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Performance of Generating Plant: New Metrics for Industry in Transition – Executive Summary

World Energy Council

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Contents

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Introduction

This is an Executive Summary of the 2010 publication "*Performance of Generating Plant: New Metrics for Industry in Transition"* produced by the four Work Groups of the World Energy Council's Committee on the Performance of Generating Plant. The complete report is available for downloading on the WEC website at www.worldenergy.org.

1. The Challenges of Measuring and Improving Performance within an Increasingly Complex Electricity Supply Sector

(Work Group 1, Chair: Scott Stallard, Black & Veatch, USA)

During the last two decades, the electric power sector has been subject to substantial changes which included regulation, market formation and structure, technology mix, and political aspects. Interestingly, such rapidly changing dynamics seem to *have permanently* altered industry make-up, rules, incentives, and ways of doing business. This begs the key question – how can we measure and compare performance across assets for the purpose of improving reliability, addressing environmental imperatives, and at the same time keeping and eye on cost of improvement to value delivered to utility/customer?

As such, best practices for measurement and analysis of performance are changed as well. Increasingly, such changes began to have significant implications for plant operations and associated metrics. Efforts of the PGP Committee to develop a better means to address such issues across the wide range of power generation assets worldwide has centered on the concept of value – value of the generation either in terms of benefit (i.e., reliability) delivered to the grid (regulated environment) or value delivered to owners (de-regulated environment). Extensive work on "commercial availability" metrics and their use has been completed; it remains clear that for the de-regulated entities, this is a critical concept.

The Committee also completed an analytical model that allows one to compare/contrast "value" delivered by assets across markets with the basic idea of providing a means to understand the differences in incentives for performance and more importantly performance improvement.

With respect to measurement of performance, the first objective is to analyze how to best address variability of the "value" of assets, given the wide diversity amongst stakeholders and their priorities. Taking into account the divisive implications of CO_2 emissions for the near term, developed and developing countries may require different performance metrics and frameworks. Specifically:

- In the absence of environmental and market imperatives, least-cost reliable generation continues to be primary performance motivator for developing countries. *In such cases, traditional data collection, analysis, and benchmarking processes remain highly relevant.*
- In developed countries, increased sensitivity to the environment and particularly fossil fuel use and its impacts on CO_2 emissions, creates further complexity with respect to short-term and long-term individual unit and system performance priorities and metrics. *In this case,* our work suggests *that further definition of means to measure performance against both financial and environmental priorities will be needed – in essence, to combine our prior work addressing commercial availability with means to address* CO_2.

Globally, GHG emissions, cost reduction, and sustainability are all beginning to target generation efficiency as a critical element of the strategy. Therefore, further analysis of efficiency metrics as key performance indicator is necessary.

Implementation of best practices with respect to efficiency improvement can have substantial implications for both CO_2 and costs of production.

Key Drivers

Ideally, given that today further de-regulation and/or privatization has largely stalled, a more stable view of performance and performance improvement metrics can be established. Unfortunately, we have, however, witnessed the opposite – major factors impacting the electric supply sector varying widely from economic downturn, to CO_2, to growth of renewables, to emergence of new technologies (largely driven by carbon) all play a role in further division of the sector in terms of roles, expectations, and key performance metrics. Major drivers include:

- **Reliability**. Supply reliability continues to be a major driver or imperative. Demand side management (DSM) is becoming more attractive as deployment of Smart Grid technologies takes place and end-use efficiency and peak demand requirements are further scrutinized.
- **CO_2 / Greenhouse Gases (GHG)**. Concerns surrounding climate change have driven unprecedented political activity, proposed CO_2 regulations and taxes, creation of regional CO_2 emissions credit markets, and discussions of global CO_2 markets/offsets. This is a transformational issue and, as such, will be further addressed in detail below.
- **Growth of Renewables**. Driven by CO_2 and sustainability motives, thousands of MW's of renewable energy are either in operation or being planned. In some cases, the intermittency and reliability of such sources (wind, solar) can place significant stress on the grid. Bio-derived fuels are being burned in both new and existing facilities. Currently, in the majority of cases, without subsidy or tax abatements, renewable energy does not compete favorably with traditional generation in terms of cost.
- **Global economic downturn**. Energy consumption and peak demand requirements have been impacted throughout the world; reduced demand has, in some cases, provided relief from capacity short regions. Interestingly, during this "pause," the viability of traditional generation assets – particularly coal – has been challenged by growing environmental opposition seeking to reduce or eliminate use of fossil fuels for new generation facilities.

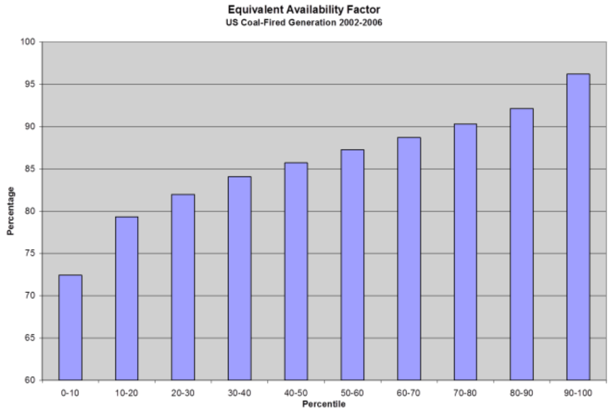
Demonstrated Value of Data and Data Analysis

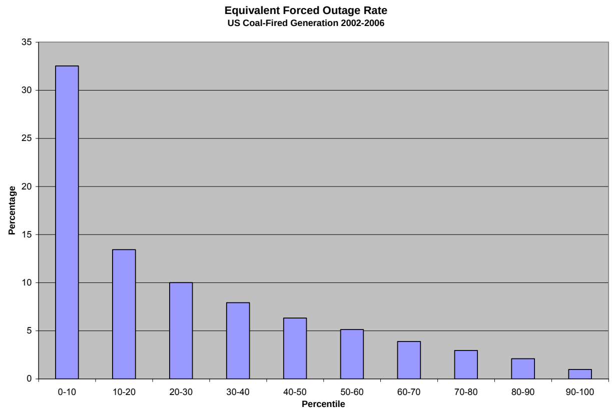
Benchmarking and other similar techniques that focus on comparison of unit performance against that of its peers remain invaluable. However, methodologies must be adapted to evaluate differences in "value" associated with different markets, regulation, and technology; this can be coupled to technical data derived from benchmarking to provide financial perspective.

