New Paths to Productivity in Power Generation
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New Paths to Productivity in Power Generation

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Faced with intense competitive pressure, conventional power producers must take decisive action to achieve long-term productivity gains. They must complement their rapid cost-reduction programs with lean management systems and new digital technologies.

**Lean Management Systems Drive Continuous Improvements**

The application of lean management in power plants can generate increased revenue and a continuous reduction of controllable costs. Producers can use lean levers to improve reliability and response times, shorten downtimes, and enable more efficient and faster startups. A continuous improvement of 2% to 3% annually is achievable, even after aggressive cost cutting of up to 35%.

**Power Generation 4.0 Revolutionizes Plant Operations**

Producers can use digital technology to drive a step-change in efficiency across the power-generation value chain and promote improvements in health, safety, and environmental protection. Remote monitoring via sensors, predictive maintenance enabled by analytics, and repairs supported by augmented reality are among the many benefits.
Conventional power producers in Europe are alarmed by the challenging conditions affecting their industry. Producers have experienced intense competitive pressure for the past decade, as overcapacity has led to dramatic decreases in load hours and wholesale prices. For Europe’s ten largest producers, the annual revenue potential per gigawatt of installed conventional capacity (whether generated by fossil fuels, nuclear power, or hydropower) has declined by more than 40% in real terms since 2005. Over the same period, many producers have seen their stock price underperform and their credit rating downgraded. Producers in other regions are confronting similar challenges.

The competitive pressure responsible for producers’ poor performance is not a cyclical phenomenon that will soon pass. Rather, it is the initial manifestation of a sweeping transformation of the industry. Over the next decade, we expect to see unprofitable power plants culled from the ranks of competitors by mergers and plant shutdowns. Unfortunately, producers’ actions to date suggest that they have not yet found a strategy for coping with the new reality. Many have obtained short-term relief by aggressively cutting costs and pursuing opportunities in the capacity or reserve markets. They have also asked governments to establish a payment system to compensate them for their installed capacity, although with limited success.

We believe that producers must take a much broader approach to survive and create long-term value. Although producers may feel that a decade has been a long time to endure the stress on their industry, manufacturers in other industries have dealt with similar competitive pressure for several decades. These companies have succeeded by using a wide array of productivity levers, far beyond traditional cost reduction and consolidation, to continually improve operational efficiency over the long term. Their experiences indicate that power producers can also capture a significant upside by rethinking their approach to improving operational efficiency.

Simply put, power producers’ survival requires taking decisive action to achieve long-term productivity gains. BCG has supported leading producers in early deployments of new productivity levers, and these programs have demonstrated the potential for significant improvements. In our experience, a continuous improvement of 2% to 3% annually is achievable—even after aggressive cost cutting of up to 35%.

In the coming years, producers must build on their initial efforts by making dramatic changes in all areas of power plant operations. Producers must complement their rapid cost-reduction programs with comprehensive lean management systems and new digital technologies that we call Power Generation 4.0.
Power Producers Must Cope with Intensifying Pressure

Before the past decade’s downturn, European power producers enjoyed comparatively favorable market conditions. Germany is a case in point. Prior to 1998, producers benefited from regional monopolies and cost-plus tariffs, significantly dampening pressure to focus on operational efficiency. The liberalization of the electricity market in 1998 led to lower wholesale prices, followed by a brief period of consolidation. Power producers captured healthy profits through 2010—prices were linked to commodity prices and the cost of carbon dioxide (CO₂) emissions certificates, both of which rose during this period.

Since 2010, power prices have decreased sharply in response to declining commodity and CO₂ prices and the increasing availability of solar- and wind-generated power capacity (promoted by feed-in tariffs for renewables). In addition, this capacity is used across borders more and more, as market coupling has expanded interconnector usage. These forces are continuously pushing down the profit margins and utilization of conventional generation. Similar effects, with some local differences, are being experienced throughout Europe as well as in other regions. (See the sidebar, “Producers Outside Europe Also Face Pressure.”)

