

Wired for performance: unlocking digital-led O&M excellence in renewable energy

Forward-thinking companies are investing significant time and money in improving the operating performance of their assets. In an industry marked by tight margins, the question is will you lead the charge or be left behind?

The future of energy will be defined by the continued expansion of renewable energy assets, but operations and maintenance (O&M) practices that are enabled by cutting-edge AI and machine learning (ML) techniques can make or break the profitability of these assets. With the industry’s rapid expansion, many companies are focusing on faster projects with lower upfront costs. Meanwhile, they are operating their assets with suboptimal practices and not building in the right measures to extract the most value from those assets. The result? A reduction of 2 to 3 percent in internal rate of return (IRR)—which equates to \$4 million to \$6 million in annual EBITDA for every GW of operating asset.¹

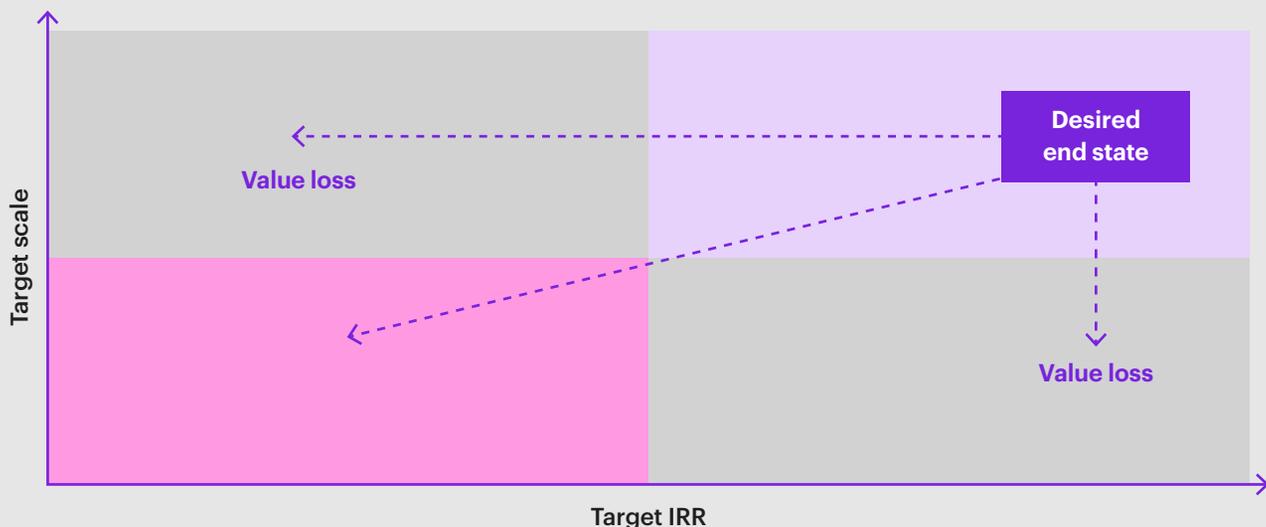
In an industry where margins are tightening, achieving O&M excellence isn’t just an advantage—it’s a necessity for profitable growth.

Renewable energy players are leaving millions on the table

We are witnessing the massive global growth of renewables, driven by supportive policies, favorable economics, and a growing push for sustainability. Over the next five to six years, the world is expected to add more than 5,500 GW of renewable energy.² Amid a rapid increase in demand, major developers are scaling up their renewable portfolios, investing billions of dollars. There is significant value at risk. Using Kearney’s value creation framework, we can estimate the financial impact of not achieving the target scale and the target IRR (see figure 1). For every GW of capacity, the opportunity loss of not reaching the target scale can be \$40 million, along with \$12 million to \$15 million for an inability to achieve the target IRR.

Figure 1

Kearney’s value creation framework can help pinpoint the financial impact for not achieving a target scale and target IRR



Note: IRR is internal rate of return.

Source: Kearney analysis

¹ The capital cost of each GW for a hybrid asset is estimated at about \$600 million; the opportunity loss for not reaching each GW of scale will lead to a loss of 18 percent (considered target IRR) of the equity portion of capital (typically 33 percent). The impact of not achieving the target IRR for each GW results in a loss of 6 to 7 percent of the equity portion of capital.

