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# Beyond-Compliance Environmental Strategies in Coal-Fired Power Plants: A Systematic Review and Integrative Framework

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**Abstract**

Coal-fired power plants face increasing pressure to improve environmental performance beyond minimum regulatory requirements. However, evidence concerning technological, managerial, social, and institutional strategies remains fragmented, limiting the development of integrated environmental management approaches. This study systematically synthesizes existing evidence on beyond-compliance environmental strategies and proposes an integrative conceptual framework for coal-fired power generation. Following PRISMA 2020 guidelines, 20 peer-reviewed studies published between January 2016 and June 2026 were selected through Scopus searching and backward reference tracking. Thematic synthesis identified four interrelated strategic dimensions: technological environmental innovation, environmental management practices, social sustainability initiatives, and external environmental drivers. Technological innovation, including emission reduction and energy-efficiency improvements, received the strongest direct support from coal-fired power studies, whereas managerial and social dimensions relied more extensively on evidence from broader organizational contexts. Drawing on the Natural-Resource-Based View and Institutional Theory, the proposed framework conceptualizes how internal environmental capabilities interact with external institutional pressures to support proactive environmental management. The framework also offers a potential analytical basis for understanding beyond-compliance practices within Indonesia's PROPER environmental rating system. However, the limited direct sector-specific evidence, heterogeneous study designs, and absence of formal methodological quality appraisal constrain the strength of the conclusions. These findings provide a multidimensional perspective on environmental performance improvement and establish a conceptual foundation for future empirical validation in coal-fired power plants.

**Keywords:** Beyond-compliance environmental approaches; Coal-fired power plant; Environmental performance; Environmental management; Sustainability

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## INTRODUCTION

Environmental performance has become a critical concern in the global energy sector, particularly in industries characterized by substantial environmental footprints, such as coal-fired power generation. Although renewable energy sources continue to expand, coal-based power plants still contribute significantly to global electricity supply (Wang et al., 2020). The operation of these plants is associated with serious environmental challenges, including

greenhouse gas emissions, air pollution, solid waste generation, and ecosystem degradation, which have intensified global efforts to improve environmental performance through technological innovation, environmental regulation, and sustainability-oriented management approaches (Batista et al., 2025; Wang et al., 2020; Zhang et al., 2019).

Prior research has extensively examined technological approaches to mitigating environmental impacts in thermal power generation. Studies on advanced combustion technologies, such as oxy-combustion systems, suggest substantial potential for reducing carbon emissions in coal-fired power plants (Kim et al., 2023). Life cycle assessment (LCA) methods have been widely applied to evaluate environmental impacts across air, water, and soil compartments (Leda et al., 2023), while thermodynamic optimization, particularly energy–exergy analysis, has proven effective in improving operational efficiency and reducing environmental burdens in thermal power systems (Kumar et al., 2024).

Despite these advances, recent sustainability scholarship indicates that technological solutions alone are insufficient to achieve long-term improvements in environmental performance. Comprehensive improvement requires environmental strategies that extend beyond basic regulatory compliance. Beyond-compliance environmental strategies are defined as voluntary environmental initiatives that exceed mandatory regulatory requirements and integrate sustainability considerations into corporate decision-making (Tatoglu et al., 2020). Organizations adopting such strategies may not only mitigate environmental risks but also strengthen resilience, legitimacy, and long-term competitiveness in sustainability-oriented markets.

External environmental drivers also play an important role in shaping corporate environmental strategies. Firms increasingly respond to regulatory pressures, stakeholder expectations, and competitive dynamics when developing environmental management practices (Zhou et al., 2020). Environmental policy instruments, including carbon pricing mechanisms, emission trading systems, and environmental disclosure requirements, have been shown to influence corporate environmental behavior in energy-intensive industries (Li et al., 2021; Yang et al., 2022). In addition, the growing prominence of environmental, social, and governance (ESG) frameworks has intensified investor and stakeholder expectations regarding corporate environmental responsibility (Chen et al., 2023; Friede et al., 2015).

Although research on environmental sustainability in the energy sector has grown substantially, the literature remains fragmented. Existing studies tend to focus either on technological emission-reduction solutions (Kumar et al., 2024; Leda et al., 2023) or on external environmental drivers, such as carbon pricing and ESG-related pressures (Chen et al., 2023; Zhang et al., 2019). Prior technology-focused reviews have generally synthesized engineering and life-cycle evidence without addressing organizational or institutional dimensions, while prior governance- and ESG-focused syntheses have rarely engaged with plant-level technical evidence; neither strand has systematically distinguished direct coal-power evidence from adjacent energy-sector or generic organizational evidence, and none has been organized around an explicit beyond-compliance boundary. Limited research has systematically integrated technological, managerial, and external environmental perspectives into a unified analytical framework for beyond-compliance environmental performance. Furthermore, few studies explicitly examine how beyond-compliance strategies interact with external drivers to shape environmental performance outcomes. This gap highlights the need for a comprehensive synthesis of environmental performance strategies to support integrated sustainability improvement in energy-intensive industries.

For the purposes of this review, beyond-compliance environmental strategies are operationalized as voluntary organizational actions that exceed applicable regulatory minimums and are adopted, at least in part, for reasons other than immediate legal obligation. This definition is used to distinguish beyond-compliance practices from four related but conceptually distinct categories that recur in the literature: (a) compliance actions taken solely

to satisfy a legal requirement; (b) regulatory responses, such as adjustments made in anticipation of tightening standards; (c) ordinary efficiency investments undertaken primarily for cost reduction rather than environmental positioning; and (d) transition or substitution strategies, such as fuel switching, whose environmental rationale may be independent of any compliance consideration. Studies included in this review are treated as direct evidence for beyond-compliance strategy only where they explicitly examine one or more of these voluntary, above-minimum practices; studies that examine technical or institutional phenomena without this distinction are treated as contextual or adjacent evidence, as detailed in the Method and Results sections.

This review's analytical logic is informed by two complementary theoretical perspectives, introduced here rather than only at the framework stage. The Natural-Resource-Based View (Hart, 1995) suggests that internal environmental capabilities, technological competence, environmental management systems, and organizational culture constitute strategic resources that can support superior environmental and competitive outcomes. Institutional Theory (DiMaggio & Powell, 1983; Scott, 2014) suggests that coercive (regulatory), normative (professional/ESG), and mimetic (peer-imitation) pressures shape organizational environmental behavior from outside the firm. Read together, these perspectives frame beyond-compliance strategy as the mechanism through which internal capabilities and external institutional pressures jointly shape environmental performance, the analytical logic that structures the remainder of this review.