Despite the strong growth in renewable power generation, the top ten European producers haven’t significantly cut their conventional power-generation capacity in the past ten years. Although saleable conventional power-generation capacity fell by 9% from 2005 through 2015, conventional power-generation capacity increased by 7% overall. Capacity utilization fell by 14% during the ten-year period, and the inflation-adjusted annual revenue potential per gigawatt of installed capacity declined by 43%. (See Exhibit 1.)

![Exhibit 1](image-url)

**EXHIBIT 1 | Power Producers Have Felt the Effects of Competition**

**CAPACITY UTILIZATION OF THE TOP TEN EUROPEAN PRODUCERS FELL BY 14% IN A DECADE¹**

**ANNUAL REVENUE POTENTIAL OF INSTALLED CAPACITY DECLINED BY MORE THAN 40%²**

*Sources:* Annual reports; Bloomberg data on wholesale forward prices (prices for power to be delivered in the following year); BCG analysis.

*Note:* TWh = terawatt hours. GW = gigawatt.

¹Utilization of conventional capacity (whether generated by fossil fuels, nuclear power, or hydropower).

²To calculate, we took the average conventional capacity utilization for the top ten producers and multiplied it by the weighted, inflation-adjusted average power price in France, Germany, Italy, and Spain.
The intensifying competitive pressure on power producers is a global phenomenon.

**US.** Producers in the US already face adverse conditions, especially operators of coal plants. The industry is shifting away from coal-based power generation, as gas is replacing coal as the predominant energy source in terms of market share. However, load hours are shrinking for both coal- and gas-fired plants. Approximately 15% of demand is met through power generated by renewable energy sources (RES), and the adoption rate of renewable energy is expected to grow sharply. Photovoltaic generation, in particular, has reduced electricity prices in periods of peak demand. Faced with shrinking margins and low load growth, producers have initiated efforts to reduce their workforce, improve processes, and make other efficiency enhancements. For each producer, the competitive pressures and the options for responding to them are determined to a large extent by regulations at the state level.

**China.** China’s power producers are experiencing pressure as a result of market liberalization reforms. Before liberalization, power producers benefited from regulated feed-in tariffs. Today, China is pursuing reforms similar to those enacted in Europe but implementing them more rapidly. Approximately 20% of the power market is already deregulated. Generation has already been fully unbundled, while transmission, distribution, and retail are in the process of being unbundled. Incentives have promoted the strong growth of installed renewable energy and nuclear power capacity. Emissions trading schemes are being tested on a local basis, and regulators plan to combine them into a national scheme, potentially leading to higher production costs. Coal-fired power plants have felt the effects of reform in terms of declining margins, power prices, and utilization. Nationally, the utilization of coal-generated installed capacity has declined to less than 5,000 hours per year, on average, while in provinces with a high share of RES, coal-generated installed capacity has fallen to 2,000 hours per year. The recent increase in the price of coal has added to the strong pressure on coal-fired power plants.

**Chile.** Chile’s conventional power producers already experience pressure from the expansion of renewable energy generation. Much of the power market is still regulated, and generation is auctioned. In last year’s auction, RES won more than half of the auctioned production for 2021 through 2041, leading to significant price reductions. Prices fell, on average, from $80 per megawatt hour to $48 per megawatt hour. To remain profitable, conventional power generators will need to manage their assets to promote greater flexibility and efficiency.

**PRODUCERS OUTSIDE EUROPE ALSO FACE PRESSURE**
Power producers have responded to declining revenues by undertaking major cost-cutting programs. The programs have aimed to reduce costs by hundreds of millions of euros, or even more at some companies. These efforts have included aggressive head count reductions, pay freezes, and, in some instances, plant mothballing or closures. However, short-term cost reductions have not persuaded investors that the industry has potential to create value over the long term. Many producers’ share price has continued to decline even as the broader market has recovered from the Great Recession. Moreover, rating agencies have pushed down the credit rating of many producers and maintain a negative outlook on their near-term performance. As of mid-2016, downgrades of European utilities by Standard and Poor’s, for example, had outnumbered upgrades over a seven-year period. Recognizing the impact of overcapacity resulting from the adoption of renewable energy, S&P lowered utilities’ debt rating to mid-BBB, only two levels above noninvestment grade.1

The Case for Applying New Productivity Levers
The clearly discernible trends of lower revenues and declining share prices point to the need for power producers to look beyond traditional cost-reduction programs for relief. The experiences of other industries demonstrate that it is possible to cope with several decades of intense competitive pressure and price deterioration by continually increasing efficiency.

