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PREDICTING FINANCIAL SURVIVAL: ALTMAN Z-SCORE INSIGHTS INTO INDIA'S RENEWABLE ENERGY INDUSTRY

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Abstract:
This study evaluates the financial health and bankruptcy risk of seven major Indian renewable energy firms from 2014 to 2023 using the Altman Z-score model, specifically its version adapted for emerging markets. As India targets 450 GW of renewable energy capacity by 2030, understanding the financial resilience of key industry players is crucial for guiding investment strategies and informed policy decisions. The selected firms, including Tata Power Renewable Energy, Adani Green Energy, Suzlon Energy, Inox Wind, NHPC, SJVN, and Reliance Power, represent a diverse mix of ownership structures and operate across the solar, wind, and hydro sectors. A quantitative approach was employed, using publicly available financial data and incorporating key ratios, including working capital, retained earnings, EBIT, and the market value of equity. The results reveal variations in financial performance: Adani Green consistently remained in the green zone after 2020, reflecting strong investor confidence and low insolvency risk, while NHPC and Reliance Power stayed in the distress zone throughout, suggesting persistent financial weakness. Suzlon Energy showed volatility but signs of recovery by 2023, whereas Inox Wind moved from stability to distress after 2017. These findings support the use of the Z-score as a financial early warning tool in capital-intensive sectors. However, the model's limitations are evident in its inability to fully capture industry-specific challenges, such as delayed subsidies, regulatory uncertainty, and long asset payback periods. The study recommends integrating financial ratios with sector-specific and qualitative indicators to enhance the analysis

Keywords: Renewable Energy, Altman Z-score model, Financial Health, Insolvency Prediction, Emerging Markets

INTRODUCTION

India's transition toward sustainable energy is accelerating, with an installed renewable energy capacity of 199.52 GW as of August 2023, reflecting a 165% growth from 2014 levels (MNRE, 2023). Driven by policy incentives, such as the Jawaharlal Nehru National Solar Mission (JNNSM) and the declining cost of solar photovoltaic technology, India has emerged as the fourth-largest renewable energy market globally (Wu, 2023). The national target of reaching 450 GW of renewable energy capacity by 2030 underscores the scale of investment and financial planning required across this sector (Ko, Fujita, & Li, 2017).

To ensure financial resilience and investment viability in this context, the Altman Z-score model serves as a critical tool. Developed by Edward I. Altman (1968), the model utilizes Multiple Discriminant Analysis (MDA) to combine five key financial ratios—encompassing liquidity, profitability, leverage, and market valuation—into a single score that categorizes firms into zones of financial health or distress. Initially applied to U.S. manufacturing firms, the model has since been adapted globally and across sectors, including energy and infrastructure (Altman et al., 2017; Mohammed, 2017).

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Its application in the renewable energy sector is both timely and essential. Firms in this space face unique financial challenges such as delayed subsidy payments, regulatory uncertainties, and long asset payback periods—factors that conventional solvency models often overlook (Ko et al., 2017; Panigrahi, 2019). The Z-score, particularly its variant for emerging markets, offers a robust predictive framework for evaluating the financial sustainability of Indian renewable energy companies. This helps investors, policymakers, and project developers mitigate financial risks and align their strategic planning with national energy goals (Chitta & Jain, 2019).

Background of the Renewable Energy Sector in India. Energy is the most essential factor in developing a nation, and we have seen the consequences of relying on conventional energy sources. So, responsible bodies decided to transition from conventional energy sources to renewable energy sources. Recognizing the need to diversify its energy sources, India began exploring alternative forms of energy. In 1981, the government established the Department of Non-Conventional Energy Sources (DNES), which was later renamed the Ministry of New and Renewable Energy (MNRE) in 1992. This department was established to promote renewable energy sources, including solar, wind, and biomass.

The renewable energy industry experienced modest growth in the 1990s and 2000s, with initial efforts primarily focused on small-scale wind and hydroelectric projects. A landmark piece of legislation, the 2003 Electricity Act, required utilities to have renewable purchase obligations (RPOs), establishing the legal foundation for the development of renewable energy in India. In the 2010s, India expedited its transition to renewable energy sources. The 2010 launch of the Jawaharlal Nehru National Solar Mission (JNNSM) set lofty objectives for the development of solar energy. Substantial legislative support, financial incentives, and declining technical costs—especially for solar power—followed. Thanks to the rapid increase in installed capacity driven by the push towards solar energy, India is currently one of the world's largest solar markets.

India committed in 2015 to sourcing 40% of its electricity from nonfossil fuel sources by 2030 as part of its responsibilities under the Paris Agreement. The government's increased focus on renewable energy was further evidenced by its development of a 175 GW target for renewable capacity by 2022, which comprises smaller quantities from biomass and hydropower, 100 GW from solar energy, and 60 GW from wind energy. Technological advancements, forward-thinking legal frameworks, and a growing emphasis on sustainability mark India's transition to renewable energy. By 2030, the nation hopes to have installed 450 GW of renewable energy capacity.

Role of the Renewable Energy Companies in the Development of India. India's development depends heavily on renewable energy companies, which promote the switch to clean energy, lessen reliance on fossil fuels, and stimulate economic growth.

Energy Security and Sustainability: By reducing India's reliance on imported fossil fuels and diversifying its energy sources, these businesses enhance energy security and support the nation in achieving its climate objectives. Big names in large-scale wind, solar, and hydro projects include Adani Green Energy, Inox Wind Ltd., and Tata Power Renewable Energy.

Employment Generation and Economic Development: In India, the renewable energy industry supports thousands of employees in operations, maintenance, building, and manufacturing. The International Renewable Energy Agency (IRENA) estimates that approximately 719,000 Indians are employed in the renewable energy industry.

Innovation and Technological Advancements: Renewable energy companies drive innovation by implementing cutting-edge technologies, such as solar photovoltaics (PV), wind turbines, and energy storage systems. By reducing solar energy costs and increasing capacity, these developments have greatly aided in the Jawaharlal Nehru National Solar Mission's" success.

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Rural Electrification and Access: Renewable energy companies play a crucial role in providing electricity to remote areas with limited grid access. Through off-grid solar power projects and microgrids, companies offer affordable and sustainable energy solutions, improving the quality of life and supporting rural economies.

Reducing Carbon Footprint: By focusing on clean energy, renewable energy firms contribute to reducing India's carbon emissions and supporting the country's Paris Agreement commitments. They help offset millions of tons of CO2 through sustainable energy projects.