This gap is particularly relevant in Indonesia, where coal-fired power plants continue to play a major role in national electricity generation and where the PROPER environmental rating system encourages companies to move beyond compliance through innovation, resource efficiency, transparency, and community empowerment (Kementerian Lingkungan Hidup/Badan Pengendalian Lingkungan Hidup Republik Indonesia, 2025b, 2025a). Despite the strategic importance of PROPER, studies linking beyond-compliance environmental strategies with PROPER-oriented environmental performance remain limited, and no study identified in this review directly evaluates PROPER outcomes; the discussion of PROPER in this manuscript is therefore presented as a proposed application of the synthesized framework rather than as a direct empirical finding. It should also be emphasized that beyond-compliance environmental practice, as discussed here, refers to incremental performance improvement within continued coal-based generation, and does not imply that such practice removes the fundamental climate and environmental impacts associated with coal combustion; the framework is intended to complement, not substitute for, broader energy-transition efforts. Therefore, this study develops an integrative framework that combines technological environmental innovation, environmental management practices, social sustainability initiatives, and external environmental drivers.

To address this gap, the present study conducts a systematic literature review (SLR) with three objectives: (1) to identify the key strategic dimensions of beyond-compliance environmental strategies; (2) to analyze the role of external environmental drivers in shaping corporate environmental practices; and (3) to synthesize existing evidence into an integrative framework linking environmental strategies and environmental performance outcomes. This need is particularly relevant in the Indonesian context, where coal-fired power plants remain central to national electricity supply and where the PROPER environmental rating system provides a structured mechanism for encouraging environmental performance improvement beyond regulatory compliance.

Beyond its contribution to environmental management scholarship, this review is also intended to support applied science education. Coal-based electricity generation, industrial environmental management, and regulatory instruments such as PROPER are concrete, real-world contexts through which science and mathematics educators can teach applied environmental science, systems thinking, and sustainability literacy. The four-dimensional

framework synthesized in this review- technological innovation, environmental management, social sustainability, and external institutional drivers offers a structured case example that can be adapted into instructional material, case-based learning modules, or student research projects on energy, environment, and sustainability within science, technology, engineering, and mathematics (STEM) curricula. In this sense, the review's contribution extends beyond industry practitioners to educators and students engaged in applied environmental science learning, which is directly relevant to this journal's scope.

## METHOD

### Research Design

This study employed a systematic literature review (SLR) to synthesize direct and adjacent evidence on beyond-compliance environmental strategies in coal-fired power plants and, given the limited size of the direct evidence base, in closely related energy-generation and organizational contexts. The SLR approach was selected because it enables a transparent, structured, and reproducible synthesis of evidence while minimizing subjective bias compared with conventional narrative reviews. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Page et al., 2021) framework, with search reporting informed by PRISMA-S (Rethlefsen et al., 2021), to ensure methodological rigor in the identification, screening, and selection of relevant studies. The review process itself was supported by the Watase UAKE platform, which assisted with structured keyword development, article screening, and PRISMA-based reporting; however, this should not be conflated with formal protocol registration. No review protocol was registered in advance on an independent registry (e.g., OSF, PROSPERO, or INPLASY) prior to screening. This is acknowledged here as a limitation, since the absence of prospective registration means that eligibility criteria, coding categories, and thematic categories cannot be independently verified as having been fixed before the authors observed the search results, which increases the risk of post-hoc adjustment relative to a prospectively registered review.

### Data Source and Search Strategy

The literature search was conducted using the Scopus database, selected for its broad multidisciplinary coverage and inclusion of high-quality peer-reviewed journals in environmental science, engineering, and sustainability research. Consistent with the author team's confirmation, the Scopus query used for the final, reported sample applied a built-in date restriction limiting results to January 2016–June 2026 at the point of search execution, rather than as a post-retrieval filter. Figure 2, which displays keyword-search results dating back to 2001, reflects an earlier, broader exploratory scoping search conducted prior to applying this date restriction, and is retained here to illustrate the overall publication trend in the topic area; it does not represent the date-restricted sample analyzed in this review, and its caption below has been revised to make this explicit. This window was selected to capture recent developments in environmental governance and sustainability practice. Per the author team's decision, the original, narrower search string was retained for this review rather than the broader string suggested during review (which would have required re-screening the entire sample):

*("beyond compliance" OR "voluntary environmental" OR "environmental performance") AND ("coal" OR "power plant") AND ("environmental management" OR "sustainability")*

The authors acknowledge that this string is narrower than an ideal search strategy for this topic, for example, it does not separately include terms such as "coal-fired power station," "ISO 14001," "eco-innovation," "cleaner production," or "PROPER," which could retrieve additional directly relevant studies and this is noted explicitly as a limitation in the Methodological Limitations section below, rather than being corrected through a new search, in order to preserve the integrity and traceability of the originally screened sample reported in Table 1 and Figure 1.

The search process was facilitated by the Watase UAKE platform, which supports structured keyword development, article screening, and PRISMA-based reporting. The platform assisted with organizing and tracking records through the PRISMA workflow and generating summary visualizations (including Figure 2); it did not generate any AI-based recommendations for including or excluding specific articles. All inclusion and exclusion decisions were made manually by the author team against the eligibility criteria stated above, and the platform's role was limited to workflow support rather than automated decision-making.