Benchmarking is a process used to evaluate various aspects of equipment performance in relation to best practice, as compared to their peers. This then allows organizations to develop plans on how to adopt such best practice, usually with the aim of improving some aspect of performance.

While, historically, the focus of such analysis has been plant reliability, the concepts can be readily extended to address efficiency, emissions, and cost objective, presuming adequate data availability.

Industry "best practices" usually associate performance with ranking. Hence, it is often useful to measure performance within the context of industry ranking, or often more simply, within the context of "deciles" or "quartiles." The distribution of equivalent availability factor (EAF) and equivalent forced outage rate (EFOR), in terms of deciles, for US coal-fired generation from 2002-2007 are shown below.





As one can see from the figures, the distributions are far from normal. The average performance for EAF and EFOR are 85.8% and 8.2%, respectively. Based on these values, the "improvement" required to improve performance from average to top quartile or top decile would be as follows.

Building on the benchmarking framework illustrated above, one can quickly see that to move from average EFOR performer to top-quartile and top-decile would require improvements of 7.7 and 10.4%, respectively.

	EAF, %	Δ to achieve Top 10%	Δ to Achieve Top 25%	EFOR, %	Δ to achieve Top 10%	Δ to Achieve Top 25%
Top 10%	96.2	10.4	2.7	0.8	7.4	0.9
Top 25%	93.5	7.7	-	1.7	6.5	-
Average	85.8	-	(7.7)	8.2	-	(6.5)

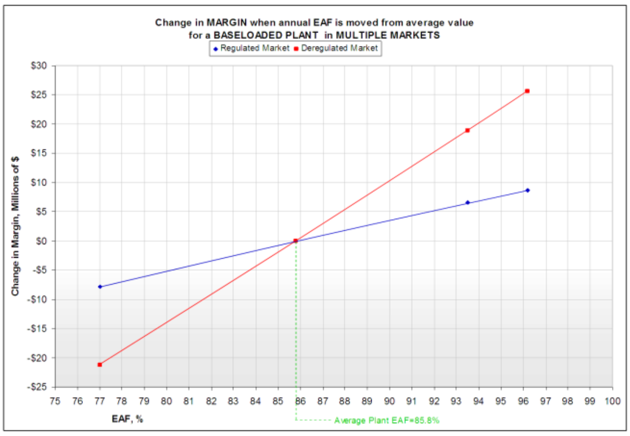
Continuing the Journey – Integrating Market, Environmental and Financial Perspectives

Today, plant operators must think in strategic and economic rather than purely technical terms. The reality is that mixed regulatory, ownership and market perspectives correspond to mixed goals, objectives, and priorities for generation entities. Varying business models, varying risk profiles, and different "obligations to serve" complicate the issue even further.

While the challenge remains essentially the same – to improve the performance of the existing generating plant – the complexity and the dynamics of the market require a re-evaluation of the means for collecting, analyzing, and benchmarking performance. Specifically, one must consider how to evaluate performance in the context of multiple objectives – reliability, availability, efficiency, environmental performance, and flexibility.

This provides concrete means for "defining capital investment and changes in O&M necessary to reach such targets and to define the costs/risks associated with such aspirations. Yet, economics must play a role – how much is the value – in terms of increased net margin from power sales worth? To address this issue, in 2007, the PGP Committee introduced the initial version of a spreadsheet-based tool[1] to be used to compare/contrast performance within the context of financial performance. It provides a medium for analyzing and presenting a thorough availability and economic comparison for various facilities, technologies, and market designs.

[1] Originally published in conjunction with WEC Performance of Generating Plant Final Report, Section 1, WEC 2007, markets, and obligations effects of market on value of performance improvement. This model has been updated to consider cost of carbon as an input to production cost and to bid strategy.

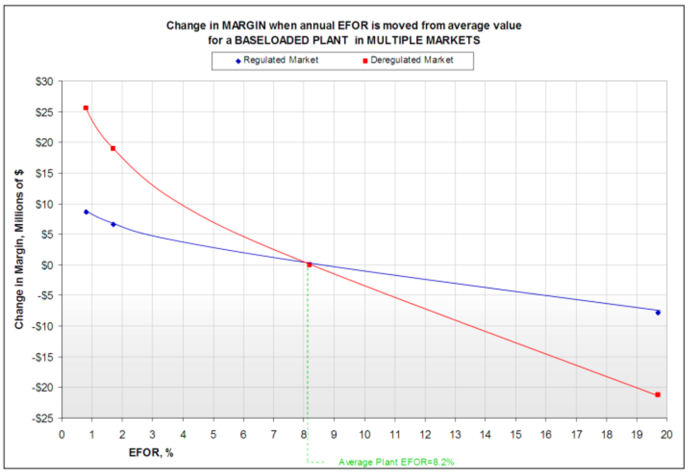


By applying this model it is possible to better understand implications of revenue gains that would be associated with improvements in EAF or EFOR; for example, considering the impacts of "value" vs. whether or not an average base-load coal plant is operating within a regulated or de-regulated market. While specifics of the market and demand need to be tailored to the actual situation, as modelled, the comparative analysis yields some interesting results.

- A large part of the financial benefits for achieving top decile performance are realized by achieving top quartile performance.
- Deregulated markets will yield potentially higher benefits to generators for incremental improvement.

The ability to understand magnitude of opportunity associated with improved performance is unquestionably a key challenge for the foreseeable future, given the critical role of existing plant to both produce needed power as well as support larger environmental performance objectives. The ability to evaluate one's performance in the context of its peers will be key.