Attracting Investments: Renewable energy companies have attracted significant foreign direct investment (FDI) as global investors see India's potential as a renewable energy hub. This influx of capital promotes infrastructure development and stimulates economic growth.

The following questions have driven the study: What is the financial health of the selected renewable energy companies? From the selected renewable energy companies, which company is located in which zone?

Recent studies have expanded the applications of Z-scores to energy, infrastructure, and capital-intensive sectors. Mohammed (2017) examined cement and power companies in Oman, confirming the validity of the Z-score in volatile markets but noting that it fails to reflect long-term strategic viability. Ko, Fujita, and Li (2017) tested the model on solar energy firms and found that while Z-scores effectively captured short-term liquidity stress, they underperformed in predicting sustainability in subsidy-driven industries. This view is echoed by Wu (2023), who explored financial resilience among renewable firms and emphasized the need to blend traditional ratios with banking and policy-based variables.

In India, Azam et al. (2023) applied the Z-score to Indian private banks, demonstrating its portability but underscoring limitations when firms are affected by regulatory caps, tax incentives, or long construction cycles, as is common in energy infrastructure projects. Despite the widespread application of the Altman Z-score across industries and countries, a notable gap remains in its contextualization within India's renewable energy sector. Existing research has applied the model to manufacturing (Odibi et al., 2015), pharmaceuticals (Panigrahi, 2019), banking (Azam et al., 2023), and cement and energy in other countries (Mohammed, 2017), but few studies have examined capital-intensive, policy-driven sectors like renewable energy in India. This sector's unique financial architecture—marked by long payback periods, delayed subsidy payments, and regulatory dependence—poses challenges that traditional Z-score formulations may not adequately address (Ko et al., 2017; Wu, 2023). Consequently, the literature lacks sector-specific empirical validation of the model's effectiveness in predicting distress among Indian renewable firms, especially when such firms play a critical role in national climate and energy objectives.

This study addresses the identified research gap by applying the Emerging Markets variant of the Altman Z-score (Altman et al., 2017) to assess the financial health of seven major Indian renewable energy companies over ten years. By incorporating variables that reflect liquidity, solvency, and profitability within the context of India's policy and investment environment, the model captures financial dynamics often overlooked by generic formulations (Panigrahi, 2019; Chitta & Jain, 2019). The use of long-term financial data enhances the robustness of the findings, while the firm-level analysis provides practical insights for investors, regulators, and financial institutions. Ultimately, this study extends the empirical utility of the Z-score to an underexplored but strategically important domain, equipping stakeholders with a more tailored and relevant framework for financial risk assessment in the renewable energy industry. To predict the possibility of bankruptcy of select Indian Renewable Energy Companies. To Assess the Applicability of the Altman Z-score Model for Predicting Insolvency.

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METHODS

Sample Selection and Scope. This study focuses on seven key renewable energy companies in India selected based on their installed production capacity and operational significance between 2014 and 2023. The companies are Adani Green Energy Ltd., Tata Power Renewable Energy Ltd., Suzlon Energy Ltd., Inox Wind Ltd., NHPC Ltd., SJVN Ltd., and Reliance Power Ltd. These firms represent a mix of private and public entities operating across various segments of India's renewable sector, including solar, wind, and hydropower. Their selection ensures a balanced representation of organizational types, ownership structures, and operational scales relevant to the national energy mission.

Data Sources and Types. The study relies on secondary financial data drawn from Company annual reports (2014–2023), publicly available balance sheets and income statements from Capitaline and company websites, as well as financial disclosures published on the Bombay Stock Exchange (BSE) and National Stock Exchange (NSE) portals. All data points, including working capital, total assets, EBIT, market value of equity, and total liabilities, were systematically extracted and normalized for consistency. Data was cross-referenced to minimize reporting inconsistencies, enhancing reliability (Altman et al., 2017).

Analytical Framework: Altman Z-Score for Emerging Markets. Edward I. Altman developed the Altman Z-score model in the late 1960s as a predictive tool for assessing a company's financial health and its likelihood of bankruptcy. Given the capital-intensive nature of renewable energy projects and India's status as an emerging market, this study applies Altman's Emerging Markets Z-score formula to account for sector-specific risks such as high leverage ratios, policy dependencies, and long payback periods. The formula is adjusted as follows: $Z=3.25+6.56X1+3.26X2+6.72X3+1.05X4Z=3.25+6.56X1+3.26X2+6.72X3+1.05X4$.
Where:

- X1 = (Current Assets - Current Liabilities) / Total Assets
- X2 = Retained Earnings / Total Assets
- X3 = Earnings Before Interest and Taxes (EBIT) / Total Assets
- X4 = Book Value of Equity / Total Liabilities
- This version omits the fifth ratio (X5 = Sales/Total Assets) to suit firms with capital-intensive but low asset turnover, which is typical of renewable energy projects (Boďa & Úradníček, 2016; Ko et al., 2017).

Rationale for Model Choice. The Emerging Market Z-score variant is better suited to India's renewable energy firms for several reasons: These companies often exhibit delayed revenue realization due to subsidy backlogs and regulatory lags, high leverage and debt-dependency are common, especially in project-financed solar and wind installations, and long-term viability depends more on equity solvency and retained earnings than on sales turnover (Panigrahi, 2019; Rahman, 2024). Using this formula helps tailor insolvency prediction to reflect the unique structural and financial characteristics of the Indian renewable energy landscape.

RESULT AND DISCUSSION

For predicting bankruptcy with more accuracy, Altman's Z-score model is revolutionary. Multivariate Discrimination Analysis (MDA) is the name given to this model. Three tables include the data that the researcher has included in this section. The measured Z-scores and matching zones for each company are shown in the first table. The second table consists of a bar chart depicting the

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companies' Z-scores. Lastly, the third table presents a pie chart illustrating the distribution of years each company has spent in each zone.