² *Renewables 2024: Analysis and Forecasts to 2030*, International Energy Agency

Inefficient O&M practices erode project value, lowering the IRR by 2 to 3 percentage points— or \$4 million to \$6 million, making it one of the most significant contributors to financial underperformance. Poor O&M strategy and execution results in lost energy output. This loss in generation directly translates to lower revenue, which ultimately becomes a key driver of IRR deterioration.

Leading companies are also struggling to meet P50/ P75 values for RE assets because of uncontrollable variations in external resources, such as irradiation and wind speed. This further impacts the asset IRR and increases the importance of using superior O&M practices to extract the most value from the assets.

In this paper, we map out a path for achieving O&M excellence by using digital tools to improve asset performance and deliver higher returns for RE companies. We also share a variety of case studies that highlight select initiatives and best O&M practices from India's leading independent power producers (IPPs), shaping assets into RE farms of the future.

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Sizing the industry's biggest obstacles

Renewable energy companies are facing a variety of challenges:

Lack of well-defined and standardized processes

The objective to quickly build RE capacity in recent years has resulted in IPPs operating multiple farms across diverse geographies. In the growth phase, the IPP portfolio typically consists of multiple wind and solar original equipment manufacturers (OEMs) along with varied technologies of wind turbines and solar panels across farms. For instance, a mid-sized IPP in India with an operating portfolio of about 2 GW can have up to 10 vintage assets consisting of three wind OEMs, two acquired assets, and panels from at least two manufacturers, with assets spread across multiple states. Such a diverse portfolio creates a complex O&M environment for IPPs and leads to ad-hoc processes of preventive maintenance planning, quality of work for breakdown maintenance, inventory management, and governance mechanism across sites.

Variations in practices, tools, workflows, and standard operating procedures often stem from differences in site-specific conditions, turbine models, solar modules, and legacy systems inherited from acquisitions. This lack of homogeneity in the O&M processes across sites makes it challenging to implement centralized management, uniformly monitor performance metrics, and scale best practices across the portfolio.

Talent shortage and skill gaps

The RE industry's exponential growth is outpacing the growth of a skilled workforce, creating a critical talent shortage. With global renewables capacity set to triple by 2030, the industry needs more than a million new workers a year, but the pipeline isn't keeping up. The gap is particularly severe in O&M, where many companies are facing difficulties in hiring qualified personnel. This results in an overreliance on a small set of skilled people, often leading to a people-dependent O&M philosophy. Additionally, constant on-the-ground churn and high turnover rates make talent retention challenging and hinder the development of a sustainable organizational culture.

Moreover, there are very few training programs that cater to the unique requirements of wind and solar O&M, leaving employees underprepared for the challenges of managing complex assets.

The shortage of skilled talent not only hampers the efficiency of O&M operations but also increases the dependency on OEMs and independent service providers, which inflates operational costs.

Ineffective data utilization

Despite the abundance of data generated by RE assets, most companies fail to harness its full potential for O&M optimization. More than 70 percent of collected operational data goes unused, leaving crucial insights untapped. Data silos across supervisory control and data acquisition (SCADA) systems, sensors, and third-party platforms further hinder real-time decision-making. Additionally, IPPs often lack access to the full spectrum of data generated by their assets, as OEMs provide selective data points, which limits comprehensive oversight.

Furthermore, the absence of in-house data and analytics capabilities results in significantly underutilized information, leaving important trends, patterns, and insights unexplored. This lack of data access and digital capability leads to suboptimal operations and delayed fault detection, and it reduces the company's ability to proactively address maintenance issues.

A nascent partner ecosystem

The RE industry includes a diverse range of companies across the value chain, including OEMs, independent service providers (ISPs), technology providers, and third-party component suppliers. However, India's renewable energy O&M landscape remains constrained by a fragmented and underdeveloped ecosystem of supporting partners. For example, off-the-shelf digital tools that use advanced analytics to improve RE generation and enhance plant reliability are rare. Most solutions are either proprietary to OEMs or require custom development by IPPs, often in collaboration with ISP partners—both of which are expensive and time-consuming to optimize.