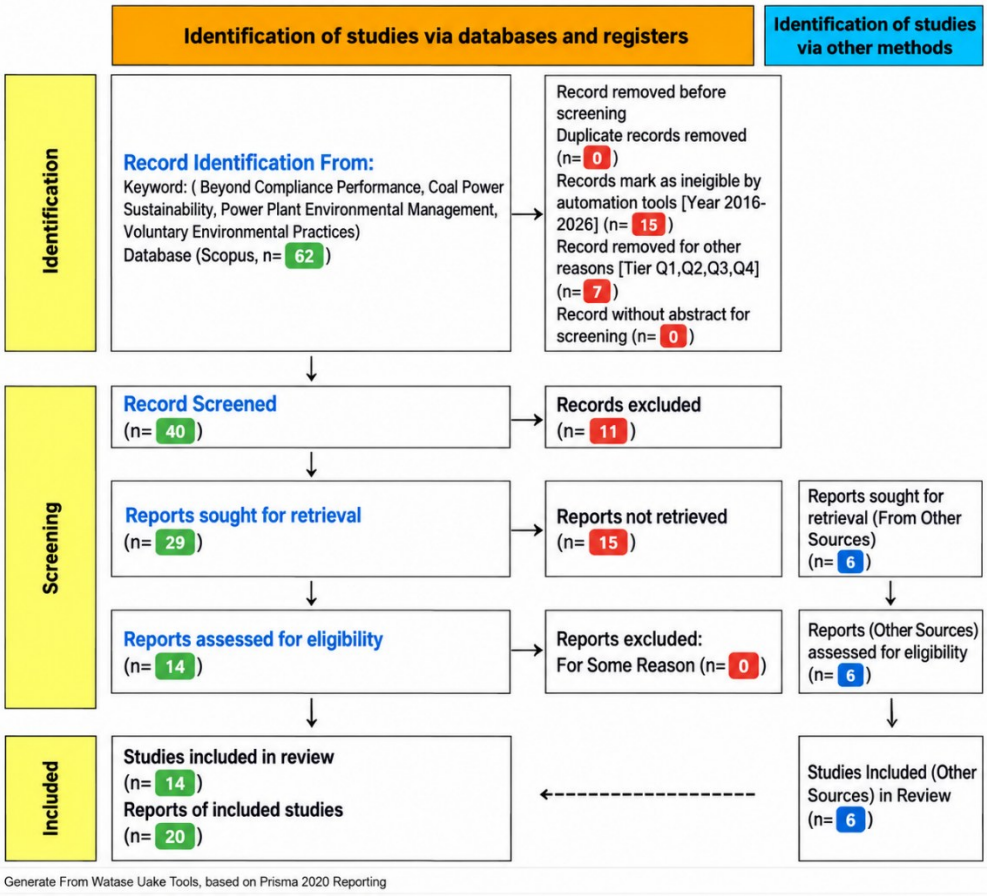


**Figure 1.** PRISMA 2020 flow diagram of the study selection process

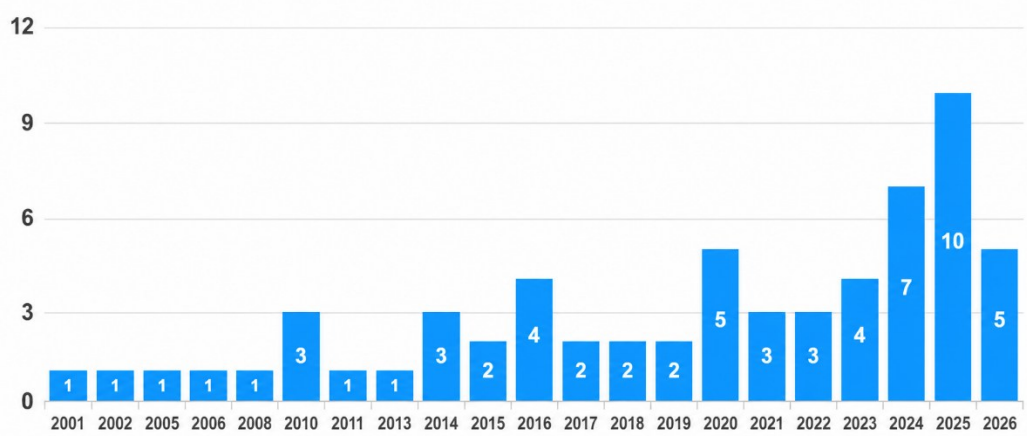


**Figure 2.** Result from keyword search

Figure 2. Publication trend from the initial, broader exploratory scoping search (not date-restricted; shown for context on the overall publication trend in the topic area). This differs from the final date-restricted sample of 62 records described above and analyzed in this review.

**Inclusion and Exclusion Criteria**

Explicit inclusion and exclusion criteria were established prior to the article selection stage to ensure consistency and methodological rigor. Studies were included if they met all of the following criteria: (1) published in Scopus-indexed peer-reviewed journals; (2) focused on environmental performance, environmental management, or sustainability-related strategies; (3) related to the energy sector or power generation systems, particularly coal-fired power plants; (4) written in English; and (5) published from January 2016 to June 2026.

Articles were excluded if they met any of the following conditions: (1) not published in Scopus-indexed journals; (2) focused exclusively on technical engineering design without broader environmental management implications; (3) did not address environmental sustainability or environmental strategy; (4) identified as duplicate or redundant records during the screening process; or (5) published in a journal whose aims and scope were not relevant to the topic of this review (e.g., journals outside the environmental science, energy, sustainability, or management disciplines). Applying criterion (5), 7 records were excluded because the publishing journal's aims and scope were judged not relevant to the review topic, rather than because of any journal-quartile or impact-ranking criterion.

**Screening, Selection, and Data Synthesis**

The screening and selection process followed the PRISMA 2020 framework. The initial Scopus search, restricted to January 2016–June 2026 as described above, yielded 62 records. During preliminary filtering, 15 records were excluded based on the predefined eligibility criteria (e.g., not published in Scopus-indexed journals, duplicate records, or document types outside the scope of this review). An additional 7 records were removed because the publishing journal's aims and scope were judged not relevant to the review topic (see Inclusion and Exclusion Criteria above). This left 40 records for title and abstract screening. Of these, 11 were excluded due to lack of relevance, resulting in 29 articles for full-text retrieval. Of these 29 articles, 15 could not be retrieved due to full-text accessibility limitations despite attempts at institutional library access and direct contact with corresponding authors, leaving 14 studies for full-text assessment; this accessibility gap is treated as a substantive source of potential bias rather than an incidental one. An additional 6 studies were identified through backward reference tracking, i.e., they were found within the reference lists of the 14 directly retrieved studies (Chen et al., 2023; Latan et al., 2018; Marchese et al., 2018; Newig et al., 2018; Tatoglu et al., 2020; Testa et al., 2018) resulting in a final sample of 20 studies. These six studies, all providing generic organizational or institutional evidence rather than direct coal-fired-power evidence (see Evidence Type in Table 1), were subjected to the same eligibility screening described above before inclusion. Although the final sample size was relatively limited, the selected studies represented relevant evidence aligned with the objectives of this review; the sample combines direct coal-fired-power evidence with adjacent energy-sector and generic organizational evidence, classified explicitly in Table 1 and used with corresponding caution throughout the Results and Discussion. Title/abstract and full-text screening were conducted by a single reviewer (the author). This is disclosed here as a limitation: because screening was not performed independently in duplicate by a second reviewer, no inter-rater agreement statistic (e.g., Cohen's kappa) is available, and the possibility of individual screening error or bias cannot be ruled out to the same degree as in a dual-reviewer design; this limitation is also noted in the Methodological Limitations section below.

A structured data extraction framework was developed to collect relevant information from each study, including research focus, methodological approach, type of environmental strategy, and key findings. Data extraction was performed jointly by the author and a colleague, who cross-checked the extracted information against each source article to verify accuracy and consistency. The "Research Gap" column reported for each study in Table 1 reflects the review authors' own interpretive judgment about unaddressed issues relative to this review's

objectives, rather than gaps stated verbatim in the original studies, and is labeled "Reviewer-Identified Gap" accordingly.

Extracted data were synthesized using thematic synthesis (Thomas & Harden, 2008), which involved three stages: (1) initial coding to identify key concepts related to environmental strategies, sustainability practices, and environmental management mechanisms within each article; (2) thematic categorization to organize codes into the broader strategic dimensions introduced in the Introduction (technological, managerial, social, and external); and (3) framework integration, in which the Natural-Resource-Based View and Institutional Theory constructs described in the Introduction were used to interpret how the four dimensions relate to one another. Consistent with the single-reviewer screening reported above, coding was performed by the same single author using a manual, spreadsheet-based coding matrix rather than dedicated qualitative analysis software (e.g., NVivo); this is disclosed as a limitation in the Methodological Limitations section below, alongside the single-reviewer screening.