Table 1. Suzlon Energy Ltd

Year	X1 = WC/TA	X2 = RE/ TA	X3 = EBIT/TA	X4=MVE/TL	X5= Sales / T A	Z-score
2023	0.026	0.265	0.715	2.035	0.918	4.096
2022	0.001	2.072	0.017	2.925	1.399	0.308
2021	0.111	2.002	0.257	1.410	0.415	-0.828
2020	0.983	6.420	-0.821	0.601	0.212	-12.303
2019	0.220	2.121	-1.582	0.858	0.667	-7.270
2018	0.214	0.091	0.062	0.729	0.763	1.536
2017	0.002	0.002	0.230	1.297	1.250	2.793
2016	0.135	0.057	0.221	1.006	0.841	2.257
2015	0.527	0.213	-0.412	0.900	0.201	-0.286
2014	0.090	0.166	0.036	0.212	0.235	0.822

Table 1 presents a detailed analysis of Suzlon Energy Ltd.'s financial health from 2014 to 2023, utilizing various financial ratios and the Altman Z-score. Distress Zone (Z-score < 1.81): Years 2022 (0.308), 2021 (-0.828), 2020 (-12.303), 2019 (-7.270), 2015 (-0.286), and 2014 (0.822) fall into the distress zone, indicating a high risk of financial distress.

Gray Zone (1.81 ≤ Z-score ≤ 2.99): Years 2018 (1.536) and 2017 (2.793) fall within this range, indicating moderate risk. Green Zone (Z-score > 2.99): Year 2023 (4.096) falls into the green zone, indicating a low risk of financial distress. It reveals significant fluctuations in Suzlon Energy Ltd.'s financial health over the past ten years. The company experienced severe financial distress in multiple years, particularly in 2020 and 2019, with extremely low Z-scores of -12.303 and -7.270, respectively. These years were marked by negative EBIT/TA ratios, indicating substantial losses.

In contrast, the year 2023 shows a remarkable improvement with a Z-score of 4.096, placing Suzlon Energy Ltd in the green zone. This improvement is attributed to better profitability (EBIT/TA of 0.715) and strong market confidence (M/TL of 2.035).

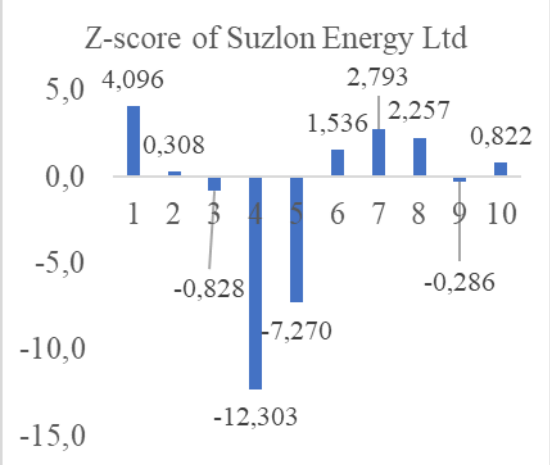

Figure 1. Z-Score of Suzlon Energy Ltd

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Figure 1 presents a bar chart of the Z-scores of Suzlon Energy Ltd from 2014 to 2023, along with their Z-score values. Suzlon Energy's Z-scores fluctuated significantly between 2014 (–0.286) and 2023 (4.096), with a sharp decline in 2020 (–12.303) due to negative EBIT/TA ratios. The trend highlights cyclical vulnerabilities linked to policy delays and debt restructuring.

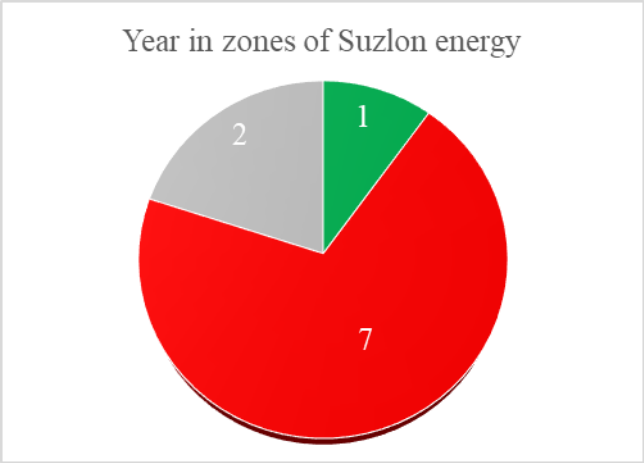

Figure 2. Pie Chart of Years in Zones

Figure 2 Pie chart displays that among the 10 years, Suzlon Energy Ltd was in the red zone for 7 years, the gray zone for 2 years, and the green zone for 1 year. A pie chart would illustrate Suzlon Energy's 10-year distribution: 70% of years (7/10) in the red zone (e.g., 2019–2021), 20% (2/10) in the gray zone (2017–2018), and 10% (1/10) in the green zone (2023). This reflects persistent financial instability despite a recent recovery.

Table 2. NHPC (National Hydroelectric Power Corporation) Ltd

Year	A = W C/ T A	B = RE(RT)/ T A	C = EBIT/TA	D=MVE/TL	E = Sales / T A	Z-score
2023	0.049	0.370	0.089	0.588	0.136	1.359
2022	0.062	0.361	0.069	0.430	0.128	1.192
2021	0.062	0.365	0.097	0.416	0.144	1.298
2020	0.069	0.348	0.105	0.349	0.152	1.279
2019	0.034	0.367	0.119	0.476	0.157	1.392
2018	0.014	0.372	0.107	0.583	0.143	1.384
2017	0.049	0.346	0.125	0.683	0.151	1.515
2016	0.136	0.363	0.099	0.518	0.143	1.451
2015	0.130	0.342	0.108	0.438	0.135	1.389
2014	0.122	0.310	0.079	0.437	0.115	1.220

Table 2 provides a comprehensive assessment of NHPC Ltd.'s financial stability from 2014 to 2023, utilizing a range of financial ratios and the Altman Z-score. Throughout this period, all years are situated within the distress zone, signifying a heightened risk of financial distress in 2023 with a

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Z-score of 1.359, compared to 1.220 in 2014. None of the years fall within the range of 1.81 ≤ Z-score ≤ 2.99, and none of the years have a value of 2.99 or above, indicating that the company remains in a state of distress throughout the period under consideration. The consistent placement of NHPC Ltd in the distress zone over the ten years implies persistent financial challenges. Despite fluctuations in specific financial ratios, the overall Z-score consistently indicates a high risk of bankruptcy. This pattern highlights the need for strategic financial management and potential restructuring to improve the company's financial health. By incorporating the Altman Z-score model in this analysis, valuable early warning signals are provided, enabling stakeholders to take corrective actions before a financial decline becomes irreversible.