The industry's challenge is to continue to find ways to not only collect and analyze the necessary data but also to provide the framework for which to extend the analysis across markets, across technology choices, and across financial realities.

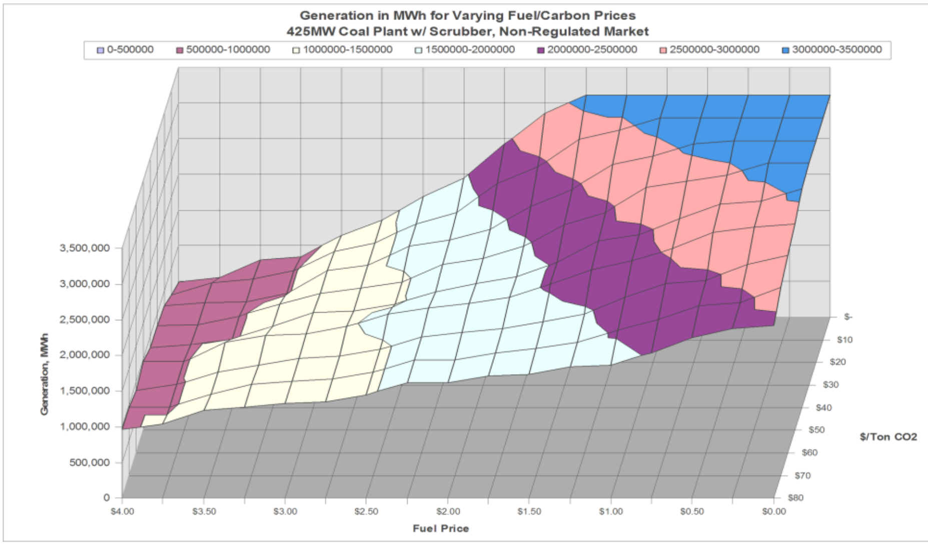


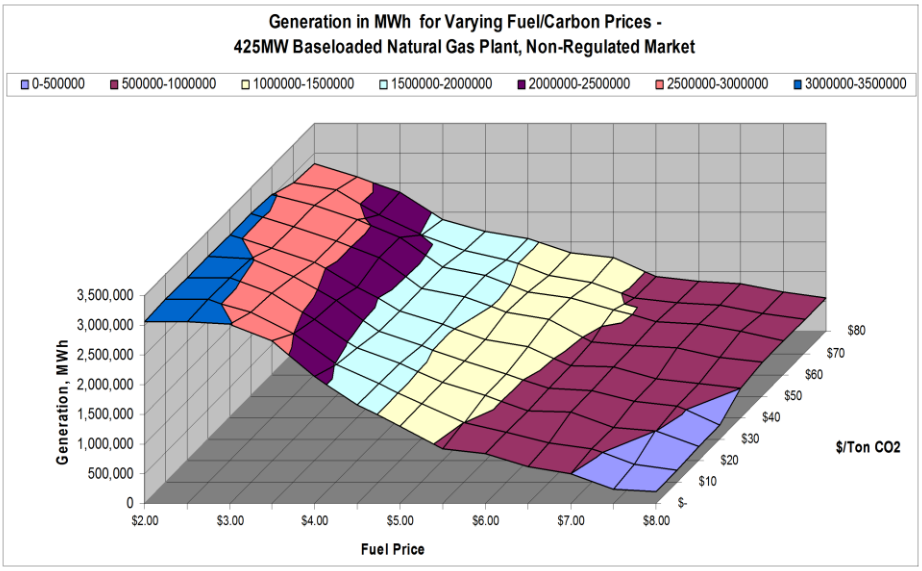
In terms of the potential impact on the energy sector, the benefits of the global comparison system are numerous and obvious. Information exchange will help improve the performance of power generating plants around the world and provide access to electricity to larger populations thus improving the quality of life for many people.

Impacts of CO_2 and Fuel Price on Asset Performance Value

The introduction of CO_2 as either a tax or via allowance will significantly impact the cost of generation for units with carbon-based fuels (coal and to lesser degree, natural gas). The purpose of this analysis is to compare/contrast how such regulations and related costs would impact value of generation versus a more traditional cost factor, the cost of fuel.

Fuel cost has historically been the one of the primary drivers associated with determining the "winners" and "losers" within the ESG.





As one of the, if not the, main cost associated with electricity production, fuel cost can vary widely from region to region, and depending on the physical location of the generating asset, transport costs (normally a component of fuel cost) can further impact relative fuel costs between generating assets.

Interestingly, price volatility such as that modelled for regional fuel prices essentially forces competition amongst generators using the same operating technology, while CO_2, as a market driver can change the competitive dynamics between technologies with differing emissions intensities.

It must be mentioned however, that potential for erosion of operating margin would exist in scenarios where coal and natural gas are competing for base-load generation in the same market.

As is shown in the above figures[2], the projected impact of a market price of CO_2 affects each generation technology in a slightly different way. For the coal based asset, increasing CO_2 prices, will more or less, uniformly impact bids price for coal-fired generation and make gas more competitive on the margin. For higher CO_2 prices, other factors being equal, gas will displace coal in base-load market.

Fuel cost on the other hand, has a much more profound impact on the dispatch level of an *individual* coal-fired generation asset, because fuel cost variations are not uniform across the market; hence, strong variations in fuel prices can be far more deterministic to the fate of that asset.