A design-appropriate quality appraisal (e.g. using the Mixed Methods Appraisal Tool, MMAT,: Hong et al., 2018) would ordinarily be recommended given that the included studies span markedly different designs, including life-cycle assessments, engineering/exergy analyses, conceptual frameworks, structural equation models, institutional analyses, and one review study. Per the author team's decision, a formal quality or risk-of-bias appraisal was not conducted for this review, and this is explicitly acknowledged as a limitation in the Methodological Limitations section below; study designs of markedly different methodological strength are instead distinguished only by the Evidence Type classification reported in Table 1 (Direct coal-fired-power / Thermal-fossil-power / Other energy-generation / Generic organizational), without a formal quality score. Susiati et al.,(2024) is itself a review study; per the author team's confirmation, it is retained in Table 1 but labeled explicitly as a secondary/review study rather than counted among the primary empirical studies.

**Methodological Limitations**

This review is subject to several limitations. First, the review protocol was not registered in advance on an independent registry (e.g., OSF, PROSPERO, or INPLASY); although the review process was supported by the Watase UAKE platform for keyword development, screening, and PRISMA-based reporting, this operational tool use does not substitute for prospective protocol registration, and its absence is acknowledged as increasing the risk of post-hoc changes to eligibility or coding criteria relative to a prospectively registered review. Second, reliance on a single database (Scopus) may have limited the coverage of relevant studies indexed in other repositories, such as Web of Science or ScienceDirect. Third, restricting the review to English-language publications may have introduced language bias by excluding potentially relevant studies published in other languages. Fourth, more than half of the full texts sought for retrieval (15 of 29) could not be accessed; because this accessibility gap may be systematically related to publisher, region, or journal characteristics rather than occurring at random, it is treated here as a substantive potential source of bias rather than a minor limitation, and the resulting sample should be interpreted with this constraint in mind; the author team attempted to mitigate this gap through institutional library access and direct contact with corresponding authors for the inaccessible articles, though these attempts were not successful for all 15 articles. Fifth, the exclusion of conference proceedings and grey literature may have introduced publication bias by favoring formally published studies. Sixth, the search string used a relatively narrow set of terms (retaining the original string rather than the broader set suggested during review, such as "coal-fired power station," "ISO 14001," "eco-innovation," "cleaner production," and "PROPER"), which may have missed additional directly relevant studies. Seventh, title/abstract and full-text screening, as well as thematic coding, were conducted by a single reviewer without independent duplicate review, so no inter-rater agreement statistic is available and individual error or bias cannot be ruled out to the same degree as in a dual-reviewer design; coding relied on a manual, spreadsheet-based matrix rather

than dedicated qualitative analysis software. Eighth, a formal methodological quality or risk-of-bias appraisal (e.g., MMAT) was not conducted for the 20 included studies; because these studies span markedly different designs (life-cycle assessments, engineering/exergy analyses, conceptual frameworks, structural equation models, institutional analyses, and one review study), the absence of a formal quality score means that methodologically stronger and weaker studies are not formally distinguished beyond the Evidence Type classification reported in Table 1, and findings should be interpreted with this constraint in mind. In addition, limited access to some full-text articles may have reduced the inclusion of potentially relevant evidence. These limitations should be considered when interpreting and generalizing the findings of this review.

## RESULTS AND DISCUSSION

### Descriptive Profile of Reviewed Studies

The 20 studies included in this systematic review indicate a gradual yet accelerating growth of scholarly attention toward environmental performance and sustainability in the energy sector. Publications appeared relatively sporadically during the late 2010s, suggesting that research on beyond-compliance environmental strategies in coal-based power generation remained limited during this period. A more consistent publication trend emerged after 2019, coinciding with increasing global attention to climate change mitigation, carbon reduction targets, and energy transition policies (Wang et al., 2020). A notable increase in publications between 2020 and 2025 further reflects the growing influence of sustainability agendas, including the expansion of Environmental, Social, and Governance (ESG) frameworks and institutional systems that encourage organizations to improve environmental performance beyond minimum compliance requirements (Chen et al., 2023).

Table 1 summarizes the key characteristics of the selected studies. The reviewed literature demonstrates substantial diversity in terms of methodological approaches, research focus, and analytical perspectives. Studies included in this review employed life cycle assessment (LCA), energy–exergy analysis, sustainability assessment, data envelopment analysis, structural equation modelling, institutional analysis, and governance-oriented research frameworks. This diversity indicates that environmental performance in the energy sector has been studied from multiple disciplinary perspectives, spanning engineering, environmental science, organizational management, and sustainability research.

**Table 1.** Characteristics of selected studies included in the systematic literature review, with evidence-type classification added in response to reviewer comments

| No | Author(s) & Year | Method / Approach | Research Focus | Key Finding | Reviewer-Identified Gap | Evidence Type |
|---|---|---|---|---|---|---|
| 1 | Howladar and Islam (Howladar & Islam, 2016) | Environmental assessment | Coal ash utilization in power plants | Coal ash can be beneficially reused for environmental sustainability applications | Integration of waste utilization strategies into broader environmental performance frameworks | Direct coal-fired- power evidence |
| 2 | Kazagic et al. (2016) | Sustainability analysis | Biomass integration in coal power systems | Biomass substitution may improve environmental sustainability in coal-based utilities | Governance dimensions of biomass integration strategies remain underexplored | Direct coal-fired- power evidence |
| 3 | Leda et al. (Leda et al., 2023) | Life cycle assessment (LCA) | Environmental impact of | LCA provides a comprehensive multi-compartment | Connecting LCA outcomes to | Other energy-generation |

| No | Author(s) & Year | Method / Approach | Research Focus | Key Finding | Reviewer-Identified Gap | Evidence Type |
|---|---|---|---|---|---|---|
| | | | photovoltaic power plants | environmental impact evaluation | corporate environmental strategy and decision-making | evidence (photovoltaic) |
| 4 | Yang et al. (Yang et al., 2022) | DEA cost-benefit analysis | Emission trading and regulatory policy | Overlapping policy instruments appear to influence environmental performance in power production | Firm-level strategic responses to overlapping environmental policy instruments | Direct coal-fired- power evidence |
| 5 | Samadi et al. (Samadi et al., 2018) | Conceptual modelling | Environmental management of power plant waste | Conceptual models may support waste mitigation strategies in power generation | Empirical validation of conceptual models within integrated environmental strategy frameworks | Thermal/fossil- power evidence |
| 6 | Feng et al. (Feng et al., 2017) | Data envelopment analysis | Sustainability efficiency of cities with coal power plants | Efficiency measurement tools may support environmental sustainability evaluation | Incorporating corporate governance perspectives into sustainability efficiency evaluations | Thermal/fossil- power evidence (city-level) |
| 7 | Aydin and Kopac (2025) | Energy-exergy analysis | Sustainability performance of coal-fired power plants | Exergy analysis suggests meaningful operational efficiency improvement opportunities | Integration of social sustainability dimensions into thermodynamic performance assessments | Direct coal-fired- power evidence |
| 8 | Tatoglu et al. (Tatoglu et al., 2020) | Strategic management analysis | Voluntary environmental management practices | Firms tend to adopt environmental practices driven by strategic motivations | Sector-specific investigations of voluntary environmental practices in energy-intensive industries | Generic organizational / institutional evidence |
| 9 | Kim et al. (Kim et al., 2023) | Sustainability assessment | Oxy-combustion technology in coal power plants | Advanced combustion technologies appear to significantly reduce environmental emissions | Interaction between technological emission-reduction strategies and broader environmental governance frameworks | Direct coal-fired-power evidence |
| 10 | Zahedi et al. (Zahedi | Hybrid energy | Environmental impact of wind-fuel | Hybrid renewable systems appear to reduce environmental | Comparative environmental evaluation of | Other energy-generation evidence |