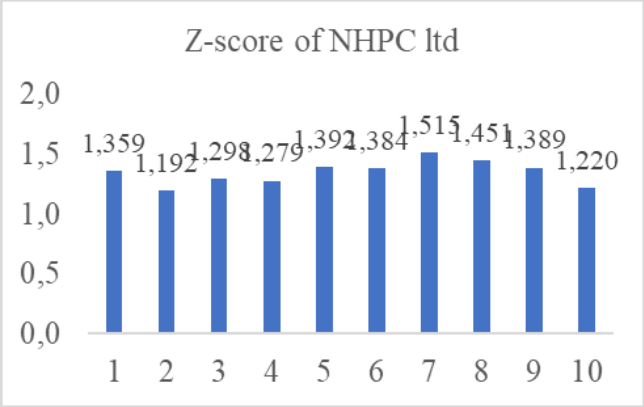

Figure 3. Z-Score of NHPC Ltd

Figure 3 presents a bar chart of the Z-scores of NHPC Ltd. from 2014 to 2023, along with their Z-score values. NHPC Ltd's Z-scores remained stagnant in the distress zone (1.220–1.515) across all years, peaking at 1.515 in 2017. A bar chart would show minimal fluctuations, emphasizing consistently low EBIT/TA ratios (0.069–0.125) and weak market value equity ratios (0.349–0.683).

Figure 4. Pie Chart of Years in Zones

Figure 4 Pie chart displays that NHPC Ltd. is in the red zone for all the years taken under consideration. A pie chart would confirm NHPC's 100% red-zone status (10/10 years), underscoring chronic financial distress despite minor year-to-year variations in working capital or sales ratios.

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Table 3. SJVN (Satluj Jal Vidyut Nigam Limited) Ltd

Year	X1 = W C/ T A	X2 = RE/ T A	X3 = EBIT/TA	X4=MVE/TL	X5 = Sales / T A	Z-score
2023	0.160	0.454	0.119	0.599	0.135	1.714
2022	0.146	0.472	0.101	0.553	0.125	1.626
2021	0.085	0.560	0.144	0.649	0.158	1.909
2020	0.199	0.535	0.178	0.537	0.179	2.075
2019	0.252	0.512	0.170	0.666	0.186	2.166
2018	0.279	0.492	0.154	0.952	0.162	2.264
2017	0.337	0.497	0.177	0.948	0.182	2.433
2016	0.334	0.481	0.175	0.796	0.167	2.295
2015	0.289	0.441	0.200	0.741	0.205	2.272
2014	0.197	0.395	0.148	0.698	0.151	1.847

Table 3 presents a detailed analysis of SJVN Ltd.'s financial health from 2014 to 2023, utilizing various financial ratios and the Altman Z-score. Distress Zone (Z-score < 1.81): Years 2023 (1.714), 2022 (1.626), and 2014 (1.847) fall into the distress zone, indicating a high risk of financial distress. Gray Zone (1.81 ≤ Z-score ≤ 2.99): Years 2021 (1.909), 2020 (2.075), 2019 s (2.166), 2018 (2.264), 2017 (2.433), 2016 (2.295), and 2015 (2.272) fall within this range, indicating moderate risk, Green Zone (Z-score > 2.99): None of the years fall within this range. It reveals that SJVN Ltd has experienced varying levels of financial health over the ten years. The company was in the distress zone in 2023, 2022, and 2014, indicating a high risk of financial distress during these years. The Z-scores for these years were below 1.81, suggesting potential financial instability.

On the other hand, the company's financial risk was moderate from 2015 to 2021, as it fell within the gray area. The Z-scores for these years varied from 1.909 to 2.433, indicating that although the company was not at imminent risk of going bankrupt, it was also not completely safe.

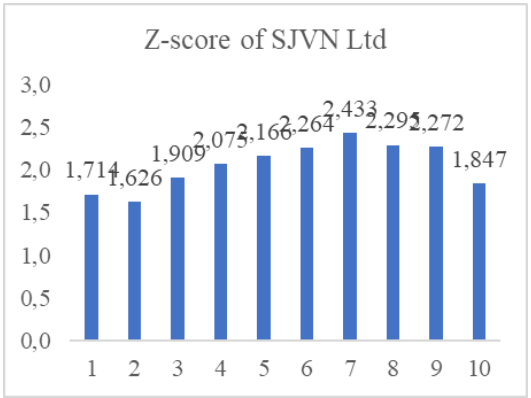

Figure 5. Z-Score of SJVN Ltd

Figure 5 presents a bar chart of the Z-scores of SJVN Ltd. from 2014 to 2023, along with their Z-score values. SJVN Ltd's Z-scores oscillated between 1.626 (2022) and 2.433 (2017), with 2014–2023 scores straddling the gray and red zones. A bar chart would highlight a peak in 2017 (2.433) due to strong working capital (0.337) and EBIT/TA (0.177), followed by a gradual decline post-2020.

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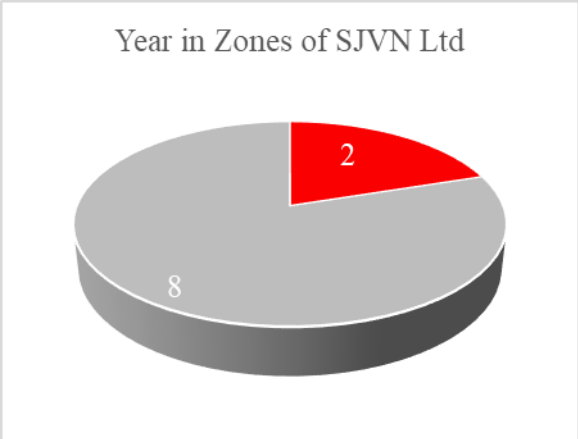

Figure 6. Pie Chart of Years in Zones

Figure 6: The Pie chart displays that SJVN Ltd. has been in the red zone for 2 years and in the gray Zone for 8 years. A pie chart would reveal 80% of years (8/10) in the gray zone (e.g., 2015–2021) and 20% (2/10) in the red zone (2022–2023), indicating moderate but persistent risk.

Table 4. Tata Power Renewable Energy Ltd.