A prime example is the US general manufacturing industry. In response to pressures arising from international competition, new technologies, and global economic crises, the industry has increased its labor productivity by approximately 3%, on average, each year over a span of 60 years. US manufacturers have achieved this impressive performance by applying a variety of efficiency levers (including automation, digitization, the specialization of work packages, and the standardization and modularization of goods) and using consolidation to capture economies of scale.

Some might argue that general manufacturing is not a valid role model, because it is much less capital intensive. But the experiences of two capital-intensive industries—chemicals and steel—confirm the view that power producers can capture significant productivity gains by applying a broad set of operational efficiency levers. The European chemical industry has increased its labor productivity by more than 2% annually during the past 15 years. By 2000, the industry had achieved a high level of consolidation by specializing in core business units while divesting peripheral units. Later in the decade, faced with Chinese competition and the global economic downturn, chemical producers recognized the need to think more broadly about how to increase operational efficiency. Among the levers driving the industry’s productivity gains have been plant optimization, specialization, and process automation. In Germany, the steel industry has increased productivity approximately threefold during the past half century, weathering several crises along the way. (See Exhibit 2.) Steel manufacturers have complemented traditional cost-cutting programs by adopting new technologies and using lean production systems to promote continuous improvement.

To emulate these industries in weathering decades of competitive pressure, power producers must complement their cost-cutting efforts by implementing lean management systems and utilizing new technologies.
Leading power producers are adapting lean principles from general manufacturing to introduce new approaches to planning, operations, and maintenance into their organizations. Although power generation differs from general manufacturing in important respects, lean principles can be applied to achieve sustainable improvements. The key is to focus on the lean concepts that are most relevant to power plants, such as stable processes, standardized processes (particularly for maintenance), and project management (especially for major maintenance efforts), rather than, for example, lean concepts relating to efficient handovers between process steps.

Like traditional lean approaches, the application of lean principles to power plant operations should target the causes of nonvalue-adding “waste.” For example, if the maintenance staff is required to perform many nonessential tasks, critical tasks may not be performed soon enough and staffing levels may be unnecessarily high. And, if different shifts are not required to follow the same processes, rework or other resource inefficiencies may result.

The sustainable improvements achieved by applying lean principles in power plants can deliver increased revenue (such as through shorter downtimes and faster and more reliable startups) and a continuous reduction of controllable costs. Best-in-class programs promote sustainable annual cost savings over the long term by continuously improving processes, enhancing workplaces, and introducing new capabilities into the organization. Employees learn to identify areas in need of improvement and determine the right measures to implement using a systematic root-cause analysis.

A major European utility has recognized the opportunity: Several years ago, the utility initiated a large-scale, top-down program to reduce costs. It pursued multiple
waves of cost reduction, attaching higher savings goals to each successive wave. However, the company understood that to achieve additional savings beyond the top-down initiatives, it must apply lean principles to improve leadership and continuously increase efficiency and quality at the process and team levels.

The utility, with BCG’s support, has successfully applied lean principles in its generation department. Several examples illustrate the improvements captured:

- **Incident Response.** To reduce the maintenance department’s workload and costs, the utility sought to decrease the number of high-priority incidents that required the immediate attention of a maintenance team. In a joint workshop, the control room and maintenance personnel refined the priorities assigned to various types of incidents. This effort improved the consistency of prioritizations and reduced the number of incidents characterized as high priority by approximately 50%, thereby reducing demand for standby maintenance. A postmaintenance analysis of incident reports improves the quality of reporting and systems on a continual basis.

