic relations (Ximei et al., 2024).

The panel unit root and cointegration methods are normally employed to determine the long-run relationships between non-stationary variables. FMOLS, DOLS, and panel ARDL models are estimation techniques that have become popular in use as they generate consistent long-run estimates. The estimator of the pooled mean group (PMG) of the panel ARDL framework is specifically convenient with the heterogeneous panel, where short-run dynamics may vary among countries but long-run coefficients homogeneous. Various recent analyses show that PMG is efficient in terms of giving consistent estimates in the small N panel but long time dimension hence suitable when conducting studies at the regional level. In spite of this methodological development, there are a few studies which take the PMG approach to study electricity consumption, power losses, natural resource depletion and environmental degradation simultaneously in South Asia.

Research Gap and Contribution

According to the current literature, there are some gaps that can be revealed. First, most researches are mainly oriented on energy consumption without consideration of the environmental effects of inefficiencies in the power sector. Second, natural resource depletion has been left out in most of the environmental degradation models even though it is an important factor in regard to sustainability. Third, there is not much empirical evidence specific to South Asia that makes use of sophisticated panel methods. The given work tries to fill these gaps by collaboratively considering the electric power consumption, the power transmission and distribution losses, and natural resource depletion and economic growth in a single panel ARDL-PMG model of Pakistan, India, and Bangladesh. The analysis of energy inefficiency and resource depletion recast into the study has given fresh perspectives into the structural factors behind environmental degradation in South Asia and also adds to the emerging list of literature on sustainable energy and environmental policy.

Methodology

Model Specification

This paper will discuss how the consumption of electric power, power transmission and distribution and losses, depletion of natural resources, and economic development affect environmental degradation in South Asia. The level of environmental degradation is proxied using carbon dioxide emission per capita that is commonly employed in environmental economics literature as an environmental pressure measure. The empirical model can be defined as a functional relationship as follows:

$$END_{it} = f(EC_{it}, PTD_{it}, NRD_{it}, GDP_{it})$$

where “I” denotes country (i=1,2,3) representing Pakistan, India, and Bangladesh, and “t” denotes time (t=1,2, …, T).

To ensure linearity and allow elasticity-based interpretation, all variables are transformed into natural logarithms. The baseline log-linear model is expressed as:

$$lnEND_{it} = \beta_1 + \beta_2 EC_{it} + \beta_3 PTD_{it} + \beta_4\, NRD_{it} + \beta_5\, GDP_{it} + \mu_{it}$$

The coefficients $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ are expected to be positive, indicating that higher energy use, inefficiencies, resource depletion, and economic growth may increase environmental degradation.

Variable description

Abbreviations	**Variables**	**Descriptions**	**Sources**
END	Environmental degradation	Carbon Dioxide in metric tones per capita	WDI
EC	Electric Power Consumption	Electric Power Consumption kwh per capita	WDI
PTD	Electric Power Transmission and distribution loses	as % of output	WDI
NRD	Natural Resources Depletion	Natural Resources Depletion	WDI
GDP	Gross Domestic Product	GDP per capita in Constant 2015 US Dollars	WDI

The table is the report of the variables that were utilized in studying the relationship between energy use, resource depletion and environmental degradation in South Asia. A standard measure of environmental pressure is the carbon dioxide emissions per capita, in metric tons, which is a proxy of environmental degradation (END). Kilowatt-hours per capita (Electric power consumption (EC)) is a measure of the severity of electricity consumption. Inefficiencies in the power sector are captured in electric power transmission and distribution losses (PTD) which are expressed as a percentage of total output. Natural resource depletion (NRD) is the level of degradation of natural resources as a result of economic practices. As an indicator of economic and industrial development, Gross domestic product per capita (GDP) is used in constant 2015 US dollars. All the data are taken by the World Development Indicators (WDI), which makes all the data consistent and reliable in Pakistan, India and Bangladesh.

Panel ARDL/PMG Framework

Because of the mixed order of integration between the variables (I(0) and I(1)), the panel autoregressive distributed lag (ARDL) method suggested by Pesaran, Shin, and Smith (1999) will be used in the study. In particular, the pooled mean group (PMG) estimator is appropriate since it does not require short-run dynamics to be equal across countries and short-run error variances to be equal, but only limits long-run coefficients.