Year	X1 = W C/ T A	X2 = RE/ T A	X3 = EBIT/TA	X4=MVE/TL	X5 = Sales / T A	Z-score
2023	0.150	0.334	0.067	0.000	0.075	0.942
2022	0.027	0.017	0.087	0.000	0.096	0.439
2021	-0.046	0.332	0.079	0.000	0.092	0.762
2020	0.021	0.008	0.074	0.000	0.083	0.366
2019	-0.103	0.429	0.077	0.000	0.076	0.806
2018	-0.013	0.472	0.072	0.000	0.057	0.939
2017	-0.032	0.016	0.051	0.000	0.044	0.198
2016	-0.120	0.026	0.125	0.000	0.134	0.439
2015	-0.108	0.011	0.131	0.000	0.124	0.440
2014	-0.002	0.006	0.087	0.000	0.089	0.383

Table 4 offers a thorough evaluation of the financial standing of Tata Power Renewable Energy Ltd. from 2014 to 2023 based on the Altman Z-score and several financial measures. Zone of Distress (Z-score < 1.81): Every year is in the distressed zone, meaning there is a significant chance of financial difficulty. With Z-scores below 1.81 annually, it indicates that Tata Power Renewable Energy Ltd. has consistently been in the distress zone over the past ten years. This suggests a significant likelihood of financial hardship at this time. Although there have been some variations in the company's financial health, it has not yet entered the gray or green zones, indicating that ongoing financial difficulties persist.

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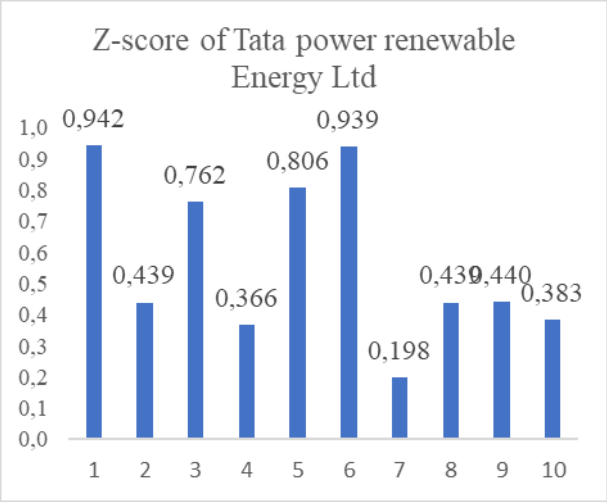

Figure 7. Z-Score of TPRE Ltd

Figure 7 presents a bar chart of the Z-scores of Tata Power Renewable Energy Ltd. from 2014 to 2023, along with their Z-score values. Tata Power Renewable Energy's Z-scores remained in the red zone for all years (0.198–0.942). A bar chart would emphasize stagnant performance, with 2017 being the lowest (0.198) due to negative working capital (-0.032) and negligible retained earnings (0.016).

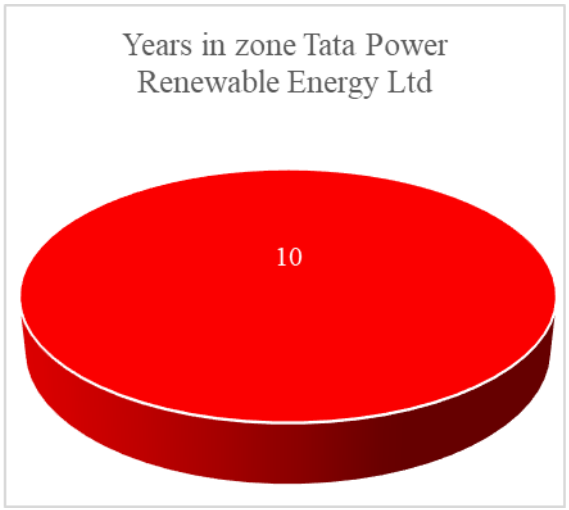

Figure 8. Pie Chart of Years in Zones

Figure 8 Pie chart displays that Tata Power Renewable Energy Ltd. has been in the red zone for all 10 years. A pie chart would confirm 100% red-zone occupancy (10/10 years), reflecting systemic financial challenges, including negative working capital and low EBIT/total assets (TA) ratios.

Table 5. Inox Wind Ltd

Year	X1= W C/ T A	X2 = RE(RT)/ T A	X3 = EBIT/TA	X4=MVE/TL	X5 = Sales / T A	Z-score

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2023	0.344	0.525	-0.016	0.802	0.154	1.730
2022	0.246	0.363	-0.067	0.815	0.172	1.243
2021	0.457	0.559	-0.039	0.636	0.206	1.789
2020	0.481	0.650	-0.065	0.171	0.219	1.595
2019	0.574	0.644	0.055	0.535	0.485	2.577
2018	0.580	0.650	-0.024	0.875	0.077	2.130
2017	0.629	0.531	0.146	1.032	0.783	3.382
2016	0.677	0.499	0.236	1.709	1.148	4.462
2015	0.876	0.525	0.225	0.000	1.073	3.603
2014	0.708	0.238	0.205	0.000	1.400	3.257

Table 5 provides a detailed analysis of Inox Wind Ltd.'s financial health from 2014 to 2023 using various financial ratios and the Altman Z-score. Distress Zone (Z-score < 1.81): Years 2023 (1.730), 2022 (1.243), 2021 (1.789), and 2020 (1.595) fall into the distress zone, indicating a high risk of financial distress. Gray Zone (1.81 ≤ Z-score ≤ 2.99): Years 2019 (2.577) and 2018 (2.130) fall within this range, indicating moderate risk. Green Zone (Z-score > 2.99): Years 2017 (3.382), 2016 (4.462), 2015 (3.603), and 2014 (3.257) fall into the green zone, indicating a low risk of financial distress.

It demonstrates that over the past ten years, Inox Wind Ltd. has experienced varying degrees of financial health. The company showed a significant danger of financial difficulty in 2023, 2022, 2021, and 2020 when it was in the distress zone. These years' Z-scores were below 1.81, indicating a possible risk of financial instability.

In contrast, the company's financial risk was modest in 2019 and 2018, when it was in the gray area. The Z-scores for these years varied from 2.130 to 2.577, indicating that although the corporation was not at imminent risk of going bankrupt, it was still not completely safe.

From 2014 to 2017, the business operated in the green zone, indicating minimal financial risk. During these years, the Z-scores were over 2.99, indicating stable and robust financial conditions.