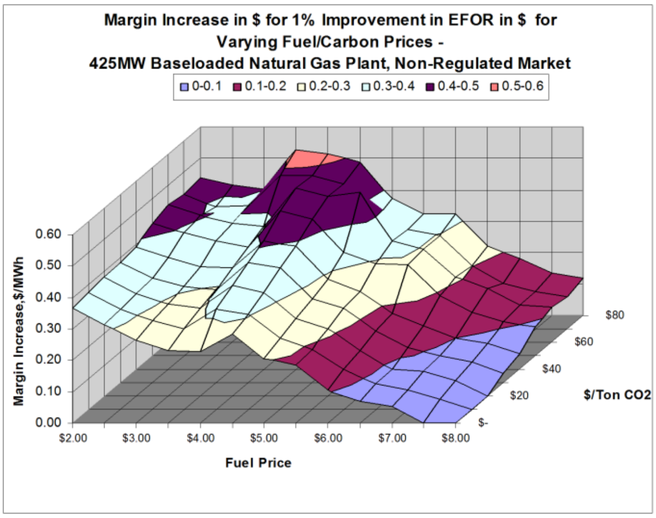
Value of 1% EFOR Improvement

Interesting trends arise when considering the "commercial value" of 1% improvement in the equivalent forced outage rate. This allows us to consider level of investment that would be prudent to invest in plant to reduce EFOR.

- For gas-fired generation, EFOR improvements have the increasing economic value, generally, as fuel prices decrease. Lower fuel prices maximize opportunity for unit to be dispatched; there is a slight upward spike in incremental value of improvement as gas plant begins to displace coal generation.
- It is important to consider overall expected fuel price vs. price volatility; as can be seen from the example, the value of improvement would vary widely if fuel price was highly volatile.
- In a competitive market, the price of CO_2 will be included in generation costs and the value of improvement for gas plant will be enhanced because, all other factors being equal, gas will reap more benefits than coal in terms of CO_2 costs.

A similar result can be seen for coal-fired generation.

- If the coal-unit is not fully in the money, decreasing fuel price will improve dispatch opportunity and, yield greater MWh of energy sales.
- CO_2 increase will be seen by the entire coal fleet; impacts will negatively affect dispatch opportunity most (and decrease margin for improvement) when fuel prices and CO_2 prices are both high. In situations where CO_2 costs are very high, incremental value of EFOR improvement is relatively insensitive to fuel price.



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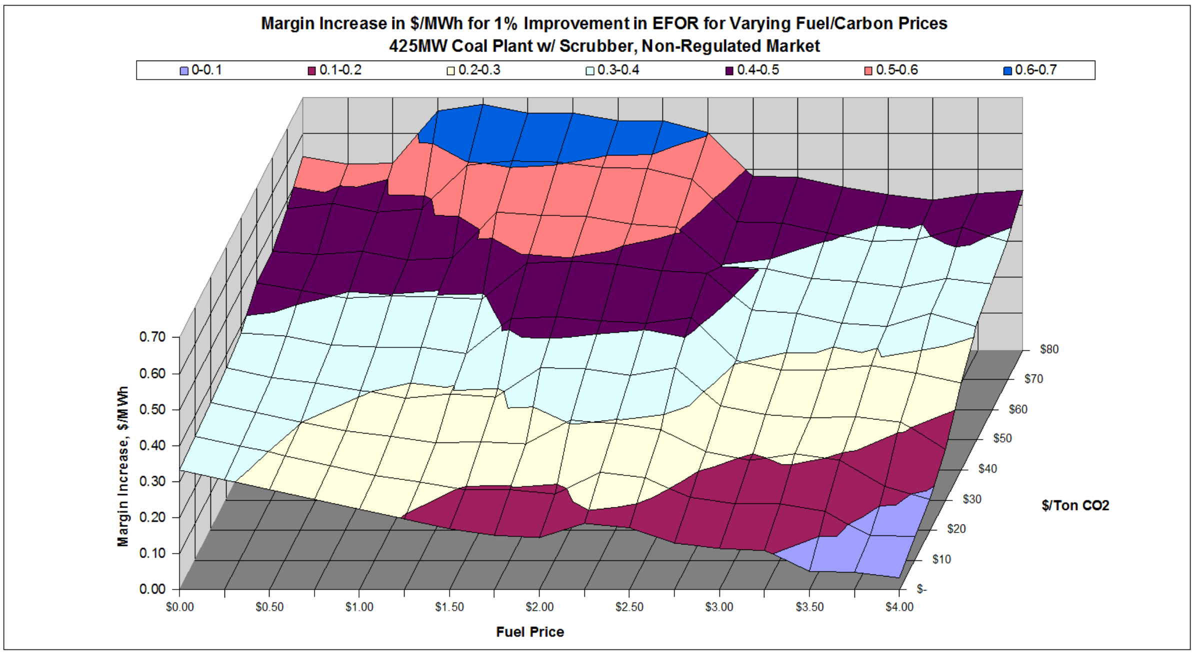
2 Surface plots presented are three dimensional and, hence, the angle of view is critically important to understanding the variations in the "surface" of the plot. To that end, please note that when necessary the direction of increasing magnitude for both the X and Y axes have been reversed if it's deemed helpful to understanding the overall impact of that particular analyses.



It should be noted that market characteristics, including sensitivity of demand to price, mix of technology, as well as fuel market characteristics can materially change the outcomes of this type of analysis; the key take away is to understand that the value of incremental improvement is likely to vary widely both across and within markets based on global (CO_2) and local (e.g., fuel costs) influences.

Efficiency Improvement

Increasingly discussions/debates about sustainability take note of value of efficiency improvement; while such discussions have largely centered on end-use efficiency and reduction of transmission losses, there is nevertheless more interest in generation efficiency improvement metrics. The PGP Committee is in the process of evaluating if/how to address efficiency within the context of its data collection and benchmarking efforts.

On one hand, the value of efficiency improvement can be considered in manner very similar to that of commercial availability; it would be possible to quickly assess incremental margin and dispatch afforded a unit with 1% greater efficiency. But, while it is relatively straightforward to assess the value of improvement, there is substantial difficulty in benchmarking due to variations in technology, fuel quality, degree of environmental equipment present, and load.

Technological innovation is one of the key challenges in addressing the greenhouse gas problem and this has several implications.

- First, while most of the current focus has been on applying technology to address high hurdles to meet enormous reduction targets, one should not discount the use of innovation/technology to address lower and more readily attainable hurdles via existing plant performance/emissions improvements.