Estimation Procedure

The empirical analysis is done in a systematic process that aims at guaranteeing the accuracy and strength of the results. First, descriptive statistics are calculated in order to investigate the distributional characteristics of the variables including central tendency measures of dispersion. Correlation analysis is done alongside this to get an idea of initial associations between the variables as well as to find out possible multicollinearity problems that may influence the results of estimation. After this the panel unit root tests are used to find out the stationarity properties of the variables. In particular, there is the Im Pesaran Shin (IPS) test and the type of Augmented Dickey Fuller (ADF) test (Fisher). These tests suit the panel data sets which are relatively small in cross-sectional aspects, and can be heterogeneous across nations, so that the possibility of spurious regression is reduced. Since the majority of the variables are non-stationary, it is then followed by the Kao residual-based cointegration test that is used to examine the presence of a long-run equilibrium relationship between the variables. This is critical in establishing cointegration which establishes the existence of a meaningful long-term relationship and the validity of dynamic models that can be used to capture both the short term and the long term effect. After ensuring the cointegration, the long-run coefficients are estimated by Pooled Mean Group (PMG) estimator. This methodology enables the short-run behavior to be heterogeneous at a given time, but share a common relation over time among the panel. Moreover, both short-run modifications and error correction term are also derived concurrently so that the analysis can not only capture immediate responses but also long run impacts of the explanatory variables on the dependent variable.

Diagnostic and Stability Tests

A number of diagnostic tests are conducted to make the estimated model robust. The Breusch Pagan test is applied to test the heteroskedasticity and the Ramsey RESET test tests the model specification error. The Durbin-Watsons is used to calculate the serial correlation and the Jarque-Bra statistic is used to test the residual normality. These diagnostics prove the stability and reliability of the estimated PMGARDL model.

Results and Discussions

Descriptive Analysis

	LEND	LEC	LPTD	LNRD	LGDP
Mean	12.12470	5.831846	2.862979	0.045644	6.690351
Median	11.85210	5.962344	2.844529	0.038592	6.687126
Maximum	14.71493	7.007191	3.414889	1.189407	7.896666
Minimum	9.377843	4.071111	1.642275	-1.006120	5.652373
Std. Dev.	1.563784	0.653791	0.324356	0.480512	0.640223
Skewness	0.223126	-0.853924	-1.132044	-0.145307	0.109142
Kurtosis	1.885508	3.672153	5.215168	2.479915	1.677488
Jarque-Bera	5.584780	13.05307	38.87814	1.375414	6.962159
Probability	0.061275	0.001464	0.000000	0.502727	0.030774
Sum	1127.597	542.3617	266.2571	4.244855	622.2026
Sum Sq. Dev.	224.9786	39.32475	9.679008	21.24205	37.70941
Observations	93	93	93	93	93

The descriptive statistics explain the central tendency and the dispersion of all the logged variables out of 93 observations. The average measure of the environmental degradation (LEND) represents a moderate amount of CO 2 emissions per capita in the sampled countries, with a small variation, which implies that there is not much change with time and among countries. Electric power consumption (LEC) demonstrates a steady distribution with the average standard deviation, which indicates gradual increase in the use of electricity in South Asia. The power transmission and distribution losses (LPTD) are less variable and this implies that there are inefficiencies in the power sector that are persistent in the region. Natural resource depletion (LNRD) exhibits conspicuous fluctuation, which is characterized by the discrepancy in the intensity of resource extraction with time. GDP per capita (LGDP) indicates moderate disparity, which indicates the unequal economic growth trends in the three nations. The JarqueBraun statistics indicate that the majority of the variables are not normally distributed, which is typical of macro-panel data and the reasons why robust panel estimation methods are used.