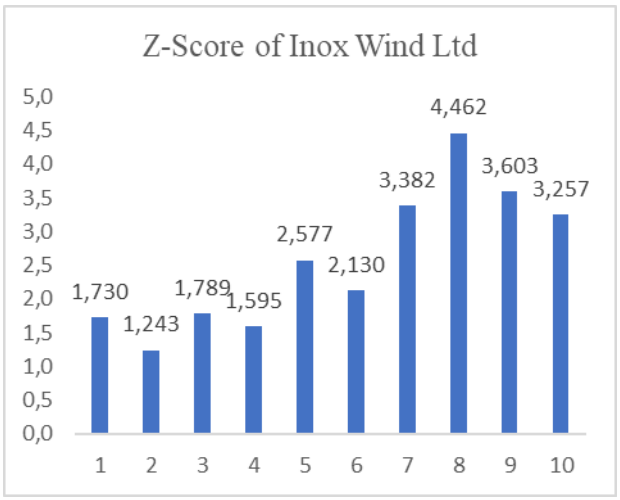

Figure 9. Z-Score of Inox Wind Ltd

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Figure 9 presents a bar chart of the Z-scores of Inox Wind Ltd. from 2014 to 2023, along with their Z-score values. Inox Wind's Z-scores fluctuated wildly, from 1.243 (2022) to 4.462 (2016). A bar chart would show a steep decline from 2016 (4.462, green zone) to 2023 (1.730, red zone), correlating with deteriorating EBIT/TA ratios (-0.016 in 2023) and a reduction in market value equity.

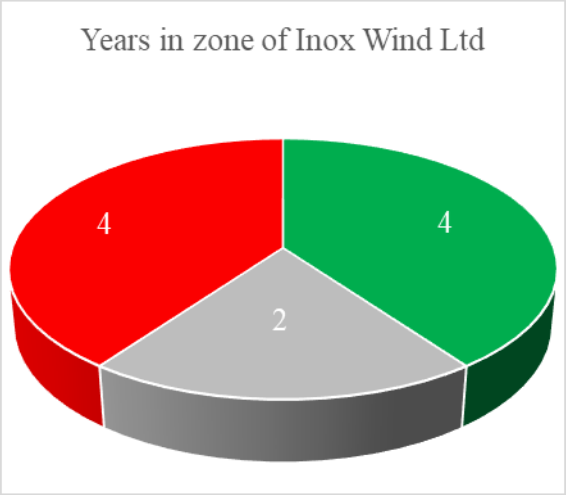

Figure 10. Pie Chart of Years in Zones

Figure 10: The Pie chart displays that Inox Wind Ltd. has been in the gray zone for 2 years, in the red Zone for 4 years, and in the green zone for 4 years. A pie chart would split Inox Wind's 10 years into a 40% green zone (2014–2017), 20% gray zone (2018–2019), and 40% red zone (2020–2023), reflecting a downward trajectory post-2017.

Table 6. Reliance Power Ltd

Year	X1= W C/ T A	X2 = RE(RT)/ T A	X3 = EBIT/TA	X4=MVE/TL	X5 = Sales / T A	Z-score
2023	0.004	0.354	0.060	0.260	0.002	0.858
2022	-0.010	0.364	0.010	0.299	0.003	0.713
2021	-0.007	0.389	0.032	0.078	0.002	0.690
2020	-0.002	0.383	0.007	0.022	0.003	0.574
2019	0.050	0.493	-0.006	0.156	0.002	0.826
2018	0.085	0.582	0.017	0.394	0.002	1.209
2017	0.102	0.580	0.016	0.556	0.002	1.320
2016	0.138	0.643	0.067	0.631	0.003	1.668
2015	0.082	0.660	0.011	0.738	0.006	1.508
2014	0.106	0.681	0.009	0.955	0.004	1.689

Table 6 presents a detailed analysis of Reliance Power Ltd.'s financial health from 2014 to 2023, utilizing various financial ratios and the Altman Z-score. Distress Zone (Z-score < 1.81): Years 2023 (0.858), 2022 (0.713), 2021 (0.690), 2020 (0.574), 2019 (0.826), 2018 (1.209), 2017 (1.320), 2016 (1.668), 2015 (1.508), and 2014 (1.689) fall into the distress zone, indicating a high risk of financial distress. The table reveals that Reliance Power Ltd has consistently been in the distress zone over the past ten

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years, with Z-scores below 1.81 each year. This indicates a high risk of financial distress throughout this period. The company's financial health has shown some fluctuations, but it has not reached the gray or green zones, suggesting persistent financial challenges.

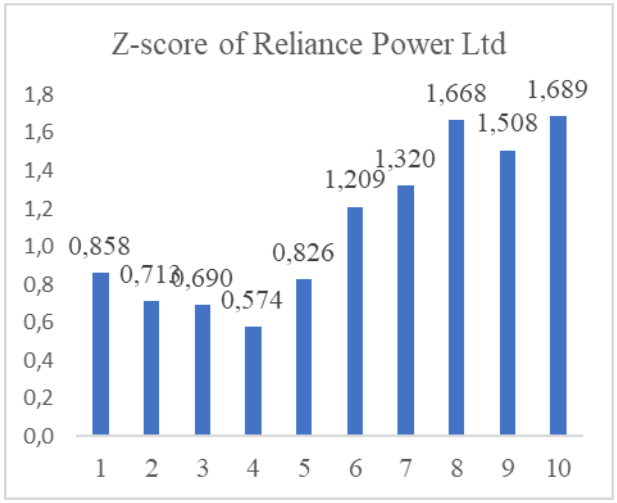

Figure 11. Z-Score of Reliance Power Ltd

Figure 11 presents a bar chart of the Z-scores of Reliance Power Ltd. from 2014 to 2023, along with their Z-score values. Reliance Power's Z-scores stagnated in the red zone (0.574–1.689), with no year crossing 1.8. A bar chart would highlight consistently poor ratios, such as negative working capital (-0.010 in 2022) and near-zero sales/TA (0.002–0.006).

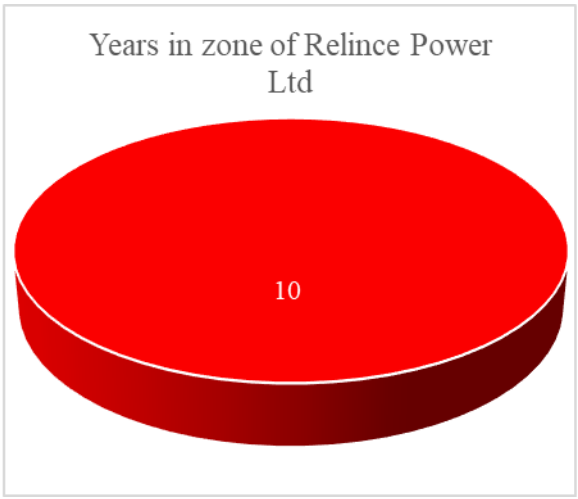

Figure 12. Pie Chart of Years in Zones

Figure 12 Pie chart displays that Reliance Power Ltd. has been in the red zone for all 10 years. A pie chart would show 100% red-zone occupancy (10/10 years), underscoring severe financial distress driven by weak profitability and liquidity.