Adding to this challenge, part of the infrastructure has begun to age, such as the older 1x series wind turbines. Servicing these aging fleets has become increasingly expensive because of the unavailability of spares and service support. Although India's ISP ecosystem has grown, it is still in early stages compared with more mature markets. ISPs face multiple challenges, including the need for advanced technical skills, high initial investment costs, and limited access to specialized tools. These factors limit their ability to scale in tandem with the rapidly expanding RE industry.

Digital-led O&M excellence for RE assets

As RE players strive for greater efficiency and reliability, traditional O&M approaches often fall short in addressing operational complexities. Digital-led O&M excellence is the best way to transform operations, creating higher efficiency, lower costs, and improved asset longevity. Companies that integrate digital into their O&M processes and use cutting-edge digital tools can streamline operations, optimize resource utilization, and enhance decision-making. For example, predictive analytics can identify potential equipment failures before they occur, allowing operators to plan maintenance activities during low-generation periods and minimize disruptions.

A well-executed digital transformation of O&M in RE assets spans multiple dimensions, not only improving operational efficiency, but also ensuring a more resilient and future-ready O&M approach as the organization scales up.

Process excellence

Robust O&M processes are the backbone of RE players that are striving to achieve best-in-class performance. Standardizing processes with clear definitions, process maps, RASIC charts, and well-defined key performance indicators (KPIs) is essential to ensure alignment and consistency across all sites.³ Process digitalization and automation, combined with seamless system integration, can significantly enhance operational efficiency and effectiveness. This must be complemented by a robust governance framework to enable continuous performance monitoring against set KPIs along with a structured mechanism to capture data from multiple streams, such as SCADA systems and equipment sensors.

Example 1: maintenance planning and management.

Asset maintenance can be enhanced by using digital tools to enable real-time monitoring and efficient task management. For instance, preventive maintenance can be made more effective by systematically logging every maintenance activity in a digital logbook in a centralized portal for periodic review. Improving data accessibility through QR codes for a task list can substantially improve operator productivity. Assisted maintenance through drones, robots, and advanced imaging tools (thermal and acoustic) can improve asset reliability.

³ RASIC is responsible, accountable, supportive, consulted, and informed.

Example 2: contract management. Structured contract management processes and governance mechanisms aligned with established KPIs and service-level agreements can enhance the performance of all parties. For instance, in wind asset O&M, defining and tracking granular KPIs, such as availability during high- and low-wind seasons along with farm and machine-level availability, enhances generation. Further, integrating leading KPIs, such as preventive maintenance compliance, into contracts with periodic reviews with contractors can also improve performance.

Case study: O&M process improvements enhance RE asset performance

A prominent Indian power producer owns a sizable wind power portfolio of RE assets in western India, with O&M services outsourced to the OEM. Although some assets were performing on par with industry peers, others were underperforming, highlighting a clear opportunity to enhance performance. To address this, the company implemented several measures for process improvements, such as defining preventive maintenance schedules and a compliance plan, conducting structured root-cause analysis and regular performance review meetings, institutionalizing periodic site visits, and conducting frequent inventory and spare audits to ensure compliance. These interventions improved availability by 5 to 10 percent and enhanced capacity utilization factor (CUF) by 2 to 3 percent across assets.

Unlocking the full potential of analytics-driven improvements will require having comprehensive access to operational data.

Analytics-based performance improvement

To enhance their asset performance, the leading RE companies are using digital and analytics in a range of applications—from basic tools to sophisticated analytics engines powered by AI. These tools are capable of processing vast amounts of operational and performance data, uncovering trends, patterns, and feasible insights that are often challenging to detect through traditional methods.

Unlocking the full potential of analytics-driven improvements will require having comprehensive access to operational data. This can be ensured by contracting with OEMs during the procurement stage to enable the right extent of data sharing throughout the life of the assets to enhance performance.

Analytics-based use cases can be applied across three dimensions:

Availability and reliability improvement. Forecast potential equipment failures by analyzing operational data to enable preventive maintenance. For instance, ML models can predict when a wind turbine or solar inverter is likely to fail, allowing for preemptive repairs or replacements.