- **Shop Floor Management.** To improve shop floor management, the utility introduced “team boards” as the basis for structured performance dialogues and efficient meetings. The boards contained lists of tasks, KPIs, and important contacts, as well as space to write suggestions for improving work. The benefits included clearly structured day-start meetings and transparency into task assignments and responsibilities. The initiative led to improvements in two key metrics: a 20% reduction in “mean time to repair” and a 30% increase in “mean time between failures.”

- **Downtime Management.** The utility sought to significantly reduce equipment downtime. A maintenance team used structured problem solving to devise an approach. The key element of the approach was to optimize each maintenance process by reducing the number of activities or performing them simultaneously. The approach also included setting the optimal standard time frame for tasks and defining control routines so that deviations could be addressed in a structured manner, such as analyzing the causes of downtime occurrences and incorporating changes into subsequent planning.

- **Waste Reduction.** The utility also wanted to reduce waste in the operations of its material-registration department. In a problem-solving workshop, the department’s staff identified waste, devised solutions to reduce nonvalue-adding activities, and defined cost-related KPIs. By implementing the solutions, they increased transparency and reduced both the initial workload and rework. In addition to improving communication, this quick win established a can-do attitude among department members and created a strong commitment to tackling more complex problems.

To successfully adopt lean management, it is not sufficient to execute a selection of lean initiatives. Rather, a power producer must transition to an integrated, sustainable lean production system that covers all aspects of business requirements, operational improvements, people management, and performance governance. A producer should start by identifying its core business requirements and objectives. It can
then apply lean tools to improve the high-priority areas of its operations. To enable the transition, the producer must attract and retain talent by building a collaborative and motivational culture and establishing KPI-based performance governance. BCG has developed and applied a proprietary toolbox to support lean transformations at utilities worldwide.

Power Generation 4.0 Revolutionizes Plant Operations

Industry 4.0 technologies—including big data, advanced robotics, and additive manufacturing—are revolutionizing industries across the globe, improving all the steps in their value chain. The time has come for power producers to join the revolution. Power Generation 4.0 is a set of technology levers that provides the basis for achieving a step-change in efficiency across the power-generation value chain and for promoting improvements in health, safety, and environmental protection. (See Exhibit 3.)

An international power producer’s implementation of a central monitoring center for its European and Latin American plants demonstrates the wide variety of ways in which Power Generation 4.0 creates value. The center enables the producer to remotely monitor performance and customize maintenance strategies for more than 100 turbines worldwide. The center also assists in the dissemination of best practices. For example:

- **Performance monitoring** should be based on real-time data, which allows the producer to perform critical actions, such as improving the thermal efficiency of turbines. The ability to perform such actions reduces dependence on original equipment manufacturers (OEMs) and allows the producer to build a critical mass of specific skills and know-how internally. Reductions in fuel consumption and emissions lead to lower costs.

- **Condition-based monitoring** should analyze sensor data, which makes it possible to more accurately estimate the remaining lifetime of parts. Having more accurate estimates allows the producer to extend the useful life of parts, which reduces maintenance costs. Furthermore, the producer can improve how it prioritizes and optimizes maintenance work. By customizing maintenance strategies and actions, the producer can manage expenditures and activities on the basis of their actual value to the plant and the condition of the various assets.

By implementing the new monitoring center, among other measures, the producer was able to reduce the number of unplanned plant shutdowns by 50% in five years, saving approximately €3 million per year.

There are many other Power Generation 4.0 use cases. For example, some utilities already use augmented reality devices, which project information (such as repair instructions or operational data for equipment) into a worker’s visual field. In contrast, the use of 3D printing (also known as additive manufacturing) to make spare parts is still in the testing stage. One OEM, for instance, recently completed the first full-load tests of turbine blades entirely produced using additive manufacturing. Such applications could potentially reduce the lead times for developing prototypes by up to 90 percent and al-
low manufacturers to provide parts on demand and tailored to customer specifications.