Table 7. Adani Green Energy Ltd

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Years	X1= W C/ T A	X2 = RE(RT)/ T A	X3 = EBIT/TA	X4=MVE/TL	X5 = Sales / T A	Z-score
2023	-0.004	0.134	0.023	5.614	0.307	3.933
2022	0.168	-0.002	0.026	11.946	0.426	7.879
2021	-0.038	0.020	0.088	22.140	0.317	13.874
2020	0.468	-0.029	0.069	5.640	0.293	4.424
2019	0.525	-0.034	0.057	1.286	0.070	1.611
2018	0.633	-0.024	0.018	0.000	0.348	1.133
2017	0.192	-0.028	-0.007	0.000	0.006	0.174
2016	-0.200	-0.004	-0.001	0.000	0.000	-0.247
2015	0.000	0.000	0.000	0.000	0.000	0.000
2014	0.000	0.000	0.000	0.000	0.000	0.000

Table 7 provides a detailed analysis of Adani Green Energy Ltd.'s financial health from 2014 to 2023, utilizing various financial ratios and the Altman Z-score. Distress Zone (Z-score < 1.81): Years 2017 (0.174) and 2016 (-0.247) fall into the distress zone, indicating a high risk of financial distress.

Gray Zone (1.81 ≤ Z-score ≤ 2.99): None of the years fall into the gray zone. Green Zone (Z-score > 2.99): Years 2023 (3.933), 2022 (7.879), 2021 (13.874), and 2020 (4.424) fall into the green zone, indicating a low risk of financial distress.

It reveals that Adani Green Energy Ltd has shown significant improvement in its financial health over the years. The company was in a distressed zone in 2016 and 2017, indicating a high risk of financial distress during these years. The Z-scores for these years were below 1.81, suggesting potential financial instability.

In contrast, the company has been in the green zone from 2020 to 2023, indicating low financial risk. The Z-scores during these years were above 2.99, suggesting strong financial health and stability. Notably, the Z-score reached its peak in 2021 at 13.874, reflecting exceptional financial performance and market confidence.

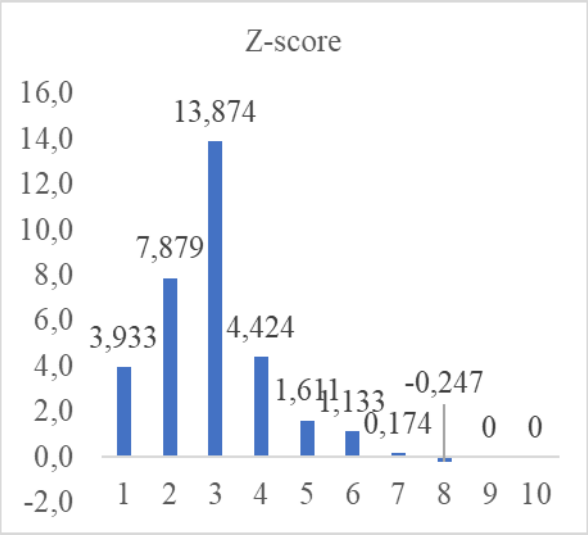

Figure 13. Z-Score of Adani Green Energy Ltd

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Figure 13 presents a bar chart of the Z-scores of Adani Green Energy Ltd. from 2014 to 2023, along with their Z-score values. Adani Green's Z-scores surged from -0.247 (2016) to 13.874 (2021), transitioning from red to green zone. A bar chart would emphasize exponential growth post-2019, driven by soaring market value equity (22.14x in 2021) and improved EBIT/TA (ranging from 0.023 to 0.088).

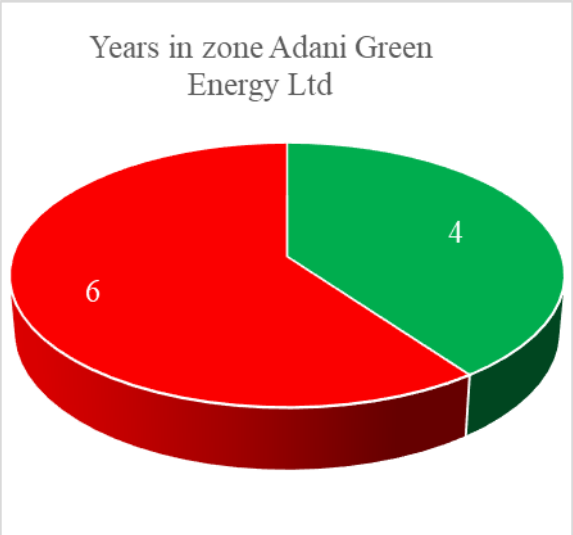

Figure 14. Pie Chart of Years in Zones

Figure 14: The Pie chart displays that Adani Green Energy Ltd. has been in the red Zone for 6 years and in the green zone for 4 years.

The financial trajectories of these firms reflect both individual corporate strategies and structural sector-wide issues.

Key Observations. The Altman Z-score analysis reveals distinct financial patterns among India's top renewable energy firms. Adani Green Energy Ltd. has consistently performed in the green zone since 2020, indicating a low risk of financial distress. This outcome reflects the firm's access to capital, high market value equity, and strategic alignment with national policy, consistent with Ko et al. (2017). In contrast, NHPC Ltd. and Reliance Power Ltd. remained in the distress zone across all years analyzed, reflecting weak liquidity, low profitability, and structural inefficiencies, particularly in public sector firms, as noted by Panigrahi (2019).

Suzlon Energy Ltd. exemplifies volatility and recovery, transitioning from a Z-score of -12.3 in 2020 to 4.096 in 2023 following restructuring efforts. Similarly, Inox Wind Ltd. declined from green-zone status in 2016 to consistent distress by 2022, reflecting declining profitability and project-based instability. SJVN Ltd., though mostly in the grey zone, has shown stagnation without significant improvement. These trajectories suggest that while some firms adapt and recover, others remain vulnerable due to weak fundamentals or delayed policy execution.

Implications for Stakeholders. For investors, the Z-score serves as a useful screening tool to assess financial health and risk. Firms like Adani Green offer strong long-term prospects, while volatile performers such as Suzlon or Inox Wind may attract risk-tolerant investors seeking recovery potential. Chronic distress in firms like NHPC and Reliance Power, however, signals caution, particularly for institutional stakeholders with low-risk appetite.