Efficiency enhancement. Streamline operations by uncovering inefficiencies in energy generation and delivery processes. Advanced tools such as digital twins enable operators to simulate different scenarios, test optimizations, and implement the best-performing strategies for maximizing generation efficiency.

O&M cost reduction. Cut costs by optimizing resource allocation and reducing reliance on manual interventions. For example, automated drones equipped with AI-powered imaging can conduct faster and more accurate inspections of solar farms or wind turbines, eliminating the need for expensive on-the-ground teams.

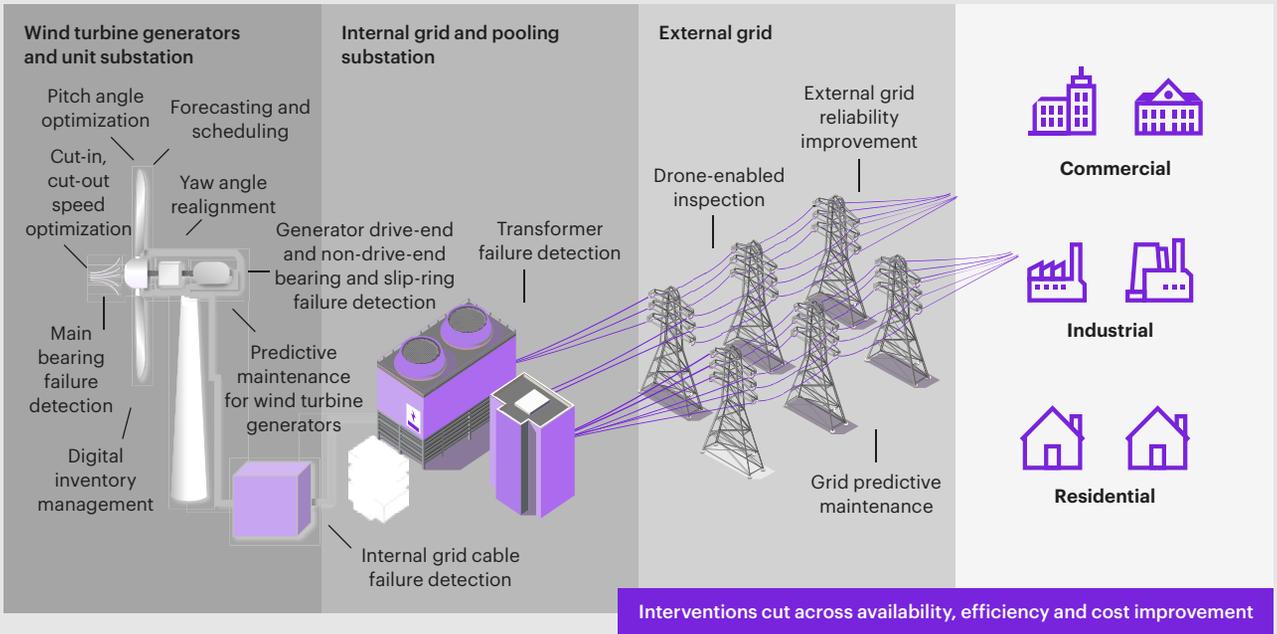
Numerous use cases can be realized across the value chain by using data from various sources. In wind power generation, for instance, SCADA data can be analyzed to optimize pitch angles and cut-in/cut-out speeds of wind turbine generators (WTGs), enhancing energy production (see figure 2 on page 5). Failure detection for critical components such as slip rings and bearings allows operators to implement proactive maintenance strategies, minimizing equipment downtime.

Figure 2

Kearney has a repository of digital interventions to enhance renewable power generation

Non-exhaustive

Example: wind use cases



Source: Kearney analysis

Exhibit A: ML-based smart yaw control for optimization of WTG operations

Dynamically adjusting yaw angles for optimal turbine alignment can enhance power generation while ensuring safe WTG operations. This is achieved through ML-based algorithms that learn from the historical machine and weather data to identify optimal actions based on the actual conditions for the respective WTG and wind farms, instead of standard predefined actions at the time of commissioning, while adhering to operational constraints (for example, mechanical stress). This can result in a CUF improvement of up to 1 percent, enhancing overall energy yield.