- Second, technologies to address carbon capture/sequestration will significantly impact overall plant efficiency (due to power required in separation process) and may also significantly alter system reliability (depending on technology's impact on plant reliability and system reserve margins).

- Finally, the increased use of renewable generation will alter the "roles" of traditional generation assets to, for example, integrate with/backstop renewable generation requiring deeper and more frequent cycling, and starts; this may introduce the need for new performance metrics for both traditional and renewable generation sources.

Conclusions

Market, regulatory, and technological forces will continue to enhance value of performance. As such, the need for tools/processes to collect, evaluate, and leverage performance data remains a priority. As noted above, critical issues to be addressed include:

- Means to collect and evaluate performance data to understand overall industry performance trends.
- Means to benchmark plant within context of its market, and to compare performance "results" vs. incentives provided by the market, regulations, etc.
- Means to factor into forward PGP mission the importance if efficiency, sustainability, emerging technologies, and mix of generation.

The PGP Committee will continue to align its efforts to support industry needs through data collection across technologies, application of benchmarking, where feasible, to support identification of best practices, and continue to develop/refine its framework for evaluation of "value" of performance.

2. The PGP World-Class Availability Database: Management Tool for a Competitive World

(Work Group 2, Chair: Mike Curley, NERC, USA)

The following is paraphrased from an April 2006 article in the *Wall Street Journal* and applies to all industries, but may be especially relevant to today's increasingly competitive electric power generation business:

Business today is awash in data and data crunchers but only a few companies have transformed this technology into a strategic weapon. Their ability to collect, analyze and act on data is the essence of their competitive advantage. These top companies are outsmarting and outmaneuvering the competition because they made information analysis and management a distinctive capability, one that is fundamental to their formula for doing business.

From a recent survey of 450 executives in 370 companies spread across 35 countries and 19 industries, a strong link was identified between extensive and sophisticated use of analytics and sustained high performance. Of the respondents, high-performance companies – identified on the basis of their ability to substantially and consistently outperform their competitors over the long term, over economic and industry cycles and through generations of leadership – were five times more likely than low performers to single out analytics as critical to their competitive edge. ("Intelligent Use of Data is a Powerful Corporate Tool", Wall Street Journal, April 27, 2006)

For the power industry, one of the critical tools to help "sophisticated use of analytics and sustained high performance" is an accurate, dependable power plant database. The PGP Committee was been at the forefront of this work and is willing to share its experience with others in the industry.

Since its inception in 1974, the Performance of Generating Plant (PGP) Committee has serviced the electric industry worldwide. The PGP Committee organised workshops, training, and other initiatives to share information, techniques and methods to increase the productivity of generating units. This work is now supported by the PGP power plant database.

The information in the PGP database can help generating companies in many different ways through all life time cycles:

- New Plants – design
- Plant strategies – goals, benchmarking, high impact outages
- Inspection scheduling
- Plant Modifications – replacement, reconfigurations
- Outage Planning

Tracking performance of generating units is essential for benchmarking and goal setting. Without it, there is no other method for evaluating how well the power plants are performing. Without plant's availability records, the plant operators cannot determine ways to improve performance of the equipment and make the plant a profit-centre for the company. The causes of unavailability must be thoroughly examined so that the limited resources of operating companies can be use in the most effective ways.

Recent developments of the PGP Database

The PGP Committee has been collecting availability information on various generating technologies from around the world. The technologies collected are:

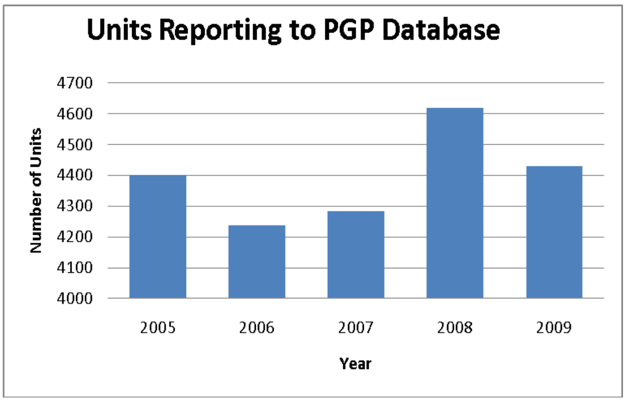
- Fossil steam units
- Nuclear
- Combustion turbines
- Combined cycle and co-generation blocks
- Hydro and Pumped Storage units
- Renewables including wind and solar

PGP now offers a new option for data collection. For many years, PGP collected data on a country-by-country basis where groups of units were reported by each country. Some countries were concerned that their data would be negatively analyzed if only one or two operating companies were presented.

In 2010, these concerns were addressed by allowing individual electricity companies report data directly to PGP. Instead of countries listed on the retrievals, the world will be divided into "regions" where the minimum reports will need to contain a minimum of 3 electricity companies from that region. This move is to maintain the confidentiality of the PGP data while allowing reporting of confidential data to PGP.

The number of units reporting has expanded. Also, for many years, the database only allowed base-loaded units to report. That weakened the full potential of the database by not allowing users to see cycling or peaking units. The barrier has been removed. All operating modes can report to PGP now.

Every generating unit reported is important. In the last several years, PGP has moved from collected data on groups of units from each country to collecting individual unit data. This unit-by-unit collection allows more specific peer-unit analysis for benchmarking and goals. As an example, here is a snap shot of units reporting to the PGP database over the last five years:



EAF Distribution Summary

Range of EAF Values	Count	Cumulative Count	Cumulative Percent
0-9.99%	11	11	1.24%
10-19.99%	2	13	1.47%
20-29.99%	2	15	1.69%
30-39.99%	5	20	2.25%
40-49.99%	10	30	3.38%
50-59.99%	18	48	5.41%
60-69.99%	57	105	11.84%
70-79.99%	127	232	26.16%
80-89.99%	333	565	63.7%
90-100%	322	887	100%

Quartiles & Deciles

Percentile	Value
Min	0.00
d1	67.89
d2	76.79
Q1	79.45
d3	81.47
d4	84.23
Q2	87.01
d6	89.38
d7	91.53
Q3	92.97
d8	94.25
d9	96.63
Max	100.00

For more reports from the PGP database, please see the full PGP tri-annual Report.