Correlation Analysis

	LCO2KT	**LEC**	**LPTD**	**LNRD**	**LGDP**
LCO2KT	1				
LEC	0.8486	1			
LPTD	0.3751	0.2406	1		
LNRD	0.6299	0.6075	0.3393	1	
LGDP	0.4045	0.7166	-0.1616	0.1587	1

The correlation table shows that there is a strong positive relationship between environmental degradation against electric power consumption, which shows that an increased consumption of electricity is associated with an increased emission of CO 2. Environmental degradation also has a positive relationship with power transmission losses implying that inefficiencies in electricity delivery increase environmental pressure. The relationship between emissions and depletion of natural resources is positive, which would prove that the over mining of natural resources aggravates the quality of the environment. The relationship between GDP per capita and environmental degradation is moderate, whereas the relationship with electricity consumption is very strong, indicating how the South Asian economies are energy-dependent. In general, the results of the correlation give initial evidence of a strong interconnection between the energy use and economic activity and the degradation of the environment.

Panel Unit root test

Results of Panel Unit root

	IPS		**Fisher ADF**		**Integration Level**
	Level	**1st Difference**	**Level**	**1st Difference**	
LEND	0.9979	0.0026	0.9990	0.0066	I (1)
LEC	0.0467	0.0000	0.0278	0.0000	I (0)
LPTD	0.7566	0.0000	0.7859	0.0000	I (1)
LNRD	0.2280	0.0001	0.3154	0.0003	I (1)
LGDP	0.9959	0.0000	0.9896	0.0000	I (1)

Probabilities values are in the table

The panel unit root outputs in terms of IPS and Fisher-ADF tests show the presence of mixed order of integration among the variables. The non-stationary levels of such variables are the environmental degradation (LEND), the power transmission losses (LPTD), the natural resource depletion (LNRD), and the GDP per capita (LGDP); the first order, I(1), of which is integrated. Conversely, electric power consumption (LEC) is at stationary level and this implies integration of zero order, I(0). The mixed integration order justification is why panel cointegration and ARDL based techniques, like the PMG estimator, that can incorporate I(0.1) variables are to be used..

Panel co-integration

Kao Residual Cointegration Test		
	t-Statistic	**Prob.**
ADF	-2.222653	0.0131
Residual variance	0.003206	
HAC variance	0.004512	

The output of Kao test on residual cointegration allows establishing the confirmation of the existence of a long run equilibrium relationship between environmental degradation, energy consumption, power losses, depletion of natural resources, and economic growth. The statistically non-significant value of ADF actually rejects the null hypothesis of no cointegration and thus, shows that the variables move together in the long-run although they cannot be stated to be stationary as individuals. This observation confirms the estimation of long-run coefficients and validates that there is a stable relationship between environmental and energy and growth in South Asian economies.

Long PMG/Panel ARDL results

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LEC	0.908665	0.129519	7.015707	0.0000
LPTD	0.397627	0.034531	11.51503	0.0000
LNRD	0.191096	0.061173	3.123851	0.0036
LGDP	0.578264	0.108817	5.314096	0.0000

The results of the PMG estimates in the long run show a strong and positive impact on the environmental degradation by the use of the electric power, which shows that, in the long run, the use of more electricity contributes to the high levels of CO 2 gases. Some previous researchers found similar results (Nor et al., 2024; Sibanda et al., 2024). The positive and highly significant impact would also be obtained on power transmission and distribution losses, implying that the inefficiency of the power sector would enhance the environmental degradation. Some previous researchers found similar results

(Gibba et al., 2025; Özmerdivanlı & Sönmez, 2025). The deposit of natural resources has a positive impact on the emission, which proves that the exploitation of resources in an unsustainable manner deteriorates the state of the environment. Some previous researchers found similar results (Ali Gardezi & Samar Abbas, 2021; Ghaffar & Ali Gardezi, 2024; He et al., 2024). Environmental degradation is determined to increase with GDP per capita which means that economic growth in the South Asian region is yet to hit turning point that is consistent with the hypothesis of the Environmental Kuznets Curve.