Similarly, in solar power generation, data from SCADA systems and advanced monitoring tools can be analyzed to detect hotspots and cracks on photovoltaic modules, optimize panel cleaning schedules, and implement predictive maintenance strategies, thereby improving the availability and overall efficiency of solar power plants (see figure 3 on page 6).

Exhibit B: advanced analytics-led module cleaning optimization

Digital twins for solar plants can enable dynamic loss monitoring as well as identify generation optimization opportunities. An asset-level digital twin can monitor and reconcile actual generation with maximum potential generation, identifying root causes leading to losses in generation. Predictive maintenance of inverters can also be enabled by failure prediction algorithms. For instance, ML models use weather, equipment, and condition parameters to provide early warning signs for heat sink over temperature failures (one of the most common failures). This approach has the potential to increase generation by 10 to 15 percent during peak irradiation days and deliver an overall annual improvement of up to 1 percent.

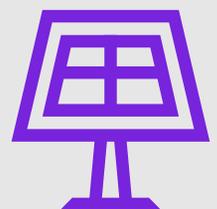
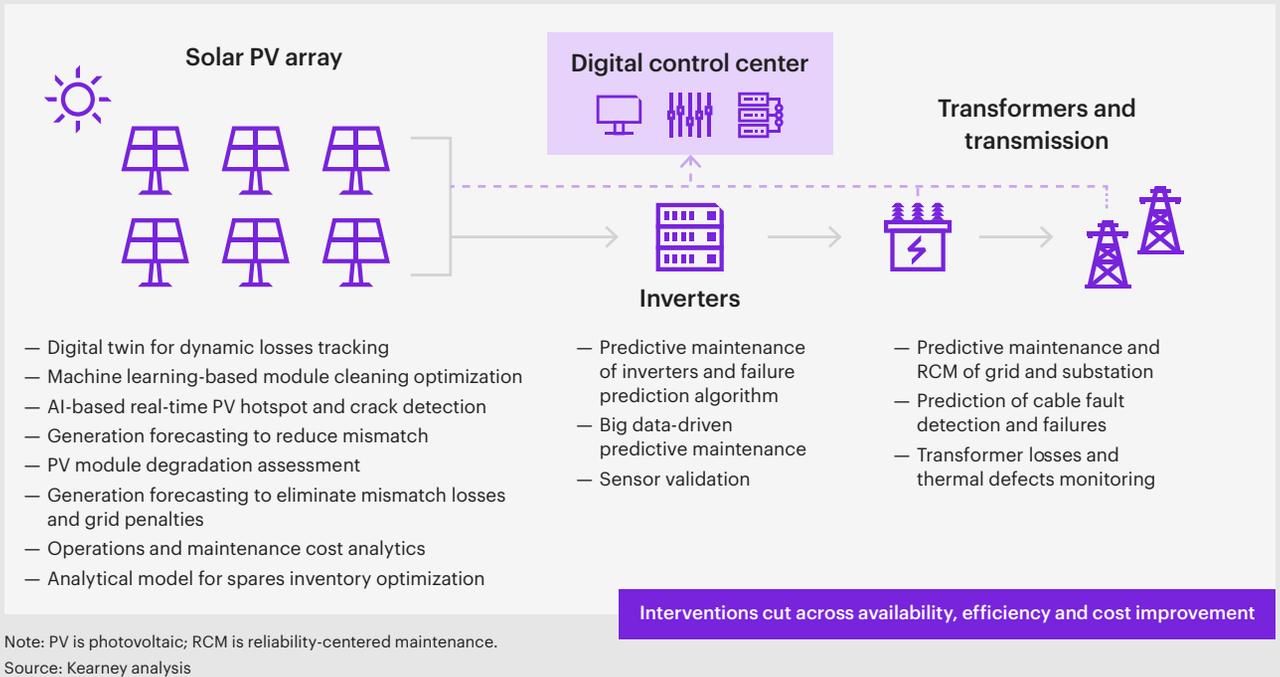


Figure 3

Kearney has a repository of powerful use cases across the value chain

Example: solar use cases



Implementing these use cases alongside the latest technologies will pave the way for the farms of the future—RE assets that harness automation, digitalization, and data-driven insights to create superior O&M practices. By embedding tools such as drones for site inspections, digital twins, and autonomous vehicles for ground fault detection, RE farms will embed digital solutions across every aspect of O&M—improving efficiency and long-term asset reliability.