| No | Author(s) & Year | Method / Approach | Research Focus | Key Finding | Reviewer-Identified Gap | Evidence Type |
|---|---|---|---|---|---|---|
| | et al., 2021) | system analysis | cell hybrid systems | impacts relative to conventional generation | hybrid vs. coal-based power generation systems | (wind/fuel cell) |
| 11 | Kumar et al. (Kumar et al., 2024) | Energy-exergy and emission analysis | Environmental performance of coal-fired thermal power plants | Efficiency improvements can significantly reduce operational environmental emissions | Integration of energy efficiency analysis with corporate-level environmental management strategies | Direct coal-fired- power evidence |
| 12 | Batista et al. (Batista et al., 2025) | Life cycle assessment (LCA) | Environmental impacts of coal-fired power plants | LCA identifies key environmental hotspots across power generation systems | Connecting LCA results to stakeholder engagement and sustainability governance mechanisms | Direct coal-fired- power evidence |
| 13 | Wang et al. (Wang et al., 2020) | Sustainability assessment | Biomass substitution for coal power | Biomass-based energy systems may improve overall environmental sustainability outcomes | Alignment of biomass substitution strategies with corporate environmental strategy and governance frameworks | Other energy-generation evidence (biomass substitution) |
| 14 | Wlodarczyk and Mesjasz-Lech (2016) | Environmental modelling | Air pollution monitoring in thermal power plants | Pollution modelling may support environmental management decision-making in power plants | Contribution of environmental monitoring systems to broader sustainability governance development | Thermal/fossil- power evidence |
| 15 | Chen et al. (Chen et al., 2023) | Quantitative ESG analysis | ESG performance and financial outcomes | Strong ESG performance is associated with improved financial and sustainability outcomes | Translating ESG performance metrics into concrete organizational environmental strategy at the firm level | Generic organizational / institutional evidence |
| 16 | Marchese et al. (Marchese et al., 2018) | Conceptual framework development | Resilience and sustainability in environmental management | Integrated governance frameworks appear essential for long-term sustainability performance | Empirical evaluation of resilience-oriented sustainability frameworks in energy-sector governance contexts | Generic organizational / institutional evidence |

| No | Author(s) & Year | Method / Approach | Research Focus | Key Finding | Reviewer-Identified Gap | Evidence Type |
|---|---|---|---|---|---|---|
| 17 | Latan et al. (Latan et al., 2018) | Structural equation modelling | Environmental strategy and corporate environmental performance | Environmental strategy appears to significantly influence corporate environmental performance outcomes | Extension of environmental strategy models to energy-intensive industries such as power generation | Generic organizational / institutional evidence |
| 18 | Testa et al.(Testa et al., 2018) | Institutional analysis | Stakeholder pressure and environmental practices | Stakeholder pressures appear to influence the internalization of corporate environmental governance practices, with a risk of symbolic/greenwashing responses | Translating stakeholder pressures into concrete operational environmental strategies within industrial sectors | Generic organizational / institutional evidence |
| 19 | Newig et al. (Newig et al., 2018) | Governance analysis | Collaborative environmental governance mechanisms | Participatory governance mechanisms appear to improve environmental performance outcomes | Application of collaborative governance frameworks in industry-specific environmental management contexts | Generic organizational / institutional evidence |
| 20 | Susiati et al.(Susiati et al., 2024) | Review study | Environmental management of nuclear power plants | Environmental governance is considered essential for sustainable energy system operation | Comparative analysis of environmental governance strategies across nuclear and fossil-based energy systems | Other energy-generation evidence (nuclear; secondary source) |

Evidence Type follows a four-category scheme: (1) Direct coal-fired-power evidence; (2) Thermal/fossil-power evidence (broader thermal generation, not coal-specific); (3) Other energy-generation evidence (e.g., photovoltaic, wind, nuclear, biomass); (4) Generic organizational/institutional evidence.
Note: Six studies (Tatoglu et al., 2020; Chen et al., 2023; Marchese et al., 2018; Latan et al., 2018; Testa et al., 2018; and Newig et al., 2018) were identified through backward reference tracking from the reference lists of the 14 directly retrieved studies, rather than through the primary Scopus search; the same eligibility screening was applied to them before inclusion.

As Table 1 shows, of the 20 included studies, 8 provide direct coal-fired-power evidence, 3 provide broader thermal/fossil-power evidence, 5 provide evidence from other (non-fossil) energy-generation technologies, and 6 provide generic organizational or institutional evidence not specific to any energy-generation technology. Findings drawn from the first two categories are treated in this review as direct or closely transferable evidence for coal-fired power plants; findings from the latter two categories are treated as contextual or theoretical support and are flagged as such wherever they inform the Discussion or the proposed framework, consistent with the reviewers' recommendation to separate direct, adjacent, and generic evidence rather than presenting all 20 studies as uniformly coal-plant-specific.

Despite this methodological diversity, the literature reveals an important imbalance. Most studies predominantly emphasize technical and operational solutions, such as emission reduction technologies, efficiency optimization, and environmental impact assessment. Comparatively fewer studies investigate managerial, social, and institutional dimensions that

shape environmental performance beyond compliance. This imbalance reinforces the fragmented nature of existing literature and highlights the need for a more integrated analytical perspective.

**Methodological Distribution of Reviewed Studies**

The reviewed studies represent a broad range of methodological approaches used to examine environmental sustainability in the energy sector. Life cycle assessment (LCA) studies evaluate environmental impacts across multiple production stages, including resource extraction, fuel combustion, and waste management, thereby providing comprehensive multi-compartment environmental perspectives (Batista et al., 2025; Leda et al., 2023). Energy–exergy analysis focuses on efficiency and environmental performance in thermal power systems by identifying opportunities for operational optimization and emission reduction (Aydin & Kopac, 2025; Kumar et al., 2024).

Governance-oriented methodologies, including structural equation modelling and institutional analysis, examine how organizational and institutional factors influence environmental strategies and performance outcomes (Latan et al., 2018; Testa et al., 2018). In addition, quantitative approaches such as data envelopment analysis and cost–benefit analysis provide insights into efficiency measurement and the effectiveness of environmental policy instruments (Feng et al., 2017; Yang et al., 2022).

Industrial waste management and environmental monitoring constitute another important methodological cluster. Studies focusing on coal ash utilization and air pollution monitoring highlight the role of waste management and environmental surveillance in supporting sustainability performance within power generation systems (Howladar & Islam, 2016; Samadi et al., 2018; Włodarczyk & Mesjasz-Lech, 2016).