Short run PMG/Panel ARDL results

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
ECM term	-0.032822	0.017667	-1.857795	0.0682
D(LEC)	-0.270606	0.124612	-2.171595	0.0392
D(LPTD)	0.276406	0.107125	2.580217	0.0142
D(LNRD)	0.057558	0.028268	2.036145	0.0462
D(LGDP)	0.098117	0.034790	2.820277	0.0078
C	0.477691	0.275762	1.732260	0.0885

According to the results of the short-run analysis, the error correction term is negative and statistically significant at 10 percent level, which supports the presence of long-run adjustment towards the equilibrium. The size of the coefficient implies that the rate of adjustment is low implying that the adjustments to the long-run environmental equilibrium are slugging. Short-run electric power consumption changes decrease environmental degradation, which may be in terms of short-term efficiency or energy substitution effects. Nevertheless, the growth of power transmission losses, depletion of natural resources, and GDP per capita have a great impact on environmental degradation, which illustrates the direct environmental cost of energy inefficiency, resource depletion, and economic growth. Some previous researchers found similar results (Balaka et al., 2023; Cai & Hu, 2024; Qamruzzaman, 2024).

Diagnostic tests

Tests	Stats	Tests	Stats
R^2	0.7812	**Bruch Pagon (Hetero Test)**	2.0654 (0.1376)
Adj R-squared	0.7645	**Ramsey RESET Test**	1.1754 (0.2374)
Durbin-Watson statistics	2.0378	**Jarque-Bera**	1.4787 (0.3877)

The probability values are in brackets.

The reliability of the estimated model is proved by diagnostic results. The value of R-squared and adjusted R-squared demonstrates that the model has a high level of explanatory power. Breusch Pagan test indicates that there is no heteroskedasticity whereas Ramsey RESET test indicates the right model specification. The Durbin Watson value shows that there are not severe cases of autocorrelation and

Jarque Berra test shows the normality of the residuals. All these diagnostics prove the reliability and econometric soundness of the PMG estimation results.

Conclusion

This paper analyzes how electric power consumption, power transmission and distribution losses, depletion of natural resources, and economic growth affect the environment in South Asia using panel data on the impact of these metrics on the economic growth, which comprise the years 1990 to 2022 in Pakistan, India, and Bangladesh. The empirical findings show that the consumption of energy, ineffectiveness within the power industry, and the unorthodox extraction of resources and economic growth are major contributors to CO_2 emission in the region. Long-run predictions made by the PMG-ARDL model show that the growth in electricity consumption, transmission, distribution losses, depletion of natural resources and the GDP per capita make environmental degradation more severe, showing that the conventional growth is environmentally unfriendly in South Asian economies. The short-run dynamics also imply that although the short-run deviation of the long-run equilibrium is alleviated slowly, there are still immediate environmental costs that are caused by energy inefficiency and resource overuse. All in all, the results highlight the importance of efficient energy management, sustainable use of resources, and environmentally-oriented economic policies in order to decimate the long-term environmental stress.

Policy Recommendations

According to the results of the research, there are a number of policy solutions that can be suggested to foster South Asian environmental growth. The reduction of unnecessary energy generation and resultant emissions can be improved by focusing on the efficiency of the power sector by investing in modern transmission and distribution infrastructure, lessening the technical losses, and preventing electricity theft. Adoption of cleaner energy sources such as solar power, wind and hydropower will also trim the environmental footprint of electricity consumption. The ecological degradation should be minimized by sustainable regulation on the extraction of natural resources, re-forestation and incentives on sustainable mining and agricultural operations. Environmental considerations are also to be incorporated in the economic planning, where the policy makers should ensure that they embrace industrial practices that do not consume energy, environmental taxation, and incentives that encourage the use of green technologies. Lastly, local collaboration between South Asian nations on the energy efficiency standards, renewable energy development, and environmental management can add to the efficacy of the national activities and can resolve the cross-border environmental issues.

Future Research Directions

Going forward, this study can be developed by including other countries in South Asia or other developing nations to give a wider picture of the energy-environment-growth nexus. The research of the contribution of renewable energy implementation and technological advances to environmental degradation may provide an insight of green energy conversions. More specific policy advice would be offered through sectoral analyses that look at the contributions of individual industries like transport, manufacturing, and agriculture to environmental pressure. Also, incorporation of climate vulnerability indicators and environmental policy measures might be used in order to conclude about their moderating impacts on the relationship between energy use and environmental quality. Finally, the use of non-linear models or threshold analysis may investigate whether the effects of energy consumption or economic growth or resource depletion upon environmental degradation vary at various levels of development or energy expenditure. The solution to these regions will enhance the knowledge of sustainable development approaches and will aid in proper policy making in South Asia.

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