Case study: digital and analytics to improve RE asset performance

A leading Indian RE company with a large solar power portfolio has adopted analytics-driven models to optimize solar module cleaning, achieving a 30 to 40 percent reduction in soiling losses. The system analyzes power generation data to send automated cleaning alerts to on-the-ground teams. The company is now implementing machine learning algorithms to accurately predict module cleaning requirements, aiming to cut soiling-related generation losses by 80 to 90 percent.

A major Indian RE IPP has embraced several digital and analytics-driven use cases across its wind, solar, and hybrid assets to enhance operations. These include ML-based weather forecasting systems, using drones for site inspections, digital twins, and condition-based monitoring of site equipment (for example, vibration pattern analysis for turbine gearboxes). The company has also partnered with third-party technology providers to execute proofs of concepts for addressing complex challenges (for example, asset generation prediction and fault detection in internal grid and feeder lines).

An Indian RE player has implemented nearly 40 advanced analytics use cases across its multi-GW solar and wind portfolio. Using big data, AI, and machine learning, these initiatives include digital twins, wind speed forecasting, power generation prediction, wake effect modeling, predictive maintenance, and more, driving innovation and operational excellence.

Operating model optimization and organization set-up

Companies must choose an optimal operating model that aligns with their strategic goals. There are three potential operating models for RE O&M: in-house, fully outsourced, or a hybrid approach. Selecting the right strategy is crucial to enable sustained asset performance. A tiered organizational structure should be developed based on the chosen model to ensure its successful implementation. The organization structure should be supported with clear role definitions of all entities and individuals, well-established interaction mechanisms, and the required capabilities.

To unlock the full potential of assets through digitally enabled O&M, RE companies will need to focus on building their organization structures with robust internal capabilities. Establishing a dedicated center of excellence for O&M, enabled by digital and analytics, can serve as a centralized hub for innovation. It can facilitate the development of tailored solutions, foster cross-functional collaboration, and ensure continuous upskilling of teams to adapt to evolving technologies.

Case study: in-house O&M enhances an Indian IPP's asset performance

A well-established RE IPP manages a large wind portfolio across India with WTGs from multiple OEMs. The company initially outsourced the O&M of all WTGs to the respective OEMs. However, after one OEM failed to meet contractual KPIs, the RE company decided to bring the O&M in-house for those machines. The IPP restructured its organization and strengthened internal capabilities to effectively manage end-to-end O&M operations. Bringing O&M in-house led to a 5 percent increase in CUF for these assets during the high-wind season in the following year.

Additionally, the IPP established a dedicated digital and analytics team to enhance its capabilities across the organization. The team has been instrumental in developing and launching various use cases at its sites.

The journey to O&M excellence

Achieving O&M excellence in the RE industry is a multiphase process. The journey can be divided into three distinct stages, each with its own characteristics, challenges, and timelines (see figure 4 on page 8):

Nascent stage. IPPs rely on OEMs for wind and ISPs for solar, with reactive maintenance approaches, minimal coordination for spare procurement, and heavy dependence on manual reporting. Limited adoption of analytics and standardized processes lead to inefficiencies and constrained scalability.