Overall, the methodological distribution demonstrates that research in this area remains dominated by technically oriented analytical approaches. While these approaches provide valuable evidence regarding operational efficiency and environmental impacts, relatively limited research integrates technical findings with organizational strategy, stakeholder engagement, and broader environmental management perspectives. This gap supports the relevance of the present review in synthesizing multidimensional environmental performance strategies.

**Beyond-Compliance Environmental Performance Strategies**

The thematic synthesis revealed four principal strategic dimensions through which organizations within the energy sector may enhance their environmental performance beyond the threshold established by minimum regulatory compliance. These dimensions comprise: (1) technological environmental innovation, (2) environmental management practices, (3) social sustainability initiatives, and (4) external environmental drivers. The interrelationships among these four dimensions are depicted in Figure 3. The four themes are not equally supported by direct coal-plant evidence: technological environmental innovation draws on the largest number of direct technical studies (e.g., Aydin & Kopac, 2025; Howladar & Islam, 2016; Kim et al., 2023; Kumar et al., 2024); environmental management practices draw on partial organizational support, combining direct and generic evidence (Latan et al., 2018; Tatoglu et al., 2020); social sustainability initiatives are supported mainly by generic participatory-governance literature rather than coal-plant-specific studies (Newig et al., 2018); and external environmental drivers draw on a mix of direct regulatory studies and non-coal-specific ESG/institutional literature (Chen et al., 2023; Yang et al., 2022). This uneven evidentiary base is a limitation of the current review, not a finding about the relative real-world importance of each dimension.

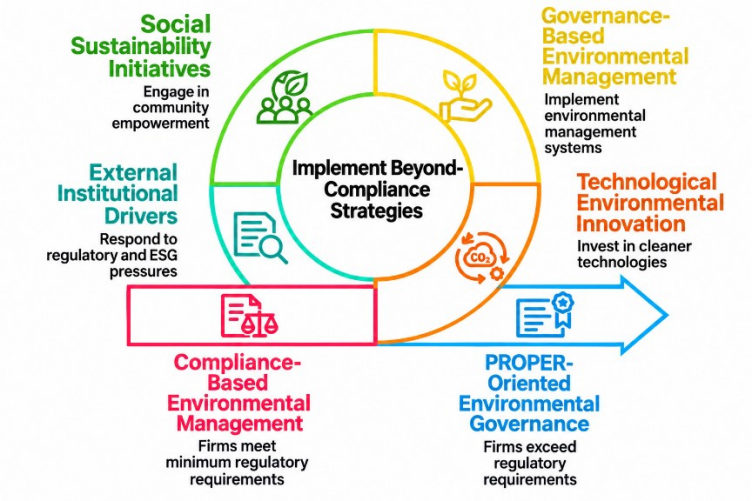


**Figure 3.** Achieving Beyond-Compliance Environmental Performance

The first dimension, technological environmental innovation, includes emission-reduction technologies, advanced combustion systems, energy-efficiency improvements, and LCA-based environmental assessment approaches. Oxy-combustion systems and energy–exergy optimization have demonstrated substantial potential for reducing emissions while improving operational efficiency in coal-fired power plants (Kim et al., 2023; Kumar et al., 2024). In addition, LCA provides a complementary framework for evaluating environmental impacts across the entire energy production chain, thereby supporting evidence-based environmental decision-making (Leda et al., 2023). The integration of renewable energy sources, including biomass substitution and hybrid systems, represents another pathway for reducing the environmental footprint of power generation (Wang et al., 2020; Zahedi et al., 2021).

The second dimension, environmental management practices, encompasses organizational systems and strategic practices that integrate sustainability objectives into daily operations. Voluntary environmental management initiatives, including environmental management systems, sustainability-oriented operational procedures, and eco-innovation programs, have been increasingly adopted to strengthen environmental accountability and organizational legitimacy (Tatoglu et al., 2020). Existing evidence suggests that organizations with strong environmental management capabilities tend to achieve better sustainability performance, indicating that managerial commitment to environmental objectives is as important as technological capability (Latan et al., 2018; Marchese et al., 2018).

The third dimension, social sustainability initiatives, includes stakeholder engagement, community development programs, and corporate social responsibility practices. Organizations operating in areas affected by energy infrastructure often implement community empowerment programs and environmental awareness initiatives to strengthen social acceptance and align environmental actions with stakeholder expectations. Participatory and collaborative mechanisms may improve environmental performance by facilitating greater stakeholder involvement in environmental decision-making processes (Newig et al., 2018).

The fourth dimension, external environmental drivers, consists of regulatory frameworks, policy instruments, and stakeholder pressures that incentivize proactive environmental behavior. Emission trading systems and command-and-control regulations have been shown to encourage the adoption of cleaner production technologies in power generation (Yang et al., 2022). Furthermore, ESG frameworks increasingly shape investor expectations and corporate environmental accountability, with evidence suggesting that strong ESG performance is positively associated with both financial and sustainability outcomes (Chen et al., 2023). Pressures from regulators, investors, and civil society may further drive the

internalization of environmental practices beyond minimum compliance requirements (Testa et al., 2018).

Environmental performance was not operationally defined, we clarify here that environmental performance, as used throughout this review, is not measured directly but is instead the general outcome construct toward which the four dimensions above are hypothesized to contribute. Candidate measurable indicators consistent with this construct, drawn from the reviewed literature, include greenhouse-gas intensity, air-pollutant emissions, water consumption, waste generation, ash utilization, biodiversity impact, regulatory or PROPER performance, and ESG score; none of these indicators is measured directly within this review's own synthesis, but they define the outcome space that future primary studies applying this framework could measure.

**Integrative Framework of Beyond-Compliance Environmental Strategy**

Based on the thematic synthesis, this study proposes an integrative conceptual framework to explain how beyond-compliance environmental strategies contribute to improved environmental performance in the energy sector. The framework integrates internal organizational capabilities and external environmental drivers to illustrate how organizations can transition from compliance-based environmental management toward proactive environmental excellence, particularly in coal-fired power generation systems.

The framework is structured around four strategic dimensions: (1) technological environmental innovation, encompassing cleaner production technologies, advanced combustion systems, energy-efficiency improvements, and LCA-based assessment; (2) environmental management practices, including environmental management systems, voluntary environmental programs, and sustainability-oriented operational practices; (3) social sustainability initiatives, including stakeholder engagement, community development programs, and corporate social responsibility practices; and (4) external environmental drivers, including environmental regulations, sustainability-related mechanisms, and ESG expectations. At the core of this framework lies the implementation of beyond-compliance strategies, which serve as the central mechanism linking internal organizational capabilities with external pressures. The four dimensions are retained here at a single, parsimonious level of analysis for accessibility to policy and practitioner audiences; we acknowledge, following reviewer feedback, that they combine elements that could in principle be separated into distinct analytical layers (external antecedents, internal capabilities, beyond-compliance practices, outcomes, and institutional recognition, with plant-level moderators and a feedback loop). Developing and empirically testing this more granular layered structure is left to dedicated follow-up conceptual work rather than the present systematic review.