Now that the PGP database collects both design and operating information, it has the capabilities to provide interesting and sophisticated analyses on unit performance. For example, there is a report on the performance of coal-fired fossil steam units in 2009.

Reports like these allow plant owners to benchmark and set goal for their units. Essential data like these allow accurate and meaningful evaluations of power plant performance.

Status Of Data Collection Efforts

The WEC PGP started collecting unit-by-unit data from its members in early 2007. The introduction of the unit-by-unit database was slower than expected. However, the pace has picked up. As of July 31, 2010 the PGP database contains:

- Years reported: 125
- Units reported: 54,279
- Total reported capacity: 8,697,084 MW
- Average capacity: 160.23 MW

It is expected that more and more data will be added to the PGP database as new electricity companies contribute to the database. Are you ready to join the global community and contribute to the PGP database?

Conclusions

Key factors influencing plant performance should be identified and examined to allow a cost/benefit analysis of any activity/programme before its implementation.

To analyse plant availability performance, the energy losses/outages should be scrutinised to identify the causes of unplanned or forced energy losses and to reduce the planned energy losses. Reducing planned outages increases the number of operating hours, decreases the planned energy losses and therefore, increases the energy availability factor. Reducing unplanned outages leads to a safe and reliable operation, and also reduces energy losses and increases energy availability factor. At the same time it reduces costs for. replacement electricity.

The access to worldwide generating plant statistics will help power plant operators with the availability records of their plants in the context of global experience. New software for collecting and new, powerful software for analyzing the results is now available to bring the world electricity producers closer together in a cooperative manner. The results will be a beneficial exchange of information to better the quality of life for the world community.

What the Future Holds in Store

The Performance of Generating Plant database will continue to grow and improve as more and more electric companies worldwide report data to it. The concerns of data confidentiality are now removed as data can be reported directly to PGP. Regional groupings of units will allow reports without disclosing the country of origin. As the database grows, it will be a more important tool for increasing the energy output of units and provide the many customers with reliable sources of power.

The access to worldwide generating plant statistics will help power plant operators with the availability records of their plants to benchmark them in the context of global experience.

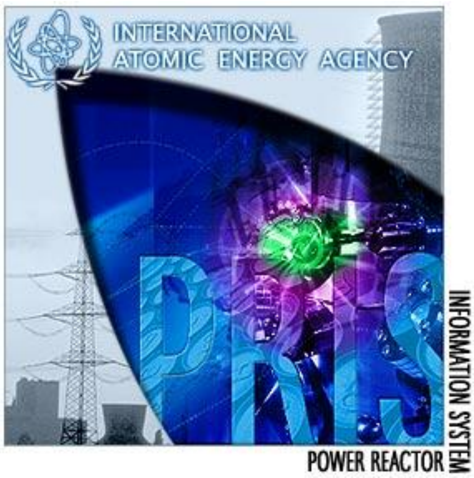
3. Nuclear Power Generating Units

This section of the report was produced by Work Group 2 of the PGP Committee, Jiri Mandula, IAEA

Since 1954, nuclear reactors have provided a source of electricity generation and the technology has been advancing since that time. Today, nuclear energy is an important part of a global energy mix. In 2009, nuclear power supplied approximately 14% of the world's electricity. For the duration that nuclear power has been used to generate electricity, nuclear power plants have accumulated more than 14 000 reactor-years of operating experience. World energy demand is expected to more than double by 2050, and expansion of nuclear energy is a key to meeting this demand while reducing pollution and greenhouse gases.

A growing number of countries are expressing interest in introducing nuclear power. While currently 29 countries use nuclear power for electricity generation, more than 60 countries have expressed such an interest in recent years and 17 of them are actively preparing nuclear power programmes to meet their energy needs.

Nuclear Power Information at the IAEA



The statistics presented in the report are based on data collected by the International Atomic Energy Agency (IAEA) for its Power Reactor Information System (PRIS). The database system covers two kinds of data: general and design information on power reactors, and performance data consisting of energy production, energy unavailability and outages. General and design information relates to all reactors that are in operation, under construction, or shutdown in the world. Performance data cover operating reactors and historical data on shutdown reactors since beginning commercial operation.

The PRIS can be used to assess nuclear power performance as it provides information on plant utilization and planned and unplanned unavailability due to internal and external causes. Due to detailed classification of energy losses and a comprehensive outage coding system, a set of internationally accepted performance indicators are calculated from the PRIS performance data. The indicators can be used for benchmarking, international comparison or analyzes of nuclear power availability and reliability from reactor specific, national or worldwide perspectives. Special care should be taken not to give priority to a single performance indicator as this could distort an objective overview. Performance indicators are a tool to identify problem areas, where improvements are necessary, but they do not provide either the root cause or the solutions.

PRIS provides PRIS-Statistics the front-end tool interface with on-line connection to PRIS through the Internet and public web-site www.iaea.org/pris.

Current Status of Nuclear Power

In July 2010 the nuclear industry is represented by 439 operational nuclear power plants (NPP) totaling 373 GWe of capacity. In addition there are 5 operational units in long-term shutdown with a total net capacity 2.8 GWe. There are 61 reactor units with a total capacity 59.2 GWe under construction.

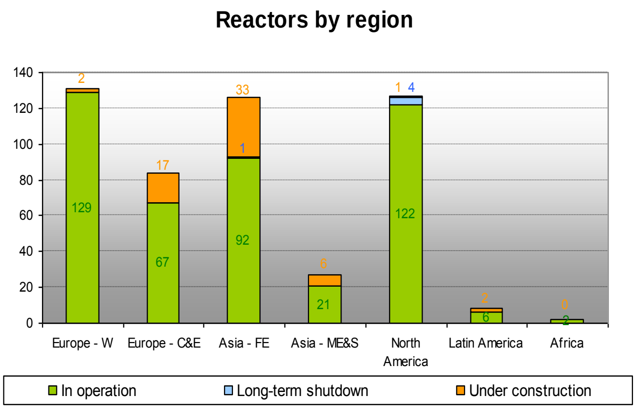
In 2010 three new units have been connected to the grid, Rostov-3 in Russia, Rajasthan-6 in India and Lingao-3 in China. Construction of eight new reactor units has been started in 2010: Ningde-3, Taishan-2, Changjiang-1 and Haiyang-2 in China, Leningrad 2-2 and Rostov-4 in Russia, Ohma in Japan and Angra-3 in Brazil.