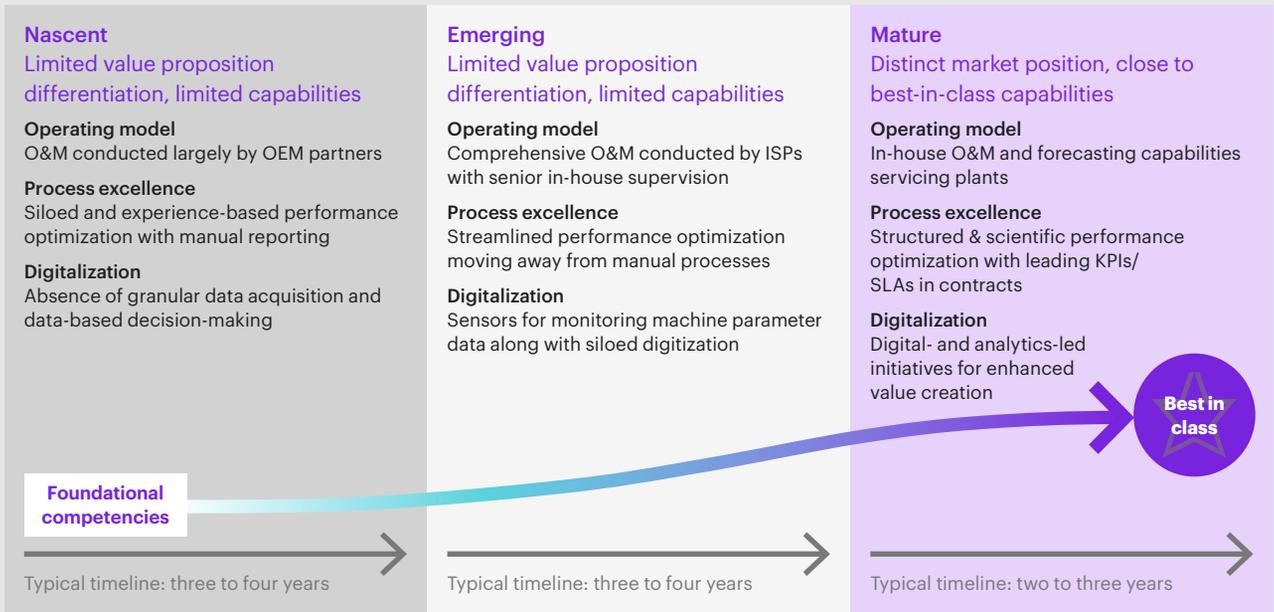
Emerging stage. IPPs begin implementing structured O&M practices, shifting toward predictive maintenance, adopting real-time monitoring systems, and establishing standardized inspection protocols. This phase enhances operational reliability, reduces downtime, and improves CUF, setting the foundation for scaled and optimized operations.

Mature stage. IPPs achieve operational excellence through advanced digital and analytics-driven solutions, structured performance optimization, and in-house forecasting expertise. By integrating data-driven decision-making and industry-leading KPIs, IPPs reduce their dependence on external partners, improve efficiency, and create sustained profitability. A strategic focus on technology, talent, and partnerships accelerates this transition, allowing IPPs to maximize asset performance, maintain long-term competitiveness, and establish themselves as leaders in the RE industry.

Achieving O&M excellence in the RE industry is a multiphase process.

Figure 4

The O&M maturity journey for IPPs evolves through three phases



Notes: O&M is operations and maintenance; IPP is independent power producer; OEM is original equipment manufacturer; ISPs are independent service providers; KPIs are key performance indicators; SLA are service-level agreements.

Source: Kearney analysis

How to achieve O&M excellence

Protecting and enhancing the value from RE assets requires identifying and incorporating best practices in daily operations.

Forward-thinking RE companies can choose from two transformation strategies:

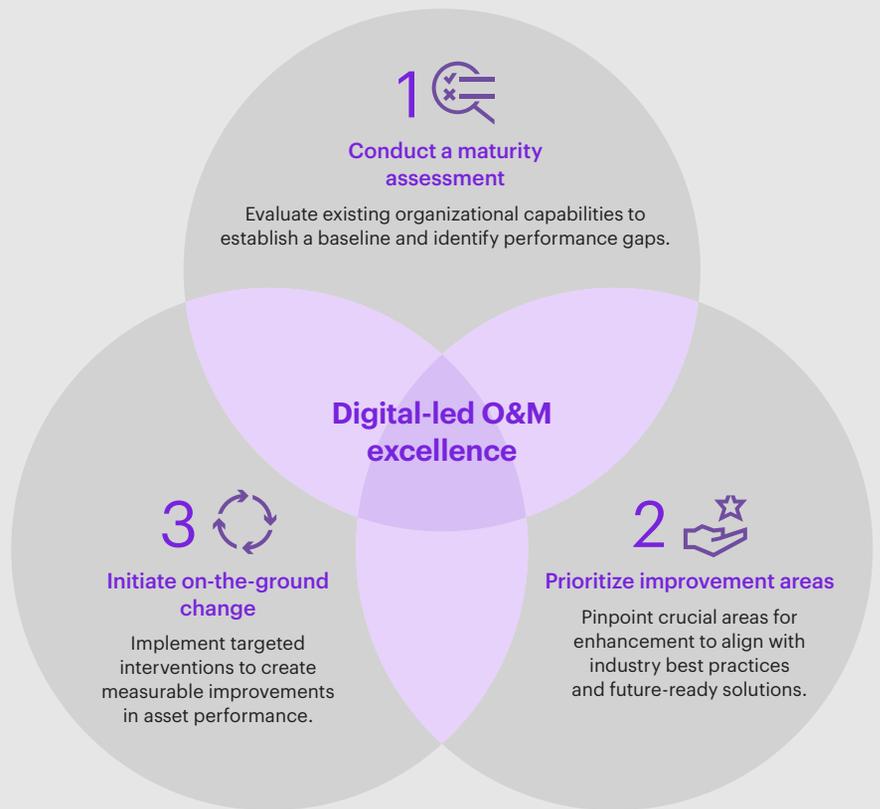
Comprehensive approach. This strategy is characterized by integrating digital-led interventions into O&M practices across all assets through a full-scale implementation. This involves defining and standardizing processes to ensure consistency across sites, while deploying analytics use cases customized to asset type and age. It also requires RE companies to determine the optimal operating model based on their partnerships with OEMs, after which they must establish an appropriate organizational structure and develop the capabilities needed to sustain and maximize the impact of the transformation.

Focused approach. This strategy is centered on integrating the targeted O&M interventions at select sites that have the highest potential to create value. This allows RE players to prioritize resources and efforts where they can achieve the most significant results. Target sites can be chosen based on asset type, fleet age, generation capacity, relationship with OEMs, and overall potential impact.

After choosing a strategy, companies can kickstart their transformation journey with a comprehensive benchmarking and maturity assessment of their structure, processes, and digital capabilities to establish a baseline and identify any gaps (see figure 5 on page 9). Improvement areas can then be prioritized to focus on high-impact initiatives to unlock immediate benefits.

Figure 5

Renewable energy companies can use a benchmarking and maturity assessment to kickstart an O&M transformation



Note: O&M is operations and maintenance.

Source: Kearney analysis

Finally, targeted initiatives can be implemented across select sites with robust governance mechanisms to track the improvement potential. Successful pilots can then be scaled systematically across the portfolio, ensuring a sustainable transformation.

Transitioning to digital-led O&M will require building the right capabilities at all levels, ensuring employees have the necessary skills and expertise. IT and operational technology infrastructure should be upgraded to seamlessly integrate digital tools. Adaptability and organization-wide change management are equally essential to aligning mindsets, practices, and systems with the broader transformation goal. Sustained success will depend on how effectively these elements come together to create a digitally mature, future-ready organization.

Transitioning to digital-led O&M will require building the right capabilities at all levels, ensuring employees have the necessary skills and expertise.

How Kearney can help

Kearney is the trusted advisor to industry leaders around the world, bringing deep market insights and a strong track record in renewable energy transformations. We have worked with more than 50 RE companies around the world, including five of the seven largest RE players and five of the eight largest OEMs. Our deep market insights are supported by our nonprofit Energy Transition Institute, which focuses on global trends in the energy transition and the strategic implications for RE companies.

In India, Kearney has established itself as the go-to firm for companies across the RE value chain, covering utilities, ISPs, OEMs, and technology providers. We have worked with all of the country's leading RE companies, covering more than 100 GW of RE capacity across more than 20 states. Our expertise spans growth strategy, O&M transformation, and digital and analytics-led performance transformations, helping companies navigate the complexities and stay ahead in a rapidly evolving market.

Our vast practical experience in building and transforming renewable energy businesses can help your company in achieving its goals. Contact us to explore this topic in more detail, receive our detailed value proposition, or request an assessment of your unique situation.

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