The use cases for Power Generation 4.0 promise to radically change the daily work of power plant employees. (See the sidebar, "Vision 2025: A Day in the Life of a Power Plant Worker.") To make the potential impact a reality, a producer must first understand the current state of its processes and the improvement opportunities. It can then determine the optimal combination of lean principles and Power Generation 4.0 levers that will enable it to capture its opportunities. This integrated implementation must address challenges that include capability building, systematic training, continuous improvement of existing work processes and standards, and cultural change.

**Getting Started**

To quickly assess its starting point on the journey to long-term operational efficiency, a power producer should answer the following questions:

- Have we thoroughly considered the full set of levers available for improving operational efficiency that is currently at our disposal?

- To what extent have our recently applied efficiency measures enabled continuous improvements rather than one-off cost savings? How effectively are we laying the foundation for sustained productivity growth?
How will power plants operate in 2025 if producers implement Power Generation 4.0? Using the example of a worker we’ll call Peter, we offer a vision.

**Robots.** Peter works at the producer’s main facility. After he parks his car in the plant’s lot, a self-driving minibus takes him to the building where his workstation is located.

**Remote Monitoring.** When Peter arrives at his workstation, he immediately sees a notification on his holographic display: after having been ramped down a few hours ago, the boiler in plant 9—200 kilometers away—is now cool enough to be inspected by a heat-resistant drone.

**Drones.** In response to the message, Peter puts on his virtual reality goggles and takes remote control of the inspection drone in plant 9. Carefully navigating the drone into the boiler, which still has an inside air temperature of 170 degrees Celsius, he uses the device’s cameras to view the welding seams.

**Remote Expert Support.** Peter discovers an area inside the boiler that needs to be repaired. The drone is capable of making the repair, but Peter is not skilled in directing the drone for this purpose. So, Peter transfers control of the drone to an expert from the boiler’s equipment manufacturer, which provides maintenance support. The expert is sitting in the manufacturer’s headquarters in Japan. He directs the drone in completing the required repairs quickly and then returns control to Peter.

**Virtual Warehouse.** Checking his holographic display after a break, Peter sees that the spare parts used for the boiler maintenance job have been automatically reordered from the supplier.

**Additive Manufacturing.** The supplier confirms that the next time those spare parts are required, its just-in-time delivery process will have the parts to the plant within three hours, which is the time required to make the parts using a 3D printer and deliver them via a drone.

**Big Data Analysis and a Digital Trading Platform.** A short time later, Peter receives two notifications. The first is from a sensor within plant 1’s primary cooling circuit: a water pump has deteriorated faster than anticipated and now reports a 70% probability of failing in the next week, indicating the need for a repair. The second advises him that new data from the utility’s weather model predicts dense fog in many locations in Europe. The resulting dip in power production from photovoltaic generators will cause a spike in the intraday power price. So that the power plant can profit from the high power prices, maintenance of the cooling water pump, which would require a temporary shutdown, is automatically delayed for 24 hours.

**Predictive Maintenance.** Indeed, the spot price for power spikes a short time later. Surprisingly, the price is
• Are our employees ready, willing, and able to autonomously identify and appropriately address inefficiencies in their daily work?

• Have we agreed on a technology roadmap for the next five to ten years that would generate efficiency gains across all areas from procurement to sales?

For many power producers, the answers to these questions will point to opportunities to realize significant improvements by taking a new perspective on operational efficiency. As in any transformation, success requires having a well-designed change management program that builds support among employees and provides them with the necessary training. Clear and consistent communications, both within the organization and externally, are essential for reassuring all stakeholders that the operational efficiency program will create long-term value.

The challenging conditions encountered by conventional power producers in recent years are here to stay. Other industries have weathered such headwinds for decades by relentlessly pursuing ever-higher levels of operational efficiency. To adapt to the increasingly competitive environment, power producers must emulate these broad-based, long-term efforts. Succeeding in this complex journey requires expertise in multiple dimensions. A producer must be able to evaluate the current state of its operations and understand how to integrate the application of lean levers and Power Generation 4.0 to generate a step-change in productivity. The first conventional producers to master the challenges of improving operational efficiency, year after year, will emerge as the winners in their crowded and diverse marketplace.

NOTE
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