Figure 1 shows that nuclear energy is concentrated in Europe, North America and the Far East (FE) where 410 of the total 439 reactors are located.

Asia and Eastern Europe are expanding their installed capacity by constructing new NPPs whereas North America and Western Europe are, in recent years, benefiting instead from power uprates of existing units.

Current expansion in Asia can be illustrated by facts that 39 of the 61 reactors under construction are in Asia and, during the last 10 years, 27 of the last 36 grid connections were in Asia.

Figure 1: Number of reactors by region



Nuclear plant operators are achieving high availability through integrated operation and maintenance programmes.

Currently, the global average EAF is around 80% and more than half the world's units operate with an EAF over 85%. Generally, as EAFs improve and approaches the ceiling of 100%, each incremental improvement becomes ever more difficult and expensive. But there is still room for improvement. Using the performance of the world's best performers over the last five years to define a practical limit yields a value around 95%.

These achievements show the efforts made by the nuclear industry for a reliable and safe operation of nuclear power plants. These improvements also reflect the impact of de-regulation and privatisation of the electricity market which have affected all electricity producers, but mainly it is a result of optimised operation and maintenance of nuclear power plants.

4. Performance Indicators for Renewable Energy Sources

{Work Group 3, Chair: Francesco Starace, ENEL Green Power, Italy)

The work presented here was created within Work Group 3 (WG3) of the World Energy Council's (WEC) Committee on the Performance of Generating Plant (PGP). The main goal is to analyze the formerly defined performance indicators and the possibility to build databases for benchmarking purposes producing original guidelines for generating plants using Renewable Energy Sources (RES).

The objective of the Work Group is to provide information and enable benchmarking for generating plants using renewable energy sources. This is in order to help improve efficiency of the systems and the design of new projects, and enable potential project participants to evaluate and make comparisons in terms of their respective performance.

Over the years of work, a lot of mainly general RES databases have been established but none seems really satisfactory for our purpose. In fact, as far as RES are concerned, there are no proper performance indicators databases for benchmarking purposes.

The Work Group has analyzed the causes for this lack of information.

The first issue regarding RES performance indicators is the lack of standard definitions for the most important indicators. For example there is an IEC working group, set up in 2007, with the aim of producing a standard to describe a common definition of unavailability categories for wind power plants. Up to now there is no international agreed definition of Availability.

Further detailed key performance indicators definitions are necessary (involving international organizations IEC/ISO).

There are few databases devoted to the performance of renewable plants and they are not well updated (Wind Stats Newsletter for wind, IEA-PVPS Task 2 for PV, the new NERC (USA) has just started in the beginning of 2010).

But, why is it so difficult? Why has it been possible with conventional power plants and not so with RES?

The first conclusion is obvious: RES business model is not comparable to the one used for conventional generation plants.

Performance not always 100% visible to owners

- Global service contracts with Manufacturers (3-5 years)
- Lack of business “maturity” in control-scada-data collection platforms for RES
- KPI definitions not well standardized
- Owners not always have a “utility” mind
- Strong competition, people are hesitant to provide information.
- “Young” business. RES companies mainly oriented towards business development, not operational excellence.
- RES promoters are a highly fragmented community (small investors, land owners, banks, real state, utilities).

Technical difficulties to overcome

- Several types of generation units per plant (i.e. wind). A lot of data required for simple plant performance analysis.
- Data management task is very hard for a medium size promoter dealing with different technology and different data formats in each single plant.
- Generally, extreme condition locations: complicated access, poor communications, lack of performance data more probable.

New Aproach

A new approach is needed. Particularities of RES business model make it not comparable with conventional generation plants in terms of performance indicators definition, treatment, collection and reporting.

In most cases only a regulatory framework in which performance data gathering is mandatory can ensure the proper operation of databases.

5. Technology Transfer : How to Make it Happen

(Work Group 4, Chair: Dr. Terry Moss, Eskom, South Africa)

Technology transfer is the process of sharing technologies to ensure that developments are accessible to a wider range of users who can then further develop and exploit the technology into new processes.

The recipients however, do not always fully understand what is needed and the suppliers are unaware of this.

Analytical studies and documented practical experience demonstrate that plant performance improvement is attributable to

- 25% improvement in technology

and

- 75% improvement in human technical and managerial skills. This highlights the importance of transferring the technology to the people involved in the operation of the plant.

The objective of Technology Transfer does not take place in isolation and it is a combination of macro as well as micro issues that need to be addressed.

The contributions from the WEC members highlight that solutions do exist and that some very successful initiatives have taken place.

Technology Transfer

In order to address “Technology Transfer – How to make it happen”, a clear understanding has to be formed regarding the scope of Technology Transfer. Two definitions indicate the extent that is covered:

First Definition: Transmission and adaptation for specific cultural, social, economic and environmental influences of ideas, information, methods, procedures, techniques, tools or technology from the knowledge holders to potential users.

Second Definition: The process of sharing skills, knowledge, technologies, methods of manufacturing, samples of manufacturing and facilities among industries, universities, governments and other institutions to ensure that scientific and technological developments are accessible to a wider range of users who can then further develop and exploit the technology into new products, processes, applications, materials or services (Wikipedia).

Transfer of Technology must be a sustainable process that ensures protection of the technology provider in a fertile, supportive, environment in which the technology is understood and capable of being applied to the benefit of the business and country.