Organizations that align technological innovation, environmental management, and social sustainability initiatives with external environmental expectations are, based on the reviewed evidence, associated with stronger environmental performance outcomes; this association should not be read as a demonstrated causal effect given the heterogeneous and largely non-experimental designs of the included studies. From a Natural-Resource-Based View (NRBV) perspective (Hart, 1995), environmental capabilities, including technological competencies, environmental management systems, and sustainability-oriented organizational culture, represent valuable strategic resources that may contribute to long-term competitive advantage (Hart, 1995; Hart & Dowell, 2011). From an Institutional Theory perspective, coercive, normative, and mimetic pressures shape organizational environmental behavior and may encourage proactive sustainability strategies (DiMaggio & Powell, 1983; Scott, 2014). Mapped onto the studies reviewed here, coercive pressures correspond to legal requirements, carbon-pricing and emission-trading instruments, and PROPER (Yang et al., 2022); normative pressures correspond to ESG standards and professional/industry expectations (Chen et al., 2023); and mimetic pressures correspond to the imitation of leading utilities or recognized environmental performers, a mechanism discussed conceptually in the institutional literature

(Testa et al., 2018) but not directly measured in any coal-plant-specific study identified in this review.

**Discussion**

Consistent with the evidence classification in Table 1, the claims below are organized by evidentiary strength: direct coal-specific evidence provides the strongest basis for plant-level recommendations; other power-generation evidence is transferable to coal-fired plants only with caution; generic corporate evidence offers theoretical support rather than plant-level proof; and conceptual or review-type evidence supports framework-building rather than causal claims. Findings drawn from each tier are labeled accordingly below.

The findings of this systematic review indicate that environmental performance improvement in coal-fired power plants may be shaped by the interaction between technological innovation, environmental management practices, and external environmental pressures rather than by any single factor in isolation (direct and generic evidence combined). This multidimensional perspective aligns with contemporary sustainability discourse, which emphasizes the integration of technological, managerial, and institutional approaches to achieve long-term environmental performance in energy-intensive industries (Wang et al., 2020).

A key contribution of this review is the demonstration that environmental performance improvement in coal-fired power plants should not be viewed solely as a technological challenge. Instead, it should be understood as a multidimensional strategic process shaped by the interaction between technical capability, organizational commitment, social legitimacy, and external environmental pressures. This finding provides a more comprehensive perspective on beyond-compliance environmental performance.

Technological innovation emerges as a central mechanism for reducing the environmental impacts of coal-based power generation. Advanced combustion technologies and energy–exergy optimization contribute significantly to emission reduction and operational efficiency improvement in coal-fired power plants (Kim et al., 2023; Kumar et al., 2024). LCA approaches further support evidence-based identification of priority intervention points across the energy production chain (Batista et al., 2025; Leda et al., 2023). However, the evidence consistently suggests that technological solutions alone are insufficient to ensure long-term environmental sustainability.

Environmental management practices are equally important because they embed environmental objectives into corporate strategy and operational processes. These practices strengthen accountability, improve organizational learning, and enhance long-term environmental commitment (Latan et al., 2018; Tatoglu et al., 2020). This finding indicates that technological investments generate optimal environmental benefits only when supported by strong organizational commitment and effective management systems.

External environmental pressures may further reinforce internal environmental management by creating incentives for proactive sustainability strategies. Regulatory instruments such as emission trading systems may encourage cleaner production and stronger sustainability performance ((Yang et al., 2022); direct evidence), while ESG frameworks intensify stakeholder expectations and corporate environmental accountability ((Chen et al., 2023); generic evidence). These patterns are consistent with Institutional Theory, which suggests that coercive and normative pressures influence organizational environmental behavior (DiMaggio & Powell, 1983).

However, institutional pressure does not guarantee substantive environmental improvement. Testa et al. (2018) caution that stakeholder and institutional pressure can produce symbolic adoption or greenwashing rather than genuine internalization of environmental practice. Following this distinction, the framework proposed here separates: (a) substantive internalization, where practices measurably change environmental outcomes; (b) symbolic certification, where formal adoption (e.g., of a management-system standard) is not

accompanied by performance change; (c) disclosure without performance improvement, where transparency initiatives are not linked to outcome indicators; and (d) community programs disconnected from environmental impact, where social initiatives proceed without a demonstrated environmental pathway. None of the studies identified in this review directly tests which of these patterns predominates among coal-fired power plants; this is noted as a priority for future empirical research rather than resolved here.

The interaction between internal capabilities and external pressures highlighted in the proposed framework aligns with the integrated perspective of Marchese et al. (2018; generic evidence), who argue that resilience and sustainability require holistic rather than isolated interventions.

**Proposed Application to PROPER**

This section presents a proposed application of the synthesized framework to Indonesia's PROPER rating system; it is not a direct empirical finding of the review, since none of the 20 included studies evaluates PROPER rating transitions, criteria, or outcomes directly. Readers should therefore treat the discussion below as illustrative reasoning rather than an evidence-based conclusion.

In the Indonesian context, the PROPER (Program Penilaian Peringkat Kinerja Perusahaan dalam Pengelolaan Lingkungan Hidup) environmental performance rating system, currently governed by Peraturan Menteri Lingkungan Hidup/Badan Pengendalian Lingkungan Hidup Nomor 7 Tahun 2025 and its implementing technical criteria (Keputusan Menteri Nomor 1375 Tahun 2025), provides a practical illustration of how institutional mechanisms can influence corporate environmental behavior. Companies seeking higher PROPER ratings are required to demonstrate integrated environmental strategies encompassing technological innovation, environmental management practices, and community-oriented sustainability initiatives. This beyond-compliance orientation provides a strategic pathway for energy-sector organizations seeking to improve environmental performance and pursue formal recognition within Indonesia's environmental rating system.

Read as a proposed application rather than a tested implication, the synthesized dimensions suggest without direct PROPER-specific evidence, that superior environmental performance may be difficult to achieve through regulatory compliance alone. Organizations that combine technological innovation, effective environmental management, stakeholder engagement, and proactive responses to external expectations may be better positioned relative to PROPER's stated criteria, though this proposition has not been empirically tested against actual PROPER rating data in this review. Concrete, measurable actions consistent with this proposed application include: setting emissions-intensity targets; implementing coal-ash utilization systems; establishing water-efficiency programs; conducting continuous environmental monitoring; pursuing ISO 14001 environmental-management-system certification; using LCA-supported investment decisions; running community environmental-monitoring programs; and maintaining transparent public disclosure, each of which can, in principle, be mapped to specific PROPER assessment criteria and to the measurable outcome indicators listed earlier in the Discussion.