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Policymakers can use these findings to identify companies that require regulatory and financial intervention. Delays in subsidy disbursals, poor RPO enforcement, and limited debt relief mechanisms contribute to persistent financial stress. Introducing sector-specific support tools, like a Green Debt Relief Fund and performance-linked tax incentives, can promote financial resilience. Managers, meanwhile, should integrate Z-score monitoring into their internal risk assessments, aligning strategic decisions with regulatory and financing cycles.

Sectoral Insights. The Altman Z-score model proves to be a relevant financial diagnostic tool for India's renewable energy sector, particularly in highlighting short-term insolvency risks. Its strength lies in quantifying liquidity, profitability, and leverage; however, it struggles to account for industry-specific elements such as delayed receivables, project gestation periods, and government policy dependence. This limitation is especially evident in public firms, where Z-scores may not fully reflect secure yet illiquid financial positions.

To improve financial assessments, Z-score evaluations should be complemented with qualitative and sector-specific metrics. These may include reliance on subsidies, tariff adjustment cycles, and power purchase agreement (PPA) durations. A hybrid approach that combines traditional financial ratios with dynamic modeling and policy analytics would offer a more comprehensive view. As India advances toward its 2030 renewable energy goals, such integrative tools will be vital for ensuring capital is directed toward financially sustainable and strategically aligned firms.

Future Research Directions. Future studies should explore enhancements to the Altman Z-score model by incorporating cash flow-based indicators and lifecycle-specific financial metrics that better capture the long-term viability of renewable energy projects. Given the sector's dependence on extended asset payback periods, regulatory incentives, and state-level disbursements, traditional Z-score ratios may fail to represent the full financial reality. Integrating variables such as debt servicing coverage, subsidy exposure, and project completion timelines could significantly improve predictive accuracy and practical utility for both investors and policymakers.

Additionally, there is scope for developing sector-specific modifications of the Z-score model using machine learning or econometric techniques that allow for dynamic weighting of financial inputs. Comparative studies between Indian renewable firms and counterparts in other emerging economies, such as Brazil or South Africa, would also help validate model portability. Further, qualitative case studies could examine how strategic financial decisions, such as green bond issuance or restructuring efforts, influence Z-score recovery over time. Such multi-dimensional approaches will be crucial in equipping stakeholders with a more robust framework to navigate the financial risks and opportunities in India's evolving renewable energy landscape.

CONCLUSION

This study applies the Altman Z-score model to assess the financial stability of seven major Indian renewable energy firms over ten years (2014–2023), revealing significant variations in financial performance across companies. Adani Green Energy Ltd. has consistently moved into the green zone since 2020, reflecting strong solvency and robust market confidence. In contrast, Suzlon Energy demonstrated high financial volatility, alternating between distress and safe zones, which underscores its recovery from past restructuring efforts. NHPC Ltd. and Reliance Power Ltd. consistently remained in the distress zone throughout the decade, raising serious concerns about their long-term financial viability. Meanwhile, Inox Wind Ltd. transitioned from the green to the red zone after 2017, indicating deteriorating profitability and weakening equity valuation. These findings validate the relevance of the Altman Z-score as a predictive tool for financial health,

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particularly when adapted to the context of emerging economies and infrastructure-intensive sectors such as renewable energy (Altman et al., 2017; Ko et al., 2017).

Policy Implications. The findings of this study underscore the urgent need for policy interventions to bolster the financial resilience of India's renewable energy sector, particularly for firms such as NHPC Ltd. and Reliance Power Ltd., which are trapped in perpetual distress. Key recommendations include:

1. Accelerated Subsidy Disbursement: Chronic delays in government subsidies (e.g., under the JNNSM) exacerbate liquidity crises, as evidenced by Suzlon Energy's negative EBIT/TA ratios from 2019 to 2020. Policymakers should implement automated, time-bound subsidy clearance mechanisms to stabilize cash flows and ensure timely payments.
2. Debt Restructuring Frameworks: High leverage ratios (e.g., NHPC's stagnant MVE/TL of 0.349–0.683) highlight the need for sector-specific debt restructuring. The establishment of a "Green Debt Relief Fund," backed by multilateral institutions, could offer low-interest refinancing options for distressed firms.
3. Tax Incentives for Long-Term Viability: The Z-score's undervaluation of long-term viability (e.g., Adani Green's post-2020 recovery) highlights the need for policies that reward sustained performance. Tax holidays for firms maintaining a green zone Z-score for three consecutive years or more could incentivize financial discipline.
4. Strengthening Renewable Purchase Obligations (RPOs): Weak enforcement of RPOs under the 2003 Electricity Act has led to imbalanced demand-supply dynamics, impacting asset turnover (X5). Mandatory penalties for non-compliance and centralized RPO tracking would enhance market stability.
5. Promoting Green Bonds and FDI: To mitigate reliance on volatile domestic debt, policymakers should incentivize green bond issuances and streamline FDI approvals for renewable projects, leveraging India's position as a global solar leader.

These measures align with India's 450 GW renewable energy targets and the UN Sustainable Development Goals (SDG 7 and 13), ensuring that financial stability complements technological and infrastructural advancements.

Lessons from Indian Renewable Firms; Adani Green Energy Ltd. – Strategic Expansion and Investor Confidence. Adani Green Energy's financial recovery, from a Z-score of -0.247 in 2016 to 13.874 in 2021, illustrates how aggressive expansion, strong market capitalization, and favorable government policy can transform firm-level solvency. Long-term PPAs and successful foreign capital infusion reflect robust strategic planning (Wu, 2023).

Suzlon Energy – Turnaround Amid Financial Turmoil. Once on the brink of collapse with a Z-score of -12.303 in 2020, Suzlon's shift to a Z-score of 4.096 by 2023 exemplifies effective debt restructuring, a reduction in operational losses, and renewed investor confidence. Its case supports Almamy et al.'s (2016) argument for incorporating restructuring signals into distress forecasting.

NHPC Ltd. – Public Sector Rigidity and Stagnation. Despite being a major hydro player, NHPC's consistently low Z-scores (1.192–1.515) signal weak liquidity and rigid cost structures. Delays in tariff revision and regulatory lag have undermined financial agility—challenges common in Indian public-sector firms (Panigrahi, 2019).

Inox Wind Ltd. – Decline from Peak Performance. Inox's drop from a green-zone score of 4.462 in 2016 to 1.243 in 2022 reveals how revenue cycles, high working capital needs, and declining EBIT can erode financial stability. This aligns with Ko et al.'s (2017) findings on subsidy-dependent wind firms facing unpredictable cash flows.

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