Technology transfer can occur within the organization both vertically and horizontally between industries or countries. It covers a broad range of business areas such as management, technology and technical operations.

Technology Transfer Environment

Before any Technology Transfer can take place, the environment in which it will happen must be understood and the following aspects should be evaluated in terms of their feasibility and applicability:.

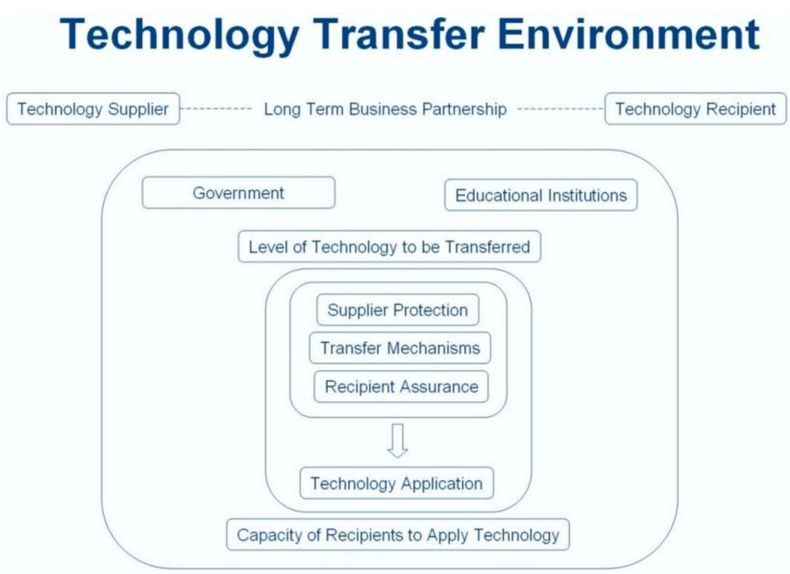
- Government Involvement
- Technology Absorption Capacity
- Challenges associated with Technology Transfer

Supplier Protection

Technology Transfer is usually not a simple process and needs sustained co-operation between all parties to achieve success. It is prudent to enter into a legal agreement as part of the contract between the supplier and the recipient in order to ensure protection of interests for both parties and a number of these are discussed in Appendix 1 to the full report indicating the circumstances under which type could be selected. Failure to provide this protection can lead to future reluctance by the technology suppliers to continue offering their technology.

Technology Transfer Mechanisms

The types of technology to be transferred influence the transfer mechanism.



Acquiring technological information through more than one channel leads to increased technology transfer, as demonstrated with the Eskom new-build contracts being the OEM equipment contracts, independent training suppliers and government sponsored ASGISA capacity building initiatives.

In the case of South Korea, transfer mechanism progression indicated a maturing process:

- Technology imports and local adaptation to enhance efficiency
- Technological licensing (use)
- Foreign Direct Investment (FDI). This is not always a preferred method for the receiving country as it can be considered as 'Buying Out' the Country rights.
- Mergers and acquisitions
- Indigenous Research and Development efforts
- Technology licensing (manufacturing)
- Strategic alliances
- Foreign firms supply in specialised sub-sectors of the industry.

Technology Transfer channels in use:

- Co-operative research programs
- Reverse engineering
- Exchange of Scientific and technical personnel
- Science and technology conference
- Trade shows and exhibits
- Open literature (journals, magazines, technical books and articles)
- Commercial visits
- Education and training of foreigners
- Government assistance programs

The Technology Supplier undertakes to train staff and management of local firms to source equipment due to lower costs or ease of access.

The Technology Supplier at the end of the contract releases some of its management staff which is then absorbed into the local market.

The Technology Supplier invests in local manufacturing facilities to meet higher quality standards, improved reliability, and higher production levels. These facilities remain after the main project has been completed.

Recipient Assurance

There are a number of issues which technology recipient will need to take into account:

- Costs of Knowledge Transfer
- Knowledge Management
- Communication
- Behavioural expectations
- Cross-culture team building
- Content
- People
- Culture
- Process
- Infrastructure

Recipient case study – Eskom:

In Eskom's case there is a shortage of skilled labour to project manage, design, operate and maintain the capital expansion project power plants. In addition there is a need to develop up to 25% more personnel to build capacity in the South African economy.

Eskom's Knowledge and Skills Transfer process is established to avail itself of the opportunity presented during the new-build program to develop the capacity of Eskom staff and targeted groups in the aspects of Design and Project

Management with the objective to be able to design and manage new build projects in the future. The staff will be identified and developed in terms of the main contract covering two phases, initially concerning the handing over from the Project and Design team of 'Power Station Design and Project Manage' manuals together with an individual Knowledge Transfer phase in which tacit knowledge is to be identified separately and converted to explicit knowledge for ease of transfer to take place.

Eskom has adopted the 4-Level Kirkpatrick model for measuring the Learning Effectiveness:

1. Learner Satisfaction, the first level, is measured using the smiley assessment form indicating the experience the learner had in the learning environment, usually the classroom.

2. New Skills acquired, the second level, is measured in the form of examinations e.g. theory testing and /or structured observable assessments, similar to the completion of a trade test in terms of an electrician's qualification.

3. Proven Competency, the third level, is measured using assessments with both the learner and the Line Manager.

4. Business Impact, the fourth level, is also measured by assessing both the learner and Line Manager separately.

The third and fourth levels while normally difficult to measure are made considerably easier to measure by measuring against the User Requirement Specification which was fully understood by Line Management and the Learner before the Learning Intervention took place.

Conclusion

The survey of current practices of technology transfer indicates that it is a complex, multifaceted process that must be actively managed at both the macro and micro to ensure levels of success.

This is achievable as noted by the feedback from the WEC members polled with a number of design, manufacturing and operating plant successes, however there are many cases where known failure has occurred.

> Sustainable transfer difficulty is experienced generally when the supplier does not understand the needs of the recipient who has difficulty in expressing in sufficient detail what is needed, this highlights the need for the supplier and recipient to engage closely in order to nurture a fuller understanding of each other's position as lifetime partners to a common goal.

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