This observation aligns closely with the philosophy underlying PROPER. The program was designed not only to assess compliance but also to encourage organizations to adopt innovative approaches that create environmental and social value. Many of the strategic dimensions identified in this review correspond directly to assessment components within higher PROPER categories, particularly Green and Gold ratings. Technological innovation contributes to resource efficiency and emission reduction, environmental management strengthens organizational learning and accountability, while community empowerment reinforces social legitimacy and long-term sustainability.

For coal-fired power plants, these findings suggest that environmental excellence requires a strategic shift from compliance-oriented management toward proactive

environmental leadership. Investments in cleaner technologies remain important, but they must be supported by strong organizational commitment, transparent management systems, and meaningful engagement with surrounding communities. Companies that integrate these elements are, on the basis of the reviewed literature, more likely to be associated with measurable and sustainable environmental improvements over time, though this remains a proposed rather than empirically confirmed relationship.

From this perspective, PROPER can be understood not merely as an environmental evaluation instrument but as a strategic mechanism that encourages continuous organizational transformation. Therefore, the framework proposed in this review provides practical guidance for organizations seeking to strengthen environmental performance while pursuing higher levels of recognition within Indonesia's environmental rating system.

## CONCLUSION

This study synthesized direct and adjacent evidence on beyond-compliance environmental strategies in coal-fired power plants through a PRISMA 2020-based systematic review of 20 peer-reviewed studies published between January 2016 and June 2026, of which 8 provide direct coal-fired-power evidence and the remainder provide broader thermal, other-energy-generation, or generic organizational evidence (Table 1). Four interrelated strategic dimensions were identified: technological environmental innovation, environmental management practices, social sustainability initiatives, and external environmental drivers. Based on these findings, an integrative conceptual framework informed by the Natural-Resource-Based View (NRBV) and Institutional Theory was proposed to explain how internal organizational capabilities and external environmental pressures may interact to shape environmental performance in energy-intensive industries; the framework is a conceptual proposition that has not been empirically validated.

This review contributes to the environmental performance literature by providing a unified analytical perspective that addresses the fragmented nature of existing research. The synthesis suggests that environmental performance improvement in coal-fired power plants should not be viewed solely as a technological challenge, but rather as a multidimensional strategic process potentially involving technological capability, organizational commitment, stakeholder engagement, and external environmental pressures; because the included evidence is heterogeneous and partly drawn from adjacent energy and organizational contexts (Table 1), this framework should be regarded as a conceptual proposition requiring empirical validation in coal-fired power plants.

From a practical perspective, the synthesized evidence suggests that organizations in the energy sector may be more likely to achieve stronger environmental performance when technological innovation is aligned with effective environmental management and social sustainability initiatives, though this proposition awaits empirical testing specifically within coal-fired power plants. In the Indonesian context, the proposed framework offers practical guidance for organizations seeking to progress beyond compliance and achieve higher levels of recognition within the PROPER environmental rating system.

Future research should empirically validate the proposed framework using survey-based, case study, or longitudinal research designs in energy-sector contexts. Expanding future systematic reviews to include additional databases, such as Web of Science and ScienceDirect, may improve evidence coverage. Comparative studies across different energy-generation systems would further enrich understanding of beyond-compliance environmental strategies in diverse industrial contexts.

## RECOMMENDATION

Based on the synthesis presented in this review, several recommendations are proposed for future research, practice, and policy. First, the integrative framework linking the Natural-Resource-Based View and Institutional Theory should be empirically validated through

survey-based, case-study, or longitudinal research designs conducted specifically within coal-fired power plants, given that only 8 of the 20 studies included in this review provide direct evidence from this sector. Second, future systematic reviews on this topic should expand the search strategy to additional databases, such as Web of Science and ScienceDirect, and incorporate a broader set of search terms (e.g., "coal-fired power station," "ISO 14001," "eco-innovation," "cleaner production," and "PROPER") to improve evidence coverage relative to the narrower string retained in this review. Third, from a practical standpoint, plant operators and environmental managers in the energy sector are encouraged to pursue beyond-compliance strategies that integrate technological innovation with environmental management systems and social sustainability initiatives, rather than treating these dimensions in isolation. Fourth, in the Indonesian context, regulators and companies engaging with the PROPER rating system may use the proposed framework as an exploratory reference for structuring beyond-compliance initiatives, while recognizing that no study identified in this review directly evaluates PROPER outcomes and that empirical testing of this application remains necessary. Fifth, comparative studies across different energy-generation systems (e.g., coal, biomass, hybrid renewable systems) are recommended to clarify the extent to which the four strategic dimensions identified here generalize beyond the coal-fired power sector.

Several barriers and methodological constraints should be considered when interpreting and building upon these findings. The limited availability of direct coal-fired-power evidence restricts the strength of sector-specific conclusions and increases reliance on adjacent energy-generation and generic organizational evidence. The absence of a formal risk-of-bias or quality appraisal across studies of markedly different designs means that methodologically stronger and weaker evidence could not be formally distinguished. In addition, the reliance on a single database, English-language restriction, and single-reviewer screening and coding process, may have constrained the comprehensiveness and reproducibility of the evidence base. Researchers extending this work are encouraged to address these constraints through prospectively registered protocols, dual-reviewer screening, and formal quality appraisal tools appropriate to mixed-design evidence synthesis.

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**AUTHOR CONTRIBUTIONS STATEMENT**
Totok Widianto: Conceptualization, Methodology, Investigation, Writing – Original Draft; Arief Rachmansyah: Formal Analysis, Validation, Supervision; Dini Atikawati: Investigation, Data Curation; Rochman Hidayat: Resources, Writing – Review & Editing; Rinda Lolita Melanwati: Formal Analysis, Writing – Review & Editing. All authors have read and agreed to the published version of the manuscript.

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| Totok Widianto | ✓ | ✓ | | | | ✓ | | | ✓ | | | | | |
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| Rochman Hidayat | | | | | | | ✓ | | | ✓ | | | | |
| Rinda Lolita Melanwati | | | | | ✓ | | | | | ✓ | | | | |

**CONFLICT OF INTEREST STATEMENT**
The authors declare no conflict of interest. One author (R.H.) is affiliated with a coal-fired power plant operating company (PT Paiton Energy / PT Paiton Operation & Maintenance Indonesia); this affiliation is disclosed for transparency and did not influence the study design, analysis, or conclusions.

**INFORMED CONSENT**
Not applicable. This study is a systematic literature review based entirely on previously published, publicly available articles and did not involve the collection of data from human participants.

**ETHICAL APPROVAL**

Not applicable. This study did not involve human participants or animal subjects; it is a systematic literature review of previously published, publicly available research.

**DATA AVAILABILITY**

The data that support the findings of this study are available within the article itself. Table 1 reports the full list of the 20 studies included in this systematic review, together with their bibliographic details, methodological approach, research focus, key findings, and evidence-type classification. The complete search strategy, including the Scopus query string, the inclusion and exclusion criteria, and the PRISMA 2020 screening and selection process, is described in the Method section and illustrated in Figure 1. No new primary data were generated or analyzed beyond the published, publicly accessible articles synthesized in this review.

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